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1. DESCRIPTION *of the* SKULL *of a* SPECIES *of* HALITHERIUM (H. CANHAMI) *from the* RED CRAG *of* SUFFOLK. By WILLIAM HENRY FLOWER, Esq., F.R.S., F.G.S., &c., Hunterian Professor of Comparative Anatomy, and Conservator of the Museum of the Royal College of Surgeons of England. (Read November 5, 1873.)

[PLATE I.]

WHILE looking, a few weeks ago, over the very rich collection of Crag fossils formed by the Rev. H. Canham, of Waldringfield, near Woodbridge, that gentleman called my attention to an unusually fine fragment of a skull, which he had been unable to identify with any known form. He very obligingly allowed me to bring it to London for the purpose of careful examination and comparison; and I have the pleasure of exhibiting it to the Society this evening.

The specimen was found in the so-called "coprolite" or bone-bed at the base of the Red Crag at Foxhall, about two miles from Waldringfield; and it presents the usual aspect of the mammalian remains from that bed. It is heavily mineralized, of a rich dark brown colour, almost black in some parts, with the surface much worn and polished, and marked here and there with the characteristic round or oval shallow pits, the supposed *Pholas*-borings. Unfortunately, before it was extracted from the matrix in which it lay, it was broken by the pick into several pieces, some of which were lost by the workmen; but all that were preserved have been skilfully reunited by Mr. Canham.

The great interest of this skull consists in its affording the first recorded evidence of the former existence of an animal of the remarkable order Sirenia in this country.

The fragment consists of the anterior or facial portion of the cranium, which has separated, probably before fossilization, from the posterior part at the fronto-parietal suture, and in a line descending vertically therefrom. This portion has then been subjected to severe attrition, by which the greater part of the premaxillary rostrum, the orbital processes of the frontals, and the zygomatic processes of the maxillaries, and other projecting parts, have been removed. In consequence of this, what may be called the external features of the skull, which are especially necessary to determine its closer affinities, are greatly marred, though enough remains of its essential structure to enable us to pronounce with confidence as to its general relationship to known forms. Fortunately the whole of the portion of the maxillæ in which the molar series of teeth are implanted is preserved; and though the teeth have fallen from the alveoli in the front part of the series, and in the posterior part are ground down to mere stumps, so that the form of the crowns cannot be ascertained in any way, many important dental characters may still be deduced from the number, form, size, and position of the sockets and roots that remain.

As the intensely hard ivory-like rostra of the ziphioid cetaceans, the tympanic bones of the Balænidæ, and the teeth of terrestrial mammals almost alone remain in these deposits to attest the former existence of their owners, it is doubtless to the extreme massiveness and density of the cranial bones, so characteristic of the order Sirenia, that we owe the preservation of so large a portion of the skull, under the very unfavourable conditions to which, in common with the other fossils of this formation, it must have been exposed.

A comparison of the fragment with the skulls of the two existing forms of Sirenia, the Manati (*Manatus*) and the Dugong (*Halicore*), gives the following results.

As regards size, the skull must have been considerably larger than that of either of those animals, as the following comparison of some of its dimensions with those of a full-sized American Manati and an Australian Dugong will show:—

	Halitherium.	*Manatus.*	*Halicore.*
	métre.	métre.	métre.
Length of upper surface from fronto-parietal suture to posterior edge of anterior narial aperture	0·115*	0·095	0·065
Height of skull from upper surface of frontal bones to lower surface of palate-bones	0·153	0·120	0·115
Width of skull in temporal fossæ, narrowest part	0·070	0·050	0·070
Width inside anteorbital foramina	0·095	0·062	0·058
Width between widest part of outer border of maxillary teeth	0·114	0·064	0·067

The posterior surface of the fragment (fig. 1) shows in its upper part the concave impression of the anterior cerebral lobes, with a

* Something should be allowed for wearing of the edges of the bone to make the comparison exact.

deep median hollow; but the *crista galli* and the cribriform plates are broken away, giving full view into the nasal cavities, divided as usual posteriorly by a horizontal partition (*P.*) into an upper or "olfactory chamber" and a lower or "narial passage." The lateral portions of this partition formed by the palate-bones (*PL.*) still remain, but its central part, together with the whole of the vomer, has disappeared. In the middle of the roof of the olfactory chamber the upper part of the stout septum formed by the strongly ossified mesethmoid (*ME.*) remains; and a prominent longitudinal ridge (*ET.*) on the lateral wall, but preserved on the right side, is all that indicates the turbinals. The whole of the sphenoids and their dependencies and the pterygoids are broken away, the fracture extending through the bodies of the palate-bones, just behind the posterior molar teeth.

The upper surface (fig. 2) includes the whole extent of the frontals, except the antero-lateral processes which form the upper margin of the orbit, which have been worn away. It is probably also due to attrition that the general surface is evenly convex from side to side, instead of laterally ridged and flat or even concave in the centre as in the existing species. The anterior edge of this surface, forming the upper boundary of the anterior nares, is evenly arched, showing no median process as in the Manati, and to a less extent in the Dugong; but this may also be due to the wearing off of the thin part of the edges of the bones. A nearly semicircular suture an inch behind this margin appears plainly to mark off a distinct pair of nasal bones (*Na.*), joining each other in the middle line and therefore widely differing from their rudimentary or suppressed condition in recent Sirenians. But, as is well known, in some species of *Halitherium* they are developed as conspicuously as in the present example*. The size and form of the anterior nasal aperture (fig. 3) is characteristically Sirenian, and in its height compared with its breadth more like that of *Manatus* than *Halicore*. Its boundary on the right side by the ascending process of the præmaxilla (*PMx.*) is well seen; but on the left this is broken away; and, as before mentioned, the anterior boundary with the greater part of the rostrum has unfortunately perished. The floor of the cavity has precisely the same general form as in the recent Sirenians.

The lateral surface of the fragment (fig. 4) shows the inner wall of the anterior part of the temporal fossa, and of the orbit, the prominent margins of the last-named cavity and the zygoma being removed, and the great anteorbital foramen thus converted into an open groove. This region presents a striking difference of conformation from both of the existing genera. In *Halicore*, in the dried skull, there is a very large vacuity between the frontal and maxillary bones, connecting the orbital cavity with the nasal fossa. In the genus *Manatus* this vacuity is greatly reduced, the thin edges of the two bones, in the form of delicate paper-like laminæ, uniting more or less completely in different skulls. In the present fossil specimen

* *H. Schinzi*, Kaup, 'Beiträge zur näheren Kenntniss der urweltlichen Säugethiere,' Heft ii. 1855, tab. ii. fig. 2.

the orbit is completely separated from the nasal fossa by a stout bony wall nearly an inch in thickness, across which the suture between the frontal (*Fr.*) and the maxillary (*Mx.*) can be clearly traced. What remains of the anterior root of the zygoma (*Zy.*) shows that this process must have been considerably more massive than in either of the existing species. The foramina of this region of the skull correspond generally with those of the Manati. Posteriorly several grooves run horizontally forward from the broken part of the skull; one of these (*a*) conducts the optic nerve to the orbit. Further forward, in the suture between the frontal and maxillary bones (at *b*) is a considerable-sized foramen (apparently accidentally enlarged on the right side) for the passage inwards of the palatine branches of the second division of the fifth nerve In front of the anteorbital foramen, in the suture between the maxilla and ascending or nasal branch of the præmaxilla, is a foramen (*c*) which transmits the branch of the same nerve and the vessels which supply the horny plate, which doubtless existed on the under surface of the rostrum. This canal is again exposed (at *d*) in its course between the bones, by the destruction of the anterior extremity of the skull.

The inferior surface (fig. 5, two thirds natural size) shows the palate and sockets of the molar teeth. The former is elongated and narrow, as in the existing Sirenians, but rather broader posteriorly than in front. Its surface is quite flat, and rounded at the edges, owing to attrition. The posterior edge is concave in outline, but more evenly rounded than in either Dugong or Manati, in both of which a deep V-shaped notch exists in the middle line, entirely wanting in the present fossil*. The suture between the palatine (*PL.*) and maxillary bones (*Mx.*) is very distinctly seen, the extent of the former being much the same as in the modern Sirenians. Near the middle line, just in front of the suture, are a pair of foramina, also found in the corresponding situation in *Manatus*; and further forward are several irregular foramina, which would indicate a considerable vascular supply to this part of the palate, as in the recent genera.

Dentition.—The number of maxillary teeth, as indicated by the alveoli, is six on each side, all placed in close contact with each other. The two most anterior have simple rounded alveoli about equal in size (0·017m. in diameter), indicating teeth with single cylindrical roots as in the Dugong, but differing in being rounded at the apex. The third appears to have had two roots, outer and inner, each rounded and smaller than those in front. The three following teeth resemble each other in form, though the most anterior or fourth of the whole series is rather smaller than the other two. They have three roots—one inner, compressed from side to side, and two supporting the outer border, each compressed from before backwards exactly as in the Manati. The general form of the tooth appears wider in proportion to its antero-posterior diameter than in that genus; but this is perhaps more apparent than real, as the minor root, as in the Manati, diverges considerably from the others, so that the deeper the section the wider the whole base of the tooth

* The notch shown in the figure appears to be due to a fracture.

appears. The teeth, on the whole, are considerably larger in proportion to the size of the skull than in *Manatus*, as well as fewer in number, but differ still more fundamentally in presenting a distinction in character in the fore and hind part of the series, a division into simple premolars and more complex molars, if these terms can be correctly employed when we have no knowledge of a succession of the teeth.

It will be seen from the foregoing description that the specimen presents many characters common to the Manati and the Dugong, and others by which it differs from both, the most striking of them being the more normal development of the nasal bones and the outer wall of the nasal fossæ, and especially the dentition, in all of which it shows a more generalized condition. From *Rhytina* it is removed still further, as that genus is characterized by entire absence of maxillary teeth.

It will be necessary now to consider its relation with the extinct Sirenians of European Miocene and Pliocene deposits.

These are generally known collectively under the generic name *Halitherum*, Kaup, though several more or or less marked subdivisions have been established. The genus is characterized by its founder, as far as the teeth are concerned, by having "two (as in *Halicore*) tusks in the steeply decurved præmaxillæ, and six tubercular molars with closed roots, increasing in size from before backwards"*. Of the præmaxillary rostrum or tusks of our present specimen we know nothing; but the general characters of the molars certainly correspond with those of *Halitherium*. In that genus, however, theree ar two forms—one to which Professor Capellini has given the name of *Felsinotherium*, founded on a very perfect specimen from the Pliocene beds near Bologna† and including the French Pliocene species figured by Gervais as *H. Serresii*‡. From these the present specimen decidedly differs in the absence of the deep notch in the posterior edge of the palate, in the position of the anterior root of the zygoma, which rises from the maxilla opposite to the penultimate and antepenultimate molars, whereas it is much further forward in the above-mentioned species, and in the larger size and greater number of molar teeth, which do not appear to exceed five in either the Italian or French species assigned to this group.

On the other hand, it approaches more nearly to *H. Schinzi*, Kaup, from the Miocene of the Rhine valley, which appears to have had six molars, the first two having single roots. Comparing it, however, with Kaup's figures § and with specimens in the British Museum, distinctions certainly of specific value can be seen, particularly in the superior size and massiveness of construction, in the form of the nasal bones and their relation to the upper ends of the præmaxillæ, the form of the hinder edge of the palate, and the greater size of

* Beiträge zur näheren Kenntniss der urweltlichen Säugethiere. Zweites Heft (1855), p. 10.

† "Sul Felsinotherio." Bologna: 1872.

‡ Zoologie et Paléontologie Françaises, 2nd ed. (1859), pls. iv. v. and vi.

§ *Op. cit.*

the molar teeth, both absolutely and relatively to the cranium generally.

Very few remains of Sirenians have hitherto been found in Belgium. My esteemed friend Professor Van Beneden has recently described and figured the much-mutilated occipital portion of a skull of an animal apparently of this order, to which he has given the name of *Crassitherium robustum**. It is obvious that there are no materials for instituting a comparison between this and our present specimen. M. le Vicomte Du Bus has given a preliminary notice of the discovery of the remains of a species of *Halitherium* in the clay at Boom, between Antwerp and Brussels †. But of the head unfortunately very little was found, and no detailed description has been published. And the same may be said of a nearly complete skeleton discovered by M. Lesseliers at Basel, near Rupelmonde, in the same neighbourhood, referred to in Professor Van Beneden's memoir quoted above.

A very thorough examination and comparison of all remains of extinct Sirenians scattered throughout the various continental museums must be made before their specific distinctions can be satisfactorily ascertained. It is quite possible that the present specimen might then be found to belong to one of the already-named species; but, as has just been pointed out, it presents characters in which it does not agree with any of those which are sufficiently preserved and well-described to admit of comparison. I think it will be most convenient to bestow upon it a specific designation, and therefore propose that of *Canhami*, to commemorate the assiduity with which its owner has collected, and liberally made available for scientific examination, the palæontological treasures of the neighbourhood in which he resides.

The subject of the origin of the very mixed fauna of the Red Crag bone-bed has been so frequently and ably discussed in the publications of this Society and elsewhere, that there is no occasion for me to enter into it at present. I would only remark in passing that the discovery of a *Halitherium* allied to the species found in the neighbourhood of Darmstadt is an additional instance to those already recorded of the existence in our Crag of forms characteristic of the Miocene fauna of the Rhine valley. It is also worthy of mention that Mr. Canham's collection contains three fine specimens of teeth of *Squalodon*, a form often found associated elsewhere with *Halitherium* ‡. On the other hand, as showing the mixed nature of the fauna, there are from the same beds some beautifully preserved teeth of *Coryphodon*—one in particular, a last upper molar, very like, but rather larger than that figured by Hébert as *C. eocænus*, from the earliest Tertiaries of France §.

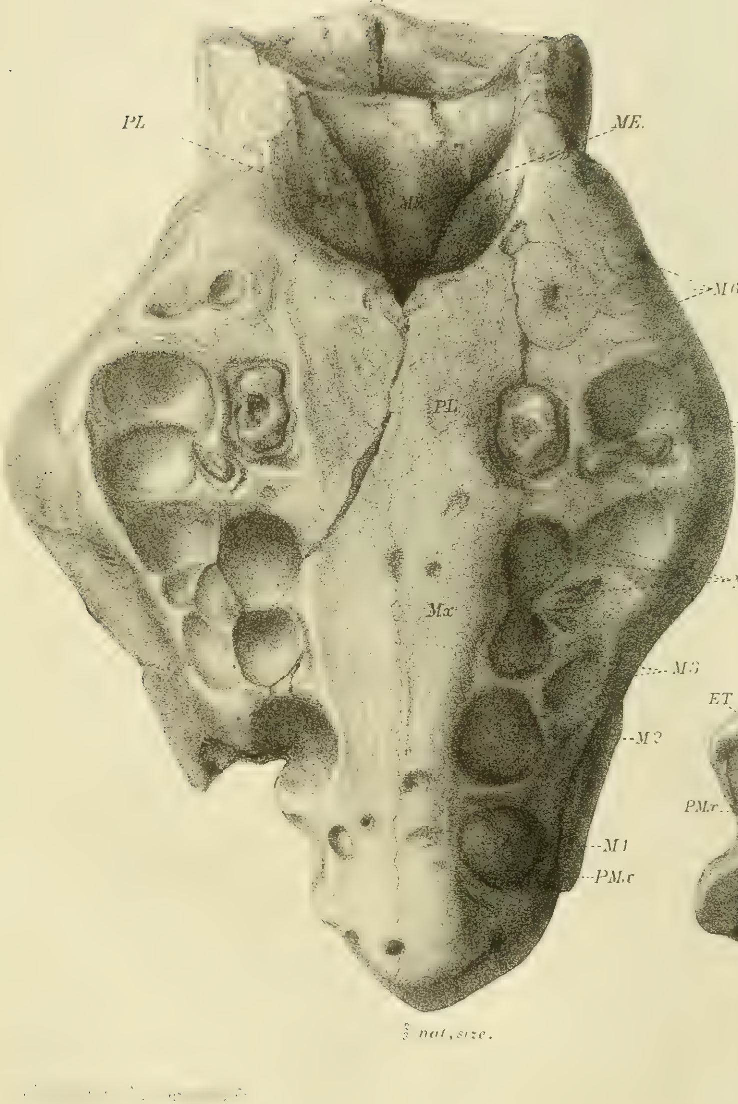
* "Un Sirénien nouveau du terrain Rupelien," Bull. Acad. Roy. de Belgique, 2me série, t. xxxii. (1871) p. 164.

† Bull. Acad. Roy. de Belgique, 2me série, t. xxvi. (1868) p. 20.

‡ One of these is mentioned by Mr. RayLankester (Quarterly Journal of the Geological Society, vol. xxvi. (1870) p. 512). The others appear to have been added since.

§ Ann. Sc. Nat. 4me série, t. vi. p. 1.

Fig. 5.



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HALITH

Fig. 1.

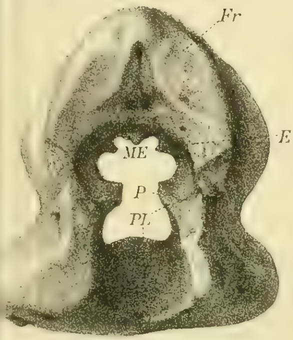

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Fig. 4.

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Fig. 3.

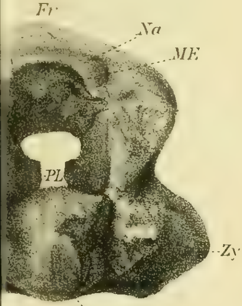

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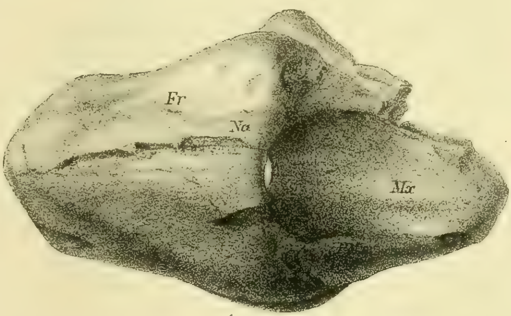
Fig. 2.



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:IUM CANHAMI.

Fig. 5.

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Fig. 1.

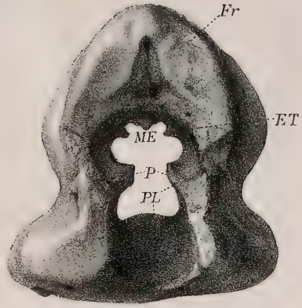

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Fig. 4.

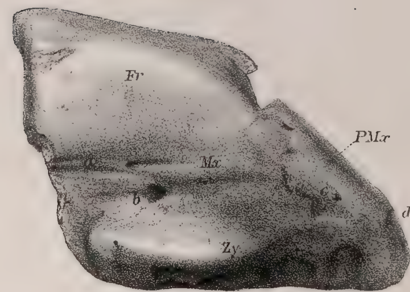

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Fig. 3.

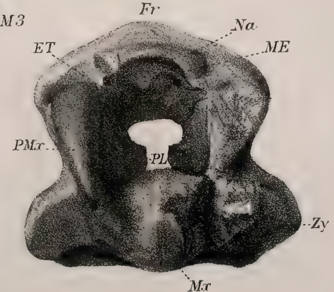

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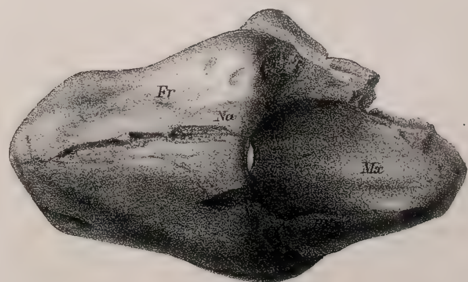
Fig. 2.



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G.H.Ford & C.L.Griesbach.

Mintern Bros. imp.

HALITHERIUM CANHAMI.

DESCRIPTION OF PLATE I.

Fig. 1. Posterior surface of the fragment of skull of *Halitherium* from the Crag.
2. Upper surface.
3. Anterior surface.
4. Lateral surface.

All one third the natural size.

5. Under surface of the same, two thirds the natural size.

Letters in all the figures:—*Fr.* frontal bones; *Na.* nasals; *Mx.* maxillary; *PMx.* præmaxillary; *ME.* mesethmoid; *ET.* ethmoturbinal; *PL.* palatine; *Zy.* zygomatic process of maxillary; *P.* (in fig. 1) remains of horizontal partition separating olfactory chamber from posterior narial passages; *a*, *b*, *c*, *d* (in fig. 4), foramina for the passage of nerves and vessels; *M* 1, 2, 3, 4, 5, and 6 (in fig. 5), sockets for the six maxillary or molar teeth.

Discussion.

Mr. Prestwich thought the specimen a most interesting addition to the derived fossils of the lower beds of the Red Crag. It was most likely derived from some of the Miocene beds which formerly existed, probably on what is now the basin of the German Ocean.

Mr. H. Woodward mentioned that in the Woodwardian Collection there was a skull of *Halitherium* from the Miocene of Darmstadt. It was, he thought, of great interest to meet with these Miocene forms in the Crag, most of the fossils of which appear to have been derived from the lower beds of the London Clay.

Dr. Leith Adams mentioned the discovery of a tooth of *Halitherium* in a calcareous bed in Malta, where also he had discovered one of the ear-bones.

Mr. Seeley pointed out that the skull presented some peculiarities, which made him doubt whether it could rightly be ascribed to *Halitherium*. He thought it might possibly belong to a new genus; at the same time he had noticed in the Crag deposits some vertebræ which he thought might be attributed to *Halitherium*.

The Chairman (Prof. Ramsay) was glad to find that so many geologists were disposed to regard the majority of the fossil bones from the Crag as derivative. He had long regarded them as belonging to a Miocene period, and probably a late one, and to a time when this country was united to the continent. When at the Crag period a portion of the surface was submerged, the neighbouring land might, however, have been still inhabited by the old Miocene fauna.

2. New Facts *bearing on the* Inquiry *concerning* Forms *intermediate between* Birds *and* Reptiles. By Henry Woodward, Esq., F.R.S., F.G.S., British Museum. (Read November 5, 1873.)

There is perhaps no single point along the whole line of defences raised by the opponents of the theory of Evolution which has been more warmly contested than the question of the significance attaching to the relationship of birds to reptiles. Professor Huxley truly remarks that "to superficial observation no two groups of beings can appear to be more entirely dissimilar than reptiles and birds. Placed side by side, a humming-bird and a tortoise, an ostrich and a crocodile, offer the strongest contrast, and a stork seems to have little but animality in common with the snake it swallows" *.

"In perfect strictness," writes the same authority †, "no doubt, it is true that birds are no more modified reptiles than reptiles are modified birds, the reptilian and ornithic types being both, in reality, somewhat different superstructures raised upon one and the same ground-plan; but it is also true that some reptiles deviate so very much less from that ground-plan than any bird does, that they might be taken to represent that which is common to both classes without any serious error."

"A *lizard* is not very far from being the centre of the circle, the periphery of which is occupied by *Chelonia*, *Ichthyosauria*, *Plesiosauria*, *Pterosauria*, and *Aves*" ‡.

If we consider for a moment what are the peculiarities presented by each of these divisions of the Sauropsida (under which great class Prof. Huxley has proposed to unite these several orders), we shall begin to perceive that the peculiar and distinctive characters which we have hitherto assumed to be expressive of the class Aves are not more remarkable than many which distinguish the divisions of the Reptilia from one another.

On what grounds, then, are their wide differentiation insisted upon by the separatists, and their combination advocated by evolutionists? In the case of those who insist on their separation, it is urged that we have no connecting links demonstrable between these widely different forms of to-day; whilst on the other hand it has already been shown by Prof. Huxley and others that there are abundant points of anatomical structure shared even by existing Aves and Reptilia, and that many of the desiderated forms, exhibiting intermediate points of structure, have already been noticed among the recent discoveries which have rewarded the labours of the geologist and palæontologist, not only in Europe, but also in America.

Admitting generally that all existing birds differ definitely from living reptiles, "one comparatively small section, nevertheless, cer-

* Huxley's Lecture, Royal Institution, February 7th, 1868.

† Proc. Zool. Soc. Lond. 1867, p. 415. ‡ *Ibid.*

tainly does come nearer reptiles than the others. Those are the *Ratitæ*, or Struthious birds, comprising the Ostrich, *Rhea*, Emu, Cassowary, *Apteryx*, and the but recently extinct birds of New Zealand, the *Dinornithes*, which attained gigantic dimensions. All these birds are remarkable for the small size of their wings, the absence of a crest or keel upon the breast-bone, and of a complete furcula, and, in many cases, for the late union of the bones of the pinion, the foot, and the skull. In this last character, in the form of the sternum, of the shoulder-girdle, and in some peculiarities of the skull, these birds are *more reptilian* than the rest; but the total amount of approximation to the reptilian type is but small, and the gap between reptiles and birds is but very slightly narrowed by their existence" *.

All the living, or recently extinct, wingless birds, however, deserve to be specially mentioned, not only on account of the more generalized type of structure which they offer, but because they present, in their distribution, one of the most interesting geographical problems to the consideration of naturalists and palæontologists.

Africa has its Ostrich †; Madagascar had its *Æpyornis*; Java and the adjacent islands of the Indian archipelago the Cassowary; Australia its Emu and extinct *Dromornis* ‡; New Zealand its *Dinornis*; South America its *Rhea*; the London Clay its *Dasornis londiniensis* §. Thus, then, we have this most ancient type of wingless running birds presenting not merely the greatest range in time, but also the widest geographical distribution over the globe of any order of its class. None of these forms, however, depart *in the main* from the avian type, and we must seek still further for modifications of even greater import than the wingless birds present.

Is there any thing in the *Pterosauria* which affords a missing link?

If we examine that remarkable group the "flying lizards," or *Pterodactyles*, extending in time from the Lias to the Chalk, we find they exhibit many adaptive modifications of the avian type, such as the great air-cavities in the bones, and the prolongation of the præmaxillæ into beaks (which were probably sheathed in horn), although the rest of the jaw was armed with teeth. But the *manus*, with its four free digits (three armed with claws, and the fourth enormously prolonged to support the wing-membrane), the non-avian characters of the pelvis and hind limbs, all depart *most widely* from the ornithic type.

But among the various additions made to our knowledge of extinct forms, some at least may certainly be claimed as affording links

* See Huxley's Lecture, Geol. Mag. 1868, vol. v. p. 360.

† Formerly the geographical range of the Ostrich extended into Arabia, Persia, and part of India, within the Historic period; but it has been exterminated by the agency of man.

‡ *Dromornis australis*, Owen, Trans. Zool. Soc. 1873, vol. viii. part vi., and Geol. Mag. 1869, vol. vi. p. 383.

§ See Trans. Zool. Soc. 1872, vol. vii. p. 123, pl. 16. This specimen was detected and its avian characters pointed out by Mr. Davies, of the British Museum.

by which to unite more closely the SAUROPSIDA to one another as a class. Foremost of these in importance must be mentioned:—

I. The discovery of that remarkable Mesozoic type of bird, the *Archæopteryx macrura* (Owen), with its peculiar reptilian-like tail, composed of twenty free and apparently unanchylosed cylindrical vertebræ, each supporting a pair of quill-feathers, the last fifteen vertebræ having no transverse processes, and tapering gradually to the extremity.

Two of the digits of the wing (or manus) have curved claws, much stronger than those of any existing bird; and the metacarpal bones appear to be quite free and disunited.

In these particulars the *Archæopteryx* certainly does exhibit a closer approximation to reptilian structure than any modern bird *.

II. The next remarkable fossil bird to be enumerated is the *Ichthyornis dispar* (Marsh), discovered by Prof. O. C. Marsh, in 1872, in the Upper Cretaceous beds of Kansas, U.S. It possessed in both jaws well-developed teeth, which were quite numerous, and implanted in distinct sockets. The teeth were small, compressed, and pointed, and all similar in character. Those in the lower jaw number about twenty in each ramus, and are all more or less inclined backward. The series extends over the entire upper margin of the dentary bone, the front tooth being very near the extremity. The maxillary teeth appear to have been equally numerous and essentially the same as those in the mandible. The jaws were, apparently, not encased in a horny sheath. The bones of the wings and legs all conform to the true ornithic type. The vertebræ were all biconcave, the concavities at each end of the centra being distinct and nearly alike. The tail does not appear to have been preserved. The bird was about the size of a pigeon. The bones do not appear to have been pneumatic, although most of them are hollow. The species, Prof. Marsh considers, was carnivorous and probably aquatic.

A second form discovered has been named *Apatornis celer* (Marsh).

Prof. Marsh thinks it probable that *Archæopteryx* possessed teeth and biconcave vertebræ. In confirmation of the former suggestion, it may be mentioned that part of a small detached jaw with teeth was detected by Mr. John Evans, F.R.S., Sec. Geol. Soc., upon the slab containing the skeleton, and possibly may have belonged to it, although referred by Prof. Owen to the "præmaxillary bone of a fish" †.

In an article published by Mr. Evans in the 'Natural History Review' for 1865, vol. v. p. 415, he carefully and critically discusses this question; and he furthermore cites the opinion of the late illustrious Hermann von Meyer, that the teeth observable in the jaw were unlike any heretofore known from the lithographic stone, although they somewhat resembled those of *Acrosaurus*. On

* See Prof. Owen on *Archæopteryx*, Phil. Trans. 1863.

† Phil. Trans. 1863, p. 33. See also article by H. Woodward in 'Intellectual Observer,' Dec. 1862, vol. ii. p. 313, and plate; and by S. J. Mackie, 'Geologist,' 1863, vol. vi. p. 1.

the whole, however, Von Meÿer concludes that there can be little doubt the jaw really belonged to *Archæopteryx*; and he expressed his conviction that this singular feathered fossil cannot be looked upon as a bird with persistent embryonic characters, but rather as a distinct type, and perfect of its kind.

In this article Mr. Evans also gives the result of his researches in reference to a certain nodular mass having a distinctly bilobed outline which he had observed upon the slab containing the *Archæopteryx*. Mr. Evans, having prepared casts of the brain-cavity of a great number of living birds, was enabled to institute a long series of careful comparisons, and to demonstrate most satisfactorily the correctness of his determination, that the mass in question represented a cast of the anterior portion of the brain-cavity of *Archæopteryx*.

III. Prof. Owen has added to his ornithological researches another Eocene bird from the London Clay of Sheppey *, to which his attention had been drawn by Mr. W. Davies, of the British Museum, who also worked it out with his own hands.

This bird, which he has named *Odontopteryx toliapica*, is rendered remarkable by the very prominent denticulation of the alveolar margins of the jaws, to which its generic appellation refers.

The denticulations are intrinsic parts of the bone bearing them, and are of two sizes, numerous smaller denticles occupying the spaces between the larger ones, which are about half an inch apart.

When perfect the skull was probably 5 to 6 inches in length; but the anterior extremity is wanting.

Prof. Owen concludes the *Odontopteryx* to have belonged to or near the *Anatidæ*, and that it was web-footed and a fish-eating bird, for which its serrated jaws would admirably adapt it.

As we have not the other parts of the bird, but the skull alone, it would be presumptuous to surmise as to the presence or absence of other modifications besides the pseudo-teeth with which the jaws are armed †.

From the extreme rarity of all terrestrial animal remains preserved in a fossil state, it may justly be concluded that many more such archaic birds, having reptilian modifications, actually existed in the Mesozoic epoch, although they may possibly never be discovered by geologists.

Passing from birds to *Dinosauria*, we are able to enumerate several forms of reptilia which appear to offer points of structure tending towards the so-called "wingless birds," or those birds which are devoid of the power of flight by reason of the relatively small size of their fore limbs and the feathers which they support.

* See Quart. Journ. Geol. Soc. for November 1873, and abstract in Geol. Mag. August 1873, p. 376.

† Many living birds, and notably the *Merganser serrator*, have a denticulated mandibular border which, although connected only with the horny covering, and not with the bones of the mandibles (as in *Odontopteryx*), yet is sufficient to prove that the presence of feathers can no longer be looked upon as necessarily implying that the beak with which they were preened must have been edentulous. (John Evans, *op. cit.* p. 421.)

I. The first of these is a small and very singular reptile from the Oolite of Solenhofen, which, notwithstanding its minute size, Prof. Huxley thinks must be placed with the Dinosaurs (the *Compsognathus longipes* of Andreas Wagner), not much more than 2 feet in length, having a small head, with toothed jaws, supported on a long and slender neck. The iliac bones are prolonged in front of and behind the acetabulum ; the pubes were long and slender. The bones of the fore limb are very small, and probably furnished with two clawed digits. The hind limb is very large, and disposed as in birds, the femur being shorter than the tibia. The proximal division of the tarsus is anchylosed with the tibia as in birds. The distal ends of the tarsal bones in the foot are not united with the three long and slender metatarsals, corresponding with the second, third, and fourth toes. There is only a rudimentary metatarsal to the fifth toe.

It is impossible to look at the structure of this strange reptile and to doubt that it hopped or walked in an erect or semierect position, after the manner of a bird, to which its long neck, slight head, and small anterior limbs must have given it an extraordinary resemblance *.

II. Much of the recently acquired knowledge of the huge *Dinosauria* of our own Secondary rocks has resulted from the earnest labours of Professor Phillips, bestowed upon the remarkable series of remains in the Oxford Museum.

We now know certainly that the *Megalosaurus*, that huge carnivorous lizard, perhaps 30 feet long, which ranged from the Lias to the Wealden, had strong but not massive hind limbs, and short reduced fore limbs, five anchylosed sacral vertebræ (Owen), the ilium, ischium, and pubis slender and bird-like, as in the Ostrich, the scapula and coracoid resembling those of the *Apteryx*. From all these considerations Professor Phillips agrees with Profs. Owen and Huxley in viewing the *Megalosaurus*, "not as a ground-crawler, like the alligator, but moving with free steps, chiefly, if not solely, on the hind limbs, and claiming a curious analogy, if not some degree of affinity, with the Ostrich" †.

What we have cited as regards the carnivorous *Megalosaurus* is true also of the vegetable-eating lizards of the Mesozoic rocks (*Iguanodon, Scelidosarus*, &c.).

The sacrum is composed of from four to six vertebræ. The pelvic bones are bird-like in form and disposition; there is a strong crest which passes between the head of the fibula and the tibia, as in birds. The tibia has a great anterior or "procnemial" crest, not seen in other reptiles, but existing in most birds, especially the running and swimming birds. The toes are reduced in number; *Scelidosaurus* has four toes and a rudiment of a fifth ; *Iguanodon* has *three*, with a rudimentary indication of a fourth.

There is evidence in "the manner in which the three principal metatarsals articulate together, that they were very intimately and

* Prof. Huxley's Lecture, *loc. cit.*

† 'Geology of Oxford and the Valley of the Thames,' by John Phillips, M.A., F.R.S., F.G.S., &c., 1871, p. 196.

firmly united, and that a sufficient base for the support of the body was thus afforded by the spreading out of the phalangeal regions of the toes." (Huxley, *loc. cit.*)

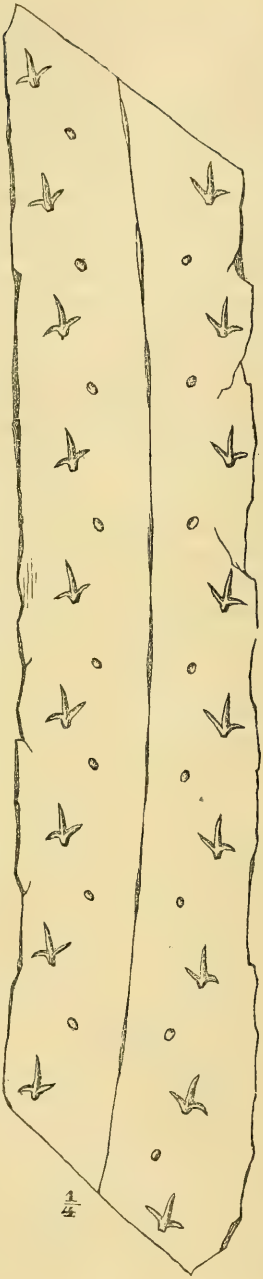
Mantell long since, and more recently Leidy, have concluded, from the great difference in the size between the fore and hind limbs, that *Iguanodon* and *Hadrosaurus*, as well as other *Dinosauria*, may have supported themselves for a time at least upon their hind legs. But Mr. Beckle's discovery of pairs of large three-toed foot-prints, of such a size and at such a distance apart that it is difficult to believe they have been made by any thing but *Iguanodon*, leads to the supposition that this vast reptile, and perhaps others of its family, must have walked temporarily or permanently upon its hind , *loc. cit.* p. 364).

Many years since, Mr. Allan Cunningham (H. M. Botanical Collector for Kew), who accompanied the Expedition to survey the Intertropical and Western Coasts of Australia, from 1818 to 1822, under Captain Philip King, R.N., F.R.S., secured a specimen of a remarkable Frilled Lizard, which had *perched* itself upon the stem of a small decayed tree, at Careening Bay, Port Nelson*. This has been named *Chlamydosaurus Kingii*, by Dr. Gray. The stuffed specimen is preserved in the British-Museum collection in a semi-erect position, its fore feet (which are *very much smaller* than the hind feet) scarcely touching the ground at the extremities of the claws. I had the advantage (in company with my esteemed colleague, Dr. Günther, the Assistant Keeper of the zoological collections of the British Museum) to hear the remarks of an Australian resident on this lizard, which is common about the gardens in the environs of Sydney. This observer reports that the lizard in question not merely sits up occasionally, but habitually runs *upon the ground* on its *hind legs*, its fore paws not touching the earth. This statement interested me immensely; and on repeating it to Prof. Huxley, I learnt that that acute observer, Mr. Gerard Krefft, of the Sydney Museum, had noted the same peculiarity. With this upright carriage, special modifications of the sacrum and pelvic bones are necessary; and, no doubt, when a specimen is dissected, this very interesting point will be corroborated by the form and articulation of the bones. As geologists, we cannot but be interested in this peculiarly modified existing type of lizard, occurring, as it does, on the continent of Australia (which has yielded such a remarkable assemblage of Tertiary and existing Marsupialia to be critically examined and chronicled by our great anatomist, Professor Owen)—a land also remarkable for the possession of many living Mollusca of Mesozoic types on its coasts.

It is noteworthy in connexion with these observations on bipedal reptilia (existing and extinct), to find that the Solenhofen Limestone, which has yielded both the long- and short-tailed *Pterosauria*, the long-tailed Reptilian-like bird†, and the long-necked short-armed Avian lizard‡ supplies a bipedal track upon one of its slabs, which

* See King's 'Survey of Australia,' 8vo, 1827, vol. ii., Appendix, p. 424.

† *Archæopteryx*. ‡ *Compsognathus*.



Track of Saurian from the Solenhofen Limestone (Ichnites lithographicus, *Oppel*), *one fourth natural size.*

reminded me at once of what *Chlamydosaurus* or *Compsognathus* might produce under favourable conditions. The slab presents a median track formed by the tail drawn along on the ground; the two hind feet with outspread toes leave their mark, whilst the fore paws just touch the ground, leaving a dot-like impression on either side of the median line (see figure). Dr. Oppel has named this track *Ichnites lithographicus* *.

In calling attention to the slab, Dr. Oppel remarks that the footsteps are ranged in two parallel lines with a middle continuous impression alternately stronger and fainter. The footsteps go in pairs. It resembles no other form of track already noticed or described from this or any other formation.

Dr. Oppel thinks *Archæopteryx* might have formed such a track, although he is unable to explain the alternate deepening of the middle track.

Remembering that the tail of *Archæopteryx* is bordered all the way by feathers, it will at once be seen that it could not leave behind a clear and simple furrow, but a broad smudge composed of many lines, like that left by a flat colour-brush drawn along upon paper.

The tail of a lizard progressing by hops and supporting itself upon its hind limbs and tail, would, however, produce just such impressions, the deepening of the furrow made by the tail being caused by the depression of the tail in making each onward hop.

Viewed by the additional light which our present knowledge of the structure of the Mesozoic Dinosauria and of the existing *Chlamydosaurus*

* Paläontologische Mittheilungen aus dem Museum des Königl. Bayer. Staates von Dr. Albert Oppel. Stuttgardt, 1862, tab. 39, p. 121.

affords, we need no longer be doubtful as to the origin of the many bipedal tracks which occur in the Trias and upwards.

Some are very probably the "spoor" of Struthious birds which may have existed fully as far back as the beginning of the Secondary Period; but most are, no doubt, due to the bipedal habit of our Secondary reptiles, a peculiarity still maintained by the Australian *Chlamydosaurus*.

Discussion.

Mr. Seeley thought that the footprints on the slab cited in the paper had been produced by some saurian, such as a Pterodactyle, the fore limbs of which were wider apart than its hind limbs, rather than by *Compsognathus*. If the foot-track had been due to a saurian walking on its hind legs only, he thought that the principal impressions must of necessity have been nearer together. He disputed the correctness of the term "adaptive modification" as applied to the air-cavities in bones. He was inclined to regard the Pterodactyle as more closely allied to birds than did the author of the paper. The condition of the carpus, as well as the tarsus, in these reptiles showed their ornithic affinities. He cited jerboas, kangaroos, and other forms, in which the hind legs were mainly used for progression, but in which the sacrum and other bones were not modified, as instances calculated to inspire caution in connecting the mode of progression with structure.

Mr. Hulke could not regard the tracks as those of a Pterodactyle, as the inner marks were much less distinct than the outer, and would therefore hardly be due to the hinder limbs, on which the weight would mainly fall.

Mr. Blanford agreed with Mr. Seeley that the mere fact of the *Chlamydosaurus* walking on its hind legs did not suffice to prove any affinity with Dinosaurians.

Mr. Woodward, in reply, stated that the two points on which he had mainly founded the paper were:—1st, the occurrence of footprints in the Solenhofen limestone, characteristic of a bipedal progression of some saurian, which had, moreover, used its tail from time to time to give it a forward impetus; and 2ndly, the method of walking of *Chlamydosaurus*. With regard to animals thus progressing, he was not prepared to accept the view that there was no corresponding modification in structure.

3. *Note on a very* Large Saurian Limb-bone *adapted for* Progression *upon* Land, *from the* Kimmeridge Clay *of* Weymouth, Dorset. By J. W. Hulke, Esq., F.G.S., F.R.S. (Read November 5, 1873.)

[Plate II.]

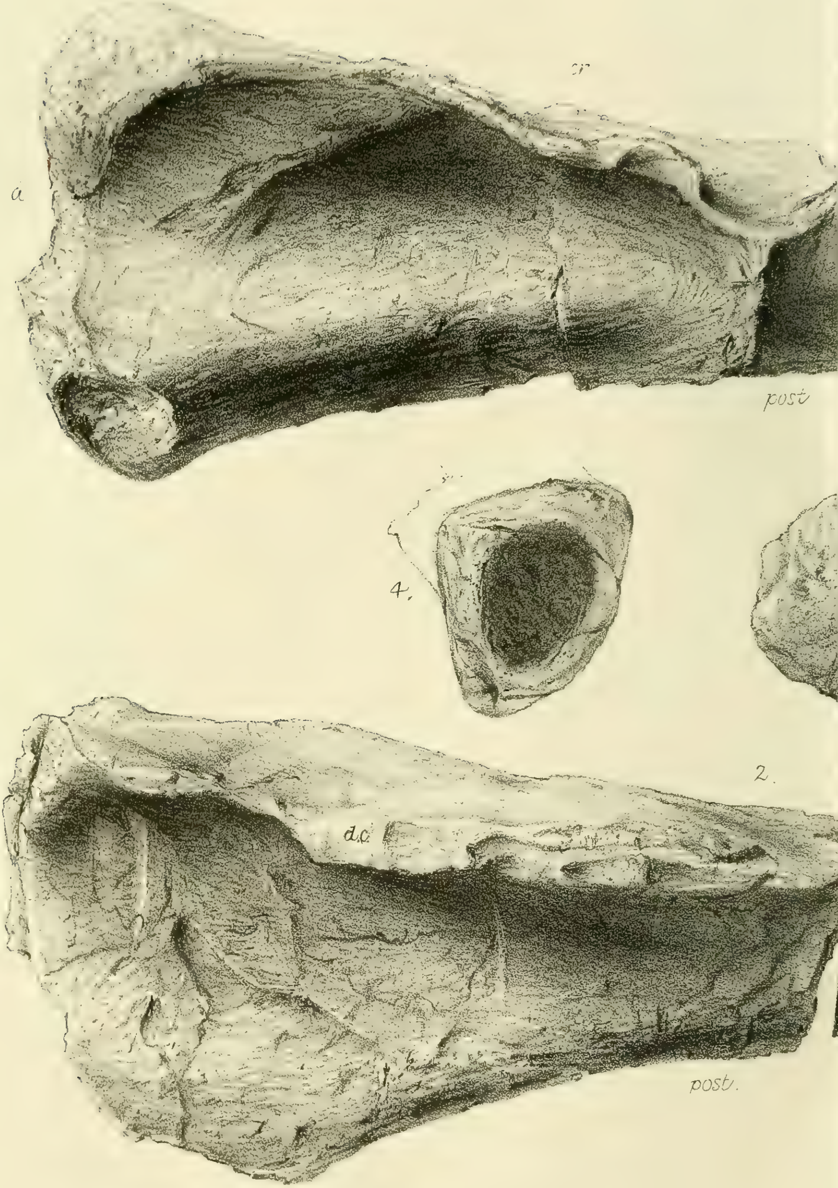
At rare intervals there have been obtained from the Kimmeridge Clay in several localities (inland and also on the Dorset coast) remains of very large reptiles differing from the contemporary Enaliosaurs (the Plio-, Plesio-, and Ichthyosaurs) by the adaptation of their limbs to walking upon dry land. On June 23, 1869, I brought before the Society a large humerus of such a reptile, which had been obtained in Kimmeridge Bay by J. C. Mansel Pleydell, Esq., a Fellow of our Society. It was afterwards presented by him to the British Museum*; and to the Saurian indicated by it I gave the name of *Ischyrosaurus*.

The subject of this note is a much larger limb-bone lately found in the Kimmeridge-clay beds, near Weymouth, by Mr. R. I. Smith, and intended to be added to the national collection. It was enveloped in large septarian masses, which stuck so closely to it that thin laminæ of the surface of the bone were unavoidably detached in stripping the matrix from it. The natural surface, where uninjured, is smooth; it has a close, fine grain resembling that of the humerus of the *Ischyrosaurus*, and quite unlike the coarse texture of many Enaliosaurian bones. The bone has been much fissured, and cemented together by spar; and some parts have been distorted by squeezing; but the general figure is well preserved†.

It has a closer resemblance to the Crocodilian type of humerus than to any other bone; and I am disposed to regard it as a humerus, the left one. Its present length is 54 inches; but the articular surfaces of both ends are wanting, and for these scarcely less than 9 additional inches can be allowed; so that the whole length of the perfect bone can hardly have been less than 63 inches. The middle of the shaft is cylindroid; its girth is 21 inches; and its horizontal transverse diameter is 7·8. Its transverse section (Pl. II. fig. 4) is a subtrigonal figure; and it exhibits a large coarsely cancellated core enclosed in a stout compact cortical ring. Towards the proximal end the width increases, chiefly by the backward sweep of the posterior border, to a present maximum of 17 inches; but this would be increased by the absent posterior moiety of the proximal surface, including the articular caput and the adjoining end of the posterior border. The outline of the dorsal or upper surface in this situation is transversely convex, whilst longitudinally it rises in a gentle curve from the cylindroid shaft to the proximal end, owing to the increased thick-

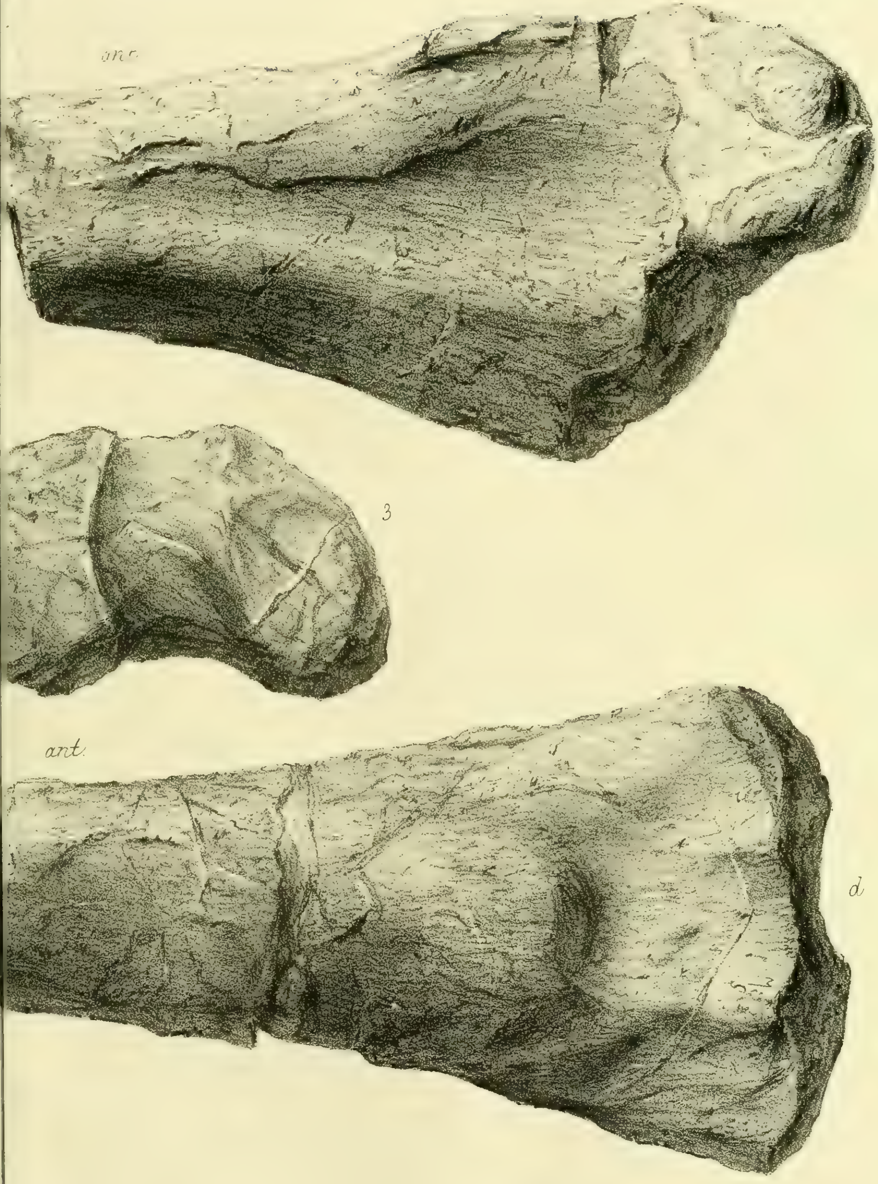
* A description and figures of it will be found in the Quart. Journ. Geol. Soc. vol. xxv. p. 386.

† In the following description the bone is imagined to be placed nearly horizontally, with its long axis perpendicular to the animal's trunk.



C.L. Griesbach

HUMERUS OF CETEOSA



M & N Hanhart imp.

ARUS HUMERO-CRISTATUS

...ral size

G.L.Griesbach. M.&N.Hanhart imp.

HUMERUS OF CETEOSAURUS HUMERO-CRISTATUS

1/8 natural size

ness required here for the support of the terminal articular caput. The distal moiety of the dorsal surface beyond the shaft expands gradually to a maximum width of 16 inches at the distal articular surface. A very long, wide, and rather deep intercondyloid groove traverses it longitudinally. The ventral surface of the expanded proximal moiety is very hollow transversely; and beyond the shaft its distal moiety in the same direction is gently convex. The distal articular surface (fig. 3) is an oblong, the long diameter of which measures 16 inches, and the short one averages 6 inches. It is divided into a pair of condyles by a very shallow vertical groove, which above joins the dorsal intercondylar groove and below ends between two low eminences at the ventral surface. The posterior border, gradually contracting from the shaft towards the proximal end, becomes here a relatively thin rounded edge. In the distal moiety this border is stouter. The anterior border in its proximal half is much wider than the corresponding part of the posterior border; it is flattened and produced downwards as a ventrally projecting crest (fig. 2, *d c.*) which greatly increases the hollowness of the ventral surface in this part. The distal moiety of this border, in its whole length, has the form of a thin, rough, very prominent crest projecting forwards. These crests form one of the most striking features of the humerus, which distinguish it immediately from the almost equally large Mantellian Pelorosaurian humerus preserved in the British Museum*, and from the almost equally huge, but rather stouter, humeri of the *Ceteosaurus oxoniensis* in the Oxford University Museum, so admirably restored by Prof. Phillips†, as also from the much smaller humerus of *Ischyrosaurus* to which I have already referred.

A general correspondence with the humerus of *Ceteosaurus oxoniensis* inclines me to provisionally refer this new Kimmeridge Saurian to the genus *Ceteosaurus* as typified in *C. oxoniensis*. Its rough strong crests suggest the specific designation *humero-cristatus* (*Ceteosaurus humero-cristatus*).

EXPLANATION OF PLATE II.

Fig. 1. Dorsal or posterior surface of humerus: *d.* distal end; *px.* proximal end; *ant.* anterior border; *post.* posterior border; *cr.* crest.

2. Ventral or anterior surface of humerus: *px.* proximal end; *d.* distal end; *ant.* anterior or outer border; *post.* posterior or inner border; *d c.* deltoid crest.
3. View of distal articular end.
4. Transverse section near middle of shaft.

DISCUSSION.

Mr. SEELEY remarked that the internal structure of the bone resembled that found in *Gigantosaurus*, and the general form of the humerus was such as might be expected did it belong to an animal of that genus.

* British Fossil Reptilia of the Wealden Formation, Supplement ii. vol. xii. p. 39.

† Geology of Oxford, p. 272.

4. Supplemental Note on the Anatomy of Hypsilophodon Foxii. By J. W. Hulke, Esq., F.R.S., F.G.S. (Read November 19, 1873.)

[Plate III.]

At the close of last Session I read a note upon some remains of an immature *Hypsilophodon Foxii* which I had shortly before obtained in Brixton Bay, Isle of Wight, from the west end of the well-known bed which crops out at the top of the cliff at Barnes Chine and dips under the beach at Cowleaze Chine. Their chief value consisted in the additional light they threw upon its dentition, and the information they afforded of the form and the proportions of the limbs. In September I was so fortunate as to obtain in the same locality parts of two individuals (one probably fully grown) which, as they illustrate some structures better than any other remains of this Dinosaur yet before the Society, have appeared to me worthy of being made the subject of a supplementary note.

The bones are imbedded in a block of sandy clay-stone which had fallen from the cliff and had been washed to and fro by the sea until some of them had become much abraded. The most important are a skull and two chains of vertebræ, each including a considerable part of the sacrum.

Skull.—This is larger than that found by Mr. Fox, which Prof. Huxley exhibited here in November 1869. Its upper surface was exposed; and I have laid bare its right side (Pl. III. fig. 1). The maxillary apparatus is broken off from the cranium proper, and twisted round so that the dentigerous border of the maxillæ and the palate now look upwards, the pterygoids resting in the lower part of the right orbit.

The upper surface of the skull is a long rhomboid (I refer now to the part behind the front of the orbits), of which the short diameter connects the stout postorbital processes; and the sides are lines drawn from these to the front of the supraorbital arch and to the extremity of a salient occipital (*Pa'.*) spine in which the parietal region terminates behind instead of presenting here the entering angle usual in lizards' skulls. Large pieces of the parietal and of the frontal bones have exfoliated, laying bare the matrix moulded to the inner surface of the vault. Between the temples this presents a ridge suggestive of a parietal crest; and between the orbits is a mesial furrow indicative of the division of the principal frontal bone. The root of the right parietal suspensory process only is preserved (*Sp.*); its direction is nearly vertical to that of the parietal crest.

The orbit is very capacious; ·4 inch below its upper border lie six of the thin bony scales of the sclerotic coat of the eyeball (*S.*).

The præmaxillæ (*Prmx.*) want the edentulous anterior extremity seen in Mr. Fox's specimen; but other parts of their structure are better displayed here, owing to their partial separation from the maxillæ.

The body of the præmaxilla is a vertical plate, ·45 inch deep from its nasal to its dentigerous border, smooth, except quite in front, where its surface is wrinkled. From each end rises a strong process. That in front is a compressed trihedral blade narrowing upwards, shorter than the posterior or outer process. Applied to its fellow of the other side it forms the lower part of the septum between the anterior nares. Its front edge seen on the surface of the snout is stout; the posterior edge is thin.

The posterior or outer process, broader and longer, is closely applied to the anterior border of the maxilla, but not suturally united with it. It overlaps the maxilla, which has a shallow groove for its reception. The dentigerous border, nearly straight, is ·65 inch long; and in this space it contains, I think in separate sockets, five mature cylindrical teeth, of which the roots, with only small portions of the crowns, now remain. At their inner side, between the second and third and the fourth and fifth teeth, two immature crowns are just visible. A large triangular palatal process, mesially united to its fellow, completely roofs this part of the mouth. From the anterior palatine foramen to the posterior extremity of the interpræmaxillary suture measures ·7 inch. This sutural margin is longer than the free posterior border, and it forms a projecting angle to which, on the right side, the front of a vomer is (*V.*) attached.

The teeth all lie behind the anterior palatine foramen; the small portion of the edge of the right jaw in front of this is smooth and toothless.

The maxillæ (*Mx. Mx'.*) are large subtriangular bones. The left is very perfect. Its straight dentigerous border, 1·6 inch long, contains an unbroken series of eleven* compressed sculptured teeth, of which the front four are smaller than the others. The hinder margin of the crown of each tooth slightly overlaps the front margin of that next behind it. The crowns are obliquely worn, the thickly enamelled outer contour being the longer. The number of præmaxillary teeth agrees with that of Mr. Fox's skull; the maxillary teeth are one more in my skull. The teeth themselves agree so closely with those described in my last note as to make any further account of them unnecessary. In front of its dentigerous part the lower border of the maxilla and its upper border converge and send forward upon the deep surface of the præmaxilla the thin grooved plate mentioned as receiving the posterior ascending process of the latter.

Above this plate the anterior border of the maxilla rises in a sinuous curve to a height of 1·1 inch above the second tooth, making here a blunt angle with its upper border, which behind this declines in a gentle hollow curve to a height of ·45 inch above the last tooth. Above this tooth, at the height of ·35 inch, the surface of the maxilla is angulated, and a strong triangular process, at least ·6 inch long, passes backwards. The uncertainty whether a narrow line obliquely crossing the junction of this process and the body of the maxilla is an accidental crack or a suture leaves it doubtful whether this process is part of the maxilla or a separate bone.

* Perhaps one tooth is missing between the second and the third.

In the body of the maxilla above the third to sixth tooth is a large subtriangular gap; it is the aperture between the orbit and external nostril seen in Mr. Fox s skull. Below this, and extending nearly the whole length of the bone, the outer surface of the maxilla is pierced by a chain of conspicuous foramina, such as are seen in the maxillæ of *Megalosaurus* and *Teratosaurus*.

The divergence of the maxillæ posteriorly partially exposes the palatal apparatus, the hinder part of which lies in the right orbit. The pterygoids (*Pt, Pt'*), not mesially joined, but separated by a fissure, have a remarkably stout body, the posterior border of which bears a very large basisphenoidal process, anteriorly limited by a prominent ridge produced downwards, and terminating angularly at the mesial border. The left pterygoid (*Pt'*) retains the root of a strong quadratic process directed outwards and backwards, in front of which the hollow outer border runs out in an ectopterygoid. In front of the pterygoids the palatals (*Pl, Pl'*) are partially visible, their inner borders also separated by a fissure. The left palatal, which is best seen, is a flat rod ·35 inch wide, with (so far as it is exposed) parallel margins. Its buccal surface is longitudinally grooved.

It is almost superfluous to remark that the skull of *Hypsilophodon*, as was, indeed, shown by Mr. Fox's specimen, is constructed after the lacertilian and not after the crocodilian pattern. In this respect, so far as the material allows of the comparison being made, it agrees with the large skull from Brooke which I brought under the notice of the Society two years ago, and provisionally referred to *Iguanodon Mantelli*.

Spinal Column (fig. 2.)—Crossing the block from right to left, at a little distance from the skull, is a continuous chain of eight consecutive vertebræ. The ventral surface of the centra is uppermost. The first three from the right are too much mutilated for description; the fourth is much abraded, the fifth less so; but the sixth, seventh, and eighth are sufficiently preserved to exhibit all their essential characters. These three last centra are inseparably anchylosed, every trace of their primitive separateness (which is still evident between each of the central (1*s*, 2*s*) to their right) has quite disappeared. The seventh and eighth centra are further distinguished by the confluence of the expanded distal ends of their transverse processes. These two marks—confluence of the vertebral centres of the outer ends of the transverse processes—make it certain that the seventh and eighth vertebræ are part of the sacrum. The sixth vertebra (*L*) has distinct transverse processes which stand out from the neural arch in the form of flattened, tapering blades, ·4 inch long. Confluent with that border of the transverse processes furthest from the sacrum, at their union with the neural arch, is a pair of articular processes, the articulating surfaces of which have an upward and inward aspect; this aspect and their position prove them to be *præ*zygapophyses (*Prz.*). A vertebra whose centrum has coalesced with that of a next sacral, which yet has its own separate transverse processes, and also whose articular processes *furthest* from the sacrum bear the characters of *præ*zygapophyses, must precede the sacrum and cannot follow it; the sixth vertebra must in fine be the last lumbar.

The length of this centrum is rather less than ·9 inch, the same as that of the fifth and fourth centra. Its form is cylindric, its contour transversely convex, and longitudinally hollow, the middle slightly contracted and the ends swollen, particularly that which is anchylosed to the first sacral. Its transverse diameter at its middle is ·6 inch, at its front end ·8, and at its posterior end somewhat more. The transverse processes of the second, third, and fourth lumbar vertebræ have slender ribs anchylosed to their extremities, a distinct knot marks the union of dia- and pleurapophysis. They differ in this respect from the corresponding vertebræ in the Alligator (*A. lucius*) and other existing crocodilians, in which the traces of the primitive separateness of the transverse process and rib disappear with the maturity of the individual.

The determination of the first lumbar carries with it that of the next succeeding vertebra, it is the first sacral (1 *s.*); we have then the first, and not the posterior moiety of the sacrum. The first and second sacral centra are much smaller than the last lumbar, a similar difference of bulk obtains in the sacrum assigned to *Iguanodon Mantelli*; but this difference does not extend to their figure, which has a general resemblance to that of the lumbar vertebræ. It too is cylindroid, constricted at the middle and expanded at its end, which gives the lower contour of the chain a sinuous outline, hollow at the middle of the centra and convex at their coalesced extremities. The swelling which marks the junction of the coalesced centra is not a uniformly tumid nodal ring; but it is greatest at the union of the sides and inferior surface, forming here a pair of small elevations similar to those in the reputed sacra of *Iguanodon Mantelli* and *Hylæosaurus*. The transverse process of the first sacral vertebra springs from the junction of this vertebra with the last lumbar, standing out from here vertically to the axis of the sacrum. It is remarkably stout, the antero-posterior diameter of its root is ·6 inch; its anterior contour merges into the lateral contour of the last lumbar centrum, greatly increasing the apparent bulk of this. At ·5 inch distance from its origin, it bends backwards nearly at a right angle to its first direction, and joins the dilated outer end of the second transverse process springing from the union of the second and first centra, and it includes with this a large subcircular loop. A third transverse process in like manner abuts on the junction of the third and second sacral centres, and from two of the loops with the second and fourth transverse processes, making in all three of those loops or nerve-foramina; but the third and fourth centra are missing, the third having been broken off just behind its union with the second. Against the strong buttress formed by the confluent dilated ends of the transverse processes on the right side lies a fragment of the right ileum (*Il.*).

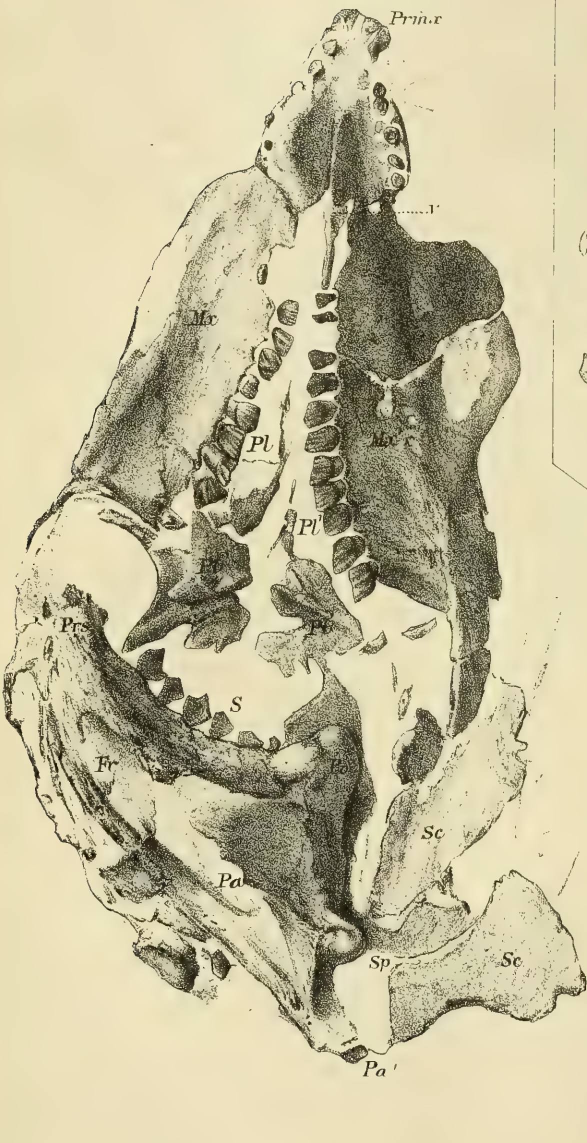
Below this chain of vertebræ lies a second chain of seven smaller vertebræ with part of a sacrum including four centra. It appeared so unlikely that this should be part of the spinal column of a second individual, and so probable that it might be the posterior moiety of the near-lying larger sacrum with part of the tail, that at first I rather hastily imagined it to be such; but unwilling to leave it doubtful, I laid bare the articular and transverse processes of the two vertebræ next the sacrum, which proved them to be lumbar. After this I could not resist the conviction that I had investigated in the same block of stone the remains of two distinct individuals; the smaller sacrum repeats all the essential features of the larger one. The third centrum (3 *s.*), missing in that, is here well preserved, as is also the second; but the first and the last lumbar centra are badly mutilated. The third lumbar centrum is better preserved than any other; its lateral surface is less convex and more plane vertically than the corresponding part of the first lumbar centrum of the larger individual.

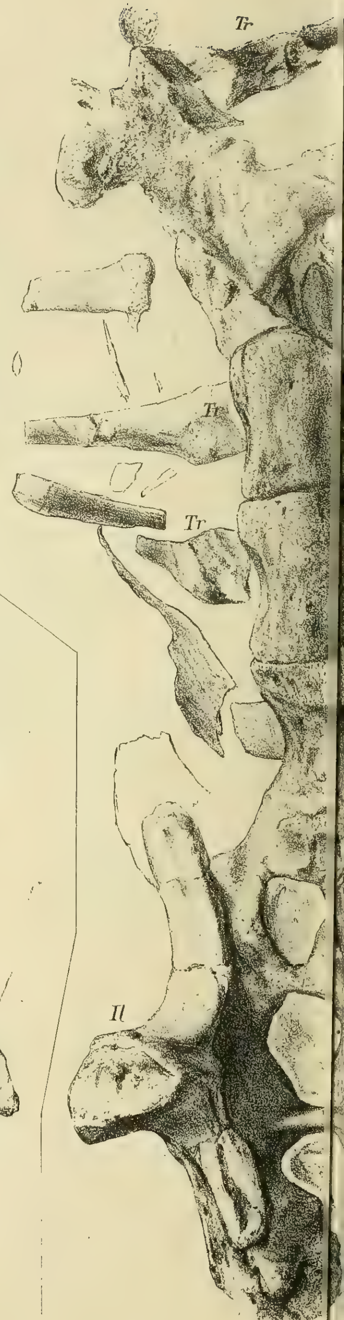
From beneath the right side of the sacrum, partly hidden by a fragment of a pelvic bone, the proximal half of the right femur projects (*Fe.*). Its inner trochanter is well preserved, wanting only the thin triangular lower angle. At its inner side is a very distinct shallow pit. Near the skull and beneath the larger chain of vertebræ, I found several very thin bony plates having one surface granular, the other smooth and furrowed by a vascular net. Their shape was irregularly polygonal; and their size varied much, some attaining an area of about 1 square inch. I regard them as thin scutes (fig. 1, *sc.*).

Prof. Owen has taken exception (Quart. Journ. Geol. Soc. vol. xxix. p. 531) to the generic distinctness of *Hypsilophodon,* and maintained its identity with the genus *Iguanodon,* basing his argument mainly on the similarity of their compressed, ridged teeth, on the peculiar mode in which these wear down, and on the spout-like form of the edentulous anterior extremity of the mandible in both. Fully recognizing these points of structural agreement as evidence of a very close affinity, it appears to me that there remain so many and so great differences as to fully justify the adoption of the separate genus *Hypsilophodon.* As I stated fully in my first note what appeared to me the chief structural differences, it is unnecessary to recapitulate them here; they were chiefly those presented by the limbs, and had respect to their form and proportions, and to the number of toes. In his paper of November 10, 1869, Prof. Huxley noticed certain vertebral differences; but his comparison did not extend to the sacra, this segment of the spinal column being hidden in the Mantell-Bowerbank fossil, the subject of the paper. I have therefore taken the opportunity which my recent acquisitions afford, to compare my *Hypsilophodon* sacra with the type specimen of the *Iguanodon-Mantelli* sacrum figured in the 'Fossil Reptilia of the Wealden Formation'*. The result is that I find the form of the vertebral centrum quite different, being cylindroid, rounded below in *Hypsilophodon,* laterally compressed, so much as to be angulated or almost keeled below, in *Iguanodon*; this difference seems to me of higher than specific value.

* Fossil Reptilia of the Wealden Formation, order "Dinosauria," p. 11.

Fig. 1.

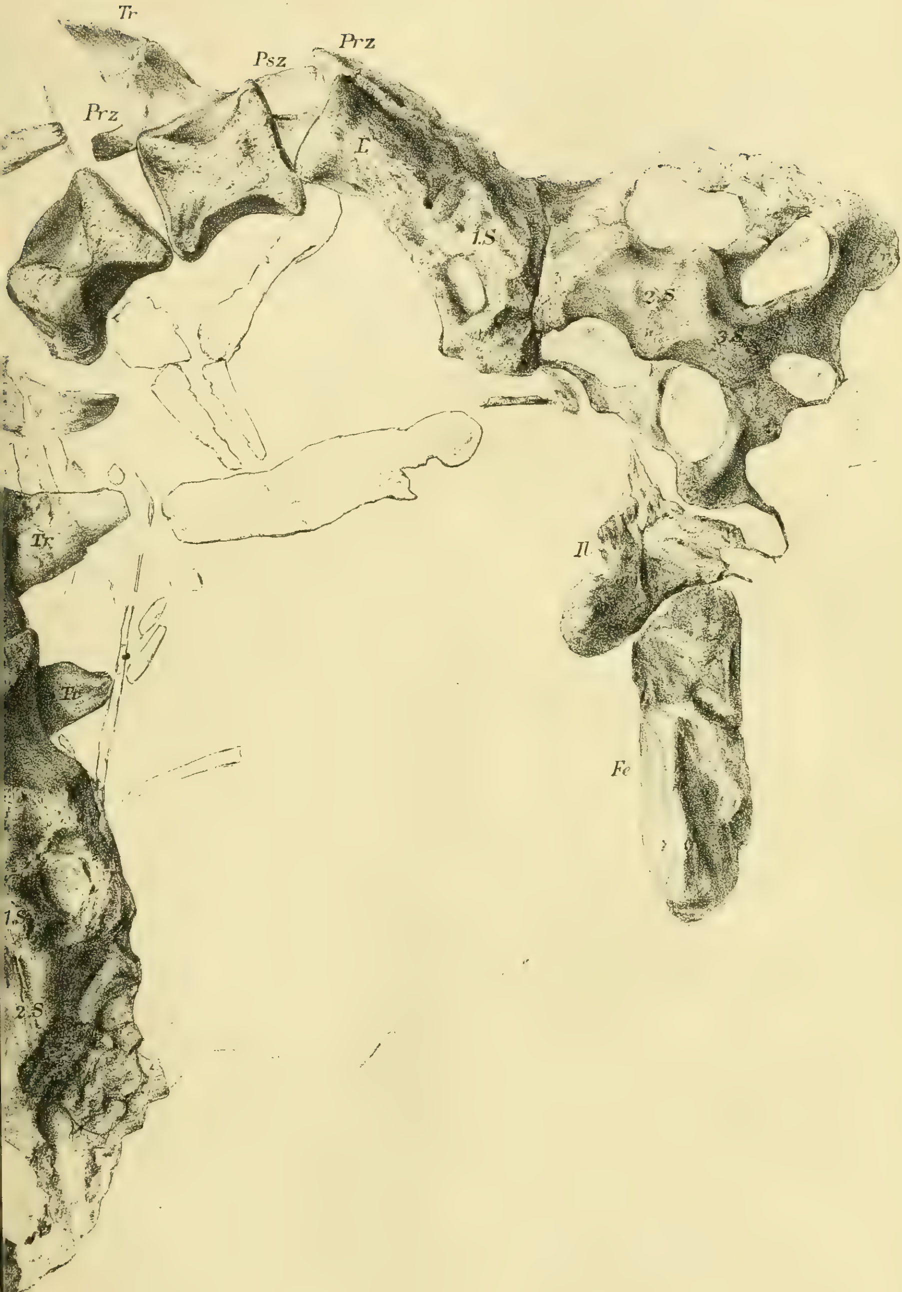




G.H.Ford & C.L.Griesbach.

HYPSILOPH

Fig. 2.



Mintern Bros. imp

ON . FOXII.

Fig. 1.

Fig. 2.

G.H. Ford & C.L. Griesbach.

Mintern Bros. imp.

HYPSILOPHODON FOXII.

EXPLANATION OF PLATE III.

Remains of *Hypsilophodon Foxii.*

Fig. 1. Skull: *Pa.* parietal bone; *Pa'.* its supraoccipital spinous process; *Fr.* frontal bone; *Po.* postorbital process; *Pro.* præorbital process; *Sp.* suspensorial process; *S.* bony plates of sclerotic coat of eyeball lying beneath orbital arch; *Mx.* right maxilla; *Mx'.* left maxilla; *Prmx.* præmaxillæ; *V.* vomer; *Pl.* right palatal bone; *Pl'.* left palatal bone; *Pt.* right pterygoid; *Pt'.* left pterygoid; *Sc.* scutes.

2. *L.* last lumbar vertebra; 1*s*, 2*s*, 3*s*, first, second, third sacral vertebræ; *Prz.* præzygapophysis; *Psz.* postzygapophysis; *Il.* ileum; *Fe.* femur.

Discussion.

Mr. Boyd Dawkins thought there was as much distinction between *Hypsilophodon* and *Iguanodon* as between *Hipparion* and *Equus,* and that this was quite sufficient to be regarded as generic rather than specific. He was not satisfied as to the additional bone in the foot in Mr. Beccles's specimen, but thought it might belong to some other part of the animal. He considered that all the teeth of *Iguanodon* were always ground flat by wear.

Mr. Seeley considered that the author was likely to substantiate his opinions. He pointed out certain differences in the structure and form of the maxillary and other bones of the skull in *Hypsilophodon* and *Iguanodon,* and especially in the maxillary. He attached great importance to the thickening of the enamel at the base of the teeth of *Hypsilophodon,* which approximated to that which was found in some mammals. The teeth commonly reputed to be those of *Iguanodon* might, he thought, belong to different species, if not genera, and showed some divergence in character. The observations on the palatal bones of *Hypsilophodon* were, he thought, calculated to throw great light on the anatomy of Dinosaurs.

5. *Note on an* Astragalus *of* Iguanodon Mantelli. By J. W. Hulke, Esq., F.R.S., F.G.S. (Read November 5, 1873.)

I am indebted to the courtesy of one of our Fellows, E. P. Wilkins, Esq., of Newport, Isle of Wight, for the opportunity of exhibiting this remarkable astragalus of Mantell's *Iguanodon*, a bone not contained in the rich series of remains of this Dinosaur preserved in the British Museum, and, so far as I can ascertain, hitherto unknown. Mr. Wilkins acquired it several years ago with other reptilian fossils obtained from the cliffs in Brixton Bay; and last September, when I paid a hasty visit to his collection, he showed it to me as a bone which had much puzzled him, and which he had been unable to determine. On learning its extreme interest, he anticipated my wish for a sketch of it by suggesting that I might take it with me to London and bring it under the notice of the Geological Society.

It has a depressed oblong figure, measuring in its long axis between the extreme limits $9\frac{1}{2}$ inches, and in its short axis $5\frac{1}{2}$ inches. The under surface has the regular pulley-shape characteristic of a movable hinge-joint (fig. 1). A well-marked median constriction separates the lateral portions, the inner of which is rather more swollen than the outer. The upper surface (fig. 2) has an irregular unsymmetrical shape, adapted to that of the distal end of the tibia of Mantell's *Iguanodon*. The applied surfaces of astragalus and tibia must have so interlocked as to have prevented all motion between them. A strong ridge passing between the anterior and posterior margins divides the upper surface into a larger antero-internal and a lesser postero-external moiety. The former of these is a wide trough strongly concave from back to front. The outer moiety slants steeply down from the dividing ridge, and it descends much lower than the general level of the inner half of the same surface, than which it is also much narrower. The inner half looks upwards, backwards, and inwards; and the outer half looks upwards, forwards, and outwards. The downward slope of the outer moiety of this surface renders the outer border of the bone very thin; it is indented at its middle by a notch; and in its present condition it does not show any mark of an articulation with an os calcis. The inner border of the bone is so stout that it might be properly termed a surface; it has a vertical depth of about $2\frac{1}{2}$ inches. The posterior border, less stout, rises quickly from its outer end, where it includes a right angle with the outer border to the ridge which divides the upper surface; and from here it curves gently downwards, rising again at its inner end (fig. 3). The anterior border, thinner than the posterior, rises from both ends in the form of a blunt lip, which belongs more to the inner than to the outer moiety of the bone (fig. 4), and was received into the entering angle and groove present in the anterior surface of the distal end of the tibia. The base of this lip in the present specimen has been fractured and pressed backwards so as to make the outer edge of the lip now appear

Fig. 1.—*Under view of Astragalus of* Iguanodon.

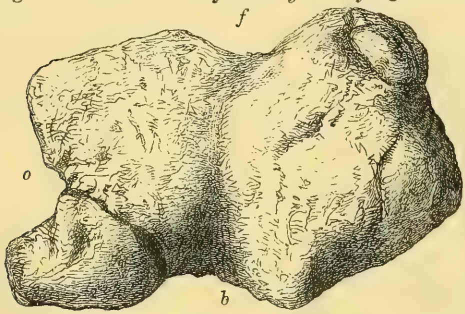


Fig. 2.—*Upper view.*

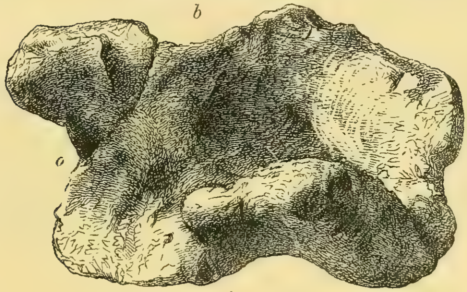


Fig. 3.—*Posterior view.*

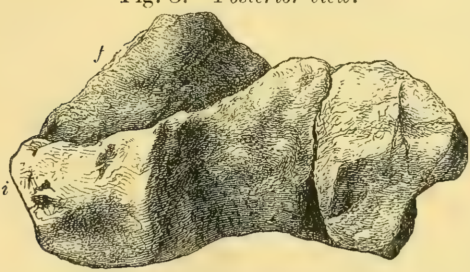
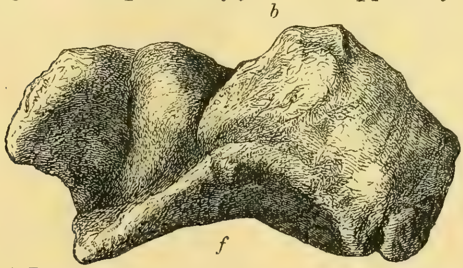


Fig. 4.—*Oblique view of front and upper surface.*



i. Inner side. *o*. Outer side. *b*. Back. *f*. Front.

continuous with the end of the ridge that divides the upper surface; but when undistorted, the ridge ended, not at the outer edge, but on the posterior surface of the lip. This lip clearly represents the ascending process of the avian astragalus.

To those who were present in June 1870, when Professor Huxley made his valuable communication "On the Affinities between the Dinosaurian Reptiles and Birds," any comments upon the bone will be superfluous; but for others who are not acquainted with that paper, I may state that, besides its value as a distinct addition to the anatomy of *Iguanodon*, it has an additional interest as constituting another link in the chain which joins these two classes. In all extant reptiles, and, excepting the Dinosauria, in all fossil ones which have a foot capable of being flexed and extended on the leg, this hinge-movement occurs between the leg-bones and the astragalus; but in the Dinosauria the tibia and the astragalus were tightly interlocked, and the movable ankle-joint was between the astragalus and the next distal segment of the tarsus, which is its position in birds. In most of these, however, the separateness of the astragalus and the tibia disappears at an early age; only in the Ratitæ does it continue to maturity. In the New-Zealand Dinornithidæ and their living successors, the Apterygidæ, I have seen it present in fully grown skeletons. In the Dinosauria the distinctness of these bones, transient in birds, persisted throughout the whole life of the individual.

6. *The* DRIFT-BEDS *of the* NORTH-WEST OF ENGLAND.—*Part* I. SHELLS *of the* LANCASHIRE *and* CHESHIRE LOW-LEVEL BOULDER-CLAY *and* SANDS. By T. MELLARD READE, Esq., C.E., F.G.S. (Read November 19, 1873.)

CONTENTS.

1. INTRODUCTION.

BEFORE treating of the stratigraphical distribution of the Low-level Boulder-clay and sands of Lancashire and Cheshire in which the shell-fragments occur, I have thought it better to discuss first, by the light of the fragments themselves, the geographical distribution of the species represented, their mode of occurrence and condition, and the nature of the matrix in which they are found—some of the problems involved in an accurate interpretation of the glacial-marine phenomena of the drift of the north-west of England.

To enable you to understand the character of the drift from which the shells were taken, I exhibit a section of the Bootle Lane Station cutting (fig. 1), in which most of the beds seen about Liverpool are typically represented. The majority of the shells have been derived from clay answering more nearly to No. 7 than to the others. No distinction, however, can be made on palæontological grounds between any of the various beds, which I have reason to think are only local developments of one system. The beds are as follows, in ascending order:—

1. Pebble-beds of the Trias (*Bunter*).
2. Shattered rock.
3. Red Sand, with tightly compacted rubble and débris of the Trias. (Ground-moraine equivalent of the Scotch till.)
4. Lowest bed of Boulder-clay (unstratified); largely composed of the red sand, containing rounded and subangular pebbles and boulders, mostly striated, of mountain-limestone, granite, syenite, Silurian grits, traps, and decomposed greenstone, &c. Also shell-fragments, as shown on the list and marked (Lower Clay), apparently quietly deposited on the red sand. A few boulders rest on the red sand.
5. Stratified sand and shell-fragments. This bed splits in two and is separated by the Lower Clay under the bridge to the S.W., the Lower Clay here resting upon yellow sand (rock débris). At the N.E. end, at *a*, it is divided by a bed or tongue of the Lower Clay. At *g* is a small bed of shingle, situated at the thinning out of the Lower Clay.

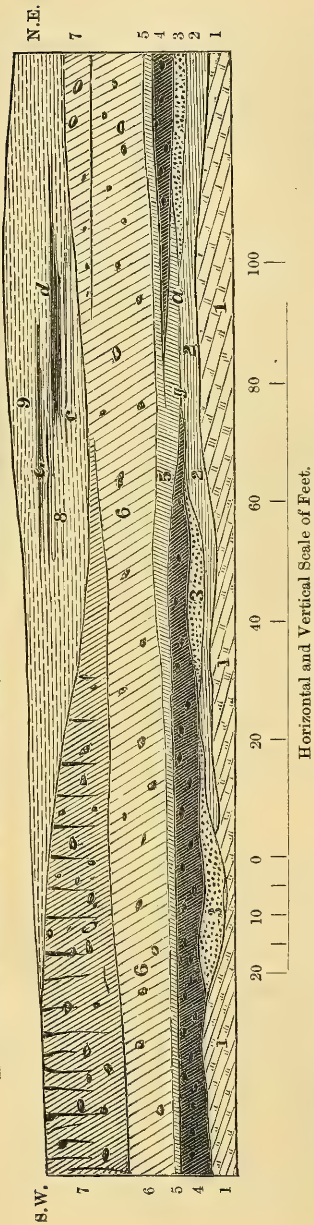


Fig. 1. *Section at Bootle-Lane Station.* (Surface-level about 120 above O. D.)

6. Bed of fine unctuous clay or marl, laminated for a few inches where it rests on sand below. Above this it is homogeneous, unlaminated, containing a small proportion of sand, and having boulders, similar to bed 4, sparsely distributed through it; contains shell-fragments. It is of a bright red brown, shining when cut with a spade. A similar clay was got out of the Huskisson Branch Dock. When washed it is shown to contain small rounded gravel.

7. The ordinary brick-clay from which most of my shells have been taken, contains more stones than No. 6, and more subangular and striated stones than No. 4. It is in constitution intermediate between 4 and 6. No. 6 imperceptibly shades into No. 7.

8. Sand-bed. At *c* containing bands of stratified clay; it is here of a red and orange colour. *d* is an intercalated bed of clay and gravel. *e* is stratified sand with thin beds of sandy blue clay.

9. Stratified yellow sand. In the upper part this contains thin beds of peat, and belongs to the "Washed Drift sand" of my "Postglacial Geology of Lancashire and Cheshire." It in fact becomes subaerial; it is capped by surface-soil*.

* Specimens of beds 4, 5, 6, and 7, were kindly examined microscopically for me by Mr. David Robertson, F.G.S., of Glasgow. He sends me the following list of Foraminifera, and says, "It does not appear that the various beds need be kept separate, seeing that there is nothing in particular in the one bed that is not in the other. . . . . *Cytheridea papillosa*, Bosquet, is the only ostracod that need be noticed, which is moderately common. There are one or two other imperfect forms not yet made out, but whose absence can be of little consequence. *Cytheridea papillosa* is not

2. Localities in which the Shells were found.

Toxteth Park.—The whole of these specimens were taken from the brickfields, and were distributed through the clay. There are thirty species. Elevation about 120 feet above ordnance datum.

Kirkdale Upper Brickfields.—Most of these specimens were taken from the clay in the brickfields near to the Kirkdale Industrial Schools, just above Bootle-Lane Station. Level about 125 feet above O. D. (16 species).

Kirkdale Lower Brickfields.—These occurred in the brickfields between the latter place and Sandhills Station. The shells are very sparsely distributed through the clay (9 species).

Bootle-Lane Station.—These shells, though belonging to the same locality as the last two, were taken from the railway-cutting, where the distinction of beds could be observed. The upper beds correspond with the beds of the Kirkdale brickfields. The shells of the lower bed were collected for me mostly by one of the men working at the excavations. Surface about 120 feet above O. D. 14 species in Lower clay, 8 in Upper clay.

Bootle Northern Outlet Sewer.—Surface-levels are between the 25 and 50 feet contours. The shells were all picked by me from the clay thrown out of the excavations. It was pretty rich in shells. To all appearance the bed was like the preceding brick-clays. A nest of decomposed greenstone boulders occurred at one spot. No. of species, 26.

Garston.—These were picked promiscuously out of the railway-cutting and dock excavations. Those from the dock were below high-water mark (9 species).

River Dee.—Taken from the face of sea-cliff between Dawpool and West Kirby, 9 species. Mr. Mackintosh has given a list of fifteen species from the lower Boulder-clay, thirteen of which I have marked Δ in this column; the other two species are *Scrobicularia alba* and

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uncommon in our Scottish glacial clays, raised beaches, and in the present surrounding seas.

In sample of bed No. 4 there were one Echinus-plate and some small pieces of Polyzoa, *Salicornaria.*

Foraminifera.

1. Biloculina ringens, *Lamk.*
2. Quinqueloculina seminulum, *Linn.*
3. —— Ferussacii, *D'Orb.*
4. Lagena sulcata, *W. & J.*
5. —— globosa, *Mont.*
6. —— marginata, *Mont.*
7. —— squamosa, *Mont.*
8. Polymorphina compressa, *D'Orb.*
9. Bulimina pupoides, *D'Orb.*
10. Discorbina rosacea, *D'Orb.*
11. Truncatulina lobatula, *Walker.*
12. Rotalia Beccarii, *Linn.*
13. Polystomella crispa, *Linn.*
14. —— striato-punctata, *F. & M.*
15. Nonionina asterizans, *F. & M.*
16. —— depressula, *W. & J.*

This last species is the prevailing form; *Lagena sulcata, Polystomella striato-punctata,* and *Nonionina depressula* are moderately common; the others are represented by ones and twos; none exceeds three."

Lacuna divaricata (Q. Journal of the Geological Society, vol. xxviii. p. 391).

N.E. of Edge-Hill Station.—A portion of these were obtained by me out of the brickfields; the remainder from the railway-cutting just above. Level about 175 feet above ordnance datum. The clay is similar in constitution to that of all the preceding brickfields. Number of species in railway-cutting, 37; brickfields, 14 species.

Warrington.—These shells were found by Mr. Pears, and are now in the Warrington Museum. They are described by Mr. Paterson as occurring in a sand-seam on the Liverpool Extension Railway between Bewsey and Sankey. I have myself examined the section, which consists of stratified beds of sand, included in the Boulder-clay. I am indebted to Mr. Darbishire for the correction of the list, the one published by Mr. Paterson being incorrect; he informs me that the condition of the shells bears a striking resemblance to those of the Blackpool Middle sands. Surface-level about 50 feet above O. D.

Birkenhead tramway-road, 13 species.

Gas-works, Linacre.—About 50 feet above O. D. These were obtained by Mr. Isaac Roberts, F.G.S., during the excavations for the gas-holders; all of them appear to have been taken from the clay (see Proceedings of the Liverpool Geological Society, 1870–1, pp. 68, 69). The individuals were more perfect than most of those found by me.

Various other Localities about Liverpool.—These were found by Mr. G. H. Morton, F.G.S., and others, and are given by him in the Proceedings of the Liverpool Geological Society, 1871–72, pp. 92 & 93.

The last column represents shells of the list, which are to be found now on the Southport or Formby shores. I am indebted to Mr. Chas. Brown, of Southport, who thoroughly worked out the conchology of the district, for these particulars. Those marked *a* were found by him alive.

Note.—For purposes of comparison, I have given Mr. Darbishire's list of Moel Tryfaen, Macclesfield, and Blackpool shells; but in addition to these there are the following species and varieties, representatives of which have not been found by me, viz.:—

Pholas candida.
Mya arenaria.
Corbula nucleus.
Tellina proxima.
Mactra elliptica.
Venus casina.
Artemis lincta.
Astarte crebricostata.
Cardium aculeatum.
—— norvegicum.
—— fasciatum.
Mytilus edulis.
Nucula.
Arca lactea.
Patella vulgata.
Dentalium abyssorum.
Fissurella reticulata.
Trochus cinerarius.
Littorina rudis.
—— littoralis.
Lacuna vincta.
Natica clausa.
—— monilifera.
Trichotropis borealis.
Fusus gracilis.
Trophon barvicensis.
—— scalariformis.
—— Gunneri.
Mangelia nebula.
—— pyramidalis.
Cypræa europæa.

[*To face page* 30.

AY ABOUT LIVERPOO

ales, as well as species found.

No.	Isaac Roberts's List.	Extracted from Morton's List.	High	pth, Range, &c.
32.	*	O	*a*	(Among stones and Fuci, and ı-water mark of neap tides, (*S. Wood*); C. and R. Crag ms; muddy and weedy locali- . Chief habitat, the shallower great numbers in from 7–10
33.	*	....	*v r*	00 fathoms; affects gravelly
34.	....	?	......	nd 650 fathoms; muddy sand, e coast of Northumberland. nd of wide distribution.
35.	....	O	*r*	entiful in the Irish Sea; be- north.
36.	*	O	*f*	low tide-marks; most variable
37.	*	O	*r*	l, sand (verge of littoral and an zones).
38.	....	O	*v r*	fathoms; gravelly and stony ark to 145 fathoms (*Beechey*).
39.	*	O	*f*	ter to 100 fathoms. Extended g glacial epoch.
40.	....	....	*c*	Pliocene (extinct in Mediter- s, living on various kinds of shell-banks.
41.	*	....	......	athoms.
42.	*	....	*f*	st generally diffused glacial (Stony ground in the lami- eep-water zones, *Jeffreys*.)
43.	....	....	*f*	. Essentially northern. Ten- –150 fathoms, *Jeffreys*).
44.	*	....	*v r*	nd coralline zones.

rcely range south of the Bri
t most prolific in Celtic and
d mostly increasing in num
land and Boreal America.

LIST OF SHELLS FROM THE BOULDER-CLAY ABOUT LIVERPOOL.

Comparative columns are given, showing the occurrence of the same species in other localities in the N.W. of England and Wales, as well as species found by others in the Low-level Boulder-clays of Lancashire and Cheshire.

No.	Species.	Low-level Lancashire Boulder-clay. Found by Mr. T. Mellard Reade. Toxteth Park.	Kirkdale. Upper Brickfield.	Kirkdale. Lower Brickfield.	Bootle-Lane Station. Lower Clay.	Bootle-Lane Station. Upper Clay.	Bootle Northern Outlet Sewer.	Garston.	River Dee. Marked Δ, found by Mr. Mackintosh.	N.E. of Edgehill Station. Brickfield.	N.E. of Edgehill Station. Railway-Cutting.	Birkenhead.	Paterson's Collection. Warrington.	Isaac Roberts's List. Linacre Gas-works.	Extracted from Morton's List. Various other localities about Liverpool.	Mr. Darbishire's List. High-level Sands and Gravel. Moel Tryfaen.	Macclesfield. Older.	Macclesfield. Newer.	Low-level Boulder-clay. "Middle Drift." Blackpool.	Recent. Now found on Southport shore. Mr. Charles Brown. Shells marked "a," found alive.		Habitat, Depth, Range, &c.
1.	Pholas crispata, *Linné*	vr	......	......	......	......	......	......	......	......	......	......	......	......	......	......	vr	......	......	• a	2	C. Crag. Burrows in various kinds of rock, clay, gypsum, and peat (*Jeffreys*).
2.	Saxicava rugosa, *Linné*	......	......	......	......	......	r	......	......	......	vr	......	......	......	......	r	......	......	......	•	2	C. and R. Crag. Burrows in limestone, chalk, and sandstones. Most generally distributed glacial shell (*Forbes*). Vertical range great, near low water to 145 fathoms.
3.	—— norve ca, *Spengl.*	......	......	......	......	......	......	......	......	......	vr	......	......	......	......	......	......	......	......	......	4	C. and R. Crag. 30 fathoms at Durham, and 82 fathoms at Shetland (*Jeffreys*). Abundant in the glacial clays of the Clyde, with valves together as if *in situ*. Only one living specimen has been found on the Norwegian coast (*Sars*). A few specimens have been obtained off the coast of Northumberland and Durham. Fossil in Mediterranean.
4.	Mya truncata, *Linné*	f	f	......	f	......	f	f	f	f	f	•	□	......	......	f	f	r	r	• a	1	C. and R. Crag. Mediterranean in glacial epoch. Sand and mud and gravel. Littoral and deep-sea down to 145 fathoms. Clyde beds *in situ*.
5.	Psammobia ferroënsis, *Chemn.*	r	r	......	......	......	r	......	......	......	r	•	□	......	......	......	f	......	......	•	2	C. Crag. Rare in glacial beds (*Forbes*). Sand and mud, 3–90 fathoms.
6.	Donax vittatus, *Da Costa*	vr	......	......	......	......	......	......	......	vr	vr	......	......	......	......	vr	vr	......	......	• a	2	Sandy shores. Littoral, near low water to 25 fathoms. Few of our bivalves more universally diffused on British shores.
7.	Tellina balthica, *Linné*	a	a	a	a	a	a	a	a Δ	a	a	•	□	*	○	r	c	f	c	• a	2	First appeared in the glacial epoch. Sandy bays and inlets. "Unerringly marks the shallow water under which Pleistocene formations accumulated" (*Forbes*).
8.	Mactra solida, *Linné*	r	......	r	r	......	r	......	Δ	r	f	•	□	......	......	r	r	r	r	•	1	C. and R. Crag. Usually littoral. Sand and gravelly sand, near low-water mark to 15 fathoms; 35 fathoms exceptional.
9.	Lutraria elliptica, *Lamarck*	f	f	f	f	......	......	......	......	......	f	......	......	*	......	......	vr	......	......	•	2	C. and R. Crag. Oozy sand and mud. Low water of spring tides to 15 fathoms; 12 fathoms in Anglesea. Abundant round the British coast.
10.	Scrobicularia piperata, *Gmelin*	r	......	......	......	r	......	......	r Δ	r	......	......	......	......	......	......	......	......	......	• a	2	R. Crag. Littoral. Estuarine mud where fresh water occasionally flows over them. Beds of mud and clay at low-water mark, and as deep as 4 fathoms (*Jeffreys*).
11.	Venus chione, *Linné*	......	......	......	r	......	r	......	......	r	f	......	......	......	......	......	f	......	......	......	5	C. Crag. 12–20 fathoms in Carnarvon Bay. "Returned southwards during prevalence of glacial conditions" (?) (*Forbes*).
12.	Tapes virgineus, *Linné*	vr	......	......	......	......	......	......	......	......	......	......	......	......	......	vr	......	......	......	......	2	C. and R. Crag. Littoral, to 145 fathoms. It appears to be more of a southern than a northern species (*Jeffreys*).
13.	Venus gallina, *Linné*	r	r	......	......	......	r	r	......	......	r	......	......	......	......	vr	r	vr	r	• a	2	Sandy coasts, near low water to greatest depths (85 fathoms, *Jeffreys*). Appears to have commenced its existence during "Newer Pliocene."
14.	—— exoleta, *Linné*	r	r	......	......	......	......	......	......	......	......	......	......	......	......	vr	......	......	......	•	2	C. Crag. Low water to 80 fathoms. Sandy bays.
15.	—— lincta, *Pult.*	......	......	......	......	......	......	......	......	......	vr	......	......	......	......	r	......	......	......	......	2	C. and R. Crag. Sand, sometimes mixed with mud; low-water mark to 90 fathoms.
16.	Cyprina islandica, *Linné*	c	c	c	......	......	c	......	c	c	c	•	□	*	⊙	c	c	......	f	•	1	Crag. 5–80 fathoms (low water to 100 fathoms, *Jeffreys*). Extended to the Mediterranean during glacial epoch. Very variable in form, being of wide range.
17.	Astarte sulcata, *Da Costa*	......	......	......	......	......	r	......	Δ	......	......	......	......	......	......	......	......	......	vr	......	1	Rare in Crag. Sand and mud, 7–85 fathoms (145 fathoms off Mull of Galloway).
18.	—— elliptica, *Brown*	r	......	......	......	......	f	......	......	......	r	......	?	......	......	f	r	......	f	......	3	Crag (only on authority of Woodward's Norwich-Crag list). 5–10 fathoms, mud (10–40 fathoms, on muddy bottom, *Forbes*).
19.	—— compressa, *Montagu*	......	......	......	r	......	r	......	......	......	r	•	?	......	......	c	......	......	vr	......	3	C. and R. Crag. 7–40 fathoms; 70 fathoms, Zetland Seas: muddy bottom. Found in 550 fathoms, cold area north of the Hebrides (*Jeffreys*). Sand, often mixed with mud.
20.	—— borealis, *Chemn.* [This I consider to be the typical fossil of the Boulder-clay, and I have found it in all localities.]	c	c	c	c	c	c	c	Δ	......	c	•	□	......	......	c	c	......	vr	......	4	Crag. Fresh single valve taken in 80 fathoms. The most southern known limit of its habitation is Kiel Bay, in the Baltic (*Jeffreys*).
21.	Cardium echinatum, *Linné*	c	c	c	c	c	c	......	c Δ	c	c	•	......	*	......	r	f	r	r	•	2	R. Crag. 7–80 fathoms. Mud and sand, and muddy gravel.
22.	—— tuberculatum, *Linné*	......	......	......	......	......	......	......	......	......	vr	......	......	......	......	......	......	......	......	......	5	Sandy bays. Low water spring tides to 12 fathoms.
23.	—— edule, *Linné*	a	a	a	a	a	a	a	a Δ	a	a	•	......	......	○	c	a	r	c	• a	2	R. Crag. Littoral, low-water mark to a few fathoms. Sand. Replaced in Greenland and Boreal America by *Cardium islandicum*.
24.	Mytilus modiolus, *Linné*	f	......	f	r	......	f	......	r	f	f	•	......	......	......	r	r	......	......	• a	1	Crag. Low water to 60 fathoms. Small at great depths. Frequents gravelly and muddy localities, most frequent from 7–30 fathoms.
25.	Leda pernula, *Müller*	vr	......	......	......	......	vr	......	Δ	vr	vr	......	......	......	......	r	......	......	......	......	4	Not in Crag. Mr. Jeffreys dredged a young live specimen in 80 fathoms, off the Shetland Isles. Arctic and Scandinavian seas, from 10–100 fathoms.
26.	Pectunculus glycymeris, *Linné*	r	......	......	......	......	r	......	......	f	r	......	......	......	......	vr	vr	......	......	......	2	Dies out in upper beds of Crag. 15–60 fathoms (7–90 fathoms, sandy and shelly gravel and Nullipore, *Jeffreys*).
27.	Pecten opercularis, *Linné*	r	......	......	......	......	......	......	......	......	r	......	□	*	......	r	vr	r	......	• a	2	C. and R. Crag. 5–100 fathoms. Common to all sandy coasts.
28.	Ostrea edulis, *Linné*	c	c	......	......	......	f	......	......	......	r	......	......	*	○	vr	vr	......	r	• a	2	C. Crag; lower beds of Red Crag. 12–20 fathoms (low water to 45 fathoms, *Jeffreys*).
29.	Dentalium entalis, *Linné*	r	......	......	......	......	r	......	......	......	r	......	□	......	......	vr	r	......	......	•	2	R. Crag. Sand, or sandy mud, 3–100 fathoms. 145 fathoms off the Mull of Galloway (*Jeffreys*).
30.	—— tarentinum, *Lamarck*	......	......	......	......	......	......	......	......	......	vr	......	......	......	......	......	......	......	......	......	5	C. and R. Crag. Low water to 25 fathoms.
31.	Littorina litorea, *Linné*	r	......	......	......	......	......	r	Δ	......	r	......	□	*	○	f	......	vr	......	•	1	Numerous varieties in R. Crag. Liable to great changes in shape and colour. (Among stones and *Fuci*, and on rocks below high-water mark of neap tides, *Jeffreys*.)
32.	Turritella terebra, *Linné*	a	a	a	a	a	a	a	a Δ	a	a	•	□	*	○	a	a	c	......	• a	2	Very rare in the Crag (*S. Wood*); C. and R. Crag (*Forbes*). 4–100 fathoms; muddy and weedy localities in great abundance. Chief habitat, the shallower sea-beds, occurring in great numbers in from 7–10 fathoms.
33.	Aporrhais pes-pelecani, *Linné*	r	r	......	......	......	f	......	......	......	r	......	......	*	......	vr	vr	vr	vr	•	2	C. and R. Crag. 4–100 fathoms; affects gravelly bottoms.
34.	Natica grœnlandica, *Beck*	......	......	......	vr	......	......	......	......	......	vr	......	......	......	?	......	......	*	......	......	3	North of Hebrides, 189 and 650 fathoms; muddy sand, 40–60 fathoms, off the coast of Northumberland. Essentially northern, and of wide distribution.
35.	Murex erinaceus, *Linné*	......	......	......	......	......	......	......	......	......	vr	......	......	......	○	r	f	r	f	•	2	5–30 fathoms. Most plentiful in the Irish Sea; becomes scarcer as we go north.
36.	Purpura lapillus, *Linné*	f	f	......	......	f	f	f	f Δ	......	c	......	□	*	○	f	f	f	r	•	1	R. Crag. Rarely lives below tide-marks; most variable of univalve Testacea.
37.	Nassa reticulata, *Linné*	......	......	......	r	......	r	......	Δ	......	r	......	□	*	○	r	vr	r	f	......	2	C. and R. Crag. Littoral, sand (verge of littoral and upper part of laminarian zones).
38.	—— incrassata, *Ström*	r	......	......	......	......	......	......	......	......	......	......	......	......	○	vr	vr	......	......	•	2	C. and R. Crag. 0–50 fathoms: gravelly and stony ground. Low-water mark to 145 fathoms (*Beechey*).
39.	Buccinum undatum, *Linné*	f	f	......	f	f	f	f	Δ	......	f	•	□	*	○	f	r	r	f	• a	1	C. and R. Crag. Low water to 100 fathoms. Extended to Mediterranean during glacial epoch.
40.	Fusus antiquus, *Linné*	r	......	......	......	......	......	......	Δ	r	r	......	□	......	......	c	r	......	r	• a	1	R. Crag. Sicilian Newer Pliocene (extinct in Mediterranean). 5–30 fathoms, living on various kinds of ground, but preferring shell-banks.
41.	—— islandicus, *Chemn.*	......	......	......	......	......	......	......	......	......	......	......	......	*	......	......	......	......	......	• Crosby.	3	C. and R. Crags. 5–80 fathoms.
42.	Trophon truncatus, *Ström*	r	f	......	......	......	r	......	......	......	f	......	□	*	......	f	f	......	r	......	3	Crag. One of the most generally diffused glacial shells; 5–50 fathoms. (Stony ground in the laminarian, coralline, and deep-water zones, *Jeffreys*.)
43.	Pleurotoma turricula, *Montagu*	......	......	......	......	......	r	......	......	......	r	......	□	......	......	f	f	r	vr	......	1	R. Crag. 3–100 fathoms. Essentially northern. Tendency to vary great (10–150 fathoms, *Jeffreys*).
44.	—— rufa, *Montagu*	......	......	......	......	......	......	......	......	......	vr	......	......	*	......	vr	......	......	......	......	1	Sand, in the laminarian and coralline zones.
	Total	30	16	9	14	8	26	9	9 | 14	14	37	12										

Shells marked 1 are species now living throughout the Celtic region in common with the North seas, and scarcely range south of the British seas.
" " 2 " now living, ranging far south into the Lusitanian and Mediterranean regions, but most prolific in Celtic and North Seas.
" " 3 " still existing in the British seas, but confined to the northern portion of them, and mostly increasing in number of individuals as they approach the Arctic Circle.
" " 4 " now known living only in European seas north of Britain, or in the seas of Greenland and Boreal America.
" " 5 " fossil in the Crag, but now restricted to British and South-European seas.

3. Mode of Occurrence and Condition of the Shells, &c.

The whole of the shells in the appended list, consisting in all of 44 species, occurred distributed through the drift. In nearly every case they were taken from the *clay* beds ; for though in the included sand-seams shells are occasionally met with, they are, as a rule, rare. Being small, fragmentary, and rolled, sparsely distributed through the clay, and not in any case found in zones or beds, it would be very difficult to make a collection from the faces of the clay in excavations; but when the clay is "cast" for brick-making, and has been subjected to heavy rain, the fragments are weathered out and are more readily found. The bulk of my specimens have been obtained in this way by my own hands, and are undoubtedly genuine.

Beds or zones of sands containing shells more perfect in their state of preservation are, however, occasionally met with; more perfect specimens than mine of some of the species have also been found in the clay, such as those taken by Mr. Isaac Roberts, F.G.S., from the excavations for the Linacre Gas-works*. The Warrington shells, which are, according to Mr. Darbishire, in about the same condition as the Blackpool specimens, were (if the locality be correctly described by Mr. Paterson†) taken out of stratified beds of sand and gravel, which I have myself inspected in the excavations of theLiverpool Extension Railway near Sankey Bridges. These stratified beds bear a closer relationship to the sands and gravels of the so-called middle drift at Blackpool than to the clays from which I have obtained most of my specimens.

Strange and puzzling as is the condition of the fragments and their distribution through the clays, it is one of the main peculiarities which should point to a correct interpretation of the way in which these beds of drift were laid down.

Professor Forbes, who has remarked on this in his admirable contribution to the literature of the Glacial period‡, which, even now, for comprehensiveness and grasp is unexcelled, and who is evidently much puzzled to account for the usual fragmentary character of the shells and their tolerably even distribution through the drift, has imagined it to be due to the ploughing up of icebergs or the great rush of ocean-currents§ ; but these suppositions, as I will presently show, cannot be more than a limited and partial explanation of a general and wide-spread phenomenon.

It is worthy of notice that the shells most generally found whole are of a form most calculated to resist pressure, and, in some cases, of quite minute dimensions. *Turritella terebra*, found everywhere in the greatest abundance, is not unfrequently perfect. *Trophon truncatus* and *Pleurotoma turricula* are also found perfect, while the large *Fusus antiquus*, and *Buccinum undatum* are generally represented

* 'Proceedings of the Liverpool Geological Society,' 1870–71. p. 68.

† Procceedings of the Warrington Literary and Philosophical Society.

‡ "Fauna and Flora of the British Isles," Memoirs of the Geological Survey, vol. i. p. 383.

§ *Ibid.* p. 384.

only by well-worn fragments of the columella. *Cyprina islandica* is invariably found in fragments, sometimes angular and sometimes worn, while the hinge, being more adapted to rolling, is usually much rounded and worn. It is quite exceptional to find a perfect valve of a bivalve, and it is confined, as far as my experience goes, to small and strong valves. I had the good fortune to find a perfect valve of *Leda pernula* at Edge Hill*. I have also a perfect valve of *Tellina balthica*, retaining part of the colouring, from the sewer in Thomas Lane, Broad Green. Some few other species occasionally occur more or less perfect; but we may safely say that, as a rule, those only are preserved which, by the peculiarity of their form, or their *minuteness* combined with their form, are fitted to resist pressure or rolling about.

Again, the association of the various species, distributed entirely without order through the clays, shows that they could not possibly have lived together on the same bottom, some being peculiar to sand, others to mud, some to rock, and others to shingle, some requiring deep water, and others shallow; so that the conclusion is irresistibly forced upon us that they must have been to a large extent transported. Had the confusion been due to the ploughing up of icebergs, as suggested by Forbes, the disturbance at each stage of subsidence would not have reached beyond a certain depth below the surface of the sea, and all below that depth would have been free. It is in fact impossible to construct a satisfactory explanation which does not allow for a successively varying depth of sea-bottom from zero up to 1400, and perhaps even 2000 feet. We have, as before shown, every reason to infer that some at least of the bottom beds of the drift, of which I purpose giving you sections and more fully explaining in my second paper, are those originally formed on the first subsidence of the land after the retreat of the ice-sheet to the mountain-districts of the north†. In several examples we see the bottom-clay reposing upon the sand ground-moraine derived from the Triassic rocks, with the line of division as sharply defined as could well be; and resting upon the sand and in the clay are boulders and pebbles, evidently transported from the north, and having their surfaces scratched, indented, and polished‡. This bottom-clay is largely composed of the red sand upon which it rests, and out of which, together with mud from more distant localities, it has been formed. This is the distinguishing difference between the inferior and the overlying clays, and varies from a strongly marked distinction, according to the proportions of the included sand, to a difference of appearance only minute. If, however, we examine the constitution of the clay itself, we find no real or appreciable distinction from that above it; for in both the same distribution of shell-fragments occurs, and the included boulders are

* Now in the possession of Mr. Darbishire.

† The existence of the ice-sheet and the proofs of the statement will be given before the subject is completed. (See also abstract of the author's paper on Glacial Striæ at Miller's Bridge, 'Proceedings of the Liverpool Geological Society,' Session 1872–73.)

‡ These are found 162 feet below the surface at Widnes, or 140 feet below the ordnance datum in the ancient bed of the Mersey. See "The Buried Valley of the Mersey," by the author, in the same volume.

of the same mineralogical type and most probably from the same parent rocks, the larger proportion being scratched and polished. Now assuming, as we are justified in doing, that the lower beds of the Lancashire clays are older than the Macclesfield and Moel Tryfaen drifts*, it is quite evident that in some of the numerous sections I shall show you we ought to find representatives of the deposits which must have taken place at all depths between the two extremes mentioned, both during subsidence and after elevation. That, however, which constitutes the great puzzle, and which led Forbes to infer the drifts to be all shallow-water deposits, is the occurrence of littoral shells, the absence of deep-sea corals, and the extremely similar, not to say identical, character which they all exhibit. It is true one part is more sandy or stony than another, one part contains gravel, and another consists almost wholly of a fine unctuous clay; but throughout are the broken and rolled shell-fragments and the scratched erratic pebbles and boulders.

It is easy, however, to see that the subsidence and reelevation of the land to a vertical extent each way of 2000 feet must, by the deflection of tidal currents (each stage of vertical movement having its own proper system of stream-tides), alternately bring every portion of the sea-bottom under its erosive action. That these tides, assisted by winds and storms, must act on the coast-lines and sweep off the shells thrown up on the beach, again to distribute their fragments over the sea-bottom, is equally evident. That tidal action is effective at much greater depths than is generally admitted, I have satisfied myself, and, having carefully studied the question, shall, I hope, at a future time bring before you sufficient facts to prove it. It also presents a probable explanation of much of the curious bedding and stratification met with so generally in the Drift. From the condition of many of the boulders and pebbles so irregularly scratched, and from a consideration of the climatic conditions of the period, pointed to by many facts, I infer the prevalence of coast-ice—an additional cause for the distribution and extreme comminution of most of the shell-specimens. It must not be lost sight of, if my explanation of the phenomena be correct, that though the shells are in fragments, they are (unless they are derivative, of which there is no proof) as truly representative of the conditions prevailing at the time of their deposition as if they had been found on the spot where they died.

4. Analysis of the List, Comparison with the present Molluscous Fauna of the British seas, and Inferences therefrom †.

The most generally diffused shell in the Lancashire and Cheshire

* It is necessary to assume this for our present purpose; but the question will be discussed *in extenso* and proof given when I deal stratigraphically with the beds.

† For the identification of most of the shells I am indebted to Mr. R. D. Darbishire, F.G.S., who has with great care gone over from time to time some pounds

Boulder-clays, as well as the one found most frequently perfect, is *Turritella terebra*. *Tellina balthica* comes next in the scale of frequency, but is seldom found perfect. *Cardium edule, C. echinatum,* and *Cyprina islandica*, always found in fragments, follow in the order given; but the typical fossil, the representative of the climatic conditions prevailing at the time the clays were laid down, is undoubtedly in my opinion *Astarte borealis*. Though not the most frequent, it is a common fossil; and I have found it in all the localities mentioned in the list, as well as in other places unrecorded. It has also been found in the same series of clays at Blackpool, Warrington, Chester, and other places, by independent observers. Unlike *Leda pernula*, which, though occurring in the same clays, is rare, or *Saxicava norvegica*, which is represented only by two fragments, *Astarte borealis* may safely be taken as indicative of the then condition of the British seas. According to Mr. Gwyn Jeffreys, "the most southern known limit of its habitation is Kiel Bay in the Baltic." *Astarte compressa, A. elliptica,* and *Trophon truncatus*, also fossils of the clay, though still existing in the British seas, are confined to the northern portion of them, and increase in number of individuals as they approach the Arctic circle. A reference to the list will also show that twelve of the remaining species are northern and Celtic shells, scarcely ranging south of the British seas. Twenty-one range far south into the Lusitanian and Mediterranean regions, but are most prolific in the Celtic and northern seas; while *Venus chione* (several well-marked hinge-fragments of which as well as other fragments I found at Edgehill), *Dentalium tarentinum*, and *Cardium tuberculatum* (only single fragments of which occurred to me) are southern shells.

Though all, with the exception of *Astarte borealis, Leda pernula,* and *Saxicava norvegica*, may be described as Irish-Sea shells, yet, if we make a fair comparison, we shall find that the Boulder-clay assemblage possesses a more northern facies than the present fauna of the British seas. If I may so express it, the area of the Boulder-clay fauna and that of the present British seas overlap; but their *centres* are considerably apart, that of the former being in a higher latitude. To assist in the illustration of this idea, I have given a column showing the species now found on the shore between Southport and Formby, the nearest locality for comparison; and reference to it will show that the most characteristic northern forms are absent. There are in addition also many Celtic and southern forms found on the same beach which are absent in the Boulder-clay.

The presence of *Venus chione* in the low-level Boulder-clays as well as in the Macclesfield drift where it was first discovered by Mr. Darbishire, is certainly a remarkable fact; but it is not an isolated one; for *Cardium aculeatum* and *C. pygmæum*, both Lusitanian forms, are found in the Scotch drift; and in the Irish drift southern forms also

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weight of fragments, and has assisted me in various ways. To Mr. Gwyn Jeffreys I owe the identification of some of the more doubtful species, and a revision of my list.

occur*. If we turn our attention to the east coast of North America, we may find a possible explanation of this curious mixture; for at Cape Cod, in latitude 42°, and, I believe, also in higher latitudes, arctic and southern forms are now dredged up alive from the same bottom†.

5. Position of the Lancashire and Cheshire Low-level Boulder-clays and sands in the Glacial Series.

A comparison of my list with that of the shells from the Middle drift at Blackpool will hardly, I think, establish the hypothesis often broached, that the so-called Middle Drift represents interglacial conditions. No doubt fluctuations of temperature occurred during the laying down of the Boulder-clay series. Though I have found about Liverpool a greater number of northern forms than occur in the Blackpool sands (the latter being, I consider, but a local development of the Drift), it is impossible to draw with safety wide generalizations from the palæontological evidence. On the other hand the so-called Lower Boulder-clay of Mr. Mackintosh at Dawpool‡ has not yielded him a more northern assemblage than the Brick or Upper Boulder-clay of Lancashire has yielded me§. It is partly on these grounds that I have ventured to group together all those beds which are typically represented in the Bootle-Lane Station, under the title of Low-level Boulder-clays and sands. Whether or not there are stratigraphical grounds for their subdivision will be discussed in my concluding paper.

For purposes of comparison I have appended a list of the Moel-Tryfaen and Macclesfield shells‖; but though, when compared with the Liverpool shells, the former shows a more and the latter a less northern facies, I do not think we can safely deduce therefrom the relative ages of the Drift in which they occur. Proximity to the mountains generating the glaciers may have been the cause in the first case, local circumstances in the latter. It is only by a consideration of their structure, position, and stratigraphy, combined with the

* Forbes notes the discovery by Captain James of *Turritella incrassata*, a Crag fossil, a southern form of *Fusus*, and a *Mitra* allied to the Spanish species in the Wexford gravels.

† It must not be lost sight of that glacial conditions in a low latitude would produce extremes of heat and cold greater than would occur in a higher latitude having the same mean annual temperature, and consequently currents of variable temperature would result. Forbes says the distribution of Mollusca depends not on latitude but temperature.

‡ Quart. Journ. Geol. Soc. vol. xxviii. p. 388.

§ See "Notes on various Shells found in Stratified Drift near Macclesfield," Memoirs of the Literary and Philosophical Society of Manchester, Session 1864–65.

‖ The Lower Clay of Bootle-Lane Station is an exact counterpart of the Lower Clay at Dawpool; but that, again, yielded me the same characteristic fossils, as will be seen on reference to the list.

oscillations of level which occurred during their deposition, that the relation of the high-level sands and gravels to the low-level Boulder-clays can be satisfactorily made out; and when this is done the palæontological evidence may very properly be taken into account.

Considering, then, all the low-level beds as a group, what position do they hold in the Glacial series? Before answering this question it will be necessary to glance at the condition of the base-rock upon which they generally rest. It may be safely asserted that wherever the Boulder-clay is removed in Lancashire and the rock exposed, if it is fitted to retain striations and groovings, there they are sure to be found. Where the rock is unfitted to receive them, it is, so far as my observation extends, ground to powder, broken up into closely compacted rubble, or otherwise displaced or shattered. Every thing bears evidence of the passage of an ice-sheet over the country in a north-westerly direction; and this, it is needless to say, represents intense glacial conditions. When, however, we come to the Marine Drift, if palæontological evidence is of any value, the climate must have been much ameliorated, being probably such as is found in the northern parts of Labrador. Thus, then, if my premises be correct, there must have been a great break or lapse of time between the cutting of the striæ and the deposition of the Marine Drift. If so, during this period the rocky surface, together with the detritus upon it, must have been subject to subaerial conditions; for I can find no evidence of any marine clays (though I have examined the base and searched for them in many places) older than those forming the subject of this paper.

If, on the other hand, we turn our attention to the east coast of England and Scotland, we find evidences of much more severe cold prevailing during the deposition of some of the beds of Marine Drift than any that are to be discovered in Lancashire. The Arctic shells found by the Rev. Thos. Brown at Elie in Fifeshire and Errol in Perthshire were declared by Dr. Otto Torel to be identical with species now living in front of the great glacier of Spitzbergen*. The Bridlington beds, on the coast of Yorkshire, have also yielded a molluscous fauna of a more arctic character than either the Lancashire clays or the Clyde beds†. Mr. Searles Wood, jun., whose elaborate investigations of the East-Anglian glacial phenomena are of so much value, also considers that he has discovered a complete series of beds commencing after the Cromer Forest-bed with a crag-like fauna, gradually developing into an arctic one, and thence shading down to the Celtic fauna of the present seas. If Mr. Wood's reasoning is correct, and be coupled with the break I have shown existing between the period of the ice-sheet in Lancashire and the deposition of the marine clays, it seems difficult to escape from the conclusion that the north-west lowlands were under subaerial conditions while the east of England was depressed below the sea-level. It would thus also follow that the low-level Boulder-clays and sands of Lancashire belong to the later glacial

* Trans. of the Royal Society of Edinb. vol. xxiv. p. 627.

† Quart. Journ. Geol. Soc. 1869, p. 97.

group; but for a full discussion of this point I must wait until I am enabled to lay further evidence before you*.

Having now sketched, though imperfectly, some of the principal elements in the formation of correct conclusions as to the age and sequence of the Lancashire Drift, I shall be enabled next to approach the question of distribution and stratigraphy, which I have investigated over a large area of the N.W. of England, with greater freedom than I otherwise could have done. As yet, however, I have not dealt with the travelled and striated blocks, boulders, and pebbles, which will fall more naturally to the concluding division of my paper, in which the structure of the beds will be described and discussed.

* The speculations on the physical geography and causes producing the climatic conditions prevailing at the time, I have omitted for further consideration and, if necessary, combination with facts to be brought forward in my concluding paper.

[For Discussion, see page 41.]

7. NOTE *on a* DEPOSIT *of* MIDDLE PLEISTOCENE GRAVEL *in the* WORDEN-HALL PITS, *near* LEYLAND, LANCASHIRE; *and on a* COLLECTION *of* SHELLS *and* FRAGMENTS *of* SHELLS *found there by* Miss M. H. FFARINGTON. By R. D. DARBISHIRE, Esq., B.A., F.G.S. (Read November 19, 1873.)

ABOUT a mile from the Leyland station, on the east side of the Bolton and Preston railway, there is an extended flat-topped hill of small elevation, which has for many years past been the chief or only source of supply for a considerable district, of coarse and fine road-gravel. The pits from which the gravel is got have been worked from the eastward. The material is screened and sorted on the ground, the stones and gravel carried away, and the refuse left to fill up holes. At present the exposed section of the hill is seen in two large excavations as a face some 40 or 50 feet in height, of which the upper 10 feet consists, under the sward, of yellow brick-clay. The remainder of the face exhibits a thick bed, 30 to 40 feet thick, of marine gravel (shingle) and sands, very rarely showing any clayey admixture. The gravel consists of pebbles of a very large variety of rocks, ranging in size from that of a cylindrical mass 8″ by 18″ down to that of coarse and fine shingle and sand. There are occasionally small layers, of slight extent and thickness, of fine sea-sand; and the whole mass rests on a bed of the same sort of sand, the depth of which has not yet been ascertained.

The accumulation of stones from different rocks and from different strata is remarkable, and will, it is hoped, be worked out hereafter. A characteristic fossil of this bed is coral from the Mountain Limestone. This occurs not unfrequently—masses, of several species, lying amongst the gravel, and, having had the matrix dissolved away, exhibiting the polypidom singularly clean and perfect. A certain small proportion of the larger stones exhibit glacial striation; and, much more rarely, small much-worn flints occur, of a grey or brown colour when fractured.

Throughout the gravel there occur very sparsely small fragments of marine shells; but near the bottom of the bed these, with whole shells occasionally, occur more frequently, immediately above the underlying mass of fine sand.

The elevation of this lower shell-bearing layer is about from 240 to 250 feet above the level of the sea. For many years past Miss M. H. Ffarington, of Worden Hall, has carefully collected shells and fragments as they occurred in these gravel-pits. The collection which she has made is remarkable for the range of species, for the abundance of specimens, and for its clear exhibition, upon the result of years of collection, of the comparative frequency of occurrence of species.

The annexed list enumerates all which have yet been identified. The names are given according to the British Conchology of Mr. Jeffreys.

In addition to its extent, the list exhibits several points of interest, and, in certain characteristic respects, points of novelty in comparison with any hitherto published lists from deposits of similar age in Lancashire or England. These are noted in the sequel.

Except where otherwise marked, all the species are represented by small much-worn fragments; but the occurrence of whole and of comparatively little-worn shells is much more frequent than in the gravel at Blackpool or the Liverpool clays.

The assemblage of species as a whole most nearly represents that of the Wexford gravels, of which it may not be too wild to consider this deposit a Lancashire representation, if not extension. The present occurrence of the larger univalves (*Aporrhais, Purpura, Murex*, *Nassa*, and *Buccinum undatum*) comparatively little worn may perhaps indicate that this bed is one of deposit at a time when the shells found in it were living at no great distance, and probably on or near a sea-beach or at the bottom of some littoral current. In this respect the facies of the collection differs from that of similar representations from the Blackpool or Liverpool beds, and resembles rather those from Moel Tryfaen and Macclesfield. One might almost conjecture that the Blackpool and Liverpool fossils were actually those of some Leyland or Macclesfield shores, further worn and widely redistributed by the waves and currents of a retreating ocean.

The list, although containing a few names of species of a northern character (*Astarte* and *Fusus*), contains also several of shells of markedly southern origin. *Venus* (*Cytherea*) *chione*, which has been identified at Macclesfield and in several of Mr. Reade's Liverpool localities, may almost be called a characteristic fossil at Leyland. *Cardium tuberculatum* (*rusticum*, F. & H.) occurs not unfrequently. One perfect and characteristic hinge of *Mactra glauca* (*helvacea*, F. & H.) was found. All these are essentially southern species. The only shell which is peculiarly arctic in character is *Fusus* (*Trophon*) *craticulatus*, Fabr., a species now living in Greenland, of which one fine and (for drift) fairly fresh-looking shell has been found. The same species was identified at Moel Tryfaen.

With this last-named exception the series from Leyland must be described as very similar to that of the fauna of the present seas along the western shores of Britain. A curious feature of it is the occurrence in comparative frequency of *Fusus antiquus*, var. *contrarius*, a Wexford fossil and common in the Crag. Another is the similar occurrence of limestone pebbles burrowed by *Saxicava rugosa*, and in some cases still enclosing the two valves of the miner.

In the following Table v. r. means that 1 to 3 specimens have occurred; r. 3 to 10; f., frequent; c., common; and a., abundant.

No.	Species.	Occurrence.	Remarks.
1.	Pholas crispata	v. r.	
2.	Saxicava rugosa	r.	
3.	—— norvegica	v. r.	(*Panopæa*).
4.	Solen siliqua	v. r.	
5.	Mya truncata	f.	
6.	Lutraria elliptica	f.	
7.	Mactra glauca	v. r.	One characteristic hinge.
8.	—— solida	f.	
9.	Psammobia ferroensis	f.	Valves and fragments very thick.
10.	Tellina balthica	a.	(*T. solidula*). Some valves extremely thickened.
11.	Tapes pullastra	v. r.	Doubtful fragments.
12.	Venus casina	v. r.	Small fragments.
13.	—— chione	f.	(*Cytherea*). Many hinges and other characteristic fragments.
14.	—— gallina, *var.* striatula	v. r.	
15.	Astarte arctica	f.	
16.	—— sulcata, *var.* elliptica	f.	
17.	—— sulcata	r.	One whole valve occurred.
18.	Cyprina islandica	f.	Many hinges and characteristic fragments.
19.	Cardium norvegicum	v. r.	
20.	—— edule	a.	
21.	—— tuberculatum	r.	Characteristic fragments.
22.	—— echinatum	c.	
23.	Pectunculus glycymeris	r.	
24.	Mytilus modiolus	f.	
25.	Pecten opercularis	r.	
26.	Ostrea edulis	r.	
27.	Dentalium entalis	r.	
28.	Littorina litorea	f.	
29.	—— obtusata	r.	
30.	Turritella terebra	a.	Very abundant, large and small.
31.	Natica catena	v. r.	
32.	Aporrhais pes-pelecani	f.	Whole and fragments.
33.	Purpura lapillus	f.	" " The shells exhibiting a crag-like variation in form.
34.	Buccinum undatum	f.	A few comparatively unbroken shells occurred.
35.	Murex erinaceus	f.	Very fine and little-worn shells occurred.
36.	Trophon truncatus	f.	
37.	—— craticulatus	v. r.	One fine shell.
38.	Fusus antiquus	f.	} About equally frequent. Shells and fragments.
38a.	—— ——, *var.* contrarius	f.	
39.	—— gracilis	v. r.	
40.	—— propinquus	v. r.	
41.	Nassa reticulata	f.	Many whole shells, with much variation in form.
42.	—— incrassata	v. r.	
43.	Pleurotoma turricula	f.	Large.
44.	Balanus porcatus	v. r.	
45.	Cliona	f.	In shells and fragments.

Discussion.

Mr. Darbishire was not prepared to accept the view of the shells in the Drift having existed on the spots where now found. He thought rather that the fragmentary remains might have been derived from the destruction of earlier beds deposited under somewhat different conditions. The occurrence at Wexford of nearly similar beds to those at Leyland pointed to a great destruction of an old sea-shore.

Mr. Gwyn Jeffreys thought that all the shells found in these Lancashire beds were just such as might have been thrown up on the shore, though the matrix in which some of them are found is not sandy. The *Trophon* discovered was *T. truncatus*, and not *T. clathratus*. Neither was he quite satisfied that Miss Ffarington's *Fusus* (or rather *Trophon*) was really *T. craticulatus*. The occurrence of *Fusus antiquus*, monstr. *contrarius*, did not surprise him, though that of *Mactra glauca* was very remarkable. He did not believe in the retiring or voluntary migration of Mollusca, though they might be transported by currents or driven away by want of food. He did not regard any of the shells as truly Arctic, and doubted whether any of them afforded clear evidence of climatal conditions.

Mr. Prestwich remarked on the progress which had been made in our knowledge of these shells since Sir P. Egerton had first called attention to the Drift in which they occur. The number of perfect specimens from Leyland was, he thought, very striking. He had some difficulty in following Mr. Reade into the large theoretical questions into which he had entered, but pointed out that the striation of the surface of the country was significant of a period of intense cold, which any alteration in the arrangement and proportions of land and water could hardly account. But in the overlying Boulder-clay the fragments of shells were all of species still existing in the neighbouring seas of the present day; and he did not think that at the time of its deposit the climate was of necessity intensely cold.

Prof. Hughes did not think that the deposits were in any way immediately connected with the Boulder-clay, to which they were long subsequent. He rather correlated them with the Hessle and Kelsey beds of the east coast. The deposits might in many cases have been formed on the shore of a sea which was eroding a cliff of Boulder-clay; and by this means there would be an admixture of the more recent shells with the redeposited boulders from the older clay. He submitted that the shells belonged to an age succeeding the true Glacial period. In the higher deposits there were still some traces of the more Arctic forms, while a more southern facies came over the fauna of the lower beds.

Mr. Charlesworth observed on the possibility of the transport of shells in the stomachs of fishes. As to the comminuted condition of *Cyprina islandica*, he remarked that in the Crag beds these shells are nearly always much cracked, even when delicate shells in the neighbourhood are perfect.

Prof. Ramsay was glad that the old view as to the successive elevations and submergences during the Glacial period was not likely to be disturbed. As to the physical causes which conduced to the extreme cold, he did not undervalue the changes in physical geography; but if the astronomical causes, the existence of which seemed now to be fairly established, would have produced the effects, he did not see why they should be ignored even if the geographical causes might suffice. These latter seemed to be at best theoretical, whereas the former seemed mathematically necessary. He was not inclined to detach the shells from the clay, and thought that during the time of their deposit there were still glaciers on the higher parts of the land. He did not agree with Prof. Hughes in regarding the beds with striated pebbles in the Vale of Clwyd as post-glacial, and could not believe that in the case of the reconstruction of the beds the striæ could be preserved and the pebbles not become smooth.

Mr. Reade, in reply, stated that his observations were intended to apply merely to the conditions under which the beds containing the shells had been deposited, and not to the period of extreme cold, for which he was quite willing to admit the potency of astronomical causes. He agreed with Prof. Ramsay in regarding the clay as a real Boulder-clay, the pebbles in it being for the most part scratched.

8. Notes *on the* Structure *sometimes developed in* Chalk. By H. George Fordham, Esq., F.G.S. (Read December 3, 1873.)

A paper on this subject (the peculiar parallel striæ found in Chalk), read before the Society last May, brought up a discussion in which such a great variety of opinion as to the origin of this structure was shown, that I thought the following few facts might perhaps be of interest.

In a pit one mile east of Ashwell, on the borders of Hertfordshire and Cambridgeshire, a small section of the "Chalk without flints" of the Geological Survey, about 40 or 50 feet above its base, is exposed. The chalk here is hard, and may be divided into layers, which differ considerably in structure. There are at least three varieties:—(1) layers of hard chalk, divided into slabs about an inch thick; (2) beds much thicker and more massive than the last; and (3) a bed of a concretionary nature. These beds are from six inches to several feet in thickness.

The concretions are marked nearly all over by the lines of this structure. I find that the lines are only found on the concretions (which are easily removed from the parent rock) and in their very immediate neighbourhood. The other beds are entirely free from any trace of the structure.

The chalk at this particular spot has not been very much faulted, and the layers can be traced without change for some little distance; it is hard; and the fossils in it, which at this place are comparatively numerous in the concretionary bed, are invariably crushed, as if by pressure: the structure seems to have no connexion with them.

These facts seem to point to a relationship between the concretions and this structure. I believe the peculiar striæ in this case are due to an incipient crystallization arising from the formation of the concretions. In support of the view that they are due to crystallization, I exhibit a specimen of iron pyrites from the Chalk of Beachy Head, attached to which is a small portion of chalk, very hard and striated. Now the chalk there is in very large masses, as much as 6 feet each way, and does not appear to be in any way anomalous in structure. It would seem that in this specimen the crystallization of the pyrites had induced a crystallization in the chalk.

I believe that in some places, however, an almost identical structure is due to slickensides, but only in *very* broken and faulted strata.

Discussion.

Mr. Seeley observed that the structure was familiar to all. If it were due to crystallization, whether incipient or otherwise, he wished to know to what combination with lime for a base the form of the crystals was due. He thought that a certain amount of phosphate of lime was present in the concretions, but was absent in similar specimens in the Upper Chalk; so that it appeared as if the same cause could not apply in both cases. The striæ were not, he thought, due to slipping or to organic growth, but might arise from some alteration in the character of the chalk.

Mr. Evans observed that the striæ appeared to be due to two causes—crystallization, whether incipient or destroyed, and slickensides. He thought that in the Ashwell specimens much was owing to the hard nodules resisting pressure better than the surrounding chalk, which, in being condensed, passed over their surfaces and produced a kind of slickensides. The same appeared to have been the case with the nodule of pyrites.

Mr. Forbes remarked that an inspection of the specimens on the table convinced him that in several instances the structure was due to slickensides, but that in others traces of a very different structure were visible, which he imagined was due to crystallization, the carbonate of lime having most probably assumed the form of Aragonite, which, owing to its instability, had lost its crystalline lustre and assumed a mealy or chalky appearance.

Mr. Judd thought that the difference between the conclusions of the two papers communicated to the Society upon this subject was mainly due to the difference between the Chalk of Yorkshire and that of the south of England. The abundance of this structure in Yorkshire had caused Mr. Mortimer to connect it with some organism concerned in the formation of the Chalk; while its rarity in the south had led Mr. Fordham to assign another and a chemical cause. He thought that it became apparent only in those parts of the Chalk through which water most readily passed, and considered that in some cases the crystallization had been that of Aragonite, in others that of Calcite. He commented on the dimorphism of carbonate of lime, which under slightly different conditions assumed different crystalline forms; and remarked that, as was the case with many igneous rocks, the structure in the Chalk only became apparent after weathering.

Mr. Meyer remarked that the striæ were most common where nodules were present, and in beds in which the fossils were crushed. So far as he had observed, they were always vertical; and he attributed them to a re-arrangement of the particles of the Chalk under pressure.

Mr. Fordham explained that two of the specimens had been taken from the sides of a fissure, and were actually slickensides. He thought that some of the nodules exhibit traces of internal structure; but it was true that the general direction of the striæ was at right angles to the lines of bedding. He was glad that his remarks had led to so interesting a discussion.

Mr. Prestwich suggested that an analysis should be made of the specimens.

9. *Notes on some* Lamellibranchs *of the* Budleigh-Salterton Pebbles. By Arthur Wyatt Edgell, Esq., F.G.S. (Read January 7, 1874.)

[Plates IV.–VI.]

It will be recollected that in the Quarterly Journal of the Geological Society, vol. xx. p. 283, there is a paper by Mr. Vicary, of Exeter, drawing attention to the pebble-bed of Budleigh-Salterton; appended to this is a description of some of the included fossils by the late Mr. Salter. Since this a paper on the Brachiopoda from the pebbles has been given (in vol. xxvi. p. 70) by Mr. Davidson. In the former paper a full description of the bed is given by Mr. Vicary, to which there is little or nothing to add. It is sufficient to say that it consists of a bed of nearly 100 feet of pebbles of various rocks, inclined at a low angle to the horizon, lying on and covered by the Trias, that the pebbles contain fossils, as a rule, unknown elsewhere in England, that the fossils in some are Silurian and in others Devonian, and that the matrix including Silurian and Devonian fossils is often identical. Through the kindness of Mr. Vicary I have been allowed to figure some of the more remarkable Lamellibranchs in his collection which were undescribed by Mr. Salter (or of which the descriptions and figures have been lost); and I have added a few of my own. This task would not have been attempted had there been any chance of a more competent person's undertaking it. The figures annexed have been submitted to M. Lebesconte, of Rennes, who has a large collection of Norman and Breton fossils; he recognizes several of them. M. Bayan, of the Ecole des Mines at Paris, has also seen them, and compared them with the collections of MM. d'Orbigny and de Verneuil; they have also been shown to M. Gaston de Tromelin, who is working at the Norman and Breton rocks.

In July last I visited M. de Tromelin at Argentan, and was much struck by the general resemblance between the fossils and rock-specimens in his collection to those in that of Mr. Vicary. The first question I asked was, "whether *Orthis redux* was by far the most abundant fossil," which is notably the case in Devon; the answer was that no other shell was nearly so frequent; and this appears to be worth noting. M. de Tromelin obligingly took me to see some beds of quartzite near Trun (about six miles from Argentan) which are used for road-metal, they are believed to be the "Grès Armoricain." It was easy to recognize in these beds the material of one of our commonest Budleigh pebbles, which is whitish hard quartzite, with a profusion of *Trachyderma* traversing it. M. de Tromelin says he has found no other fossil in it. Mr. Vicary tells me he has never found any thing in the same pebble with *Trachyderma*; nor have I. These beds of quartzite are nearly vertical, as far as can be observed, the *Trachyderma*-tubes being almost horizontal; the bedding is otherwise obscure. The strike appears to be about N.W. and S.E.

I cannot help thinking that a closer acquaintance with the beds of Normandy and Brittany will assist persons acquainted with the Budleigh-Salterton bed to refer each pebble to its proper origin, though the resemblance between the Silurian and Devonian quartzites of France in some cases is very great indeed. The figures given here are all of the natural size*.

MODIOLOPSIS ARMORICI (Salter). Pl. IV. figs. 1, 1*a*. (Mr. Vicary's collection.)

Syn. *Modiolopsis armoricana*; *M. armorica*, Bigsby, 'Thesaurus Siluricus;' *Avicula prima*, D'Orbigny, 'Prodrome.'

This figure has been recognized by all the three above-named gentlemen; and M. Bayan found a specimen in M. de Verneuil's collection labelled "*Modiolopsis armoricana*, Salter. *Avicula prima*, D'Orb." The figure given by Salter, Q. J. G. S. vol. xx. pl. 16. fig. 1, is, as I believe, the interior cast of this; such interior casts are common and variable in form. I have figured one from my collection, Pl. V. fig. 6. As it is clearly not an *Avicula*, I have kept Salter's name.

MODIOLOPSIS LEBESCONTI, sp. nov. Pl. IV. figs. 2, 2*a*. (Mr. Vicary's collection.)

The outline of this, which I take to be an interior cast, differs from that of any other in Mr. Vicary's collection. The cast is ovate, rather gibbous at about one third from the hinge; and the gibbosity decreases more rapidly towards the hinge-line than towards the ventral margin. The pallial impression is visible in places in a strong light. Length 2 in. 7½ lines; breadth (from hinge-line to ventral margin) 1 in. 7 lines; thickness 4 lines. I have ventured to name this after M. Lebesconte, of Rennes, as I am informed that, though known in May, it has received no name.

SANGUINOLITES? sp. (CONTORTUS, Salter?) Pl. IV. figs. 3, 3*a*. (Mr. Vicary's collection.)

This appears to be crushed; but Mr. Vicary informs me that it was not considered by Mr. Salter to be so. The left valve is convex along the hinge-line, while the right valve, from the beak to the anal angle, is concave. The beak of the left valve curves over the hinge-line, which is straight; it is marked by irregular lines of growth. Length of hinge-line 1 in. 2 lines; from hinge-line to ventral margin 10½ lines. It answers, as well as can be observed, to the genus it is here referred to; it bears a label "allied to *Sanguinolites contortus*," which I believe to be in Mr. Salter's writing. This form is recognized by M. Lebesconte as French.

* Since the above remarks were written, I hear from M. de Tromelin that the pebbles of Bayeux and Carentan are fossiliferous, *Orthis redux* being common in them. They occur in the Trias, as do the Budleigh pebbles.

AVICULOPECTEN TROMELINI, sp. nov. Pl. V. fig. 1.

This is the exterior of a shell in my collection; the broken ear is much better seen on the other half of the pebble, and shows the shell to have been almost if not quite equilateral. The radiating ribs are well developed, and alternate towards the centre with smaller ones; these latter are indistinct and irregular towards the sides. Measurement from beak to ventral margin $1\frac{1}{2}$ inch; breadth across the shell 1 in. 7 lines.

PTERINEA, sp.? Pl. V. figs. 2, *2a*. (Mr. Vicary's collection.) (Compare *P. lineatula.*)

The surface of this is not well enough preserved to be sure of it. I have a specimen from Gahard, which may be the same. M. Lebesconte recognizes it.

PTERINEA, sp. Pl. V. fig. 3. (Mr. Vicary's collection.)

This is a very globose inflated form, with an acute wing on the anal side of the beak and concentric lines of growth; length from point of wing to beak rather more than 6 lines. Mr. Vicary has other larger specimens.

PTERINEA RETROFLEXA (Hisinger). Pl. V. fig. 4. (Mr. Vicary's collection.)

This is so like some forms of this very variable shell that I can give it no other name. Length from buccal to anal angle 1 in. 5 lines; from hinge-line to ventral margin $8\frac{1}{2}$ lines. It is recognized by M. Lebesconte.

PALÆARCA, sp. Pl. V. figs. 5, *5a*. (Mr. Vicary's collection.)

Two specimens are figured which differ from the *Palaarca secunda* of Mr. Salter; the angle made by the anal slope with the hinge-line is much more obtuse, and the hinge-line longer in proportion to the shell; the teeth also appear to differ. It is recognized by M. Lebesconte.

AVICULA, sp. Pl. VI. fig. 1. (Mr. Vicary's collection.)

A distinct form, but very imperfect.

CLEIDOPHORUS? Pl. VI. figs. 2, *2a*.

M. de Tromelin thinks this may be a *Cleidophorus*; the buccal muscular impression is doubtful. It is in my collection.

PTERINEA, sp. Pl. VI. fig. 3. (Mr. Vicary's collection.)

The cast of an exterior from Gahard is before me exactly resembling this in outline; M. Lebesconte recognizes it. M. Bayan thinks it may be *Avicula matutinalis*, D'Orb. Pl. VI. fig. 5 also represents a specimen of this species.

LUNULACARDIUM VENTRICOSUM. Pl. VI. figs. 4, *4a*. (Mr. Vicary's collection.)

Very like M. Barrande's genus *Silurina*; the beak is slightly inclined to the left; it has radiating ribs; from beak to ventral margin 1 in. $3\frac{1}{2}$ lines; thickness of the valve shown 4 lines. Named by Mr. Etheridge.

CTENODONTA, sp. Pl. VI. figs. 6, *6a*, *6b*, *6c*. (Mr. Vicary's collection.)

Very inflated; the incurved beaks are nearly a line apart, hinge-line short, with four teeth visible in each valve, muscular scars on both sides of the beak strongly defined, pallial impression visible on the buccal half. Recognized by M. Lebesconte. From beak to ventral margin nearly 9 lines; length 1 in. $4\frac{1}{2}$ lines; thickness of both valves nearly 8 lines.

ORTHONOTA? Pl. VI. fig. 7. (Mr. Vicary's collection.)

The grain of the matrix is too rough to make much of this; it is very like some specimens in Jermyn Street from the Upper Silurian beds. M. de Tromelin recognizes it.

EXPLANATION OF PLATES IV.–VI.

Shells from the Budleigh-Salterton pebbles, natural size.

PLATE IV.

Figs. 1, *1a*. Modiopsis armorici (*Salter*).
2, *2a*. Modiolopsis Lebesconti, sp. nov.
3, *3a*. Sanguinolites? (contortus, *Salter*?).

PLATE V.

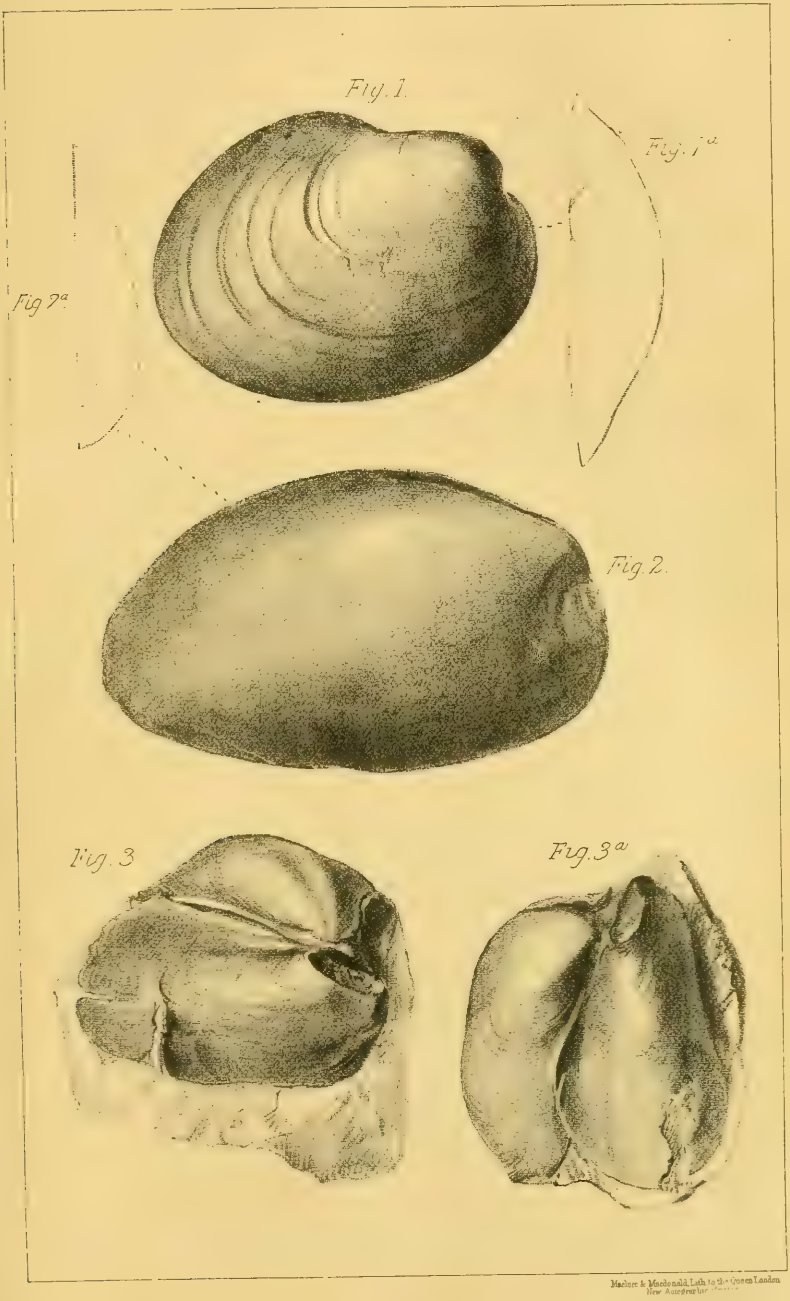
Fig. 1. Aviculopecten Tromelini, sp. nov.
2. Pterinea, sp. (lineatula?); *2a*. portion of surface enlarged.
3. Pterinea, sp.
4. Pterinea retroflexa (*Hisinger*).
5, *5a*. Palæarca, sp.
6, *6a*. Modiolopsis armorici, internal cast (?).

PLATE VI.

Fig. 1. Avicula, sp.
2, *2a*. Cleidophorus?
3. Pterinea, sp.
4, *4a*. Lunulacardium ventricosum.
5. Pterinea, sp.
6, *6a*, *6b*, *6c*. Ctenodonta, sp.
7. Orthonota?

DISCUSSION.

Prof. RAMSAY commented on the value of the paper. The distance of the parent rocks, the rolling of the pebbles, and their travelling from south to north, threw considerable light on the physical condition of the Triassic period. If the New Red Sandstone were, as was now generally supposed, of lake origin, the information given was of still higher interest.



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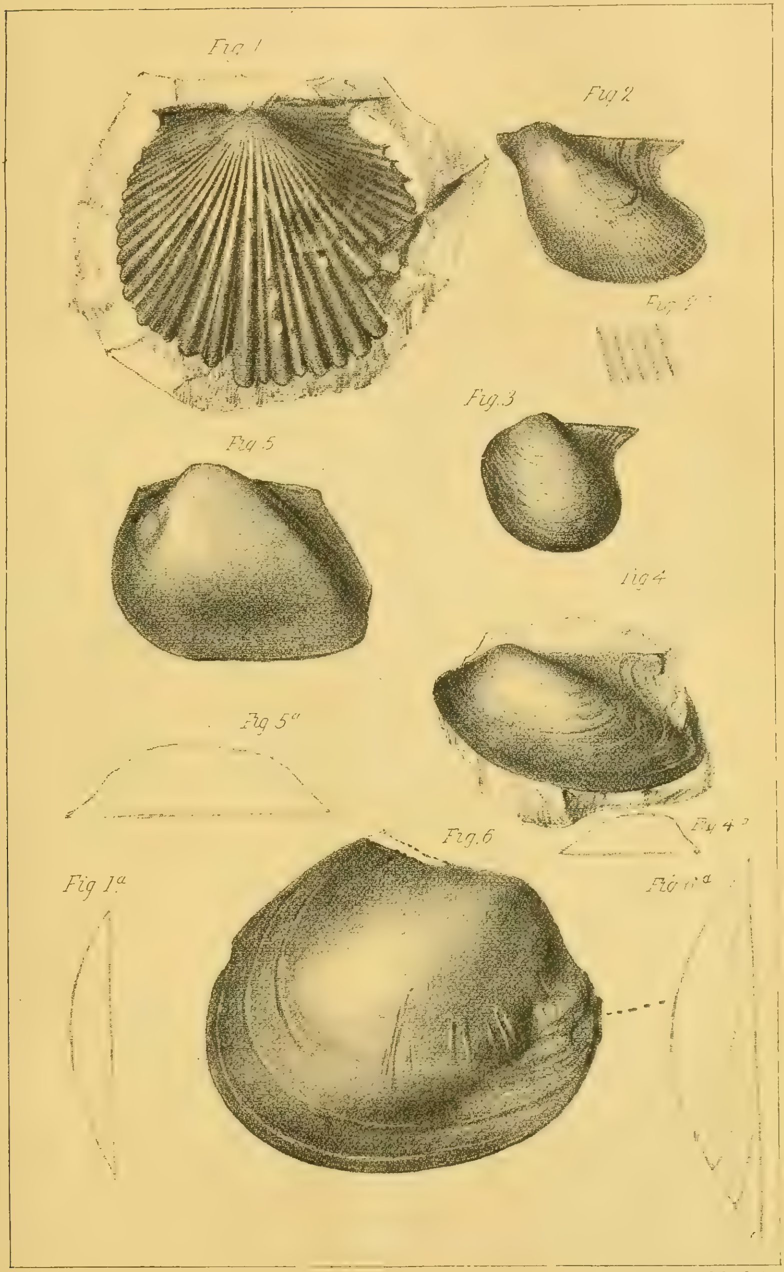
BUDLEIGH-SALTERTON FOSSILS.



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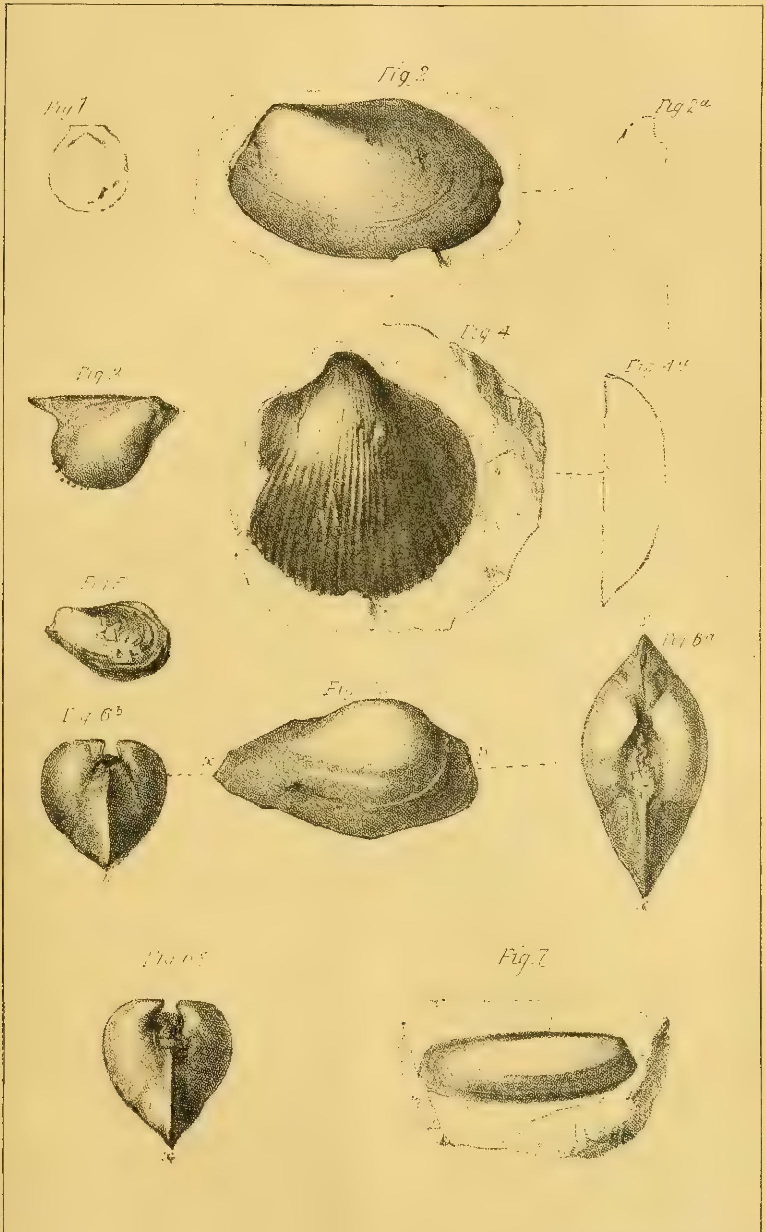
BUDLEIGH-SALTERTON FOSSILS.



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BUDLEIGH-SALTERTON FOSSILS.

Mr. Godwin-Austen observed that one of the remarkable features of the Budleigh-Salterton-beds was the presence of fine sandy deposits, both above and below, which at once suggested a difficult question as to what could have been the condition under which they were deposited. He thought that they might be connected with some glacial action, especially as blocks of porphyry, 25 tons in weight, had been transported from the neighbourhood of Exeter and deposited in the Triassic beds, which could hardly have been effected otherwise than by ice. In the same manner as the shingle of Lake Superior is carried away and redeposited by shore-ice, so he thought it possible that some action of the same kind might during a portion of the New Red Sandstone period have drifted materials off from the French shore of the Triassic lake, and deposited them in this shingle-bed at Budleigh-Salterton. In conclusion, he alluded to the loss which the Society had sustained in the death of Professor Louis Agassiz, its distinguished foreign member, to whom the now generally accepted term *roches moutonnées* and other evidence of glacial action, so often mentioned in the course of the evening, was due.

Mr. Whitaker pointed out that in the slaty rocks at Mevagissey in Southern Cornwall, there were quartz reefs of similar material to the material of the pebbles at Budleigh-Salterton, and recommended a careful examination of these reefs before accepting the Breton origin of the pebbles as conclusively established. The deposit at Budleigh Salterton was, he believed, a lenticular mass of no great extent.

Mr. Etheridge remarked that Mr. Salter had long ago been of opinion that the fossils in the pebbles were of French origin. Mr. Tawney, also, had examined the beds near Torbay and Babbacombe, and found the lithological character curiously like that of the pebbles. He did not, however, think that any of the same fossils had been found in them; nor had they been found in the Mevagissey beds in Cornwall.

Mr. Hicks thought that we were going too far in search of the original home of the fossils, which might have been in some rocks destroyed during the formation of the Channel.

10. *On the* Mud-craters *and* Geological Structure *of the* Mekran Coast. By Lieut. A. W. Stiffe, late Indian Navy, F.R.A.S. (Read December 3, 1873.)

[Communicated by Prof. Ramsay, F.R.S., V.P.G.S.]

The coast of Mekran (the ancient Gedrosia) extends in an east and west direction for about 500 miles, between the town of Sonmiâni, on the Pûr Ali river near the frontier of Hindustan, and Râs Jâshak, near the entrance point of the Persian Gulf (fig. 1).

It is an almost rainless district, but occasionally subject to heavy storms of rain not of long duration, and generally occurring in the winter months. Sometimes no rain falls during the whole year, or even for two years successively. There are no rivers of any size; but the large watercourses after heavy rain discharge large volumes of water.

The appearance of the coast is singular, and the hills near the sea are all of similar formation—table hills with abrupt, almost perpendicular sides, fantastic peaks, pillars, and pinnacles rising out of extensive plains of clay being the universal type.

These clay plains are irregularly veined in places with crystalline gypsum, and are impregnated with saliferous matter, which effloresces on the surface. It need hardly be added that nearly the whole country near the sea is a desert.

The hills in the vicinity of the coast are of various heights above the plain, and rise above 2000 feet in some places: they are chiefly composed of beds of clay from 50 to 1500 feet in thickness above the sea-level, capped and sometimes alternating with coarse, friable, fossiliferous calcareous strata from 5 to 30 feet in thickness, the whole either horizontal or dipping at a small angle. Beyond Jâshak to the westward, and Râs Kûcheri to the eastward, the formation appears similar; but the strata are highly inclined, probably at an angle of from 40° to 60°, the ridges of the hills being separated by great anticlinal valleys.

Fossils have not been observed in the clay; but the calcareous beds are composed entirely of marine organic remains, in parts distinct and perfect, forming a shelly breccia, and passing into a more or less compact limestone.

These beds, as indicated by the fossils, are referred by Mr. Etheridge to the Miocene epoch. He says:—

"The shells appear to me to be of Miocene age, although all are mere casts, and therefore it is very unsafe to pronounce definitely as to their age. I cannot determine them to belong to the modern species of the Persian Gulf. The casts of *Conus*, *Cypræa*, and *Ostrea* are certainly not those of existing species; and the mass of shelly breccia containing *Dentalium*, *Cardita*, *Astarte*, *Venus*, *Trochus*, *Arca*, and *Tellina* I believe to be of more modern date, if not recent.

"The unctuous argillaceous deposit at Râs Farsah upon which the terrace of shelly beds lies, is bored by the living *Lithodomus* allied to the Indo-Pacific *L. attenuatus*. They appear to be vastly abundant in the clay, which is riddled by the perforations in all directions and at all angles.

"The genera of shells occurring in the shelly layer, believed to be of Miocene age, are *Eburna*, *Ostrea*, *Cypræa*, *Conus*, and *Cardium*; and all occur in the form of casts."

The surface of these beds is in some places strewed with pebbles, much water-worn, composed of jasper and quartz, &c., and possibly of trappean origin.

With the possible exception of the craters to be shortly referred to, the writer has observed no traces of volcanic action on this coast. Within the Persian Gulf, however, a similar formation, which extends along the entire north coast, and forms all the large islands, has been much disturbed by the protrusion of recent volcanic matter.

Near Jâshak, at the western end of the coast, is found a hot spring, of a temperature of 128°, situated near high-water mark, and but little above the sea-level. It is unimportant in volume, and has six or seven little surface-basins close together. The water emits a strong odour of sulphur, and forms a stalagmitic deposit round its margin*. There are also springs of pure hot water near Karâchi beyond the eastern boundary of the region.

As might be expected from the nature of the formation, a vast amount of denudation has taken place, and is still in progress, which would be much accelerated but for the almost rainless nature of the country. The clay being gradually removed by rain, when it occurs, or in the sea-cliffs by the action of the waves, the upper stratum falls in great masses or slabs, and forms a talus, which in some degree protects the base of the cliffs from further disintegration.

On the inland faces of the hills, ravines and precipitous valleys are formed in the same manner; and the surface-crust of the ground, cracked and broken in every direction, often presents an appearance such as might be the result of an earthquake.

A typical section at Guadur is given in the diagram (fig. 2): the immense space between the cliffs has, it is presumed, been removed by denudation. The several projecting headlands, and the island of Astola, apparently all belong to the same group, and stand as remnants showing the original extent of the formation.

In some parts, as at the great headland called the Malân, large masses of the clay are constantly falling with a dull roar, breaking up into clouds of dust. From one cliff the writer has watched a succession of such landslips for an hour with hardly any intermission.

The mud-craters, which have hitherto been attributed to volcanic action, are, it is believed, peculiar to this coast. They are found over an extent of about 200 miles of coast from Guadur to Râs Kûcheri. Probably the most characteristic group is that near the latter place, where there are a number close together, some of which may be termed extinct, others being in action. These craters vary

* It is regretted that the specimen for analysis has been mislaid.

in height from 20 to 300 or 400 feet above the plain; and a probable section is shown in the diagram (fig. 3). They rise out of the clay plain many miles from any hills, and are cones of clay of very regular form, with truncated tops, and sides at an angle estimated at about 40°, or whatever the limiting angle or angle of rest of such mud may be.

The largest one ascended by the writer was about 100 feet wide on top, and nearly circular; it resembled a cup filled to the brim with semiliquid mud somewhat thicker than treacle, which slowly and only now and again overflowed, trickling down the outside of the cone, but scarcely sufficient in quantity to reach the base. From time to time an ebullition of gas or air took place from the surface of the pool.

Mr. Ward has kindly analyzed the mud ejected, and found it to consist chiefly of clay with a large admixture of carbonate of lime and a small proportion of quartz sand. The aqueous part contains much chlorine, a little sulphuric acid, a little lime, with soda and a trace of potash. No magnesia was detected in the solution. It would therefore probably be merely a water containing common salt with a little sulphate of lime.

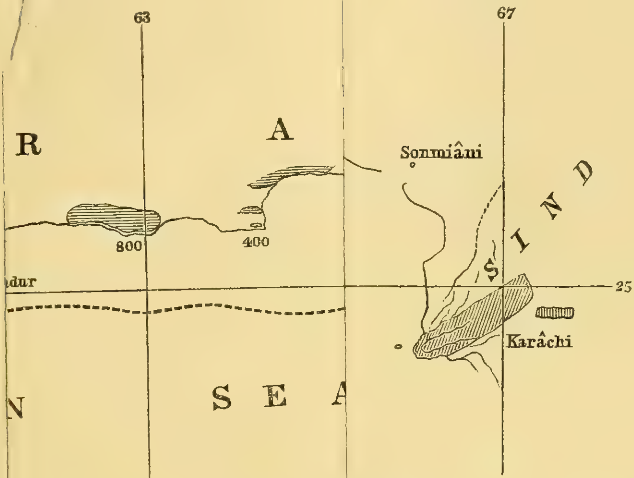
The edge or lip of the cup was very narrow, in parts barely allowing room to walk round it, and being quite soft under foot. A plummet on being thrown in from the side sank rapidly from 50 to 60 feet, when it stopped, apparently from the friction of the line against the side, there being no means at hand of lowering it over the centre. There is no heat accompanying the phenomenon; and there is no reasonable doubt that the walls of the cones are formed entirely by the accumulated overflow and induration of mud.

It is therefore a question whether it is necessary to resort to volcanic agency, or whether hydrostatic pressure alone is not quite sufficient to account for these mud-springs, as they may perhaps be more appropriately called.

The thickness of the clay deposit below the level of the plains is unknown; the veins of gypsum seem to indicate it is not merely superficial, or derived fram the denudation of the hills. From the form of the sea-bottom it is possible that the same clay beds which form the hills attain a considerable thickness below the present sea-level. The sea-bottom for some miles from the coast is of similar nature and appearance to the clay of the plains, with a depth of water increasing gradually to 20 or 30 fathoms and then sinking suddenly and (in several places, at least) quite precipitously to a depth of from 300 to 400 fathoms.

There is some evidence of the existence of these curious craters under the sea. Near Jâshak I discovered a shoal, three miles off shore, rising suddenly from 13 fathoms to a height of only 10 feet below the surface. It is very small, not a ship's length across, and composed of clay which, on the shoal part, was so tenacious that the lead could hardly be disengaged when let go on it. It is unusual to find so small a shoal unless of rock; and it is suggested that it may be probably of similar origin to the craters on shore.

The natives state that the action of these craters (the amount of of Mekran Coast. [To face p. 52.]



marine cliff.

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[*To face p. 52.*]

Fig. 1.—*Sketch Map e Mekran Coast.*

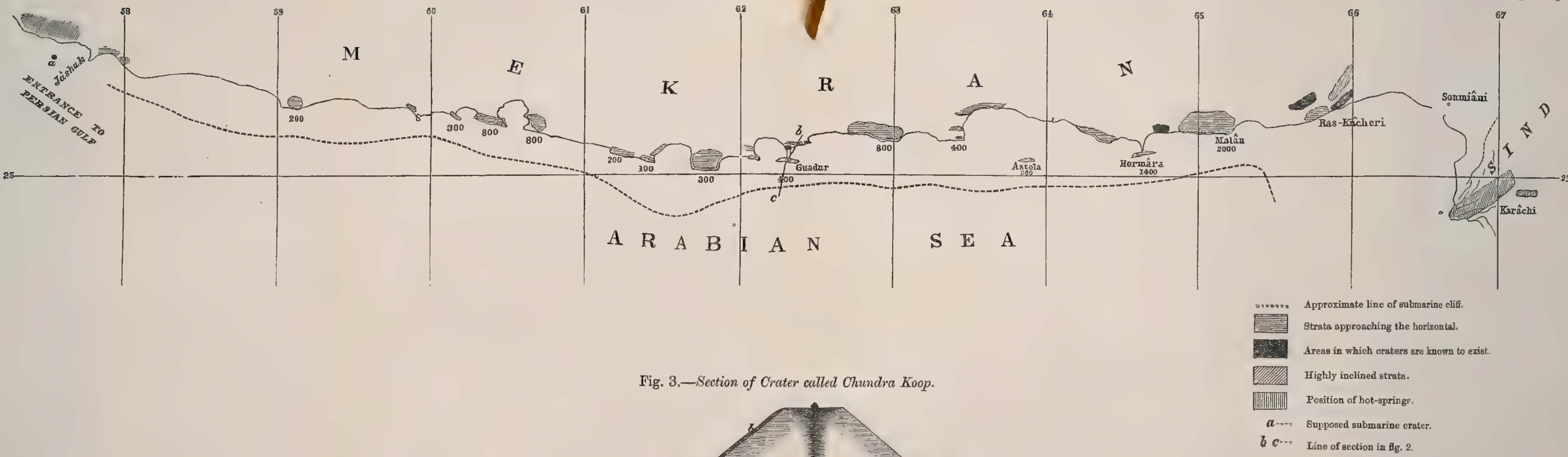
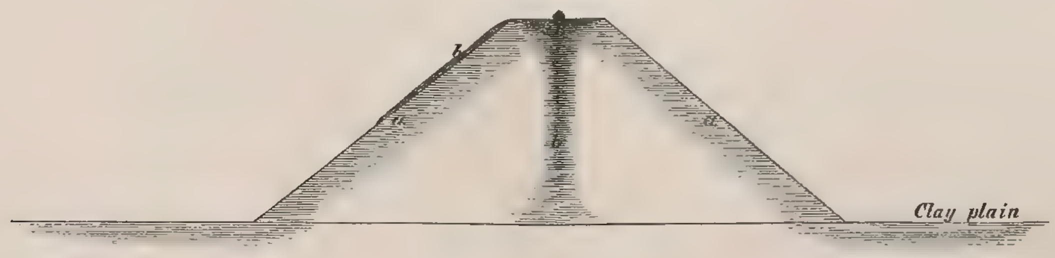
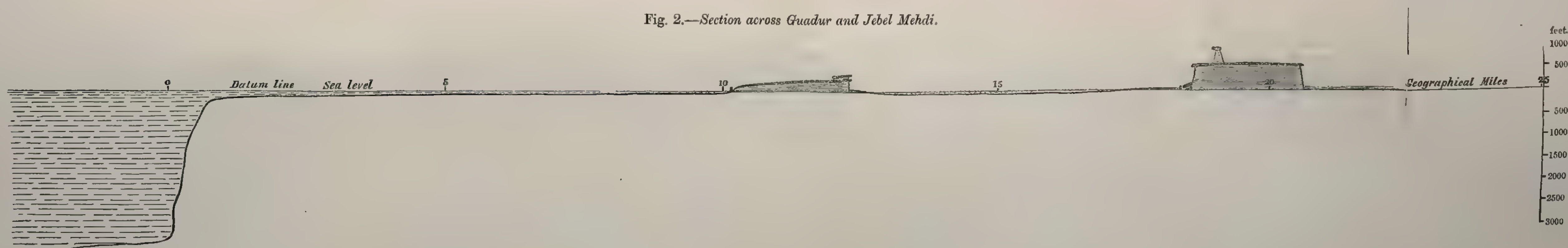


Fig. 3.—*Section of Crater called Chundra Koop.*



a. Dry mud. *b.* Liquid mud.

Fig. 2.—*Section across Guadur and Jebel Mehdi.*



The natives state that the action of these craters (the amour ebullition and discharge) is much increased at spring tides; and this the writer has heard from several different sources.

None have been heard of more than a few miles from the shore, so far as the writer is aware.

As to the causes of the present configuration of the coast, it is suggested that since the deposit of the Miocene beds the great submarine cliff may at one period have been raised above the sea, which then washed its base—that the coast then subsided, probably to near the present level, when the beds were removed from the edge of the great cliff to the present coast-line—and that the coast may have been depressed below its present level sufficiently to allow the sea to produce the present inland cliffs, since which it has been again slightly raised.

The presence of *Lithodomus* in the clay considerably above the present sea-level seems to warrant, at any rate, the latter hypothesis.

The author's time when visiting the places on the coast has been much taken up with his duties connected with the telegraph cable, which is his excuse for the incompleteness of the information and of the series of fossils.

Discussion.

Mr. Evans thought that the fact of the mud from some of the cones having ceased to flow was in favour of the theory of their being due to hydrostatic action, the outflow ceasing when the pressure was insufficient to overcome the resistance, and a fresh vent being found elsewhere.

Mr. Forbes had frequently observed the mud-craters of Peru, which were undoubtedly due to volcanic action, though in many instances the outflow was cold, or nearly so. In the cases described by the author, however, it was possible that they might be due to another cause.

Prof. Phillips mentioned a spring which rose through mud in Bridlington Harbour, from which the outflow varied both with tide and rain. The spring tides in the Persian Gulf might effect a rise in the mud-craters by obstructing some passage by which water from the upland was discharged into the sea. Were this so, the upward movement in the crater would on each occasion probably occur somewhat later than the high tides.

Mr. Seeley remarked on the presence of undoubted volcanic action in the district, in the shape of hot springs &c., and therefore questioned the propriety of bringing in hydrostatic pressure to account for the phenomena.

Mr. Miller cited the mud-volcanoes of Iceland as instances of pure volcanic action, and drew a distinction between the occurrence of mud-craters near the sea and at a distance from it.

The Author, in reply, observed that he had merely suggested the possibility of the outflow being due to hydrostatic pressure, and did not insist upon it. He stated that there was ample evidence of volcanic action at a distance of 200 or 300 miles from the district he had described.

11. *On the* Mode *of* Occurrence *of* Diamonds *in* South Africa. By E. J. Dunn, Esq. (Read December 17, 1873.)

[Communicated by Professor Ramsay, F.R.S., V.P.G.S.]

The conditions under which diamonds occur in South Africa are quite different from those of every other known locality, and are so unusual as to deserve the earnest attention of all geologists.

It is quite certain that the present "dry diggings," such as "Colesberg Kopje," "Du Toit's Pan," "De Beer's," "Bultfontein," and "Jagersfontein," are being worked in the rock which has brought the diamonds to the present surface; they all possess certain common features of very marked character. Each area is more or less circular in form (fig. 1, *a*); the boundary of each is usually horizontal, or nearly horizontal, shale. At the junction, and back for a distance of from one to several feet, the edges of the shale are bent sharply *upwards* (fig. 1, *b*).

The contents of these "pipes" in the shale are the same in all cases, and show distinctly that they are of igneous origin. The base is more or less decomposed gabbro (?) or euphotide (?), through which are scattered particles, fragments, and huge masses of shale, nodules of dolerite, occasional fragments of chloritic schist, micaceous schist, and gneiss. The principal *foreign* ingredient is the shale, which in many places, particularly at Colesberg Kopje, is thoroughly comminuted, forming a *breccia*, with euphotide (?) as a base. Where large masses of shale occur, the lines of bedding, as might be expected, are not horizontal, but lie in all directions.

From the forms, contents, and general features of the pipes, it is reasonable to infer that they are merely the channels that connected ancient volcanic craters with deep-seated reservoirs of molten rock.

On sinking into these pipes, the following sequence, with slight variations, occurs:—First, from a few inches to several feet of red sand, or sandy soil, brought into its present position by the agency of wind. Even within the last 20 years portions of the neighbouring country have been stripped of soil down to the bed-rock, and other portions covered by such means.

Then a layer of tufaceous lime, from a few inches to 8 or 10 feet thick, generally much harder and purer on the surface, shading gradually underneath into the decomposed rock from the altered pyroxenic minerals of which it has doubtless been formed. The segregation of the lime to the surface would be materially assisted by climatic conditions; for in this subtropical region rain usually falls in heavy showers during the summer. No sooner is the rain over than the intense heat causes rapid evaporation.

Lower still is the very friable decomposed euphotide (?), so soft and crumbling that, for a few feet, it may be almost dug out with a spade.

It is of greenish or yellowish colour; a considerable portion of it is altered into serpentinous material; gradually, as the depth increases, it becomes firmer. For a depth of from 30 to 40 feet, cracks, joints, and irregular cavities filled with red sand from the surface penetrate; with the sand, and showing that it has come from the surface, are fragments of ostrich-egg-shell, small rounded grains of chalcedony, agate, &c., identical with the same substances mixed with the surface-soil. There are also veins of calc-spar and nodules of iron pyrites.

At 100 feet in depth, at Colesberg Kopje, the rock is very dark in colour, much more compact, and less altered than near the surface. At 130 feet, the greatest depth so far attained, the rock becomes compact, tough, and shows the original texture, though the constituents are altered, notably the pyroxene or augite into bronzite*.

From the surface down, the following minerals are met with in the altered rock, viz. garnet, calc-spar, mica, bronzite, augite, diopside, diallage, iron pyrites, &c.

The entangled blocks of shale and sandstone are frequently altered, the latter sometimes into quartz rock.

Disseminated throughout the decomposed rock, diamonds are met with, from the enormous size of over 150 carats down to minute ones only the 100th of a carat in weight. Still smaller ones probably occur, but are too minute to be observed.

Many of the diamonds are beautifully formed crystals; but a large percentage consists of fragments and broken crystals; and it is a noticeable fact that the corresponding pieces, even when the original crystal was of large size, are *never* found, though most carefully looked for. This would argue very forcibly against the supposition that the euphotide (?) rock in which the diamonds are now found is their original matrix or "mother rock."

At the same time, it is marvellous that it contains such a rich sprinkling of glittering gems if not the original matrix. Colesberg Kopje, for instance, is but $12\frac{3}{4}$ acres in area, and has been dug out to a depth of from 80 to 90 feet, yielding some millions' worth of diamonds. Some of the *claims* have produced immense numbers of diamonds. One claim, 30×30 feet, worked out to a depth of 100 feet, was recently sold for £4000.

A very well known fact on the diamond-fields, and one rather in favour of the euphotide (?) being the *mother rock*, is that each of the pipes furnishes diamonds easily distinguishable from those found in the others. Bultfontein produces small white stones, occasionally specked and flawed, but very rarely coloured; while Du Toit's Pan, within half a mile, seldom yields other than coloured stones. So well marked are the characteristics of the diamonds from the various diggings, that diamond-buyers can generally tell by the appearance of a stone the locality it has come from.

Denudation has effected great alterations since the shales were so completely penetrated by igneous matter; it is therefore not so

* Specimen recently sent by Sir H. Barkly.

surprising that not a vestige of a crater, or of any of the usual subaerial products of volcanoes, has been found in S. Africa.

A brief sketch of the various intrusive rocks of S. Africa will help to explain their relation to the one under notice.

The oldest are the diorite dykes of Namaqualand, running about east and west, extremely rich in copper ores, frequently very micaceous. They were formed subsequently to the "Namaqualand Schists" (pre-Silurian), but do not penetrate the "Table Mountain Sandstone" (Devonian ?). Penetrating the same rocks, gneiss and metamorphic, are dykes of granite, syenite, and porphyry, probably of the same age as the diorites.

The extensive intrusive action by which thousands of square miles of *Dicynodon*-shales were penetrated by enormous dykes and lateral sheets of dolerite, took place at a much more recent period, as the "Stormberg beds" (containing coal and abundant fossil plant-remains, such as *Sphenopteris elongata*, *Pecopteris odontopteroides*, *Cyclopteris cuneata*, &c.) are penetrated by doleritic amygdaloids &c., while the "Sundays-River beds" (Middle or Upper Oolite) are not intersected by any intrusive rock.

The most recent and, at the same time, most interesting eruptive rock in S. Africa is the "Trap Conglomerate," or breccia, apparently a doleritic rock, which in places becomes a conglomerate on account of the intermixture of pebbles and boulders of other rocks, while in other places it is filled with angular fragments forming a friction-breccia. It extends continuously in a horse-shoe form for several hundred miles in length, varying from 1 to 3 miles in breadth, and throwing off many bifurcations. Detached outliers are not uncommon. It penetrates the diamond-field rocks at Pniel, and contains fragments of amygdaloid entangled in its mass.

It is possible that the diamond-bearing rock filling the pipes belongs to one or the other of the last-mentioned intrusive outflows.

Areas similar in every respect to those worked at the diamond-fields occur near Schietfontein (see fig. 1), about 200 miles from the present workings, while Jagersfontein is 70 miles distant in another direction. Those near Schietfontein have not yet been proved; but as all similar places at the fields have yielded diamonds, it is probable that they will also when properly opened.

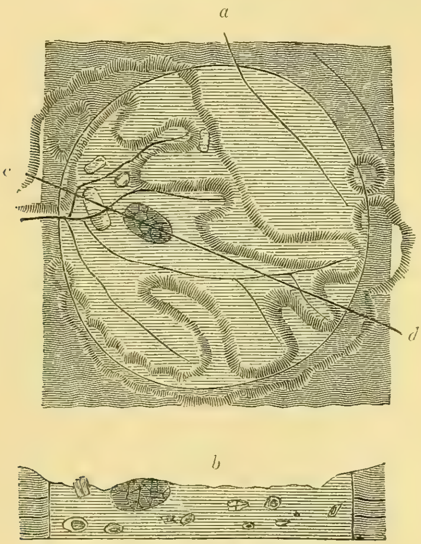
Near the diggings it is by no means an easy task to find the pipes, through the accumulation of surface-soil; but at Schietfontein the boundary can be traced to a foot by means of the upturned edges of the shale.

The variety of rocks occurring within a very limited area surrounding Pniel, on the Vaal river, is very noticeable, and would require considerable attention to the details of their occurrence before satisfactory conclusions could be arrived at. There are dolerites, diorites, amygdaloids, porphyries, trap-breccia, &c. Near Du Toit's Pan the rock, which is of doleritic character, presents very different texture and colour within a few yards. Along the banks of the Vaal "almonds" of quartz that have weathered out of amygdaloid cover the surface of the country, in places, several inches deep. Where masses of shale have been entangled in the igneous rock, it has been altered into *hornstone.*

Diamonds have been distributed from their original position in the igneous rock by three distinct agencies—water, ice, and the wind.

To the action of running water the diamond-bearing drifts of the Vaal river are referable. They are of two dates. The older one,

Fig. 1.—*Plan and Section of Pipe on Fisher's Farm, Shietfontein.*
(Scale, 10 chains to 1 inch.)



a. Plan. *b.* Vertical section in line *c d.*

apparently Postpliocene, occurs at a higher level than the other, as outliers along the present valley (its present position) indicate that the Vaal has deepened its course since the old drift was deposited.

The famous Pniel Kopje was of this age, the depth of sinking, about 30 feet, consisting of a few feet of fine gravel, composed of agates, chalcedony, amygdaloid, dolerite, &c., with some garnets, ilmenite, topaz, quartz, and diamonds. Below this, in places, was a hard layer of conglomerate, the pebbles cemented with lime. The remainder of the drift was composed of large boulders of igneous rock, exceedingly tough and hard, with fine drift containing diamonds filling the interstices. The bottom is soft igneous rock, probably dolerite.

At Gong Gong a calcareous conglomerate occurs high above the recent drift, and appears to belong to the same age as the Pniel drift. Wherever worked, along the course of the Vaal, diamonds

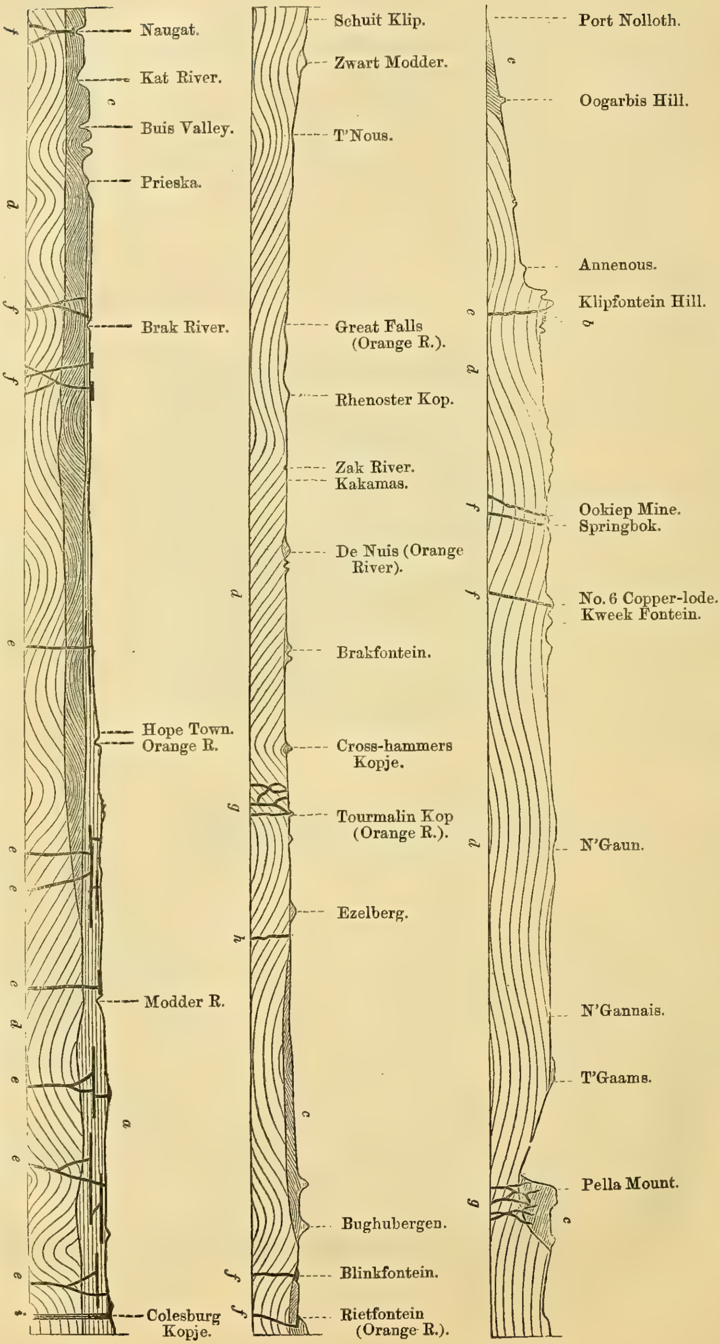


Fig. 2.—*Section from the Atlantic at Port Nolloth to Colesberg Kopje.* (Horizontal scale, about 27 miles to 1 inch; vertical scale, 10700 feet to 1 inch.)

a. Upper Dicynodon-beds (Carboniferous). *b.* Table Mountain Sandstone (Devonian). *c.* Namaqualand Schist (Metamorphic). *d.* Gneiss. *e.* Doleritic dykes. *f.* Diorite dykes. *g.* Granite. *h.* Porphyry. *i.* Gabbro (?).

were found in this drift. Some localities have yielded immense quantities, as Pniel, Klipdrift, &c.

The newer one, or "recent" drift, occupies the present river-bed. It differs in composition from the older drift, in containing a larger percentage of sandstone pebbles and pebbles of soft rocks. Its general colour is greyish, while the older drift is of a reddish colour. The newer drift contains the same well-rounded polished pebbles of agate &c. as the older one.

Diamond-workings have been successfully prosecuted for a considerable distance along the Vaal river. In the newer drift "Cawood's Hope" was an unusually rich digging; while Waldeck's Plant yielded the largest diamond yet found in S. Africa; its weight is 288 carats.

The gems found in the drift-workings are of finer quality, and invariably command a higher price than those obtained from the various "dry diggings."

A very extensive development of "glacial conglomerate" spreads over the country along the course of the Orange River, west of Hope Town (lat. 29° S.). Further west it leaves the river to the north, and spreads as a belt through Bushmanland. Isolated tracts occur near Beaufort West.

At Prieska, on the Orange river, diamonds were found in this conglomerate. Several have been found on its surface between Prieska and Hope Town, notably the "Star of S. Africa."

Systematic search is not likely to meet with much reward in the case of this conglomerate, as the very nature of its formation forbids the hope of diamonds being thickly distributed in it.

Many of the hard boulders are scored and scratched in such a manner as to leave no doubt concerning its origin.

That the wind has acted as an agent in the distribution of diamonds, though perhaps of small ones only, is clearly proved by their occurrence in the drifting sandy soil at Du Toit's Pan. It has, no doubt, been the means by which the streaks of sand found to a considerable depth in the pipes were supplied.

A complete series of the diamond-field rocks has been placed in the British Museum. Their arrangement in the country is shown by the accompanying section from Port Nolloth to Colesberg Kopje (fig. 2).

Discussion.

Mr. Maskelyne complimented the author on the contribution which he had made to geological science, by showing that the rock in which the diamonds occur is confined to the pipes such as he had described. He was able, from specimens which he had examined, to state positively that this certainly igneous rock differed essentially from the dolerites and other igneous rocks in the neighbourhood. He would not attempt to give it a name, whether gabbro, euphotide, or any other designation. The materials, so far as they could be determined in their present altered condition, were such as would not build up any one of the known rocks. There were garnets, and minerals resembling clinochlore, smaragdite, phlogopite, diallage, and calcite, and apparently another mineral entirely serpentinized. The diallage was the true diallage, viz. a mineral of augitic type. The mineral resembling clinochlore was, he had proved, vermiculite; and the phlogopite was not improbably Jeffreysite. The calcite had been thought to have been derived from the decomposition of augitic silicates; but this he doubted. One specimen, from a depth of 130 feet, exhibited a completely serpentinous metamorphosis, which had involved one mineral as yet undetermined, but probably enstatite. The absence of felspars in all the rocks but one was singular; in one specimen from Bultfontein, however, there was an abundance of kaolinite, proving the original presence of a felspar. He thought that the fracture of the diamonds might be due to the breaking up of the rocks in which they are now found. A fact pointed out by the late Prof. Rose, viz. that the octahedral faces of diamonds became grooved after burning by triangular striations, was of great importance in considering the changes these rock-fragments had undergone, as many of the diamonds from the upper beds had their surface striated in this manner. It would be a question of interest to observe whether those from the lower depths were similarly marked and equally shattered.

Mr. Forbes observed that, owing to his not having had the opportunity of examining the rocks in question, he could not speak as to their nature; but as he looked upon the rock gabbro as being in the main composed of triclinic felspar with diallage, he could not regard any of the rock-specimens shown as entitled to this name, especially as they, as a rule, were even devoid of felspar. The black rock, found deepest, appeared to him to resemble one of the altered basalts, in which Zirkel had shown that the olivine was changed into a peculiar greenish serpentine-like mineral.

Mr. Dunn, in reply, stated that he had merely made use of the term gabbro as a provisional name. There could, he thought, be no doubt of the volcanic origin of the rock; and, moreover, near Bultfontein and elsewhere, there were sheets and dykes of dolerite, but quite different from the rocks in the pipes. Some of the fragments in the matrix were fragments of shale, mica-schist, and hornblende, which had probably been brought up into the pipes from below.

Prof. Ramsay remarked on the wide application of the term gabbro, which could hardly be said to imply any distinct mineralogical character. Looking at the question broadly, the facts seemed to be, that among nearly horizontal shales there were patches of rock of approximately circular form, with the shale turned up around their edges, and altered for a certain distance. The appearances were therefore those of the extrusion of a heated or molten body by expansion from below; and possibly, as the author suggested, other traces of eruption had been removed by subsequent denudation. He could not regard the rocks in the pipes as in any way metamorphic in the usual acceptation of the term. Though the volcanic origin of those rocks might be accepted, he thought it more probable that the diamonds were brought up from some subterranean metamorphosed rock, than generated in the lava.

12. *Observations on some* Features *in the* Physical Geology *of the* Outer Himalayan Region *of the* Upper Punjâb, India. By A. B. Wynne, F.G.S. &c. (Read December 17, 1873.)

[Plate VII.]

Contents.

1. The geographical position of the Upper Punjâb is too well known to require detailed description; and it will be sufficient to say that the country to which the following observations mainly refer is that part of "the land of the five rivers" in which the Jhilam * (Hydaspes of the ancients) and the Indus or Abba Sin ("Father of Waters") flow rapidly through rocky channels before finally leaving the hills. (See Map, Pl. VII.)

The principal British stations in the country are those of Jhilam, Rawul Pindi, Abbottabad, Fort Attock, and the Hill Station of Murree †.

2. The geological structure of the ground with reference to the points to be noticed may be generally stated thus:—This section of the Outer Himalayas consists of a varied assemblage of rocks. The crystalline, granitoid, syenitic, and schistose rocks, with abundance of greenstone dykes, found far in among the hills, are succeeded by slates and limestones (of possibly Silurian age) unconformably overlain by Triassic and perhaps older rocks, which may be provisionally

* Always pronounced by natives Jhælum.

† Koh Mari, or the Mountain of Mari, from an old Mahomedan shrine, or Zyarut, now a Hindoo temple. The station and locality are very commonly called by the natives Mushæri, a village of that name being situated in the glen below.

called infra-Triassic. The Triassic beds are, again, unconformably succeeded by Jurassic limestones, Cretaceous limestones, and a mass of Nummulitic limestone and shaly strata, all three resting conformably, the newer on the older.

From the Trias upwards and inclusive, the rocks consist so largely of limestones that the country formed of these Secondary and older Tertiary strata may be comprehensively spoken of as a zone of limestone hills or "Hill-limestones." Exterior to this zone is another of hills (occasionally high) and broken plains composed of a mass of sandstones and clays, with conglomerates, the whole of enormous thickness and of Tertiary age. These sandstones, clays, and conglomerates have been subdivided in this and in other districts into groups, among which Eocene (Nummulitic) and Miocene (Sivalik) stages have been recognized.

3. The relation of this outer zone to that of the hill-limestones, is to form one of the principal subjects of the present communication.

4. So far as is known to the writer, the belt of Tertiary sandstones, clays, and conglomerates just now mentioned passes along the whole southern foot of the Himalayan Mountains, beneath the thick alluvial accumulations of the plains, from Assam to Afghanistān, with but one exception, where an outer edge to the belt is seen brought up on the northern flanks of the Salt range in the Punjâb and along its tortuous extension trans-Indus. The width of the belt in this part of the Punjâb is thus fixed at from 50 to 60 miles; but it decreases westward and turns to the south along the Indian flanks of the Suliman Mountains.

Beneath the outer edge of the Tertiary belt the Salt range partly repeats the systems found in the Himalayan hills, but with very considerable differences as to the number and extent of the formations, and also as to their lithological or petrological and palæontological characters*.

Beyond the Salt range to the southward stretch the flat deserts of the Punjâb and Sind, broken only by a small cluster of elevations called the Korana hills, the rocks of which, according to Dr. Fleming (Journal Asiatic Soc. Beng. vol. xxii. 1853, p. 444) appear to belong to one of the older groups, perhaps older than any of the Salt-range rocks, and not far removed from the Metamorphic or Crystalline series.

5. Geological information in a published form respecting the district under notice is rather scanty and uncertain; but the whole region lies within the area of Dr. Albert Verchere's map appended to his voluminous paper read before the Asiatic Society of Bengal (1866–67). Dr. Fleming's reports, previously alluded to, treat of the Salt range only; and a small memoir on the Geology of Sir Ban Mountain, near Abbottabad (Mem. Geological Surv. Ind. vol. viii.) deals chiefly with the local geology of that mountain. Some official correspond-

* The comparison has not been as yet fully worked out; but enough of evidence has been collected to warrant this statement, the palæontological differences noticed having been confirmed by Dr. W. Waagen's inspection of the rocks, in company with the writer.

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	SALT RANGE, UPPER PUNJÂB.	
Post-Tertiary	Kunjure post-tertiary or drift. ——Unconformity——	Ku
Miocene............	Tertiary sandstone-and-clay zone, viz.:— Conglomerate sandstone and clays: bones &c. &c. Soft grey sandstones and red clays	Te
Eocene	Thick red clays and grey sandstone. Greenish sandstone: crocodilian remains and fossil wood. Nummulitic limestone. (That of the hills absent in the Salt range?) ...	
Cretaceous.........	Olive sandstone: few fossils.	
Jurassic............	Sandstone, limestone, and shale (fossils).	
Triassic	Green shales, limestones, &c. (fossils), and red sandstones and shale. Salt pseudomorphs.	
Infra-Triassic		
Carboniferous ...	Limestones, dolomite, &c.: fossils.	
Silurian ?	Upper sandstone, age unknown. *Obolus*- or *Siphonotreta*-zone, dark shale.	
	Lower or purple sandstone. Red gypseous marl and rock salt, precise age unknown.	
Metamorphic		
Crystalline		

* I

NOTE.—It appears from a paper by M

ence with the local government, and a Report by Mr. H. B. Medlicott, in 1859, on the subject of coal said to exist in the Murree hills, have been printed; and there are other scattered geological allusions to portions of the district; but in none of these, so far as the writer is aware, are the structural relations between the different rock-groups discussed at length or with any accuracy of detail*.

The nearest places to the Upper Punjâb which have been systematically explored by officers of the Geological Survey of India, are, first, the Himalayan regions for many miles north-west and south-west of Simla, lying between the rivers Ganges and Ravee (which may be called the Simla area), examined and ably reported upon by Mr. H. B. Medlicott (Mem. Geol. Surv. Ind. vol. iii. pt. 2); and, secondly, a region situated further in the interior of the N.W. Himalaya, explored by Dr. Stoliczka† (see Mem. Geol. Surv. Ind. vols. iii. & v.).

These two regions, however, are separated by a wide gap, including the whole of the valley of Kashmere, from the Upper Punjâb, which the researches of Mr. Drew (for some years geologically employed by the Kashmere government) would doubtless, if published, go far to fill up in a satisfactory manner. Something is already known of this intervening country from the papers of Major Godwin-Austen and others published by the Geological Society, from Dr. Verchere's paper already mentioned, and a few other sources, but not sufficient to enable the formations and groups on each side to be connected across so great an interval, though intermediate links undoubtedly exist.

6. In order to present a concise view of the rocks entering into the structure of the Upper Punjâb and N.W. Himalaya, so far as yet definitely ascertained, the local series of the former are placed, in the table opposite, side by side with the classifications of Mr. Medlicott and Dr. Stoliczka, as given in the memoirs referred to.

This table will show that in the outer Himalaya of the Upper Punjâb, as well as in the Salt range, several geological formations are represented. Five of these likewise occur in Dr. Stoliczka's classification of the Western Central Himalayan sections; but in the Simla area, from want of palæontological evidence, while there are eleven groups distinguished, the Eocene and Miocene formations only are identified. There is a suggestion doubtfully put forward by Mr. Medlicott, partly on the authority of the MM. Schlagintweit, that the Krol rocks may be Nummulitic, though his observations tended to negative this; and it has been also thought not unlikely that they may be Triassic; but of the ages of the groups below nothing is known.

Major Godwin-Austen, Messrs. Davidson, Etheridge, S. P. Woodward, Dr. Verchere, and M. de Verneuil have shown that Carboniferous Limestone occurs in Kashmere, and, according to Drs. Ver-

* Since the above was written, a short paper by the writer on the geology of this region has appeared in the Records Geol. Surv. Ind. vol. vi. part 3, p. 59.

† Dr. Stoliczka's deputation with the present expedition to Yarkand, will, it is expected, much extend his former valuable researches, with which his new observations will form an interesting and connected series.

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	SALT RANGE, UPPER PUNJÂB.	OUTER HIMALAYA, UPPER PUNJÂB. Mount Sir-ban * &c.	OUTER HIMALAYA, SIMLA COUNTRY. Ganges to Ravee. (Medlicott.)	N.W. CENTRAL HIMALAYA, SUTLEJ TO UPPER INDUS. (Stoliczka.)
Post-Tertiary	Kunjure post-tertiary or drift. ——Unconformity——	Kunjure post-tertiary or drift. ——Unconformity——	Indo-Gangetic-plains deposits. .... *Sub-Himalayan Series.*	....
Miocene............	Tertiary sandstone-and-clay zone, viz.:— Conglomerate sandstone and clays: bones &c. &c. Soft grey sandstones and red clays	Tertiary sandstone-and-clay zone, viz.:— Conglomerates and clays and sandstone: bones ...... Soft grey sandstones and red clays: bones and obscure plants.	Tertiary sandstone-and-clay zone, viz.:— Sivalik conglomerates, sandstones, clays: bones. ——Unconformity—— Nahun lignite sandstones and clays.	Mammaliferous deposits of Tibet.
Eocene	Thick red clays and grey sandstone. Greenish sandstone: crocodilian remains and fossil wood. Nummulitic limestone. (That of the hills absent in the Salt range?) ...	Gray and purple sandstone and purple clays: bones and obscure plants. (Murree beds.) Variegated and gypseous clays and limestone: fossils, as bones and Nummulites &c. ——Abnormal junction or fault—— Nummulitic limestone and shale of hills.	——Unconformity—— Subathu { Kasaoli grey and purple sandstones. Dugshai purple sandstones and red clays. Subathu fine silty clays with limestones. (Nummulites.) } ——Unconformity—— *Himalayan Series.* Krol Limestone. Nummulitic † ? Trias?	
Cretaceous........	Olive sandstone: few fossils.	Thin-bedded limestone; no fossils known. Impure ferruginous limestone: fossils	Infra Krol. Carbonaceous shales or slates, *age unknown.*	Chikkim shale. Chikkim limestone. .... } Cretaceous.
Jurassic............	Sandstone, limestone, and shale (fossils).	.... Limestone (fossils) and Spiti shale (fossils). ——Unconformity——	Blini. Limestone and conglomerate, *age unknown.*	.........Gieumal series. Spiti shale. } Jurassic.
Triassic	Green shales, limestones, &c. (fossils), and red sandstones and shale. Salt pseudomorphs.	Thin-bedded limestone and slaty shale: fossils. Dolomite and *Megalodon*-limestone.		Tagling limestone. Para limestone. } Triassic.
Infra-Triassic		Siliceous dolomite over red sandstone and shale. ——Unconformity——		Liling series?
Carboniferous ...	Limestones, dolomite, &c.: fossils.	(As yet undiscovered.)		Kuling series? } Carboniferous.
Silurian?	Upper sandstone, age unknown. *Obolus-* or *Siphonotreta*-zone, dark shale. Lower or purple sandstone. Red gypseous marl and rock salt, precise age unknown.	Dark Attock slates &c.; no fossils known.	Infra Blini. Slates, *age unknown.*	Muth series? Babeh series? } Silurian.
Metamorphic		Metamorphic.	Metamorphic.	
Crystalline		Syenite and Trap.	Crystalline and subcrystalline, &c.	

* Pronounced Seer-bun. † Doubtfully referred by Mr. Medlicott to this age.

NOTE.—It appears from a paper by Mr. Medlicott (Records Geol. Surv. vol. vi. part 3, p 52), that the Sivalik rocks may be either Older Pliocene or Upper Miocene.

chere and Stoliczka, very possibly Triassic rocks also. In this territory, too, the presence of the granitoid and schistose rocks of Hazára in the Upper Punjâb has been ascertained, and likewise that of the outer Tertiary belt of sandstones, clays, &c., while the Krol limestone has been conjecturally identified in the feudatory state of Poonch, to the south-west of the Kashmere valley, by Mr. Medlicott.

7. There can be scarcely a doubt that several of Mr. Medlicott's divisions of his sub-Himalayan series are present in the Upper Punjâb; indeed we have the advantage of his personal identification of some of them in this district, and also, among the next older rocks, his provisional recognition of the Krol limestone near Murree. To attempt a further comparison of the lower rocks of the Upper Punjâb with those of the Simla area, until organic remains have been found, would be little better than guess-work; they have therefore been bracketed in the table; but the Infra-Blini rocks seem, from description, to resemble those we have called the Attock slates. If this could be established, resemblances might also be found among the Metamorphic and Crystalline groups.

With respect to the part of the series older than Tertiary, it appears strange that the more central Himalayan regions traversed by Dr. Stoliczka should present a closer analogy to the outer Himalaya of the district under notice than the Simla area does; but from the table given it will be seen that such is the case.

8. The physical conditions of the Upper-Punjâb rocks, both in the Salt range and in the outer Himalayan hills, include contortion and faulting; but the disturbance, in part at least, of the Salt range has been much less than in the latter hills, and differs somewhat in kind. For instance, in the Salt range most of the complexities are produced by extensive land-slippage of ground previously more or less the scene of disturbance, while in "the hills" intense contortion, inversion, and faulting have taken place. A feature common to both localities is the prevalence of dips towards the more elevated masses of the Himalaya and Hindoo Koosh Mountains *.

The intervening Tertiary sandstone, clay, and conglomerate zone, where the ground has a plain or plateau form, frequently presents nearly as much contorted disturbance as either the Salt range or the outer Himalayan hills.

In this Upper Punjâb country too, the normal Himalayan strike of the rocks and ranges alters abruptly in the Jhilam valley (as noticed by Mr. Medlicott) from a bearing of E. 35° S. to N.E. and S.W., marking a change in the direction of the disturbing forces. North-easterly, or more east and westerly, lines of strike prevail elsewhere over the district, except towards Kohat and the Bunnoo

* During a recent visit to Kashmere this dip towards instead of from the great mountain-axes of the Himalaya, so common on the outer flanks, was found to occur also in the chain running along the N.E. side of the valley, where the glens of the Sind and Siddur and other rivers cross the strike, exhibiting strong dips to the north-eastward, and some fine escarpments of Carboniferous Limestone, slate, and other rocks presented the opposite way. Local curves over axes parallel to the range also occur.

frontier, where the westerly run of the rocky ridges is, so to speak, crushed against that of the stronger nearly north and south run of the Suliman range.

The hills forming the outworks of the Himalaya in this district, may be said roughly to vary from below 5000 to over 9000 feet above sea-level, the higher elevations of 14,000 and 15,000 feet belonging to lofty chains forming integral portions of the above mountain-system. The most lofty peak, perhaps, in view from the higher hills between Murree and Abbottabad is that of Nanga Pârbat (Nunga Parbut), 26,000 and odd feet, situated near Astor, north of the Kashmere valley. The Salt-range elevations reach from 2000 to 5000 feet above sea-level; and the intervening plateau to the north may be taken at 1700 feet, the altitude of Rawul Pindi Station.

9. One peculiarity to be mentioned before passing on is, that a decided difference exists between the physical geology of the outer Himalayan regions and that of the Salt range, akin to the difference between the Alpine and extra-Alpine characters of European rock-groups*. Taking the *Obolus-* (or *Siphonotreta-*) zone of the Salt range and the Attock slates of the Himalayan hills to be both Silurian†, they are marked by characters petrographically entirely distinct, and from the Silurian upwards to the Miocene there is no formation common to both localities which does not present in each strong dissimilarity both in lithological aspect and in the assemblage of contained organic remains, though the latter prove the rocks to be Triassic, Jurassic, Cretaceous, or Eocene, as the case may be, with the same certainty in one locality as in the other.

There appears, then, to be a parallel between the Alpine and extra-Alpine and the Himalayan and extra-Himalayan features of these two distant regions; but the diversity of character in this district has been contended for no further in the ascending series than above the Eocene, because the Miocene forms a part of the great Tertiary sandstone, conglomerate and clay belt, which is in contact on different sides with both Himalayan and extra-Himalayan rocks‡. Even in the Miocene formation, however, some

* The verification of this is due to the Palæontological officers of the Geological Survey of India.

† The reasons for provisionally assuming the Attock slates to be of Silurian age are their similarity of position to those of Dr. Stoliczka's Himalayan sections, and the recorded fact of Dr. Falconer and Major Vicary having discovered the existence of Silurian fossils in the mountains drained by the Cabul river (Quart. Journ. Geol. Soc. vol. vii. p. 38), mountains which may be fairly supposed to be formed by an extension of the slates known to project westward into the Peshawur valley beyond Attock.

‡ Pending the possible discovery of Carboniferous rocks in the outer Himalaya of the Upper Punjâb, it may be as well to state that among the Kashmere Carboniferous fossils occurring within the *Himalayan region*, species probably identical with those of the Salt range have been determined; but it remains to be seen whether the whole Carboniferous fauna of one locality is or is not identical with that of the other. The rocks are certainly different: limestones occur in both; but the dark slaty fossiliferous Carboniferous rocks of the Siddur valley in Cashmere have no similarity to any of the Salt-range Carboniferous beds with which the writer is acquainted.

dissimilarity may be traced, inasmuch as the sandstones and clays which rest with apparent entire conformity upon the Nummulitic limestones of the Salt range, differ in character from those beds of the outer Tertiary belt which are brought into violently discordant junction with the hill-limestones of the outer Himalaya *.

The recurrence of these mountain and extra-mountain features, so to speak, at such great distances may indicate a connexion between the former conditions of deposition and the early history of the great chains themselves; at least causes which would affect the distribution of land and water appear most competent to have originated the diversity †.

10. In the table given at p. 63 an effort has been made to correlate the newer Tertiary series of this part of the Punjâb with the succession in the Simla area, as gathered from Mr. Medlicott's description; but it may be as well to give a slightly more comprehensive account of these Upper-Punjâb newer Tertiary beds, for the sake of comparison with the series recorded by that gentleman (see Report previously cited).

From the sections exposed in the river Indus, and numerous observations over the Pot'war or Sind Saugor Doab (which has been called also the Rawul Pindi plateau), it appears that the only natural base of these rocks of any extent to be met with is along their upturned edge flanking the northern slopes of and rising on to the Salt range. Here, notwithstanding the perfect parallelism of the sandstone and clay beds to the strong underlying Nummulitic limestone, the absence of subjacent erosion of the latter, and the great length of the apparent conformable contact, there is reason to suspect that the conformity may be but local and not general, or else that the Salt-range Nummulitic limestone is not a strictly synchronous extension of the Nummulitic limestone to be found in other parts of the district.

A. The bottom rocks of this region are soft or harder grey or greenish sandstones, in places slightly calcareous, alternating with red, or sometimes dull grey or greenish olive clays. The contained fossils are blocks of petrified timber, crocodilian and chelonian bones and plates, with rarely (derived, or perhaps sometimes contemporaneous?) Nummulites in the lower part.

B. Where the Nummulitic limestone has thinned out, these beds rest on some of the older groups of supposed Cretaceous or Triassic age, and they are overlain by a strongly marked zone (B) of red

* The rocks of this belt have been stated to possess more or less affinity with those of the Simla area; but they differ *en masse* and in detail from the large Tertiary deposits newer than Eocene (Nummulitic) of the distant province of Kutch. It remains to be seen whether and where a transition between the two types may be found, one of these types belonging to the Himalaya region, the other more nearly associated with the southern extension of the Suliman chain, two great mountain-ranges which inosculate near the frontier of the Punjâb, where the whole of the Tertiary rocks resemble in character those of the Salt range and outer Himalaya.

† It is perhaps hardly necessary to note that the features referred to in this section as bearing relation to the mountain-ranges include, in consequence of this relation, more than the common mutability of formations.

clays containing harder slightly calcareous layers interstratified with grey sandstones. The upper and lower boundaries of this group are quite indefinite; and the only fossils found in it besides obscure plant-markings are small fragments of bones. So far as position goes, this zone seems to correspond more or less with another to be presently noticed under the letter E.

C. The upper part of the red band just mentioned passes gradually into a great thickness of soft pulverulent grey or light bluish sandstones, alternating with red clays and occasional bands of light-coloured slightly ferruginous conglomerate, which sometimes contain bones, and pebbles of Nummulitic limestone enclosing small Nummulites. The strong light-coloured sandstones have here and there thin layers of lignite, the carbonized remains of fossil plants or trees; and the zone has been called the "red and grey group."

D. Above these red and grey beds the sandstones continue of much the same character; but the alternating clays are frequently of an orange-drab or pink colour, and towards the top the series gradually passes into a thick set of incoherent boulder- and pebble-beds, sometimes cemented so as to form conglomerates, the pebbles of which are a most heterogeneous assemblage derived from the crystalline, igneous, and limestone rocks of the Himalaya. In the sandy beds associated with this conglomerate portion of the group fossil bones also occur; and from the waste of the softer strata the gold of the Pot'war country is apparently obtained.

Throughout the whole of the foregoing and among the rocks next to be mentioned are numerous beds of a fine pseudo-conglomeratic aspect, composed of a sandy calcareous matrix charged with small clay concretions and sometimes ferruginous nodules. These beds not unfrequently contain fragments of bones.

E. So far the succession has been traced from the Salt-range bottom beds upwards; but on coming to the northern side of the Tertiary sandstone, clay, and conglomerate belt, we find a change in the formation. Here the series may be followed downwards from the group D through C; but in the place of the red zone B is a very great thickness of purple and grey and purplish-grey or blue sandstones, of much harder nature than any of those previously described, with polished metallic-looking films, as of iron or manganese, on joint-surfaces, alternating with purple or reddish clays not unfrequently having a nodular structure. The sandstones are often veined with carbonate of lime and penetrated by obscure plant-impressions; and more rarely they enclose imperfect bone-fragments.

Along the southern edge of this band its beds pass without any abrupt or marked change into the "red and grey series" C; but on the northern side, at the base of the limestone hills (or where all is hilly ground, then contiguous to the hill-limestones), there are many alternations of purple and red beds, with grey and yellow muddy calcareous strata, associated with dark olive, blackish purple, or greenish-grey shaly and sandstone bands, in the vicinity of which a zone of very red clay, including layers, veins, and masses of white and reddish gypsum, may be frequently observed. The light-yellow earthy calcareous beds are crowded with Nummulites and large *Rotalinæ*, *Ostreæ* and other Bivalves, with a few Gasteropods, while more solid limestone, of a lavender-grey colour, found nearer to the gypsum, contains a few thin-shelled Gasteropoda resembling some species of *Planorbis*, but no Nummulites that could be observed. Near these latter bands, and generally not far removed from the gypseous zone, the beds (most frequently those which are calcareous or limestone), are in places impregnated with petroleum, affording a scanty supply, for some time utilized in lighting part of the station of Rawul Pindi with gas.

11. These varied strata along the inner or mountain margin of the zone E, are subject to some amount of change both as to quantity and composition. At certain localities the dark olive-coloured beds are more largely developed, containing some whitish quartzose gravelly bands; in some parts bright purple clays, in places highly ferruginous, predominate, associated with massive dark bituminous limestones enclosing very small Foraminifera, and closely resembling in character the Nummulitic "Hill-limestones." At other localities the ordinary purple beds have interstratified with them but a few limestone layers, or sandstone, or marly bands, containing, as usual, quantities of Nummulites, *Rotalinæ*, Orbitolites ?, and some fragmentary bones, while in yet other places the dark olive and greenish beds are locally absent. The layers just described form the oldest portion of the outer Himalayan Tertiary sandstone and clay zone along its junction with the "Hill-limestones," though to an observer approaching the foot of the hills the almost constant inversion of the strata would make them appear newer than the main mass of the subdivision E, which has been provisionally called the "Murree beds" from its prevalence at the hill station of that name.

This group E, from many of its characters, appears closely to correspond with Mr. Medlicott's Nahun group; but the lower portion would seem to present most of the features of his Subathu division (Mem. Geol. Surv. Ind. vol. iii. pt. 2, pp. 11, 12, &c.)*.

12. The whole of the Outer Himalayan Tertiary sandstone and clay belt, from the limestone hills on the north to the Salt range in a southerly direction, has presented, so far as yet known, no single instance of a clear unconformity or overlap within its limits, while its entire aspect, notwithstanding much contortion, is that of parallel sequence throughout. No erosion of any of its beds prior to the deposition of others upon them has been observed; and yet it must be remembered that some of the layers, and these on different horizons, contain rolled pebbles of fossiliferous Nummulitic limestone, proving breaks to have occurred subsequently to the deposition of this rock. It cannot be asserted with accuracy whence these

* The description of the Nahun group in this Report would answer in a general way for all the Tertiary sandstones &c. below the conglomerates of our group D; and these conglomerates would answer well to the Sivalik beds, with which some of them have been identified by Theobald and Falconer (Journ. Asiatic Soc. Beng. 1854, p. 651).

rolled pebbles were derived; but other fragments associated with them appear to have come from a northerly direction rather than from the Salt range, where apparent conformity has been stated to exist*.

13. This state of things seems widely different from that of the Simla area, where Mr. Medlicott, who speaks of the Murree rocks as Subathu, and the beds next succeeding the Salt-range Nummulitic as Sivalik (Memoir previously referred to), has found two strong unconformities or overlaps—namely, between his Sivalik and Nahun, and between his Nahun and Subathu groups; further, Mr. Medlicott has found the whole of the outer Tertiary detrital zone of the Simla area from the base of his Subathu group upwards discordant to the Himalayan and Hill series, and discordant to each other, all three of his divisions transgressively reaching and resting upon the older rocks.

Referring to the Report of the Simla area, it appears impossible to disagree with the author's conclusions as to the relations of the newer rocks in that country. Here, however, the structural features differ from those he describes, and the breaks may not have existed to the same extent; but this supposition interferes with the connexion he would establish between their existence and the mode of elevation of the Himalaya—unless a difference may have existed also in the kind of formative agency which produced the Himalayan extension towards the Upper Punjâb.

14. The junction of these newer Tertiary rocks with those forming the higher of the Outer Himalayan hills, both in the Simla area and in the Upper Punjâb, is one apparently marked by much the same features of disturbance, distortion, and inversion, or abnormal superposition in the Tertiary strata along the contact (characters also known to prevail in the Alps, see Medlicott's "The Alps and the Himalayas," Quart. Journ. Geol. Soc. vol. xxiv. p. 34 &c.), the chief resemblance being that in both regions a disturbed and abnormal junction of these Tertiaries with the hill rocks occupies the same geographical and orographical position among the outer hills or at their foot, and the chief difference lying in the fact that in the Upper Punjâb there is but one prominent zone of such abnormal junction (that coincident with the boundary between the Hill-limestones and the outer Tertiary belt), while in the Simla area this feature is said to be repeated at least three times (Report cited).

In the district under notice this junction follows a line describing an arc of a circle having a radius of 60 miles, and its centre some 72 miles N. 20° W. from Rawul Pindi, the western continuation of the line passing with less curvature just north of the station of Kohat, whence it enters the Affreedi and other Afghan hills. (See

* Mr. Medlicott states that the sandstones and clays of the upper sub-Himalayan groups [*i. e.* Sivalik?] rest upon a denuded surface of the Nummulitic limestone of the Salt range (Memoir quoted, p. 91). Nothing of the kind has been observed from end to end of the Salt range by the writer, but the contrary, as above stated. This, however, is no reason for assuming a foregone conclusion on the part of Mr. Medlicott, based upon his observations in the Simla area.

Map, Pl. VII.) Its eastern extension, from the point where the arc touches the Jhilam river, turns abruptly northwards along the right bank of that stream, then, crossing the sharp angle formed by this river near Mozufferabad, bends to the south-westward, lying generally high up on the flanks of the Kyjnâg range in Kashmere. At the village of Oori in this territory it crosses the Jhilam (here called the Vedusta) with a bearing which would take the line along the outer flanks of the Peer Punjal chain.

The rocks of the outer Tertiary belt in the Upper Punjâb, and as far as they have been seen in Kashmere, which are in contact with the limestones and other rocks of the hills, unlike those of the Simla area, belong to one subdivision only, namely the Murree beds (E), *i. e.* Subathu or Nahun, as the case may be. On the inner or "Hill" side of the line, however, different groups of the hill-rocks come into contact with these Murree beds. Strong Nummulitic limestone (a portion of which was conjecturally identified with the Krol limestone of the Simla area by Mr. Medlicott, *l. c.* pp. 91, 92) occurs commonly in this position; but sometimes the rocks in junction are of Cretaceous or Jurassic age, as shown by the Ammonites, Belemnites, and *Trigoniæ* which they contain, while in the Kashmere territory, if any dependence is to be placed on a somewhat distant view, the Murree beds are sometimes in junction with metamorphic or semimetamorphic slates, with crystalline rocks and with hardened and altered-looking limestones, in which, what appeared to be the distorted forms of small *Rotalinæ* drawn by cleavage were recognized, giving ground for the conjecture that near Oori, where the observation was made, some representative of the Hill Nummulitic beds was present *.

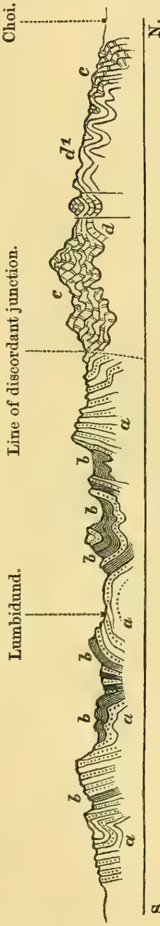
15. The local relations of the contact † are tolerably uniform in their discordance, the hill-rocks being crushed into most complicated folds, while the Murree beds are either less contorted or vertical or inclined, frequently underlying *towards*, seldom *away* from the hills, and then only at high angles. How closely similar these features of the contact may be to those of the Simla area it is not easy to assert without having inspected both; but from the descriptions given they seem to have a general resemblance; Mr. Medlicott's study of the circumstances led to the belief that the junction with the hill-rocks marks a limit of deposition of the Tertiary beds from the base of the Subathu upwards, these having been deposited on a denuded surface of the hill-rocks, and the whole subsequently reduced by disturbance (of both simultaneously) to their present complex condition. In the Upper Punjâb country, evidence of any denudation of the Hill-limestones preceding the deposition of the Murree beds (considered as equivalents of the Simla-area Subathu

* Here, as usual, inversion appeared to be the rule, these limestone rocks overlying bright red and green clays and purple sandstones, clays, &c. of the Murree type.

† It should be stated that actual contact is seldom seen along this line of junction, though the rocks *in situ* on different sides frequently approach each other very closely.

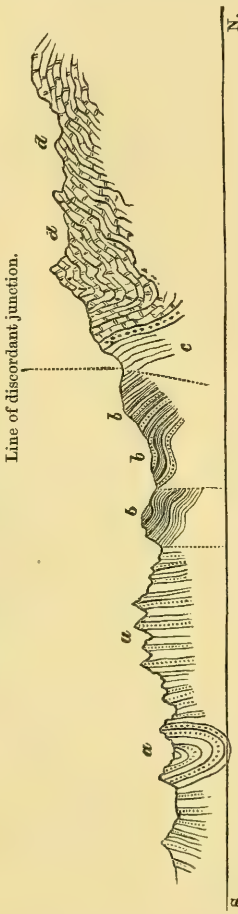
or Nahun) has never been detected; and the features which expose Jurassic or other rocks beneath the Eocene limestones and shales of the hills at the line of contact, are those produced by the same action of denudation which has affected the Murree beds themselves. Nor is the line of contact in the Upper Punjâb strictly a limit of deposition confining the appearance of either the hill-rocks on one side or

Fig. 1.—*Section across the Chita range at Lumbidund, near the Indus.* (Length about 6 miles; hills 1500–2000 feet.)



a. Murree beds. *b.* Limestone bands, with Nummulites &c. *c.* Hill- Nummulitic Limestone. *d.* Jurassic. *d*¹. Jurassic, Cretaceous, or Triassic unfossiliferous Limestone.

Fig. 2.—*Generalized Section at Shahka-Noorpoor, N.E. by E. from Rawul Pindi.* (Length about 3 miles; highest hills 4000 feet.)



a. Murree beds. *b.* Limestone bands (Nummulitic), gypseous red and greenish-grey shales. *c.* Jurassic Limestone. *d.* Hill- Nummulitic Limestone.

the Murree beds on the other. For instance, a mass of grey slaty shales with associated red rocks, both containing Nummulites and possessing the aspect of the Subathu portion of the Murree group, occurs in the hills crossed from the Peshawur valley southwards by the Meer-Kulan Pass, and lying far to the north of the abnormal contact-line situated under the southern foot of Nilab Gash mountain, on the Indus below Attock. Red and variegated gypseous rocks resembling those in the Murree group previously mentioned, occur far down in the ravine of the Haro river near its source, and at Doongagully on the new mountain-road from Murree to Abbottabad, while the possibility of the extension of the hill type of Nummulitic limestone southwards beneath the Pot'war country is supported by its reappearance at the hill of Khâiree Moorut, ten miles south of the junction-line referred to, and west by south from Rawul Pindi.

Although the line of junction presents ordinarily the appearance of a single line of contact (often concealed owing to its position at the foot of hills), this is not a constant condition; for it is accompanied in places by somewhat parallel lines of the same kind situated within very short distances, and traceable into close convergence, if not into absolute unity, with the main one (see section, fig. 3). It also throws off a branch north of Rawul Pindi, having all the characters by which it is itself distinguished, and bringing the same sort of Lower Murree rocks into junction with the Hill-limestones. This branch, diverging at an acute angle from the north side of the line, passes westward along the outer foot of the ridge behind which are the ruins of the ancient Taxila at Shah-ka-deri.

The whole aspect of the contact along this line presents none of the features or irregular outlines which might be expected to result from unconformity, overlap, or limit of deposition; and, further, it might be urged that nowhere along the junction are the newer rocks on one side of the line or its branches made up of any recognizable detritus of the older beds on the other side; nor, indeed, are any prominent coarse detrital deposits, such as might indicate an adjacent shore, to be found in the lower strata of the Murree group, a few minor beds of coarse sandstone at one part of the junction only (in section, fig. 3, b^1) having been met with along the whole region of contact from Oori to Kohat, a distance of fully 200 miles. Nor does it appear that the basal beds of the known Tertiary deposits in the Simla area along their inner (and even more extended) boundary, differ in these respects from the junction beds of the Tertiary belt with the "Hill-rocks" in this region.

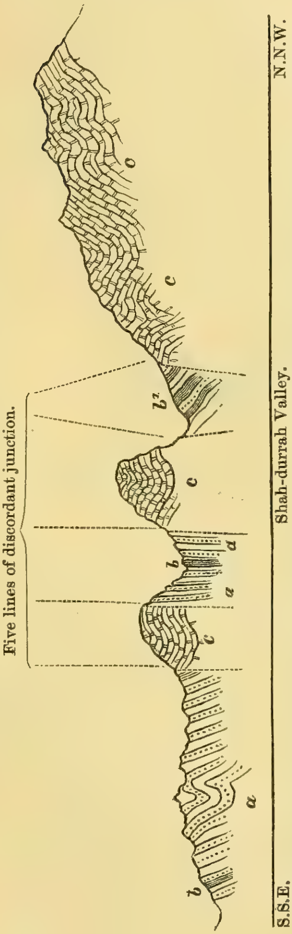
The contact here, on the contrary, presents straight or but slightly curved lines, like those of fractured dislocation, without sinuosities resembling deep bays, creeks, or promontories; nor are there visible signs of islands lying off the supposed ancient coast, the detached elongated hill of Khâiree Moorut being apparently enclosed between lines of fault.

In a case of ordinary unconformity or overlap subjected to denudation, discordant patches of the Murree beds might be expected to occur resting on the older rocks; but these have not been met with, any detached portions which have been found being apparently let in among the older rocks by faults, rather than folded into contortions.

16. Under all these circumstances it is difficult to recognize in this and the Simla region the same relations among formations or groups, several of which may be fairly considered identical and in

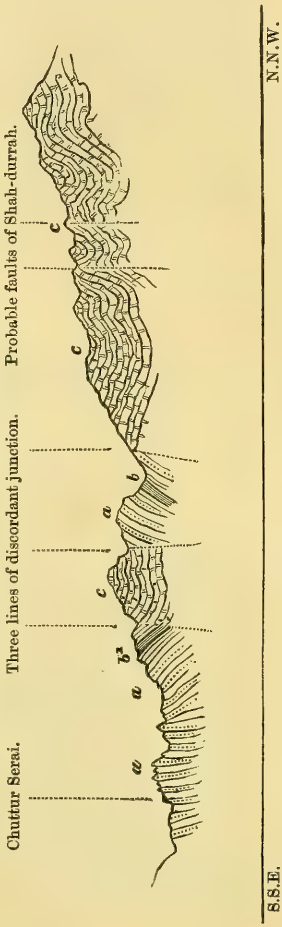
the same orographical position. Even in the Simla area a fault-like character is attributed to the abnormal junction; and had we here the transgressive overlap of different portions of the Tertiary series on to the hill-rocks, it might be easier to assimilate the features of the two areas and to admit for this district Mr. Medlicott's view that the junction-line is not one of fault but of unconformity.

Fig. 3.—*Section crossing Shah-durrah Valley*, N.N.E. *from Rawul Pindi.* (Length about 5 miles; highest point about 5000 feet.)



a. Murree beds. *b.* Limestone bands. *b*¹. Limestone bands in red gypseous and grey clays and shales, with limestone layers (Nummulitic). *c.* Hill- Nummulitic Limestone.

Fig. 4.—*Section at Chuttur Serai*, N.E. *from Rawul Pindi.* (Length about 3 miles; highest point about 5000 feet.)

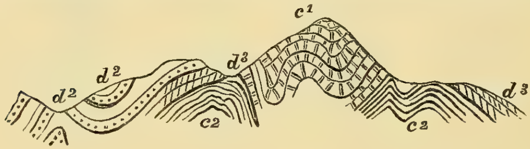


a. Murree beds. *b.* Nummulitic-Limestone bands. *b*¹. Gypseous and other clays and limestones (Nummulitic). *c.* Hill- Nummulitic Limestone.

Placing the more northern contact-lines as indicated in the foregoing observations, and those of the Simla area also, upon a map of small scale, they seem, thus reduced, to possess considerable irregularity, favouring the idea of unconformity, as in the case of the deep *sinus* coinciding with the bend of the Jhilam at Mozufferabad; but it should be remembered that the depth of this bay is twenty miles on its shortest side, lying within British territory, on the right bank of the Jhilam, that this side is there nearly a straight line, and as strongly resembles a fault separating highly contorted rocks as any other portion of the contact. Examined in the same way, other parts of the junction lose much of their apparent sinuosity.

17. The sudden change in the direction of the ranges and strike of the rocks in the Jhilam valley has been already mentioned; and in this connexion it is somewhat singular to mark that on the further side of that river from our district, in the tributary valley of the Poonch (Kashmere), occurs the nearest instance of the unconformity contended for by Mr. Medlicott, at a place called Dundelee. The strike of the rocks (E. 35° S.) belongs to the same system as that of the Himalaya east of the Jhilam valley; and the section as given in Mr. Medlicott's report is extracted (fig. 5) for comparison with those

Fig. 5.—*Section at Dundelee, Poonch Valley.*
(From 'Mem. Geol. Surv. India,' vol. iii. pl. 2, p. 96.)



c^1. Krol group. c^2. Infra-Krol. *d*. Subathu group.

within our district (figs. 2, 3, and 4) and lying about 45 miles to the west-north-west.

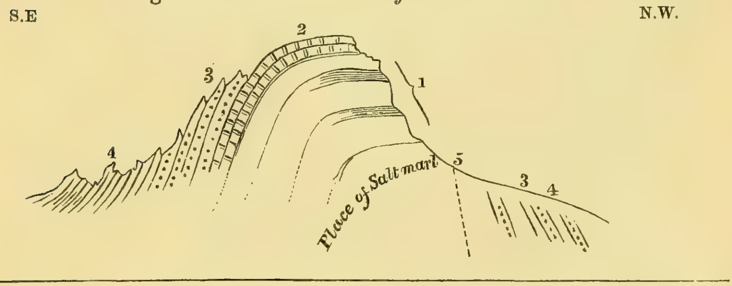
The "hard blue limestone," c^1, in this section, taken by Mr. Medlicott to represent his Krol subdivision, if it is the same as that of Mochipoora Mountain (as may be gathered from a footnote at p. 92 of the Report), is most probably Nummulitic, or might also include some of the Triassic limestones of that range; at any rate it would appear to belong to the Hill-limestone rocks. c^2 is said to be composed of "thin carbonaceous slaty shales," which, if they are the same as those of Shah-durrah, mentioned in the succeeding passage, probably belong to the zone marked d^3 in the section fig. 5; indeed this might be inferred from the parallelism to the latter which Mr. Medlicott mentions. d^2, red sandstone and clays, and d^3, nummulitic clays (and limestones?), are evidently the same as those of the Murree beds previously described under letter E. If the slaty shales c^2 pass conformably below the limestone c^1, they probably represent some of the many hard splintery shaly beds of the Mochipoora nummulitic rocks.

Of course, without having seen the Dundelee section, these remarks upon it are given with reserve; still it is much nearer to our district than to the Simla area, and this must be the excuse for an attempt to interpret it according to Upper-Punjâb experience.

Independently of the question whether the beds c^2 in this section belong to the central ridge or to the flanking rocks, those marked d^2 and d^3 (the description of which so exactly coincides with the Murree group) still appear unconformable to c^2, the central limestone; and yet there is only wanting an apparently very probable line of fault on each side to make this section resemble a modification of the same kind of feature as is represented in our Shah-durrah and Chuttur sections (figs. 3 and 4), where the discordance has no similarity to unconformity.

It may also be instructive to compare this Dundelee section with another in the Pot'war district, some 60 miles to the S.W., taken N.W. and S.E. across Diljubba Mountain, part of a chain of hills which runs from the Salt range almost directly towards Dundelee, but vanishes before reaching the Jhilam river. The strike of the beds is parallel to that of the ridge; and the section is given from memory.

Fig. 6.—*Section across Diljubba Mountain.*



1. Salt-range series, including Cretaceous?, Triassic, Silurian, and Salt marl &c.
2. Nummulitic Limestone. 3. Grey Sandstones, Red Clays, &c. A (bones).
4. Red zone B. 5. Fault.

The Nummulitic limestone in this section has not its full development; but it shows well the parallelism between this and the succeeding strata. The fault shown is the probable extension of a long fracture, most strikingly seen further to the west; and no sign of unconformity appears in the section.

Whether the movements connected with the origin of the Himalaya (as out-thrust produced by settlement, &c.), to some of which Mr. Medlicott ascribes the succession of abnormal junctions of the outer Tertiary zones, may have differed in kind, intensity, or in number as well as in direction here, is as yet mere matter of speculation; but it is at least possible that in the neighbourhood of this region the greater variety in the bearings of the vast mountain masses may be accompanied by greater complexity in their structure.

18. The only attempt to explain the structure of the Tertiary belt in this Upper Punjâb region with which the writer is acquainted is that given in Dr. Verchere's paper before the Asiatic Society, where a diagrammatic section occurs at p. 104.

In this the contorted lower Miocene (Murree) beds are made to thin out towards the south, where they are overlapped by the Sivalik or upper rocks, these also thinning out towards the bulk of the Murree series, which latter is shown to rest unconformably upon porphyry, felstone, &c. In support of this section there seems to be nothing to advance. No trace has been found of the overlap of the two series as shown; and the rocks against which the lower group rests are not porphyry and felstone, but limestone and shale. This is the case from Murree westward to Kohat; and even at Oori, in Kashmere, the Murree group was found in junction with limestones, as already mentioned, and the latter with metamorphosed schistose rocks; nor could the representation of the locality given in another of the same author's sections be recognized.

19. The general features of the outer Tertiary junction with the hill-rocks will have been gathered from the foregoing remarks; but the difficulty remains of asserting the non-existence of unconformity along a complex boundary, only because nothing of the kind can be observed. On the other hand it is equally difficult to rest satisfied from the evidence obtainable that the discordant junction marks a limit of unconformable deposition. Reverting to the sections of this district appended, there is nothing in them contrary to the existence of faulting; the crucial-test section of Mr. Medlicott near the Markunda river has no parallel among our observations; and though the unconformity which it exhibits (Report cited, p. 108) be unquestionable, there seems to be room left to doubt its applicability beyond the boundary line on which it occurs, which is also that of the newest subdivision beneath the alluvium as well as of the coarsest beds, most palpably formed from detritus of the neighbouring rocks, among the three groups of the Simla Tertiary series.

Nor does it appear reasonable to suppose that the basal contact of these outer Himalayan Tertiary beds must have everywhere occurred along a denuded cliff-line, which is a part of the supposition advanced for the Simla area. If so, the continuous-cliff-line conditions would in all probability have to be extended from the Simla area to the Punjâb, a distance of some 600 miles, or, for all we can tell, even to the whole Indian frontage of the Himalaya range, or from this to the Alps. It may fairly be asked, does any coast-line, ancient or modern, present an unbroken cliff-line of this length, or one so little marked by indentations?

The circumstance that the line of abnormal contact is also a geological boundary limiting the *main* development of this part of the Tertiary formation, at first sight greatly favours the idea of unconformity. Supposing the Upper-Punjâb contact, however, to have been caused by displacement, there is nothing in this demanding that the newer beds should continue persistently far beyond their present general limits, or if they did even to a greater extent than is known, the denudation of this country would have been amply sufficient to have removed them from all prominent positions*. In

* Notwithstanding this, the writer's impression must be stated that these beds of the Tertiary formation had no widely extended range over the Outer Hima-

the hilly and contorted limestone-and-slate country lying just northward of the line of contact, there are two distinct unconformities (see table) observable without difficulty, notwithstanding local contortion and faulting; and this being the case, it is not easy to conceive why unconformity should be invisible along the sharply defined contact of the hill-limestones with the outer Tertiary zone.

20. Having thus failed to find in this line of contact proof of either conformity or unconformity of the adjacent rocks, it only remains to glance at the general structure of the country, in order to see if there are any points observable likely to aid in arriving at a fairly satisfactory explanation of the facts.

A feature common to the structure of the whole of the Upper Punjâb is prevalence of lateral changes in the series of which it is formed. Thus the great Nummulitic deposits of the Salt range die out to the east, as do also the Carboniferous, the fossiliferous portion of the Trias, and some other groups of that region; while others, again, disappear westward; so that each end of the range presents an almost entirely different section. In the hills to the north also the Cretaceous rocks have a local development, the Trias of different regions differs, and the character of the Jurassic beds is inconstant.

These changes are not, as a rule, connected with perceptible unconformity, the northern Jurassic group being the "exception which proves the rule," but seem to have resulted from gradual thinning out of the beds, their original partial deposition in detached patches, or difference of the rock-forming materials.

The outer Tertiary belt presents a sort of gradation or transition towards the hill-character; for we find among the rocks of the Murree zone harder beds than elsewhere, limestones also occasionally appear, and some of these are dark in colour, as the hill-beds usually are, and contain in places the same kind of minute organisms, chiefly undetermined Foraminifera. The prevalent reddish or purple colour of the group changes too; and grey shaly bands appear of quite the same aspect as those of the hill-rocks, in the part of the series nearest to the latter. None of these shales nor any alternations of the beds with limestones characterize the basal portion of these newer Tertiary layers in the vicinity of the Salt range.

The Nummulitic limestones of the Salt range, with their large Bivalves and Gasteropoda, have the appearance of shallow-water origin, while the diminutive organisms of the hill-Nummulitic Limestone would seem to have inhabited greater depths.

Another common feature of the country is contortion of its strata, this disturbance having affected some of the very newest Tertiary beds, so as to place them in a vertical position, and having almost everywhere thrown the rocks into more or less complicated folds,

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layan hill-country. Their great extent along the base of the Himalaya might favour the supposition that they stretched also in other directions; but in a country where we have hills 7000 ft. in altitude, entirely composed of these newer Tertiary rocks, considerable masses of them might be expected to occur in the lower and contorted limestone hilly ground north of the main boundary, if they had ever covered that region. Such masses are almost entirely absent.

which have in many cases been pushed over from the direction of the mountains so as to produce inversion of the strata. As instances of this, may be mentioned the complication near the mouth of the Chichalee pass, westward of Kalabagh (trans-Indus)*, the convolutions along the escarpment or slopes of the Affreedi hills overlooking Kohat, and the well-marked case on the hill road from Shaal'-ditta to Khanpoor, northwards from Rawul Pindi, where the Jurassic series behind the outer ridge, with its characteristic band, one mass of a large *Trigonia* (like *T. ventricosa*, Krauss), almost horizontally overlies the Nummulitic limestoue.

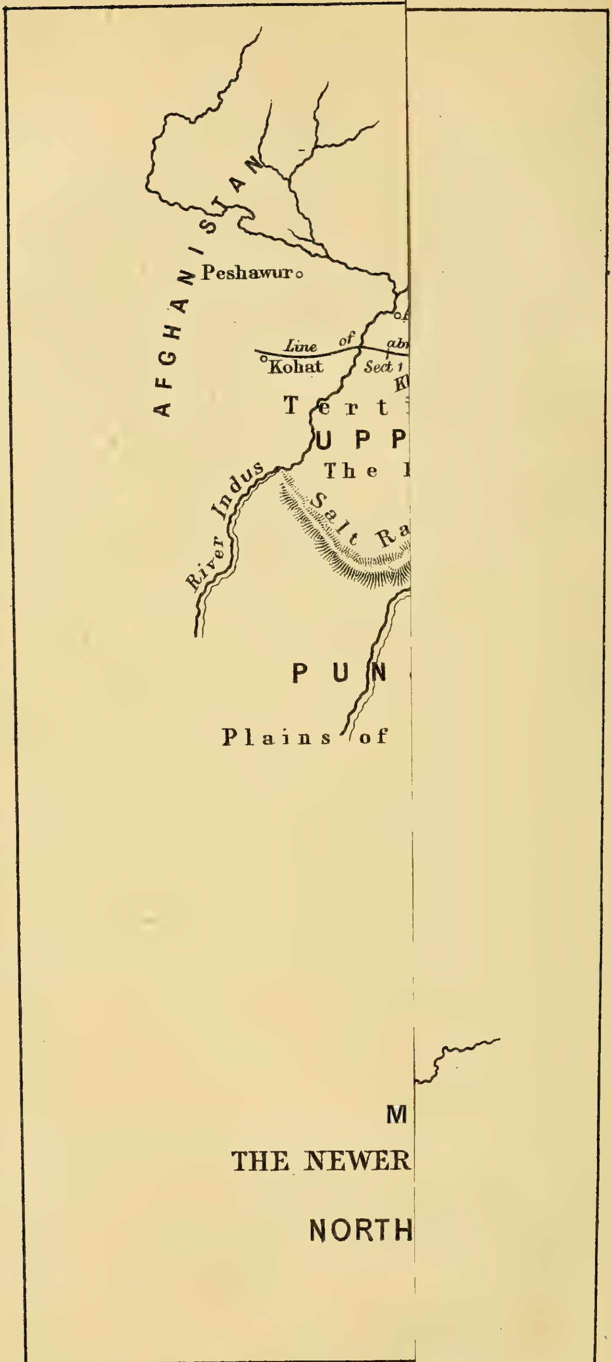
It must be admitted that, were these numerous foldings and contortions expanded and restored to their original horizontality, or any thing like it, the area occupied by the now contorted rocks would be much greater than it is at present.

21. All geological formations being subject to lateral variability, it would seem from the foregoing remarks that those of this district are no exceptions to the rule, if, indeed, the variability is not unusually pronounced throughout the local formations. Hence it does not seem improbable that the red Tertiary zone of the Salt range may correspond to the Murree group of the northern side of the Tertiary belt, so that, if we could eliminate the line of abnormal contact bounding the latter, we should have an ascending sequence from the Salt-range Nummulitic to the newest rocks of the formation on that side of the belt, and to the north another ascending sequence from the hill- Nummulitic Limestone, but one formed under different conditions of depth of water, contemporaneous with the former, yet only in a general way, neither succession being wholly without evidence of interruption, in the small rolled pebbles of fossiliferous Nummulitic limestone previously mentioned.

It is possible that the hill- Nummulitic Limestones alternated somewhat in their upper portion with the purple and grey Murree beds, in favour of which the similarity of certain of the basal limestones and shales to those of the hill- Nummulitic rocks, may be again noticed as indicating a slow change of condition, although the two groups are now separated by the most abrupt discordance, disturbance, and displacement. This change, too, may have taken place over a much wider area than that now occupied by the rocks, if the lateral expansion caused by restoring the contorted beds to their original horizontality be granted, thus enlarging the space within which thinning out might have occurred.

With regard to a separation from an early Tertiary period between the Salt range and northern hill-regions, this seems possible. The nature of the outer Tertiary belt suggests a shallow-water origin; and yet in the Murree beds alone a thickness (which no reason exists to doubt) of a mile and a half, or nearly 8000 feet, has been observed, while 10,000 or 15,000 feet does not appear at all too much for the whole series: but this means 2500 fathoms; and the impossibility of

* Noticed by Dr. Fleming, who gives a somewhat imperfect illustrative section across the inversion. See his report to Gov. of India, Journ. Asiat. Soc. Beng. 1853, pp. 266, 267.



F. Dangerfield lith.

associating such a depth with the idea of a shallow sea or lake constrains one to call in the aid of subsidence to account for the accumulation. Subsidence, however, can hardly be universal any more than elevation; so that an idea of limitation is suggested for the area receiving the deposits and consequent denudation round the border. The first clear evidence of this in the case before us dates from a considerable height in the post-Nummulitic series.

22. In conclusion it may be inferred from the foregoing observations that the physical relation between the outer Himalayan limestones, &c., and the adjacent great Tertiary belt are obscure in the Upper Punjâb, and that the local facts hardly warrant the close application of arguments used to explain some similar relations in the Simla area. Palpable unconformity has not been found along the region of contact, nor any positive evidence leading to the conviction that it exists.

Inversion of the lower strata of the outer Tertiary band is common close to the line of contact; but this is not surprising, the violent disturbance which has affected all the rocks having inverted some of the hill-limestones within a comparatively short distance of the junction. It would also appear that the Simla area possesses a structure more easily comprehended from the fact that the outer Tertiary zone has a definite Nummulitic (Subathu) base resting on rocks of uncertain age, while here Nummulitic rocks certainly occur on both sides of the same outer Tertiary abnormal boundary. This abnormal junction-line is evidently a feature inseparably connected with the causation of the great mountain-chains, preserving, as it does, a parallelism to the axes of the outer ranges; and whether it marks an invisible break in the series or not, the conviction is strongly impressed on the observer that it is chiefly due to intensity of disturbance amounting to fracture and dislocation, combined with more or less complicated inversion, the result of lateral pressure along a region which has suffered, and from the same cause, a similar thrust to that affecting the place known as the *spring* of any ordinary arch.

The detailed examination of the upper Punjâb has not been completed; and only the general facts bearing upon the peculiar junction-boundary of a large and important group of the local rocks have been considered, with the impression that it is only by collecting such facts and comparing them with others similarly obtained that the nature and value of obscure points in physical geology can be arrived at.

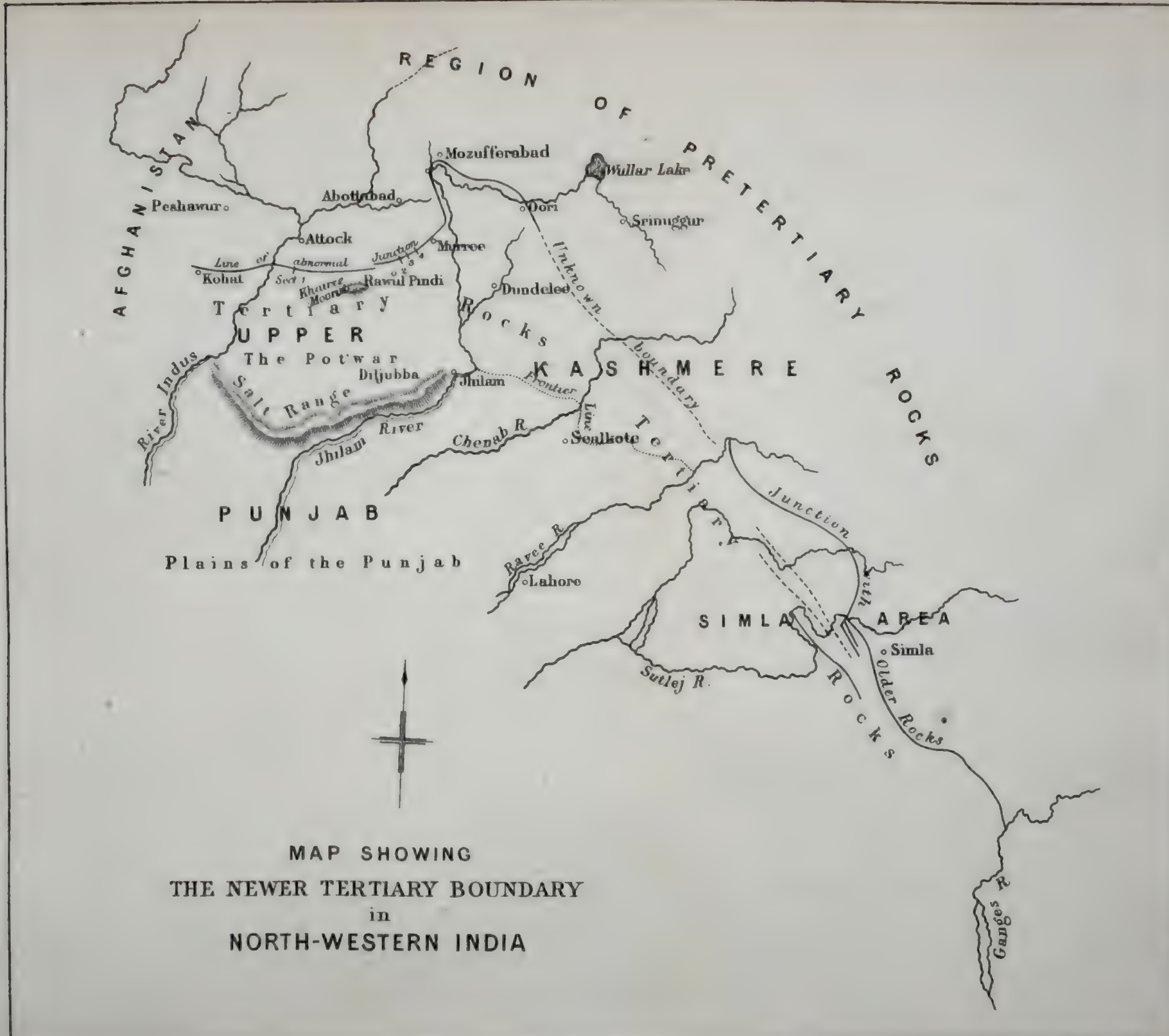
EXPLANATION OF PLATE VII.

Sketch Map showing the Newer Tertiary boundary in North-western India.

Discussion.

Mr. Drew gave some further explanation of the author's views and of the geology of the district.

Prof. Ramsay agreed with the author as to the analogy between



MAP SHOWING
THE NEWER TERTIARY BOUNDARY
in
NORTH-WESTERN INDIA

F. Dangerfield lith.

the outer ridges of the Himalayas and those of the Alps, and also as to the difficulty in such cases of distinguishing between an inversion and a fault. From the different conditions as to metamorphism of the Miocene and Eocene rocks in the Alps, he had been led to question the fact of the inversion, and now found that most Swiss geologists had come round to the opinion that the present position of the beds was not due to mere inversion but to actual dislocation. He thought this might also prove to be the case in the Himalayas.

13. *The* Physical History *of the* Valley *of the* Rhine. By A. C. Ramsay, LL.D., V.P.R.S. (Read February 4, 1874.)

[Plate VIII.]

Having on several journeys, extending over more than twenty years, had occasion to traverse the valley of the Rhine, from the plains between the sea and Cologne to its sources in the Alps, I have long desired to explain, if possible, the physical origin of the valley, and especially of the part that lies between the Drachenfels and Basel. Other occupations for the last thirteen years prevented me from revisiting the greater part of the ground; and I had therefore no opportunity of testing the truth of such hypotheses as had occurred to me.

Last summer I revisited the country, spending nearly six weeks on the investigation of the subject; and the following paper embodies the broader conclusions at which I arrived. First, however, it may be useful briefly to sketch the great features of the valley of the Rhine, from its sources to its mouth.

The Rhine is usually stated to have two principal sources—that of the Vorder-Rhein (in a glacier region), 7689 feet, and that of the Hinter-Rhein, where it springs from the Rheinwald glacier, 7268 feet above the level of the sea. Both are in the Canton of Glarus. The accumulating waters, swelled by many tributary streams, pass through the Lake of Constance, 1305 feet above the sea; and thence, hemmed in between the lower slopes of the Schwarzwald and the eastern end of the Jura, the river flows westerly as far as Basel, where it is 803 feet above the sea. A little above that city it escapes from the immediate neighbourhood of the hills, and, suddenly bending, flows northerly through the great gravelly inclined plain that lies between the mountains of the Vosges and the Hardt and those of the Schwarzwald and the Odenwald. This plain extends north for about 170 miles to Mainz and Bingen, where it is about 272 feet above the sea, showing a fall between Basel and Mainz of 531 feet. The average slope of the plain is therefore $0° 2' 3''$, or about 3 feet $1\frac{1}{2}$ inch per mile. In its broader parts the plain is from twenty-five to thirty miles in width.

At Bingen, the Rhine suddenly enters the gorge, which, inclusive of the larger windings of the river, is about sixty miles in length, as far as Rolandseck, near which a second great plain of the Rhine begins, at first narrow, but below the Siebengebirge broadening rapidly, to form still lower down the modern delta which merges in the vast plains that bound the German Ocean between Calais and the Elbe.

The chief questions which I now attempt to decide are, what is the origin of the present features of the plain that extends between Basel and Mainz, and also of the gorge between Bingen and

Rolandseck, through which the waters of the Rhine escape into the lower plain?

Looking south from the hills above Bingen, or from the northern slopes of the Taunus, the impression readily rises in the mind that the vast plain, bounded on all sides by hills, must have been a lake at a very recent geological period, and that the opening of the gorge was the cause of the drainage of this supposed body of water 170 miles in length. Several observers have entertained this idea, at least in conversation with me; and this popular notion may be found printed in Baedeker's Guide-book. The opening of the gorge was formerly sometimes attributed to the disturbance and wide fracture of the Devonian strata through which the river runs, though it is unlikely that this view is now at all generally held.

For many years I also inclined to the hypothesis that the long plain above the gorge might have been a lake in geological times comparatively recent. I also thought it not unlikely that the action of glaciers might at least have assisted in the work of excavating the hollow, bordered as it is on three sides by well-known old glacier-regions—Switzerland on the south, the Schwarzwald on the east, and the Vosges on the west; and this year I determined to put the whole question to the proof.

As I proceeded with the work, I could find no signs of moraine matter on the slopes near Bingen and Mainz, no evidence that the glaciers of the Schwarzwald and the Vosges had ever been large enough to descend into the plains of the Rhine, or that the great old glaciers of Switzerland had ever reached the Rhine valley as far as Basel; and therefore glaciers seem to have had nothing to do with the excavation of the hollow. Point by point, all the other circumstances that might have helped to support a post-Miocene lake-theory also gave way; and beginning anew with fresher and sounder data, founded on more accurate knowledge of the physical geography and geology of the area than I previously possessed, I at length arrived at certain definite conclusions.

In connexion with the subject, it is of importance to endeavour to ascertain approximately the geological date at which the waters of the Rhine began to flow in their present course; and to do this it is necessary to state briefly some of the later events relating to the history of the Alps, and of the Miocene strata of Switzerland and the Rhine.

It is well known that the Alps, as a mountain-range, existed in some form before and during the deposition of the Miocene strata (see Map, fig. 2); and considering the length of time that has elapsed since the beginning of that epoch in those regions, and the amount of waste that all the preexisting Alpine rocks have undergone during and since that period, it may perhaps be assumed, notwithstanding the subsequent elevation that attended the disturbance of the Miocene rocks, that relatively to the Miocene deposits the Alps may have been during Miocene times as high above the level of the sea as they are now.

One of the most striking proofs of the waste of these older Alps during Miocene times is found in the well-known conglomerates or

Nagelfluh of the Righi, the Rossberg, and the other subalpine hills that flank the older mountains, continuously over great spaces, and at intervals elsewhere, all the way from the Rhine near its entrance into the Lake of Constance to the Lake of Thun, and which again appear on the north side of the Lake of Geneva, near Vevey (Map, Pl. VIII). Nor are these conglomerates confined to one precise geological horizon.

The statement also is often made that, during the deposition of the Miocene strata, the Jura as a mountain-range had no existence. This is a slight overstatement of the case; but, without going into details, it is sufficient for my present purpose to mention that in the opinion of Mr. Merian, of Basel, and, I believe, of other Swiss geologists, the range of the Jura in a very rudimentary stage preceded the deposition of the Miocene strata—so far, that the pre-Miocene formations had been somewhat disturbed and considerably denuded, so as to form a kind of low undulating plain, afterwards entirely buried in the Miocene waters.

During the deposition of the Miocene strata the whole of the region now occupied by the Jura, and of the area that lies between that range and the Oberland, and far to the east into Bavaria and the dominions of Austria, was generally but little raised above the level of the sea and frequently depressed below it, as witnessed by the occurrence of marine beds among the Miocene freshwater strata, not in one middle band or subformation, as is sometimes stated, but in several occasional interstratifications, by no means universally spread throughout all the Swiss area (Map, fig. 2).

There is also every reason for the belief that the patches of Miocene rocks in the Jura (Map, Pl. VIII), both freshwater and marine, were originally united to the larger mass that forms the lowlands of Switzerland. On the elevation of the whole territory, and the more special disturbance and denudations consequent on the uprising of the Jura, the Molasse that lay on the Mesozoic formations of that range was converted into a series of outliers still existing in the large synclinal basin-shaped hollows, which, as broad mosses and green meadows, so frequently form the upper valleys of the hilly land of the area, and which have been so well described by Professor Desor. These outliers of one original stretch of Molasse thus easily carry us to the confines of Basel. If this be true, it establishes a direct original continuation of the Miocene strata with those of the basin of Mainz, between Basel and Mainz, including in the word Miocene (for the sake of brevity) all the subformations classed by some geologists, both in Switzerland and Germany, under the terms Oligocene and Miocene (Map, Pl. VIII.).

These Miocene strata form much of the country bordering the plain of the Rhine, near Basel and thence to Mulhausen and still further west, rising in high tabular masses of flat-lying strata which overlook the broad flats of alluvial gravel that lie between the Schwarzwald and the southern end of the Vosges. Thence they skirt the plain on the right bank of the river as far north as Freiburg; and on the left they appear at intervals to the west of the alluvium, all the way from Mulhausen to Mainz and the neighbourhood of Bingen. Between the two last-named towns and the country west of Worms they form broad tablelands, in great part consisting of flat, or nearly flat, strata of limestone, rising in places from 300 to about 450 feet above the plain of the Rhine (as shown in fig. 3, marked *a*). An isolated patch, surrounded by alluvium, according to Von Dechen's map, rises in the very middle of the great plain west of Carlsruhe, rather more than half way between Basel and Mainz.

Taking all these circumstances into account, there is good reason for the belief that the whole of that part of Germany *which is now the valley of the Rhine*, between Basel and Mainz, was once filled with Miocene strata (Map, fig. 2), the precise thickness of which is to me unknown. If we consider what is now concealed by the alluvium (Map, Pl. VIII.), and the thickness of the exposed tabular masses irrespectively of the removal of any overlying beds by denudation, then the original plain must have formed the surface of a set of strata from 300 to 500 feet thick, and probably more.

During their deposition, and when completed, these strata, together with those of Switzerland, were bounded on the south by the pre-Miocene Alps, on the east by the mountains of the Schwarzwald and the Odenwald, on the west by the Vosges, and on the north by the hilly Devonian plateau, of which the mountains of the Taunus form part, and through which the gorge of the Rhine now passes between Bingen and Rolandseck (see Map, fig. 2). This deep gorge, however, had then no existence; and at that time the Rhine had not begun to flow; for the drainage of the area under review was partly in the contrary direction, or from north to south, during the deposition of the Miocene freshwater strata of the basin of Mainz and the northern part of Switzerland. The facts as understood by some of the continental geologists are, that the freshwater Miocene rocks between Mainz and Basel were altogether deposited, not in a great lake or lakes which were sometimes invaded by the sea, but rather in the alternating freshwater and marine beds of a river and river-mouth, in this respect resembling the estuarine interstratifications of the Purbeck, Wealden, and fluvio-marine Eocene formations of the Hampshire basin. In certain strata the pebbly beds of this Miocene river can be traced all the way from a northern tract formed partly by the present strata of the Kaiserstuhl, whence brooks flowed to mingle their waters with tributary streams bearing gravels coming from those parts of the old Miocene continent now called the Schwarzwald and the Vosges. These conglomerate beds, with distinctive pebbles showing whence they came, can be traced as far as Delsberg, in the Bernese Jura, having always travelled south.

The foregoing summary of events of the Miocene age is necessary, otherwise the second part of my argument would not be clearly intelligible.

The upheaval and general disturbance of the Miocene strata over large European areas* altered the physical geography of the older

* And others with which we are not concerned in this paper.

continent in a remarkable manner. The Alps received a new elevation along with the adjacent Miocene rocks, which, previously not much above the level of the sea, now, in the heart of Switzerland, vary from about 1200 to 5800 feet in height. In like manner, though elevated in less degree, and much less disturbed as regards curvature of the strata, the Miocene beds that lie between Basel and Mainz were also upheaved; so that now those strata attain elevations of at least 1000 feet above the sea near Basel, and probably of not less than from 700 to 800 feet near Mainz.

The general result was, that in all those parts of Central and Northern Europe with which I have now to deal the systems of drainage were wonderfully altered, and in some cases almost entirely remodelled.

In Switzerland the amount of disturbance and elevation of the Miocene strata having been greater than that of the Miocene beds in the valley of the Rhine, the effect of watery erosion in the Alps must have been proportionate during all the time that the Crag formations of England and Belgium were being deposited; and during this period more than the rudiments of many of those valleys were formed that afterwards were filled by and, over much of the lowlands, entirely buried beneath the great glaciers of Switzerland, when the cold of the glacial epoch attained its maximum.

Along the lines of these early valleys, between the Oberland and the Jura, such as that of the Aar, there can be no doubt that the glacier sheets lay thickest, and the amount of glacial erosion must therefore have been greatest; and very important changes in the outlines of hill and valley were the result. Some of these I have long ago discussed, and I will not renew the subject; but this seems certain, that, after the post-Miocene upheaval of the Alps, the present main drainage of the area began before the glacial episode, and was in many important respects only established by the influence of glaciers. The upper valley of the Rhine was at that time filled by a river of ice which, joined with others, covered the valley more than halfway from Schaffhausen to Basel, while from its western edge and end the liquid river followed its present general direction, hemmed in between the Jura on the south* and the lower hills of the Schwarzwald that bounded the river on the north. Its level must then have been higher than now in this part of the channel.

While these were some of the effects of the post-Miocene upheaval of the Alps and the lowlands of Switzerland, including the Jura, it is also my opinion that by the same upheaval the contiguous area of the Rhine between Basel and Mainz was tilted, so that the main drainage in what is now the basin of Basel and Mainz flowed in a direction opposite to that which it followed during the Miocene epoch; that is to say, the new tilting of the country (fig. 1) ended in producing a thorough drainage that flowed from south to north instead of from north to south.

About a hundred miles east of Basel, following the windings of the Rhine, the Lake of Constance is 1305 feet above the sea, and

* Or, rather, the northern continuation of the rocks of the Jura.

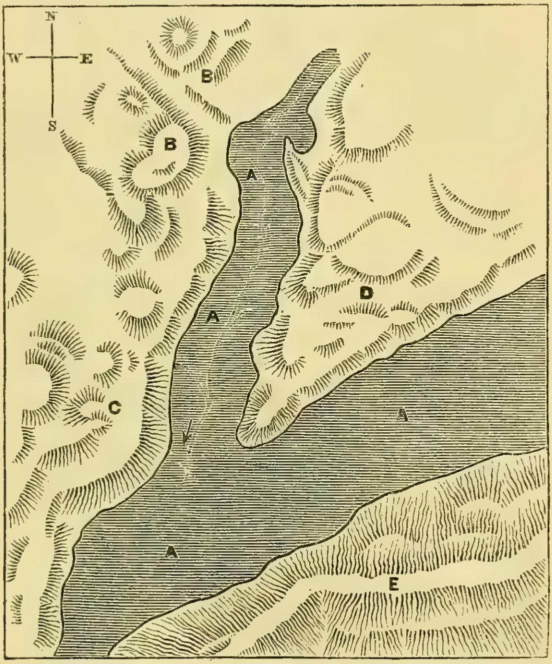
502 feet above the average level of the river at the bridge of Basel. Assuming, as the data seem to warrant, that the basin of Basel and Mainz was filled with Miocene strata to a height of more than 300 feet at Basel above the present plain of the Rhine, there was still ample fall for the river springing from the end of the old Rhine glacier, or even at a later date from the level of the Lake of Constance, for the Rhine to have flowed along the inclined plain of Miocene rocks that, at levels of at least from 300 to 500 feet above the present plain, once extended from Basel to Mainz and the neighbourhood of Bingen. I have already stated that the present fall from Basel to Mainz is 531 feet. In the older epoch adverted to, even allowing the Miocene strata of Mainz to have attained a height of 500 feet above the level of the present plain, there may still have been a fall in the river-channel on the surface of the ancient plain of more than 300 feet between Basel and Bingen. This is equal to about 1 foot 9 inches per mile, an inclination amply sufficient to have carried forward at a rapid rate the waters of the Rhine. At this epoch of the history of the river, the general arrangement of the rocks must have been somewhat of the kind shown in fig. 1.

Fig. 1.—*Hypothetical Section along the Valley of the Rhine.*

1. Post-Miocene hills of Switzerland on the south (Jura &c.). 2. Pre-Miocene rocks where the gorge now begins near Bingen, on the north. 3. Mountains of the Schwarzwald &c. on the east side of the valley. 4. Plain of Miocene strata inclined from south to north, over which the Rhine flowed, and bounded on the west by the mountains of the Vosges.

In this manner I consider that it must have happened that the river originally flowed along the surface of a high inclined plain of Miocene strata that then filled the valley of the Rhine, from the confines of Switzerland to what is now the southern end of the gorge. When this system of drainage began, the deep river-gorge that now separates the Taunus and the Hundsruck had no existence (see Map, fig. 2). The hilly slopes on either side were, so to speak, unbroken; and a mere minor shallow valley, the bottom of which was as high as the edge of the present gorge, received and carried northward the waters of the Rhine. By degrees the great river flowing at this high level began to scoop out a channel, which gradually deepened and became bounded by cliffs. Just in proportion as the channel of the gorge deepened, so the Rhine, wandering through the long inclined plain of Miocene rocks between Basel and Bingen, by degrees had its surface-level lowered through the ordinary processes of watery erosion. The wide alluvial flat through which the river, studded with islands, now flows, shows that in modern times the Rhine has often changed its channel, winding hither and thither all across the plain between the Schwarzwald and the Vosges, and leaving terraces sometimes remote from its present banks. As it acted then and is doing now, so it must have acted in the post-Miocene times recorded in this memoir, till at length

Fig. 2.—*Map showing the Distribution of Miocene strata north of the Pre-Miocene Alps, in the area now occupied by the Rhine between Basel and Mainz.*



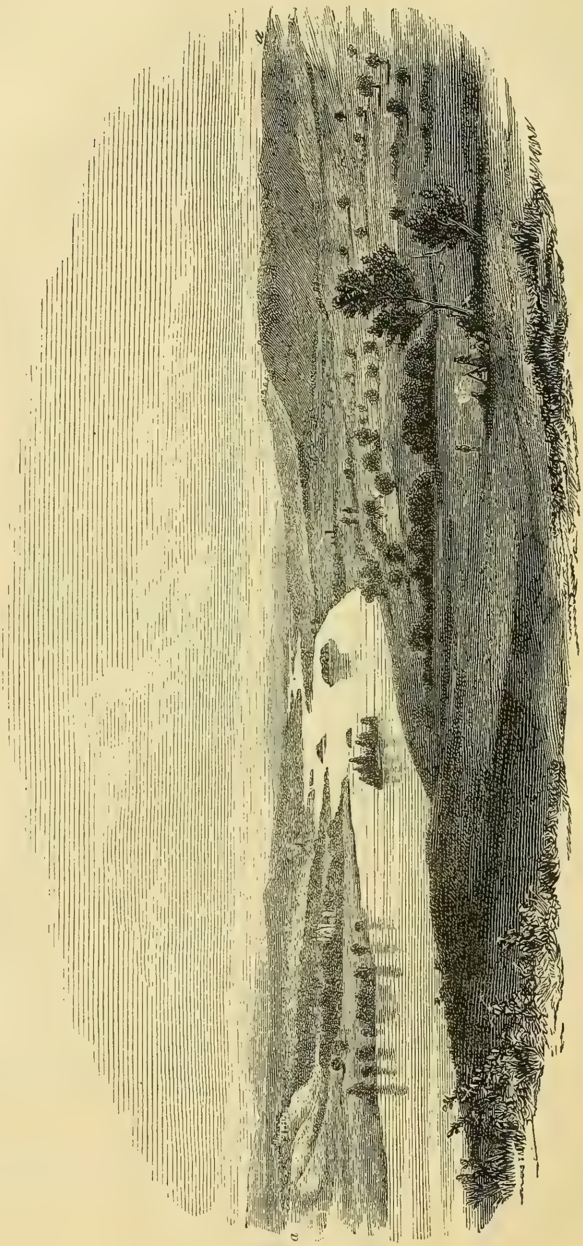
A A. Miocene strata. B, C, D. Pre-Miocene mountains (Schwarzwald, Vosges, &c.), bordering Miocene waters. E. Pre-Miocene Alps, bordering Miocene waters.

(The arrow indicates the direction of the drainage in part of what is now the Rhine valley.)

the greater part of the high plain of Miocene strata was worn away; and the tabular uplands near Basel and Mainz now bordering the modern plain remain to attest the amount of denudation that the valley has suffered by watery erosion.

This hypothesis readily accords with the occurrence of stratified banks of gravel at various levels above those of the more modern river-terraces which are common in the plain. If also much of the Loess be only river-mud of a comparatively ancient date, and perhaps partly of glacier origin, this view helps to account for its

Fig. 3.—*Picture of the Rhine and Tabular Hills of Miocene Rocks south of Bingen.*



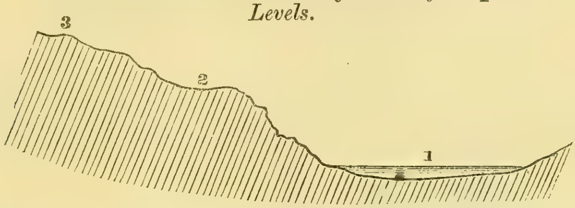
a a. Tabular hills of Miocene rocks bordering the plains.

being found at many different levels on the slopes that flank the Rhine valley, far better than that of a hypothetical partial submergence of the country which converted a large part of the valley into a kind of freshwater estuary. Thus the Jurassic hills between Herholz and Ettenheim on the right bank are partly covered by these old river-deposits to heights of about 200 feet above the river, while lower down, as at Worms, the Loess rests on river-gravel close to the great plain; and at Eltville the Loess covered with vineyards descends to the level of the Rhine. As the river by degrees lowered the level of the plain, it left its finer detritus at these and many other levels.

While this plain still retained its original high level, and the Rhine, as already stated, flowed through the upland slopes formed of Devonian rocks now lying between Bingen and Königswinter, it first began to form the gorge; and as this work of watery erosion went on, the water, constantly deepening its channel, at length scooped it to its present depth.

The traces of its temporary levels as the river cut its way down, may still be seen on the cliffs high above the present surface of the water. Thus on the hill behind Bingen, called the Rochusberg, on the spur of Devonian quartz rock on which the Hotel Hartmann stands, there is a chapel, called St. Roche, standing on the relics of a plain 341 feet above the river, and which a little further west rises to a height of nearly 400 feet. This plateau, also in a fragmentary shape, is continued further down the Rhine. Where the gorge begins, going down the river, it presents the outline shown in fig. 4.

Fig. 4.—*Section across the Rhine Valley, showing the present and old Levels.*



1. The present level of the Rhine. 2. Part of an old level of the river.
3. Part of the hilly ground beyond, that formed the original river-bank.

Lower down the river, below Niederheimbach, the left bank, looked at in front, presents the aspect shown in fig. 5.

The plain, 3, slopes gently to the north; and numerous gullies or minor valleys, which open out just above the present bank of the Rhine and end in the plain above, have been produced by atmospheric decomposition and rain and snow during the time that the river has been cutting its way from 3, its higher, to 1, its present level.

At Wellmich, looking down the river, the general appearance of the high banks is given in fig. 6, which shows the terraced plain on the left bank receding to the north in a gradual perspective, the more hilly ground to the right and left that bounds these terraced plains not being visible from this point of view.

Fig. 5.—*View of bank near Niederheimbach.*

1. The present level of the Rhine. 2. The cliffy ground of the west side of the gorge. 3. An old river-plain. 4. The more distant hills that bounded the earlier river-valley.

Fig. 6.—*View near Wellmich.*

Fig. 7.—*View on the left bank of the Rhine, near Salzig.*

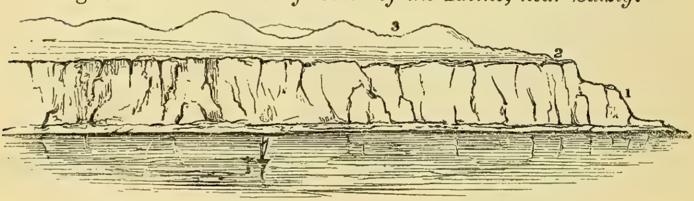
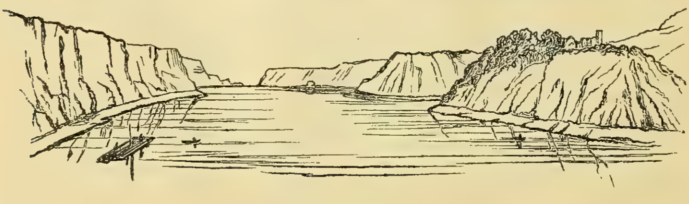


Fig. 7 represents the left bank of the Rhine at Salzig, still further down. The lower part (No. 1) is cliffy, above which there is the same kind of plain, 2, gently inclined northward, and which like those already noticed marks an old level of the river about 400 feet above its present channel. No. 3 marks the undulating hills beyond, as in fig. 5.

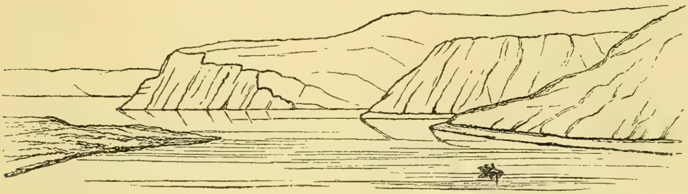
The general aspect of much of the country between Coblenz and Bingen is given in the following rough sketch of part of the scenery, looking up the river (fig. 8).

Fig. 8.—*View, looking up the Rhine, between Coblenz and Bingen.*



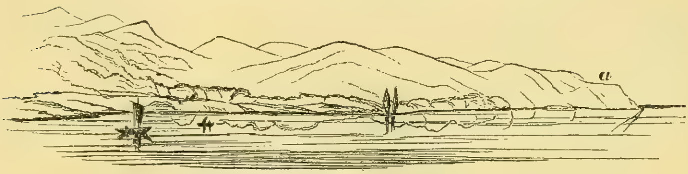
In this diagram high terraced plains are well marked, and the same kind of form is occasionally repeated at different levels. The same general outline is seen near Rheineck (fig. 9), where the terraced form above the river cliff is well preserved. Finally, just about the

Fig. 9.—*View near Rheineck.*



mouth of the gorge above the Siebengebirge, looking up the river, the long hilly slopes on the coast are seen descending towards the Rhine, as in fig. 10, ending in a terrace (*a*) similar in height and

Fig. 10.—*View near the Siebengebirge, looking south.*



general character to those previously mentioned. In fact from end to end of the gorge there are constant recurrences of these forms, on approximately corresponding levels above the Rhine, and at other elevations besides.

As the gorge was being gradually cut out and deepened, and as a consequence of this the Rhine, wandering through the plain beyond Bingen, by degrees lowered the surface of that broad part of the valley; so just in proportion the Maine, the Neckar, the Murg, the Kinzig, the Elz, and other tributary rivers also lowered their channels: in other words, when the Rhine flowed at a higher level, the valleys of the tributary streams were also proportionately higher; and this remark equally applies to the tributaries of the Rhine on either side of the gorge, such as the Lahn, the Moselle, and many smaller streams. By this means we arrive at the post-Miocene history of the deepening of river-valleys over very large areas; and the reasoning now applied to the Rhine is equally applicable to the Danube and other European rivers of equal importance.

One other minor point remains with regard to the history of the Rhine. When the great Rhine-glacier, aided by tributary streams of ice, spread westward in the valley some distance below the junction of the Rhine and the Aar, vast quantities of moraine-matter must have been shed from its western end or edge. The large bodies of water that then flowed from a glacier so enormous carried great part of this moraine-matter down the course of the river, just as the streams that issue from the smaller glaciers of to-day attack the terminal moraines and restrict their growth.

A necessary consequence of the powerful flow of such a large body of glacier-water must have been to carry the waterworn stones onward to Basel and into the flats beyond; and in time, as the river changed its channel and wandered hither and thither across the plain, the gravels got scattered over the whole of its area. The thick strata of sand, loam, and gravel that form the present plain of the Rhine are therefore in great part the waterworn débris of old moraines, just as the gravels of the plains of Piedmont and Lombardy are relics of the moraines of the gigantic glaciers of the Italian side of the Alps. This view of the origin of the gravels of the Rhine was pointed out to me thirteen years ago by Professor Desor, of Neuchatel, though I do not recollect that he has printed any thing on the subject.

The substance of the foregoing remarks may be summed up as follows:—

1. During portions of the Miocene epoch the drainage through part of the valley that lies between the Schwarzwald and the Vosges was in great part from north to south, or, in other words, from the hills north of Mainz into the area now occupied by the Miocene rocks of Switzerland.

2. After those physical disturbances and elevations that closed the so-called Miocene epoch in these regions, the direction of the drainage was reversed, and thus it happened that:—

3. After passing through the hill-country between the lake of Constance and the place where Basel now stands, the Rhine flowed along an elevated plain formed of Miocene rocks, the relics of which still exist between Basel and Mainz.

4. At the same time the Rhine flowed in a minor valley through the upland country formed of the Devonian rocks that now constitute the Taunus, the Hundsruck, and the contiguous high land lying northerly towards Bonn.

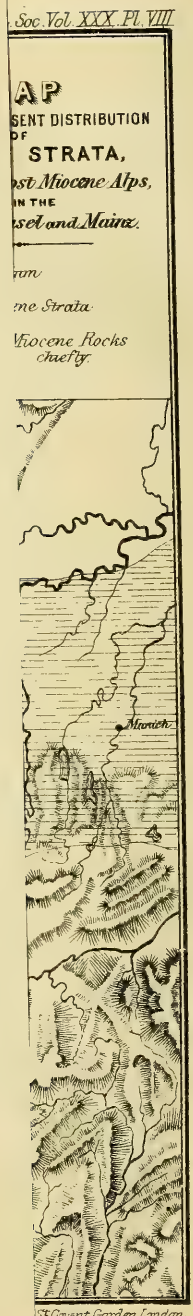
5. Then by the ordinary erosive action of the great river the gorge was gradually formed and deepened to its present level, and—

6. Just in proportion as the gorge deepened, so the gently inclined Miocene strata of the area between Mainz and Basel were also in great part worn away, so as to leave the existing plain, which to the uninstructed eye presents the deceptive appearance of once having been occupied by a great lake*.

* Since this memoir was sent to the Geological Society I have read a learned paper sent to me by Professor Fridolin Sandberger "On the Upper Rhine Valley in Tertiary and Diluvial Times" (Das Ausland, No. 50, Dec. 15, 1873).

This memoir, which is of the highest value, contains a great amount of information on the relations, stratigraphical and palæontological, of all the formations found in the valley of the Rhine from the Upper Bunter Sandstone down to the times of the Loess and superficial gravels.

Professor Sandberger only here and there incidentally touches upon the physical questions to which I confine myself, and apparently had no intention of going into the details by means of which I attempt to prove what I conceive to be the physical history of the valley, especially in its later stages. Wherever he does touch on these subjects, however, there is no discrepancy in our views. On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AP
SENT DISTRIBUTION
OF
STRATA,
st Miocene Alps,
IN THE
sel and Mainz.
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Miocene Rocks
chiefly
Munich
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EXPLANATION OF PLATE VIII.

Map showing the present distribution of Miocene strata north of the post-Miocene Alps, and in the basin of Basel and Mainz.

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the contrary there seems to be agreement, a circumstance on which I may be permitted to congratulate myself. With Professor Sandberger's permission I trust soon to publish a translation of his memoir.

From M. Merian, of Basel, and Professor Studer, of Berne, I received much valuable collateral information, which helped me to work out the theory propounded in this memoir.

MM. Dufrénoy and Elie de Beaumont attribute the original formation of the plain of the Rhine, between the Vosges and the Schwarzwald, to the sinking of the highest part of a long, gently curved arch formed by the ancient junction of the rocks of these mountains above the space now occupied by the valley. This space, according to these distinguished authors, was let down by a series of faults, which produced the scarped sides of the mountains on either side of the great valley of the Rhine (Explication de la Carte Géologique de la France, vol. i. p. 437).

Dr. Hibbert, in his celebrated 'History of the Extinct Volcanos of the Basin of Neuwied on the Lower Rhine,' 1832, states the theory propounded by M. Elie de Beaumont, and seems partly to consider that, previous to the deposition of the Tertiary deposits, the solid strata of the Rhine gorge "would be shaken to their very foundation; while during their very forcible elevation deep fissures or, according to a late phraseology, deep valleys of disruption (vallées d'écartement) would ensue, ... in which case, owing to the attriting power of torrents contained in such fissures during an incalculable period of time, it would not be always easy to distinguish such appearances as have originated amidst the convulsive effects of uplifting causes, from those which have been caused during an incalculable lapse of ages by the persistent degradation of meteoric agents." He thinks that the Moselle, with all its windings, has "the close resemblance of a deep fissure or split," and the same of the Brühl and the Nette—that the gorge of the Rhine between Andernach and Rheineck, and thence towards Cologne, was formed "by the same common convulsion," and, indeed, "that the valley of the Rhine, as far even as from Bingen to Bonn, was originally an immense fissure, suddenly induced by causes of violence;" and to this and other fissured valleys he attributes different dates. All of these were antecedent to the Tertiary period, or probably so (pp. 10–14).

Again, following M. Boué, he considers "the valley from Mayence to Basel one of the ancient marine basins of Europe during the Tertiary period," and that a barrier of high land stretched across "the present site of the Straits of Bingen," so that "this marine basin had no connexion with the present channel of the Rhine from Bingen to Cologne."

"Its waters flowed in a direction quite opposite to that which they now maintain, being from north to south, while its southern extremity [about Basel, I presume] was connected with the other marine basins of Europe by means of narrow channels." The more modern view is that it was directly and broadly connected with the freshwater and occasional marine interstratifications of the Swiss Miocene strata, which, quoting from M. Boué, he states to consist of marine and freshwater débris of shells &c. confusedly intermingled by frequent débâcles (p. 17). The basin of Neuwied Dr. Hibbert also considers to have been a lake which was partly drained by the convulsively disrupted fissure which now forms the gorge of the Rhine between Andernach and Linz; and this drainage of the lake was helped by "the fissured channel of the Brühl, which was probably a remote effect of the volcanic eruptions which in this district distinguished the commencement of the Tertiary epoch" (p. 19). The different statements seem to me to be not quite consistent with each other; but they may be partly understood as rather expressing the opinions of M. de Beaumont and M. Boué than Dr. Hibbert's own opinion. Further explanation is perhaps wanted in my memoir respecting the basin of Neuwied and the valley of the Brühl; but I may return to this subject in a future memoir.


MAP
SHOWING THE PRESENT DISTRIBUTION
OF
MIOCENE STRATA,
North of the Post Miocene Alps,
AND IN THE
Basin of Basel and Maine
Alluvium
Miocene Strata
ODEN WALD
JURA

Discussion.

Mr. Campbell, in illustration of the paper, and of the effects which running water is capable of producing, brought forward some views in Daghestán and the Caucasus. Very considerable tracts of this country are drained by cañons, very narrow, but some hundreds of feet in depth; the streams which pass along them are principally fed by melting snow.

Prof. Hughes doubted the view which referred the present Rhine to any configuration of the country due to the original level surface of the Miocene while it ignored the post-Miocene elevation of the Alps and Jura. He had traced the lava from the Forniche Kopf, near Andernach, down to within 100 feet of the present Rhine. He thought, therefore, that the Rhine began to cut back a channel by rapids and waterfalls, from the Rolandseck end, at the first appearance of the land above the Miocene sea, and before the close of the earth-movements and volcanic eruptions which seem to be connected with the later Miocene, but that it took the river so long to eat its way back as far as Bingen that it had time to wind about and form a broad valley in the upper part of its course—that the river continued to run at the higher level at the Bingen end until, at a comparatively far less remote period, the gorge was eaten back through this flat valley; and when once the river had got through the harder rocks near Bingen, it soon disposed of the softer beds in the Mayence basin.

Mr. Koch was inclined to think that the Jura chain had existence in Miocene times, as beds of that age lay horizontally in hollows in the Jurassic rocks. He quite agreed with Prof. Ramsay as to the terraces along the sides of the Rhine gorge.

Mr. Tiddeman did not see the difficulties suggested by Prof. Hughes.

The Duke of Argyll remarked that if the physical history of the Rhine were established, it would throw much light on that of other great rivers. He considered the paper of great value, but suggested a doubt whether the history assigned would account for all the phenomena exhibited along the course of the river. There appeared to have been at the commencement of the existence of the river several upheavals of the land, but subsequent to the main upheaval of the Alps. He regarded the channel of the river as entirely due to fluviatile action, but he confessed to having some doubt whether the erosion of the river alone could have effected the enormous amount of denudation exhibited in the district. He inquired whether there was not a possibility of some marine denuding power also having been at work. He also inquired as to the flexure of the rocks and subterranean movements affecting the conditions of the case, especially in connexion with the angles at which the Miocene strata are tilted. A third question alluded to by Prof. Hughes was as to the volcanic action that had gone on in the valley of the Rhine; and he wished to know whether that might not also have conduced towards the present contour of the valley. As to the terraces, he accepted the author's view as correct; but the question still remained as to how far the gorge was due to gradual erosion and how far to some subterranean action.

Prof. Ramsay, in reply to Mr. Hugh Miller, stated that the detritus brought from the north was found in Switzerland, and that Prof. Sandberger considered that at the time of its transport the Jura was not in existence. He had conversed with all the principal Swiss geologists; and it was from them he learnt that, along what is now a part of the valley of the Rhine, a river flowing southwards, during episodes in the Miocene period, carried pebbles from the north along its course. This river must have dated back even to Eocene times. In reply to Prof. Hughes, he stated that the attribution of the volcanic outflows to Miocene times was somewhat problematical, and that there was some probability of their belonging to a more recent period. Neither did they affect the district mainly under consideration. There was no great succession of terraces, but one main terrace of fluviatile origin, of which extensive traces remained. Similar terraces occurred on the Moselle. In reply to the Duke of Argyll, he stated that he did not think that volcanic action had any thing to do with the formation of the gorge. The Miocene strata lay in an approximately horizontal direction, and were not tilted in such a manner as to suggest that their absence in the basin was due to any disturbance of the strata. They must, in his view, have been of necessity scooped away by the action of flowing water.

14. *The* Origin *of some of the* Lake-basins *of* Cumberland. By J. Clifton Ward, Esq., Assoc. R.S.M., F.G.S., of the Geological Survey of England and Wales. (Read January 7, 1874.)

[Plates IX. & X.]

First Paper.

The subject of the origin of lake-basins is one which has received considerable attention at the hands of several eminent observers, and notably of Professor Ramsay. At the present time I propose to discuss the origin of those depressions in which some of our Cumberland lakes lie, taking as examples Derwentwater and Bassenthwaite, and Buttermere, Crummock, and Loweswater. The two former lakes I have myself carefully sounded; the latter were sounded many years since by Mr. P. C. Crosthwaite; and the depths obtained by him will here be made use of, with some observations of my own.

The first point is to obtain a true idea of the proportions and depths of the lakes as compared with the surrounding mountains. For this purpose I have drawn a number of sections on a true scale (the same vertical and horizontal), both in the direction of the length of the lakes and transverse to that direction. In the case of the longitudinal sections (figs. 1–3), outlines of the mountains on the left sides of the respective valleys are inserted, with their true height, and the lakes are indicated by deep-black lines of a thickness corresponding to the various depths. To form a strictly accurate idea of the original size of the lakes, the following points must also be taken into account. Both Derwentwater and Buttermere must formerly have extended nearly a mile higher up their respective valleys (see Map, Pl. IX.). Derwentwater and Bassenthwaite were once continuous, though now parted by some three miles of alluvial land. Buttermere and Crummock were likewise originally one, though three quarters of a mile of alluvium now separates them. The filling up of the head of Derwentwater is due to the matter brought down by the river Derwent and the Watendlath beck; and the soundings for a mile and a quarter north of the mouth of the Derwent show how this process is still going on, the depths for that distance only increasing from 5 to 18 feet, there being much deeper channels on either side the northern part of this shallow tongue (fig. 17). The Barrow beck has also done its share of work in forming an alluvial fan projecting into the lake, and in shallowing the parts immediately beyond. The tract of alluvium between Derwentwater and Bassenthwaite has been formed by the river Greta flowing from the east, and the Newlands beck and its tributaries flowing from the south and west. The head of Buttermere has been filled up by the detritus borne down by the Gatesgarthdale and Warnscale becks, flowing westwards on either side of

Honister Crag; and the alluvium separating Buttermere from Crummock is mainly the product of Mill beck flowing down from the north, and Sourmilk Gill from the south, upon the opposite side.

In the absence of borings the thickness of these alluvial deposits cannot be estimated; but it might be that, formerly, the greatest depths of the original long lakes were at points somewhere between Derwentwater and Bassenthwaite in the one case, and Buttermere and Crummock in the other.

The figures 5–10 and 13–16 inclusive, give the forms of the lakes in transverse section, while figs. 1, 2, & 3 represent their longitudinal sections along the lines of greatest depth.

When the true dimensions are thus laid down to scale, the point that first strikes one is the insignificance of the hollows in which the lakes lie as compared with the elevations of the surrounding ground. But since these lakes are not sheets of water merely dammed back by moraine mounds, but lie in hollows scooped out of the solid rock, it becomes an interesting and legitimate question to inquire what was the agent which produced the hollows.

Now I think there is no doubt whatever that the principal valleys of the district in which these larger lakes lie are of very great age. After more than four years' intimate acquaintance with mountain and valley, the fact is very strongly impressed upon my mind that all the grand mountain-sculpturing to be met with here is due to the apparently weak agents now in operation, the powers of the atmosphere, wind, rain, frost, and running water. Nor can I see any reason to doubt that the elaboration of our present Lake-district scenery has been going on uninterruptedly, though very likely at different rates, at least ever since the close of the Carboniferous period, and perhaps from an earlier date still. It will thus be seen that I do not consider our Cumberland valleys to be merely gigantic ice-grooves formed by a mammoth ice-cap, as was recently suggested to this Society by Mr. Campbell to suit the case of Ireland; but, rather, I look back through long past ages during which these valleys were being sketched out, formed, and deepened, under very varying circumstances and climates, now under almost tropical conditions, and now beneath an arctic mantle of snow and ice—sometimes when the district was far higher above the level of the sea than it is now, and sometimes perhaps when at a lower elevation. In all probability glaciers have moved down these old valleys at more than one period previous to the modern Glacial; and though they may have effected a large amount of denudation by attrition and transport, yet did they hinder the work of the denuding agents for long ages after, just in proportion as they left the country with a smooth and polished surface against which the atmospheric powers might beat for long in vain. Such considerations as the foregoing lead me to conclude that the lake-hollows are of very recent date, geologically speaking, and represent the removal of but some of the last rock-shavings by nature's tools. And what the special tool was which effected this we have now to consider.

Professor Ramsay has ably shown the difficulties which attend an explanation of the formation of rock-basins by such agents as the sea, running water, and mere weather-action, or by rock-disturbance, special depression, or the formation of gaping fissures. Certainly the lakes in question do not appear to have been formed by any such actions. They bear no marks of marine action, even supposing the sea capable of scooping out smooth hollows in closed fiords running far inland. Such hollows are not now being formed by running water, but rather filled up through its action. They do not lie in synclinal troughs of rock; for the general direction of the two sets of lakes is directly across and at right angles to that of the strike of the rocks. No one could suppose that the shallow basins represented in these diagrams were special areas of depression, when the contour of their bed is seen to conform so closely to that of the hills on either side, and the lie of the rocks shows no evidence of so limited a movement. Neither can they possibly be regarded as resulting from great fissures having taken place; for the rocks show no signs of such at either end of the long shallow troughs, or on either side; nor, as far as I can tell, do the lakes lie along lines of fault, with the exception of Derwentwater, which is bounded on the east side by a fault throwing together the hard Volcanic Series of Borrowdale and the soft Skiddaw Slates (fig. 13).

These lakes are, indeed, merely long shallow basins with a smoothed and well-scratched inner surface, worn out of the Skiddaw Slate, which is much crumpled, cleaved, and comparatively soft. The smoothing and the scratching of the rocks, in the direction of the length of the lakes, may be traced at many points passing under the water; so that there is no doubt that the hollows have been at one time filled with glacier-ice; and it remains to be seen how far in these cases Professor Ramsay's theory of the glacial origin of lake-basins will hold good.

In a former paper, on "The Glaciation of the Northern Part of the Lake District"*, I brought forward details to prove that at the period of greatest glaciation the large glaciers were more or less confluent, and that the greater part of the district was almost completely enveloped in ice. In the longitudinal sections (figs. 1 & 3), however, I have made the thickness of the ice no greater than the highest ice-scratches pointing down the valleys clearly warrant. In many cases ice-rounded rocks are common above the point at which the highest scratches are seen; but for our present purpose we will ignore this further evidence and take a *low estimate* of the thickness of the old glaciers. At the very outset of our examination a difficulty will present itself to some minds. If we take the case of the old Borrowdale glacier and mark its course along the valley of the Derwent, over the present sites of Derwentwater and Bassenthwaite, we are struck by the great flatness of the ground for full thirteen miles, from Seathwaite to the lower end of Bassenthwaite lake, ten miles of which is occupied along the line of section either by existing lake or alluvium representing former lake. If, then, we had to consider the old glacier a line of ice by itself, arising in the part

* Quart. Journ. Geol. Soc. vol. xxix. p. 422.

of the Derwent valley above Seathwaite, and having no other outward push but that due to gravitation down the two-and-a-half-mile slope from Allen Crags to Seathwaite, and to molecular gravitation throughout its length, we might be inclined to question the possibility of its moving over the thirteen miles of flat ground and scooping out lake-basins in its course. But just as the river Derwent now receives very many tributaries, some as large as itself, from the valleys and mountains on either side, and yet does not occupy a much wider channel, but acquires a faster flow and greater power of moving material onwards with it, so did the old Borrowdale glacier, the former representative of the Derwent, receive additional impulse from the numerous glacier sheets shed off the mountains on either side and down the tributary valleys. Let us see what this additional impulse really means. Above the village of Rosthwaite there met several large ice-streams. The Derwent glacier proper received reinforcement from ice coming down from Sty Head, out of Sourmilk Comb between Grey Knotts and Base Brown, and down the valley in which Comb Gill now runs due north from Glaramara. Just above Rosthwaite it was joined by the Stonethwaite glacier, made up of the Longstrath and Greenup ice-streams (see fig. 11). The union of these two glaciers (Derwent and Stonethwaite) formed the main Borrowdale glacier, which had then to be forced through the narrowest part of the valley, between Rosthwaite and Grange, a great ice-sheet moving over the fell-tops on the east side more or less coalescing with it (see Map, Pl. IX., and fig. 12).

The old Rosthwaite Lake, of an oval form, and nearly a mile in length, occurs, it should be noted, just beyond the junction of the Derwent and Stonethwaite glaciers, and where the ice, after having its rate of flow somewhat checked at the junction, would have acquired an additional impetus (see Map, Pl. IX.). About Grange the ice-sheet shed off Brund Fell and down the Watendlath valley joined the main glacier on its escaping from the so-called jaws of Borrowdale (just about Castle Crag, fig. 12). Thus increased in mass, the ice was urged through the valley, over the present site of Derwentwater, between Cat Bells* and Bleaberry Fell (fig. 13). I have little doubt that the pressure in a N.N.W. direction was here so great that the western side of the glacier partly escaped over the Cat Bell ridge—especially through the Hause Gate, between Maiden Moor and Cat Bells (fig. 3)—and became confluent with the Newlands glacier upon the other side. It is just about this part of the valley (fig. 13) that the greatest depth of Derwentwater is found—a depth, however, very slight as compared with the thickness of the ice, the former being 70 feet, and the latter something like 1100. Tracing the course of the glacier still further down the valley, it seems that about Keswick it was joined by several other large ice-sheets. There were the Newlands and Coledale glaciers wedging in about Braithwaite, and the western part, at any rate, of the great ice-sheet coming down the Thirlmere valley, pressing along the Naddle

* Skelgill Bank in fig. 13 is the northern end of the Cat Bells range.

vale, and over the low ridge towards Keswick (see Map, Pl. IX.). Besides these, sheets of ice of greater or less size probably descended the southern slopes of Skiddaw and came down the valley of the Glenderaterra. The main valley, just below Keswick, is about three miles in width, between Braithwaite and Latrigg; and it seems almost certain that the confluent glaciers occupied the whole width to the thickness at least of a thousand feet. Only two or three miles further down, however, this great volume of ice had to pass through a part of the valley not more than a mile wide at its base, between Barf and Dodd (fig. 14), beyond which it was able to escape to the west and east of the present Bassenthwaite Lake, mainly at first, I should fancy, to the west (over into Wythop vale, fig. 15), on account of the pressure from ice-sheets probably shed westward and north-westward from the lofty mountain mass of Skiddaw. It will be seen that the deepest part of Bassenthwaite is along the western side, just where resistance to the westward trending of the glacier would be most felt; and at the same time it is evident what a small proportion the depth of the long narrow trough bears to the probable thickness of the ice*.

Turning next to the examination of the case of Buttermere, Crummock, and Loweswater, we are struck at once with the difference in form of the valley-bottom, when seen in section (figs. 5–10), from that of the valley in which Derwentwater and Bassenthwaite lie (figs. 13–16). In the latter case the contour is like a more or less wide flat-bottomed pan, in the former (Buttermere, Crummock, and Loweswater) like a round-bottomed basin.

The head source of the Buttermere glacier was upon Fleetwith, below Grey Knotts, whence ice-streams flowed down on both north and south sides of Honister Crag, uniting with one another to form the main glacier just at the head of the present Buttermere Lake, where the valley is narrowest, the mountains on either side the most lofty, and where also the greatest depth of the present lake is found (see Map, Pl. IX., and figs. 5 & 19). The two ice-streams are represented in fig. 4, and the glacier after their union in fig. 5. It will also be noticed on reference to fig. 1 that the present lake commences just at the foot of the steeper part of the glacier-bed, and that beyond this point to the further end of Crummock there is scarcely any incline.

Besides the small glaciers shed down the steep hill-side from Burtness† and Bleaberry Tarn‡ Combs, a considerable ice-stream, coming down the Mill-Beck valley, must have joined the main glacier and helped to swell its mass (fig. 6). In my former paper I showed that the Buttermere glacier on approaching Mellbreak was probably split into two branches, the main mass continuing down the valley, but a part of its left side being pressed across the low watershed by Black Beck, just north of Scale Force (fig. 7), to join

* It should be borne in mind that a glacier, like a river, has its motion checked on approaching a narrow part of its valley bed, and flows more swiftly on its escape. Example, the strait between Barf and Dodd.

† Between High Stile and High Crag. ‡ Between High Stile and Red Pike.

another ice-stream flowing northwards down Mosedale from Gale Fell (see Map, Pl. IX.). Any part of the ice-mass thus got rid of from the main valley at this point, however, was probably more than made up for by the ice poured down from the flanks of the Grasmoor and Whiteless Pike range. Between the northern end of Mellbreak and Grasmoor, the valley is again considerably reduced in width; and along this lower half of the lake its depth is greatest. Escaped from this narrow part, the main mass of the glacier continued down the vale of Lorton, reinforced by ice shed off from the west sides of the lofty Grasmoor and Whiteside range; and it is certain that at one time, at any rate, the left limb of the glacier passed over the present site of Loweswater, and partly enveloped Low Fell. This must have been at a time when the outward thrust of the ice was sufficiently powerful to push a portion of the glacier westward up an incline of 75 feet in a distance of a mile and a half, from Crummock to Loweswater (fig. 2). At the east end of Loweswater other ice-streams from the south met this branch of the main glacier; and the whole mass was squeezed through the narrow valley between Carling Knott and Low Fell (fig. 10), in which Loweswater now lies, its deepest part (60 feet) being midway between these highest points (fig. 21). A mile and a quarter beyond the upper end of Loweswater the ice would pass over the low watershed at Sosgill (fig. 2) into the flat country beyond.

I think that when the following points are carefully considered —the fact of the lakes under examination being but long shallow troughs, the thickness of the glaciers which moved along the valleys in which the lakes now lie, the agreement of the deepest parts of the lakes with the points at which, from the confluence of several ice-streams and the narrowing of the valley, the onward pressure of the ice must have been greatest—one can hardly resist the conclusion that the immediate cause of these lake-basins was the onward movement of the old glaciers, ploughing up their beds to this slight depth, in the way Professor Ramsay's theory suggests. At the same time it should be noticed that in the case of Buttermere and Crummock—lying in a valley with rounded bottom, as seen in cross sections—the action is merely a slight deepening of the basin, or the formation of a smaller basin of similar general form at the bottom of the larger; whereas in the case of Derwentwater and Bassenthwaite the action has been to produce a long shallow groove, of varying width, upon the flat bottom of the wide pan-like valley—this groove in the case of Bassenthwaite being situated (for probable reasons before noticed) markedly at one side of the pan, close under the rising sides.

It may be urged by some that the fact of the deeper lakes being situated in the valley bearing the glacier of least thickness is against the idea of the lake-basins being formed by the ice; but I think, in this case, the fact is rather due to the original forms of the respective valleys, the same or a less amount of rock-scooping giving rise to a deeper lake in an originally round-bottomed valley than in a flat-bottomed one.

At a future time I hope to test the results here obtained for these lakes by bringing forward like details in the case of some of the other lakes, and notably Wastwater, and also in a similar way to consider the origin of the many mountain-tarns scattered throughout the district. This latter subject leads me to make the remark that a great service would be rendered if some one could be induced, during the summer months, to visit the various tarns with a small light canoe and sound their depths. The work is one I would mostly gladly undertake myself; but as my official business will not allow me the necessary time, I must leave it, hoping some one may be found to do it out of pure love for scenery and science.

EXPLANATION OF PLATES.

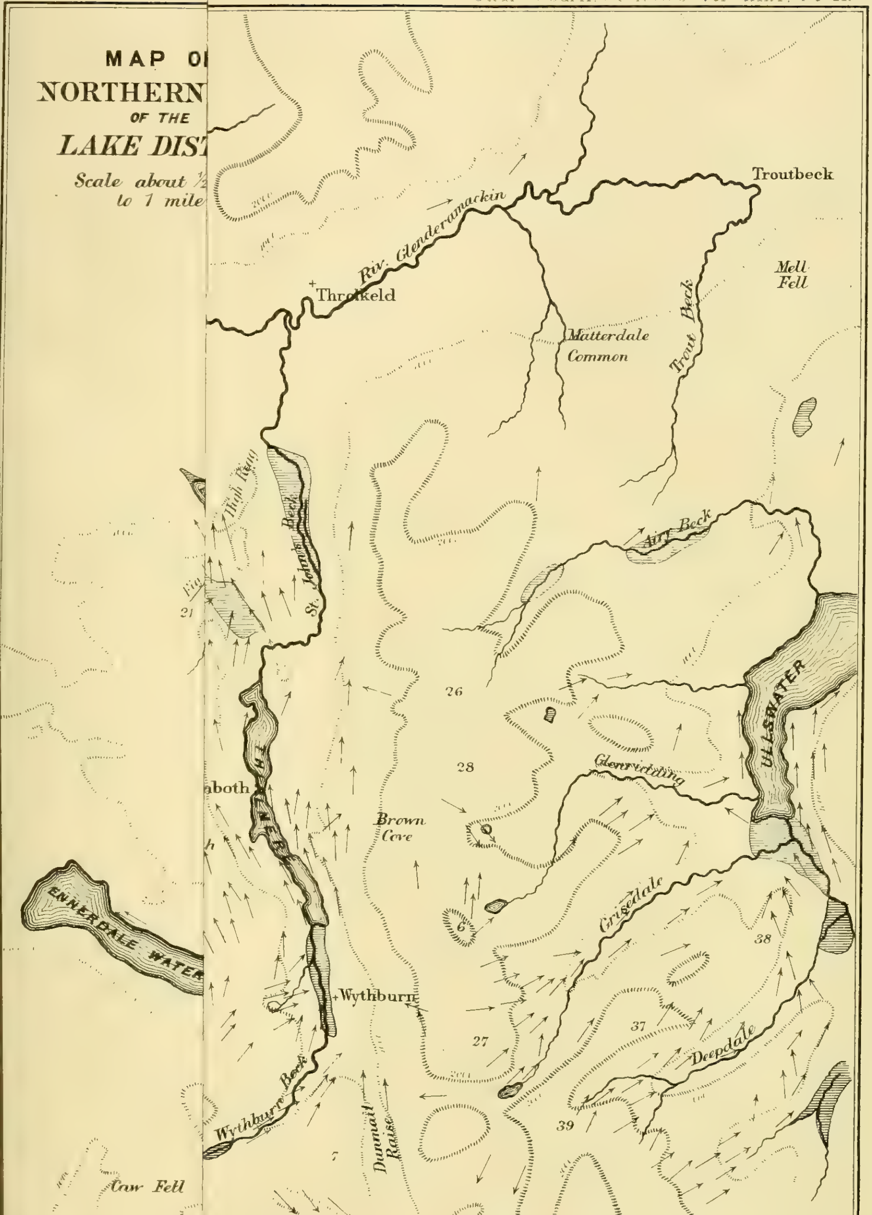
Plate IX.

Map of the northern part of the Lake district, showing the direction of ice-scratches by arrow-marks, and the lines along which the transverse sections in Plate X. have been drawn.

Plate X.

Horizontal sections to illustrate the form of the valleys, the depth of the lakes, the height of the mountains, and the thickness of the ice; together with plans of the five lakes: all on a true scale of 1 inch to 1 mile.

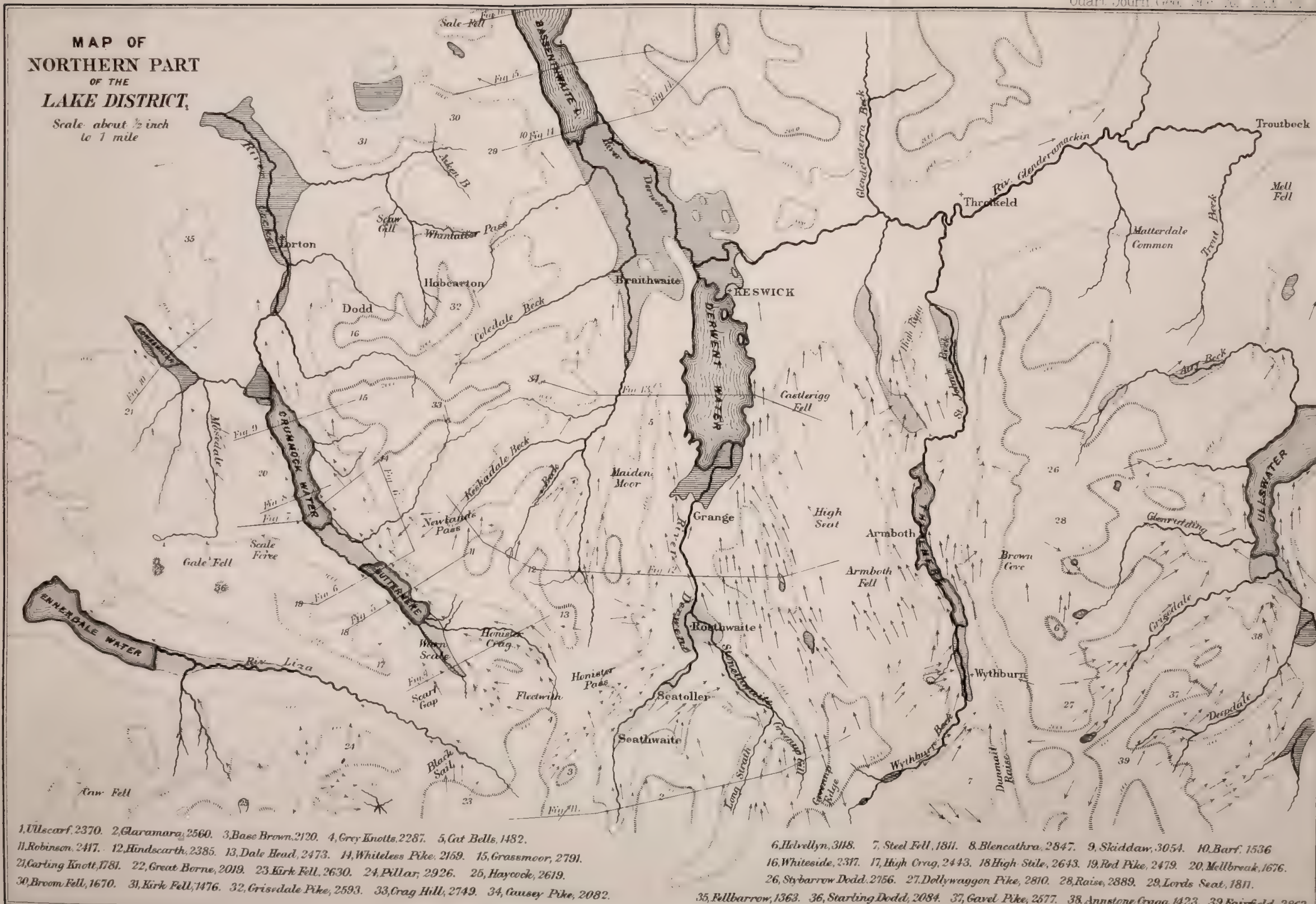
Fig. 1. Longitudinal section of the Buttermere and Crummock valley, from Grey Knotts to Low Fell.
2. Longitudinal section of the Loweswater valley, from the foot of Crummock Water to Sosgill.
3. Longitudinal section of the Derwent valley, from Allen Crags to the foot of Bassenthwaite Lake.
4. Transverse section of the head of the Buttermere valley, from Scarf Gap to Dale Head.
5. Transverse section across the deepest part of Buttermere, from High Stile to Robinson.
6. Transverse section across the lower end of Buttermere, from Red Pike to High Snockrigg, and High Snockrigg to Whiteless Pike.
7. Transverse section across the head of Crummock Water, from Black Beck to Whiteless Pike.
8. Transverse section across Crummock Water, from Scale Knott to Rannerdale Knotts.
9. Transverse section across Crummock Water, from Mellbreak to Grasmoor.
10. Transverse section across the deepest part of Loweswater, from Carling Knotts to Low Fell.
11. Transverse section across the head of Borrowdale, from Great Gable to Ullscarf.
12. Transverse section across Keskadale, Newlands vale, Borrowdale, and Watendlath vale, from Knott Rigg on the west to High Tove on the east.
13. Transverse section across the deepest part of Derwentwater, from Causey Pike to Bleaberry Fell.
14. Transverse section across the head of Bassenthwaite Lake, from Lord's Seat to Skiddaw.
15. Transverse section across the deepest part of Bassenthwaite Lake, from a little south of Wythop Hall to Ullock Pike.
16. Transverse section across Bassenthwaite Lake, from Sale Fell to Little Knott.



1, Ullscarf, 2370. 2, Glar Steel Fell, 1811. 8, Blencathra, 2847. 9, Skiddaw, 3054. 10, Barf, 1536.
11, Robinson, 2417. 12, Hin High Crag, 2443. 18, High Stile, 2643. 19, Red Pike, 2479. 20, Mellbreak, 1676.
21, Carling Knott, 1781. 22 56. 27, Dollywaggon Pike, 2810. 28, Raise, 2889. 29, Lords Seat, 1811.
30, Broom Fell, 1670. 31, Dodd, 2084. 37, Gavel Pike, 2577. 38, Arnstone Cragg, 1423. 39, Fairfield, 2862.

up Lakes.

Mintern Bros. Lith.



Contours 1000 ft. 2000 ft. 3000 ft. Filled up Lakes.

The points of the Arrows indicate the Ice marks.

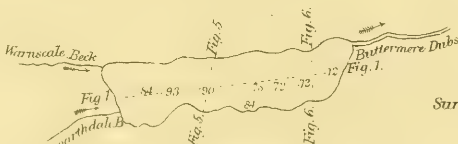
Mintern Bros. Lith

Surface of Water 226 Ft.

Fig. 18. *Bassenthwaite Lake.*

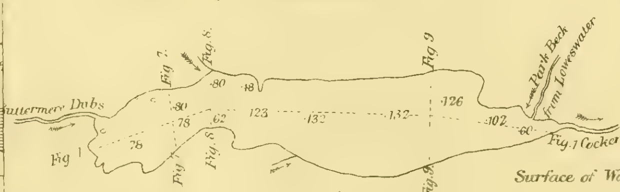
Surface of Water 238 Ft.

Fig. 17. *Derwentwater*



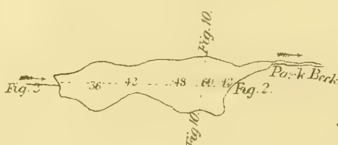
Surface of Water 331 Ft.

Fig. 19. *Buttermere*



Surface of Water 321 Ft.

Fig. 20. *Crummock Water*



Surface of Water 396 Ft.

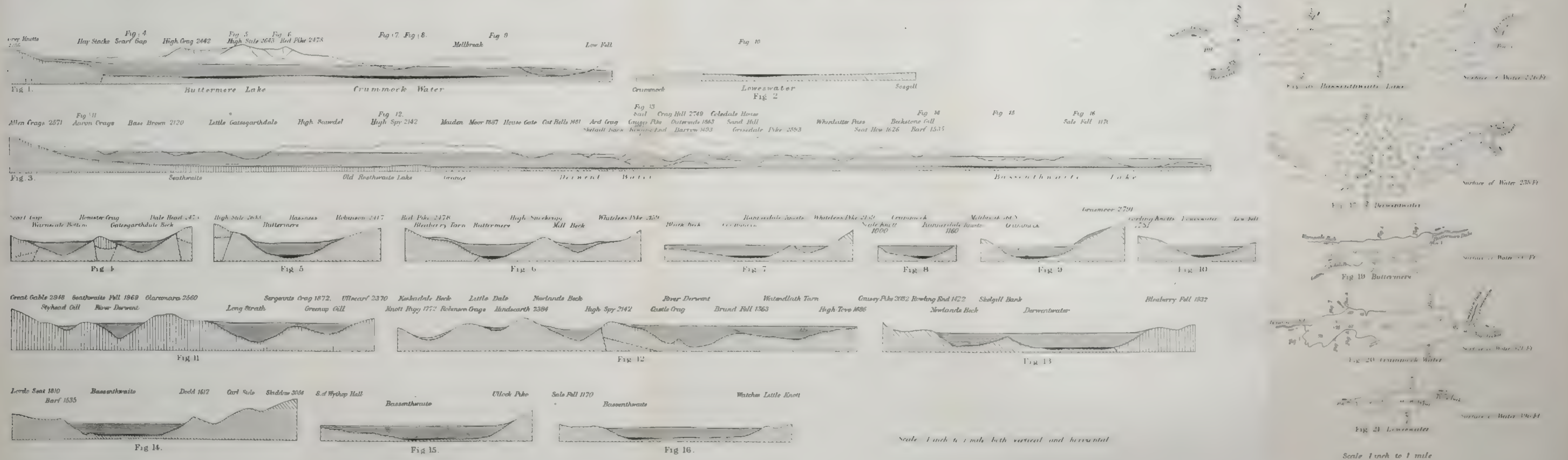
Fig. 21. *Loweswater*

Scale 1 inch to 1 mile.

Lakes with their soundings, depths in feet.

Mintern Bros. Lith.

PLANS AND SECTIONS TO ILLUSTRATE PAPER ON "THE ORIGIN OF SOME OF THE LAKE-BASINS OF CUMBERLAND" BY J. CLIFTON WARD.



Scale 1 inch to 1 mile both vertical and horizontal

Scale 1 inch to 1 mile

Lakes with their soundings, depths in feet.

Volcanic Series of Borrowdale — Skiddaw Slates — Glacier ice

The marks thus "Fig. 10" shew where transverse sections cross the longitudinal

Note. The Pattern Lines adopted to distinguish between the two formations, bear no relation to either bedding or cleavage

Fig. 17. Plan of Derwentwater,
18. „ Bassenthwaite Lake,
19. „ Buttermere,
20. „ Crummock Water,
21. „ Loweswater,

with depths given in feet, and dotted lines along which the sections run.

Discussion.

Mr. Campbell said that he had listened with great pleasure to the able paper of the author. He was not himself acquainted with the Lake-district; but he knew many similar districts in which similar phenomena existed. He agreed with the author's conclusion, that these lake-basins were the result of glacial erosion. But if ice could do so much, it might have done more. In confirmation of the author's views, Mr. Campbell said that in the Caucasus there are very few lakes. He had found no glacial phenomena in the whole range, except one small moraine near the only lake in Daghestán.

Mr. Evans inquired what effect the varying hardness of the strata, their trend and dip, might have had on the formation of the basins, and how the presence of islands was to be explained. He mentioned that at the present day the rainfall at Seathwaite was in some years nearly 200 inches, which, if there were sufficient cold, would suffice even now for an enormous supply of ice.

Mr. Seeley inquired whether the position of the lake-basins in the supposed glacier had any definite relation to the positions of smaller affluent glaciers, and whether the lake-basins were to be attributed to that relation.

Mr. Godwin-Austen remarked on the acceptance which Prof. Ramsay's views had received, and the support which they were receiving. There was little doubt of the former existence of ice over a large portion of this part of Europe; but whether it could have existed in such thickness as was required by some geologists was another question. He doubted as to the power of glaciers to drive ice forward to any great extent over land either up a slope or over a horizontal space. He considered that the paper would add a great interest to the country to which it related.

Capt. Douglas Galton disputed the power of ice to act in a manner materially different from that of water. Owing to the friction of the ice at the bottom of a glacier, he thought its flow would be so much retarded that its excavating power would be almost annihilated.

Mr. Ward, in reply, stated that the basins in all the cases he had cited were excavated in the Skiddaw slate, the hardness of which was nearly uniform. The dip of the strata was very variable, but he could not point to any spot where the depth of the lake was connected with the dip. The islands in Derwentwater might be the result of an old moraine left by the glaciers in retreating up the valley. The position of the lakes was in the direct line of the principal glaciers. The thickness of the ice was proved by the existence of scratches along the sides of the valleys, such as could not have been produced in any other way. The probability was that the ice had been even thicker than shown by these marks. Though the laws of motion of ice were the same as those of water, yet the action of a hard body was of necessity different from that of a liquid.

Prof. Ramsay was so accustomed to meet with papers such as this, confirming his original views, that he was almost becoming weary of the subject. He considered, however, that the sections given by the author on a true scale were of very great value, as calculated to give a correct idea of the actual phenomena, and as showing the value of De la Beche's maxims with regard to such diagrams. He inquired whether there could be any difficulty in a body of ice, some thousands of feet in thickness, cutting out such inconsiderable hollows as those shown, just in the same manner as running water sometimes excavates its channel more deeply at one spot than another, if from local circumstances the nature of its motion is increased.

15. Geological Notes *on a* Journey *from* Algiers *to the* Sahara. By George Maw, Esq., F.G.S. &c. (Read February 52, 1874.)

[Plate XI.]

During the spring of 1873 I paid a short visit to the province of Algiers, and beg to lay before the Society the result of my observations on the main geological features of the district between Algiers and the Sahara.

The military road running almost due north and south from the Mediterranean coast of Algiers to the borders of the desert at L'Aghouat, the most southern French military outpost, and crossing nearly at right angles the prevalent line of strike and trend of the high and low ground, suggested itself to me as affording the most comprehensive section in a continuous line that could be selected for my object, which was to compare the geological features of Algeria with those of Marocco observed during my visits to that country in the years 1869 and 1871.

Very little has heretofore been written about the geology of Algeria; and, indeed, the best published maps fall short of giving a correct delineation of even the hill- and valley-systems of the country.

My line of route of 285 miles and 3° of latitude (viz. from 36° 47′ N. to 33° 48′ N., or a trifle over 210 miles in a direct line) included 30 miles by rail, from Algiers to Blidah, thence by *diligence* over the Lesser Atlas, through the gorge of La Chiffa to Medeah, and thence over the high land of the Tell to Boukhari, along a well-engineered road which at present terminates at a point about 110 miles from Algiers (See Map, Pl. XI.). From Boukhari to L'Aghouat, for the remaining 200 miles over the Salt Plains and Hauts Plateaux, communication is kept up by a small omnibus, running every fifth day along a rough track almost devoid of bridges, little better than a caravan-route, and which would be quite impassable to ordinary European vehicles. The dotted line on the map indicates my route, and the black line the section represented in the diagram Pl. XI., in which an occasional feature lying a little east or west of the actual line of section has been introduced. The fine double lines crossing the main line of section indicate the strike of the beds.

In general terms the portion of Algeria crossed in my route may be described as a great plateau of an average height of 3000 feet, bounded on the north by the range of the Lesser Atlas, in precisely the same way as the great plateau of Spain is backed up on its north side by the Pyrenees, and shelving off to the north in slopes and terraces to the sea-level of the Sahara. In detail, the general mass must be viewed as a series of high plateaux, separated by intervening plains at a relatively lower level; these plains appear to correspond with the former relative level of the Sahara submergence, their present height indicating the subsequent rise of the land, and represent a great Postpliocene anticlinal, to which the more ancient foldings of the Mesozoic and Tertiary beds are subordinate in their effect on the contour of the country.

I purpose, in the first place, to follow my route as an itinerary, and to describe the contour and geological features in passing from north to south, and then to summarize my observations in the order of stratigraphical sequence.

The coast in the neighbourhood of Algiers presents, in the absence of cliffs and escarpments, the same character as the Marocco sea-board of the Mediterranean and the coast-lines of Corsica and the Reviera already referred to in previous papers. The hill- and and valley-system of the land shelves under the adjacent sea, without the intervention of distinct escarpments, indicating, as I believe, that the existing coast-level is so recent that the sea has not yet had time to excavate a cliff-boundary. The palæontological evidence on the connexion of Europe and Africa in Postpliocene times brought forward by Mr. Boyd Dawkins in his paper "On the Physical Geography of the Mediterranean during the Pleistocene age" (Popular Science Review' for April 1873) supports the view of the recent origin of the existing Mediterranean coast-line.

Raised Coast-beaches.—I am informed by Mr. Tristram that a series of raised concrete shell-beaches occurs on the Mediterranean coast to the west of Oran, ranging in height above the sea-level from 200 to 600 feet. The fragments exhibited were obtained by him at Mers-el-Kebir, at a height of 400 feet; and among them Mr. Gwyn Jeffreys has determined the following species:—*Pecten opercularis, Pectunculus glycymeris, Cardium edule, Venus gallina, Turbo rugosus,* and *Fusus corneus,* all common Mediterranean and Pliocene species.

Neighbourhood of Algiers.—The city of Algiers is built up the side of a high boss of land standing out as a promontory on the west side of the bay, and separated from the higher land of the Lesser Atlas and Tell Plateau by the level plain of the Mitidja, the submergence of which to the extent of 200 or 300 feet would separate the high boss as an island. It is about eight miles across from north to south, and the same distance from east to west. It includes the oldest rocks observed on the line of section, viz. mica-schist and gneiss, with intercalated quartzite, disposed as an anticlinal with a north and south strike. Its highest point, about 800 feet above the sea, is a little to the west of Fort de l'Empereur, from which the beds dip nearly east and west at an inclination of 30°.

Skirting these ancient micaceous rocks, Tertiary beds are superimposed as terraces ranging round the Bay of Algiers to the S. and S.E. of the city, and ascend in the vicinity of Moustafa-Supérieur nearly to the summit of the hill. They have a prevalent dip of from 10° to 20° S.E. and E., and consist of soft, calcareous, cream-coloured freestone, here and there tufaceous, occasionally including beds of compact limestone, and closely resemble in mineral character the Calcaire grossier. They abound in shells, among which Mr. Etheridge has determined the following—*Pecten jacobæus, Arca, Cucullæa, Modiola,* sp., casts of *Cerithium, Natica,* sp., and fragments of *Pecten* and *Ostrea*; and he supposes them to be of Miocene age, and possibly in part Pliocene. The Museum at Algiers contains a few corals from these beds.

Remains of Postpliocene mammals have also been found in the neighbourhood of Algiers; and the skull of a fossil ox (*Bubalus antiquus*), remarkable for the immense length of its horn-cores (about 20 inches) is preserved in the museum. It was found in excavating stones for the road to the Penitentiary of Bab-Azzoun, near Algiers. It resembles in mineral character the Tertiary fossils, and was probably imbedded in rearranged débris from the Tertiary freestone beds.

The Plain of the Mitidja.—The railway, for about eight miles, skirts in a S.E. direction the bay of Algiers close to the sea, then turns south by La Maison Carrée through some cuttings of shingle and loam, and by a westerly bend at once enters the plain of the Mitidja at a height of 100 feet above the sea. The Mitidja is a level plain, about eight miles across, running out to the sea at the southern extremity of Algiers Bay, and separates the high boss of land against which Algiers is built from the range of the Lesser Atlas, forming its northern boundary. The plain consists of sandy loam intercalated with pebble-beds, and rises almost imperceptibly westwards, from the sea-level at Algiers Bay to the neighbourhood of Blidah, where a fan-shaped delta of shaly débris stretches from the foot of the Atlas half across the plain. This appears to have been deposited during the submergence of the Mitidja by the stream which debouches from the back of Blidah. Blidah station is situated about halfway up the regularly sloping delta, at a height of 500 feet; and the town of Blidah a mile higher up, at a height of 650 feet, and about a mile from the foot of the Atlas range. From Blidah station the rail again descends the western slope of the delta, till it reaches the average level of the plain at the station of La Chiffa, at a height of about 350 feet. The low ground is here left; and turning due south we enter the gorge of La Chiffa—a sinuous pass through the Lesser Atlas, closely resembling many of the lateral valleys of the Pyrenees.

The Lesser Atlas.—Trending nearly due east and west, on the south side of the plain of the Mitidja, is the Lesser Atlas, the only range included in the section which, either in structure or altitude, can lay claim to the title of a mountain. Compared with the noble chain south of the city of Marocco, rising 13,000 feet above the sea, the Algerian chain looks dwarf and diminutive, In altitude it scarcely averages 4000 feet, and few points exceed 5000 feet. It presents the character of a single rounded ridge, here and there rising up as separate blunted points. Very few of the intervening depressions occur at a lower elevation than 2500 or 3000 feet. Viewed from the south side, the mountainous aspect disappears, as it forms the northern boundary of the high tableland of the Tell, almost equalling it in height, excepting that here and there the summits rise up as shrub-covered hills above the general level of the Tell plateau. In structure, the Lesser Atlas of Algeria bears no analogy to the great Atlas of Marocco. It includes no eruptive rocks; nor did I observe a single eruptive rock on the line of section from Algiers to L'Aghouat.

At the foot of the Lesser Atlas, flanking the Mitidja, small isolated fragments of Tertiary beds are seen clinging to the older rocks, and, it is probable, were once continuous with the Tertiary beds on the north side of the plain near Algiers; as these fragments, both at the back of Blidah and at the entrance of the gorge of La Chiffa, run up into the Atlas valleys, they must have been deposited since the Atlas assumed its existing contour.

The central mass of the range, exposed in a number of sections in the gorge of La Chiffa, consists of a hard, close-grained, dark blue, argillaceous rock, commencing with a small anticlinal at the entrance of the gorge, and then dipping south at a high angle, averaging from 50° to 60° and occasionally 70°, or almost vertical, with a strike nearly east and west, corresponding with the trend of the chain. The rock is here and there slightly cleaved, the cleavage being nearly coincident with the stratification.

At first sight the Atlas rocks appear to be a distinct series from those forming the base of the Tell plateau; but after a careful working-out of this part of the section, I think it probable that they are merely an altered condition of the lower members of the great series of Mesozoic beds (probably of Cretaceous age), of which the Tell and the Hauts Plateaux are composed, the prevailing character of which resembles that of our Lower Lias. On the north side of the range, strata of this aspect are seen in the bed of the stream by the first bridge south of Blidah, and are replaced a mile further south by the more slaty rock of the Atlas, with a similar strike and dip. Again, at the south end of the gorge of La Chiffa the slaty rock graduates into stratified alternations of hard bands with intervening clayey shales; and these, between the south end of the gorge and Medeah, give place to a great mass of grey marly shales, here and there somewhat schistose, which are seen to underlie the Tertiary series forming the capping of the Tell.

The Plateau of the Tell consists of an irregular tableland, of an average height of 3500 feet, about 30 miles across, extending from the Lesser Atlas on its northern boundary to Boghar on its southern escarpment. In ascending from the gorge of La Chiffa, the Mesozoic grey shales and marls are lost, and the capping of the northern half of the Tell is seen to consist of a Tertiary series extending about 14 miles from Medeah to within a mile of Berouaguïa, as an irregular undulating synclinal, presenting a series of escarpments at its northern and southern boundary respectively, facing north and south, and including bright red marls resting on the Mesozoic rocks, overlain by calcareous freestones containing fossils, interstratified with grey and variegated marls, the whole having a collective thickness of from 300 to 500 feet. The fossils are very obscure, most of them occurring only as casts, and few of the species are determinable. Mr. Etheridge has determined the following genera, and from their general facies thinks the series may include beds of both Pliocene and Miocene age, viz. *Solen*, *Cyprina*, *Arca*, *Pectunculus*, and several species of *Ostrea* and *Pecten*.

The calcareous freestone is highly ferruginous, and contains deposits of hydrous sesquioxide of iron, undistinguishable from the iron-ores of the Northamptonshire Oolites.

After the Tertiary escarpment is crossed near Berouaguïa, at a height of 4000 feet, the road rapidly descends to a level of 3100 feet, and for a few hundred yards a sharp anticlinal of hard grey slaty rock similar to that of the Atlas is passed; from this point to near Boghar the road, at a level of from 3150 to 3600 feet, passes over an undulating country, the higher parts of which are crowned with forests of *Pinus halepensis*. Overlying the anticlinal above Berouaguïa, beds apparently identical with those in the southern half of the gorge of La Chiffa again set in and extend without interruption to the southern escarpment of the Tell, at Boghar. In physical aspect they resemble our Lower Lias, and consist of dark bluish marls, often *en masse*, but occasionally interstratified with well-defined thin courses of hard calcareous and argillaceous rock. These beds are highly contorted, and present a succession of dips both north and south at high angles, occasionally vertical, and arranged in shortly repeated series of synclinals and anticlinals, the valleys nearly always occurring on anticlinals. The strike of these contorted beds is locally variable, but maintains a general east and west direction. I obtained no fossils between Berouaguïa and Boghar; but at Boukhari (a neighbouring village, situated on an outlying spur of the Tell plateau), I collected the following species:—*Ostrea*, allied to *O. multicostata*, a fragment of an *Ostrea* allied to *O. cyathula*, *Ostrea* allied to *O. callifera*, *Pullastra* (sp.), *Pleurotomaria* (sp.), and several examples of *Pecten* which are supposed by Mr. Etheridge to be of Miocene age. In the museum at Algiers, there is a small series of fossils from the neighbourhood of Boghar, which I have had photographed. It includes some large *Ostreæ*, which Mr. Etheridge and Professor Phillips think may be of Tertiary age, but possibly Cretaceous; there are also some Lower-Cretaceous fossils from the same locality, viz. a *Turrilites*, an *Ammonites* allied to *A. Deshayesii*, a *Trigonia*, an *Inoceramus*, and an *Astarte*; also an Urchin, of the genus *Micraster* or *Toxaster*. This series is important, as affording a key to the age of the great mass of stratified beds of the Tell plateau, and tallies in age with some Lower-Cretaceous fossils of other species obtained by Mr. Tristram in 1861 on the northern escarpment of the Hauts Plateaux. The beds at Boukhari are apparently on the same horizon as the Boghar escarpment; and I am inclined to think that the rather imperfect series of fossils I obtained from the neighbourhood of Boukhari may be of Cretaceous age, especially as their general facies resembles the fossils I collected from the Neocomian beds at Saffe, on the coast of Marocco.

Between Boghar and Boukhari the road descends the southern escarpment of the Tell plateau to the valley of the Cheliff and the great low-level plain of the northern Sahara, situated at a height of

2150 feet. The Arab village and French fortress of Boghar is situated near the summit of the escarpment, at a height of between 3000 and 4000 feet, from which a magnificent view is obtained. Looking north, the nearer parts of the Tell plateau are seen, capped with forests of *Pinus halepensis,* the distance being bounded by the summits of the Lower Atlas. In a southerly direction, the great level plain of the northern Sahara spreads out as a sea-like expanse, bounded on the southern horizon by the mammillated chain of the Djebel Sahari, the curious notched outline of which is faintly seen in the extreme distance. The level plain runs up amongst the outlying spurs of the Tell plateau, which die out like promontories and islands resting on the flat expanse. From Boghar we look directly down into the valley of the river Cheliff, which rises in the plain of the Northern Sahara at a height of a little over 2000 feet. It is the most important river in Algeria. Its waters, like those of nearly all the North-African rivers, are very turbid. It first flows northward through a winding ditch-like channel between high banks of alluvium, and then westward into the Mediterranean a little to the east of Oran. In the alluvial banks of the Cheliff, near Boukhari, Mr. Tristram found some Hippopotamus-bones. The species was not determined, and the specimens have unfortunately been lost.

At the caravansary of Bou Guezoul, twelve miles south of Boukhari, the outlying spurs of the Tell plateau are left behind, the road terminates, and we enter on the great plain covered with *Artimisia, Sueda, Salicornia, Chenopodium,* and other salt-loving plants, perhaps indicating by their presence a comparatively recent marine submergence. The uniformity of the plain is only broken by an occasional low escarpment of gypseous and variegated marls, which are well exposed near the caravansary of Aïn Oussera.

These marls appear to be inferior to the fossiliferous beds of Boukhari and the Tell; but they are for the most part shrouded over in the plain by a deposit of grey loam, which, throughout the district included in the section, seems to mark the limit of the Sahara submergence. This loam, as well as the older beds that come to the surface, are in many places coated with a calcareous surface-crust similar to that observed in the Marocco plain, the formation of which was, I believe, due to the great heat of the sun, in alternation with heavy rain, quickly drawing up and evaporating from the substratum water containing calcareous matter in solution.

The Djebel Sahari.—The low-level plain of the Northern Sahara is crossed, in a direction nearly east and west, by a single range of hills known as the Djebel Sahari, towards which the plain rises from north and south to the third caravansary of Guelt-el-stel, at an altitude of 2900 feet. The Djebel Sahari, which are probably 700 or 800 feet high and 3500 feet above the sea-level, consist of a steep anticlinal of hard yellow sandstone, rising up from beneath the gypseous marls here and there isolated as dome-shaped masses, with escarpments facing both north and south. Denudation has sculptured the range into a curious mammillated series of hills, separated by deep indentations, which are conspicuous from a great distance. Between these hills and the northern escarpment of the Hauts Plateaux, the low-level plain continues for about fifteen miles, first descending from the anticlinal of Guelt-el-stel to a level of 2550 feet, and then gradually ascending to the Rocher de Sel at the foot of the Hauts Plateaux, at a height of 2800 feet. This second plain appears to be a repetition, dipping south, of the gypseous and saliferous marls of Aïn Oussera, on the north side of the Guelt-el-Stel anticlinal. Two large salt-lakes (the Sebka Zahrez) occur at a height of 2550 feet in the plain, a little to the south of the Djebel Sahari; and a little further south nitre is obtained by evaporation from square pans excavated in the grey marls.

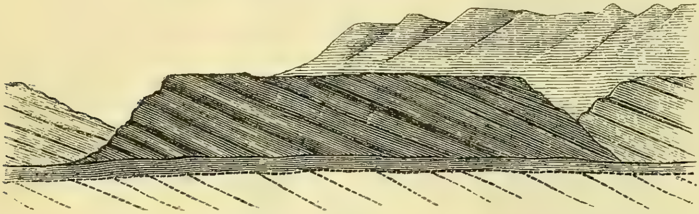
The plain south of the Djebel Sahari is covered with a deposit of grey silty loam, before referred to as the "Sahara loam;" and here we have clear evidence of recent marine submergence in the occurrence between the Djebel Sahari and the Hauts Plateaux of an extensive range of sandhills. I am also informed by Mr. Tristram that raised beaches of concrete shell-beds, similar to those on the coast, occur in this neighbourhood. He does not mention their altitude, which, however, cannot be less than from 2000 to 2500 feet. They form a most important point in the evidence of the Sahara submergence, to which I shall have to make further reference.

The Rochers de Sel, or, in Arabic, Hadjar el Mehl, forming the first and most northern escarpment of the Hauts Plateaux, rise up from the northern boundary of the plain, which here attains a level of 2850 feet near the fifth caravansary. *The Rochers* attain a further height of 300 or 400 feet, and present a strangely weird aspect. The mass consists of dark grey marls, mixed with rock-salt and gypsum, and interstratified with hard grey argillaceous rock-bands, the whole presenting a broken and tumbled arrangement. In one place the strike is nearly north and south, and dip nearly vertical; but the general dip and strike correspond, as far as I could ascertain, with the general dip and strike of the northern escarpments of the Hauts Plateaux, the beds of which the saliferous marls appear to underlie. The salt-mountain is capped with great blocks of tumbled rock scattered about in the wildest confusion, the placement of which is evidently due to the dissolution of the intercalated and underlying salt-marls; and I am inclined to think that the irregular dip and strike of the beds *in situ* has been materially influenced by the failure of support from the dissolution of the salt-rock, just as in some glacial beds the melting of intercalated ice is supposed to have brought about a confused and contorted arrangement. From these beds I obtained an *Ostrea* allied to *O. carinata*. Mr. Tristram has given me two specimens of *Exogyra sinuata* and an *Ostrea* allied to *O. cyathula* he found here in 1860; and Mr. Etheridge thinks they are of Cretaceous or Neocomian age.

The Hauts Plateaux.—From the south of the Rochers de Sel, the ground rapidly rises in a series of terraces, forming the northern escarpments of the Hauts Plateaux. Immediately to the south of the salt-rock near the fifth caravansary, bright red and green marls are exposed in the banks of the Oued Melh, dipping south at an angle of 35°. These bright-coloured marls appear to overlie the grey saliferous marls of the salt-mountain, and form the base of the series of the Hauts Plateaux. Their well-marked mineral character enables their horizon to be identified in several localities further south. The Hauts Plateaux may be described as a great synclinal, about 35 miles across, forming an open tableland of an average height of 3700 feet, bounded north and south by successive series of terraced escarpments. The beds are probably of Lower Cretaceous age, and apparently a repetition of those of the Tell Plateau, consisting of grey gypseous marls alternating with well-defined courses of hard fine-grained argillaceous and calcareous stone. The town and fortress of Djelfa is situated near the centre of this tableland, at a height of 3600 feet; seven miles further south the road attains its highest point, at a height of a little over 4000 feet, which, however, is not the actual summit, as higher terraces both right and left surmount the main level of the plateau, and probably attain a level of about 4700 feet. The road now descends the southern escarpment, crossing over the same series of beds dipping north that were passed in ascending from the Rochers de Sel to Djelfa; and at Aïn-el-Ibel, the sixth caravansary, the bright red and green marls seen near the salt-mountain are again exposed, underlain by a conglomerate at a height of 3300 feet. Mr. Tristram, in his 'Great Sahara,' records the occurrence of irregular beds of lignite in this neighbourhood.

From the Hauts Plateaux to L'Aghouat.—From Aïn-el-Ibel, the road gradually descends over an undulating plateau of red and yellow sandstone, probably a recurrence of the sandstone thrown up in the anticlinal of Guelt-el-Stel. The sandstone south of Aïn-el-Ibel dips 21° N.N.E., and further south gradually decreases in inclination till within a mile or two of the seventh caravansary of Sidi Makhelouf, where level strata of red sandstone, forming apparently the crown of the low anticlinal are reached; these are the lowest beds exposed in this part of the section. At the caravansary of Sidi Makhelouf, 2725 feet above the sea, the sandstone on the south side of the anticlinal commences to dip S.S.W. at an angle of from 10° to 15°. At this point the open plateau merges into a valley shut in by ranges of the beds overlying the sandstone. These present scarped faces on either side of the gradually narrowing strath. Between Sidi Makhelouf and Metlili, at a height of 2700 feet, several low sandstone hills (Fig. 1) rise out of the valley, and are remarkable for their perfectly flat tops at a uniform level independent of their stratification, which inclines at an angle of 15°. I can only account for their contour by marine denudation. Here also the fundamental sandstone begins to be shrouded over by grey loam, which is continuous with the grey loam covering the open Sahara plain further south; it is noticeable that this superficial deposit sets in at exactly the height at which it occurs north of the Hauts Plateaux, near the Rochers de Sel, and at the height at which the isolated range of

Fig. 1.—*Flat-topped Sandstone Hills between Sidi Makhelouf and Metlili.* (2700 feet above sea-level.)



Grey loam in bottom of valley.

sand-dunes occurs in the same locality. I shall further on refer to these evidences of the former extent of the Sahara submergence.

At Metlili the flat valley narrows to a mile and a half in width, and follows a direct southwest course. It is bounded by symmetrical escarpments 250 feet high, composed of gypseous marls interstratified and capped with harder strata, the irregular denudation of which has resulted in a singular range of isolated bosses and pinnacles separated by little lateral ravines. Near Metlili, bright red and green marls similar to those at Aïn-el-Ibel and those near the Rochers de Sel are again observed in the bottom of the valley; so that the escarpments bounding it probably correspond with the beds of the Hauts Plateaux; the upper part may be on a higher horizon. The road here follows for a few miles the line of strike, but on turning S.E. gradually passes an ascending series of beds, under which the red and green marls are lost; and turning through a break in the eastern escarpment, where the flat valley widens out, drifted sand and sandhills commence; the open plain is now approached, into which the cliff-like escarpments die out as isolated ridges running N.E. and S.W., separated by flat-bottomed valleys about a mile wide. The scene is most singular, and at once suggests to the eye the submergence of the older land beneath a newer deposit, which continues as a level plain as far as the eye can reach. Three or four parallel ridges, separated by intervening straths, terminate the high ground, each alternate flat occurring between dip slopes and on denuded anticlinals (Fig. 2); the final escarpment, dipping N.W. at an angle of 25°, presents a cliff-like amphitheatre facing the great plain (Fig. 3). Beyond this, at a distance of about three miles, isolated rocks with a complementary escarpment facing N.W. rise up out of the plain, and dip away S.E. at a steep angle under the shroud of grey loam and sandhills. On one of these rocks L'Aghouat, the most southern French fortress in this part of Algeria, rises up from an oasis amid an immense grove of date-palms, and presents a picturesque association of Arab mud houses, French military buildings, and a new mosque. The town is situated at a height of 2333 feet above the sea. The great altitude at which the sandhills commence in its neighbourhood, was a fact I had not anticipated, as further to the N.E., south of Biskra, the desert plain is on the level of the sea,

Fig. 2.—*Section of Escarpments on the borders of the Sahara Plain, near L'Aghouat.*

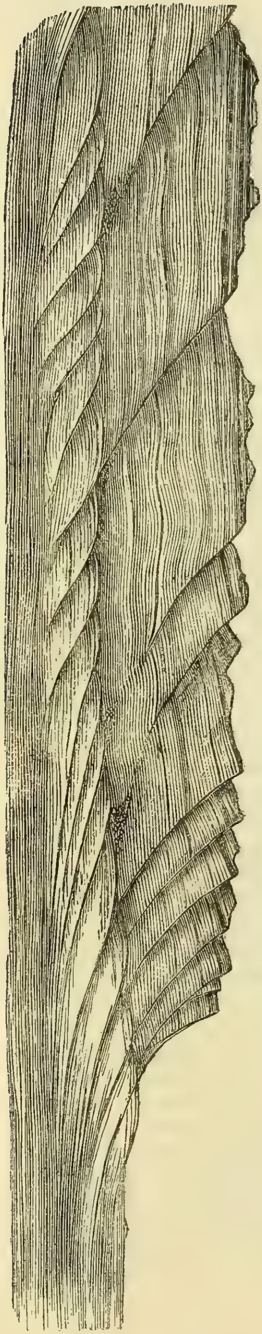


Fig. 3.—*Last Cliff south of the Hauts Plateaux, facing the Sahara Plain, L'Aghouat.*

and the French surveyors have ascertained that some of the lagoons in the neighbourhood are below the sea-level. From inquiries I made at L'Aghouat, I ascertained that the plateau on which it is built spreads out as a promontory in a south-easterly direction towards the level of the main desert, descending by slopes and terraces to the sea-level. Mr. Tristram tells me that red sandstone, which he supposes to be of Triassic age, rises up in the M'Zab country to the S.E. of L'Aghouat. This is probably a recurrence of the red sandstone which comes to the surface in the Sidi Makhelouf anticlinal.

Although there is good evidence of a Posttertiary submergence of the district surrounding L'Aghouat, the high level of the sandhills may also be partly attributed to the agency of wind, the effect of which in transporting sand to great distances must be seen to be fully realized. My approach to L'Aghouat was through a blinding sand-storm, which was still in full force on the following day, when on ascending one of the rocky eminences over the town I obtained my first view of the desert plain. A bitter east wind was blowing, and the light was quite subdued by the sand-storm. Looking south over the plain I could but dimly see the level horizon through the murky haze; and nearer the sudden gusts of wind were picking up from the desert cloud-like patches of sand, and whirling some of them away towards the great smoky mass of moving sand in the distance, and heaping up the nearer clouds in talus-like slopes against the boundary escarpments. To the north, terrace upon terrace of the cliffs of the Hauts Plateaux, piled up in receding lines, formed the boundary (Fig. 4). The near view was equally remarkable. East and west I looked along a broken ridge of rocks, completely isolated in the plain, crowned by handsome French buildings and long lines of fortifica-

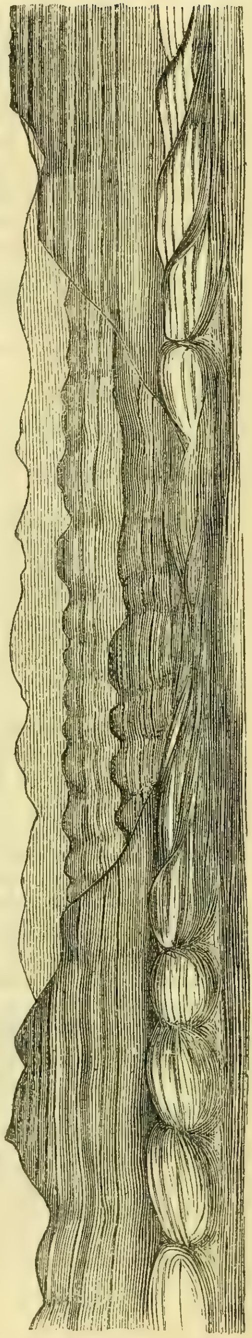
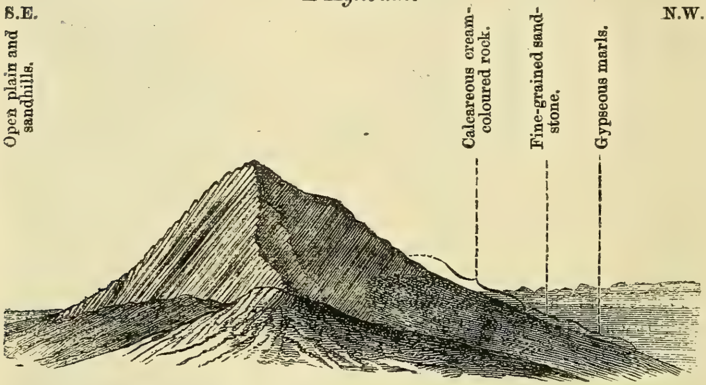


Fig. 4.—*Southern Escarpments of the Hauts Plateaux, facing the Sahara Plain, as seen from L'Aghouat.*

tions. Lower down on either side of the rocky ridge were the Arab flat-roofed habitations, built of sun-dried mud bricks, embosomed in a dense forest of date-palms, many of them from 90 to 100 feet high; and stretching away from this dark green and brown mass, lines and patches of light green vegetation spread out into the desert, where its thirsty sand was sucking in the last drainings from the oasis. During my stay at L'Aghouat, I took sketches and sections of several of the escarpments and rocky outliers (represented in Figs. 3, 4, and 5), the most important of which is the Rocher de Chien, W.S.W. of the town, a jagged hill (Fig. 5), rising up 300 feet

Fig. 5.—*Rocher de Chien, an isolated Rock, Sahara plain, west of L'Aghouat.*



out of the sandy plain, and consisting of a hard calcareo-argillaceous rock, with a N.E. and S.W. strike, dipping S.E. under the plain at an angle of 65°. At the foot of its N.W. escarpment occurs a calcareous cream-coloured rock, with casts of fossils, including a *Chemnitzia* or *Turritella*, underlain by a fine-grained sandstone, with casts of bivalve shells, which Mr. Etheridge thinks may be of Miocene age. The sandstone is succeeded by grey gypseous marls, which are lost under the Posttertiary deposit of grey loam, filling up as a plain two miles wide the denuded anticlinal between the Rocher de Chien and the boundary escarpment to the north. The lower beds of marl and sandstone on the north side of the Rocher de Chien have a less steep inclination than the overlying rock, and dip S.E. at an angle of about 35°. The face of the main escarpment N.E. of the town (Figs. 3 and 4) presents the following succession of beds in ascending order. At its base white gypseous marls, interstratified with bands of fine-grained white stone, occur as a low terrace a little in advance of the cliff face, and dip 15° N.N.E. with a W.S.W. and E.N.E. strike. The main face of the cliff consists of grey marls interstratified with hard bands and gypseous green marls; and its jagged summit is capped with hard calcareous bands, containing curious concretionary masses, which are very fossiliferous, including a spatangoid Urchin, which Dr. Wright thinks may be a

Hemiaster or *Penaster*, resembling *Penaster Fournelli*, from the Hippurite limestone (*Brissus*?), *Avicula*, *Inoceramus*, *Lucina*, *Cardium*, *Arca*, *Byssoarca*, *Cardita*, *Cyrena*? *Cucullæa*, *Clavatula*, &c. These stand out as bosses from the matrix, with a weathered black surface, and look like blotches of black mud; the colour is only skin-deep, the mass of the nodules being of a pale grey. They are excessively hard and difficult to break, and probably consist of ferruginous chert. The view from the summit of the escarpment is very singular. To the south the eye ranges over the great plain interrupted only by the rocky ridge of L'Aghouat; looking north a gentle dip-slope descends to the flat valley about a mile wide, bounded on the opposite side by a complementary dip-slope, with a repetition in reverse of the beds seen in ascending the first escarpment. The second ridge is soon crossed; and on descending its escarpment facing north, another flat valley about a mile wide is reached, bounded on its opposite side by an escarpment facing S.E. The view from the summits of these ridges presents a series of ranges running N.E. by S.W. (Fig. 2), nearly buried by a Posttertiary deposit of grey loam, forming flat valleys about a mile wide, each alternate valley occurring between dip-slopes and in the centre of a denuded anticlinal, suggesting to the eye the levelling up by a recent deposit of a series of hills and valleys that had originally been of greater height and depth. The level valley-bottoms of loam are obviously an inland extension of the plain, and were deposited when the Sahara sea ran up as fjords between the promontories of older land that branched out from the isolated land of Algeria.

Lignite occurs in several localities N. of L'Aghouat, viz. in the Djebel Amour at Kusra and at Berich, also at El Kheicha on the banks of the Oued M'Zi, a branch of the L'Aghouat river, where it is a metre thick, and overlain by black rock; but I had not an opportunity of seeing it *in situ*. Fossil plants are said to occur a day's journey N.W. of L'Aghouat, and are probably associated with the lignite formation. The only locality where the lignite has been observed *in situ* by a geologist is that noticed by Mr. Tristram at Aïn-el-Ibel, where it occurs near the horizon of the band of bright red and green marls exposed in several localities on my line of section, and probably a little above the horizon of the salt deposit of the Rochers de Sel.

Of the occurrence of other minerals, the following localities were named to me at L'Aghouat:—

Nitrate of potash is found near Touat, manganese at Outhed el Abiod, lead at Oued Sidi Bilgassem, and copper at Berich; but I could not ascertain the mineralogical conditions under which the lead and copper occur.

My return journey from L'Aghouat, following the same line of route, enabled me to check and correct the altitudes and fill in additional details in the section.

Stratigraphical Summary.—In conclusion I will give a general summary in stratigraphical sequence of the formations and of the successive changes of level and contour of the district comprised in the section. Of *eruptive rocks* there are no traces in any part of the district between Algiers and L'Aghouat. The oldest rock is the boss of *micaceous schists* and *gneiss* at the back of Algiers, striking nearly north and south and dipping away east and west from a low anticlinal, the crest of which occurs near the Fort de l'Empereur at the summit of the hill.

Rocks of the Lower Atlas and Anticlinal north of Berouaguïa.—The pass through the gorge of La Chiffa exposes hard slaty rocks, dipping south at a high angle and somewhat cleaved, which appear repeated as an anticlinal on the south side of the higher part of the Tell Plateau. They contain no fossils; and but for their being conformable to the overlying Neocomian beds, I should, judging from their physical character, place them on a much lower horizon. There is no satisfactory evidence as to their age. They strike N.N.E. by W.S.W., and closely resemble in mineral character the nearly vertical slaty shales on the northern flanks of the Great Atlas south of the city of Marocco.

Sandstones of Guelt-el-Stel and Sidi Makhelouf.—In the denuded plain separating the Tell from the Hauts Plateaux, and again on the south side of the Hauts Plateaux, red and yellow sandstones are thrown up as anticlinals, between which the overlying beds of the Hauts Plateaux form an elevated synclinal. There is no palæontological evidence as to their age; but they resemble the Bunter in mineral character, and are overlain by red marls resembling the Keuper. A similar succession of beds of Triassic age occurs in the south of Portugal; and I am informed by Mr. Tristram that red sandstone, supposed to be of Triassic age, comes to the surface at Warigla in the M'Zab country, S.W. of L'Aghouat, probably as a third anticlinal.

Saliferous Marls of the Rochers de Sel.—The northern escarpment of the Hauts Plateaux is the only point in the section where the saliferous marls are clearly exposed. I must take exception to the view expressed by Mr. Tristram, in his 'Great Sahara,' that they are "an eruption of argillaceous calcareous mud and rock-salt upheaved across the Secondary and Tertiary deposits." Although they appear isolated, they occupy a well-marked horizon in the Mesozoic beds at the base of the Hauts Plateaux; and though absent in similar positions at other parts of the section, they are clearly interstratified between the sandstones below and the red marls, grey marls, and rocky courses above. In mineral character they resemble the salt deposit at Bex, in Switzerland. Crystals of salt and gypsum are intimately mixed up with the grey marls. Ten or fifteen miles north of the Rochers de Sel, the presence of these marls is indicated by the two great salt lakes, or Zahrez; but south of the Hauts Plateaux, although their horizon can be identified, I observed no salt deposits; and if they occur in the north Sahara plain, their presence is obscured by the surface-deposit of grey loam and calcareous crust.

The patchy occurrence, so to speak, of the salt corresponds with the isolated distribution of salt rock in the Keuper of Worcestershire and Cheshire.

Red and Green Marls.—Overlying the red sandstones, a thin series of very bright red and green marls is exposed as a low escarpment in the north Sahara plain between the Tell and the Hauts Plateaux, near the Rocher de Sel at the foot of the Hauts Plateaux, at Aïn-el-Ibel at the foot of the southern escarpment, and again on the south side of the Sidi Makhelouf sandstone anticlinal from which the marls have been denuded. It is probable the red marls are brought up by rolls of the surface in several parts of the north Sahara plain both north and south of the Guelt-el-Stel anticlinal, but are obscured by the calcareous surface-crust, sand, and other superficial deposits.

Grey Marls and rocky bands of the Hauts Plateaux.—Immediately in upward succession from the band of red and green marls is an immense series of dark grey marls, interstratified with argillaceo-calcareous bands, resembling the Lias, the collective thickness of which cannot be less than 1500 feet. They compose the great synclinal of the Hauts Plateaux and the contorted mass of the Tell Plateau, separated by the denuded plain of the northern Sahara. From these beds I obtained no fossils; but as they immediately overlie the saliferous marls of the Rochers de Sel containing *Exogyra*, they are probably Cretaceous. These beds also extend south of the Hauts Plateaux to the borders of the Sahara at L'Aghouat, where they are overlain by

The Fossiliferous Beds of L'Aghouat.—These occur in conformable succession from the marls of the Hauts Plateaux, and consist of gypseous marls interstratified with bands of fine-grained stone, and capped with limestone containing curious black concretionary nodules full of fossils, which Mr. Etheridge considers are of Miocene age. It is probable that these beds may also occur on the summit of the Hauts Plateaux, but were not observed along my line of route, which was below the highest platforms of rock seen to the right and left.

Tertiary Beds of the Tell and Algiers.—The only other Tertiary beds included in the section are, first, the soft yellow calcareous freestone flanking the anticlinal of gneiss and mica-schist of the Algerian promontory, at a height of from 100 to 900 feet above the sea; and, secondly, the red and grey marls and ferruginous freestone of Medeah, capping the Tell Plateau as an irregular synclinal, and occurring at a height of from 2500 to 4000 feet, probably of Miocene age. The great difference in height at which these two masses of Tertiary beds occur within a short distance, is an important point in the physical geology of the district presently to be referred to.

Posttertiary Deposits.—To the north of the Lesser Atlas, the plain of the Mitidja consists of grey loam interstratified with shingle-beds, commencing at the sea-level south of Algiers, and ascending inland by a gentle slope to a height of from 200 to 300 feet. Again, on the south side of the Atlas and Tell, the great plain of the northern Sahara is covered with grey loam and occasional sandhills from a height of 2000 feet on its northern side to a height of 2700 feet on its southern boundary; and after crossing the Hauts Plateaux, the same deposit sets in on its southern side, commencing in the intervening valleys at a height of 2700 feet, and gradually descending in the open Sahara plain to a height of a little over 2000 feet, where it is overlain by sandhills.

The raised beaches along the coast, ranging in height from the sea-level to 600 feet, and similar beaches inland south of the Tell Plateau, occurring at an elevation of 2000 feet, may be contemporaneous in age with the Sahara loam.

In addition to these deposits, which are evidently marine, the alluvium of the valley of the Cheliff, near Boukhari, containing bones of the Hippopotamus, and the superficial calcareous crust, coating both the Sahara loam and the older beds, may be enumerated as the most recent formations in Algeria.

Succession of Events, and Changes of Level.—(1) The oldest land on the the line of section is the anticlinal of mica-schist near Algiers. As the north and south strike is nearly at right angles to the strike of the neighbouring Atlas and of the Mesozoic beds of the Tell and Hauts Plateaux, which do not seem to have been affected by the mica-schist upheaval, these beds must have been more recently deposited.

(2) The upheaval of the Mesozoic rocks may have been contemporaneous with the first upheaval of the chain of the Lesser Atlas, striking N.E. by E. and S.W. by W., with which the strike of the Mesozoic beds corresponds.

(2) A long period of denudation followed, which removed at least a thousand feet of Mesozoic strata from the area of the north Sahara plain, and commenced moulding the rocks of the Lesser Atlas into hill- and valley-contour; but there is no clear evidence as to the amount of this denudation, which was Pre- and Posttertiary.

(4) A subsidence of at least 3000 feet during the Tertiary period, in which were deposited the Miocene beds capping the Tell and similar beds at Algiers, fragments of which are seen skirting the denuded ravines of the Atlas.

(5) An elevation of at least 4000 feet of the Tell Plateau, and a lesser elevation of at least a thousand feet of the district north of the Lesser Atlas chain, including what is now the plain of the Mitidja. I am inclined to think that the north face of the Lesser Atlas was a Posttertiary line of fault of at least 3000 feet; otherwise it is difficult to account for the great altitude of the Tertiary beds on the Tell compared with the height of those surrounding Algiers.

(6) A long period of denudation followed, during which the Tertiary beds were removed from the plain of the Mitidja, and a further denudation took place of the Mesozoic beds from the north Sahara plain.

(7) This was followed by a Posttertiary depression, which I shall term the Sahara submergence, during which the formation took place of the concrete shell-beds along the Mediterranean coast to a height of 600 feet, and similar beds on the south or inland side of the Tell Plateau at a height of at least 2000 feet. The deposition of shingle and loam in the plain of the Mitidja at a height of from 100 to 300 feet, was probably contemporaneous; and to the same period of submergence must be ascribed the formation of loam-beds and sand-hills on

the northern Sahara plain at a height of 2700 feet, and on the open Sahara south of the Hauts Plateaux at a height of from 2700 to 3000 feet, as well as the coast-denudation of the flat-topped sandstone hills at Sidi Makhelouf at a height of 2700 feet.

At this time the Algerian promontory was an island, separated from the Atlas and Tell by a strait six or seven miles wide, now the plain of the Mitidja. The Lesser Atlas rose directly from the sea, into which its streams were bringing down subaërial débris, and depositing the great delta-like mass of drift on which Blidah is built. Crossing the Atlas and Tell we should soon reach another inland sea some fifty miles wide, now represented by the north Sahara plain, out of which the range of the Djebel Sahari rose as a chain of islands; and its southern limit is now well recorded by the long range of sandhills on the southern margin of the plain north of the Hauts Plateaux. The Hauts Plateaux formed another range of isolated land running nearly east and west, 30 miles wide; and on its southern side fjords ran up among the valleys and debouched at L'Aghouat into the open Sahara sea, some 800 miles across, which separated by a broad expanse of water the islands of the Tell and Hauts Plateaux from the highlands of Central Africa.

(8) *Reelevation of the Land.*—An upward movement followed the Sahara submergence, the extreme limit of which, whether represented by the present height of the land, or attaining a higher level, is open to question. It is, however, certain that an emergence of the highlands of Algeria took place to the extent of about 3000 feet; but the reelevation appears to have been greatest to the south of the chain of the Lesser Atlas. The contour of the limit of elevation, as indicated by the present level of the marine deposits of the Mitidja and Sahara plains, would represent a wide low anticlinal, gradually rising from the sea-level at Algiers across the plain of the Mitidja to a height of 2700 feet at the north side of the Hauts Plateaux, and then descending from 2700 feet on its south side to the sea-level in the open Sahara. The extent of the elevation following the submergence of the Sahara, is a question of considerable interest. In a former paper read before the Society, and in a paper read before the British Association at Liverpool, I recorded several facts in proof that the present coast-line of the Mediterranean, in several far-removed localities, is gradually subsiding; and Mr. Boyd Dawkins, in his paper on the physical geography of the Mediterranean, has on palæontological and other evidence pointed out the probability that during the Pleistocene age the land now forming its shore-line stood at a height of about 3000 feet above its present level. Again, moraines were observed by Dr. Hooker, Mr. Ball, and myself in the Great Atlas south of Marocco, at a height of from 6000 to 7000 feet, in a latitude where no perpetual snow now lies at 12,000 feet; so it is probable that the land stood at a much greater elevation when these moraines were formed.

On the other hand, Sir C. Lyell has suggested that the former diminution of temperature and extension to lower levels of alpine glaciers was probably the result of diminished temperature due to the Sahara submergence; but the Great Atlas chain to the N.W. would probably have partaken of the general depression, and the comparatively low level at which moraines there occur would have been brought still nearer the sea-level, counterbalancing the effect of increased refrigeration. A small glacier still exists at a height of between 8000 and 9000 feet in the Sierra Nevada south of Granada, in latitude 37°; and supposing the Great Atlas had partaken of the elevation of 3000 feet assumed by Mr. Dawkins as the Postpliocene height of the present Mediterranean boundary, a corresponding altitude of the Great Atlas of from 15,000 to 16,000 feet would probably have afforded sufficient height for the bearing of similar small glaciers at existing temperatures. The high land of Algeria has certainly been elevated 3000 feet since the Sahara submergence; and it is probable that its maximum elevation may have reached 6000 feet in Postpliocene times, since which a gradual subsidence of 3000 must have taken place and appears to be still going on.

EXPLANATION OF PLATE XI.

Fig. 1. Section across Algeria, from Algiers to L'Aghouat, Sahara. Vertical scale 1 inch to 9000 feet; horizontal scale 3¼ inches to 30 miles.

2. Map of route from Algiers to L'Aghouat. The line of route is indicated by a dotted line, the line of section by a thick black line, and the strike of the beds at different parts by fine double lines.

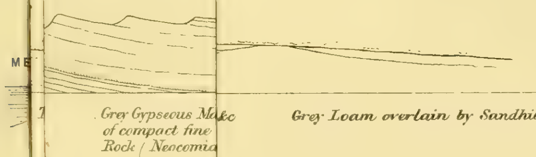
Discussion.

Mr. W. Boyd Dawkins considered an elevation of from 2000 to 3000 feet necessary to allow of that migration of animals through Spain and Sicily, to and from Europe and Africa, which took place in Pleistocene times; and this view appeared to be confirmed on physical grounds by Mr. Maw. He believed that a great axis of disturbance ran east and west along the course of the Mediterranean; and to this the strike of the beds observed by Mr. Maw was parallel. It is a remarkable fact that the change in the level of the Sahara observed by Mr. Maw should be the same as that which has taken place in the Mediterranean area, but in the opposite direction. Probably the elevation of the Sahara was coincident with the depression of the Mediterranean.

Mr. Bauerman called attention to the excellent drawing of a desert escarpment exhibited by Mr. Maw. He said that this drawing perfectly represented what is to be seen in every dry desert country, like the north of Africa or Arabia. In the latter country the succession of the beds of Neocomian and Tertiary age was similar to that observed in Algiers. He thought that the disturbances attributed by Mr. Maw to the dissolving out of salt, were in reality due to the dissolving of gypsum.

Mr. Davidson remarked that thirty years ago M. de Verneuil found many fossils in the region to which Mr. Maw's paper related. These included a great *Ostrea*, *Terebratulæ*, and other forms which were both Miocene and Pliocene.

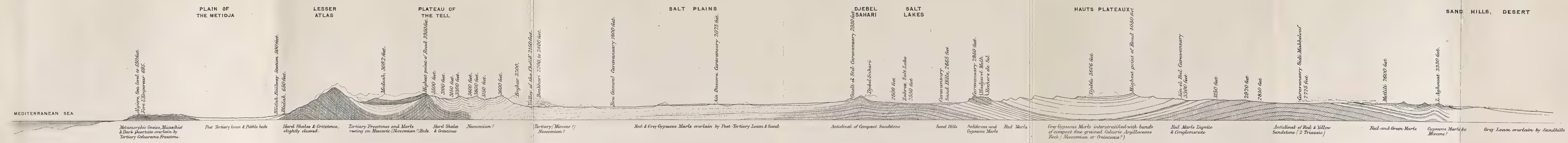
HA HILLS, DESERT



G. Ma

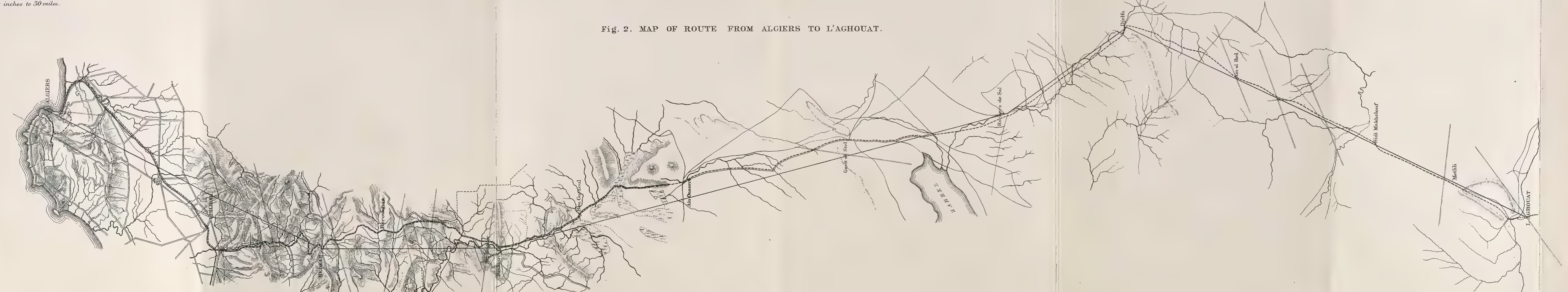
Mintern Bros. lith.

Fig. 1. SECTION ACROSS ALGERIA FROM ALGIERS TO L'AGHOUAT, SAHARA.



Vertical Scale, 1 inch to 9000 feet.
Horizontal Scale 3½ inches to 50 miles.

Fig. 2. MAP OF ROUTE FROM ALGIERS TO L'AGHOUAT.



G. Maw del. April 1873.

Mintern Bros. lith.

Prof. RAMSAY asked for information as to whether there was evidence of a great sea having extended across the north of Africa at a comparatively recent period, as he thought that this would explain certain ethnological phenomena. He was struck by the difference of the elevation of that part of the Sahara visited by the author from that described by Prof. Desor.

Mr. PRESTWICH considered the occurrence of recent shells at so great a height something quite new. The former French observers had referred to their occurrence on the Sahara itself, and below the level of the sea. Subsidence appeared to be still going on.

The Rev. Mr. HOUSMAN remarked that the eastern coast of Spain was still rising.

Mr. EVANS observed that the existence of such tracts of high and absorbent soil as those described might, with even a moderate amount of rainfall, account for the supply of water to the Artesian wells with which the lower part of the Sahara is dotted. He mentioned that *Cardium edule* and *Buccinum gibberulum* had been found in the Sahara by Desor, and that the latter had been considered identical with a shell now found on the N.W. coast of Africa.

Mr. MAW briefly replied, and stated that the sandy plain near L'Aghouat referred to in his paper was a tongue of elevated land, east of which, at all events, the desert stretched away at or near the sea-level; and this was undoubtedly submerged during the period of depression. He thought that the sea also probably extended westward at the same time, perhaps to the Gulf of Guinea.

16. *On the* Trimerellidæ, *a* Palæozoic Family *of the* Palliobranchs *or* Brachiopoda. By Thomas Davidson, Esq., F.R.S., F.G.S., &c., and Professor William King, Sc.D. Honoris Causa, Queen's University in Ireland. (Read February 25, 1874.)

[Plates XII.–XIX.]

Contents.

I. Bibliography of the Trimerellids.

The important group of shells forming the subject-matter of this memoir is, comparatively speaking, of recent acquisition in palæontology; for, though two of its species were made known in 1853, under the designations of *Obolus Davidsoni* and *O. transversus**, it is only of late years that a beginning was made towards gaining a correct view of its remarkable internal features. So little understood were the interiors of these species at first, that they were confidently, but erroneously, referred to the genus *Obolus* by one of the present writers. Billings did not escape the same error when he described his *Obolus canadensis*†.

The next stage, one decidedly in advance, was gained by Billings, who, finding some Canadian specimens with a singular interior, was led to institute a new genus for them under the name *Trimerella*—observing, at the same time, that it "is allied to *Obolus*, but from which it differs in the possession of longitudinal septa"‡. He erred again, however, in describing another species of the present family under the name *Obolus galtensis*§.

In 1867, Lindström published an important paper, describing some specimens found in the Island of Gotland as far back as 1859, and which he had no hesitation in referring to the genus *Trimerella* of Billings, throwing at the same time further light on the internal structure of the group. He also referred to some specimens of the

* Davidson, Introduction Br. Foss. Brach. p. 136, 1853.
† Report on the Geological Survey of Canada, p. 28, 1857.
‡ Pal. Foss. Geol. Canada, i. p. 166, June 1862. § *Ibid.* p. 168.

so-termed *Obolus Davidsoni* which had been discovered in the same island *.

For the first time, in 1868 the public became acquainted with the fact that an objection had been made by Prof. Hall against the generic allocation of the so-termed *Obolus Davidsoni*, though (bowing to the opinion of other authorities) he was induced to name an allied species *Obolus Conradi* †.

In 1870, Dall, from not being well acquainted with the characters upon which Billings had founded his genus *Trimerella*, and only having before him Lindström's description of the Gotland specimens above referred to, was led to propose for the latter the separate generic designation, *Gotlandia* ‡.

All along our friends were either supplying us with specimens, or with an account of their discoveries; so that, with close attention to both, we felt justified in believing ourselves enabled to throw additional light on the group. In the mean time others were still working on the same subject. Hall brought out a short notice, in the early part of the summer of 1871, which contained a description, with names, of his proposed genera *Rhynobolus* and *Dinobolus* §. Dall published a second paper giving further details (already known to ourselves) on the internal characters of *Trimerella*, abandoning at the same time his genus *Gotlandia*. In this paper Dall briefly referred to the different known species of *Trimerella*, and added two or three new ones ‖.

During the same year Meek published a description of *Trimerella ohioensis* ¶; and Billings brought out a supplement containing a fuller description of his *T. acuminata* **; while, in the same year, Quenstedt briefly noticed the genus *Trimerella*, along with *Obolus*, *Schmidtia*, *Obolella*, and *Acrites* ††.

On the 29th of December, 1871, Billings published a short notice of a new genus, *Monomerella*, which, he intimated, would be soon fully described, and illustrated by us from both Canadian and Swedish specimens. He also proposed another genus for his *Obolus canadensis* under the name *Obolellina* ‡‡.

In April, 1872, Hall published a reissue of his paper "printed in March, 1871," to which is added a plate illustrating the interior of *Trimerella*, and the ventral valve of his so-termed genus *Rhynobolus*. In the same month, Billings brought out a fuller account, with figures, of his genus *Obolellina* §§.

* Öfv. Vet. Ak. Förh. vol. xxiv. p. 253, 1867; and Geol. Mag. vol. v. p. 441, 1868.

† Twentieth Annual Report of the Regents of the University of the State of New York, p. 368, 1868.

‡ American Journal of Conchology, vol. vi. p. 160, 1870.

§ Notes on some new or imperfectly known forms among the Brachiopoda: March 1871; and Neues Jahrbuch, p. 989, 1871.

‖ American Journal of Conchology, vol. vii. p. 79, 1871.

¶ American Journal of Science and Art, vol. i. 3rd ser. p. 305, April 1871.

** Ibid. June 1871; and Annals and Mag. of Nat. Hist. 4th ser. vol. viii. August 1871.

†† Petrefactenkunde Deutschlands, p. 669, &c. 1871.

‡‡ Canadian Naturalist, New Series, vol. vi. p. 220, 1871. §§ Ibid. April 1872.

On the 20th of August, 1872, the writers of this memoir communicated to the Geological Section, at the Brighton Meeting of the British Association, a paper entitled "Remarks on the genera *Trimerella*, *Dinobolus*, and *Monomerella*," in which they endeavoured to point out the characters pertaining to the Trimerellids, as well as the place this family should occupy among the Palliobranchs*.

Before concluding the present section, it may be mentioned that, up to this date, about eighteen species of fossils belonging to the group we are engaged with have been described, or notified, and that seven different names have been proposed for the genera in which to include them. Some of these names, it has been admitted, are synonyms, or belong to one and the same genus; certain others have been proposed for groups which cannot, we think, take a generic rank. We are consequently led to restrict the number of genera to three—namely, *Trimerella*, *Monomerella*, and *Dinobolus*. These constitute our family *Trimerellidæ*. Another genus, *Lingulops*, has been proposed by Hall for a curious fossil: we propose giving a description of it in this paper; but we are yet undecided whether it is a Trimerellid, or a Lingulid.

We now subjoin a list of the species:—

Trimerella grandis, *Billings*.
—— acuminata, *Bill.*
—— Lindströmi, *Dall.*
—— Billingsii, *Bill.*
—— ohioensis, *Meek.*
—— wisbyensis, *Dav. & King.*
—— galtensis, *Bill.*
Monomerella Walmstedti, *Dav. & King.*
—— prisca, *Bill.*
Monomerella orbicularis, *Bill.*
—— Lindstromi, *Dav. & King.*
Dinobolus Conradi, *Hall.*
—— canadensis, *Bill.*
—— Davidsoni, *Salter.*
—— transversus, *Salter.*
—— Woodwardi, *Salter.*
—— Schmidti, *Dav. & King.*
—— magnifica, *Bill.*

As soon as it became known that we had decided on preparing the present memoir, specimens from every one who had them were sent to us. Dr. Lindström, Professors Hall, Fr. Schmidt, and Walmstedt, Messrs. Fegrœus, Bergman, Dall, Whitfield, Etheridge, and Meek, and several Dudley friends furnished us with the best things in their possession, with a liberality and courtesy we cannot forget, as did also Mr. Billings (Palæontologist of the Canadian Geological Survey), Sir W. Logan, and Mr. Selwyn. To all we beg to return our sincere thanks.

II. Chiefly descriptive of their Internal Parts.

The family *Trimerellidæ* includes both transversely and longitudinally elongated species, also thick- as well as thin-valved ones. The species are generally of considerable size, the largest known measuring nearly 4 inches in length. Their shell-substance is chiefly calcareous, though in certain thin species the lime may

* Printed in full in the 'Brighton Daily News' newspaper for the 21st of August, 1872; also in the Geol. Mag. vol. ix. Oct. 1872; and in the Annals and Mag. of Nat. Hist. for the same month.

possibly have been small in quantity compared with the corneous element*.

The species often fail in neatness or regularity of form, especially in their umbonal region. This part is often massive and strongly projecting, and, it may be, ecurving, incurving, or twisted to one side. Some species have it obtusely and regularly rounded. All the species apparently have had their outer surface smooth, or marked with lines of growth, coarse in some, and fine in others: slight traces of diverging longitudinal lines are occasionally visible.

Guided by certain evidences indicating the existence of two of the chief organs belonging to shells of their class, it is readily seen that the Trimerellids have had the large valve pedunculated, and the smaller one characterized with oral or (the so-called) brachial appendages; it is therefore proposed to name the former the pedicle (Pl. XII. figs. 1, 3, 5), and the latter the brachial valve† (Pl. XII. figs. 2, 4, 6).

The *pedicle-valve* has the cardinal face of its umbo flattened so as to form a triangular space or *area*, which differs remarkably in size according to genera and species. The longitudinally elongated species have the largest area; while in those that are transversely elongated it is small. As in other Palliobranchs, the area is made up of different parts; two, however, possess exceptional features.

The *deltidium* (Pl. XII. figs. 1 a, 3, 7 a), carved, as it were, out of the central portion of the area, is comparatively level, in relief, or an excavation: it is crowded with fine imbricated transverse laminæ, in general arching towards either the point of the beak or the hinge-line. At, and parallel to, its broad end or base, there is a narrow inclined *band*-like space or *deltidial slope* (b), distinguished by a few faint longitudinal lines: it is, however, often so slightly developed as to be with difficulty observed. Next to the deltidium, or on each side of it, are what may be called the "*delti-*

* No microscopic sections of the shell have been made; as in all the specimens possessing remains of the shell-substance that have been under examination, these remains, owing to their being a methylosed replacement of calcite, or dolomite, are not in a condition favourable for the retention of any original histological characters. On this point, see "Monograph of *Spirifer cuspidatus*," Annals and Mag. of Nat. Hist. 4th series, vol. ii. July 1868; and "Histology of the Test of the Class Palliobranchiata," Transactions of the Royal Irish Academy, vol. xxiv. pp. 453, 455.

† The pedicle- and brachial valves respectively correspond with those usually called ventral and dorsal. While describing the various parts which characterize the Trimerellids, our references will be confined to the figures or diagrams given in Pl. XII., unless otherwise stated; and we shall distinguish similarly situated parts (irrespective of whether they are homologous, or analogous) of the two valves—those of the pedicle- [or ventral] valve by roman letters, and those of the brachial [or dorsal] one by italics. It must not be expected that certain of these parts will be found unless diligent and prolonged investigations are devoted to them: they are to be sought for, not only by allowing the light to fall, on places where they occur, in every favourable direction, but even at different times of the day, and in different states of the atmosphere. We do not say that our diagram figures are, strictly speaking, correct representations; but we offer them as reliable approximations, subject to immaterial corrections. Such, we believe, will not vitiate the descriptions herein given of the interior of the shells under consideration.

dial ridges" (c), prominent in some species, more or less flattened in others, and marked with arching laminæ: they are each defined on its outer side by a well-marked incised line. The deltidial ridges terminate near the hinge-margin, each as a *cardinal callosity* (e), which is extremely variable in form and size. The *areal borders* (d), usually narrow and transversely scored, differ in nothing from those in other Palliobranchs.

In front of the deltidial slope is situated a tolerably well-defined *cardinal facet* (f), the long axis of which corresponds to the transverse direction of the hinge-line: it varies much in size according to species. This part generally inclines or falls towards the cavity of the shell: in one species, however, as will be noticed hereafter, the inclination is in the opposite direction. Although in some cases the cardinal facet passes without any marked break into the inner surface of the valve, it is often raised by the hinge underneath becoming thickened.

The part beneath the cardinal facet thus raised, while in many species its thickness is in no way diminished vertically, is in some others materially reduced in lateral dimensions, thereby presenting itself under the form of a thin vertical hinge-supporting plate or *cardinal buttress* (h).

The parts belonging to the hinge of the *brachial valve* are rude and extremely variable in form: one of them may be variable in position. The central portion of the hinge in certain species shows nothing remarkable, no marks or prominences—due possibly to erosion; but in others it distinctly displays an excavation or *cardinal scar* (Pl. XII. fig. 2*v*), as in *T. ohioensis*, also apparently in *T. Dalli* (Pl. XV. fig. 2). The excavation is bicupped in *T. ohioensis* (Pl. XVI. fig. 7); but the same species also presents it transversely grooved (Pl. XVI. figs. 4, 5, 6). There is no prominence in these cases. In some other species, however, the cardinal scar, though in general badly seen, appears to be situated on an elevation—rounded, or squared, and more or less developed, according to species. Nay, in the same species, as in *T. Lindströmi*, the elevation varies much in size, certain individuals having it very small, others very large and standing out like a great tooth—so large that it must have dipped deeply into the umbonal cavity of the pedicle-valve: fig. 3, Pl. XIV., represents the elevation in its median size. In short, the cardinal scar is so variable that to give a description of it applicable to any one species would be a somewhat difficult task.

The hinge of the brachial valve is further characterized by another variable part. Though absent in several species, there exist in others two depressions or *cardinal sockets* (*e*) on the hinge, one on each side: when well defined (which, however, is seldom the case) by a prominent border on the inner side, the cardinal sockets appear to have received the cardinal callosities belonging to the pedicle-valve*.

* Lindström, who has represented the lateral margins of a species of *Trimerella* "grooved by a furrow which helps to close the valves more tightly" (Geol. Mag. vol. v. p. 14), seems to think that this was the only provision the genus had for a dentary apparatus. We cannot help thinking that he has taken too

In certain species (*Monomerella prisca*) the hinge of the brachial valve or, rather, we believe, its outside, is strongly striated transversely: this peculiarity may be considered the same as the transverse lines on the areal borders. In some cases the point of the umbo of the brachial valve is replaced by a cavity (*Mon. Walmstedti*, Pl. XVII. fig. 3), apparently due to erosion; in others (*Trimerella ohioensis*, Pl. XVI. figs. 5 & 6) it is rounded.

As regards the parts belonging to their interior, the Trimerellids are peculiarly distinguished. In the medio-longitudinal region of the posterior half of both valves there is what may be called a *platform* (j and *j*), large or considerably elevated in some species (Pl. XIV. figs. 2, 3, 6, &c.), small and even excavated in others (Pl. XVI. fig. 8, Pl. XVIII. fig. 13, Pl. XIX. fig. 4). In most cases the largest and most elevated platform occurs in the brachial valve. Generally both valves have the platform medio-longitudinally depressed on the top, and rounded at the sides, thereby giving it a biconvex surface: it also presents characters which, while constant in certain genera and species, undergo marked modifications in others. Thus in most Trimerellas each platform is distinguished by two tubular cavities—*platform vaults* (k, *k*)—short, or nearly obsolete in certain species, and in others running underneath the platform in its entire length: the vaults are separated by a median partition (Pl. XVI. figs. 1, 2, 3). In a few species the platform is solid, or a little raised above the inner surface of the valves, with the slightest indication of vaults (Pl. XVI. figs. 8, 9). In *Monomerella* this part, though well developed, is not vaulted in either valve; it is the same in *Dinobolus*.

Returning to *Trimerella*, the median partition is prolonged into the anterior half of the shell under the form of a *median plate* (l, *l*). It characterizes both valves, but is always the largest or longest in the brachial valve (Pl. XIV. figs. 2, 3, &c.). Some congeneric species appear to have had no plate (Pl. XVI. figs. 8, 9).

To complicate the camerated character of the Trimerellids, in the species which have a cardinal buttress this part divides the interior of the umbo (of the pedicle-valve) into two hollow sections or *umbonal chambers* (i), large and wide-mouthed in the Monomerellas, long and tubular in *Trimerella Lindströmi*. There are species, however, belonging to both these genera, also *Dinobolus* generally, without umbonal chambers; though in some cases indications of them occur. Occasionally there are appearances of them in the brachial valve: an unusually developed case occurs in this valve of *Trimerella Lindströmi*, as shown by the pair of *postlateral* prominences (casts)

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limited a view, probably arising from an examination of a specimen with long lamelliform borders, such as occur, one on each side, on the hinge of *T. ohioensis* (Pl. XVI. fig. 7). In this species, however, there is a deepish hollow on the inner or posterior side of each border, and seemingly corresponding callosities on the hinge (where angulated) of the pedicle-valve: the latter may have belonged to the deltidial ridges. So variable are the cardinal sockets and cardinal callosities, that we are quite prepared to meet with specimens having lamelliform borders developed or *elongated* somewhat as represented by Lindström.

in fig. 7, Pl. XIV. Nothing is more singular than the aspect of the interior of the typical Trimerellids—some, as will now be understood, having two specialized cavities (*Monomerella*), others four (Pl. XIV. fig. 6, Pl. XV. fig. 4[d] &c.), and others six (*T. Lindströmi*, *T. Dalli*, &c.).

It may be stated, subject to correction, that the platform in each valve is marked by four sets of scars, which, for the present, we shall merely distinguish by the names *medians* (m, *m*), *anteriors* (n, *n*), *laterals* (o, *o*), and *postmedians* (p, *p*). The postmedians, we believe, are a set having no relation to the others.

In addition to the foregoing, the entire family is characterized by a submarginal *crescent* (q, r, s, *q*, *r*, *s*) confined to the posterior half of each valve. It varies to some extent in each genus, also in different species: even different individuals of the same species do not unfrequently present variations that seem to depend on differences of age, thickness of the valves, and other peculiarities. As a consequence, this part, or merely a portion of it, may present itself in relief, excavated, obscurely, often partially in any of these conditions, or complicated by successive enlargements of its area; so that we feel a difficulty in representing it otherwise than diagrammatically, or in giving a description that is strictly accurate when applied to any single case. Closing these preliminary remarks, the crescent may be described as formed of three portions—the *crown* (q, *q*), *sides* (r, *r*), and *ends* (s, *s*). The crown consists of a line running along the hinge, from each side of which it descends into the cavity of the valves at the origin of their postlateral margins: this portion, in the brachial valve, is pointed in the middle of the hinge (Pl XII. fig. 6, *q*); while, in the pedicle-valve, it passes along and close to the outer edge of the cardinal facet. The sides, which are pointed oval in shape in the typical genus, pass forward along and a little within the postlateral margins of the valves. The ends, for the most part obscurely defined, occupy the space between the widest portion of the platform and the adjacent margin of the valve.

Somewhat similar in outline to the crown is a submarginal impression occurring in the anterior half of both valves: it resembles a small arch or *archlet* (u, *u*), is simple in form, consists of two halves, has its two bases attached one to each end of the crescent, and throws itself forward to within a short distance of the anterior margin of the valves, apparently to a less extent in the pedicle than in the brachial one.

On each side of both valves one member of a pair of linear *transverse scars* (t, *t*) strikes off from near the point of junction of the crescent and archlet to the widest part of the platform, thence in front of the latter part to the median plate: the other member makes a similar traverse on the opposite side, and terminates at the same place.

Reverting to the hinge of the pedicle-valve, there is situated on the cardinal facet an oval-shaped scar or *lozenge* (g), having its long axis in the transverse direction of the valve. It is formed posteriorly by a line that runs parallel and near to the deltidial slope, and anteriorly by what may be supposed to be another line running close to the crown of the crescent. There is much obscurity in the part under consideration, especially its anterior; for generally the latter portion, and the line forming the crown of the crescent, are so interblended as to prevent either one or the other being individually defined: still we occasionally perceive appearances favouring the idea that they are distinct.

Besides the foregoing there are some other scars that require noticing. In the pedicle valve of certain Trimerellas there is an appearance of an impression (fig. 1, w) situated below the hinge, and on the cardinal buttress: in the Monomerellas two impressions occur (fig. 3, w) similarly situated, *i. e.* at the base of the cardinal buttress or at the posterior end of the platform (j): and in *Dinobolus Davidsoni* there are two distinct marks (inadvertently omitted in fig. 5, w) below or on the outer edge (which is rounded off) of the hinge. Suspecting that all these may form one and the same set, we propose to call them *subcardinal scars*.

The brachial valve of *Monomerella* and *Dinobolus* equally shows in a similar position (that is, in front of and below the middle of the crown of the crescent, or near the centre of the umbonal cavity) a well-marked impression (figs. 4 & 6, *w*). There are faint indications of the same scar in *Trimerella ohioensis* (Pl. XVI. figs. 5 & 6).

Trimerella and *Monomerella* have in their pedicle-valve a pair of *umbo-lateral scars* (x, figs. 1 & 3), a member being situated close to and below each cardinal callosity (e). An apparently corresponding set, but slightly marked, occurs in *Dinobolus* (x, fig. 5), occupying a somewhat similar position.

The brachial valve of *Monomerella* exhibits an analogous pair (fig. 4, *x*) within the crescent, a member being situated close to each of its sides.

III. Myology and other Characters of the Family.

We shall now offer some suggestions as to which organs the various scars respectively belonged to; but before proceeding further we find it necessary to anticipate a point which will be treated of in another section.

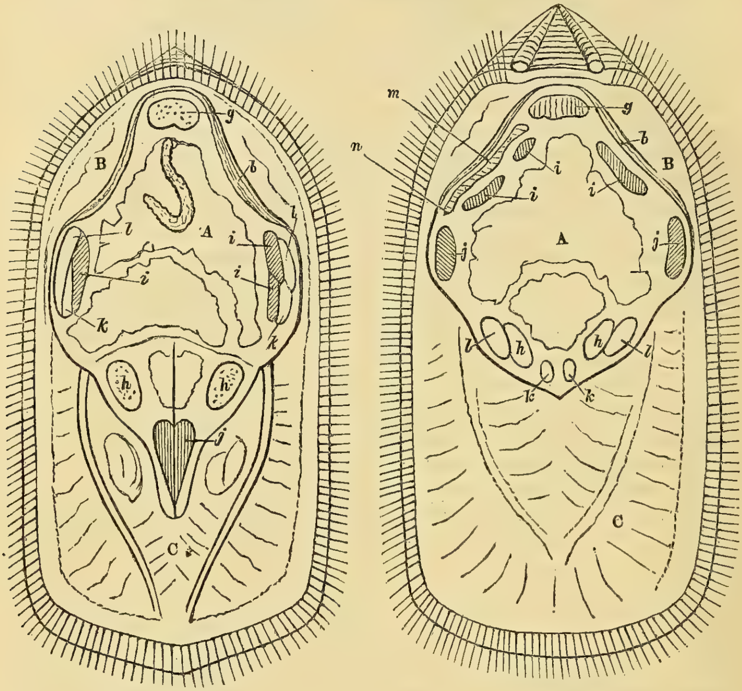
Having failed in making out any satisfactory resemblance between the Trimerellids and Terebratulids in their internal parts, we were led to extend our investigations to another family. It was with this object that one of us entered upon an examination of the various muscles, and scars belonging to them, that characterize *Lingula anatina**. The result has been attended with much more success than in the case of the Terebratulids.

In the species named, the valvular muscles are of two kinds, *direct* and *slanting*. The direct muscles are an anterior pair, situated in the central region of the shell, and a single one, lodged in the umbonal cavity. The slanting muscles are four pairs:—one pair,

* Annals and Mag. of Nat. Hist. 4th ser. vol. xii. July 1873. When speaking of the muscles and other parts of *Lingula anatina*, our references will be made to the figures in Plate II. accompanying that paper. Sketches after the two principal figures are given in the annexed woodcuts in the following page.

transmedial, crossing in a backward direction from the middle of the sides of the posterior half of the brachial valve to the reverse sides of the pedicle-valve; the remaining three pairs (laterals) pass from

Fig. 1.—Lingula anatina, *to illustrate the Scars in* Trimerella.



g. Umbonal muscle. *h.* Central muscles. *i.* Transmedial muscles: *b.* Parietal band. *j, k, l.* Lateral muscles (*j*, anteriors; *k*, middles; *l*, outsiders). A. Splanchnocœle. B. Pleurocœles. C. Brachiocœle.

the sides of the same half of both valves to points further forward and adjacent to the median line of the shell, but without crossing it.

Reverting to the Trimerellids, we shall make one or two suggestions respecting the subcardinal scars (w, *w*). First, they may have belonged to a muscle corresponding with the umbonal one of *Lingula.* If, as appears probable, the single umbonal muscle, just referred to, is the homologue of the two posterior adductors of *Discina,* there is no reason against assuming that the presumed corresponding muscle of the Trimerellids has been simple in certain genera (Pl. XII. fig. 1, w), and compound or double in others (figs. 3 & 5, w)—or divided at its attachment in one valve, and undivided in the other. Second, they may be the same as the part in the brachial valve we have called the cardinal scar (*v*, fig. 2)—a view, however, which requires the pertaining muscle to have been divided at its extremity, one division attached to the hinge, and the other to the umbonal cavity. But another idea regarding the cardinal scar (*v*) has been adopted by Dall, that it afforded attachment to a muscle homologous with that belonging to the cardinal process of the Terebratulids. Certainly from its position, and especially when seated on an elevation, as in *Trimerella Lindströmi*, this scar has much the appearance of being identical with the process characteristic of the hinge in the family just referred to; but we think a more correct appreciation of its true relationship is involved in the suggestion that it is homologous with the small pair of postlateral or converging muscles, of which, as in *Discina*, a member passes from near each side of the pedicle- or flat valve to the space between the posterior adductor muscles in the brachial or convex valve. This suggestion, it must be understood, does not necessitate the abandonment of the idea that the scar (w, *w*) belonged to the umbonal muscle: only, instead of this muscle being divided, with a division implanted on each side of the pair of converging muscles, as in *Discina*, it may have been simple in some cases, and have passed *between* the latter muscles. Such an arrangement would be the reverse of what prevails in *Discina*; but it does not seem to be opposed by any valid objections.

With respect to the *slanting* muscles of *Lingula*, we strongly suspect that the transmedial pair was absent in the Trimerellids—the close union of the valves at the hinge, or the possession of a dentary apparatus, rendering impossible any lateral movement of the valves in their posterior or umbonal region, such being the function of the transmedials.

The three remaining pairs of slanting muscles, which have been generically designated *laterals*, and severally named "anteriors," "middles," and "outsiders," appear to us to have characterized the fossil family.

The "anterior" pair of *Lingula* may correspond with, in the Trimerellids, the anterior scars, *n* *, of the brachial valve, and the *ends* of the crescent (s), of the pedicle one; the "middle" pair with the median scars, m, of the pedicle-valve, and the *ends* of the crescent, *s*, of the brachial one; the "outside" pair with the lateral scars, o, of the pedicle-valve, and the *ends* of the crescent, *s*, of the brachial one. In accordance with these suggestions, the letter *s* (that is, in the brachial valve) denotes a compound scar; but, instead of being triple, as in *Lingula* (which, it must be borne in mind, has, in addition, one of the terminations of the transmedial muscle implanted in the corresponding part), it would be double.

Moreover, in *Lingula anatina* a pair of slanting muscles is implanted in the brachial valve, adjacent to, or upon the mediolongitudinal ridge, a member on each side, where the scars left by the muscles are generally well seen. We have already assumed these scars to correspond with those lettered *n* in figs. 4, 6, that is, on the

* We have not lettered that portion of the platform in Pl. XII. fig. 2, where, apparently the scars would be situated, as there are grounds, presently to be noticed, for believing that they were in this instance transposed to the median plate (*l*).

projecting or anterior portion of the platform belonging to the brachial valve of *Monomerella* and *Dinobolus*; which genera, it will be seen, have no median plate, or only a rudimentary one. But considering that in the brachial valve of *Trimerella* this part is as well developed as the ridge in *Lingula*, or even more so, we are strongly persuaded that it or its posterior end was marked by the scars in question.

If the median plate of the brachial valve were not a muscular fulcrum of the kind, it would have to be considered merely *analogous* to the medio-longitudinal ridge of *Lingula*, and not its *homologue*; or, instead of belonging essentially to the splanchnocœle, it must be an integral part of the brachiocœle. The latter view, however, has nothing in its favour; on the contrary, in all known living Palliobranchs (and most of them have it) the ridge, when present, lies within the splanchnocœle, and serves as a muscular fulcrum.

The corresponding plate in the pedicle-valve of *Trimerella* may have been subordinated in the same way; but we are more inclined to believe that it merely strengthened the platform, as we think was also the case with the rudimentary one in the brachial valve of *Dinobolus* (fig. 6, *l*).

The aberrant *Trimerella Billingsii* and *T. galtensis* do not possess the median plate in the brachial valve: in these cases the muscles would be attached to the anterior portion of the platform, as in *Dinobolus* and *Monomerella*.

Besides their use as muscular fulcra, it may safely be admitted that the platforms, to some extent, supported the viscera. We are induced to refer the postmedian scar (*p*, fig. 6) to the ovaries. These organs have been allocated by Dall and others to the platform-vaults; but their usual position in living Palliobranchs would require them to be lodged in, or connected with, the *posterior* portion of the splanchnocœle. We are consequently more disposed to believe, considering their postlateral situation in *Rhynchonella**, and in other shells of its class, that the ovaries were similarly situated in the Trimerellids†: the large umbonal cavities characteristic of certain species, seem well adapted for containing them.

The platform-vaults appear, from their contiguity to the usual *locale* of the liver, to be the most likely receptacles for the divisions of this organ‡. Another view has been taken respecting the use of

* Hancock, Transactions of the Royal Society, vol. cxlviii. pl. lx. fig. 3, 1858.

† Certain genera, especially *Camarophoria* and *Pentamerus*, have hollows in the umbo of the pedicle-valve, not only corresponding with, but evidently fulfilling the same office as, the umbonal chambers of the Trimerellids. Many years ago one of the writers, studying *Camarophoria multiplicata*, expressed his belief that the spaces within the "vascular circles" occurring in this species "were the seats of reproduction." Monograph Permian Fossils, p. 116.

‡ In our previously published "Remarks on the genera *Trimerella*, *Dinobolus*, and *Monomerella*," we instanced the excavated scars of *Obolus*, which have an overlapping posterior margin, thereby approaching in appearance to the platform-vaults of *Trimerella*; but these are undoubtedly due to muscular attachment. In *Leptæna Dutertrii* the myophore of one of the valves is doubly vaulted, possibly for holding portions of the liver and a case homologous with the platform-vaults of *Trimerella*.

these vaults. Lindström supposes them to have been hollows in which the muscles were implanted*. We have searched for impressions likely to have resulted from such implantation, but without success; and it appears highly improbable that the vaults, which run the entire length of the platforms up to the hinge in certain species, could have served this purpose†.

We may leave for a short while the consideration of the internal parts of the Trimerellids to take a passing notice of the hinge-characters. These clearly show that the shells have been furnished with a massive pedicle, closely agreeing in its attachments with that of *Lingula*. As in this shell, the proximal extremity of the pedicle in the fossil (doubtless in the form of a flatly compressed cylinder—that is, with two flattened faces) was evidently attached by one of its *faces* to the entire surface of the deltidium, the imbricated laminæ of which are the marks of attachment. The pedicle of *Lingula* is further attached by the *end* of the same face, also by two lateral extremities or lobes, the former to a narrow lineated space in front of the deltidium, and each of the latter to a point on both sides of the narrow space‡. It cannot be objected that the deltidial slope (b) of the Trimerellids marks the attachment of the *end* of the adhering face of the pedicle; and we strongly suspect that the deltidial ridges (c) and cardinal callosities (e) have resulted from the attachment of the lateral lobes. In certain of these fossils, especially in *Trimerella galtensis*, the deltidium displays a deep median groove (Pl. XVIII. fig. 13), called by Hall the "central pedicle-groove," a peculiarity we would suggest as being due to the strong attachment of the middle part of the adhering face of the pedicle, as evidence of the kind occasionally occurs in specimens of *Lingula anatina*. It requires to be mentioned that in the latter shell the face, end, and lobes spoken of belong to the *corneous sheath* of the

* Lindström, who speaks of the platform-vaults as "prolonged muscular scars," states that the corresponding parts in *Lingula* are occupied by two impressions of the adductors. Geol. Mag. vol. v. p. 442, 1868.

† In a letter received by us from Mr. Whitfield, dated the 4th of Dec., 1871, he states, "In relation to the uses of the cavities beneath the plate [platform], they certainly could not have contained any part of the adductor muscles; but, from the large size of these muscles necessary to work such large and, in one species [*T. ohioensis*], ponderous shells, the greater part of the surface of this part (the cardinal half) of the shell would necessarily be taken up by them, and there would be but little space left for the pallial sinuses containing the testes or ovaries; and the plate [platform] is consequently raised to get these large muscles out of the way in the centre of the valve, and to let the organs (sexual) pass beneath them. This I conceive to be the use of them. I have often thought the matter over when explaining these and allied forms. In one form, *Pentamerus galeatus*, many of which I have examined, I know the roughened spaces known as ovarian spaces are carried inwards, close to the sides of the thin central septum, leaving no space between them such as we see occupying the centre of *Orthis* and allied forms, as well as in most Brachiopoda."

‡ We have previously noticed the two incised lines in connexion with the deltidial ridges: these lines, we believe, are likewise produced by the attachment of the lateral lobes; also the corresponding lines occasionally seen on the area of certain Spirifers. The transverse striæ on the areal borders, as well as those on the outside of the hinge in the brachial valve, are evidently due to epidermal or external lines of growth, as in *Lingula*.

pedicle. Besides these parts, this organ is attached by the end (compressed) of its *inner fleshy or muscular cylinder* to an ellipsoidal space in front of the narrow lineated band, and behind the umbonal muscle. The part similarly situated in the Trimerellids, and named lozenge (g, figs. 1 & 7), we attribute to the attachment of the same cylinder. Referring again to *Lingula*, the submarginal portions of the posterior half of its valves are distinguished by a *compound* scar consisting of:—a *line* on the hinge; two *expansions*, one near each of the postlateral margins; and two *longitudinally elliptical* spaces, one connected with each of the expansions, and terminating at about the transverse median line of the valves. The *first* is formed by the postparietal of the splanchnocœle; the *second*, their inner side by the post-lateroparietals of this chamber, and their outer side by the posterior primary vessels belonging to the pleurocœles; the *third* mark the attachment of the slanting muscles, which are limited on their outer side by the lateral walls of the splanchnocœle.

That the crescent of the Trimerellids is made up of the same parts (though subject to modifications, as exemplified in *Dinobolus*), its crown, sides, and ends respectively representing the first, second, and third, is a proposition which, we think, requires nothing further for its establishment.

In *Lingula anatina* the splanchnocœle is bounded in part by another wall, the anteparietal. The transverse scars (t, *t*) in *Trimerella* occupy a similar position, evidencing that they were produced by the same wall. A further agreement consists in the anteparietal of the recent shell running forward, in the brachial valve, with a duckbill-shaped outline, considerably into the brachiocœle; for doubtless a similar peculiarity obtained in the fossil through the attachment of the same wall to the sides of the median plate, as it does to the corresponding ridge of *Lingula*, with this difference, however, that the projection would be longer, and its base narrower. There is no appearance of the transverse scars starting off from any place in *front* of the platform: they run close up to the median plate, thence *apparently* forward, and along each side of it; which would necessarily cause the attached portion of the anteparietal projection, *i. e.* in the brachial valve, to be comparatively narrow.

The *archlet* was evidently produced by the attachment of the anterior pair of primary vessels. In *Lingula anatina* these vessels do not, strictly speaking, unite at their anterior extremity; and it appears to have been the same in *Trimerella*, as the archlet seems often to open at its apex. In the brachial valve of the Trimerellas (*T. grandis*, Pl. XIII. fig. 2 b) the archlet has also a remarkable agreement in form with the course pursued by the pair of primary vessels in the recent species referred to. The opposite valve of the latter shell shows the same vessels, but more shortened: the archlet belonging to the corresponding valve of the fossils possesses a similar peculiarity. We have not yet met with any impressions producing secondary vessels.

It will be understood that we are now in the brachiocœle—the chamber holding the arms or labial appendages. So far no convoluted impressions referable to these organs have occurred to us: they have been found in other fossils*. Such impressions, however, may yet be detected, especially of the apical portion in the pedicle-valve.

In some specimens a shallow submarginal groove is present, which is all we have seen that could be attributed to the setal band. It is extremely doubtful, from the construction of the hinge, that this organ would be carried round the posterior margin of the valves, as in *Lingula*.

IV. Affinities of the Family.

Dall places the genus *Trimerella* in the family *Lingulidæ*; of which he makes two divisions (*Lingulinæ* and *Obolinæ*), remarking that its nearest affinities are with *Lingula* and *Obolus*, but adding "perhaps it may be eventually placed in the second division of the family"†. Hall, referring to his *Dinobolus Conradi*, prefers the same allocation, asserting that it is closely allied to *Obolus*‡. The same may be said of Billings, who states that "both *Trimerella* and *Monomerella* are subgenera [evidently a mistake for subgroups] of *Obolus*:" he also adds that his *O. canadensis* and *O. galtensis* belong to "a third group" §.

Quenstedt, the only continental palæontologist who has touched on the subject of its affinities, includes *Trimerella* in his family *Ungulitæ*; which he makes to consist of *Obolus*, *Schmidtia*, *Obolella*, and *Acrites* ||.

One of the points that has led these authors to affine *Trimerella* with *Obolus* is possibly the resemblance there is between the crescent of the former and certain scars which curve forward from the hinge of the latter. Until one of us had ascertained that the scars alluded to in *Obolus* represent the posterior adductor muscles of *Discina*¶, and not other organs, as in *Lingula*, we were also inclined to take the view of our colleagues: now, however, as will be understood from what is stated in the previous sections, we have abandoned it**.

Believing that the Trimerellids are closely related to the Lingulids, but distinct as a family, we shall next enter upon a comparison between the two groups by tabulating their differences and agreements:—

* Such as *Productus*, *Chonetes*, *Strophalosia*, *Strophomena*, *Koninckina*, *Anolotheca*, *Davidsonia*, &c.

† American Journal of Conchology, vol. vi. part 2, p. 153, 1870.

‡ Twentieth Annual Report of the Regents of the University of the State of New York, 1868; and revised edition, p. 376, 1870.

§ Canadian Naturalist, vol. vi. no. 2, p. 222.

|| Petrefactenkunde Deutschlands; Die Brachiopoden, p. 668, 1871.

¶ Ann. Nat. Hist. ser. 4, vol. xii. p. 13.

** It may be mentioned that an examination of a large number of specimens belonging to the genera *Obolus*, *Schmidtia*, *Obolella*, *Acrites*, &c. have led us to group them all together under the family *Obolidæ*, proposed by one of the writers in 1850: See Monograph of Permian Fossils, p. 81.

Points in which the Trimerellids may be said to differ from the Lingulids.	*Points in which the Trimerellids may be said to agree with the Lingulids.*
1. Calcareous shell-substance.	1. Deltidium and its accessories.
2. Closed at the hinge.	2. Mode of attachment of the pedicle to the deltidium.
3. Dentary, though rudely.	3. Muscular system generally.
4. Brachial valve with a cardinal process.	4. Splanchnocœle in its general outline.
5. Apophysary system generally elevated platforms, one in each valve; and the platforms in the type genus doubly vaulted.	5. The possession of pleurocœles.
6. Absence of transmedial muscles, and modifications of the umbonal muscle.	6. General arrangement of the vascular system.
7. Setal band not carried round the hinge.	7. The combination of certain parts or organs, producing thereby the posterior crescent.

The differences between the two groups, we contend, are quite sufficient to warrant the step we have taken in making of each a distinct family; while, on the other hand, their points of agreement are so numerous as to show that they are intimately related. *Obolus* is placed by Dall in the family *Lingulidæ*; but its close relationship to *Discina* opposes the allocation. This relationship alone prevents our placing the Trimerellids in any family group which embraces *Obolus*, though we are quite ready to admit that both belong to one and the same great division in their class.

At first sight the Trimerellids, considering their general external resemblance to *Uncites*, *Stringocephalus*, and other genera, might be considered to belong to the great subclass, *Clistenterata*; but, although certain parts belonging to their hinge seem to favour a different view, it cannot but be admitted that the consensus of their characters completely establishes them as Tretenterates*.

V. Geological Range, Chronogenesis, and Evolution of the Family.

The Trimerellids, as will be seen hereafter, characterize two consecutive geological systems—the Cambro-Silurian, and Silurian. Neither the Cambrian † nor Devonian rocks have as yet yielded any repre-

* *Tretenterata* (open-gut) and *Clistenterata* (closed-gut) form two great subdivisions of the Palliobranchs or Brachiopoda. The names *Pleuropygia* and *Apygia*, proposed some years ago by Bronn, stand for the same groups. The latter, being a negative term, is totally inadmissible; while the former not only prejudges and limits the position of an important organ in a variable group of shells, but it seems likely to turn out to be no more than of sectional value. The singular aperture, and tube, respectively characterizing the hinge-plate of the brachial valve of *Athyris pectinifera*, and *A. concentrica*, also the foramen occurring, *in addition to an open deltidium*, in the umbo of the pedicle-valve of several other palæozoic shells apparently belonging to the Leptænids, Spiriferids, Obolids, and Rhynchonellids, may be regarded as indicating, in such cases, the *posterior position* of the intestinal outlet.—W. K.

† We include in the Cambrian system the formations below the Arenigs—namely, the Tremadocs, Ffestiniogs, Menevians, and Longmynds: as such it answers to the Primordial group of Barrande. The Arenig, Llandeilo, and Bala

sentatives. All the known species of *Trimerella* and *Monomerella*, hitherto only found in Sweden, the United States, Canada, and Russia, are from beds equivalent in age to the Wenlock and Aymestry formations of Great Britain. *Dinobolus*, however, has obtained a more extended vertical and horizontal range: of the seven forms at present known, *D. Schmidti* (a Russian species), *D. magnificus*, and *D. canadensis* (both from Canada) are Cambro-Silurian—the two species last-named having been found in the Trenton or Black-river Limestone, about the horizon of the English Upper Llandeilo or the base of the Caradoc. *Dinobolus Conradi*, confined to the United States, belongs to the Niagara Limestone (Upper Silurian). *D. Davidsoni* appears to have been found in the Llandovery formation, as well as in that of the Wenlock in Sweden; but it, with *D. Woodwardi* and *D. transversus*, chiefly characterizes the Wenlock in the counties of Shropshire and Staffordshire: the latter three are the only British species known belonging to the family.

It is a remarkable peculiarity in *Lingula anatina* that the post-lateral parietals of the splanchnocœle, unlike the membranous counterparts in other Palliobranchs, are highly muscular—so much more than seems to be needed to protect the viscera as to give rise to the idea that they also served to some extent to keep the valves together. It is therefore not improbable that in some forms related or belonging to the Lingulids the muscularity of the walls referred to was still more developed, thereby causing them to become approximately valvulars or adductors. From this condition to complete specialization, such as is presented by the pair of postadductor muscles that characterize *Discina*, seems to be an easy gradation. *Obolus* may be cited as an additional example. Although a considerable number of Cambrian Tretenterates, usually recognized as *Lingulidæ* or Linguloid shells, are known*, it nevertheless happens that information regarding certain of their internal characters is too limited to enable palæontologists to select any of them as constituting the gradational form in question. A better source seems to offer itself in the family under description.

Neither *Trimerella* nor *Monomerella* appears likely to assist us, inasmuch as the scars (*sides* of the crescent) due to the post-latero-parietals do not differ notably from their equivalents in *Lingula*. In *Dinobolus*, however, the same scars are strikingly different; each one has a composite structure, with two, or more separated indentations strongly marked—showing that it has been produced by a muscle, or muscles, unusually large and powerful. Though evidently belonging to the postlateral walls of the splanchnocœle, very little modification

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or Caradoc formations we group together: and in justice to the labours of Sedgwick and Murchison, also in accordance with the compromise proposed by the first cited of these illustrious men, we name them collectively, as others have already done, the Cambro-Silurian system.

* See paper "On the Earliest Forms of Brachiopoda hitherto discovered in the British Palæozoic Rocks," Geol. Mag. vol. v. no. 7, July 1868, by one of the present writers. Some minute American fossils, described by Hall, Billings, and others, may be included in the same category.

of the muscles represented by the scars referred to would seemingly convert them into specialized adductors.

The peculiarity exhibited by the *sides* of the crescent, as just noticed, is of importance in our present inquiry, inasmuch as it characterizes the *earliest* genus of the Trimerellids; and of equal importance is the fact that *Dinobolus* is the least calcareous of its group. This genus therefore stands out not only as an initial form, but as indicating the period of development or chronogenesis of the family. We may go further, and assume that, while the Trimerellids strongly retain many of the leading characters of the *more ancient* family (*Lingulidæ*), the genus *Dinobolus*, by its crescent, discloses a relationship to another group strongly differentiated by its myology. Assuming this to be correct, we shall have to account, on the doctrine of evolution, for the creation* of the Trimerellids out of some primordial or early form possessing a stronger tendency to become characterized with specialized adductor muscles, situated like the postadductors of *Discina*, than is displayed in the recent *Lingula anatina*. There is no improbability in the idea that a generalized form will yet be discovered, either in the Cambrian or early Cambro-Silurian rocks, bringing *Discina* and *Lingula*, also *Obolus*, into close myotic relationship *inter se* and with *Dinobolus*. Such a form would constitute the root from which the Trimerellids have originated.

VI. Physiography of the Seas tenanted by the Trimerellids, as compared with that of the Cambrian Seas.

One of the peculiarities which characterize the Trimerellids as a family, in comparison with the related group the Lingulids, is the chemical composition of their shell-substance. The latter family comprises forms whose valves are in great part corneous (consisting of the organic "basement membrane" of Bowerbank), with additions of calcium phosphate and carbonate—the phosphate being the largest in amount; whereas the former one includes essentially calcareous species.

These differences seem to be in intimate relation with certain physiographical phenomena that distinguished the Cambrian from the Cambro-Silurian and Silurian periods.

In the Cambrian period, and, as far as known, before the Trime-

* The terms creation and evolution, it requires to be understood, are not used as meaning the production of one species (hypothetically an interreproductive group) *independently of*, or *out* of another, in the second case effected solely by extraneous agencies or circumstances. One doctrine is unscientific; the other is based on phenomena of no more than a secondary or subsidiary character. Evolution, taking it to be exemplified by metagenesis and metastomotosis, respectively characterizing the Hydrozoa and Batrachia, is obviously the result of *innate* formative action adapting itself to extraneous influences or conditions: the cases referred to do not differ in their causation from the great progressive mutations which the life-system of our planet has passed through, as revealed by palæontology. The variations produced in plants and animals by external influences constitute a highly important study, giving rise, if considered in connexion with the doctrine of *innate adaptive* formativity, to the noblest and most exalted conceptions that man is capable of forming.—W. K.

rellids were in existence, limestones are no more than exceptional deposits amongst their argillaceous and siliceous associates. On the contrary, in the Cambro-Silurian and Silurian Periods (that is, during the rôle of the Trimerellids), as ever since, depositional phenomena became remarkably characterized by calcareous elaborations.

It is equally noteworthy that the Cambrian life-system is but poorly represented by forms in whose skeletons calcium compounds are essential constituents. Although representing groups most of which afterwards included members possessing a massive calcareous framework, the Cœlenterates, Mollusks, Echinoderms, and Crustaceans of the Cambrian period had slender skeletal structures, in which lime was not particularly abundant; and they thus stand out in striking contrast to their massive successors of subsequent periods.

Doubtless in the Cambro-Silurian and Silurian seas — those tenanted by the Trimerellids—ordinary marine calcium compounds prevailed as at present. But, in view of what has already been stated, are we to suppose that such compounds did not occur to the same extent in Cambrian seas? Or are we to imagine that the Cambrian organisms were incapable of abstracting lime from the medium they lived in? As few, we think, will be found to entertain the latter idea, it may be dismissed to leave room for the consideration of the other one.

It is well known that the Archæan rocks * are of enormous thickness. In the British Isles they consist of the ordinary metamorphics, composed of silacid minerals. In North America, especially in Canada, where they apparently comprise two (or more) unconformable series—Laurentian and Labradorian—they include both silacid and silo-carbacid rocks †. The "zones" ("bands," or "masses") of "Crystalline limestone," of the Canadian Geological Survey, which constitute the silo-carbacid group, attain an aggregate thickness of some thousands of feet ‡.

The Cambrian rocks, though varying in certain respects in different regions, agree pretty generally in their lithological features.

* Dana, rejecting the term "eozoic," which has been applied to them "to indicate the morning of that great creative day in which the lower forms of animal life were introduced upon our planet" (*Dawson*), distinguishes the Laurentian and associated metamorphic rocks, older than the primordials, by the name Archæan. This change very properly does not reject the idea that undoubted or indisputable organic remains may yet be found in such rocks; for it is quite likely that the term *eozoic* will share the same fate as that of *azoic*, as proposed originally for the Cambrians.

† For the distinctive characters of these rock-divisions, see a paper in the Geological Magazine, January 1872, entitled, "The Microscopic Characters of a Silo-carbacid rock from Ceylon; and their Bearings on the Methylotic Origin of the Laurentian 'limestones.'"

‡ In both the upper and lower series of the Archæan rocks, "the united thickness of which in Canada cannot be less than 30,000 feet, and probably much exceeded it," there are several zones of limestone. Of these it has been ascertained that three at least belong to the lower series." The "Zone of Grenville limestone [the lowest of the series] is in some places 1500 feet thick." At Clarendon the Archæan rocks have a "thickness of 4000 feet, about two thirds of which (2666 feet) consist of Crystalline limestone."—*Logan*, *Geology of Canada*, p. 31, 1863.

Now, as regards the silacid members of the Archæans, there is no difficulty in understanding how they have given rise to the argillites and sandstones of the Cambrians. But where are the limestones that we ought to expect would have been formed by contemporary reproduction out of the Silo-carbacid rocks? We cannot be satisfied with the answer if it refer to the American cases represented by the *primordial* limestones of Belle Isle, Troy (N.Y.), and other places, or the calciferous sand-rock usually included in the Potsdam formation*.

Turning next to the British Cambrians, we shall be met by a still less satisfactory answer. The Longmynds, Menevians, Ffestiniogs and Tremadocs, which range from twenty thousand to thirty thousand feet, or more, in aggregate thickness, consist of all the rock-forming materials except the one we are searching for. The lapse of time during which the argillites and sandstones of these groups were in process of formation must have been immense; and not only are they divested of limestone, but calcareous fossils are exceedingly rare in them.

The cases cited form one of the most difficult problems in primordial geology; for considering the "masses" of "Crystalline limestone" characterizing the American Archæans, the totally incommensurate amount of calcareous rocks amongst the Cambrians seems to be unintelligible: and the difficulty is further increased by the fact that contemporary organisms rarely had skeletons in which lime is the predominant constituent.

We shall make no attempt to solve the problem: all we can do at present is to call attention to the subject.

Certainly, it may be said in conclusion, there are some grounds for believing that great physiographical differences prevailed between the Cambrian and the succeeding periods—that great changes in life and sedimentation, of a persistent nature, began during the early portion of the Cambro-Silurian, and have been maintained ever since. The Trimerellids appear to have played no unimportant part in the beginning of these changes.

VII. Diagnosis of the Family.

Class Palliobranchiata, De Blainville†.

Subclass Tretenterata, King‡.

Family *Trimerellidæ*, Davidson & King§.

Shell-substance of the valves calcareous. Species generally massive, especially in the umbonal region. *Umbo* of the pedicle-valve often

* The limestones of the Quebec group are excluded, as they are now generally considered to be on the horizon of the Lower Llandeilo formation; and it is even possible that the Calciferous sand-rock is at or near the base of the Cambro-Silurian system, and equivalent to the Arenig group.

† *Brachiopoda*, Cuvier 1805; Dumeril, 1806; Lamarck, 1809; and of the generality of palæontologists. *Palliobranchiata*, Blainville, 1824.

‡ Annals and Mag. of Nat. Hist. 4th Ser. vol. xii. July 1873.

§ Cuvier's name, Brachiopoda, is a misnomer, as it is now generally admitted large; pointed; projecting variously; solid, or hollow: its hinge-face with a well-developed area. *Area* usually of considerable size; with a large *deltidium*, which is solid throughout. *Hinge* of both valves rudely or faintly dentary: *that* of the *pedicle-valve* thick; entire in its whole length; and more or less elevated; supported in the latter case by an upright rib or *cardinal buttress* of varying thickness; with a wide median space or *cardinal facet* enclosing a lozenge-shaped scar: that of the *brachial valve* with a more or less elevated median prominence, or depression. Attached to the interior surface of the posterior half of both valves is a more or less elevated *platform*; which is medio-longitudinally situated, and solid, or doubly vaulted: from the middle of its anterior end a *median plate* occasionally projects into the anterior half of the valve, especially the brachial one. Both valves have a compound impression or *crescent* running a little within the margins of their posterior half, including the hinge. A submarginal impression or *archlet* characterizes the other or anterior half of the valves.

The detailed description already given of the various parts characteristic of the family renders it unnecessary to add any thing by way of general observations. Variations of these parts, to a considerable extent, occur in the whole group. It is principally on the variations of the platform, and other parts belonging to the cardinal region, that the genera *Trimerella, Monomerella* and *Dinobolus* are founded. As in other families, the present one is not without species which cannot be satisfactorily allocated generically.

VIII. The Genus Trimerella and its Species.

Genus *Trimerella*, Billings, 1862*. *Obolus* (*galtensis*), Billings, 1862. *Gotlandia*, (Dall), 1870. *Rhynobolus* (*galtensis*), Hall, March 1871. *Obolellina* (*galtensis*), Billings, Dec. 1871.

Valves thick; longitudinally oval. *Umbo* of pedicle-valve usually massive; solid; occasionally double-chambered; irregularly projecting. *Area* of considerable size; longer than wide. *Deltidium* large. *Hinge* generally thick, and elevated; rudely or slightly dentary; and variously modified in different species. *Cardinal facet* large. Crescent rather well defined in typical species. *Platforms* elevated, and doubly vaulted; occasionally solid, and slightly raised.

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that the brachial appendages are not locomotory organs. It seems probable that locomotion is effected by the pedicle, at least in shells in the young state: this view is supported by Morse's observations on *Lingula pyramidata*, and by the evidence of Stoliczka, who, from what he saw of *Lingula anatina* on the coast of Arrakan, is inclined to believe that it is capable of changing its place actually by movements of the pedicle: see Mem. Geol. Survey of India, vol. iv. 1, p. 5. Blainville's name, Palliobranchiata, is unobjectionable, as the pallial lobes are the principal respiratory organs.

* Geological Survey of Canada, Palæontology, p. 166, 1862. The name *Trimerella*, like *Monomerella* and *Dinobolus*, is unfortunately not above criticism.

Median plate occurring generally in both valves; longest in the brachial one.

Type species *Trimerella grandis*, Billings.

The genus varies much in some of its chief characteristics. The umbo of the pedicle-valve, usually large, subconical, and occasionally double-chambered, is exceptionally flattened in *T. Billingsii* and *T. galtensis*; and the hinge of these species is consequently very slightly elevated: on the contrary, in *T. Dalli* the umbo is prominently double-chambered, as in the next genus. The hinge has a central part, projecting in certain species, and excavated in others. In *T. Billingsii*, and *T. galtensis*, the platforms are slightly raised or depressed, a peculiarity which remarkably differentiates them from the typical species.

The genus *Rhynobolus*, proposed by Hall for *Obolus galtensis*, appears at first sight to possess sufficient distinctive characters; but, comparing its type with *T. Billingsii*, we cannot see how it can be separated from the latter generically: both species are similarly characterized by flat longitudinally-elongated valves, a flattened umbo in the pedicle-valve, a large area and deltidium, and solid or slightly elevated platforms. The distinctions made out by Hall for *T. galtensis* appear to us to be insufficient; as through the depression of its platforms the anterior portion of these parts, including their scars, show nothing more than what is seen in *T. Billingsii*. Both species may be considered aberrant forms of the genus; the former departing somewhat further from its type than the latter.

TRIMERELLA GRANDIS, Bill. Pl. XIII. figs. 2, 3.

Trimerella grandis, Bill. Geol. Survey of Canada, Palæontology, p. 166, fig. 151, 21 Jan. 1862. Dall, American Journal of Conch. vol. ii. part 2, p. 160, 1870, vol. vii. p. 82, 1871. Quenstedt, Petrefactenkunde, p. 172, pl. lxi. fig. 42, 1871. Hall, Explanation of figures in "Notes on some new or imperfectly known forms among the Brachiopoda," pl. xiii. figs. 11–16, 1872. Dav. and King, Report of Brighton Meeting of Br. Assoc. 20 August, 1872.

Shell much longer than wide; broadly rounded anteriorly; tapering posteriorly to an almost pointed beak; greatest breadth at about two thirds from the beak; surface smooth. *Pedicle-valve—beak* slightly curved: *area* a little more than a quarter of the length of the shell: *deltidium* rather raised, but longitudinally depressed along the middle: *deltidial ridges* well defined: *platform* rather wide; occupying nearly the entire posterior half of the shell; biconvex; and most elevated at its anterior margin; its vaults of greater, or lesser depth: *median plate* extending to a short distance forward along the bottom of the shell: *crescent* of large size: *archlet* about the width of the platform; and passing a little way in advance of the median plate. *Brachial valve—hinge* with a slightly projecting cardinal process: *crescent* with sides and ends of considerable width, and well outlined: *platform* comparatively narrow, occupying half of the valve; its vaults of greater or lesser depth: *median plate* extending to within a short distance of the anterior edge of the shell, dividing it into two lateral portions: *archlet* wider than the platform, passing forward to the end of the median plate.

The discovery of this remarkable species is due to Mr. Billings, who, in January 1862, published a short description, with figures, of an internal cast. He also at the same time proposed for it a new generic appellation, stating that it was allied to *Obolus*, but differed from this genus in the possession of three longitudinal septa in each valve *. Some good figures of the interior of the shell, taken from gutta-percha squeezes, were subsequently published by Professor Hall, in 1872.

Billings, when noticing the muscular scars of the present species, states that "on each side" of the platform "there appears to be a small ovate muscular impression as in *Obolus*." The specimen which displays this impression was kindly placed in our hands by Mr. Billings. At first we imagined he had correctly interpreted it; but our subsequent investigations, as stated in another place, have convinced us that the interpretation is not correct.

The impression on each side of the platform belongs to the crescent, which, as already shown, has its parallel in the posterior half of both valves of *Lingula*; therefore, instead of having been produced by the postadductors, it is more likely to have been formed by the implantation of the post- and post-lateral parietals of the splanchnocœle and other organs characterizing the genus referred to. These organs, as elsewhere made known, it is highly probable, produced the *crown* and *sides* of the crescents; but the *ends* of the crescents (terminating in a line intersecting the anterior portion of the platform) are formed by a scar, or rather scars, which there is every reason to believe resulted from the posterior attachment of a group of slanting or lateral muscles †.

The ends of the crescents escaped our notice when fig. 2 *b*, Pl. XIII. of the present species was drawn: indeed it was only after becoming acquainted with the parts corresponding with them in *Lingula* that they disclosed themselves to us. On the right side of the specimen, as represented by the figure just noticed, there is tolerably well seen, as in the annexed woodcut (fig. 2), the scar *s*, which, from its relative position, we have no doubt is due, as in *Lingula anatina*, to the posterior attachment of the lateral muscles.

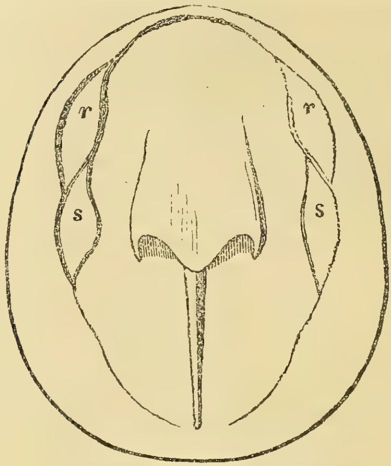
The interior of the umbo in the pedicle-valve looks as if it were to a slight extent doubly chambered; the chambers separated by a wide cardinal buttress ‡. The hinge, on the top of the last part,

* We have shown elsewhere, there exists in reality but one septum—that is, the *median plate*—the other two forming the sides of the platform: the name *Trimerella* is therefore a misnomer.

† See paper on "*Lingula anatina*," Annals and Mag. of Nat. Hist. 4th Series, vol. xii. July 1873; also woodcuts in p. 132.

‡ Two figures of this species, representing apparently young individuals, given by Professor Hall (Preliminary Notice, 1872, pl. xiii. figs. 14, 15), show the umbonal chambers rather well developed, and separated by a narrow cardinal buttress.

Fig. 2.—*Brachial valve of* Trimerella grandis.



r, *sides*, and *s*, *ends* of the crescent.

shows something like a hollow that may have been the seat of attachment of the umbonal muscle.

Trimerella grandis, chiefly in the form of internal casts, appears to be a very abundant fossil in the Guelph limestone—a rock immediately overlying the Niagara limestone (Upper Silurian), at Hespelar, Galt, New Hope, Elora, Guelph, also at Ontario, in Canada West, or about four hundred miles from Montreal. In the last locality some specimens have been found three inches and a half in length by two in breadth and one in depth.

Trimerella acuminata, Billings. Pl. XV. figs. 4–7, and Pl. XVI. figs. 1, 2.

Trimerella acuminata, Bill. Memoirs of the Geol. Survey of Canada, Palæontology, p. 167, fig. 151, 21 Jan. 1862. (?) Lindström, Öfversigt af Kongl. Vet. Akad. Förhandlingar, p. 253, pl. xxi. figs. 3, 4, 1867. Dall, American Journ. Conch. vol. vii. part 2, p. 82, 1871. Bill. Am. Journ. Sci. Arts, 3rd ser. p. 471, June 1871. Billings, Notes on *Trimerella acuminata*, Annals and Mag. of Nat. Hist. 4th ser. vol. viii. p. 140, August 1871. Dav. and King, Report of Brighton Meeting of Br. Assoc. 20 August 1872.

Shell large; massive; longitudinally oval; broadly rounded in front; tapering in its posterior half: *surface* smooth, or strongly marked at intervals by concentric lines of growth. *Pedicle-valve* moderately convex: *beak* produced; somewhat rounded at its extremity: *deltidium* triangular; very wide; deeply concave; strongly marked with anticlinal lines: *deltidial ridges* well pronounced: *areal borders* narrow: *deltidial slope* narrow; marked from side to side by fine lines: *hinge* depressed, or concave in the middle: *cardinal facet* large; passing down with a considerable inclination to the cardinal buttress, from which it is separated by a well-defined edge: *platform* extending to about half the length of the valve; strongly depressed along its surface; with perpendicular lateral walls: *vaults* extending to a little way underneath the central part of the hinge: *cardinal buttress* low; standing approximately at a right angle to the plane of the shell; as wide as the platform: *umbonal chambers* extending to some distance under the hinge outside of the deltidium. *Brachial valve* deeper and more convex than the opposite one: *hinge* raised in the middle; with a strong lamelliform cardinal process: *platform* well developed; a little longer than that of the opposite valve; its *vaults* of considerable depth: *median plate* much elongated.

Mr. Billings, to whom palæontolgists are indebted for the discovery of this species, and who was the first to give a brief description of it, accompanied by a figure of a fragment of the internal cast of the ventral valve, informs us that the largest specimen he has seen is three inches and a half in length, by three inches in width. He also states "there is sufficient to show that this species is quite distinct from *T. grandis*. If a section were made across the beak of a perfect shell of *T. acuminata*, it would show four perforations arranged in a curve, exactly as in the similar section of the Swedish species figured by Dr. Lindström. But if the beak of *T. grandis* were cut across, it would show only two orifices, and they would be the homologues of the two lateral perforations [our *umbonal chambers*] in the section of *T. acuminata*, because in *T. grandis* the two central tubes [our *platform-vaults*] do not extend into the beak, but terminate before they reach it."

According to our mode of describing its interior, the species under description shows six "perforations"—four in the pedicle-, and two in the brachial valve. It is extremely difficult to give all the "perforations" in one view: our figure 4^d, Pl. XV. only shows those (vaults) belonging to the platforms: there are, however, in the pedicle-valve of the specimen represented other two (umbonal chambers), one on each side of the umbo.

The deltidium is usually wide and concave, giving the area a singular appearance. The hinge is remarkable in having its middle in the pedicle-valve concave, and the corresponding part in the opposite valve convex: the convexity of the latter part is increased by the lamelliform cardinal prominence (Pl. XV. fig. 4^d). The cardinal facet exhibits the lozenge faintly, though with close inspection its bordering lines may be made out. There are two small "umbo-lateral scars," one at the entrance, and on the outer side, of each umbonal chamber (fig. 1, x, Pl. XII.). The scars on the platform and crescent, though far from satisfactorily defined (Pl. XV. fig. 4^a), appear to be formed and arranged as represented in Pl. XII. fig. 1.

T. acuminata occurs chiefly in the state of casts *, in the Guelph

* We have succeeded in making some very good gutta-percha moulds from some of these casts.

limestone immediately overlying the Niagara limestone (a rock equal in age to the Aymestry limestone of England, or about that level, according to Mr. Billings) at Hespelar, Galt, Elora—villages situated near each other in Ontario (Canada West). Mr. Weston, of the Geological Survey of Canada, has discovered several new specimens in the localities, already mentioned in our description, which have yielded *T. grandis*: among these are two exhibiting casts of both valves in connexion. Mr. Weston discovered also at Hespelar an incomplete specimen, measuring three and a half inches in length, which showed that the shell was smooth, or marked only by concentric lines of growth. Well-characterized internal casts of *T. acuminata* were likewise found by Dr. Lindström in several parts of the Island of Gotland, as far back as 1859, in rocks about equivalent in age to those of Canada.

The species appears to have had a very extended horizontal range; for it occurs in the same horizon in Canada, the United States, and in Sweden.

Trimerella Lindstrœmi, Dall. Pl. XIV. figs. 1–7.

Trimerella? Lindström, Öfversigt af Kongl. Vetenskaps-Akademiens Förhandlingar, p. 253, pl. xxi. figs. 1 & 5 to 9, 1867. *Gotlandia Lindstromi*, Dall, American Journal of Conch. vol. ii. part 2, p. 160, 1870. ? *Trimerella*, Dall, vol. vii. part 2, p. 84, 1871. Dav. and King, Report of Brighton Meeting of Br. Assoc. 20 August, 1872.

Shell very massive; longitudinally oval; anterior half broadly rounded; posterior half tapering rather rapidly to the extremity of the beak, which is pointed; greatest breadth at about one third of the length of the shell from the anterior margin: *surface* smooth or marked with concentric lines of growth. *Pedicle-valve* very thick; rather less deep than the opposite one; sloping from the point of the umbo to the anterior margin: *area* equilateral; triangular; rather longer than one fifth of the length of the shell: *areal borders* rather wide: *deltidium* flat, or raised; wide; triangular; with a more or less marked longitudinal depression along the middle: *deltidial ridges* and *callosities* prominent; crossed by strongly indented lines or ridges: *deltidial slope* variable; occasionally its lines appear to be coarse: *cardinal facet* large; variable in its inclination: *umbonal chambers* resembling tubular perforations: *platform* and *vaults* nearly as in *T. grandis*. *Brachial valve* massive; moderately and uniformly convex, especially about the umbo: *hinge* generally with a large, massive, projecting cardinal process in the centre; and two depressions, one on either side: *platform* and *vaults* agreeing pretty nearly with those in *T. grandis*.

Trimerella Lindstrœmi varies remarkably in its cardinal features; the variations in some cases being highly puzzling. The cardinal process is rude and inconstant in shape: the variety given in Pl. XIV. fig. 3 (the part answering to the cardinal scar *v* in fig. 2, Pl. XII.) may be regarded as showing its median state of development—some specimens exhibiting it lower, others even more elevated. In the latter state it appears to have fitted like a tooth into a deep excavation in the hinge or near the origin of the platform (Pl. XIV. fig. 5), thereby apparently effacing both the cardinal facet and buttress: this excavation is bounded posteriorly by a perpendicular wall. Whether the facet was situated on the wall is a point on which it is difficult to offer any more than a suspicion. A similar difficulty attaches to the excavation; was it produced by the attachment of the umbonal muscle? A variation in the opposite extreme is represented in fig. 2, Pl. XIV., which shows the facet, with the lozenge, occupying a place seemingly corresponding to the bottom of the excavation seen in fig. 5. But certain appearances, presented to us, favour the suspicion that the facet and lozenge were situated on the posterior *wall*, rather than at the *bottom* of the excavation. In most of the Trimerellids the facet dips forward from the deltidium,—suddenly, we should say, in the present species, if represented only by such individuals as that in fig. 5; but other specimens exhibit it with a moderate inclination, as in *T. acuminata* (Pl. XV. fig. 4 a); while in the one represented in fig. 2, Pl. XIV., it actually inclines backwards or in the opposite direction. The umbonal muscle may or may not have been attached to the bottom of the excavation in fig. 5 specimen; but it is difficult to point out its locality of attachment in fig. 2 specimen: possibly it was attached at the origin of the platform, where occasionally there is something like a scar.

The dentary system, taking it to be represented by the deltidial callosities in the pedicle-valve, and the cardinal sockets in the opposite one, is equally variable; though, possibly, some of the appearances of variation may be due to erosion. The callosities are strong bosses in certain specimens, and thick plates in others; it is therefore possible that the appearances which led Lindström to believe in the groove-and-ridge mode of articulation were presented by an extreme case of lamelliformity *.

The umbonal chambers are of small calibre, being little more than tubular perforations. Lindström has given a figure † showing their presence in an early stage of growth, also that their tubular form was persistent. Such a case strongly favours the idea that the chambers were for some particular purpose; otherwise it is difficult to understand why they have not been filled up with organic accretions. The umbonal cavity of the brachial valve in the specimen represented in our fig. 7, Pl. XIV. is doubly chambered; the large size of the conical prominences (casts), on each side, shows that the chambers have considerable depth and width.

The platforms do not appear to be so large as in the last species: they resemble more closely those of *T. Billingsii*, particularly in having short vaults. The scars are represented with approximate correctness in fig. 2, Pl. XIV. The submarginal impressions, generally indistinct, are resolvable into the typical crescent.

* The specimen in question, which we have not seen, is preserved in the Museum of Stockholm.

† Geol. Mag. vol. v. pl. xx. fig. 9.

Specimens of this remarkable fossil were first discovered by Dr. Lindström in 1859, and soon afterwards forwarded for examination to one of the writers of the present memoir, accompanied by a MS. description and figures; but it was only after the publication by Billings of his genus *Trimerella* in 1862 that certain other characters of the shell were determined by Dr. Lindström. His material being more complete than that upon which the genus was founded, he published, in 1867, a description and figures of the species, but without giving it a name. He was, however, mistaken in believing that the vaulted platform is smooth, and had no impressions of muscular scars upon it, as these occurred to us very plainly on one of his specimens, thus confirming the idea entertained by Billings in 1862.

In 1870 Mr. Dall, from not quite understanding the characters of Mr. Billings's genus *Trimerella*, and those of Dr. Lindström's species, proposed for this last a new generic appellation, *Gotlandia*; but in 1871 he corrected the mistake. In the same year he described the species under the designation of ? *Trimerella Lindstrœmi*.

Some specimens have been found three inches in length by two and a half in breadth and one in depth.

We are informed by Dr. Lindström that this species may be regarded as one of the most characteristic fossils of the Silurian rocks of the Island of Gotland. Almost everywhere may be discerned fragments of it on the weathered surface of the limestone—often transverse sections of both valves; so that the hard crystalline rock seems to be almost entirely made up of them—to such an extent that it might be termed the "*Trimerella* limestone." There are, nevertheless, a few localities where tolerably good specimens may be collected, such as at Klinteberg, Fole, Iamsugnen, a limestone quarry in the parish of Olham, at Furillen on the east steep coast of Gotland, Widlansudd, situated quite at the extremity of the island, and in Fårö on the north coast of Gotland.

It is, however, only within the range of the "Central Gotland" beds of the islands of Gotland and Fårö that *T. Lindstrœmi* (with *T. acuminata*) has been found. These beds have been considered by Dr. Lindström and by Sir R. Murchison equivalent to the Aymestry rocks of England, a view fully supported by fossil evidence. We are indebted to Dr. Lindström, to Prof. E. Walmstedt of the University of Upsala, and to Herr Fegrœus for many specimens of this species.

Trimerella Billingsii, Dall. Pl. XVI. figs. 8 & 9.

Trimerella Billingsii, Dall, Am. Journal of Conch. vol. vii. part 2, p. 82, pls. 1, 2, 1871*.

Shell longitudinally oval; compressed: *umbonal region* projecting; twisted to one side. *Pedicle-valve*—*deltidium* large; wide; transversely striated; slightly excavated; strongly bordered at sides by the

* The fossil referred to *T. Billinsgii* in this paper was so labelled by Mr. Dall; but he must have mistaken some other specimens for this species, as the longitudinal section given in his fig. 3 appears to have been taken from a specimen of *Trimerella grandis*.

deltidial ridges, and in front by a tolerably well-defined *deltidial slope*. The *cardinal facet* appears to be small. The *platform* is solid, long, and large, but of slight elevation: it has a raised ΛΛ-shaped anterior margin the side divisions answering to the openings of rudimentary vaults. The *median plate* scarcely exists, and extends to no more than a line in advance of the anterior termination of the platform. Scars occupy the anterior half of the platform: some strongly marked are situated near its front border. The *crescents* are faintly indicated.

This remarkably compressed species is one of those aberrant forms which render it difficult to diagnose a generic group, or to determine what genera they should be placed in. It has much the appearance of *Trimerella grandis*; and therefore seems naturally to fall into the same genus. Another species, next to be described, stands out prominently as a still more aberrant form. *T. Billingsii* does not possess any thing like a dentary system: its pedicle-valve has no median plate; but the centre of the anterior margin of the platform is somewhat prolonged. Besides the scars on the anterior half of the platform, there are linear impressions (answering to the transverse scars, t in fig. 1, and *t* in fig. 2 of Pl. XII.) passing in front of the rudimentary vaults. The platform and the openings of its vaults have much the appearance of a flattened nose, with the nostrils and their rim prominently exposed.

All we have seen of this species is the internal cast, measuring two inches three lines in length by one inch five lines in width, of a single pedicle-valve, found by Mr. Billings in the Guelph Limestone at New Hope, West Canada.

TRIMERELLA (?) GALTENSIS, Billings. Pl. XVIII. fig. 13; and Pl. XIX. figs. 4 & 4[a].

Obolus galtensis, Billings, Geol. Survey of Canada, Pal. p. 168, fig. 151, 21 Jan. 1862. *Trimerella minor*, Dall, Am. Journ. of Conch. vol. vii. p. 83, 1871. *Rhynobolus galtensis*, Hall, Report on the State Cab. of Nat. Hist. preparations of Pal. New York, p. 5, March 1871. *Obolellina*, Bill. Can. Nat. vol. vi. p. 222, 29 Dec. 1871; also April 1872. *Dinobolus*, Dav. and King, Report of Brighton Meeting of Br. Assoc. 20 August, 1872.

Shell compressed or moderately convex; tapering rather sharply behind; broadest, and rounded anteriorly. *Pedicle-valve* flatly convex: *area* large; long; nearly an equilateral triangle: *deltidium* raised; occupying a considerable portion of the area; crossed by strong imbricated lines; with a broad deepish furrow along its entire length: *areal borders* transversely striated: *platform* wide; very slightly raised; its anterior very obtusely V-shaped. *Brachial valve* slightly convex: *platform* V-shaped; scarcely raised, or an excavation; deeply marked with scars, which give it a tripartite appearance: *crescent* well pronounced, especially at the crown, the middle of which is pointed, the point directed backward.

Under the name of *Obolus galtensis* this shell was very briefly described in 1862 by Mr. Billings, who at the same time gave an incomplete figure of an internal cast of the dorsal valve. In 1871

Mr. Dall also published a very brief description of the ventral valve under the designation of *Trimerella minor*, n. sp.?* Later, in March 1872, Prof. Hall noticed this shell, calling it *Rhynobolus*; and in December of the same year he gave a fuller account of it.

Only slight traces of the crescent have been observed in the pedicle-valve. The hinge and beak bear considerable resemblance to those of *T. Billingsii*. We suspect that Dall, Hall, and others view what we call the deltidium in a different light from ourselves—they taking the median furrow to represent this part; we, on the contrary, look upon the *whole* as forming the deltidium. There are only slight traces of the deltidial ridges: Hall, however, has represented one of them prominently on the left side of the area. The scars on the platform of the brachial valve form three sets:—one on the ante-median portion, which is circular or slightly lozenge-shaped; the second or median set immediately behind (partly represented in fig. 4[a], Plate XIX.); the third with its two members separated by the last set, and diverging backwards.

Trimerella galtensis has been placed in different genera. Billings at first considered it to belong to *Obolus*, but afterwards included it in his genus *Obolellina*: Dall placed it in *Trimerella*: Hall constructed his genus *Rhynobolus* for it: and the present writers, on a former occasion, allocated it in *Dinobolus*! It certainly differs in some important features from the typical forms of *Trimerella*, having partly sunk platforms and no vaults; but so does *T. Billingsii*, though not to the same extent. In the last species, as already noticed, the platforms are considerably reduced (at least the one belonging to the pedicle-valve), nearly to the exclusion of the vaults.

The absence of vaults in *Monomerella*, it may be readily seen, causes the platform in the pedicle-valve to be considerably modified; and evidently their absence in the present species has given the platform of the same valve its peculiar character. We are quite ready to admit that in its apophysary system *T. galtensis* offers a close approach to *Monomerella*; also, looking at the scars on the platform of the brachial valve, that it very closely agrees in this respect with *Dinobolus*: but, with the exception of these scars, we see very little resemblance between this and any of the known species of the latter genus. Were it not that its umbonal characters are characteristic of *Trimerella*, we might have been induced to give the present species a different generic allocation: our views in this matter are generally influenced by the peculiar characters of *Trimerella Billingsii*: besides, excepting the form of the scars on the platform, we see very little resemblance between *T. galtensis*, and any of the known species of *Dinobolus*. Another most important difference prevails: in the shell under description the crescent shows no appearance of the composite structure (the strong indentations) which characterizes the inner border of the sides of the same part

* Both Mr. Billings and the authors of this paper, who have seen the specimen upon which it was established, are able to assert that Mr. Dall's *Trimerella minor* was founded on one of the typical forms upon which Mr. Billings had originally instituted his *Obolus galtensis*.

in the latter genus. The present species appears to us to be an extreme aberrant form linked to *Trimerella* by means of *T. Billingsii.*

Some well-preserved internal casts of both valves have been procured by Mr. Billings and Prof. Hall from a light-yellow rock of the Guelph Limestone (Upper Silurian) at Galt, Ontario, in Canada. The largest examples, we have seen, measured—length one inch eight lines, breadth one inch one line.

TRIMERELLA OHIOENSIS, Meek. Pl. XVI. figs. 3–7; Pl. XIX. figs. 1, 2.

Trimerella ohioensis, Meek, Sill. Am. Journ. Sci. & Art, p. 305, April 1871. Dall, Am. Journ. of Conch. vol. vii. part 2, p. 83, pl. ii. figs. 3, 4, 1871. Dav. & King, Report of Brighton Meeting of Br. Assoc. 20 August, 1872.

Shell large; massive; globose, or longitudinally oval; anteriorly broadly rounded; greatest breadth towards the middle: *beak* moderately produced; occasionally much incurved: *exterior* smooth. *Pedicle-valve* moderately convex, or flattened: *deltidium* large; wide; triangular; deeply concave: *platform* commencing almost immediately under the hinge, and extending to about two thirds of the length of the valve: *vaults* very large and deep: *median-plate* tolerably long. *Brachial valve* with an incurved umbo: *cardinal process* variable; well developed: *platform* commencing under the hinge; deeply vaulted: *median-plate* considerably elevated; extending to within a very short distance of the margin of the valve.

This, which may be considered a typical form, is more tumid than any of the preceding species. Mr. Meek states that on comparing specimens of *T. ohioensis* with *T. grandis* he found them quite different and distinct—that proportionally *T. ohioensis* is a much broader shell, and differs in having the beak of the dorsal valve strongly incurved beyond the plane of the connecting edges of the two valves—that it is also more convex, its ventral valve more arched, and the rostral cavity of its dorsal valve deeper. The platforms and vaults, in their length, resemble those of *T. acuminata.* We have not become acquainted with its platform-scars and crescents; but certain obscure indications of the former are observable close to the almost perpendicular hinge-wall and below the cardinal process: they seem to have been produced by the attachment of a valvular muscle, possibly the umbonal. The hinge, much elevated in the middle of the brachial valve, presents different appearances through modifications in the mode of the attachment of the muscles belonging to the cardinal scar, *v*; which in certain individuals appears as a ridge running along the hinge (figs. 5 & 6, Pl. XVI.); while in others it is double cup-shaped (fig. 7, Pl. XVI.). Meek mentions that "the centre of the hinge appears to have been furnished with a massive gently rounded cardinal process."

Through the liberality of Mr. Meek, Mr. Joseph Henry, Prof. Hall, and Mr. Whitfield, we have been able to examine a number of well-preserved internal casts. These vary considerably; for while some examples are almost spherical, or as wide as long, others are a good deal longer than wide. Mr. Meek assures us that some specimens are nearly four inches in length, two and a half in breadth, and one inch and a half in depth. The breadth is also greater in some specimens, as we possess an internal cast in which it measures three inches.

T. ohioensis abounds in the Niagara Limestone (Upper Silurian) at Genoa, Ottawa Co., Ohio; Sinking Springs, Ohio (I. S. Newberry). According to Mr. Dall one valve was found in the Guelph Limestone of Canada.

TRIMERELLA DALLI, Dav. & King. Pl. XV. figs. 1–3.

Trimerella Dalli, Dav. & King, Report of Brighton Meeting of Brit. Assoc. 20th August, 1872.

Shell ovate, or longitudinally oval: surface smooth. *Pedicle-valve* flatly convex, especially along the middle: *beak* prominent; nearly straight; about one fifth the length of the shell; with two *umbonal chambers* rather deep, conical, separated by a strong *cardinal buttress*: *crescent* tolerably well pronounced: *platform* divided at its posterior end by an extension of the buttress into two lateral portions; wide and short: *vaults* not of much depth: *median plate* of small extent. *Brachial valve* uniformly convex: *cardinal process* an excavated projection: *platform* long; extending to the middle half of the valve: *vaults* rather short: *median plate* much elongated.

Several internal casts of the present fossil were sent us for examination by Mr. Billings. After taking gutta-percha squeezes from them we arrived at the conclusion that they are distinguishable from all other species of the genus chiefly by the presence of deep umbonal chambers separated by a lamelliform cardinal buttress. These characters approximate the species to the genus *Monomerella*.

The largest example that has come under our notice measured 1 inch 4 lines in length, 1 inch 1 line in breadth, and 8 lines in depth.

T. Dalli occurs in the Guelph Limestone at Hespelar, Canada West; where it was found by Mr. Weston.

TRIMERELLA WISBYENSIS, Dav. & King. Pl. XIII. fig. 1.

Trimerella wisbyensis, Dav. & King, Report of Brighton Meeting of Brit. Assoc. 20th August, 1872.

Brachial valve nearly circular, or a little wider than long: *platform* moderately long; depressed along its middle: *vaults* extending underneath the platform to apparently half its length: *median plate* long *.

Of this species all we know is the internal cast of a single dorsal valve, 13 lines in length by 11 in breadth, found by Dr. Lindström in the Upper Silurian (Wenlock) near Wisby, in Gotland.

* Traces of the crescent are visible on the hinge. Although our figure represents the platform as if complete, we suspect that it was larger than represented. Its surface shows median and lateral scars.

IX. Monomerella and its Species.

Genus Monomerella *, Billings, 1871.

Shell thick; circular, or transversely oval, in its marginal outline. *Pedicle-valve—umbo* usually large; projecting; double-chambered: *area* of considerable size: *deltidium* large: *hinge* generally thick and elevated; ledge-shaped; depressed or concave in the middle portion: *cardinal facet* a wall-like space rising out of or behind the ledge or flat of the hinge: *cardinal buttress* strong; lamelliform: *platform* flat; slightly elevated; widest, highest, and very obtusely angulated in front. *Brachial valve—umbo* rounded: *hinge* moderately thick: *platform* trilobed; usually with a thin margin.

Type species, *Monomerella prisca*, Billings.

The unvaulted character of its platforms, large umbonal chambers, and certain other characters differentiate this genus remarkably from *Trimerella*. The platform of the pedicle-valve, which widens out from behind, has its front formed by two edges meeting at a very obtuse angle. The platform of the brachial valve is widest behind, and conspicuously trilobed, the latter character deeply incurving its sides anteriorly: its surface is divided, answering to the attachment of three sets or pairs of muscles—a lateral pair, with a member belonging to each of the lateral lobes, a median pair belonging to the space between the lateral lobes, and an anterior pair belonging to the anterior lobe.

The cardinal facet reminds one of the perpendicular wall behind the deep excavation that characterizes the hinge in certain varieties of *Trimerella Lindstrœmi* (Pl. XIV. fig. 5)—a peculiarity strongly favouring the idea that in such varieties the cardinal facet was situated similarly to what it is in the present genus, particularly as traces of the lozenge have occurred to us on the "wall-like space" belonging to the hinge of its typical species. The dentary system of *Monomerella* does not form a prominent feature: we only find evidence

* Mr. Billings, in a letter bearing the date 5th May, 1871, notified to me the discovery of a species (which he forwarded at the same time for examination, see Pl. XVII. fig. 5, the type of *Monomerella*) that appeared to him to "look like a cross between *Obolus* and a *Trimerella*," and added "What shall I call it?" I at once perceived that the species was referable to the same genus as another fossil (herein named *M. Walmstedti*), occurring in Sweden; a figure of the pedicle-valve of which had likewise been communicated to me by Dr. Lindström, on the 18th of December, 1869, with the intimation that it belonged to another genus, more akin to *Trimerella* and *Obolus* than the others (alluding to some other genera spoken of in the letter). Inadvertently overlooking for the moment the fact last noticed (for which I feel some apology is due to both Dr. Lindström and the public), and as both the Swedish and the American fossils required a new generic name, I left it to Mr. Billings to impose one; which he did in the 'Canadian Naturalist,' published December 1871. It has been considered necessary to mention these circumstances, that Dr. Lindström's discovery and opinion might be adequately recognized.

The figure above alluded to represented the valve we have figured in Pl. XVII. fig. 2. Dr. Lindström had also sent me a figure of the brachial valve (the one represented in Pl. XVIII. fig. 3), in a letter dated so far back as the 18th January, 1860.—T. D.

of it, apparently sockets, in the brachial valve of *M. Walmstedti*. The cardinal process, slightly developed, is only known to us in this species. We entertain considerable doubt as to the transverse lines occurring apparently on the hinge of *M. prisca* being the representatives of this part: their position *behind* the crown of the crescent strongly favours our scepticism. The genus includes the following species.

MONOMERELLA PRISCA, Billings. Pl. XVII. figs. 5–8.

Monomerella prisca, Bill. Can. Nat. vol. vi. p. 221, 29 Dec. 1871. Dav. & King, Remarks on the genera *Trimerella* &c., Report of Brighton Meeting of Brit. Assoc. 20th August 1872; Annals & Mag. Nat. Hist. Oct. 1872, and Geol. Mag. Oct. 1872.

Pedicle-valve obscurely triangular; with rounded angles; longer than wide; greatest breadth at about two thirds of its length from the beak; tapering posteriorly; very much flattened; convex only at the sides: *umbo* almost straight; about one third of the length of the valve: *area* broadly triangular: *deltidial ridges* moderately wide: *areal borders* narrow; raised; strongly marked with transverse lines: *deltidial slope* and *cardinal facet* well developed: *hinge*, in its central portion, much depressed: *umbonal chambers* wide-mouthed: *cardinal buttress* strong; prolonged to some distance along the bottom of the valve: *platform* moderately large; obtusely angular in front; with one of its sets of scars striated longitudinally, and strongly sulcated obliquely. *Brachial valve* almost circular; nearly straight in front; evenly convex; and deeper than the opposite one: *hinge* slightly raised or convex in its middle portion; transversely striated on what appears to be its outer or exposed portion: *crescent* in parts strongly marked: *platform* large; V-shaped; round and projecting at its antemedian point; very slightly elevated above the surface of the valve; its scars tolerably well shown.

This species is strongly marked by characteristic features, especially its wide deltidium. Its various muscular scars are generally well displayed. In the brachial valve three pairs (anterior, median, and lateral) are well seen on the platform: the anterior pair is depressed below the median pair. The subcardinal scar, *w*, is rather conspicuous in the umbonal cavity. The hinge appears to be unusually slight in depth, showing nothing more than the crown of the crescent, which forms a deepish furrow. On the outside of the hinge there is a strongly striated surface; the striæ parallel and running transversely: probably this feature represents the epidermal lines on the area of the corresponding valve of *Lingula**. The anterior portion of the crescent, apparently its ends, widens out a little, and presents a compound appearance. A pair of umbo-lateral scars, *x*, lies within the crescent, a member on each side, at its departure from the hinge.

The pedicle-valve also shows its scars for the most part rather obviously: two pairs, one behind the other, occur on the platform;

* Our figure does not represent the striæ so fully as could be wished; they are in reality more numerous, forming a deeper band, and run out straighter.

the hindermost or posterior lying close against the cardinal buttress; the anterior a strongly striated pair. There are also faint indications of a third pair situated at the ante-median point of the platform. A pair of small umbo-lateral scars, x, occurs on the outer side, a member in each, of the umbonal cavities, corresponding to a pair similarly situated in *Trimerella*. The deeply excavated hinge gives a prominent appearance to the cardinal facet: faint but determinable traces of the bordering lines of the lozenge occur on the last part.

The largest example that has come under our notice measures 2 inches in length by 1 inch and 10 lines in breadth.

Internal casts of this species, discovered by Mr. T. C. Weston, of the Geological Survey of Canada, do not appear to be rare in the Guelph Limestone (Upper Silurian) at Hespelar, Ontario, in Canada. Specimens showing the exterior of the shell have not yet been discovered; but it was in all probability smooth, or nearly so, as appears to be the case with all the species of Trimerellids hitherto discovered.

MONOMERELLA WALMSTEDTI, Dav. & King. Pl. XVII. figs. 1–4, and Pl. XIX. fig. 3, 3[a]?

Monomerella Walmstedti, Dav. & King, Remarks on the Genera *Trimerella, Dinobolus*, and *Monomerella*, Brighton Meeting of Brit. Assoc., 20th August 1872; Annals & Mag. Nat. Hist. 4th ser. Oct. 1872; and Geol. Mag. vol. ix. Oct. 1872.

Shell somewhat triangular; with rounded corners; very thick; broadest anteriorly; tapering posteriorly; front flatly rounded. *Valves* almost equally deep; most convex in the umbonal region: *surface* smooth or marked by fine concentric lines of growth. *Pedicle-valve* flattened anteriorly: *beak* large; massive; slightly incurved: *area* wide; equilatero-triangular: *deltidium* broad; flat; strongly laminated: *deltidial slope* narrow, but well defined: *deltidial ridges* wide; flattened: *hinge* deeply depressed or excavated in its middle; projecting to a point in its centre; and backed by a nearly perpendicular wall: *cardinal facet* situated on the back-wall of the hinge: *umbonal chambers* deep; and wide-mouthed: *cardinal buttress* stout; extending to some little distance along the bottom of the valve: *platform* obtusely angular in front; more or less excavated laterally by three pairs of scars. *Brachial valve* evenly convex in its posterior half: *umbo* much incurved: *hinge* transversely ridged, and raised in the middle portion; somewhat excavated at the sides: *platform* with a V-shaped anterior outline; sharp, and raised at the edges; excavated on its surface by three sets of scars.

The proportions of this species are variable: one example, apparently of ordinary size, measured 1 inch 8 lines in length by 1 inch 5 lines in breadth and 10 lines in depth.

Monomerella Walmstedti, although agreeing very closely with the last species, is characterized by some well-marked differences. The umbo of the pedicle-valve is more elevated; while that of the opposite valve is more rounded or incurved. The hinge of the brachial valve is thicker; has its middle portion more elevated, becoming, it would appear, a rounded cardinal prominence; and it is excavated on each side, or where the dentary sockets occur in *Trimerella*. Instead of the outside of the hinge being transversely striated, it shows the centre of the umbo excavated.

The hinge-characters of the pedicle-valve resemble those of *M. prisca*. The cardinal facet is similarly situated, equally large, and shows traces of the lozenge, as well as the crown of the crescent. The platform (except in being more elevated) and the umbonal chambers are also in close agreement with those in the latter species. The crescent is not conspicuously marked in either valve.

Very perfect specimens, in separate valves, of this remarkable species were discovered, as far back as 1867, by Dr. Lindström, at Klinteberg, Central Gotland, in a rock considered to belong to the Aymestry formation. These specimens are preserved in the Museum of Wisby; and other examples may be seen in that of Stockholm. Some internal casts of the same species were found by Herr Fegrœus in the same formation in the island of Fårö, north of the mainland of Gotland. We are also under obligations to Prof. F. Schmidt, of St. Petersburg, for kindly enabling us to add copies of sketches of casts, probably representing the species under description, which were found by Count Keyserling at Kerkaw, in Livonia, Russia, in rocks considered to be the equivalent of the Wenlock Group in England: the original sketches were found among the papers left by the late Dr. Pander.

MONOMERELLA LINDSTRŒMI, Dav. & King. Pl. XVII. figs. 9, 9 *a*.

Pedicle-valve transversely elliptical: *umbo* moderately produced: *umbonal cavities* shallow, and wide-mouthed: *cardinal buttress* rather stout; attenuated; considerably elongated in advance of the hinge: *platform* long, and wide; the elongated portion of the buttress passing nearly to its front edge; striated longitudinally; somewhat rugose transversely; its front edge obtusely angulated. *Brachial valve* transversely elliptical in outline; flatly rounded in the middle: *platform* with anterior lobe a little more elevated than the lateral lobes.

We are only acquainted with this shell from a single cast showing both valves in conjunction, and measuring 11 lines in length by 17 in breadth and 5 in depth. We therefore can only describe it imperfectly: but the character and shape of the cast leave no doubt of its belonging to a well-marked species—and different from either of the preceding in being much wider than long, and more compressed.

Monomerella Lindstrœmi was procured by its discoverer (after whom it has been named) from a calcareous bed of the age of the Wenlock formation in the neighbourhood of Wisby, in Gotland.

MONOMERELLA ORBICULARIS, Billings. Pl. XVII. fig. 10.

Monomerella orbicularis, Bill. The Canadian Naturalist, vol. vi. p. 221, 29th Dec. 1871; Dav. & King, Report of Brit. Assoc. Meeting, Brighton, 20th August 1872.

"Broadly ovate, nearly circular, lenticular, both valves moderately convex. The casts seem to show that a thin plate extends forwards a short distance from the cardinal edge, supported by the septum. The length and width appear to be about twelve or fifteen lines" (*Billings*).

Only two internal casts of this species appear to have been found. The platforms are of the usual form: that in the brachial valve is excavated; and at its posterior end is situated the subcardinal scar, *w*, which is well pronounced. The crescent in the same valve has its crown rather deeply impressed on the hinge; and its sides are expanded, though not shown in the drawing (fig. 10).

We are indebted to the kindness of Mr. Billings for the opportunity of examining the original and typical specimens. It occurs in the same formation and locality with *M. prisca.*

X. Dinobolus and its Species.

Dinobolus *, Hall, 1871.

Obolus, Davidson, 1853; Lindström, 1867; Hall †, 1868.
Dinobolus, Hall, "March 1871." ‡
Rhynobolus (in part), Hall, 1871.
Ungulites, Quenstedt, 1871.
Obolellina, Billings, Dec. 29th, 1871 §, &c.

Shell circular, or generally wider than long. *Valves* moderately thick. *Pedicle-valve* with a slightly prominent evenly formed umbo: *area* wider than long: *platform* more or less sinuated; widely V-shaped; and slightly raised in front: *crescent* prominently marked in its crown and sides: *hinge* moderately thick; with a rounded edge, on which and in front of the cardinal facet is a pair

* The synonymy of the present genus, and the quotations added, have influenced us in the adoption of the name *Dinobolus.*

† "Some years since, having these fossils under consideration, I proposed a new generic name for them; but sending drawings to Mr. Davidson, he gave me the opinion of himself and Mr. Woodward that they belonged to the genus *Obolus*. There are certain points of difference, however, which I have been inclined to believe are of generic importance; and I am not entirely satisfied in referring them to that genus, as illustrated, though closely allied to it" (Twentieth Report of the State Cabinet, p. 368). (It is only fair I should admit that Professor Hall is correct in his more recent statement [see 'American Journal of Science and Arts' for August 1872, p. 20] that, in a letter of date 31st October, 1862, he proposed to me the generic name *Conradia* for this fossil.—T. D.)

‡ 'Notes on some new and imperfectly known forms among the Brachiopoda. "This pamphlet was published in March 1871, and a number between twenty-five and thirty copies delivered to me at the time. The type was left standing in order to print a large number to be accompanied by a plate of figures then in progress, with descriptions of the same. Of these copies the greater part were distributed in the United States soon after publication. Copies were sent to the Geological Society of London, to Mr. Davidson, M. Barrande, Dr. Lindstrom, Dr. Geinitz, and others. The pamphlet is noticed in the 'Jahrbuch' for 1871, p. 989. On the 7th of April, 1871, the printing establishment of Weed, Parsons, and Co. was destroyed by fire, together with the Twenty-third Report of the State Museum (printed to nearly 200 pages), the lithograph-stones, and every thing else pertaining to the work."—*Op. cit.*

§ Canadian Naturalist, vol. vi. p. 222, 1871; and p. 330, April 1872; also American Journal of Science, April and May 1872.

of subcardinal scars, w. *Brachial valve* rather tumid at the umbo: *platform* somewhat strongly trilobed; its outer margins a little raised; its antemedian portion rounded, projecting, and terminating in a slightly developed *median plate*: *crescent* a strongly marked linear scar on the hinge; arching forward in front of the cardinal facet; inner border of its sides with strongly marked indentations—one near the hinge, another further forward; outer border a fine line: a rather strongly marked *subcardinal* scar, *w*, in the umbonal cavity: a large rhomboidal *postmedian scar, p,* in front of the latter.

Type species, *Obolus Conradi*, Hall.

The somewhat general description given in the above diagnosis points out some of the chief differences between the present genus and the preceding ones. In the latter the area is longer than wide; consequently the umbo is much more projecting. In *Dinobolus* development of the valves is in general bilateral rather than longitudinal; and the areal characters are, as a consequence, not well exhibited: nevertheless the hinge shows the crown of the crescent rather conspicuously. This last part in both valves differs from its equivalent in *Trimerella* and *Monomerella*: the *outer* border of its sides is a simple line which runs off from the hinge along and within the postlateral margins of the valves, as in these genera; but the inner border, instead of also being a simple line, is irregular in width, and composite in structure, being broad and strongly indented—at least in two separate places: the ends of the crescent are not well defined, arising from interblending growths. The platforms nearly resemble those of *Monomerella*; but the one belonging to the pedicle-valve has its front sinuated (sometimes five-lobed),—not straight, as in the genus referred to. The umbonal cavity of the pedicle-valve shows a tendency to become double-chambered, the division being caused by a slightly developed cardinal buttress (Pl. XVIII. fig. 7, 7*a*). This region shows a very small pair of umbo-lateral scars (Pl. XII. fig. 5x) below the subcardinal scars, w, already noticed. The deltidium and other parts belonging to the area are imperfectly displayed in all the specimens we have examined; though in one species (*D. canadense*, not examined by us), according to Mr. Billings's figure of it, copied in Pl. XIX. fig. 7, the deltidium appears to be well developed. The dentary system is probably rudimentary. The platforms occasionally show a tendency to become vaulted.

The genus embraces *D. Conradi*, *D. Davidsoni*, *D. canadensis*, *D. transversus*, *D. magnificus*, and some others which may be mere varieties.

Dinobolus Conradi, Hall. Pl. XVIII. figs. 1–5.

Obolus Conradi, Hall, Twentieth Annual Report of the Regents of the University of the State of New York, p. 368, 1868; and revised ed., p. 375, 1870.

Trimerella Conradi, Dall, American Journ. of Conch. vol. vii. part 2, p. 83, 1871.

Dinobolus Conradi, Hall, Preliminary Notice, Twenty-third Report on the State Cabinet of New York, p. 3, March 1872: Dav. & King, Report of the Brighton Meeting of Brit. Assoc. 20th August, 1872.

General form orbicular; depressed; broadly rounded anteriorly; tapering rapidly in the umbonal region. *Pedicle-valve* flatly convex: *area* small: *deltidium* concave: *platform* undulated on its surface; sinuated, and elevated in front: *cardinal buttress* slightly but obviously developed: *crescent* conspicuously displayed. *Brachial valve* rather tumid at the umbo: *platform* sinuated, and raised at the sides; produced, and depressed in its antemedian portion: *median plate* short: *crescent* conspicuously displayed in part.

Of this important species some specimens have attained to 1½ inch in length by 1 inch 11 lines in width; but the larger number of specimens that have fallen under our notice presented almost equal length and breadth. In a specimen measuring 11 lines in length, the platform of the pedicle-valve is to some extent doubly vaulted, the vaults attaining two lines in depth (Pl. XVIII. fig. 2, *n*); but in none of the other examples we have seen did they exceed a line or a line and a half.

Dinobolus Conradi occurs in a dolomitic limestone belonging to the upper part of the Niagara group (=Upper Silurian), at Leclaire, Iowa; also at Racine, Wisconsin, United States of America.

Dinobolus Davidsoni, Salter. Pl. XVIII. figs. 6–11.

Obolus Davidsoni, Salter, MS.; Woodward, Manual of the Mollusca, p. 240, 1856; Davidson, Mon. Brit. Foss. Brach. vol. i. Introduction, p. 58, pl. 4. figs. 30–39, 1866; Salter, Murchison's Siluria, 2nd ed. p. 543, 1859; Lindström, Sil. Brach. of Gotland, Öfversigt. af. K. Vet. Akad. Förhandl. p. 375, 1860.

Dinobolus Davidsoni, Dav. & King, Report of Brighton Meeting of Brit. Assoc. 20th August, 1872.

General form slightly wider than long; subequivalve; compressed: *surface* marked with concentric lines of growth. *Pedicle-valve* moderately convex: *umbo* very short: *area* and its component characters small: *crescent* well defined in its crown, the central part of which curves forward; its sides and ends complex: *hinge* a T-shaped ledge, the top branches forming its sides, and the perpendicular part forming the cardinal buttress: *platform* with sides straight, and diverging from its posterior end; a broad sinuated front; and a strongly undulating surface. *Brachial valve* moderately convex: *crescent* well defined at its crown, the centre of which is pointed, the point directed backward: *platform* trilobed in outline; its central lobe or terminal extremity projecting, and depressed below the lateral lobes: close behind is situated the *postmedian scar, p,* which is rhomboidal in outline: further behind is the *subcardinal scar, w.*

This species occurs occasionally so well preserved that it has afforded the principal characters diagnosed for the genus, especially the scars on and near the hinge, also those belonging to the platform. The crescent, as will have been observed, is instructively displayed in some of the English specimens: it is also well shown in a cast we have been favoured with by Dr. Lindström, and which remarkably confirms the accuracy of the drawings (made previously to our seeing the cast) of this part, as represented by fig. 6 of Pl. XII. The platforms have the usual scars—three pairs on each—very well displayed. The postmedian scar, *p*, in the brachial valve, has all the appearance of being a visceral impression.

Dinobolus Davidsoni, the first discovered form among the Trimerellids, was erroneously referred, in 1853, by one of the writers to *Obolus*; with which genus it seemed at the time to bear the closest affinity, especially as nothing was then known of the shells composing the family under description.

From near Dudley, chiefly as internal casts. Mr. C. Ketley informs us that all the specimens have been found in certain beds of the lower or "thick" band of limestone of the Wren's Nest. These beds are supposed to have their equivalents exposed at the Rushall Canal, near Walsall; where also similar specimens were obtained during the cutting of the canal many years since. At Dudley tunnel have been found a few specimens, doubtfully considered to be *D. Davidsoni*, in the lower strata. Their absence in the higher strata, with the reverse order in another species, *D. transversus*, may be perhaps considered worth notice. In the island of Gotland it is very abundant: and in rocks of a similar age, near Wisby, slabs may be seen covered with scores of indifferently perserved internal casts and impressions of the shell. It is stated to occur at Ferriters Cove, Kerry, Ireland.

DINOBOLUS CANADENSIS, Billings, sp. Pl. XIX. fig. 7.

Obolus canadensis, Bill. Report of the Geol. Survey of Canada for the year 1857, figs. 20–23 (not fig. 19).

Obolellina canadensis, Bill. Can. Naturalist, vol. vi. p. 222, 29th Dec. 1871; and April 1872, figs. 1–5.

Dinobolus canadensis, Dav. & King, Report of Brighton Meeting of Brit. Assoc. 20th August, 1852; Annals, and Geol. Mag. for same year.

General form longer than wide. *Pedicle-valve* slightly and gently convex: *beak* somewhat prominent; very slightly incurved: *area* rather wide: *deltidium* deeply excavated*. *Brachial valve* convex, especially in the umbonal region†.

In 1857 Mr. Billings included in the present species both elongated and wide forms: of late, however, he has formed of the latter a distinct species, the next but two under description. Not having had the advantage of examining specimens of *D. canadensis*, we are obliged to depend entirely upon the description and figures of it published by Mr. Billings. As now restricted the species is exceptional in form.

Width usually about 2 inches; but some fragments that have been found undoubtedly belonged to individuals which were 3 inches

* Billings states that the exterior of this valve is not clearly shown in any of his specimens.

† Billings has figured the interior of the brachial valve, which partly shows the characteristic platform and scars.

wide. As the shells that are wider than long have been removed to another species, possibly the fragments noticed belong to it.

This species is stated to occur in the Black-river limestone at Fourth Chutes of Bonne Chère, Pauquette's rapids; and in the townships of Stafford and Westmeath, county of Renfrew, Canada. Its geological position seems to be about the horizon of the Upper Llandeilo—that is, below the Caradoc formation.

Dinobolus transversus, Salter. Pl. XVIII. fig. 12.

Obolus Davidsoni, var. *transversus*, Dav., vol. i., General Introduction, p. 136, fig. 53, 1853; Sil. Brach. p. 59, pl. v. figs. 1–6, 1866.

Dinobolus Davidsoni, Dav. & King, Report of Brighton Meeting of Brit. Assoc. 20th August, 1872; Annals, and Geol. Mag. of the same year.

General form much wider than long; compressed. *Valves* externally marked by fine striæ parallel to their margins. *Brachial valve* thick, and elevated in the umbo-cardinal region; thence thin and flattening out to the margin: *crescent* strongly impressed at its sides; obscurely impressed at its ends: *platform* depressed; very slightly raised at its margins; well defined posteriorly: *postmedian scar*, *p*, subrhomboidal; sharply differentiated from the platform scars: *subcardinal scars*, *w*, in close contact with the latter.

Very little is known with reference to this species, only a cast of the interior of the brachial valve having been found: it exceeds 2½ inches in breadth by nearly 2 inches in length, indicating a large size for the species, apparently larger than any of the others. It differs from *D. Davidsoni* in being wider and more depressed—also in its internal characters, as denoted in the diagnosis. The sides (apparently their inner border) of the crescent, which are considerably apart from the lateral margins of the valves, have the peculiarities characteristic of other species, but still more exaggerated.

Dinobolus transversus occurs in the calcareous shales at the top of the Wenlock limestone in the neighbourhood of Dudley; and at the Rushall canal, near Walsall, Park Hall.

Dinobolus Woodwardi, Salter.

Obolus Davidsoni, var. *Woodwardi*, Salter, MS.; Dav. Sil. Brach. p. 60, pl. v. figs. 7, 8, 1866.

Dinobolus Davidsoni, Dav. & King, Report of Brighton Meeting of Brit. Assoc. 20th August, 1872; also in Geol. Mag., and the Ann. & Mag. Nat. Hist. of the same year.

Certain undetermined differences observable in an imperfect cast, which is transversely oval and marked with concentric lines of growth, led Mr. Salter to suggest that it might belong to a species distinct from *D. transversus*: possibly, however, when better known, it may prove to be no more than a variety. It occurs in the Wenlock limestone of Dormington, Woolhope, and in the associated shales near Dudley.

Dinobolus magnificus, Billings. Pl. XIX. fig. 8.

Obolus canadensis (in part), Billlings, Geol. Survey of Canada for 1857, fig. 19 (published in 1858).
Obolellina magnifica, Bill. Can. Nat. for April 1872, p. 17, fig. 7.
Dinobolus magnificus, Dav. & King, Report of Brighton Meeting of Brit. Assoc., 20th August, 1872.

We have not seen specimens of this species. Mr. Billings has given the figure of one valve only, showing nothing more than its exterior. He states, however, that the "dorsal valve" is "transversely broad ovate; width about one fourth greater than the length, uniformly and moderately convex; apical angle about 130 degrees; cardinal edges nearly straight or gently convex for about one third the length of the shell; sides and front rounded, the latter more broadly than the former. The area seems to be obsolete altogether or merely linear; the ventral valve is depressed convex, with a large beak slightly incurved; area with a wide triangular peduncular groove, no lateral furrows; surface of both valves concentrically marked with imbricating lines of growth. In a specimen which appears to have been about 20 lines in length the height of the area is nearly 3 lines."

Dinobolus magnificus, excepting being wider and less long, offers a close resemblance to *D. transversus*. It occurs in the Black-river formation (Lower Silurian) along with *D. canadensis*.

Dinobolus Schmidti, Dav. & King. Pl. XIX. figs. 5 & 6.

This species, only known from two specimens, is almost circular; obtusely tapering at the beak: valves moderately convex: surface smooth. It closely resembles *D. Conradi*; but seemingly differs therefrom in being of less width. The pedicle-valve, the only one we are acquainted with, possesses impressions characteristic of the genus.

Professor F. Schmidt, after whom we have named this species, discovered in 1873 the specimens above noticed at Kirna, Esthonia, Russia. They occurred in the Lyckholmer Schicht (2^a of Schmidt's Classification), which he considers to be nearly equivalent to the Caradoc of Great Britain, and the Trenton limestone of North America.

Appendix.

a. Lingulops Whitfieldi, Hall. Pl. XIX. figs. 9, 9*a*.

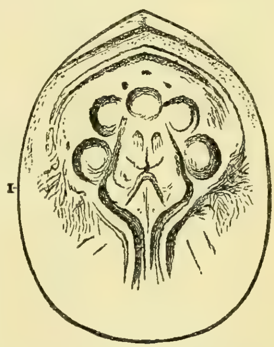
In his recently published "Notes on some new or imperfectly known forms among the Brachiopoda," &c., Professor James Hall states that "in a late examination of some Lower-Silurian species, usually designated as Lingula, one of them was found to possess a muscular impression differing entirely from any described Linguloid species. The ventral (?) valve presents a small area with a narrow pedicel-groove; a large lobed muscular impression, which in the cast extends as a narrow groove towards the base of the shell. The character of the area and foramen differ from the typical forms of *Lingulella*; though in that genus the form and character of the muscular impression has not been determined, as far as I am aware. For this shell I propose the name LINGULOPS" *.

In plate 13, fig. 2, of the "Generic illustrations" attached to the "Notes" the author has given a view "showing the arrangement of some of the muscular and parietal scars, and also the ramifications of the vascular lines, which, although originating at nearly the same points as in recent *Lingulidœ*, do not extend so far back towards the beak."

Professor Hall has liberally supplied us with gutta-percha squeezes of this interesting form; and as his description and figure do not afford sufficient information respecting its characters, we have been induced to publish the following observations.

The fossil, which is less than two lines in length by one in width, is an impression or cast, of the interior and outline of a single valve: it shows, however, some characters in a remarkably fine state when examined by a good pocket-magnifier. Hall's figure, taken from the natural impression or the fossil itself, exhibits these characters with a faulty appearance; our gutta-percha squezees show them in relief, and depressed, exactly as they would present themselves in the inner side of the valve. Even our figure in Pl. XIX. is not so satisfactory as could be desired, as certain points have only occurred to us since the plate was struck off; for which reason we have given an additional figure in the annexed woodcut (Fig. 3).

Fig. 3.—Lingulops Whitfieldi, *interior magnified.*



The most striking features are:—first, the posterior semicircular broad zone, with an inner sinused border; second, the arched fillet situated below the hinge, and on the zone; third, the central space marked with scars; and, fourth, the linear impressions occurring in the anterior half of the fossil. The fourth feature, no doubt, represents the median plate, and the pair of primary vessels belonging to the brachiocœle; the third obviously forms the apophysary system; the second is evidently the equivalent of the crescent characterizing the Trimerellids; but the first we cannot properly identify with any part belonging to the Palliobranchs.

Hall is evidently disposed to believe that the fossil represents the pedicle-valve ("ventral"): we, however, entertain a strong idea that it belongs to the opposite or brachial valve, notwithstanding the statement that it "presents a small area with a narrow pedicel-

* Preliminary Notice; twenty-third Report on the State Cabinet of Natural History for the Palæontology of New York, March 1871, p. 2, and reprint of the same, March 1872, pl. 13. fig. 2.

groove." The gutta-percha squeezes in our possession show very faintly what has been taken for the "groove" (much less so than is represented by Hall, and which even appears too much like a notch in our original figure): there is something like a depression; but, considering two peculiarities to be noticed presently, we believe it to be nothing more than such as occasionally occurs on the hinge of the brachial valve of *Lingula anatina*.

The peculiarities alluded to belong to the crescent and the median plate. In the pedicle-valve of *Trimerella*, as will be recollected, the crown of the crescent has a *forward* curve in the middle, due, we believe, as in *Lingula*, to this portion having been forced out by the pedicle; while the crescent in the brachial valve has a pointed crown, with the point directed *backwards*: now it is the latter peculiarity that plainly presents itself in *Lingulops*. The other peculiarity equally sustains our view; for in the Trimerellids, as also in *Lingula*, the pedicle-valve has a short or rudimentary median plate, whereas in their brachial valve this part is well developed and elongated as it evidently is in *Lingulops*.

Believing that the fossil is a brachial valve, we feel tempted to offer a suggestion in connexion with the semicircular zone. In *Lingula anatina* a broadish flattened organ, called the setal band, is attached, chiefly at both its sides, by a muscular cord to the valves (differing somewhat in each) a little within their margins: in the brachial valve the setal band is *uninterruptedly* (not being interfered with by the pedicle, as in the pedicle-valve) carried round the hinge behind the umbonal muscle. Our suggestion is that, while the semicircular zone itself formed the seat of the mass of the setal band *, the arched fillet was produced by the attachment of the outer muscular cord and associated vessels; also, that the inner scalloped border is mainly due to the attachment of the posterior and post-lateral walls of the splanchnocœle †.

We have yet to explain the peculiar sinused character which gives the semicircular zone such a striking resemblance to a moorish arch. The inner side of the zone is cut out by five sinuses—one in the middle, and two on each side—only opposite ones being equal. The sinuses are each the outer side of a circular scar, its inner and imperfect side lying near or against the central apophysis or platform: it is only lately that we have been able to make out the form of the sinuses. Let us next try to explain their origin. The middle sinus, we have little doubt, has been produced by the umbonal muscle pressing against the postparietal or posterior wall of the splanchnocœle. It might be suggested that the lateral sinuses have been formed in the same way by other muscles; but as *Lingula* is not characterized by any similarly situated (at least the brachial

* The entireness of the zone at its apex forms another evidence in favour of the valve being the brachial one.

† See "On some characters of *Lingula anatina*," Annals and Mag. of Nat. Hist., 4th series, vol. i. July 1873. The setal band and its modifications in the brachial valve are shown in the two woodcuts already given in a preceding page of the present memoir (p. 132).

valve*), we prefer the idea that they represent certain viscera; and they may be recesses produced by the pressure of ovarian lobes against the inner side of the postlateral walls of the splanchnocœle.

The vascular impressions in the anterior half of the fossil are, in their arrangement, unlike any thing we have seen in the Trimerellids, or in *Lingula*; for they run at first in front of the platform, and next along each side of and close to the median plate. In the Trimerellids and in *Lingula* they strike directly out from the sides of the platform, and take a more or less submarginal direction. At their origin, and in the medio-lateral region of *Lingulops*, the vascular impressions are much obscured by apparently others of the kind, seemingly numerous and passing off to the margins. The ends of the semicircular zone merge into the same regions, and are equally obscured. Neither our figure, nor Hall's gives any thing more than a faint approximation to the true characters and grouping of these impressions.

We think it probable that lateral muscles similar to those characteristic of *Lingula* were implanted in the same regions. Much difficulty attaches to gaining a satisfactory clue to the similarly situated scars in the Trimerellids.

Considerable resemblance prevails between the platform of *Trimerella* and the apophysis of *Lingulops* in their outline; and the resemblance appears to be equally close in their scars: there is apparently a lateral, a median, and an anterior pair.

With reference to the position which *Lingulops* occupies, the characters, as now made known, evidently relate it both to the Trimerellids and Lingulids; but, while thus affined, we feel undecided as to which family it should be placed in. So long as the other valve remains unknown the safest plan will be to waive this subject, and simply join with Hall in regarding the fossil as a "Linguloid form."

Lingulops Whitfieldi is stated to be a "Lower Silurian species;" but its locality has not been mentioned, further than that it is in the United States.

b. Chelodes† Bergmani, Davidson & King. Pl. XVIII. fig. 14, 14 *a b c*.

If doubts prevail in our minds as to the family to which *Lingulops* belongs, we have doubts of a far wider bearing with reference to the fossil now to be described. Out of respect to our friend Dr. Lindström, who, believing it to be related to them, wished it to be described along with the Trimerellids he so kindly placed in our hands for description, we append an account of this fossil. As it possesses some characters seemingly resembling those peculiar to the pedicle-valve of a Palliobranch, the following description has accordingly been drawn up.

* In the *pedicle-valve* of *Lingula anatina* the transmedial muscles have their attachment similarly situated. Were the fossil the same valve we should have had little hesitation in referring the lateral sinuses to these muscles, notwithstanding their being single on one side and double on the other in *Lingula*.

† Claw-shaped.

Pedicle-valve thick, claw-shaped, slightly geniculated across the middle: the geniculation forms the base of the beak, which is a little less than half the length of the valve, and almost an equilateral triangle in outline. One face of the beak is flatly convex, and slightly lineated transversely: the opposite face or *area* is concave, and crossed by rather strong curving lines. The other half of the fossil has parallel lateral margins, and a squarish end with a slight sinus in its middle. One face, the external one, is flatly convex, and marked with regular and rather distinct lines of growth running parallel to the end. The opposite face or cavity has an outline formed by the sides and end of the convex face, also by the curved basal side (or hinge) of the area: its surface has two slightly raised oval tracts situated one on each side, separated for the most part by a medio-longitudinal hour-glass-shaped furrow, and united by an arcuated band lying near and parallel to the hinge: the oval tracts are marked by curving subdivided ribs; and the uniting band is somewhat tuberculated. The hinge is thin, undercut, and marked in the middle by a pointed tooth-like process; which has been inadvertently omitted in fig. 14.

There is something in favour of this singular fossil being related to *Trimerella*. Its general form does not depart much from that of *T. Billingsii* and *T. galtensis*. The same may be said of the "beak." The "area," it is true, shows no appearance of a deltidium; but it may be surmised that this part has been developed at the expense and obliteration of the areal borders,—a tendency of the kind being displayed in several Trimerellas. The "hinge" is thin, and projecting or ledge-shaped—not an improbable modification; and it has actually a central V-shaped projection (the "pointed tooth-like process"), reminding one of the curving middle that characterises the crown of the crescent in the pedicle-valve. Even the characters belonging to the cavity may be considered as placing this fossil among the Palliobranchs, inasmuch as the lateral tracts have a striking resemblance to the convoluted impressions representing the labial appendages, such as are seen in *Davidsonia*, certain Spirifers, and Productuses. The curved connecting band might be supposed to represent the highly muscular portion forming the base of the arms. Still, notwithstanding these remarkable points of resemblance, it is our opinion that *Chelodes Bergmani* is not a Palliobranch: on the contrary, we are strongly inclined to the belief that it belongs to a section of the Cœlenterates, represented by *Calceola* and *Goniophyllum*. In contending for this position we are unfortunately at issue with Dr. Lindström, than whom no one has paid so much attention to the section in question: nevertheless, feeling that our view requires more than an incidental notice, we hope to be able to publish a paper on another occasion giving our reasons for maintaining it.

Chelodes Bergmani was discovered by Herr Bergman, to whom we dedicate it, at Klinteberg (a hill about 120 Swedish feet above the sea), Isle of Gotland, in the central Gotland formation,—an equivalent in age to the Aymestry limestone of England.

DESCRIPTION OF PLATES.

Plate XII.

Diagram figures of the cardinal and internal parts of *Trimerella* (figs. 1, 2, 7, 8), *Monomerella* (figs. 3, 4), and *Dinobolus* (figs. 5, 6).

Pedicle- or Ventral Valve.	*Brachial or Dorsal Valve.*
a. Deltidium.	*a.*
b. Deltidial slope.	*b.*
c. Deltidial ridges.	*c.*
d. Areal borders.	*d.*
e. Cardinal callosities.	*e.* Cardinal sockets.
f. Cardinal facet.	*f.*
g. Lozenge.	*g.*
h. Cardinal buttress.	*h.*
i. Umbonal chambers.	*i.*
j. Platform.	*j.* Platform.
k. Platform vaults.	*k.* Platform vaults.
l. Median plate.	*l.* Median plate.
m. Median scars.	*m.* Median scars.
n. Anterior scars.	*n.* Anterior scars.
o. Lateral scars.	*o.* Lateral scars.
p. Postmedian scars.	*p.* Postmedian scars.
q. Crown } Crescent.	*q.* Crown } Crescent.
r. Side } Crescent.	*r.* Side } Crescent.
s. End } Crescent.	*s.* End } Crescent.
t. Transverse scars.	*t.* Transverse scars.
u. Archlet.	*u.* Archlet.
	v. Cardinal scars.
w. Subcardinal scars.	*w.* Subcardinal scars.
x. Umbo-lateral scars.	*x.* Umbo-lateral scars.

Fig. 1. *Pedicle-valve* of the genus *Trimerella*, principally from specimens of *T. grandis.* k, *vaults* passing under the *platform*, j ; i, chambers in the umbo, one on each side of the *cardinal buttress*, h. The *umbonal chambers* and their casts are exhibited in fig. 2 *c*, and fig. 2, Pl. XIII.

2. *Brachial valve* of the same genus, principally from *T. grandis* and *T. ohioensis.* The scars, *s* (also their correspondencies, s, in the pedicle-valve), are usually difficult to define ; but the left-hand one, as shown in a woodcut in the text (p. 146), has been satisfactorily made out in one of the specimens we have examined.

3. *Pedicle-valve* of *Monomerella*, chiefly made up from *M. prisca* and *M. Walmstedti.* h, a perpendicular plate supporting the hinge (cardinal buttress) ; it is thinner than usually in *Trimerella* : x, *umbo-lateral scars* that occur one on the outer side of each *umbonal chamber*, i.

4. *Brachial valve* of the same genus. The scars, *x*, probably occur in *Trimerella*, fig. 2 ; but they have not been satisfactorily detected (apparently a pair of corresponding scars, x, occur in the *pedicle-valve* of *Trimerella*, fig. 1) : they are very obvious, however, in a cast of *Monomerella prisca.*

5. *Pedicle-valve* of *Dinobolus*, chiefly from specimens of *D. Davidsoni* and *D. Conradi.* The pair of *subcardinal scars*, w, is on the edge (rounded) of the hinge. The pair, x, are below the latter, each member in a shallow depression corresponding to an internal chamber.

6. *Brachial valve* of the same genus. *p* has much the appearance of a visceral scar. The parts, *r* and *s*, have been determined from a number of good examples of *D. Davidsoni.* Taking in the line that runs off from the hinge a little distance along and within the postlateral margins of the valve (the line was detected on the right of one of these

margins), the part *r* (*side* of the *crescent*) corresponds to the same part in *Trimerella* and *Monomerella*, except that its inner boundary is much thicker, and has a compound structure: probably the inner portion of the deep impression situated at the angle, near the hinge, is the homologue of the scar, *x*, in *Monomerella*, fig. 4. The *sides* of the crescent, as represented in fig. 5 (pedicle-valve), may not be strictly accurate.

7. Area and hinge of *pedicle-valve* of *Trimerella*.
8. Medio-longitudinal section of the *area*, *hinge*, *platform*, and *median plate* of pedicle-valve of the same genus. i, *umbonal chamber* on left side of the cardinal buttress, h; k, *platform vault* on left side of the *median plate*, l.

Plate XIII.

Fig. 1. *Trimerella wisbyensis*, n. sp. Interior of the brachial valve, from a gutta-percha squeeze taken from an internal cast. Wisby strata (= Wenlock), near Wisby, Gotland.

2. *Trimerella grandis*, Billings. 2, internal cast of pedicle-valve (minus the beak): 2 *a*, internal cast of brachial valve: 2 *b*, interior of brachial valve: 2 *c*, restoration of the pedicle valve: 3, natural cast of pedicle valve. Guelph limestone (Upper Silurian), Hespelar, Canada.

Plate XIV.

Figs. 1, 1*a*, 1*b*. *Trimerella Lindstrœmi*, Dall. Exterior of a large specimen. Central Gotland (Aymestry limestone), Klinteberg, Gotland.

2. —— ——. Interior of pedicle-valve. Wialmsudd, Gotland.
3. —— ——. Interior of brachial valve. Klinteberg, Gotland.
4. —— ——. Restored longitudinal section of both valves.
5. —— ——. Fragment of a pedicle-valve, showing the deep depression below the hinge.
6. —— ——. Transverse section across both valves.
7. —— ——. Internal cast of the brachial valve. Island of Fårö. Collection of Herr Fegrœus. The projections on each side of the posterior end are casts of umbonal *chambers*.

Plate XV.

Figs. 1, 1 *a*, *b*, *c*, *d*, *e*. *Trimerella Dalli*, n. sp. From an internal cast. Guelph limestone, Hespelar, Ontario. 1, cast of pedicle-valve; 1*a*, of brachial valve; 1*b*, of both valves in conjunction; 1*c*, interior of pedicle-valve, from a gutta-percha squeeze; 1 *d*, N, vaults, exposed under platform; M, umbonal cavities, separated by the *cardinal* buttress, seen in fig. 1 *c*; 1*e*, interior of brachial valve,—N, one of the *platform vaults*.

2. —— ——. Interior of brachial valve, showing cardinal process. Same formation and locality.

3, 3 *a*, *b*. —— ——. Internal cast, tolerably perfect, in the Museum of the Geological Survey of Montreal: *a*, brachial valve; 3, pedicle-valve.

4, 4 *a*, *b*, *c*. *T. acuminata*, Billings. Internal cast of both valves in conjunction, from the Guelph limestone, Hespelar, Ontario: Museum of Montreal. 4 *d*, mould in gutta percha taken from the umbonal region of same cast, showing the cardinal process projecting into the interior of the shell and towards the pedicle- (upper) valve.

5. —— ——. Internal cast of pedicle-valve, with one of the projections (cast of platform-vault) broken.

6. —— ——. Internal cast of a pedicle-valve, from original example figured in 1862. Hespelar; Museum of Montreal. The three lines are furrows defining two long platform-vaults.

7, 7 *a*. —— ——. 7, internal cast; 7 *a*, gutta-percha squeeze, slightly restored at the margin. Guelph limestone (Upper Silurian), Hespelar, Canada; Museum of Montreal.

Plate XVI.

Fig. 1. *Trimerella acuminata.* Interior of brachial valve: N, cavity under platform exposed.

2. Interior of pedicle-valve: N, cavity under platform exposed; O, umbonal chamber. These moulds were taken from the internal cast figured in Pl. XV. fig. 4: the beak is added in fig. 2. Guelph limestone, Hespelar, Ontario.

3. *T. ohioensis*, Meek. Internal cast, showing the pedicle-valve.

4. —— ——. The same cast, showing the hinge-characters of both valves. Niagara Group, Upper Silurian, Otwa County, Ohio.

5. —— ——. Internal cast of brachial valve. Same locality.

6. —— ——. Gutta-percha mould taken from the hinge portion of the cast so as to show ridge-like cardinal process, &c. Specimens 3 to 5 were sent us for illustration by Mr. Meek.

7. —— ——. Gutta-percha mould of brachial valve, taken from an internal cast in the possession of Mr. Whitfield, of Albany. This mould shows the cardinal process in the form of two circular depressions in the centre of the hinge, also indications of rude articulation (elongated plates) of the valves. From the Niagara Group of Yellow Spring, Ohio.

8. *Trimerella Billingsii*, Dall. Internal cast of pedicle-valve.

9. —— ——. Gutta-percha mould taken from the same cast so as to show the interior of the valve. Guelph Limestone, New Hope, West Canada: Museum of Montreal.

Plate XVII.

Figs. 1, 1*a*, *b*. *Monomerella Walmstedti*, n. sp. A perfect testiferous specimen. "Central Gotland," Klinteberg, Gotland: Museum of Wisby College.

2. —— ——. Interior of pedicle-valve.

3. —— ——. Interior of brachial valve. Same museum and locality.

4. —— ——. Internal cast of pedicle-valve. Same formation: Island of Fårö. Coll. of Herr Fegrœus.

5, 5 *a*, *b*, *c*. —— *prisca*, Billings. Internal cast of both valves in conjunction. Fig. 5. The pair of scars (the impression on middle) belong to the brachial valve. Guelph Limestone, Hespelar, Ontario: Museum of Montreal.

6, 6 *a*. —— ——. 6, internal cast of pedicle-valve. 6 *a*, gutta-percha mould taken from the same cast, showing the interior of the valve. Same locality and museum.

7. —— ——. Interior of the pedicle-valve, taken in gutta-percha from a large internal cast. Same locality.

8. —— ——. Interior of brachial valve of same species, taken in gutta-percha from an internal cast. Same locality.

9, 9 *a*, *b*, *c*. —— *Lindstrœmi*, n. sp. 9, 9 *a*, internal cast. 9 *b*, showing both valves in conjunction. 9 *c*, interior of pedicle-valve from a gutta-percha mould. "Wisby Strata," near Wisby, Gotland.

10, 10 *a*. —— *orbicularis*, Bill. 10, external cast of brachial valve; 10 *a*, of pedicle-valve. Guelph Limestone, Elora, Ontario: Museum of Montreal.

Plate XVIII.

Fig. 1. *Dinobolus Conradi*, Hall. Interior of pedicle-valve from a gutta-percha mould.

2. —— ——. Another specimen. Same valve, showing deep vault, N, extending under the platform. From Niagara limestone, Leclaire, Iowa. Collection of Prof. Hall.

3. —— ——. Interior of brachial valve.

4. —— ——. Internal cast of pedicle-valve.

5. —— ——. Natural cast of brachial valve. Same museum and locality.

6, 6 *a*. —— *Davidsoni*, Salter. Exterior. Wenlock shale, near Dudley.

Figs. 7, 7 *a*. *Dinobolus Davidsoni*. 7, internal cast of pedicle-valve: 7 *a*, interior of same valve taken in gutta-percha from internal cast. Wenlock, Dudley. Dudley Museum.

8, 8 *a*. —— ——. 8, internal cast of brachial valve. 8 *a*, interior of same valve from a gutta-percha mould taken from same specimen: the two valves are in juxtaposition in the cast.

9. —— ——. Interior of pedicle-valve. This specimen, which shows no undercut under the platform, is taken in gutta-percha from an internal cast. Dudley. In the Museum of Practical Geology, London.

11, 11*a*. —— ——. Internal cast: from the "Central Gotland" (=Wenlock) of the neighbourhood of Wisby, Gotland.

12. —— *transversus*, Salter. Internal cast of brachial valve. Top of Wenlock, Dudley. Dudley Museum.

13. *Trimerella galtensis*, Bill., sp. Interior of pedicle-valve. Guelph limestone, Galt, West Canada. Collection of Prof. Hall.

14, 14 *a*, *b*, *c*, *d*. *Chelodes Bergmani*, n. g. et n. sp. The tooth-like process in the centre of what appears to be the hinge is not represented. "Central Gotland" (=Aymestry limestone), Klinteberg, Gotland. Collection of Herr Bergman.

PLATE XIX.

Fig. 1. *Trimerella ohioensis*, Meek. Exterior of brachial valve; showing also area and deltidium of pedicle-valve.

2. —— ——. Internal cast of pedicle-valve. Upper Silurian, Otwa, Ohio county. After drawings by Mr. Whitfield, communicated by Prof. Hall.

3, 3 *a*. ? *Monomerella Walmstedti*. 3, internal cast of pedicle-valve: the projections are casts of umbonal chambers: 3 *a*, internal cast of brachial valve. Upper Silurian, Kerkaw, Livonia, Russia. After MS. drawings by the late Prof. Pander, communicated by Prof. Schmidt.

4, 4 *a*. *Trimerella galtensis*, Bill., sp. 4, internal cast of brachial valve; 4 *a*, interior of same, enlarged. Upper Silurian, Galt, Canada. Museum of Montreal.

5, 6. *Dinobolus Schmidti*, n. sp.? Pedicle-valve: internal casts. Lower Silurian; Küna, Esthonia, Russia. From specimens forwarded by Prof. F. Schmidt; and the only two examples of the genus hitherto found in Russia.

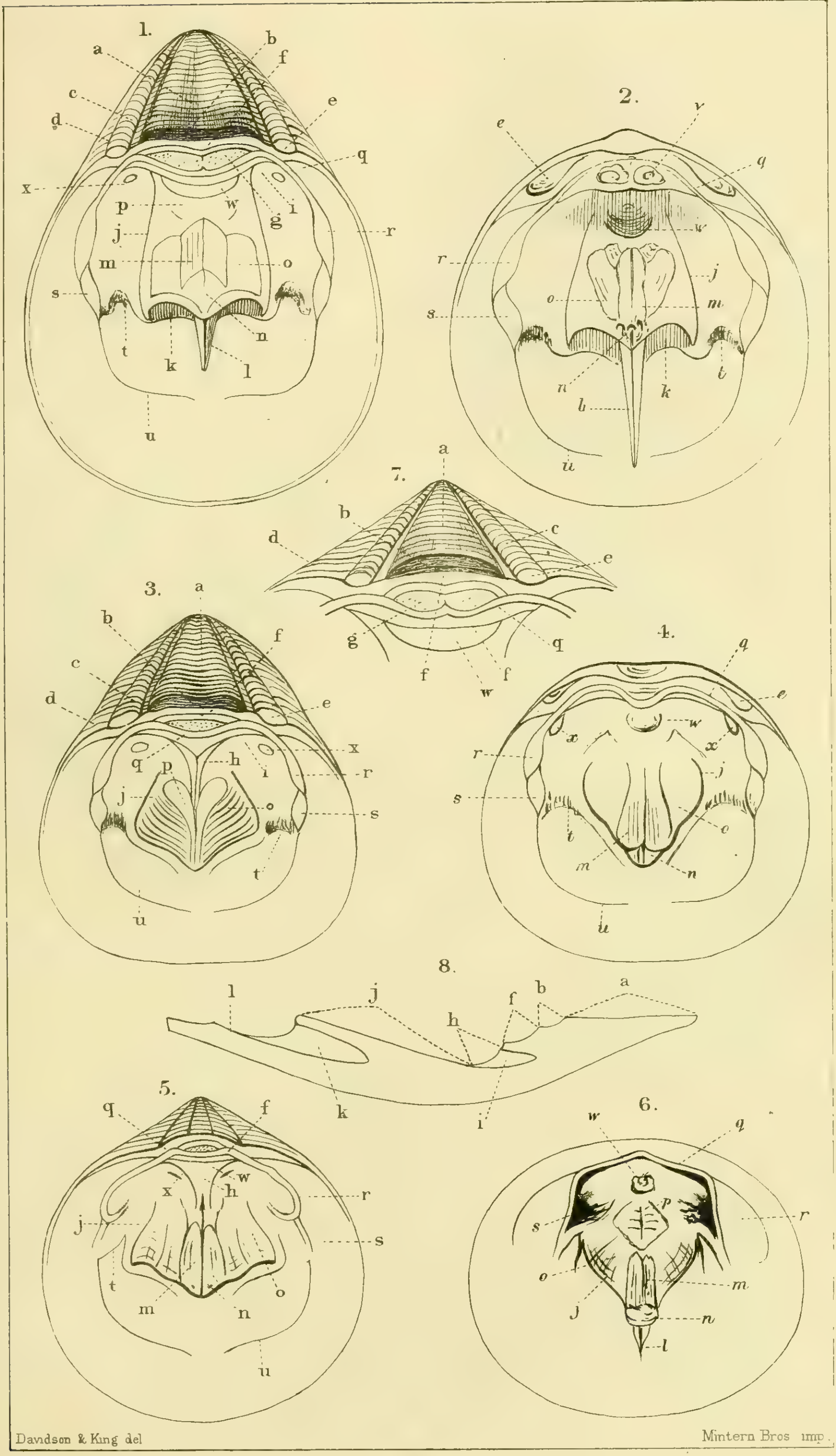
7. *Dinobolus canadensis*, Bill., sp. After a figure published by Mr. Billings. Trenton or Black-river limestone. Lower Silurian, Canada. Museum of Montreal.

8. *Dinobolus magnificus*, Bill., sp. After a figure published by Mr. Billings. Same locality and museum.

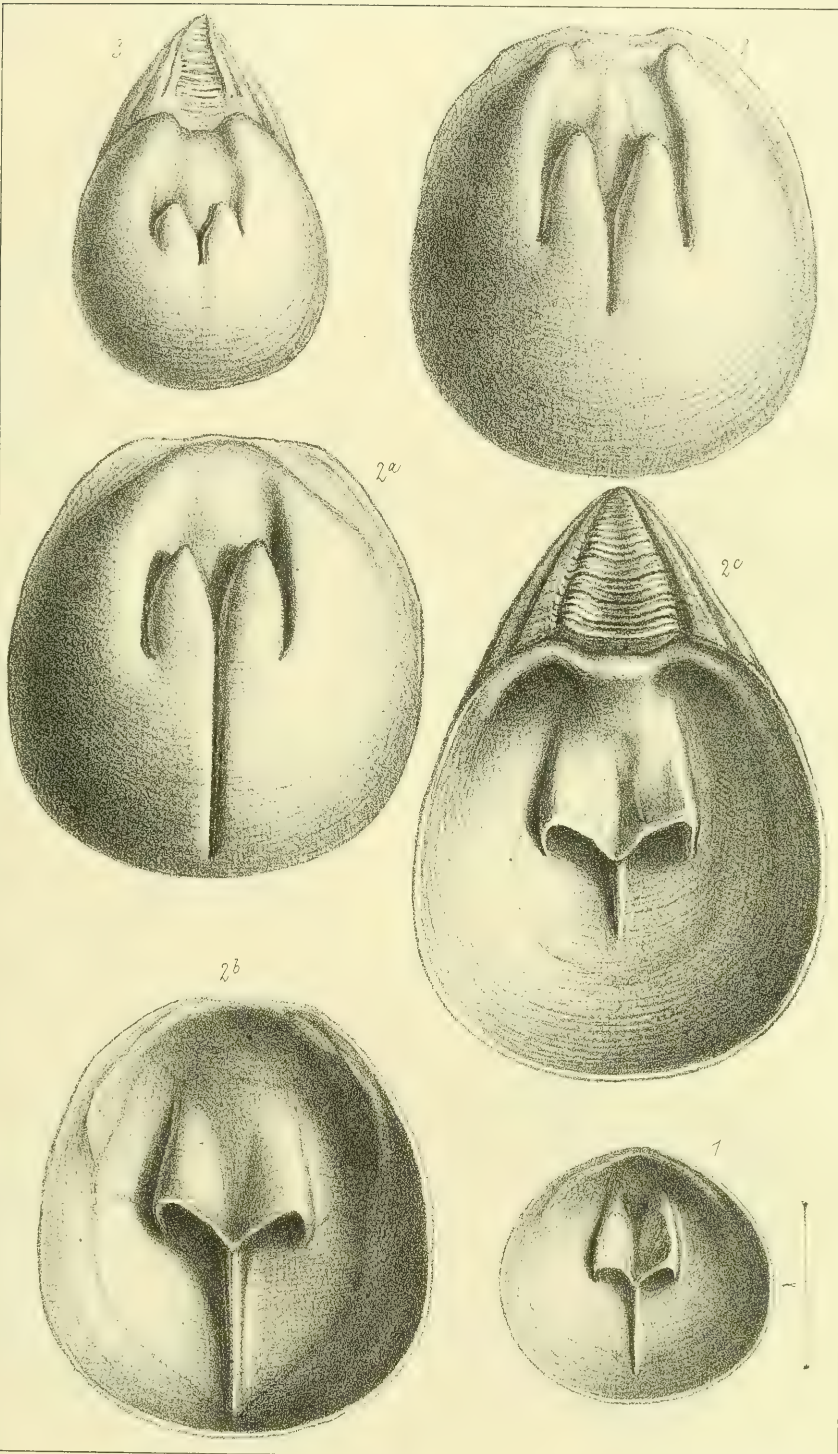
9, 9 *a*. *Lingulops Whitfieldi*, J. Hall. 9, natural size: 9 *a*, interior of brachial (?) valve, much enlarged. Lower Silurian, United States, America. Collection of Prof. J. Hall.

DISCUSSION.

Mr. HICKS remarked that the oldest known Lingulid is *Lingulella primæva*. The *Lingulæ* in the earliest rocks increase in size as they approach shallow deposits; and higher up, namely in the Lingula-flags, a change takes place in their form. In the Menevian beds, which were deposited in a deep sea, the shells are small. Mr. Hicks thought, therefore, that we must admit these changes to be due to changes in the conditions of existence. The *Lingulæ* had been declared to be allied to the Annelids; the Trilobites were also allied to the Annelids; and these three are the earliest known forms of



TRIMERELLIDÆ.



Thos Davidson del et lith.

M & N Hanhart, imp.

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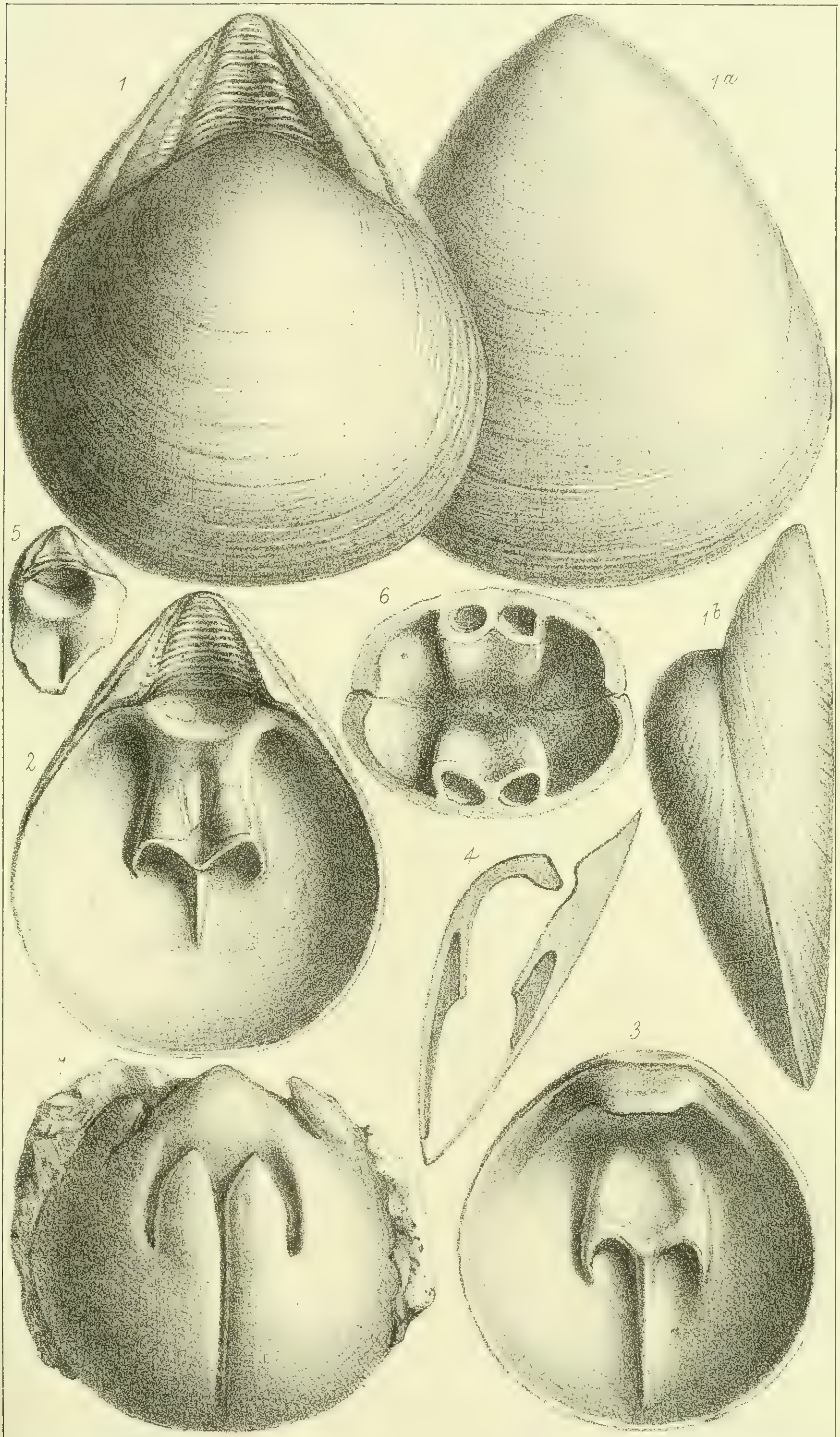

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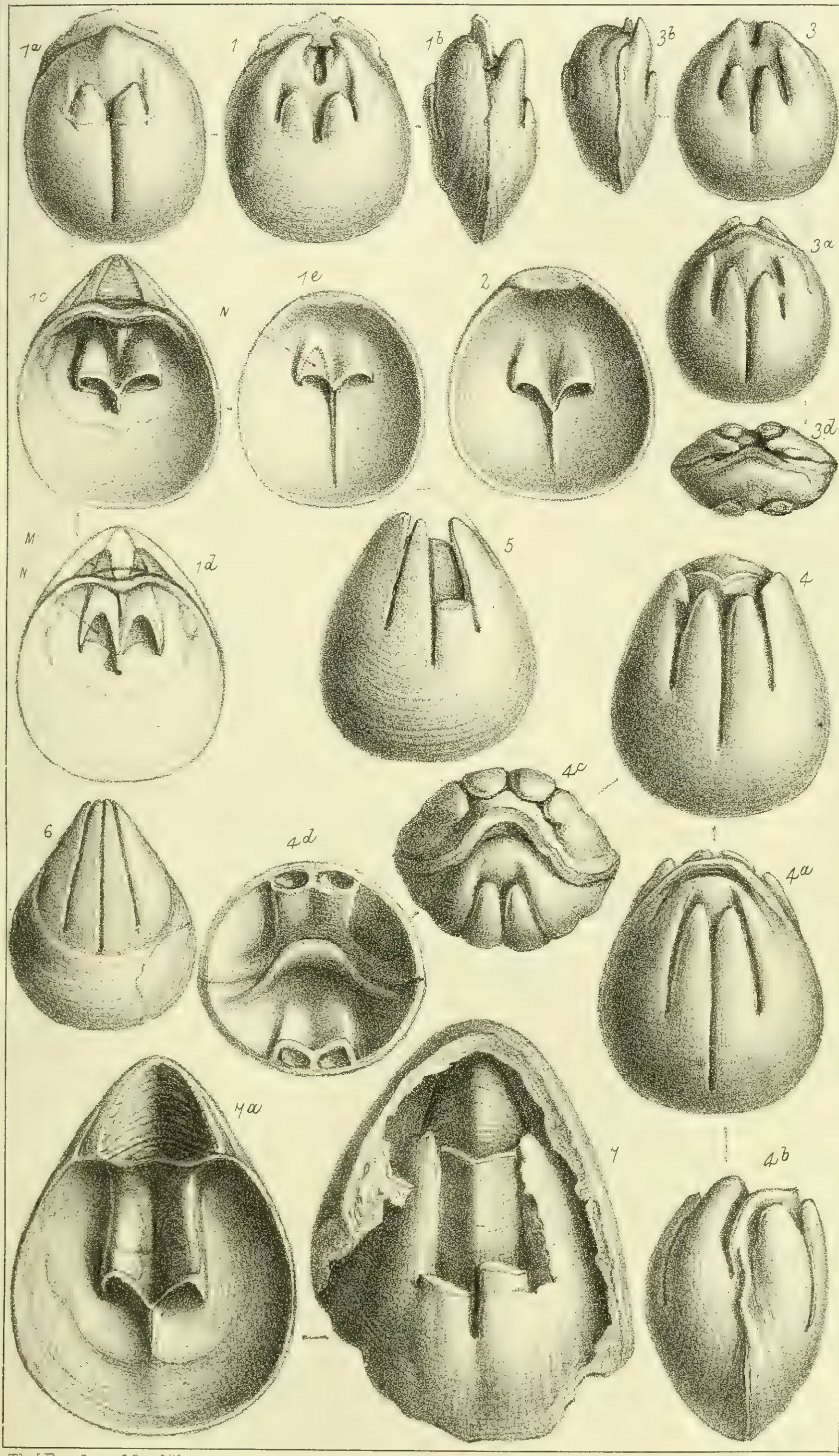

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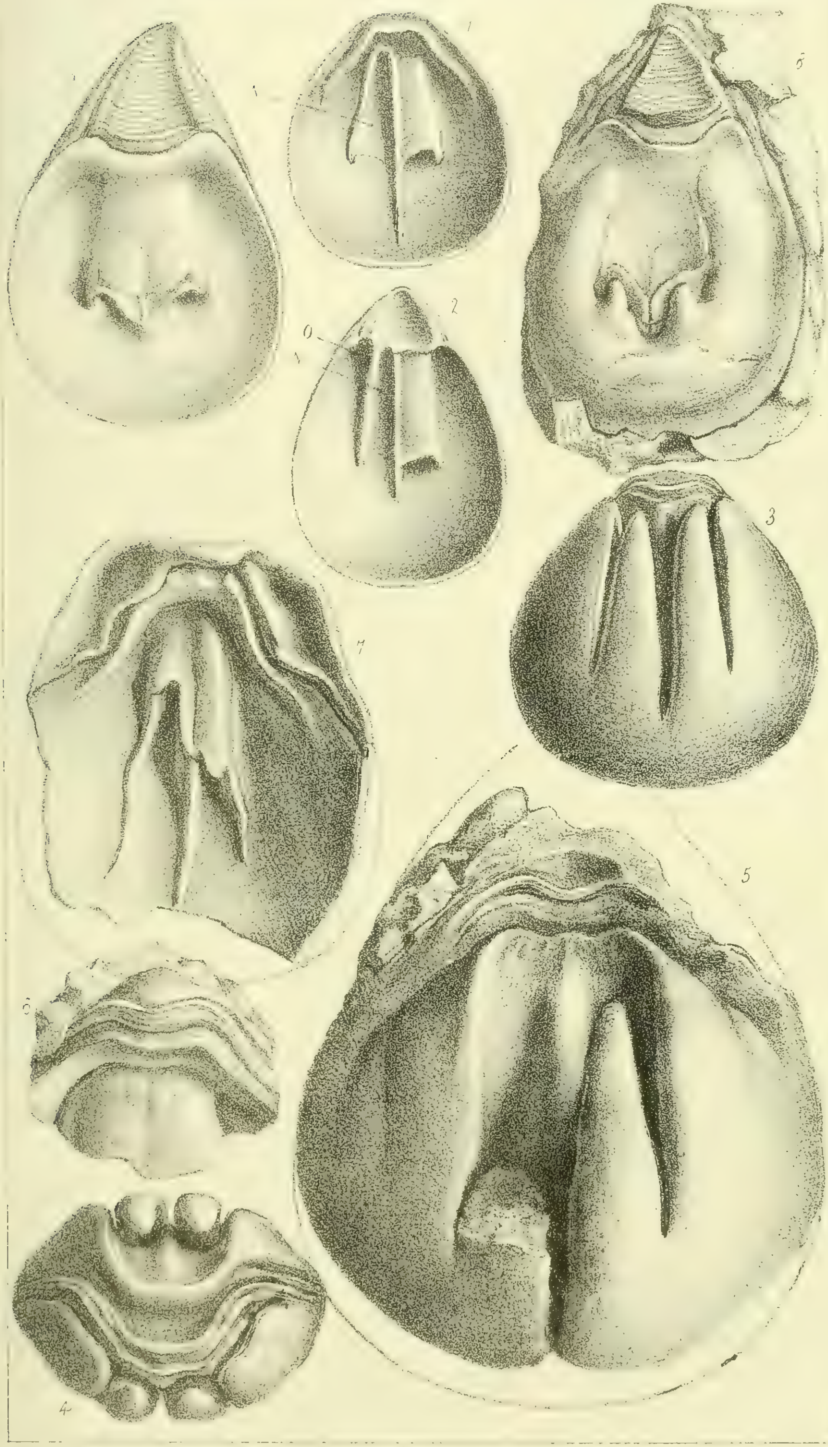

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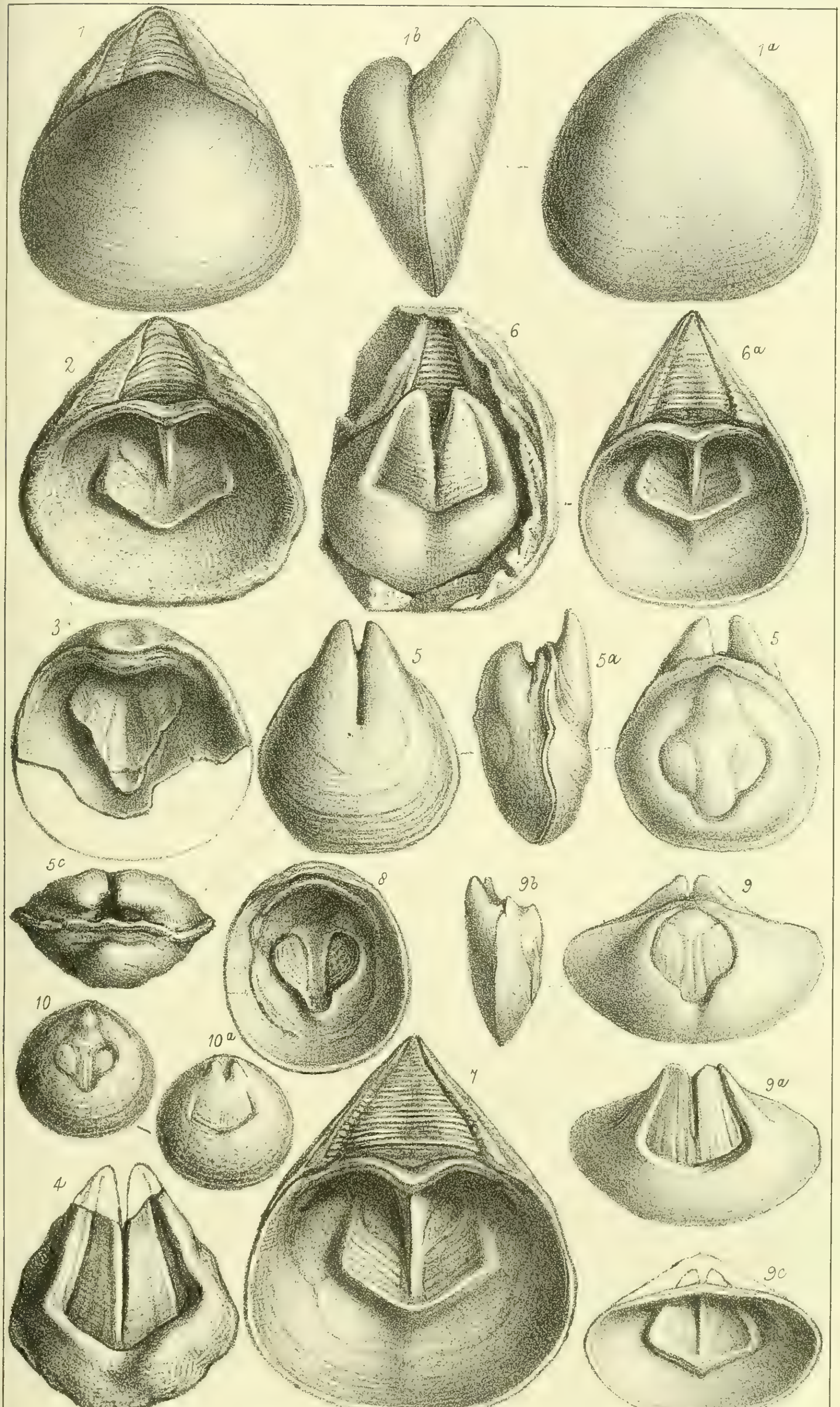

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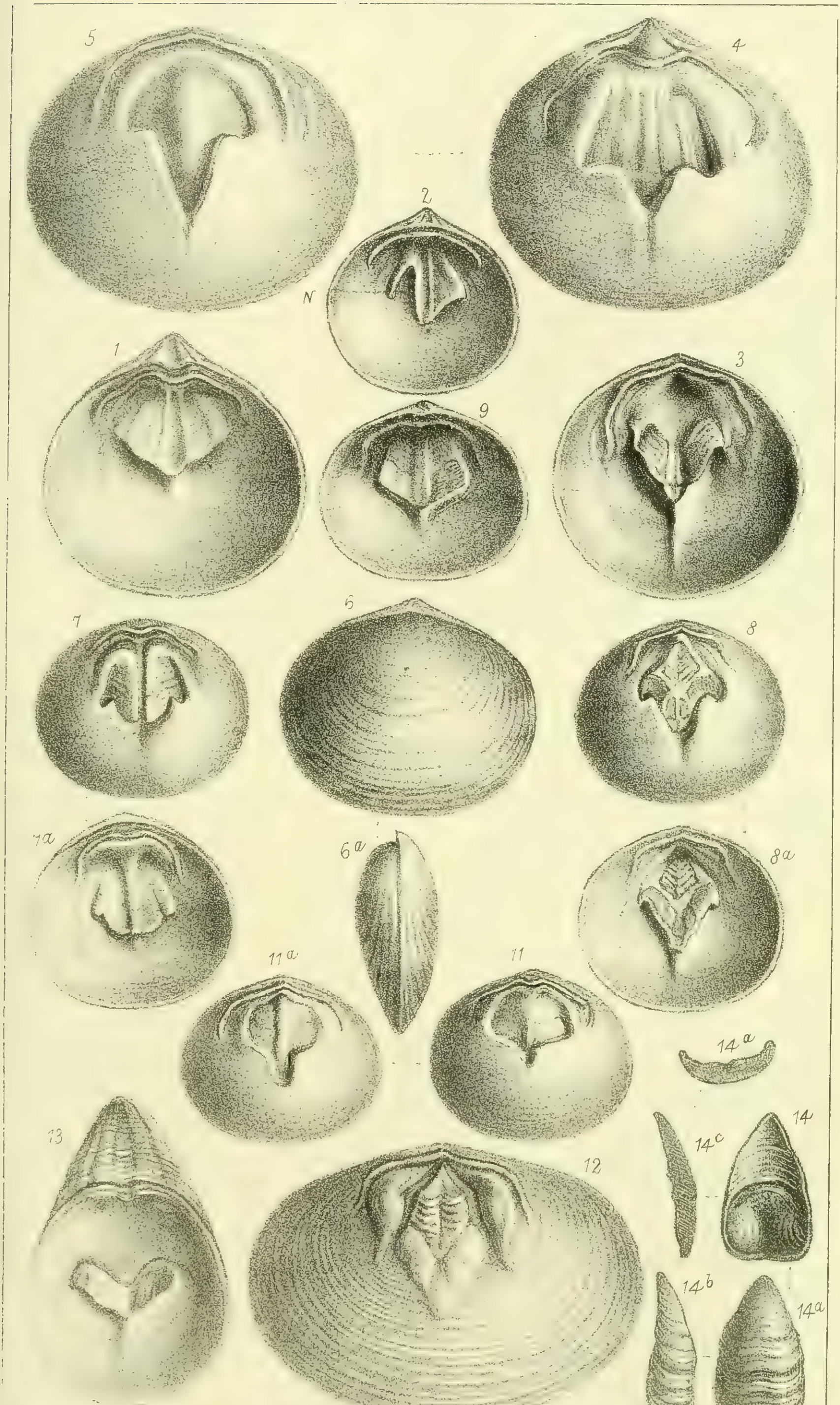

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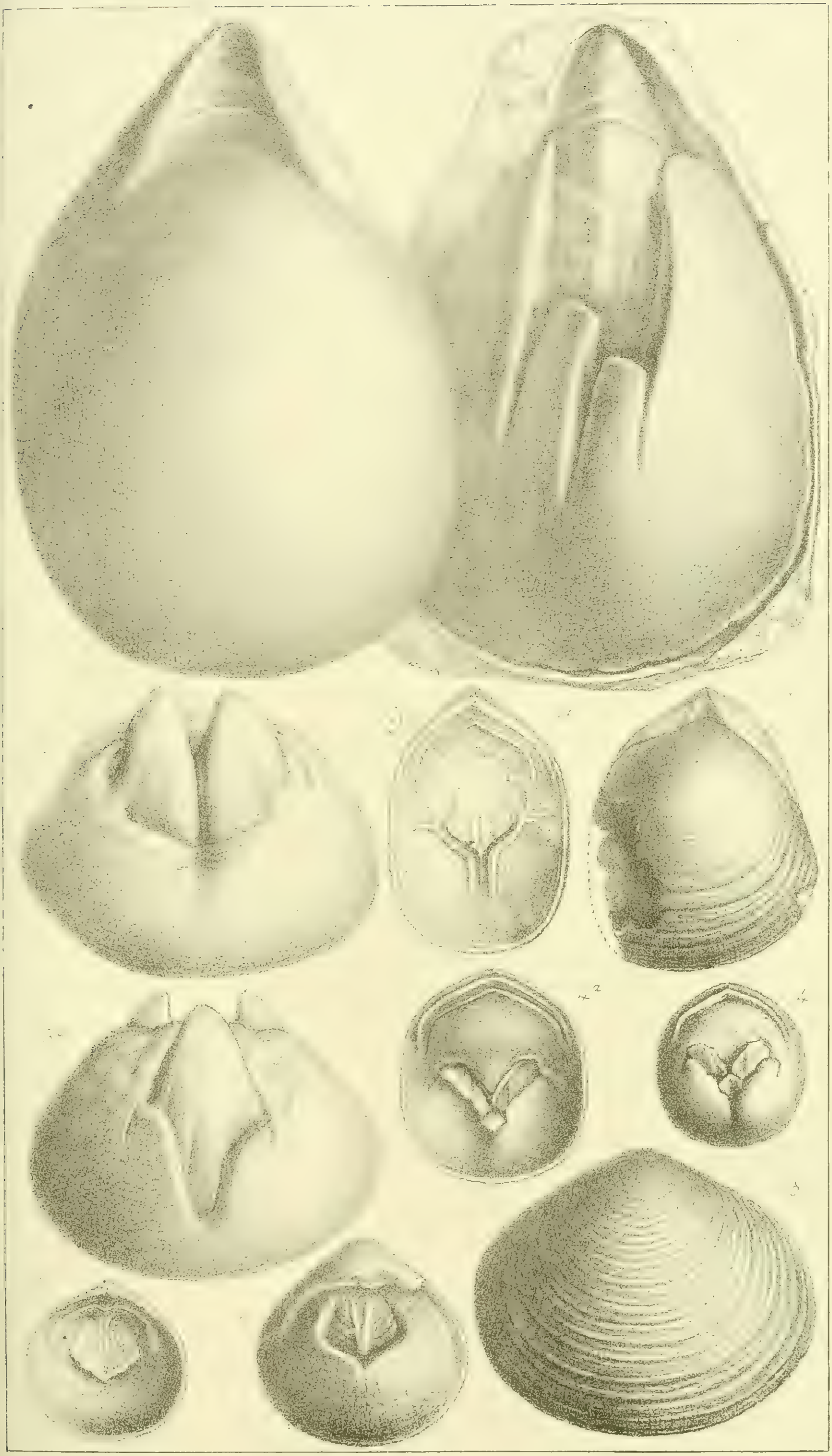


Thos Davidson. del. et lith.

M.& N. Hanhart. imp.

TRIMERELLIDÆ.

life. It would be well worth while to follow the inquiry how far they were related.

Prof. Ramsay was delighted to hear the opinion expressed by Mr. Davidson, that the distinction of species was merely an abstract idea. He had always considered that the apparent distinction of species was due to the absence of the connecting links. He was thankful to Mr. Davidson for stating that in different geological formations there were forms which had received distinct specific names but which he could not distinguish otherwise than by their derivation. Mr. Hicks had spoken of the three forms of organisms which occur deep down in the Cambrian, and founded an argument upon their rarity. But Prof. Ramsay had long maintained the heterodox opinion that the Lower Cambrian was a freshwater formation, in which marine deposits are here and there intercalated. He looked forward to the future discovery of marine Lower Cambrian beds with a much richer fauna, and considered that it was only from accidental circumstances that the fauna of the Lower Cambrian is so poor.

Mr. Etheridge also called attention to the poverty of the Lower Cambrian fauna in Great Britain.

Mr. Boyd Dawkins remarked that the most lowly organized forms seemed to be the most persistent.

17. *On the* Traces *of a* Great Ice-sheet *in the* Southern Part *of the* Lake District, *and in* North Wales. By D. Mackintosh, Esq., F.G.S. (Read January 7, 1874.)

(Abridged.)

[Plate XX.]

[After a few introductory remarks on *roches moutonnées*, the distinction between primary and subsequent striæ, &c., the author proceeds to consider the main subject of his paper as follows.]

A tabular statement of facts will, I think, clearly show that the primary or most persistent glaciation of the south-central part of the Lake District, must have been produced by an ice-flow capable of ignoring the drainage of the country to a much greater extent than could have resulted from any system of confluent glaciers strictly so called.

	Primary glaciation.
Far Easdale (near Grasmere), rocks generally smoothed from between	N.N.W. and N.W.
Entrance to Far Easdale (east side), striæ from	N.W.
East of Easdale House, striæ from about	N. 10° W.
Near Sourmilk waterfall, striæ from	N.W.
Near Blind Tarn moss (crossing the outlet), striæ from...	N. 30° W.
On summit of the rock and bog tableland between Easdale and Great Langdale up to at least 1700 feet above sea, *roches moutonnées* smoothed from about ...	N.N.W.
Striæ on ditto from	N.N.W.
A short distance north of High Close, striæ from	N. 40° W.
Top of High Close col, striæ from	N.
East of Chapel Stile (Great Langdale), striæ from	N. 30° W.
North of Elterwater Village, rocks smoothed and striated from	N. 26° W.
Bottom of Great Langdale west of Elterwater Village and south-west of Chapel Stile School, rocks smoothed and striated from	N.W.
On roadside (up hill) from Elterwater Village to Dale End, striæ from	N. 40° W.
Higher up on same road, striæ from	N. 40° W.
North of Little Langdale Tarn, striæ from	N.W.
Between Little Langdale Tarn and Blea Tarn, striæ from	N. 30° W. and N.W.
Near the Parsonage (Grasmere), striæ from about	N.W.
East of Town End (Grasmere), striæ from	N.N.W.
Roches moutonnées between Town End and Whitemoss quarry, smoothed from about	N.W.
At Whitemoss quarry, striæ from about	N.W.
Rydal valley (about 1 m. north of Wordsworth's house), striæ from	N. 10° W.
Near Ambleside (on Grasmere road), striæ from	N. 20° W.
Near Ambleside Church, striæ from about	N. 15° W.
Rocks on north side of Loughrigg Fell, smoothed from about	N.N.W.

	Primary glaciation.
Loughrigg Tarn and the neighbourhood, striæ from about	N.N.W. and N. by W.
In one place crossed by striæ from about N.W.	
North side of Brathay valley (between Loughrigg Tarn and Clappersgate), striæ from	N.W.
Crossed by striæ from a little N. of W.	
Near Pull (on road from Clappersgate to Hawkstead), striæ from about	N. 27° W.
Quarry near Mr. Atkinson's house (north-west of Windermere), striæ from	N. 30° W.
Crossed by later striæ from N. 10° W.	
Windermere churchyard, broad grooves from	N. 25° W.
Crossed by sharp striæ from N. 10° W.	
Near Mr. Pritt's house, Bowness, striæ from	N. 30° W.
In front of a house called the Ferns, Windermere, striæ from between	N. 20° and N. 30° W.
Near Rev. Mr. Stock's house, Bowness, striæ (possibly secondary) from	N. 10° W.
Near Crossings (Windermere) broad grooves, from between	N. 20° and 23° W.
Crossed by striæ from about W. 35° N., and a few grooves from about N. 33° W.	
About halfway between Windermere and the Lake, striæ from	N. 33° W.
Orrest Head (Windermere), smoothed from about	N.N.W.
Top of a high ridge called School Knott (near Windermere), crossed by great grooves from	N. 33° W.
Near Ings (east of Windermere) a number of large *roches moutonnées* smoothed from about	N.N.W.
Broad grooves and striæ on ditto, from between	N. 20° and 30° W.
Rocks at a considerable height on west side of Troutbeck valley, smoothed from about	N.N.W.
Watershed between Style End (Kentmere) and Long Sleddale, striæ from	N.
West of Stavely Parsonage, primary glaciation from about	N.W.
Crossed by large grooves from nearly	W.
Near entrance to Tilberthwaite valley (about High Yewdale, Coniston), rocks extensively smoothed up hill from about	N.
North side of Church Beck valley about halfway between Coniston and Copper-works, rocks extensively grooved obliquely down hill from about	N.
Crossed by striæ running in direction of valley or from N.N.W.	
Near Copper-works, striæ (covered with stratified sand and gravel) from	N.N.W.
Between Copper-works and Paddy End, striæ from	N. 30° W.
At mouth of Reddale valley above Copper-works, striæ from	N.W.
On steep slope above Copper-works, rocks extensively striated down hill from about	N. 10° W.
Roches moutonnées on nearly opposite slope, smoothed up hill from about	N.
Between Duddon Bridge and Seathwaite Church, *roches moutonnées* with parallel undulations and striæ coinciding in direction, from about	N.N.E.

It will be seen from the above statement of facts that the primary ice-marks embrace an area extending from near Style End and Stavely (Kentmere), on the east, to nearly as far west as Stickle Tarn and the Coniston Old Man *—and from Far Easdale on the north to as far south as Bowness and Church-beck valley, Coniston. In the neighbourhood of Windermere they average about N. 27° W., and run generally up hill. About Ambleside their average direction is nearly the same. Around Grasmere they average about N. 40° W. To the north-west and west of Grasmere, in the upland valleys and on high ridges, they average about N. 30° W. South of Grasmere and in Great Langdale they average about N. 35° W. In the Coniston district they average a little W. of N.

In the neighbourhood of Windermere and Bowness, the ice, besides moving generally up hill, must have ascended and passed over Orrest Head (700 feet above the sea), crossed a high ridge called School Knott (760 feet) at right angles †, and the upland valley between Windermere and Stavely at nearly right angles. North-west and west of Ambleside it must have obliquely crossed Rydal water, and a high, if not the highest part of Loughrigg Fell (1100 feet). East of Grasmere it would appear to have smoothed the side of Rydal Fell up nearly to the summit; but, so far as yet known, the ice must chiefly have ignored the configuration of the ground in a district extending for some miles to the north-west, west, and south-west of Grasmere. From the north slope of Far Easdale, it must have obliquely crossed the dale, smoothed the rocks on its south side up hill, then crossed a high ridge, descended into Easdale, smoothed the rocks obliquely across the dale, marched from the bottom of the dale (900 feet) up hill to the top of a ridge more than 1700 feet above the sea. This ridge consists of hard volcanic breccia and other felspathic rocks; the summit is a narrow tableland consisting of alternate rock-basins and bosses; the rock-basins are partly filled with peat and water; and many of the bosses are *roches moutonnées*. Nowhere in the Lake District have I seen such a striking series of mammillated rocks: they have been considerably roughened by the weather; but the regular curvilinearity of their forms has been perfectly preserved. From the appearance of the surface of the great tableland on the north-west (which reaches a height of between 2300 and 2500 feet), and the rounded rocky eminences on its southern border, it can scarcely be doubted that the ice went over it; but I did not examine the ground further west than Stickle Tarn. From the top of the ridge just described the ice must have gone down into great Langdale, smoothing the sides of the projecting rocks which faced it or looked up hill, and leaving the down sides cliffed or jagged. Numerous examples of this smoothing of the sides of the rocks which offered the greatest

* The parallel undulations and striæ of Duddon valley, though probably primary, as they coincide in direction with the valley, may at present be left out of consideration.

† The ice-flow which crossed School Knott must have come from at least as far as Rydal (a distance of about 7 or 8 miles), and moved the greater part of the way over longitudinally level ground, and the latter part up hill.

resistance to the descending ice, may be seen on the north side of Great Langdale from High Close westwards; many of them were pointed out to me by E. B. Wheatley Balme, Esq., of High Close. The ice in obliquely crossing Great Langdale (about 300 feet) in one place nearly coincided in direction, without altering its course, with a bend in the valley. A greater number of distinctly striated *roches moutonnées* may be seen in the lower part of Great Langdale than perhaps anywhere else in the Lake District: they extend to the base of the ridge called Lingmoor on the south side of Great Langdale; and the eastern part of this ridge is striated in such a manner as to leave no doubt that the ice passed over it. In some places further west there are indications of the ice having ascended the north side of the highest part of Lingmoor (about 1500 feet), and glaciated Side Pike, nearly 1200 feet; but the rocks are much dilapidated and their bases scree-strewn. On the south side of Lingmoor the striæ and *roches moutonnées* clearly point to ice having descended from its summit; so that it may safely be inferred that the ice-flow crossed over Lingmoor from Great into Little Langdale. In the Coniston-Old-Man area we meet with phenomena which cannot be very satisfactorily explained without supposing that the ice-sheet continued its march not only across Little Langdale, but (after a westerly deflection of its course) up the northern slopes of the Coniston Fells, over ground at least 2000 feet above the sea, down into Church-beck valley (600 feet) *, and up the side of the ridge on the south, beyond which I have not traced the ice-marks. As, however, it is barely possible, though not probable, that the ice which accomplished such feats among the Coniston Fells may have belonged to an ice-dome rising to a great height above the northern part of the Fells, and sloping down towards Little Langdale, we may principally direct our attention to the Easdale and Langdale ice-sheet until the Coniston mountains have been more extensively examined, especially to the north and north-west of the Copper-works.

Source of the Easdale and Langdale Ice-sheet.—Several years ago I noticed that the northern part of the Lake District must have been mainly glaciated from the south; and Mr. Ward has brought his S. and N. ice-marks to within two miles of where my N. and S. ice-marks begin, as may be seen from his map (Quart. Journ. Geol. Soc. vol. xxix. pl. xv.). It is impossible that a strip of ice not two miles in breadth could have originated two ice-flows in opposite directions, and both of them many miles in length. The northern ice-flow may have taken place at a later period than the southern; but however this may have been, I think it may be regarded as certain that the southerly ice-flow could not have performed the feats above specified without being backed up on the north by an ice-dome rising to a great height and covering many square miles of country to the north of Far Easdale. Until the central part of the Lake District

* At intervals along the whole of the northern slope of Church-beck valley N. and S. primary striæ may be seen running obliquely down hill. The instance noticed in the tabular statement is perhaps the best-defined.

has been carefully searched for ice-marks further west and east (but especially further east) than the area treated of in this paper, it might be going too far to invoke an ice-flow assailing the Lake District from without, and overriding an area extending west and east from the Duddon valley to Kentmere, if not to the West Riding of Yorkshire, and as far south at least as Morecambe Bay.

Traces of an Ice-sheet in North Wales.—The state of the basin of the Irish Sea between the Lake District and North Wales, at the time of the greatest development of the ice, cannot be well ascertained without a wider induction of facts than we at present possess. The north-western side of Snowdonia has been principally glaciated from the S.E. and S. or in the direction of the lower valleys. In the high-level valleys, as long ago shown by Professor Ramsay, there are striæ which indicate a thickness of ice sufficient to have enabled it to cross minor ridges and hollows, and to move along the sides of hills at great altitudes. During recent visits to North Wales I saw many glaciated surfaces between the Vale of Conway and Capel Curig, the striæ varying from between S.W. and W.S.W., and indicating an ice-flow capable of ignoring hills and valleys. In the great Ogwen Pass, near a farm-house called Wern-go-ischaf, I found an extensive rock-surface striated at right angles to the pass (or nearly N. and S.) which a small glacier coming down from above did not seem capable of explaining, especially as the lines did not coincide in direction with the small lateral valleys on the right and left. To the south of the Snowdonian range of mountains I happened to alight on a number of phenomena which clearly indicated the southerly movement of a great ice-sheet capable of ignoring or crossing deep valleys, and which probably had its source in an ice-dome covering the peak of Snowdon and the surrounding heights, and levelling the area between Snowdon and Moel-wyn. The group of mountains of which Moel-wyn is the principal, furnishes evidences of the former existence of such an ice-sheet. On the southern side of Bwlch-cwm-orthin (which separates the head of Cwm Croesor from Cwm Orthin) away from any valley, and at a height of more than 1800 feet above the sea, I found a number of rock-surfaces, smoothed, mammillated, and striated from about W. 30° N. There is a possibility of these surfaces having been glaciated by floating ice; but when viewed in connexion with *roches moutonnées* at a lower level, soon to be noticed, I think it is more probable that the agent was land-ice of a thickness sufficient to fill up and override the upper part of Cwm Croesor before it found its way to the irregular plateau on which the glaciated rocks occur. Between Cwm Croesor and Beddgellert mammillated rocks may be almost everywhere observed; but the greatest display occurs immediately to the south of the bare and craggy felstone ridge called Yr Arddu; I believe they are unequalled in any part of Wales or, perhaps, in the Lake District. Their regularly rounded and approximately dome-shaped forms, not exceptionally, but as a general rule, furnish an unquestionable evidence of a great flow of land-ice, as icebergs would have tended to flatten and plane down projecting rocks, though, under exceptionally favourable circumstances, they might have left rocks more or less rounded. These *roches moutonnées* are not in a valley, but on an irregular plateau. They occur at various heights, and must have been smoothed by ice which moved independently of the drainage of the country. Indeed the ice by which many of them were smoothed must have come over Yr Arddu. They are so much smoothed that it is often difficult to tell the precise direction from which the ice came; but taken in connexion with a number of striæ, the direction would appear to have been approximately N. The ice may have radiated from the Snowdonian dome south-easterly towards Bwlch-cwm-orthin and southerly towards Yr Arddu. East of Moel Wyn the mouth of Cwm Orthin is magnificently mammillated, as long ago mentioned by Professor Ramsay; and a survey of the surface-configuration would, I think, lead to the conclusion that the mammillation was principally caused by a great ice-sheet and not by a corry glacier.

The above remarks on the primary glaciation of a part of North Wales are intended as supplementary to those on the Lake District, and not as exhaustive of the subject.

[The author concludes with observations on the correlation of the drifts of the Lake District with those of North Wales, the relation between lake-basins, drifts, and moraines, the commencement of the great submergence while the land was deeply covered with ice, &c., &c.]

EXPLANATION OF PLATE XX.

Map intended to show the positions and directions of the primary striæ and rock-smoothing in connexion with the surface-configuration of the principal area described in the paper.

Discussion.

Mr. Ward was inclined to regard the scratches in the Lake-district described as due to the confluence of several glaciers, so as to form a large mass of ice, the pressure of which enabled it to travel over the ridges separating the valleys, especially at their lower ends. If the phenomena could be explained in this manner, he thought it needless to invoke the existence of a large general ice-sheet. If such a thing had existed, it must have brought some of the rocks from the north and deposited them in the district; and this was not the case.

Mr. D. C. Davies thought that the author had left some circumstances out of view, especially the difference of dates of the striæ on the Welsh mountains, which had been cut at different times during the elevation and depression of the land. He instanced the occurrence of fragments of Scotch granite in gravels at an elevation of from 1500 to 2000 feet above the sea.

Prof. Ramsay observed that some years ago he had attempted to show that Anglesea had been glaciated by ice that had come from the north in the Cumberland district, and attributed this circumstance to the preponderance of this northern ice over that from the Snowdon range, which was, as it were, set aside by it. He was inclined to think that the Menai Straits, the direction of which coincided with the main lines of glaciation in Anglesea, might be due to the same cause.

18. Discovery *of* Foraminifera, &c., *in the* Boulder-clays *of* Cheshire. By William Shone, Esq. (Read March 11, 1874.)

[Communicated by D. Mackintosh, Esq., F.G.S.]

In the Quarterly Journal of the Geological Society for November 1872, Mr. D. Mackintosh described the Upper and Lower Boulder-clays of Cheshire, and he also appended lists of the Mollusca found therein.

I cannot add any thing to Mr. Mackintosh's description, it being a most accurate, full, and exact account of the lithological and stratigraphical characteristics of the drift-clays of Cheshire. For some time I had been searching for Foraminifera in these clays in the vicinity of Chester, but failed to find them. Last September, however, my friend Mr. J. B. Manning (Constable of Chester Castle) happened to find in the Upper Boulder-clay of Newton-by-Chester a boulder bored by *Saxicava rugosa,* in the cavities of which fragments of the shells remained. Wishing to possess these fragments, he proceeded to wash them out; but in doing so he observed that the holes were not filled with the red clay in which the boulder was found, but with sand. On examining this sandy débris beneath the microscope, we found that it contained several shells of *Polystomella crispa.* Mr. Manning thereupon remarked, "if we are to succeed in finding Foraminifera in the Boulder-clay we must look for stones with holes in them."

It then occurred to me that the turbinated shells of *Turritella terebra* would offer a still more effective shelter to the Foraminifera. I happened to possess a considerable number of these shells, gathered from a newly exposed railway cutting, which passed through Upper Boulder-clay at Newton-by-Chester; so I put the idea at once into practice by washing out the substance which filled the inner whorls of the *Turritellæ.* After pouring off the fine muddy particles there remained behind a sandy residuum, in which Foraminifera, Ostracoda, Sponge-spicules, and the spines of *Echini* were abundantly distributed. The Foraminifera were in a most perfect state of preservation—so perfect, indeed, that I found it impossible to distinguish the fossil forms taken out of the *Turritellæ* of the Upper Boulder-clay from the recent ones of the same species which I had gathered along the shores of the estuary of the Dee.

On examining a number of *Turritellæ,* I observed that some were entirely filled with a remarkably fine *greyish white sand,* others only partly filled with it, though invariably that portion of the shell nearest the apex; while some *Turritellæ* were wholly filled with the *red clay* in which they were imbedded. I found that the Foraminifera &c. occurred in those shells which were wholly or partly filled with the greyish-white sand, and that the *Turritellæ* filled with the red clay scarcely contained any Foraminifera &c.

The fact that the *Turritellæ* filled with the greyish-white sand yielded abundantly Foraminifera and Ostracoda, and that those wholly filled with the red clay in which they were imbedded contained scarcely any, would appear to suggest that the former had been transported to their present positions by the same agency which brought the pebbly gravel and striated erratics which lie mingled with them in the clay.

On examining the clay in which the *Turritellæ* lay imbedded, I found that it contained from three to six shells of Foraminifera per cubic inch. I obtained from it about twenty Foraminifera of five species identical with those occurring in the *Turritellæ*, but more worn and fossilized*. I will not, however, at present venture an opinion as to whether the Foraminifera found *free* in the clay lived *in situ*, or were washed out of *Turritellæ* filled with them previously to being transported hither from some distant shores.

I am indebted to my friend Mr. J. D. Siddall, Chester, for the names of the Foraminifera, and to the Rev. H. W. Crosskey, F.G.S., and G. S. Brady, Esq., F.G.S., F.L.S., for those of the Ostracoda.

In the following list U. B. C. signifies Upper Boulder-clay, and L. B. C. Lower Boulder-clay.

	Where found.		
OSTRACODA.			
Cythere villosa	In *Turritellæ* from	U. B. C., Newton,	Chester.
—— antiquata	,,	,,	,,
—— tuberculata	,,	,,	,,
—— Jonesii	,,	,,	,,
—— dunelinensis	,,	,,	,,
—— tenera	,,	,,	,,
Cytheridea punctillata?	,,	,,	,,
Cytheropteron nodosum	,,	,,	,,
Cytherura angulata	,,	,,	,,
Eucythere? argus................	,,	,,	,,
Loxoconcha tamarindus	,,	,,	,,
—— impressa	,,	,,	,,
Paradoxostoma arcuatum ...	,,	,,	,,
—— flexuosum	,,	,,	,,
—— ensiforme?	,,	,,	,,
ANNELIDA.			
Spirorbis nautiloides	,,	,,	,,
ECHINODERMATA.			
Spatangidæ, fragments of spines	,,	,,	,,
Cidaridæ, too much broken to identify species	,,	,,	,,
SPONGIDA.			
Triradiate sponge-spicula ...	,,	,,	,,

* See note on p. 29 of Quart. Journ. Geol. Soc. vol. xxx. for list of sixteen species of Foraminifera found in the Boulder-clay of Liverpool by Mr. Reade, F.G.S.

	Where found.	
	In *Turritellæ* from	
FORAMINIFERA.		
Biloculina ringens, very rare	U. B. C. Newton-by-Chester.	L. B. C. Dawpool.
Triloculina oblonga, uncommon	” ”	” ”
—— trigonula, rare	” ”	” ”
Quinqueloculina seminulum, common	” ”	” ”
—— secans, frequent......................	” ”	
Lagena sulcata, rare	” ”	
—— lævis, rare	” ”	” ”
—— striata, rare	” ”	
—— globosa, rare	” ”	
—— marginata, rare......................	” ”	
—— squamosa, rare	” ”	” ”
Cristellaria crepidula, rare	” ”	” ”
Nodosaria scalaris ?, very rare	” ”	
Dentalina communis ?, very rare	” ”	
Polymorphina lactea, not common ...	” ”	
Uvigerina angulosa, very rare	” ”	
Globigerina bulloides, frequent	” ”	” ”
Textularia variabilis, frequent	” ”	” ”
—— difformis, frequent	” ”	” ”
—— globulosa, uncommon	” ”	
Bulimina pupoides, very fine large shells, common	” ”	” ”
—— marginata, uncommon............	” ”	” ”
—— ovata, not common	” ”	” ”
—— elegantissima, frequent............		” ”
Bolivina plicata, frequent		” ”
Discorbina rosacea, frequent............	” ”	
Planorbulina mediterranensis, frequent	” ”	
Truncatulina lobatula, frequent	” ”	” ”
Rotalia Beccarii, frequent and well developed................................	” ”	” ”
—— nitida, small and rare	” ”	” ”
Polystomella crispa, frequent	” ”	
—— striato-punctata, frequent	” ”	
Nonionina umbilicatula, frequent......	” ”	” ”
—— depressula, uncommon............	” ”	” ”

On comparing the recent Foraminifera from the tidal reaches of the Dee with the same species from within the *Turritellæ* in the Upper Boulder-clay, Mr. Siddall and I found it impossible to distinguish the one group from the other, except that *Rotalia Beccarii* and *Bulimina pupoides* are finer in the Boulder-clay.

The general facies of the Foraminifera of the Upper Boulder-clay appears to indicate a shallow sea, into which large quantities of fresh water intermittently flowed.

According to the observations of Mr. Mackintosh, the Upper Boulder-clay of Cheshire, Lancashire, and Cumberland cannot be traced much higher than 500 feet above the present sea-level. The Foraminifera and Mollusca I have found in the Upper Boulder-clay of Chester, so far, appear to confirm Mr. Mackintosh's conclusions. When the surface of this part of England was submerged beneath the Upper Boulder-clay sea, and the striated erratics from the Lake-district, borne on floating ice, were being dropped on the muddy bottom consisting of this clay, there must have been large volumes of fresh water poured into it, especially when the accumulated winter's ice and snow melted before the increasing heat of summer. Would not such an addition of fresh water to a shallow sea be likely to have the same effect upon the Foraminifera of that period as the freshwater of tidal rivers has upon the recent Foraminiferal fauna characteristic of estuaries?

I may here mention that the Foraminifera and Ostracoda from the *Turritellæ* in the Lower Boulder-clay of Dawpool bear a more fossilized appearance than those from the *Turritellæ* in the Upper Boulder-clay of Newton-by-Chester. The Ostracoda from the Dawpool clay have not yet been named.

I trust that those interested in the fauna of the English drifts will endeavour to search for Foraminifera &c. in these glacial deposits. I believe that the distribution of the *Turritellæ* containing Foraminifera and Ostracoda &c. will be found to be coextensive with the distribution of the Lake-district erratics in the Boulder-clays.

Note.—For the results of the Rev. H. W. Crosskey's and Mr. David Robertson's investigations of the fauna of the Post-tertiary fossiliferous beds of Scotland, see the 'Transactions of the Geological Society of Glasgow,' vols. iii. and iv.

Note on Mollusca from the Boulder-clay at Newton, near Chester.

CONCHIFERA.

1. Mytilus edulis, *Linné.*
2. Cardium echinatum, *L.*
3. C. edule, *L.*
4. Cyprina islandica, *L.*
5. Astarte sulcata, *Da Costa.*
6. A. borealis, *Chemnitz.*
7. Tellina balthica, *L.*
8. T. calcaria, *Ch.*
9. Mactra solida, *L.*; var. elliptica, *Brown.*
10. Mya truncata, *L.*
11. Saxicava rugosa, *L.*

GASTEROPODA.

12. Lacuna divaricata, *Fabricius.*
13. Littorina rudis, *Maton.*
14. Turritella terebra, *L.*
15. Aporrhaïs pes-pelecani, *L.*
16. Purpura lapillus, *L.*
17. Buccinum undatum, *L.*
18. Murex erinaceus, *L.*
19. Trophon truncatus, *Ström.*
20. Fusus antiquus, *L.*
21. Nassa reticulata, *L.*
22. Pleurotoma pyramidalis, *Str.*

All the above except *Astarte borealis* and *Pleurotoma pyramidalis* inhabit the British coasts, and are littoral or sublittoral. *A. borealis* and *P. pyramidalis* are more northern species [J. GWYN JEFFREYS].

DISCUSSION.

Mr. EVANS remarked that there seemed to him to be two principal points for discussion in the paper:—first, whether the Foraminifera cited were peculiar to brackish water; and, secondly, whether the *Turritellæ* had been transported.

Mr. Gwyn Jeffreys said that the Foraminifera sent by Mr. Shone are exactly the same as those found on the coasts of Great Britain. The *Turritellæ* presented a puzzling question. The Foraminifera inhabit the Laminarian zone, and their light shells are thrown up at the edge of high water, so that they would naturally fill any shells that might be lying on the shore about that line. The *Turritellæ* might have been transported by ground-ice. The species was *Turritella terebra*, the common European species. Mr. Jeffreys remarked that we know comparatively little of the Arctic fauna at present, and that it was highly desirable that an expedition should be sent to investigate the marine fauna of high northern latitudes.

Prof. T. Rupert Jones stated that the *Rotaliæ* are not identical all round the coasts, those from different localities presenting different characters, as may be plainly seen in the *Rotalia Beccarii* of the Adriatic and of the English coasts. Various circumstances seem to act in changing the forms, especially whether the animals have inhabited deep or shallow water, or water more or less fresh. The *Globigerinæ* have thicker shells in deep than in shallow water. When ill-nourished, Foraminifera alter in the style of their outline.

Prof. Hughes remarked upon the difference of opinion prevailing as to the geographical affinities of the shells found in this deposit, and as to the origin of the deposit itself. He discussed the question of the origin of the clay, and came to the conclusion that it was not a true Boulder-clay, but derived.

Mr. Seeley referred to a Boulder-clay, at March, in Cambridgeshire, containing Foraminifera now common on our present shores.

19. *On the* Correspondence *between some* Areas *of* Apparent Upheaval *and the* Thickening *of* Subjacent Beds. By W. Topley, Esq., F.G.S., Geological Survey of England and Wales. (Read February 4, 1874.)

Contents.

1. *Introduction.*—The fact that the Secondary strata of England vary considerably in thickness as we trace them over any wide area is very well known. Professor Phillips long ago observed the south-easterly thinning of the Oolites in the Midland Counties *; and Professor Hull, in 1859, read before this Society a Memoir on this subject, giving the results obtained by himself and others engaged on the Geological Survey†. Recent investigations as to the probable extension of the coal-measures under the south-eastern counties, have again drawn attention to this subject; and much information bearing upon it is contained in the Reports of the Royal Coal Commission.

In the following paper I shall endeavour to show that, from these facts, some important conclusions may be drawn concerning the observed *dip* of the strata, and the disturbances which the strata are assumed to have undergone, conclusions which I think cannot be denied if the facts be granted, but which have hitherto been overlooked.

It is known that the Tertiary and Cretaceous beds under London lie in a "basin," whilst as we recede from London the beds *rise* at varying angles; so that strata which occur at considerable depths under London attain great elevations in the surrounding districts. It has always been assumed that this is due to an *upheaval* of the beds in the direction in which they rise. I think, however, that if we allow the full weight to known facts as to the thinning out of beds (facts which every one accepts), we must conclude that this is in many cases an erroneous assumption. In some cases the observed dip and rise of the beds can be wholly accounted for by the known or inferred thinning and thickening of the beds.

Not, however, the thinning of beds the dip of which is seen; although this has some small effect. But we must take into account the *sum of the thinning of all the underlying beds.* If we do this, we can often account, not for a part only, but for the whole of the observed dip.

* Manual of Geology, p. 303.

† "On the South-easterly Attenuation of the Lower Secondary Formations of England," Quart. Journ. Geol. Soc. vol. xvi. p. 63.

2. *The Jurassic and Triassic Rocks of Central England**.—As an illustration of the thinning out of the Oolitic rocks of this area, we may take a section from Leckhampton to Burford (fig. 1).

Leckhampton Hill is one of the prominent points of the Cotteswold escarpment; and here the thickness of the Inferior Oolite has been carefully measured. If the summit of this hill were capped by Great Oolite, the base of that formation would be at an elevation of nearly 1000 feet. At Burford, which lies 19 miles a little to the south of east of Leckhampton Hill, the average elevation of the base of the Great Oolite is about 400 feet. In ordinary geological language we should then say, that from Leckhampton Hill to Burford the beds have a dip of 600 feet in 19 miles.

Along this line the exact amount of the thinning of the Inferior Oolite and Upper and Middle Lias is well known, and that of the Lower Lias may be approximately inferred. At Leckhampton the thickness of strata intervening between the base of the Great Oolite and the base of the Lias is about 1200 feet; at Burford the total thickness is probably under 200 feet. There is therefore a difference in thickness between the two places of about 1000 feet of Lower Jurassic strata, whilst the dip of the Great Oolite is only 600 feet in the same distance. Therefore the thinning out of the lower beds will far more than account for the observed dip of the higher beds.

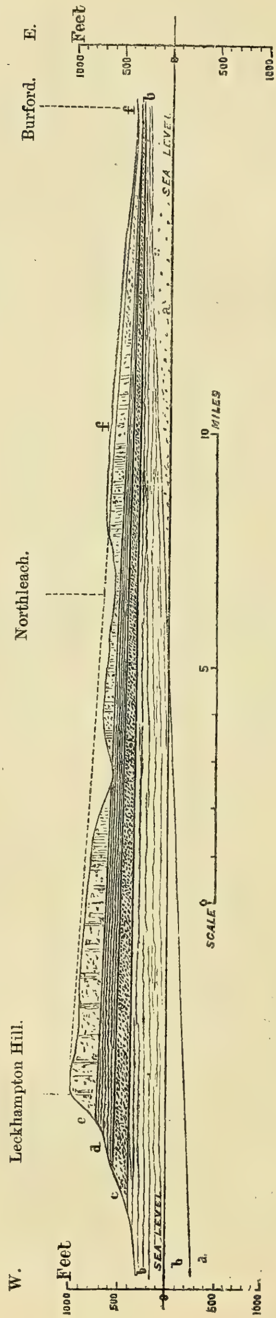
To make the matter more plain, let us refer both geological horizons under consideration to the present sea-level. The base of the Great Oolite at Leckhampton would be 1000 feet above the sea-level; at Burford (19 miles distant) it is 400 feet above the sea; therefore the dip of the Great Oolite is from west to east, 600 feet in 19 miles. The base of the Lias at Leckhampton is about 200 feet *below* the sea-level, at Burford it is about 200 feet *above* it; therefore the dip of the base of the Lias is from east to west, 400 feet in the same distance of 19 miles.

But we have here only considered the thinning of the Inferior Oolite and Lias, whereas it is known that the New Red series thins in like manner in the same direction. The amount of this thinning cannot be even approximately known between these two places; but it will probably be several hundred feet.

The thickness of the Trias in Cheshire is given by Professor Hull as 5600 feet, and about 600 feet in East Warwickshire; it is probably absent under Oxford. From Cheshire to Warwickshire the Trias thins 5000 feet in about 80 miles, or about 62 feet per mile. If this district were covered by higher Secondary rocks, the dip of

* The data for the observations are taken from Prof. Hull's paper already referred to, and from the same author's Geological-Survey Memoir, on Sheet 44. [It was pointed out by Mr. Bauerman and Mr. Etheridge, during the discussion upon this paper, that borings near Burford have proved the thinning of the Lower Lias to be less rapid than had formerly been supposed. Therefore the westerly dip of the base of the Lias would be less than that shown in the figure. The chief point of my argument, however, still remains, that the easterly dip of the Great Oolite can be entirely accounted for by the thinning of the Inferior Oolite and Upper and Middle Lias.]

Fig. 1.—Diagram Section (omitting Faults) from Leckhampton Hill to Burford, to show the Thinning-out of the Lias and Inferior Oolite and the consequent Easterly Dip of the Great Oolite.



a. New Red.
b. Lower Lias.
c. Marlstone.
d. Upper Lias.
e. Inferior Oolite.
f. Great Oolite.

these rocks would be affected by this amount, besides that resulting from the thinning of the higher Secondary rocks themselves.

We see, then, that in estimating the dip of the beds in any such district, our results will vary according to the rocks which are exposed in it. But inasmuch as our knowledge of the great movements which have affected the earth's crust is generally deduced from such observations, this liability to error becomes a very serious matter.

We infer, for instance, because of what we know of the dip of the Great Oolite in Gloucestershire and Oxfordshire, that the beds have been upheaved towards the west and north-west, which has resulted in a dip to the east and south-east, or towards the London basin. But if, over this area, denudation had gone much further than it has done, and all the Oolites down to the higher part of the Lower Lias had been swept away, we should observe that the beds along this line were approximately flat; and we should infer that there had been no upheaval here, or that the net results of such movements as had taken place had been to leave the beds in a horizontal position. If the whole of the Lias had been denuded, we should infer a slight *westerly* dip or *from* the London basin. If denudation had gone far into the Trias, sweeping away the whole of the higher Secondary rocks, we might have inferred a considerable westerly dip *.

3. *The Oolitic Rocks of Yorkshire.*—These afford another very striking example. It is known that the entire Oolitic series, which is so magnificently developed in the northern part of the county, is absent under the Wolds, and that the Red Chalk there rests directly on the Lower Lias. In part, no doubt, this is due to the great unconformity between the Cretaceous and Oolitic rocks; but it is also partly due to actual thinning of the strata, the Lower Oolites having disappeared entirely in this manner.

In order to estimate the amount of the dip which is due to this thinning, we have only to compare the small actual southerly fall of the bottom of the Inferior Oolite along the base of the western escarpment with the great southerly dip which the Coral Crag would have if it now stretched (as once it did) along the top of that escarpment. But this is not all; for the Lias itself is thinning in the same manner, and we find that the base of the Lias undergoes comparatively small changes of level along the same north and south line.

4. *The Carboniferous Rocks of Yorkshire.*—The Carboniferous Limestone series of Yorkshire has a general dip, from the high land of

* Since this paper was read, Mr. Whitaker has kindly drawn my attention to the following remarks by Sir W. V. Guise, in his address to the Cotteswold Naturalists' Field Club, April 19, 1869. Referring to the meeting of the Club held on March 25, 1868, Sir W. Guise says:—"Mr. Lucy mentioned his having recently made an excursion in the Cotteswolds round Stow and Burford, and called attention to the gradual thinning out of the beds in a northerly [?] direction. On the authority of Mr. Hull's Memoirs, to illustrate Map 44, Geological Survey, he stated that, while at Cleeve Cloud the Inferior Oolite attains an elevation of 1130 feet, the Cornbrash south of Burford is not much more than one half that height. *This, however, is in some degree due to the greatly diminished thickness of the underlying strata in the latter locality.*"

the great Penine escarpment, towards the east and south-east. In this direction the beds, as a whole, thin out *. In part, then, the westerly rise of the beds is due to the westerly thickening. A noteworthy exception to this easterly and south-easterly dip occurs between Wharfedale and Wensleydale, where the beds have a northerly and north-easterly dip, from what Professor Phillips has called the "Wharfedale Axis" †. Now it is near Wharfedale that the Lower or Scar Limestone series attains its maximum thickness. The top of this series—the upper limit of the "main limestone"—is a well-defined line; and by it Professor Phillips has estimated the dips. But the dip of this bed is partly produced by the thinning of the underlying mass of the Lower Limestone; therefore the "Wharfedale Axis" is partly due to unequal thickness of underlying strata.

5. *The Carboniferous Rocks of Derbyshire.*—The rapid south-easterly attenuation of the Millstone Grit and Yoredale Rocks in Derbyshire is well known. From 3500 feet on the west of Sheffield (between the Bradfield and the Rivelin valleys) the beds diminish to 1500 feet a few miles north of Belper, a distance of about 20 miles ‡.

The highest bed of the Millstone Grit has therefore, *from this cause alone*, a dip of 2000 feet in 20 miles, which is rather more than 1°. What further proportion of the dip may be due to the thinning of still lower beds we do not know. If the Millstone Grit here were entirely covered up by Coal-measures, we might be in ignorance of this rapid thinning, and we should probably refer the "dip" of these Coal-measures to upheaval or depression.

6. *The Weald.*—Perhaps the most striking and most important example of apparent upheaval being partly due to thickening of strata, is that afforded by the Weald.

Up to the year 1855, when Mr. Godwin-Austen read before this Society his memorable paper on the extension of the Coal-Measures §, no one doubted that the Lower Cretaceous and Oolitic rocks passed beneath the London basin. The Wealden Beds were supposed to thin away somewhere, but to be replaced by Oolitic strata, the whole of the beds under the Chalk being bent into a synclinal supporting the London Tertiary basin.

Under these circumstances it was natural to infer that the strata had been uniformly folded into basins and anticlinals, and that the dip of beds exposed at the surface was a true index to the dip of those below.

But when it became apparent that the succession was incomplete, that in fact the entire Lower Cretaceous and Jurassic series were absent under London, but gradually came in and thickened as we receded therefrom, the question was entirely changed ||.

* Prof. Phillips's Geology of Yorkshire, Part ii., Mountain Limestone District, 1836, pp. 19, 32, 41, 46, 77, 175–7.

† *Loc. cit.* p. 137.

‡ See the Sections by Messrs. Green, Foster, and Dakyns, in the Geology of .... parts of Derbyshire, p. 139, Mem. Geol. Survey, 1869.

§ Quart. Journ. Geol. Soc. vol. xii. p. 38.

|| Some of the difficulties which are here referred to concerning the upheaval of the Weald, appear to have presented themselves to Mr. J. E. H. Peyton. See his lecture on the Boring at Netherfield, St. Leonards-on-Sea, 1873.

The rise of the Cretaceous beds towards the central anticlinal of the Weald is too well known to need description here. The base of the Gault, which is 940 feet below sea-level at the Kentish-Town well, would be rather more than 2000 feet above the sea, if the Lower Cretaceous beds were restored over Crowborough Beacon, the highest point along the central anticlinal of the Weald. We may therefore take 3000 feet as the difference of level of the base of the Gault between the centre of the Weald and Kentish Town. For the present we will leave out of consideration the minor anticlinals of the Weald, and will speak only of the great and general anticlinal.

At Kentish Town the Gault rests almost directly upon Palæozoic rocks *; at Crowborough there would be at least 2000 feet of strata between them. How much more than this there may be we shall shortly know by the sub-Wealden boring. But supposing, in order to simplify the subject, that the Palæozoic rocks are met with at a depth of 940 feet below the sea, then is it not plain that the actual rise of the Gault towards the centre of the Weald is accounted for by the gradual thickening of the underlying beds? The palæozoic floor would be a horizontal line (disregarding still the minor folds); the Oolitic, Wealden, and Neocomian strata would all dip to the north, the higher beds dipping more rapidly than the lower; the Gault would have the maximum dip of 3000 feet in 36 miles.

If it be true that great movements which have affected the strata near the surface have had an equal influence on those below (and upon this assumption a large portion of our geological theories are based), then the converse of this should be equally true:—If in any area we can show that deeply buried strata are undisturbed, should we not infer that no great disturbance has affected the overlying rocks, and that the dip of these higher beds must be due to some other cause?

But since the beds with which we are now dealing are partly of freshwater origin, we cannot apply the same reasoning to them as we can to those which are wholly marine. The thinning of the Jurassic rocks may be due to failure of sediment in a south-easterly direction, where was probably the open sea; this is rendered likely by the fact that the limestone beds of the Great Oolite do not, so far as they can be observed, thin in that direction. If the Wealden rocks were deposited in a delta, the direction in which the freshwater sediment failed would also be that in which marine conditions most prevailed. But, so far as we know, marine or estuarine forms are, in the English Wealden beds, confined to the highest and lowest members of that series, and where the beds are seen to thin out against the old rocks they are still of freshwater origin.

This thinning out, however, may have been against the old shore-line of the estuary or lake; and in that case the supposed horizontal position of the palæozoic floor would probably be due to an upheaval of the bed of the lake or delta, or to a sinking of the old land. This necessarily complicates the question, so far as the Weald is concerned;

* There has been doubt as to the age of the lowest rocks found in this well; but Mr. Prestwich now regards them as Old Red Sandstone.

but even after making every allowance for this, we are still compelled to admit that the dip of the higher Cretaceous beds is partly due to thinning of the underlying Neocomian beds.

The main line of watershed of the Weald runs from near Fairlight westwards along, or near to, the main anticlinal line, as far as the western extremity of the Hastings beds, near Horsham; it then turns northwards over the Weald Clay, and goes over the top of Leith Hill, on the Lower Greensand range. The top of the Weald Clay attains its maximum height at Leith Hill, where it is about 750 feet above the sea. If the Weald Clay here had only the thickness which it is known to have further east, it would be necessary to assume that the main Wealden anticlinal, or the line along which the lower beds attain their greatest elevation, passes under Leith Hill; in which case the main anticlinal and the main line of watershed would coincide, as they usually do. From an examination of railway-cuttings between Dorking and Horsham, it is now certain that the Weald Clay must be of unusual thickness there, probably not much under 1000 feet.

The result of this is, that if we consider only the base of the Weald Clay, we see that the main anticlinal lies near Horsham, where we should expect to find it: if we consider only the top of the Weald Clay (or the base of the Lower Greensand), we see that the main anticlinal lies under Leith Hill.

Mr. Beckles some years back published some notes in the Journal of this Society upon the Lowest strata of the cliffs at Hastings*. He there describes a set of beds, the highest member of which is a peculiar sandstone, which, when exposed in large masses on the shore has the appearance of a pavement; hence it has been called the "Tessellated Sandstone." At several places between Hastings and Cliff End sandstone of this character is seen, which by Mr. Beckles is believed to be the same bed; but this lies at very different depths below the base of the Ashdown Sand. Either, then, Mr. Beckles is mistaken as to the position of these sandstone beds, or the beds between them and the base of the Ashdown sand thicken out enormously in a comparatively short distance. This thickening would occur just where the anticlinal comes; in fact the "Fairlight anticlinal," which is assumed to have affected the Ashdown Sand and overlying beds, would be largely accounted for by this thickening. For this reason, and also because the "tessellated sandstone" cannot be continuously traced, I have always thought that Mr. Beckles was mistaken in the matter; but the numerous instances which we have considered of dips and anticlinals being produced by thickening of underlying strata, certainly very much weakens one of the arguments against Mr. Beckles's view†.

* Vol. xii. p. 288.

† Mr. A. Tylor has remarked upon the thinning of the lowest Wealden beds of the Sussex coast. In describing a section of the coast, which is given in the paper, he says:—"The passage of some beds of sand-rock into clay is well shown on the east of Hastings......; and the thinning of the Castle Rock on the same line is also shown. The bearings of the same strata to the west, through St. Leo-

7. *Observations on Basins.*—We have seen that there is a very general tendency for beds to thin towards the dip, and to thicken towards the rise; but the illustrations given are of strata which support geological basins. With the strata forming the basins themselves the reverse appears to be often the case; they thicken towards the centre of the basin.

This is certainly the case with the Lower Tertiary strata of the London basin; it seems to be also the case with the Hampshire basin. Professor Hébert informs me that the same thing occurs in the Paris basin; whilst the Lower Cretaceous beds which support that basin thicken as they rise to the west.

It is a point of common knowledge amongst the mining engineers in the north of England that the strata of the Newcastle coal-field thicken towards the centre of the basin. The seams of coal are at a greater distance apart along the centre of the basin than towards its western margin, the easterly dip being somewhat greater in the lower seams than in the higher. The difference of the dip due to the general easterly thickening is of course usually small; but it occasionally happens that the difference is very marked, and in consulting colliery plans it is necessary always to bear in mind to which seam the plans refer.

Besides the general easterly thickening of the strata, there are occasionally local thickenings of certain parts, the result of which is to cause undulations in the overlying beds which are *apparently* the result of movements of the strata. I may just mention one case, although (as the area in question is not yet published by the Geological Survey) I cannot give full details, which, indeed, are not necessary. An important seam of coal on the north-east of Morpeth had been worked at Ashington to its regular outcrop on the west; borings carried through the Boulder Clay still further west proved that this seam rolled in again in a small basin, in which a large colliery (Longhirst) is now working. A deep bore-hole put down at the outcrop of the Ashington seam proves that some sandstones which underlie it are of great and unusual thickness there; from this we may infer that the "anticlinal," which throws out the upper seam for a short distance, is due, largely if not entirely, to the local thickening of this sandstone. Yet if these were rocks which were not deeply explored for mining-purposes, and if we reasoned only by what we see at the surface, we should certainly refer the anticlinal and synclinal in question only to movements of the strata.

8. *Conclusion.*—Whatever value may be attached to many of the foregoing remarks, I think this much is certain: enough has been said to prove that great caution is necessary in reasoning, from the observed dip of beds, to any conclusions as to great movements of the earth's crust. In fact, it would seem that we can never feel

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nard's to Bexhill, are of considerable interest, as they appear to lose much of their thickness before they pass under the highest part of the Hastings Sand series and the overlying Weald Clay of Pevensey."—Quart. Journ. Geol. Soc. vol. xviii. p. 252, 1862.

absolutely certain that any observed general dip is wholly due to disturbance. The dip may often be so great that we may be quite sure that some part of it is due to this cause; but it will generally happen that the proportion of the dip due to disturbance, and that due to possible thinning of subjacent beds, cannot be determined.

Besides the question of the movements which the earth's crust has undergone, there is another question involved in this inquiry, of special interest just now; that is, the influence which such movements have had in producing the present features of the surface.

Most geologists now believe that this influence has been but small, that it has had little or no *direct* effect in producing the present surface-features, and that it has only been exerted in guiding the action of the denuding agents now quietly at work around us. But others still believe that the direct influence of disturbance of the strata has been very great. As regards the Weald it has long been held, chiefly through the writings of Mr. Martin and Mr. Hopkins, that in the original upheaval of that area a system of longitudinal and transverse fissures was formed, which not only marked out, but immediately form the valley-systems.

It is, perhaps, scarcely necessary to remark that there are other signs of disturbance met with in the rocks besides the rise and dip of beds. There are sharp flexures and contortions of strata, as well as actual fractures and faults, which can only be due to movements of the rock-masses.

But, after taking all these fully into account, I believe that, as the result of this inquiry, one supposed cause of the formation of surface-features is materially weakened; and yet the fact that great denudation has taken place remains. Not only so, but the amount of denudation which has actually taken place is greater than is generally supposed. For if the strata which now remain are thicker at their outcrops and at their escarpments than they are further to the dip, we may fairly assume that the strata which once stretched beyond the present escarpments were thicker than any which are still preserved.

Discussion.

The Rev. Mr. Fisher remarked that he had always considered that the Palæozoic rocks under London had formed an axis against which the Secondary rocks had abutted, instead of their being carried over the old rocks, as shown in the diagram. He presumed that there would be difficulty in any natural cause constantly leading to the thickening of strata at some particular spot during successive epochs so as to form a ridge in a certain position, and argued that the shattered condition of the flints in some tilted rocks showed that they had been violently upturned.

Mr. Seeley thought the paper extremely suggestive, though possibly its suggestiveness had been carried too far. If the author's views were correct, the sea in which the beds had been deposited must have been of enormous depth; but of this we had no evidence. He could not believe that the Chalk or any other sedimentary deposit could in the process of deposition assume such dome-like forms as would be necessary under the author's hypothesis.

Prof. Hughes considered that there were two kinds of thickening—(1) by deposits from a shore-line, or (2) by sediment accumulating in a basin. The instances adduced appeared to be the result of the thickening of strata in a basin. He accepted the cautions of the author as to hasty deductions from the dip of strata at the surface.

Mr. Bauerman considered that the Lower Lias was of greater thickness at Burford than supposed by the author.

Mr. Topley, in reply, stated that he did not dispute the fact of the Palæozoic rocks being much disturbed and crumpled, nor did he deny that there may have been some disturbance of the upper beds. What he wished to point out was that the disregarding of the fact that strata thickened in certain directions might be, and had been, a fruitful source of error.

20. *On the* Occurrence *of a* Tremadoc Area *near the* Wrekin *in* South Shropshire, *with* Description *of a new* Fauna. By Charles Callaway, Esq., M.A., B.Sc., &c. (Read March 11, 1874.)

(Communicated by Dr. H. A. Nicholson, F.G.S.)

[Abstract.]

The author stated that in an exposure of light-green micaceous shales dipping south-east at 50° at Shineton, near Cressage, which are represented as of Caradoc age in the Geological-Survey Map, he found a series of Trilobites and other fossils which induced him to regard these Shineton shales as belonging to the Lower Tremadoc series. He described as new species *Asaphus Eos*, *Conocoryphe Salteri*, *C. angulifrons*, *Platypeltis Croftii*, *Conophrys salopiensis*, *Lichapyge cuspidata*, *Lingulella Nicholsoni*, *Metoptoma Sabrinæ*, and *Theca lineata*. The author regarded these shales as the equivalents of beds containing *Dictyonema* found near Malvern and at Pedwardine.

Discussion.

Mr. Etheridge differed entirely from the author, and thought the fossils exhibited by him were of Caradoc age.

Mr. Hicks was inclined to refer the fossils to the Upper Llandeilo; but the fragments exhibited were not sufficient to enable the species to be determined.

21. *On* Murænosaurus Leedsii, *a* Plesiosaurian *from the* Oxford Clay. Part I. By Harry G. Seeley, Esq., F.L.S., F.G.S. (Read May 13, 1874.)

[Plate XXI.]

While on a visit to Charles E. Leeds, Esq., M.A., of Exeter College, Oxford, a gentleman whose specimens have more than once enriched the writings of Professor Phillips, I was shown a Saurian in such perfect preservation as previously, so far as I am aware, had rarely been seen except from the Lias. It was gathered from the Lower Oxford Clay (a stratum abounding in Plesiosaurians in the middle of England) in Huntingdonshire, in fragments almost innumerable, which have been adjusted and reunited with remarkable skill and zeal by the labours of Mr. Charles Leeds and his brother Mr. Alfred Leeds, so that now the animal displays:—the front and hinder parts of the skull; the lower jaw, somewhat over a foot long; a vertebral column of 79 vertebræ, from which, however, nearly all the tail is missing—the vertebræ preserved being 44 cervical, 3 pectoral, 20 dorsal, 4 pelvic, and 8 caudal; numerous ribs; the coracoids and scapulæ; the pubes, ischia, and iliac bones, together with both fore and hind limbs. Whether the tail has become a prey to the casual collector's unscientific mania for bones I know not; but these remains, being the fruit of long zealous collecting and care, could obviously only have been gathered in a district where competition was kept subordinate to scientific spirit. Finding that this noble specimen (from which hardly any important part except the tail is lost) indicated in my opinion a new genus as well as a new species, Mr. Charles Leeds volunteered to write from my dictation the account of the animal which I am thus by his kindness able to submit to the Geological Society. The short time at my disposal compelled me to leave the hind limbs undescribed, to form hereafter the subject of another communication, when I hope to offer to the Society some account also of the other undescribed or imperfectly indicated Plesiosauria from the Oxford Clay, with which this species may be properly compared.

The Skull.

The skull is represented by the premaxillaries, portions of the maxillary bones, the frontal bones, supraorbital, postfrontal, parietal, basisphenoid, exoccipital and basioccipital bones, and the lower jaw.

The premaxillaries carry five teeth on each of the bones, which are connected by a nearly straight median suture. They have the surface rough and irregular on the superior and lateral parts as well as on the palate, the roughnesses being due to a conical bulging of the bone around the entrance to nutritive bloood-vessels. Each premaxillary bone is triangular in front; but no sutures can be seen separating the bones from the nasal bones behind, perhaps because the premaxillary bones extend back to the nares as in *Plesiosaurus*. The anterior alveolar border is convex and measures $2\frac{3}{4}$ inches round the lateral curve on each side. The posterior median bird-like or lizard-like extensions of the premaxillaries (unless they are nasals blended with the premaxillaries) are narrow and smooth, meet each other in a penthouse ridge in the median line of the skull, and join the frontal bones at a distance of 5 inches from the rounded extremity of the snout*. The frontal bones are about $2\frac{3}{4}$ inches long, and terminate backward in the foramen parietale, the posterior border of which is formed by the parietal bones. The frontals are flattened bones, with a groove on each side of a slightly elevated median ridge; the suture between them is distinct; they measure $1\frac{1}{2}$ inch from side to side where narrowest, are compressed from above downward; and nearly the whole of the outer parts of the under-surfaces form the upper borders of the orbits; the sides of the bones are subparallel; they are slightly concave from side to side. They may have small distinct supraorbital ossifications in front, above the orbits, though from the state of fracture in which the specimen was found this is not quite certain. From the posterior angle, in which they join the parietal bone, the narrow postfrontal bones are given off. The postfrontals are then directed outward and slightly forward, and are traversed by a ridge which divides their outside surface into anterior and posterior areas. The foramen parietale is large, and is directed downward and backward, increasing in size as it descends. The parietal bone is greatly compressed from side to side, forming a sharp longitudinal keel above; as in the nearly mature fowl, it shows no trace of a median suture, though the frontals are separate; it measures $2\frac{1}{4}$ inches from front to back, and terminates posteriorly in a straight, transverse, almost smooth and flat, vertical suture: the bone widens from side to side from before backward, and becomes compressed at its outer posterior border. The hinder part of the parietal bone is occupied on the underside by a small part of the cerebral surface. This is concave from side to side, and straight from front to back, with a slight median ridge. This surface in front was probably occupied by the small lizard-like cerebral lobes which, as among Teleosaurs, were prolonged forward into two long olfactory nerves; posteriorly the cerebral surface is more excavated, seemingly for the posterior border of the cerebral lobes, which was raised above the portion of the brain which succeeded it next behind.

The basisphenoid is united by suture with the basioccipital bone; like the basisphenoid of *Ichthyosaurus*, it appears to be perforated by the carotid, which passes obliquely through it. The basisphenoid appears to be underlapped by the basitemporal or by a backward prolongation of the presphenoid bone.

The basioccipital bone is $1\frac{1}{2}$ inch long. It is remarkable for having a nearly hemispherical surface for the occipital condyle, to which the exoccipital bones do not contribute as they do in many Plesiosaurians

* This interpretation differs from Prof. Owen's account of the bones in *Plesiosaurus*, but agrees with a memorandum of my own on the bones in *Plesiosaurus Zetlandicus*, at York.

and in *Teleosaurus.* The basioccipital condyle is short from front to back, and has its chief extension from above downwards, indicating that the head of the animal had more vertical than lateral movement; the condyle is margined by a slight depression. The under surface of the bone, as usual, is concave from side to side and prolonged outward and downward into strong short lateral processes. The exoccipital bone is preserved only on one side, where it is slightly fractured. It does not appear to be perforated for the hypoglossal nerve or for blood vessels. Its external surface is narrow, flat, and inclined obliquely towards the median line of the cranium; it terminates behind in a sharp border, which is inclined obliquely inward and forward so as to make the foramen magnum pyriform.

The anterior nares, which are imperfectly preserved, appear to be small, and situate $3\frac{3}{4}$ inches from the anterior termination of the skull and about $1\frac{1}{8}$ inch from each other.

Lower Jaw.

The lower jaw is 13 inches long. The symphysis is 2 inches long, with the symphysial suture obliterated. In length the rami are gently convex on the outer side. The jaw is broadest from side to side at the coronoid process, where it measures $6\frac{1}{2}$ inches in width, and $1\frac{1}{2}$ inch in vertical depth. At this point, on the underside of the jaw, the dentary bone ceases to be prolonged backward: it looks obliquely downward, outward, and forward; its surface is rough, and towards the symphysis is pitted with the apertures of blood-vessels and nerves. On the underside of the anterior symphysial part of the jaw a concavity runs parallel to its inner border. Each ramus appears to have sockets for twenty-one teeth. The portion of the dentary bone interior to the aveolar margin in the front part of the jaw is an inch wide, becoming narrower behind; it is oblique and convex, but is more vertical at its backward extension. At $4\frac{1}{2}$ inches behind the anterior extremity of the symphysis it is overlapped by the splenial bone, which in front is only half as deep as the inner border of the dentary bone which it overlaps. The surfaces of both dentary and splenial bones are marked with the canals for many small blood-vessels, while the canal for Meckel's cartilage is open for at least 5 inches in front of the articulation of the lower jaw. Posteriorly to the coronoid process the jaw is compressed from above downward so as to be only 1 inch deep; its upper part is formed by the coronoid bone, its lower part by the surangular bone. The coronoid appears to extend backward so as to form the anterior border of the articulation of the lower jaw. The articular surface is quadrate, about $1\frac{1}{16}$ inch from side to side, and less than 1 inch long; it is concave from front to back, with a slightly elevated oblique ridge passing from the inner anterior corner to the outer posterior side; the posterior margin of the articulation is elevated, and consists of an inner and an outer part. The articular bone appears to be small, thin from above downward, superimposed upon the angular bone; it widens the jaw from side to side; and below the articulation the angular bone is compressed from side to side to form a rounded heel. The heel behind the articulation is $1\frac{3}{4}$ inch long; at first it is triangular in section from being flattened above, but tapers posteriorly in all ways and terminates in a rounded vertical concavity about $\frac{1}{2}$ an inch in diameter. The extreme width of the lower jaw over the articulations is $5\frac{1}{2}$ inches; the heels approximate still more and appear to have measured $4\frac{1}{4}$ inches from side to side; but the left heel is fractured.

The hindermost teeth look directly upward; but as they approach the front of the jaw they are necessarily directed more and more outward and forward.

Vertebral Column.

The vertebral column, as preserved, comprises 79 vertebræ, which I group as 44 cervical, 3 pectoral, 20 dorsal, 4 pelvic, and 8 caudal. No vertebræ appear to be missing in the series; and probably these numbers, except for the missing tail, give the vertebral formula of the species. Arranged end to end, as Mr. Leeds has placed them, they measure about 13 feet; so that with the missing part of the tail the length of the vertebral column may have been something under 15 feet, or nearly as long as in *Plesiosaurus macropterus* from the Lias, though the proportion of length of head to length of body probably comes nearest to *Plesiosaurus dolichodeirus*, where it is one to thirteen.

Cervical Vertebræ.

The atlas and axis are anchylosed; and all trace of their union with the wedge-bones is obliterated. From front to back these vertebræ measure rather less than $2\frac{1}{4}$ inches. The atlantal cup for the basioccipital is imperfectly preserved; it is $1\frac{1}{8}$ inch deep, but appears to have been narrower. The whole mass widens from side to side behind the posterior articular surface of the centrum, being nearly circular, $1\frac{1}{4}$ inch from above downward and $1\frac{3}{8}$ inch from side to side; it is flattened, but slightly concave. The neural arches are not preserved, but appear to have been distinct from each other; and the arch of the axis was more developed than that of the atlas. The neural canal is flat below and smooth, and $1\frac{3}{4}$ inch long, so that, as is usual in Plesiosaurians, the inferior wedge-bones prolong the articulation for the basioccipital bone forward considerably on the inferior margin. A hypapophysis is developed in the median line of the underside, but does not reach within $\frac{1}{2}$ an inch of the hindmost articular surface; anteriorly it is broad, strong, and rounded, posteriorly sharp and compressed from side to side, but not greatly developed. The cervical ribs of these vertebræ are broken away; that of the atlas appears to have been very small, while that of the axis does not differ in its articular facet from that of an ordinary cervical vertebra.

The seventh cervical vertebra (Pl. XXI. fig. 1) has the centrum

$1\frac{1}{2}$ inch long, with the articular surface in front $1\frac{1}{2}$ inch wide and rather less than $1\frac{1}{4}$ inch deep; on the posterior surface these dimensions are somewhat exceeded. The articular surface of the centrum is concave, more so in front than behind; both surfaces are margined by a groove, which indicates the union of the epiphysis with the centrum. The centrum is greatly compressed in its upper half from side to side, and is therefore concave from front to back laterally; below the middle on each side there is a sharp slightly elevated ridge, which dies away at the articular margins. At the junction of the side of the centrum with its base the cervical ribs are given off: each is attached by a narrow ovate surface about an inch long, is compressed from side to side, directed downward and a little outward and backward in a curve. The anterior margin of the rib is convex in length and sharp in edge; the posterior margin is concave from above downward, and rounded from side to side; the inner surface of the bone is flattened; but the outside is more convex: the free end of the bone terminates in a concavity indicating a cartilage. The suture between the neural arch and the centrum is obliterated. The total height from the base of the centrum to the top of the neural spine is $3\frac{1}{4}$ inches. The length from the front of the anterior zygapophyses to the back of the posterior zygapophyses is $2\frac{1}{4}$ inches. The anterior zygapophyses project about $\frac{1}{4}$ of an inch in front of the centrum; the posterior zygapophyses project about $\frac{1}{2}$ an inch behind it. The anterior zygapophyses are large oval facets looking upward and inward; the part of the neural arch behind them is constricted; and from their base on each side a ridge arises which is prolonged backward, upward, and outward to form the upper margin of the posterior zygapophysis (which measures $\frac{3}{4}$ of an inch from side to side) and form the limits of a small table from which the neural spine arises; below this oblique ridge the posterior portion of the neural arch is compressed from side to side; above it the neural arch rises 1 inch. The neural spine terminates in a sharp short posterior border, a little concave and nearly vertical, and has a sharp long anterior border inclined obliquely backward.

In passing down the vertebral column the vertebræ get steadily longer from back to front, and steadily larger; the neural spines become a little wider, from back to front, and stronger; and at the eighth vertebra the cervical rib has the usual hatchet-shaped pattern. Lower down the vertebral column the antero-posterior ridge on the side of the centrum becomes shorter and less elevated, and finally disappears about the thirty-second vertebra; the oblique ridge between the anterior and posterior zygapophyses gradually becomes more horizontal and less elevated, so that in the lower part of the neck there is no trace whatever of a platform from which the neural spine arises. From about the fifteenth vertebra to about the thirtieth the neural spine, which has become much widened, is compressed from side to side, and terminates upward in a long flat cartilaginous surface, and has its anterior border nearly vertical, and its posterior border inclined obliquely forward. In the seventeenth vertebra, which has the centrum $1\frac{7}{16}$ inch long, the neural spine rises more than 2 inches above the zygapophysial ridge, while the vertebra measures $4\frac{3}{4}$ inches in extreme height. In the middle of the neck the articular surface of the centrum becomes much more circular, and appears to be, relatively to its size, rather less deeply cupped. In the twenty-fourth vertebra the centrum is $2\frac{1}{16}$ inches from side to side in front, and $1\frac{7}{8}$ inch from above downward; at the side it measures more than $2\frac{1}{4}$ inches from back to front. The circumference of the articular surface has now become roughened for the attachment of small connecting vertebral ligaments. The upper part of the body of the centrum remains still greatly compressed from side to side. The extreme height to the top of the neural arch is $5\frac{3}{4}$ inches; the zygapophysial ridge is nearly horizontal; and the sharp anterior process of the neural spine extends forward between the anterior zygapophyses of that vertebra, and divides the posterior zygapophyses of the preceding vertebra from each other; the neural canal is remarkably small and triangular, higher than wide, and higher behind than in front.

In the thirty-third vertebra (fig. 2) the centrum is $2\frac{1}{4}$ inches long, in front $2\frac{1}{4}$ inches deep, and about $\frac{1}{16}$ to $\frac{1}{8}$ of an inch wider. The articular surfaces are relatively flatter, while the margin external to the epiphyses is now becoming wider. The posterior articular surface is about $2\frac{1}{2}$ inches wide and $2\frac{1}{4}$ inches deep. The zygapophyses are, in front, on their inner articular surfaces *concave* from above downward, so that they almost meet in a median line, forming the lower half of a cylinder. The extreme height to the top of the neural arch is 7 inches; the extreme width over the zygapophyses is $3\frac{1}{2}$ inches; the antero-posterior extent of the top of the neural spine is $1\frac{3}{4}$ inch; the anterior border of the neural spine is slightly concave from above downward. Between the posterior zygapophyses, convex from above downward, there is a median slit into which the lower anterior margin of the neural spine of the succeeding vertebra is wedged, thus constituting a new kind of vertebral joint, comparable in complexity to that of Iguanoid lizards and serpents, though of somewhat different mechanism and function.

In the thirty-ninth vertebra (fig. 3) the neural canal becomes considerably larger; the vertebral articular surfaces are becoming flatter; the cervical ribs are wider in their attachment, and incline more markedly to the posterior border of the centrum: this vertebra has an exostosis on the right posterior articular margin; its height to the top of the neural spine is rather more than $7\frac{1}{4}$ inches. The neural spine is $1\frac{5}{8}$ inch from back to front in the middle. The neural spine reaches its extreme height in the fortieth vertebra, where it extends to $7\frac{1}{2}$ inches. The posterior zygapophyses are margined above by a slightly elevated ridge.

In the last cervical, the articulation for the rib, which in the three preceding vertebræ has been rising on the side of the centrum and becoming circular and elevated, is now higher than wide and inclined a little backward. The centrum increases in flatness, and the neural spine is inclined slightly backward; the articular edges are more than usually compressed and expanded; and the nutritive foramina are very much smaller than in the early part of the neck, in which there is only one pair. In length from back to front the centrum is diminished to rather less than 2 inches; its width from side to side is increased to $2\frac{3}{4}$ inches, while from above downward the centrum measures $2\frac{1}{4}$ inches.

Pectoral Vertebræ.

In these vertebræ the face of the centrum is somewhat larger than in the terminal neck-vertebræ, and has a small central pit; the articulation for the rib is long and oblique, formed partly by the neural arch, partly by the centrum; it is longest in the middle pectoral, broadest in the third. The under surface of the centrum is rounded from side to side in the first, flatter in the second, while in the third it is so flat on the under surface as almost to make an angle with the sides, a character which is slightly exaggerated by compression. The neural arches are imperfectly preserved, but appear to be inclined a little backward as in the last cervical.

Dorsal Vertebræ.

The neural arch is not well preserved in the dorsal vertebræ till the seventh; and none of the neural arches of the dorsal vertebræ retain their transverse processes for the attachment of the ribs. The centrum is modified in form, owing to the rib being raised on to the neural arch; it is flat on the underside from back to front, very slightly concave there from side to side, and has its sides considerably compressed, and shows below the middle on each side a large nutritive foramen. What was in the cervical vertebræ the pit in the centre of the articular surface of the centrum now becomes slightly elevated, with a central puncture, in some respects recalling a Pliosaurian character. The zygapophyses retain the singular method of articulation already described in the later cervicals. The neural spines now, however, widen in antero-posterior extension, while from below upward they are extremely compressed from side to side. In all the vertebræ both of neck and back the neurapophyses join the centrum after the manner characteristic of *Plesiosaurus,* and show no approach to the circular pedicles of *Pliosaurus.* The transverse processes of the seventh and succeeding vertebræ are directed upward and outward from the part of the neural arch in front of the posterior zygapophyses; these transverse processes are compressed from above downward in a sigmoid fold, being higher in front than behind, and convex above in front, and concave behind, with corresponding folds below.

The tenth dorsal vertebra has the centrum much as in the vertebræ already described, except that the circumference of the articular margin of the centrum is now becoming much sharper and losing the rounded edge seen in the neck; the base of the transverse process is getting shorter from back to front; the sides of the neural spine are subparallel; it is $1\frac{7}{8}$ inch wide, truncated as usual at the uppermost end, which is 7 inches from the base of the centrum;

the neural arch is inclined very slightly backward. Beyond this vertebra, which is the middle of the back, the vertebræ get gradually smaller, and the neural spines shorten, though they retain their breadth. The sixteenth dorsal has the centrum $1\frac{7}{8}$ inch long, and measures $6\frac{1}{4}$ inches from the base of the centrum to the top of the neural spine; the position of the transverse processes remains unchanged, but the base of the pedicle has become shorter from front to back, and is rhomboidal in section.

Pelvic Vertebræ.

The neural arch is not preserved in the pelvic or sacral vertebræ, and the form of the centrum is modified in consequence of the descending position of the transverse process. The two middle pelvic vertebræ appear to have the centrum shorter from back to front than the others, measuring only $1\frac{1}{2}$ inch. The articular surface of the centrum appears to be somewhat depressed from above downward, and to be more concave than in the dorsal region, while the underside is less convex from side to side. The transverse process is strong, and subquadrate where broken off at the base. In the last pelvic vertebra the transverse process appears to have been much larger than in the others, and to have come away from the centrum by a sutural surface $1\frac{1}{4}$ inch deep by $1\frac{1}{8}$ inch wide, which stands up from the centrum with an elevated margin.

Caudal Vertebræ.

In the next three vertebræ the caudal rib has descended to the side of the centrum, and is marked by a large thick fragment of a rib, which appears to have been anchylosed to the centrum. These vertebræ are less than $1\frac{1}{2}$ inch long, and have the articular centrum-margins bevelled as in the neck. As in the pelvic region, the neural arch rises from a more anterior part of the centrum than is the case with the dorsal vertebræ, and is shorter from back to front. The third caudal has the neural arch preserved, and shows that the zygapophysial facets still retain their quarter-cylinder form: the extreme height from the base of the centrum to the top of the neural spine is 5 inches. The neural spine is directed backward, and tapers from below upward, where it is rather more than an inch from back to front, and is somewhat expanded from side to side at its superior termination.

The fifth caudal (fig. 5) is the first which gives indications of a chevron bone, and that only on the left side. The facets for these bones in the succeeding vertebræ are singularly large and elevated, and somewhat triangular in form. They raise the side of the centrum near them, and are so placed that the chevron bones attached to them never impress the articular surface of the succeeding vertebræ (fig. 4), in this differing from *Plesiosaurus* and recalling *Mosasaurus*. In the fifth caudal the centrum is $1\frac{1}{2}$ inch from front to back, $1\frac{1}{8}$ inch from side to side, and $1\frac{1}{2}$ inch from above downward. As in all the other vertebræ, the posterior measurement is slightly longer than the anterior measurement. The articular margins do not stand up from the centrum as in the cervical region; and the upper part of the centrum is but slightly compressed laterally, so that the sides of the bone are not very concave from back to front. The pedicles to which the chevron bones were attached have left rough granulated surfaces, which do not enter into the posterior face of the centrum; they look obliquely downward and backward; and often one is somewhat larger than the other; and occasionally the chevron bones were anchylosed to them*.

The Coracoids.

The extreme width of the coracoids from side to side immediately behind the articulations is rather less than 14 inches. The bones are imperfectly preserved, the whole of their interior and posterior parts being broken away; moreover they are crushed at the articular surfaces, except in the median line. As much as is preserved of the median suture measures 4 inches in length and 2 inches in depth; the surface is pyriform, tapering most rapidly behind. The two bones appear to have been placed during life very nearly in the same plane. The abdominal surface behind the broad thick anterior part and within the curved lateral parts was a shallow basin; and externally the bones presented a corresponding bulging, which in the median line of the body formed a marked keel; externally, at right angles to this keel, where thickest, the bone is compressed and extends transversely as a rounded surface towards the point where the articular surfaces for the scapula and humerus meet, but does not reach them. The whole of the articular surface for the scapula lies in front of this rounded ridge, which has a concave outline in front on each side, with the concavities approximating anteriorly so as to form a strong median process, which extends further forward than any part of the articular surface for the scapula. In front of this rounded transverse ridge the inner side of the bone is prolonged anteriorly, so as to form a compressed anterior extension of the coracoid, very thin and deeply concave in its antero-posterior extension of nearly an inch, and very slightly concave from side to side. It is broken away towards the median line of the animal; but towards the outer anterior surface it widens and thickens, blending with the adjacent bone to support the articulation for the scapula. The length of the scapula-articulation is rather over $2\frac{1}{2}$ inches; it looks obliquely forward and outward. In its compressed state it is $1\frac{1}{4}$ inch deep where it joins the articular surface for the humerus, which is about equally long and concave from before backward, and from below upward; its anterior margin is 6 inches, and its posterior margin $7\frac{1}{4}$ inches from the median line. The least width across both the coracoids from side to side is $9\frac{3}{4}$ inches at a distance of 7 inches behind the anterior apex of the bones; the extreme posterior extension is $13\frac{1}{4}$ inches behind the most anterior

* I have occasionally seen similar caudal vertebræ from the Kimmeridge Clay; and about five years ago Mr. Charlesworth showed me a series of cervical, dorsal, and caudal vertebræ from the Kimmeridge Clay of Ely, with the caudals similar; but they belonged to a distinct species.

point; the bones have extended further backward; but at the point where fractured they would have measured 14 inches from side to side. The outermost lateral margin is flat, concave from before backward in a continuous sweep; the bones are convex from side to side, and considerably compressed towards the distal end. The coracoids have no anterior articular surfaces in the median line of the body.

The Scapulæ.

The scapulæ are of a form distinct from that seen in any described Plesiosaurian genus. They are imperfectly preserved, but were placed inclined inward and forward, like the scapulæ of *Plesiosaurus.* The inferior surface is flat from side to side, and concave from before backward. The bone is four-sided, comprising two posterior portions; the articulation for the coracoid is $2\frac{1}{2}$ inches long, and the humeral surface rather more than 2 inches long; the diameter of the bone between these extremes is $3\frac{1}{2}$ inches; its extreme length as preserved, measured from the junction of the two posterior sides to the junction of the two anterior sides, is about 5 inches. The inner margin, forming the outer part of what would usually be the scapulo-coracoid foramen, is compressed and sharp, and concave, so as to continue the curve of the front border of the coracoid bone; the outer margin is nearly straight and sharp, making an angle with a part of the bone, which is prolonged from the abdominal to the dorsal part of the body. The lateral part is at about a right angle with the inferior surface. Posteriorly and inferiorly the anterior process is thickened and rounded, the ridge being prolonged downward and outward to the inner and anterior humeral margin. The surface of the bone between this ridge and the scapulo-coracoid foraminal border is oblique, looks inward, and is concave in each direction. The anterior portion may have extended much further forward, being exceedingly thin; but its form is such as to suggest that no clavicular bones or interclavicle existed, and that the bones may have met so as to complete the one large foramen which they indicate.

The Pelvic Bones.

All the pelvic bones are preserved. The pubes and ischia each unite to form more marked median keels than that formed by the coracoids, while the pubes and ischia do not meet each other in the antero-posterior median line, as in *Plesiosaurus*, so as to form two foramina, but constitute one foramen, $8\frac{1}{2}$ inches from side to side, which is slightly indented by the forward mesial angular margin of the ischia behind, so that it measures $3\frac{1}{2}$ inches from back to front in the median line, and four inches from back to front where longest, midway in each lateral moiety.

Neither ischium is perfectly preserved; and each bone lies entirely behind its articular junction with the pubis. This line of union is transverse and looks forward, and is nearly $1\frac{1}{2}$ inch long, while the articular surface for the femur is fully $2\frac{1}{2}$ inches long; but its shape is probably altered by compression. The external surface of the bone is slightly convex in each direction, and measures 7 inches from the median line to the femoral margin; its least width is $2\frac{7}{8}$ inches at about 2 inches from the femoral surface. The anterior margin is sharp and compressed and concave, the concavity looking forward and slightly inward. The bone appears to have had the usual triangular form seen among Plesiosaurs; but its thin posterior expansion is not entirely preserved; its posterior border is sharp and compressed, thinner than the anterior border, concave in a curve which extends inward and backward to within about $2\frac{1}{2}$ inches of the median line, where its antero-posterior extension is $4\frac{1}{2}$ inches measured from border to border. The median symphysis is thick; rather less than 3 inches of it is preserved antero-posteriorly; and, as compressed, it is more than $1\frac{1}{4}$ inch deep. The inner side of the bone is concave from side to side as well as concave from back to front. The bones meet at an angle of 120°.

The pubis is thin, and only the posterior portions are preserved; the antero-posterior extent of the symphysis appears to be about $6\frac{1}{2}$ inches; but this is inferred from the two incomplete bones.

The bone is thickest at its posterior side and becomes exceedingly thin anteriorly. The width of the bone from the posterior point of the symphysis to the outermost margin of the femoral articulation is 8 inches; the ischiatic union extends $1\frac{3}{4}$ inch behind this line; and its innermost margin is within $4\frac{1}{2}$ inches of the symphysial line. The outer margin of the pubis is compressed from side to side, and directed outward, so that $3\frac{1}{2}$ inches in front of the femoral articulation the concave outer margin is more than $8\frac{1}{2}$ inches from the median line. Like the ischium, the bone is slightly convex on its external side, slightly concave on its abdominal surface; a slightly inflated thickening runs parallel to the lateral border.

The iliac bones are 7 inches long. The articular surfaces appear to have been somewhat expanded so as to extend over the upper part of the head of the femur; but it is difficult in the present state of the specimens to determine by what surfaces each could have joined the pubis and ischium so as to form the acetabulum.

Each bone is compressed from side to side, $2\frac{1}{2}$ inches broad at the proximal end, and expanded at the sacral end in the same direction to a width of two inches, its least width in the middle being $1\frac{1}{8}$ inch. The anterior border from above downward has a slight sigmoid flexure from side to side; but its anterior lateral margin is nearly straight and about 6 inches long. The posterior margin is concave, and 5 inches long. The compressed sacral end is convex from before backward, and inclined backward. Half an inch below the uppermost margin the inner side shows scars, 1 inch long, of two sacral articulations.

The Fore Limb.

The fore limb is much smaller than the hind limb. The humerus is 10 inches long, and but slightly expanded at the proximal end of the cylindrical shaft; and this expansion appears to be due to the development of the great trochanter in a transverse direction to the distal expansion, which is $5\frac{1}{2}$ inches from side to side. The bone is compressed slightly from the proximal to the distal end, being about $2\frac{3}{4}$ inch deep proximally and $1\frac{3}{4}$ inch distally. The anterior border is slightly concave; the posterior border is much more concave, especially towards the distal end. In the middle the shaft is about 2 inches in diameter. There are strong roughnesses towards the proximal end, indicating the attachment of muscles; and a slightly elevated longitudinal ridge marks the middle of the posterior border of the bone. The distal articular surface is divided into two flattened areas, apparently with cartilaginous margins back and front, to which bones may not have been articulated.

The ulna and radius are short from above downward, as in *Plesiosaurus*, and quite distinct in form from those bones in that genus. The radius is compressed from side to side towards the external border, and thickened towards the ulnar border; it is more than $2\frac{1}{2}$ inches from side to side, and is nearly 2 inches from above downward where deepest, near the external border. The humeral surface is slightly convex; the distal surface is slightly concave from side to side; it shows a short second facet for the middle carpal. The ulnar surface is deeply concave from above downward.

The ulna is shorter from above downward on its radial margin, where it measures about 1 inch, than on its external border, which is convex, and in extreme depth from above downward measures nearly 2 inches. The bone is about $1\frac{1}{4}$ inch through from side to side, and $1\frac{3}{4}$ inch along its proximal articular surface. The distal end includes two articular surfaces, of which the posterior is rather the smaller. The surface facing the radius is concave from above downward, and appears to have been occupied by muscle while the external margin, like the external margin of the radius, was cartilaginous. There are six thick polygonal carpal bones preserved. They appear to have formed two rows of three each. The longest is about $1\frac{1}{2}$ to $1\frac{3}{4}$ inch long by $1\frac{1}{4}$ inch deep. The phalanges are strong and thick, like those of *Pliosaurus*, and not compressed from side to side, as in typical Plesiosaurs. Towards the distal end of the limb they become short, and have the proximal and distal ends of the bone greatly expanded relatively to its length. There appear to have been five digits; but the number of phalanges in each is not known.

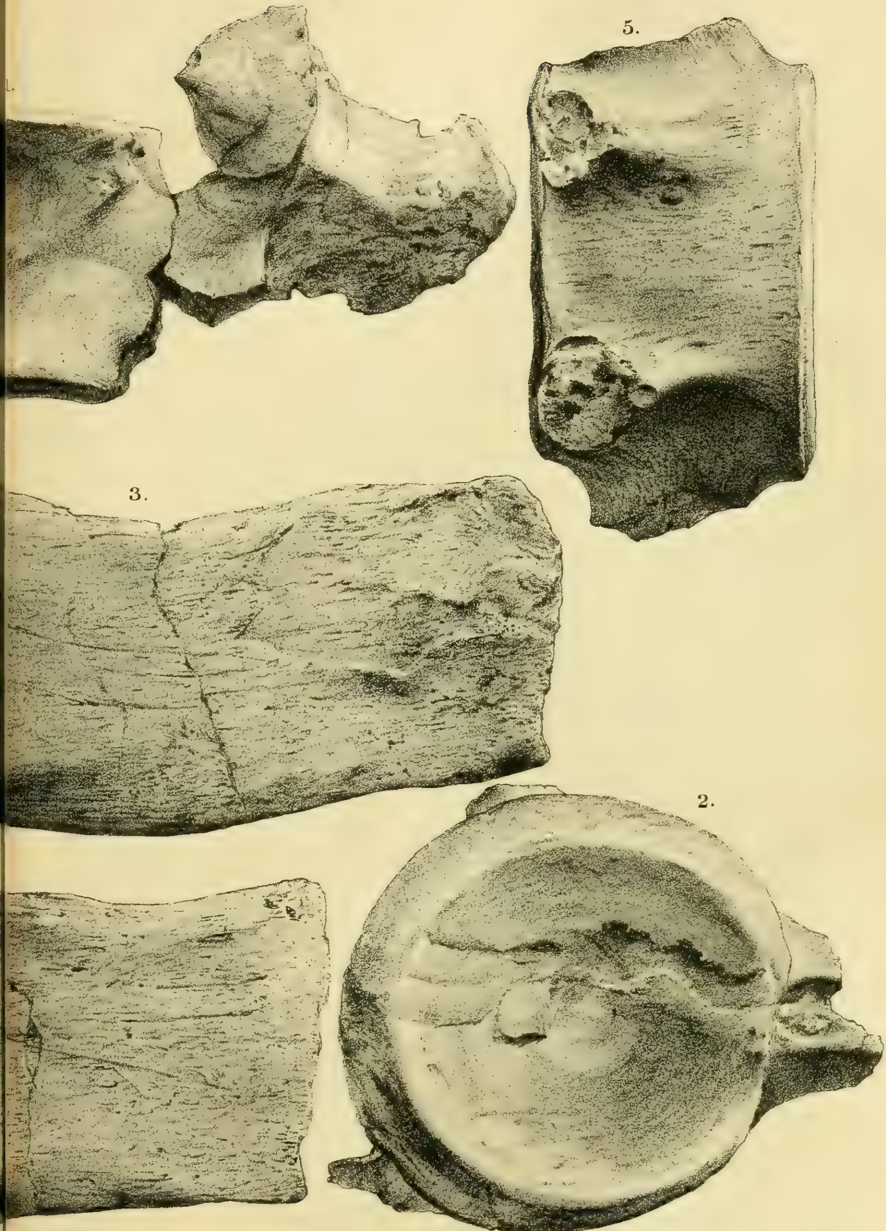
EXPLANATION OF PLATE XXI.

Fig. 1. Right side of seventh cervical vertebra of *Murænosaurus Leedsii*.
2. Front view of thirty-third cervical vertebra.
3. Left side of the thirty-ninth and neural arch of the thirty-eighth cervical vertebræ.
4. Front view of centrum of third caudal vertebra.
5. Under surface of centrum of fifth caudal vertebra.

4.

G.H.Ford & C.L.Griesbach.

MURÆNOSA



1. 5. 3. 2.

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Mintern Bros. imp.

MURÆNOSAURUS LEEDSII.

22. *On the* Upper Coal-formation *of* Eastern Nova Scotia *and* Prince-Edward Island *in its* Relation *to the* Permian. By J. W. Dawson, LL.D., F.R.S., F.G.S., McGill College, Montreal. (Read March 25, 1874.)

This formation was first distinguished as a separate member of the Carboniferous system in Eastern Nova Scotia by the writer, in a paper published in the first volume of the 'Journal of the Geological Society,' in 1845—and was defined to be an upper or overlying series superimposed on the productive Coal-measures, and distinguished by the absence of thick coal-seams, by the prevalence of red and grey sandstones and red shales, and by a peculiar group of vegetable fossils.

Subsequently, in my paper on the South Joggins* and in my 'Acadian Geology,' this formation was identified with the upper series of the Joggins section, Divisions 1 & 2 of Sir William Logan's sectional list, and with the Upper Barren Measures of the English Coal-fields and the third or upper zone of Geinitz in the Coal-formation of Saxony†.

Still more recently, in a 'Report on the Geology of Prince Edward Island,' 1871, I have referred to the upper part of the same formation the lower series of sandstones in Prince-Edward Island, not previously separated from the overlying Trias‡.

In Prince-Edward Island, however, where the highest beds of this series occur, they become nearly horizontal, and are overlain apparently in a conformable manner by the Red Sandstones of the Trias, which differ very little from them in mineral character. It thus happens that, but for the occurrence of some of the characteristic Carboniferous plants in the Lower series and of a few equally characteristic Triassic forms in the Upper, it would be difficult to affirm that we have to deal with two formations so different in age.

In connexion with this, the entire absence of the Permian system, not only here but throughout Eastern America, raises the question which I have already suggested in 'Acadian Geology,' whether the conditions of the Upper Coal-formation may not have continued longer here than in Europe, so that rocks in the former region constituting an upward extension of the Carboniferous may synchronize with part at least of the Permian. On the one hand, there seems to be no stratigraphical break to separate these rocks from the Middle Coal-formation of Nova Scotia; and their fossils are in the main identical. On the other hand, where the beds are so slightly inclined that the Trias seems conformable to the Carboniferous, no very marked break is to be expected; and some of the fossils, as the conifers of the genus *Walchia*, and *Calamites gigas*, have a decided Permian tendency.

* Quart. Journ. Geol. Soc. vol. x. † Acadian Geology, p. 149.

‡ 'Report on the Geological Structure of Prince-Edward Island,' by J. W. Dawson, LL.D. &c., and B. I. Harrington, B.A., Ph.D.

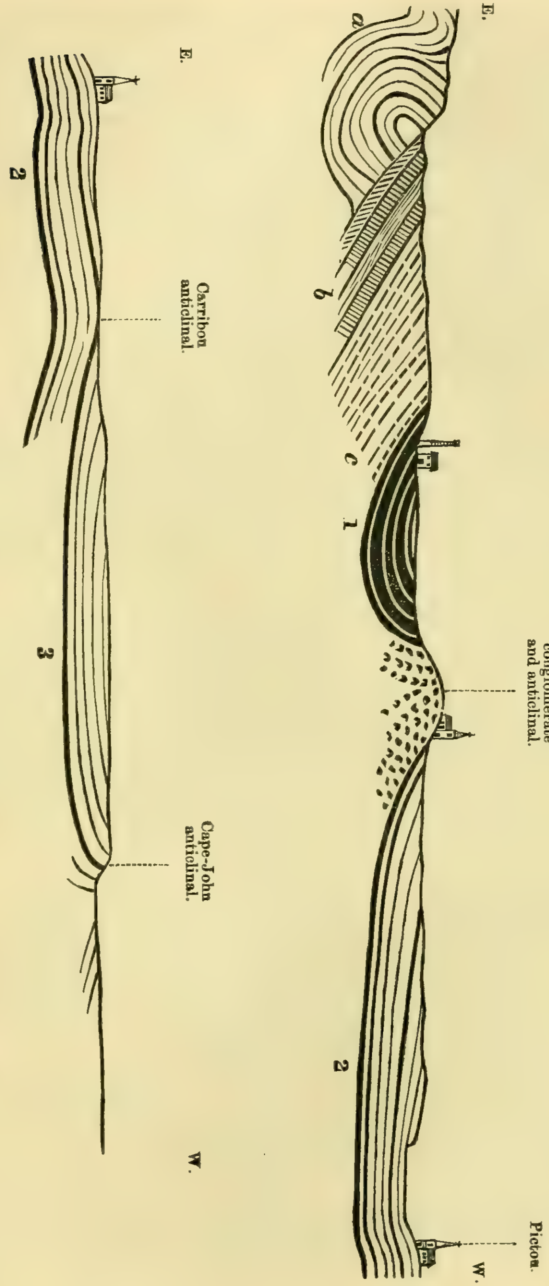
On the whole, in the 'Report' above referred to, I declined to separate the red beds of the Lower Series in Prince Edward Island from the Newer Coal-formation. Prof. Geinitz, however, in noticing my Report*, and also in a private letter, expresses the opinion that the fossils have, as an assemblage, so much of a Permian (or Dyadic) aspect that they may fairly be referred to that formation, more particularly to its lower part, the Lower Rothliegende. Attaching, as every one must, great weight to the judgment of Prof. Geinitz on such a point, I have in recent visits to Nova Scotia reexamined the more instructive sections of the Newer Coal-formation on the eastern coast of that province, with the view of ascertaining whether any stratigraphical or palæontological line can be found to divide the Upper Coal-formation series of my former papers into two members or to separate it from the Middle Coal-formation. The results of this reexamination and their bearing on general geological questions I propose to state shortly as follows:—

The Carboniferous district of Pictou county, extending for about 45 miles along the shores of Northumberland Strait, exposes in that distance in coast- and river-sections the whole thickness of the Carboniferous system, arranged in three *synclinal forms* (see Section, fig. 1). The first or eastern synclinal (No. 1 in the Section), extending from the older metamorphic rocks on the eastward and southward to a line running nearly east and west through the town of New Glasgow, consists entirely of the Lower Carboniferous, Millstone Grit, and Middle Coal-formation, and contains all the known workable Coal-measures of the county. Its northern boundary, the New-Glasgow anticlinal, brings up a bed not recognized in the other Nova-Scotia Coal-fields—the New-Glasgow Conglomerate, an immense mass, believed in some parts to be 1600 feet in thickness†, and containing boulders 3 feet in diameter, with pebbles of all sizes, many of its largest stones being composed of the hard brown or purplish sandstones of the Lower Carboniferous. Its stratigraphical position is that of the upper part of the Millstone Grit or lower part of the Middle Coal-formation; and it is evidently an exceptional bed, representing an immense bar or beach of gravel and stones stretching from the eastern end of the metamorphic chain of the Cobequid Mountains across the Pictou Coal-field, and protecting those deep swamps in which the Pictou main coal, 36 feet thick, and its black shale roof, more than 1000 feet thick, were deposited. The theory of this remarkable deposit, one of the most singular connected with any Coal-field, is fully discussed in the second edition of my 'Acadian Geology.' I may merely remark that, facing as this bed does the open sea stretching to the northward in the Coal-formation period, it is not unreasonable to suppose that it indicates the action of heavy ice grounding on the shores behind which grew the *Sigillaria*-forests of the Coal-swamps. The arrangement of the beds in

* Neues Jahrbuch, 1872.

† This is Sir W. Logan's estimate, and is warranted by the breadth which the bed occupies in the Section; but there are indications that it thins rapidly toward the dip.

Fig. 1.—*General Section of the Carboniferous rocks of Pictou, Nova Scotia.*



a. Silurian. *b.* Lower Carboniferous. *c.* Millstone Grit.
1. Middle Coal-formation. 2 & 3. Upper Coal-formation and Permo-Carboniferous.

the first synclinal, which is that of the great Pictou coal-beds, has recently been worked out in much detail by Sir W. E. Logan and the late Mr. E. Hartley.

The second or middle synclinal (No. 2 in the Section) extends from New Glasgow to Carribou Harbour, and centres in the deep indentation of Pictou Harbour. On its southern side it contains, north of New Glasgow, the depauperated equivalent of the Middle Coal-formation; and the remainder of it is occupied by the Newer Coal-formation, whose newest beds, however, are not represented in this trough. The low anticlinal which separates it from the third trough brings up nothing older than the lower part of the Newer Coal-formation.

The third synclinal (No. 3 in the Section) extends from Carribou Harbour to Cape John, and, stretching westward through the Cumberland Coal-field, shows in its centre the newest beds of the Upper Coal-formation.

It is to be observed that in these synclinals the north-west sides have steeper dips than the south-east sides, and consequently occupy a less breadth on the map. The south-east sides also show the best and most continuous sections; and for this reason I shall select the section from New Glasgow to Pictou Harbour, and that from Carribou Harbour towards Cape John, as typical of the lower and upper parts of the Upper Coal-formation.

1. *Section on the East River of Pictou.*

1. On the river-section, below New-Glasgow bridge, the conglomerate is succeeded in ascending order by a grey concretionary limestone 20 feet thick, associated with sandstone and shale, and containing in some layers great numbers of the *Spirorbis* which I have described as *S. arietinus**, and whose habits of life were probably not dissimilar to those of *S. carbonarius*, so abundant in the Coal-measures. This limestone does not appear in the immediate river-section, but on the flank of the conglomerate east of New Glasgow.

2. Above this is a series of black shales and underclays with grey sandstones and some reddish and purple shales, and thin seams of bituminous shale and coal. These beds contain *Stigmariæ*, *Lepidodendra*, Entomostracans and fish-remains, the fossils and the mineral character of the beds alike corresponding with those seen in the upper part of the Coal-measures south of the conglomerate. The thickness of these beds is about 400 feet.

3. This series is succeeded by a thick grey sandstone holding *Calamites*, *Calamodendron*, trunks with aerial roots (*Psaronius*), &c., 30 to 50 feet thick. This appears at the mouth of Smelt Brook and in several quarries to the eastward of that place.

4. Above this is a second series of dark shales and under-clays,

* 'Report of Geol. Survey of Canada.' This limestone may be compared with the "*Spirorbis*-limestone" of the Shrewsbury, Lancashire, and Warwickshire Coal-fields in England. See Hull 'Coal-fields of Great Britain.'

and bituminous shales associated with grey sand-stones and containing fossils similar to those of the series below. It especially abounds in fish-scales and *Cythere*; and several of the fishes are specifically identical with those of the upper part of the Middle Coal-measures as seen in the southern trough, south of New Glasgow. These beds are about 200 feet thick. Mr. H. Poole has described them in the 'Canadian Naturalist' for August 1860.

5. The beds up to this point may be considered the equivalents of the Middle Coal-measures or of the upper part of them, and are now succeeded in ascending order by thick grey and reddish sandstones and reddish and grey shales, including, however, thin coaly bed and underclays, and clays with nodular limestone. These may be regarded as belonging to the Upper Coal-formation; and their aggregate thickness as far as Pictou Harbour may be 2000 feet. They contain *Calamites*, trunks of *Dadoxylon materiarium*, *Lepidodendron*, *Pecopteris arborescens*? and *Neuropteris*.

The dip of the Conglomerate is high; and that this is not altogether due to false stratification is shown by the fact that to the eastward of New Glasgow the limestone and the Coal-measure beds rest on the Conglomerate at an angle of 45°; but this rapidly diminishes to 20°, and in the greater part of the section it is only from 8° to 6°.

The line of demarcation between the Middle and Upper Coal-formations is not marked here by any great physical break, but merely by the cessation of the characteristic beds of the Middle Coal-formation and the change to sandstones associated with red shales.

At first sight it might appear that as the beds north of the Conglomerate dip uniformly to the north, and mostly at slight angles, and those south of its outcrop are much more disturbed, there might be evidence of unconformability. This, however, is due to a line of fault extending along the outcrop of the Conglomerate, and to the greater relative disturbance of the beds of the southern synclinal.

2. *Section west of Carribou Harbour.*

This Section exposes the south side of the third or northern synclinal, and may be supposed to begin not far above the base of the Upper Coal-formation. It extends in ascending order obliquely across the synclinal for about ten miles along a coast in which the beds are on the whole well exposed, with uniform dips of about N. 30° E. magnetic, or nearly true north, and at an angle of about 10°; and no break or evidence of unconformability exists throughout the series, which amounts here in thickness to about 2500 feet.

The lowest beds seen in this section at the mouth of Carribou River are red and grey shales, and grey, red, and brown sandstones, including a small bed of coal 5 inches thick, with *Stigmaria*-rootlets in the underclay; and at Carribou Island, nearly in the line of strike, there is a somewhat thicker bed of coal. The overlying series may be described as consisting of indefinite alternations of shales, mostly deep red, with sandstones, grey, red, and brown, the latter sometimes coarse and pebbly, and occasionally in thick massive beds. Several of the beds of shale contain concretions of limestone, in one case forming a nearly continuous bed, and with no fossils except a few casts of a *Cythere*. In one of the lower beds of sandstone seen on Carribou River there are concretions of grey copper, and fossil trunks of trees penetrated by this mineral; and some of the fossil trees found in the sandstones on the coast are partly mineralized with sulphate of baryta.

The only material difference in mineral character is that red beds become more prevalent toward the upper part of the section, where the general character of the beds is precisely that of the supposed Upper Coal-formation rocks at Miminigash, Governor's Island, and Gallas Point in Prince-Edward Island, and on the coast of New Brunswick at Cape Jourimain*.

The following statements, reduced from my sectional lists, will serve to illustrate these points of mineral character.

In the whole section the sandstones, including the argillaceous sandstones, are to the shales in the proportion of about two to one in vertical thickness, and the grey and buff sandstones are about equal to those which are brown and red, while the red and mottled shales greatly preponderate over those which are grey.

In the lower half of the section, extending to the mouth of Toney River, the grey sandstone, red sandstone, and shales (mostly red) are in the proportions of $4\frac{1}{2}$, 3, $6\frac{1}{2}$. In the upper half of the section they are in the proportions of $4\frac{1}{2}$, $5\frac{1}{2}$, 3; so that red sandstones become decidedly more prevalent in the upper part, where there is also a greater proportion of coarse pebbly sandstones and of light-red shale with greenish stains.

If we compare this with the upper part of the Joggins section as given in Sir William Logan's lists, we find a thickness of 2267 feet; and if we regard the Ragged-Reef Sandstones as equivalent to the heavy sandstones at the base of the Pictou section, it is possible that the upper part of the latter is not represented at the Joggins. Taking the proportions of sandstones and shales at the latter place, we find them to be grey sandstone 12, red and brown sandstone 1, shale 10; so that here the proportions of sandstones to shales are not very dissimilar to those in the lower part of the Pictou series, but the grey sandstones are greatly more prevalent. Like those in the upper part at Pictou, some of the upper beds at the Joggins are coarse and pebbly, a character not observed, in either Coal-field, in the sandstones of the Middle Coal-formation.

If, on the other hand, we turn to Prince-Edward Island, the geological relations, and especially the fact that the outcrops on Prince-Edward Island correspond with the extension of two of the New-Brunswick Carboniferous anticlinals, would lead us to believe that the upper Coal-formation beds seen at Gallas Point, and amounting to about 800 feet in vertical thickness, must belong to the upper part of the Pictou series, or may even reach some way above its summit. Accordingly we find the proportions of the

* Report on Prince-Edward Island.

several rocks to be grey sandstone 2, red and brown sandstone 4, shales 2, or a still greater proportion of red sandstone as compared with Pictou. All this accords with the idea of a gradual increase of red beds in approaching the summit of the formation, so that the upper Coal-formation passes in its upper part into beds having more the aspect of some parts of the Lower Dyas or Permian. No true dolomite is present in these beds; but Dr. Harrington's analyses show that some of the thin beds of concretionary limestone are highly magnesian, and the sandstones contain concretions of sulphate of copper, while the fossil trees which abound in them are often mineralized with sulphates of copper and iron, and sulphate of baryta.

Fossils of the Upper Coal-formation.

Fossils are by no means so abundant in the Upper as in the Middle Coal-formation, and they are chiefly vegetable. One of the most characteristic plants is *Dadoxylon materiarium*, a species with simple medullary rays, drifted trunks of which abound in a calcified or silicified condition in the sandstones. The fine specimens of the *Sternbergia* pith of this species which I described in 1857 * and 1871 † are from this formation. In the upper beds leafy branches of the genus *Walchia* are common fossils, probably belonging to trees of the genus *Dadoxylon*, the only pines which accompany them. Calamites are also abundant, especially *C. Suckovii* and *C. Cistii*; and *Calamodendron approximatum* is not uncommon, while *Calamites gigas* occurs rarely in the upper part. *Annularia sphenophylloides* is a characteristic plant in the lower part, and *Cordaïtes simplex* is very abundant in some beds. *Lepidodendra* are rare, and represented principally by a species which is identical with, or very near to *L. pictoense*. Among ferns the most abundant species are *Pecopteris arborescens* and a variety of *Alethopteris nervosa*. *Stigmariæ* and *Sigillariæ* are much less frequent even in the lower part than in the Middle Coal-formation, and have not yet been recognized in the upper part.

The following tabular view may serve as a summary of the flora of the Upper Coal-formation as at present known. The first two columns represent the upper and lower parts of the Upper Coal-formation in Nova Scotia; and the third column represents that of Prince-Edward Island. Of the species all but about ten, or more than three fourths, have been found in the Middle Coal-formation also. It will be observed that the number of species, which in all is much smaller than that in the Middle Coal-formation, becomes rapidly reduced in the upper part, and that there is a considerable similarity between the upper series in Nova Scotia and that in Prince-Edward Island. This is further noticeable in the great prevalence of specimens of *Dadoxylon materiarium*, *Walchia*, *Cordaïtes simplex*, and *Pecopteris arborescens* in this part of the formation in both districts.

* Proc. Amer. Association, 1857, Canad. Nat. vol. ii.

† Report on Prince-Edward Island.

Species.	Upper Coal-formation.		
	Nova Scotia.		Prince-Edward Island.
	Lower part.	Upper part.	
1. Dadoxylon materiarium, *Daws.*	*	*	*
2. Walchia (Araucarites) gracilis, *Daws.*	......	*	*
3. —— (——) robusta, *Daws.*	......	......	*
4. Sigillaria scutellata, *Brongn.*	*		
5. Stigmaria ficoides, *Brongn.*	*		
6. Calamites Suckovii, *Brongn.*	*	*	*
7. —— Cistii, *Brongn.*	*	*	*
8. —— gigas, *Brongn.*	......	......	*
9. —— arenaceus? *Jäger*	......	......	*
10. Calamodendron approximatum, *Brongn.*	*		
11. Annularia sphenophylloides, *Zenker*	*	*	
12. —— longifolia, *Brongn.*	*	*	
13. Sphenophyllum emarginatum, *Brongn.*	*		
14. —— longifolium, *Geinitz*	*		
15. Cyclopteris oblongifolia? *Göpp.*	*		
16. —— heterophylla, *Göpp.*	*		
17. —— fimbriata, *Lesq.*	*		
18. Neuropteris flexuosa, *Brongn.*	*	*	
19. —— cordata, *Brongn.*	*	*	
20. —— heterophylla, *Brongn.*	*		
21. —— rarinervis, *Bunbury*	*	*	*
22. —— auriculata, *Brongn.*	*	*	
23. —— angustifolia?, *Brongn.*	*		
24. Odontopteris Schlotheimii, *Brongn.*	*		
25. Sphenopteris latior, *Daws.*	*		
26. —— alata?, *Brongn.*	*		
27. Alethopteris nervosa, *Brongn.*	*	*	*
28. —— Serlii, *Brongn.*	*		
29. —— acuta, *Brongn.*	*		
30. Pecopteris arborescens, *Brongn.*	*	*	*
31. —— abbreviata, *Brongn.*	*		
32. —— unita, *Brongn.*	*		
33. —— rigida, *Daws.*	......	*	*
34. —— oreopteroides, *Brongn.*	*	*	*
35. —— Bucklandi?, *Brongn.*, or ? Massilionis, *Lesq.*	......	......	*
36. Beinertia Gœpperti, *Daws.*	*		
37. Palæopteris acadica, *Daws.*	*		
38. Cordaïtes simplex, *Daws.*	*	*	*
39. Lepidodendron pictoense, *Daws.*	*	*	
40. —— undulatum, *Sternb.*	*		
41. Lepidophloios parvus, *Daws.*	*		
42. Lepidophyllum, (various sp.)	*		
43. Pinnularia	*	*	
44. Trigonocarpum Nœggerathii, *Brongn.*	*		
45. ——, sp.	......	......	*
46. Rhabdocarpus insignis, *Daws.*	*		
47. Antholithes squamosus, *Daws.*	*		

There is unfortunately no recognized Permian in Eastern America wherewith to compare the fossils of the upper member of the Newer Coal-formation; but inasmuch as the Coal-formation of Nova

Scotia is, as I have elsewhere shown, more nearly allied in its fossils to that of Europe than to that of the interior of North America; and as the Permian flora consists to a great extent of survivors from the Coal-formation, it will not be unfair to compare the above list with the species in Geinitz's and Göppert's Memoirs on the European Permian.

The very abundant *Dadoxylon materiarium* is a tree of the same type with several species found in the European Permian, as for instance *D. saxonicum*, Reich., and *D. Schrollianum*, Göpp. *Walchia* is also regarded as characteristic of the European Dyas; but as it is not improbable that it represents merely leafy branches of *Dadoxylon*, it belongs to the Carboniferous as well. One of our species, however, is very near to *W. piniformis* of the Dyas. *Calamites arenaceus*, whether or not an internal axis of *Equisetites*, is Dyadic in Europe; and some of my specimens may well belong to *C. leioderma* of the European Permian. *C. gigas* is a decidedly and peculiarly Permian species. *C. Suckovii* and *C. Cistii* are Permian as well as Carboniferous in Europe, as is also *Calamodendron approximatum*. *Annularia longifolia* is Permian as well as Carboniferous. *Neuropteris rarinervis* is peculiarly American and very widely distributed; but it is questionable if some of its larger-leaved varieties are not identical with European forms known by other names. *Neuropteris flexuosa*, *N. cordata*, and *N. auriculata*, as well as *Pecopteris* (*Cyatheites*) *arborescens*, *P. oreopteroides*, and *P. abbreviata* are both Carboniferous and Permian; and the species which I have compared doubtfully with *P. Bucklandi*, and with *P. Massilionis* of Lesquereux, has strong points of affinity with *P. densifolius* of Göppert. *Cordaïtes simplex* is a peculiar American species, but nearly allied, according to Geinitz, to his *C. Rœsslerianus* from the Lower Dyas. Finally Geinitz thinks the *Trigonocarpum* from Prince-Edward Island to be the same with his *Rhabdocarpus dyadicus*.

We thus have an undoubted palæontological resemblance between the upward extension of the Carboniferous in Nova Scotia and Prince-Edward Island and the Permian of Europe, though in the former regions no stratigraphical break enables us to establish on that ground any well-marked line of division. Taking into consideration the great thickness of the Carboniferous in Nova Scotia and the large development of this Upper Permo-Carboniferous member, it would not be surprising that in this last we may have a chronological equivalent of part at least of the European Permian.

We have no evidence as to age derivable from marine shells. The highest marine limestone known to me, a bed near Wallace Harbour, which I described many years ago in the Journal of this Society *, belongs to the base of the Newer Coal-formation, and contains *Productus cora*, *P. semireticulatus*, and *Aviculopecten simplex*, all characteristic Lower Carboniferous forms.

In Prince-Edward Island the Upper Carboniferous and the Trias are appparently conformable, and may almost be said to pass into

* See also 'Acadian Geology,' p. 214, 2nd edition.

each other, though in Nova Scotia the Trias rests unconformably on the Carboniferous. I believe, however, that this apparent conformity in Prince-Edward Island, and the resemblance of the two series in mineral characters, arises from the almost horizontal position of the Carboniferous beds, and from the circumstance that the Trias has been in part formed from their waste. The Triassic fossils, though few, are of species quite distinct from those of the Carboniferous. Further details as to the relations of these formations in Prince-Edward Island will be found in my Report on that island.

To sum up, it may be said that the beds which overlie the Coal-field of Pictou and extend into Prince-Edward Island, and which constitute the upper part of the Upper Coal-formation, have such strong points of resemblance to the lower part of the European Permian, both in their mineral character and organic remains, that they may fairly be named Permo-Carboniferous, a name already applied to certain marine limestones in the West, in which the Carboniferous graduates upward into the Permian. They may also be held to some extent to bridge over the gap which in Eastern America separates the Carboniferous from the Trias.

I may add that in Nova Scotia the Lower Carboniferous beds are usually more hardened and altered than those of the Middle Coal-formation, and the latter more than those of the Upper Coal-formation. Moreover there are instances in Nova Scotia of local unconformability of the Lower Carboniferous beds; and the New-Glasgow conglomerate affords evidence of extensive denudation of the Lower Carboniferous before the deposition of the productive Coal-measures. These facts indicate the long duration of the Carboniferous period and the extent of the physical changes which it included; and it is evident that, had unconformability or extensive local denudation occurred somewhat higher in the system, it might have been regarded as forming the base of an overlying Permian series.

I have discussed somewhat fully the relations of the flora of the Lower Carboniferous to those of the Devonian on the one hand, and of the Upper Members of the Carboniferous on the other, in a 'Report on the Fossil Plants of the Lower Carboniferous and Millstone Grit,' recently published by the Geological Survey of Canada *. I hope that I may be able at some future time to describe and illustrate fully the plants of the Upper Coal-formation in the same manner.

Discussion.

Prof. Ramsay agreed with the author in thinking that these Upper Carboniferous rocks represented the Permian, and that there is a gradual passage from the Carboniferous to the Permian. In North Staffordshire there is some evidence of this passage, but not in other parts of England. Mr. Binney had argued that the Permian is the uppermost part of the Carboniferous series; but this is not true in the English area, although it is true if we consider the

* Montreal, 1873.

globe in general. The Coal-measures are grey, black, and blue; but in the upper portion they sometimes change to a red tint. During the Coal-period we have evidence of estuarine conditions; but subsequently the access of the sea was cut off, and the Permian rocks were formed in vast inland lakes.

Prof. Hughes remarked that the group referred to by Principal Dawson under the head of Permo-Carboniferous could not be considered as in any way proving a passage from Carboniferous to Permian, seeing that the Permian was altogether wanting in Eastern America, unless the fossils approached those of undoubted Permian in Europe. But he pointed out that many large portions of the so-called Permian of Europe had been already proved to be only stained Carboniferous. The fossil lists were founded on a wrong classification of the rocks, which had not yet been set right. Believing, therefore, that the Permian system must be broken up and part given back to the Lower New Red and Magnesian Limestone series, previously so well established, and part to the Upper Carboniferous, he was inclined to refer the Permo-Carboniferous of Principal Dawson to the latter, the difference in the plants being only such as might reasonably be expected between the newer and older portions of a series representing immense lapse of time and changing conditions. Principal Dawson had shown that the beds in question were similar in almost all but colour, and conformable to the underlying undoubted Carboniferous. If, therefore, they were higher than any Carboniferous beds of England, they must be synchronous with the lower part of the unrepresented time between the Carboniferous and so-called Permian; but being more closely connectod with the lower rocks, he saw no necessity in the present state of our knowledge for such a term as Permo-Carboniferous.

Prof. Ramsay could not agree with Prof. Hughes in his opinion as to the value of the term Permian. The staining of rocks occurs in two ways—namely, by infiltration from above through overlying beds, and by direct deposition. Silurian rocks are often stained in the former manner.

Mr. Evans remarked that this paper had given rise to an interesting discussion. The fact of the two deposits being conformable in one place and unconformable in another, did not, in his opinion, necessarily convert them into one system. He thought there were symptoms that the Permian would eventually be regarded as Upper Carboniferous. He believed that there was a third mode in which rocks were stained—namely, by the oxidation of iron already existing in the beds.

23. *The* SECONDARY ROCKS *of* SCOTLAND. Second Paper*. *On the* ANCIENT VOLCANOES *of the* HIGHLANDS *and the* RELATIONS *of their* PRODUCTS *to the* MESOZOIC STRATA. By JOHN W. JUDD, Esq., F.G.S. (Read January 21, 1874.)

[PLATES XXII. & XXIII.]

CONTENTS.

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* In the first published paper of this series (*vide* Quart. Journ. Geol. Soc. vol. xxix. p. 97) I found it possible, in a single communication, not only to discuss the nature and origin of the remarkable physical relations of the vestiges of the Secondary strata on the east coast of Scotland, but also to reconstruct from them the history of the several Mesozoic periods as exemplified in that district. This, however, was only accomplished by extending the paper to a somewhat unusual length; and in dealing with the strata of the same age on the western coast, I have found it impossible, such is the complication of the questions involved in their study, to deal with both branches of my subject in a single paper. Consequently I have confined myself, in the present communication, to a description of the positions and relations of the fragments of Secondary strata, and a discussion of the causes to which these are due. In a third paper, which is already in an advanced stage of preparation, I propose to illustrate the succession of geological events in the Western Highlands during the Mesozoic periods; while in a fourth paper I anticipate being able to conclude the account of my studies of these rocks by an endeavour to deal with those problems of ancient physical geography and general palæontology for the solution of which these remarkable fragments of Secondary strata supply such valuable materials.

I. *Introduction.*

For the preservation of the most valuable illustrations of the institutions, manners, and arts of Ancient Rome, the archæologist is indebted to the action of a volcano: the relics of Pompeii have survived in consequence of being buried under the ejections of Vesuvius. To a similar agency, operating at a distant epoch and on a far grander scale, the geologist owes the escape from destruction, in the Western Isles of Scotland, of most wonderful monuments of physical change and highly interesting records of life-history during the Secondary periods; for such, indeed, are those remarkably preserved fragments of sedimentary rocks which it is the object of this memoir to describe.

As he prosecutes an examination and comparison of all the circumstances under which the scattered relics of the Secondary formations present themselves in the West of Scotland, the geologist will be again and again impressed by the extent of the protective influence which the vast masses of Tertiary lava have evidently exerted upon the subjacent stratified rocks. And when he has concluded that survey, he can scarcely have failed to arrive at the conclusion that, but for this protective influence, every vestige of the Mesozoic deposits in the district must have been inevitably swept away by denudation*.

* Those familiar with the geology of Central France will at once recall the manner in which the sheets of basaltic lava capping the great plateaux have, in so many cases, secured the preservation of masses of the lacustrine strata on which they rest, every trace of which must otherwise have been swept away by denuding forces. (*Vide* Scrope's 'Geology and Extinct Volcanos of Central France,' p. 7 &c.)

When, therefore, we reflect upon the remarkable combination of circumstances to which we are indebted for the preservation of these interesting records of the whole series of Secondary formations (from the Trias to the Upper Chalk inclusive) we cannot fail to be impressed by the accidental (and often, indeed, exceptional) nature of the conditions upon which the escape from destruction of fossiliferous deposits has in so many cases depended. It would be difficult to adduce a more striking illustration of the necessarily great imperfection of the geological record than that which is suggested by these strangely preserved fragments, of what were evidently once widely spread formations representing geological periods of vast duration.

It is impossible rightly to understand the features presented by the Secondary rocks in the Western Highlands without carefully studying, in the first place, their relations to the great masses of igneous rocks among which they lie. These relations are of the most intimate and often complicated character. Not only have the fragments of Mesozoic strata which had escaped denudation at the commencement of the Tertiary period, been buried under vast accumulations of lava sheets to the depth of hundreds and even thousands of feet, but they are often, as I shall show hereafter, penetrated by igneous masses connected with three distinct periods of volcanic activity, from the influence of which they exhibit every conceivable stage of metamorphism; and, further, their fragments are found, often in great abundance, imbedded in the vast masses of scoriæ and ashes which have been ejected from the volcanic vents. In order, therefore, to reconstruct the history of the Mesozoic period, it is necessary to carefully restore and reunite all these scattered fragments of evidence; for the same volcanic agency that has so wonderfully preserved the records, has at the same time unfortunately, in too many instances, sadly mutilated and defaced them.

I shall show, moreover, that although during nearly the whole of the Secondary periods the volcanic forces were dormant in the district, yet that era was preceded, as well as followed, by an epoch of the most intense and prolonged igneous activity. The influences of this earlier period of volcanic action in determining the characters of the Secondary deposits, although less marked than those of the succeeding eruptions of the Tertiary period, are nevertheless clearly traceable. Further, many of the peculiarities and anomalies presented by the Secondary rocks in this district appear to find an adequate explanation in the circumstance that they were deposited in the interval between these two periods of violent igneous activity, and that the areas which they occupy may therefore naturally be supposed to have been subject to frequent and excessive disturbance.

But while many points of great importance with respect to the Secondary rocks are thus dependent for their elucidation on a careful study of the volcanic products with which they are so intimately associated, much new light is at the same time thrown upon the nature, age, and history of the latter by an examination of the relations which subsist between them and the interesting fragments of fossiliferous, and thereby *dated*, rocks of the Mesozoic periods.

In this manner we are led to many very interesting conclusions with regard to the chronology of the various rocks of the Scottish Highlands.

Moreover, as I hope to be able to show, the prosecution of this research concerning the relations between these sedimentary and eruptive rocks, is calculated to throw new light upon some of the obscurest problems of physical geology.

Under these circumstances, I have considered it advisable to confine myself in the present communication to this question of the mutual relations between the Secondary and Volcanic rocks of the west coast of Scotland—a question of much complication but at the same time of the highest interest—reserving for a future occasion the details of the history of the Mesozoic periods in the district, as deduced from the palæontological and physical evidence.

1. *History of Previous Opinion on the subject.*—The very intimate manner in which the Secondary and Volcanic rocks of the Hebrides are associated with one another not unnaturally led the earlier geological observers to regard them as being of contemporaneous age. This opinion received its first shock in 1851, through the discovery by the Duke of Argyll of the leaf-beds of Ardtun, and the determination by Professor Edward Forbes of the Miocene age of the fossil plants contained in these deposits*. It then became evident that a part at least of the Volcanic rocks of the Hebrides belongs to the Tertiary period. In 1865 Professor A. Geikie had arrived at the important conclusion that the vast sheets of igneous rock lying between the Secondary strata in the Hebrides are in every case *intrusive*, and therefore not *contemporaneous* with those rocks; and on a review of all the facts of the case, he was led to announce his conviction that the whole of the volcanic rocks under consideration belong to the Tertiary period †. This conclusion I have been able to confirm by showing that the volcanic rocks in question unconformably overlie even the youngest members of the Chalk.

The unmistakably volcanic origin of the so-called "trap rocks" of the Western Isles had been noticed by many observers; and some of these, especially Dr. Macculloch ‡ and Professor Geikie §, have dwelt upon the evidently close relations between these and the Plutonic rocks of the district. The Duke of Argyll has remarked on the manner in which the two classes of igneous rock, as seen in a section in Mull, appear to graduate into one another—and also on the indi-

* Quart. Journ. Geol. Soc. vol. vii. pp. 89, 103.

† Proc. Roy. Soc. Edinb. vol. vi. (1866–67), p. 72, and Quart. Journ. Geol. Soc. (1869), vol. xxvii. p. 283. I gladly take the present opportunity of bearing witness to the great value of Professor Geikie's researches among the volcanic rocks of Scotland. Although the conclusions at which I have arrived are, in many cases, very different from the opinions which he has expressed on some of the phenomena of this interesting district, I think that in almost every case it will be found that the points in which he differs from myself are those in which he has put forward useful suggestions of a tentative character rather than the results of direct observation. In almost every case of the latter kind, I am happy to be able to confirm his great accuracy and acumen.

‡ 'A Description of the Western Isles of Scotland,' 1819.

§ Quart. Journ. Geol. Soc. vol. xxvii. p. 282.

cations of the volcanic character of the mountain of Beinn More, in the same island, afforded by the highly scoriaceous character of its materials*.

Although many very valuable geological observations have been placed on record by Dr. Jameson, Boué, Dr. Macculloch, Principal J. D. Forbes, and Prof. A. Geikie, but little has been hitherto done in the systematic examination of the relations of these old volcanic rocks. The characters of the minerals and rocks themselves, have, however, been much more successfully investigated by several of these authors. Dr. Macculloch's mineralogical knowledge was so large and accurate that the lapse of more than fifty years has failed to deprive his descriptions of the rocks of this district of their interest and value; and very recently one of the greatest masters of the methods of petrological research, Prof. Zirkel of Leipsic, has supplemented these early observations by a series of careful re-examinations of the same rocks, to the results of which I shall have occasion to refer more particularly hereafter.

2. *Volcanic Origin of the rocks constituting the great plateaux of the Hebrides and the North of Ireland.*—The rocks which constitute such extensive plateaux, both in Ulster and the Hebrides, have long excited attention and interest in consequence of the remarkably picturesque forms which are assumed by them at certain points where the columnar structure is finely developed; this is especially the case with those justly celebrated localities the Giant's Causeway and the isle of Staffa. That the rocks which present these remarkable characters are of volcanic origin, and indeed constitute the remains of great lava-streams, is a fact which was clearly recognized by some even of the earliest geological observers †; and the more minutely and carefully the phenomena presented by the rocks connected with active or recently extinct volcanoes have been examined, the more strikingly has the soundness of this conclusion been made apparent.

At the present day the volcanic origin of these rocks may be regarded as so far an established portion of geological science as to render quite superfluous on this occasion any details of the grounds on which it rests. Whether we regard the chemical composition of the different varieties of rock, or their mineralogical constitution (especially as this is revealed to us by the microscope), or the peculiarities of their petrographic structure, such as the remarkable vesicular and columnar features which they exhibit,—we are alike struck by the perfect identity of characters between them and the materials of recent lava-streams. Innumerable minor features serve to confirm this conclusion—such as, among others, the highly vesicular or scoriaceous character of the upper and under surfaces of the great masses, the inclusion between them of layers of scoriæ,

* Brit. Assoc. Report (1867), Trans. of Sections, p. 55, and Address to Geol. Soc. 1873, Quart. Journ. Geol. Soc. vol. xxix. p. lxxv.

† *Vide* Sir Joseph Banks, in Pennant's 'Voyage to the Hebrides,' p. 267; A. Mills, in Phil. Trans. for 1790, pp. 73–100; Macculloch, Syst. of Geol. (1831), vol. ii. p. 114, &c.

lapilli and ashes, or the vestiges of ancient soils and vegetation, and the indications exhibited by the surfaces on which these rock masses lie of having been subjected to the action of heat.

One of the most striking points of similarity between these old lavas and those seen to be actually connected with existing volcanoes has, through a very prevalent misinterpretation of the appearances presented, been generally overlooked. I refer to that remarkable peculiarity, connected with the columnar structure, which is nowhere better exhibited than in the beautiful caves of Staffa, and which has been so clearly described by Mr. Scrope as giving rise to such conspicuous features at Pont Gibaud, the Coiron, La Gravenne de Souillols, Jaujac and other points in Central France*. In all these cases the same lava stream is found to be composed of two portions, which at a short distance appear to be very distinctly separated from one another. The lower of these divisions, which usually occupies about one third of the thickness of the lava stream, is composed of very regular, upright, and generally jointed columns, the articulations of which often exhibit remarkable curved surfaces and angular processes. The upper part of the stream, however, presents strikingly different characters, being made up either of nearly amorphous basalt or of thickly clustered columns of small diameter, these being usually curved and twisted in the most remarkable manner. All who have visited Staffa will at once call to mind the contrast presented by the thick upright pillars which form the "Colonnade" and the sides of Fingal's Cave, and the thin, gracefully curved, and intricately interwoven shafts which form the Buchaille, the Clam-shell Cave, and the roof of Fingal's Cave. A careful examination will convince the geologist that the two varieties of columnar basalt form parts of the same lava stream, and are not, as is usually stated in guide-books and geological manuals, the product of two distinct and superposed flows. In the beautiful basaltic columns of the Giant's Causeway, in those of Carsaig, Ulva, and many less known, and more inaccessible localities, I have been able to verify the correctness of this observation.

Mr. Scrope, in an incidental allusion to the phenomena presented by Staffa †, shows that the very striking identity of its features with those so clearly described by him as occurring in Auvergne, had not escaped his observation. He has suggested that the sharp distinction in characters between the two portions of the same lava stream, is due to the different conditions under which they have parted with their heat—that of the upper portion having escaped by radiation, and that of the lower portion by conduction through the subjacent rocks.

3. *Subaerial Origin of these old Volcanic rocks.*—Accepting, then, as amply demonstrated, the conclusion that in these rocks of the North of Ireland and the Hebrides we see the vestiges of extensive lava streams, the next problem which presents itself to the geologist is

* *Vide* 'The Geology and Extinct Volcanos of Central France,' 2nd edit. (1858), pp. 57, 163, 191, &c.

† 'Volcanos,' 2nd ed. (1872) p. 99.

the following:—Were these lavas poured out upon a terrestrial surface? or were they the product of a series of submarine eruptions?

On this question very diverse opinions have been maintained by different authors, the majority, however, being in favour of the submarine origin of the rocks. This opinion has, in a great degree, arisen from the long prevalent idea that the lavas in question were contemporaneous with the Secondary strata with which they are often so intimately associated. We have already pointed out how this opinion has been gradually dissipated—first by the discovery of the Ardtun fossils by the Duke of Argyll, and secondly through the recognition by Professor Geikie of the *intrusive* character, and therefore *subsequent* age, of the sheets of igneous rock which lie in the midst of the Mesozoic strata. With the supposed evidences of the Secondary age of these lavas the grounds on which their submarine origin was maintained have also disappeared; and from the overwhelming and irresistible mass of evidence which I am now able to adduce upon the subject, it will, I think, be accepted as conclusively demonstrated that the lavas were unquestionably of *subaerial* or *terrestrial* origin.

The first point to which it is necessary to allude, is the total absence of marine sediments and fossils, of contemporary age, interstratified with the great lava sheets which we are considering. It is true that this evidence is of a negative character; but when we reflect on the duration of the periods required for the gradual accumulation of these enormous masses of lava, and on the ample proofs which exist of the occurrence of long intervals of time between the outflow of sheets now directly superimposed the one upon the other, we cannot but be impressed by the consideration that, if such an accumulation of lavas took place upon the sea-bottom, beds of stratified materials containing marine organisms must, at some points at least, have been deposited in the intervals between the successive outflows of igneous rock. The actual comparison of the volcanic rocks of the Hebrides and Ulster with others of undoubted submarine character, like those of Central Scotland (which we shall have to refer to more particularly in the sequel, and in which the interbedding of masses of aqueous and igneous origin respectively is such a constant and characteristic feature), lends additional weight to the presumption against the submarine origin of the former.

But this presumption, derived from indirect and negative evidence, must be regarded as a conclusion satisfactorily established by all who will examine and weigh the strong, numerous and cumulative proofs of a direct kind which can be adduced in its support. These it will be necessary briefly to detail.

The highly vesicular and scoriaceous character of many of the Tertiary lavas seems to be inconsistent with the supposition that they have been poured out under a considerable depth of water, the pressure of which would probably prevent that extensive liberation of volatile materials which has so evidently taken place. Some of the lava beds must, in consequence of this operation, have originally constituted a mass as porous as a sponge, though subsequently converted, by the chemical action of infiltrating water, into solid amygdaloidal rocks *.

In the second place I would direct attention to the nature of the surfaces over which the first emitted lavas have flowed. Thus, in the North of Ireland, where the lavas rest directly upon the chalk, the old surface of the latter was not only one of great irregularity, abounding in hills and valleys, but it is almost everywhere covered with an accumulation of perfectly angular chalk-flints; these superficial deposits, too, often fill "sand-pipes," which penetrate for considerable distances into the mass of the chalk rock. No one familiar with the characteristic modes of weathering of the chalk can fail to recognize in these appearances the evidences of subaerial action. At other points, as indicated by Portlock in the case of Slieve Gallion and Rathlin Island, there are found, interposed between the old chalk soils and the superincumbent lavas, beds of lignite containing wood and amber, which are unquestionably the remains of old forests belonging to the period immediately preceding that of the emission of the lavas. In other cases, again, as in Morvern, we find, in a similar position, thick beds of unstratified ash or volcanic dust†. But in no instance, so far as I am aware, do the surfaces of the rocks immediately underlying the lavas exhibit the slightest indication of having been subjected to the action of marine denudation.

In the third place, when we examine the deposits interposed between the different lava sheets, and which were evidently formed during the intervals between their eruption, we find numerous indications of the prevalence of terrestrial, fluviatile, and lacustrine conditions, but never in any instance of those of a marine character.

(1) Bands of clay or earth, usually only a few inches in thickness, and of a bright red colour, very frequently occur between the sheets of Tertiary basalt both in Scotland and Ireland. These appear to be identical in character with the beds of *soil* formed by the weathering of the surface of one lava stream and destroyed by burning when overwhelmed by a new sheet of lava. This phenomenon, as pointed out by Sir Charles Lyell, is frequently exhibited in existing volcanoes ‡.

* By this infiltration various minerals have been formed in the cavities of the vesicular lava. By very simple chemical reactions the felspars yield zeolitic minerals, while the pyroxenic constituents are converted into various hydrous, magnesian, and ferruginous silicates. More complete decompositions result in the production of chalcedony and calcspar. It is a noteworthy circumstance, capable of frequent verification in the district under consideration, that in rocks containing numerous amygdaloidal cavities the mass of the rock is always much decomposed, and often has passed into a "wackose" condition, through the partial removal of its materials by solution.

† These beds precisely resemble in character those which are found in connexion with volcanoes but recently extinct. Thus, for example, in the island of Lipari we find a fine-grained ash of chocolate-brown colour, full of small decomposed fragments of white colour (probably fragments of crystals of felspar), which is quite undistinguishable from the rock referred to in the text.

‡ "On the Lavas of Etna," &c. Phil. Trans. 1858, pt. ii. p. 711. During a recent examination of many of the most interesting volcanic districts of the

(2) Masses of vegetable matter, at times containing recognizable trunks and branches of trees, in some cases converted by the heat of the overflowing lava into a kind of charcoal, and at others constituting beds of lignite or coal, which are often of fair quality and considerable thickness, but seldom of great extent or very constant character, are by no means of unfrequent occurrence between the sheets of Tertiary lava. Such relics of the vegetation of the periods during which the great sheets of basaltic lava were formed have been found at many points in Ireland—also in the Isle of Mull, near Carsaig, at Loch Lathaich and Loch Scridain—in Morvern, Ardnamurchan and the islands of Eigg and Canna—and in Skye, at Talisker, Scoribreck, Portree, Camiskianevig, Loch Grisornish and other points. Attempts to work these masses of coal and lignite have been made at various times, especially at the Giant's Causeway in Antrim, at Carsaig in Mull, and at Portree in Skye. In the case of the last-mentioned locality 500 or 600 tons of fuel is said to have been obtained; but, as might be anticipated, the deposits have been found to be too irregular in thickness and inconstant in character to repay the cost of extensive operations. Owing to the high price of coal, the well-known lignite bed at the Giant's Causeway was again opened out by the country people during the winter of 1872; and I thus had an opportunity of studying its characters. It is evidently the vestige of an old *forest* overwhelmed by a lava stream. At its base is an "underclay" formed from the decomposition of the older lava bed on which it rests, and intermingled with much vegetable matter; the substance of the lignite itself is made up of great masses of wood, still very clearly exhibiting its tissues; while the upper portions of the mass, which are in contact with the overlying lava, have been converted by heat into a kind of charcoal.

(3) In the interesting section of Ardtun we have evidence of *mud streams* (such as are so commonly formed in the vicinity of volcanoes in action) having overwhelmed and buried the deposits of fine sediment with leaves that had accumulated in pond-like hollows of an old land surface. These mud streams have evidently, during part of their course, flowed over a disintegrated surface of the chalk rocks of the district, and have thus caught up in their mass many unworn chalk flints and angular fragments of the highly indurated Scottish chalk *. The remains of many similar old mud

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Mediterranean area (which, through the kindness of Mr. Scrope, I have been enabled to make since this paper was read) I have had the opportunity of seeing how completely in this, as in innumerable other instances, the products of still active volcanoes agree with those which are connected with vents long since extinct, like those on the west of Scotland.

* At the time of the discovery and description of the interesting Ardtun beds the fact of the existence of rocks of chalk and flint *in situ* in the island of Mull was unknown. The angular fragments in the mud-stream of Ardtun, which have been called lapilli, are really portions of the peculiar indurated siliceous chalk of the district, as, indeed, seems to have been strongly suspected by the Duke of Argyll at the time. The manner in which fragments of rock of all sizes, many of them perfectly angular, are mingled together in a fine-grained paste, seems to me to be inexplicable on any other supposition than that

streams, but without the interesting accompaniments of the leaf-beds and entangled chalk detritus which occur at Ardtun, have been found by me in various parts of the Hebrides. An example of a very thick mud-stream buried under lava occurs on the shores of Loch Tuadh in Mull, opposite to the adjoining island of Ulva.

(4) Professor Geikie has called attention to the existence at the Innimore of Carsaig of a bed, mainly composed of chalk flints, which is interposed between the sheets of basaltic lava and attains in some places a thickness of 25 feet. A careful examination of this very interesting deposit convinces me that we have here preserved portions of an old *river-gravel,* formed by a stream which flowed over the surface of the land, in the interval between the outflow of the two lava streams which enclose it. The gravels are composed of flint detritus of every degree of fineness, mingled with rounded fragments of the local hard chalk and of the basaltic lavas of the district; the deposit, which thins out rapidly both eastward and westward, exhibits the alternations of beds of coarse and fine-grained materials, with occasional seams of sand and loam, the whole being marked by much false-bedding; indeed, so far as it is exposed in the sections, this interesting mass of gravels, included between the Tertiary basalts, is perfectly similar in every respect to the familiar gravels of existing rivers. It is evident that the stream which formed these gravels must, in the higher part of its course, have flowed through a valley cut in the chalk strata. I have found in other cases masses of gravel formed wholly of pebbles of the different igneous rocks, which have all the appearance of having been formed by streams cutting valleys in the older lavas and covered up by subsequent outbursts; but these of course exhibit much less striking characters than the deposit of the Innimore of Carsaig.

(5) At very numerous points, both in the North of Ireland and in the Western Isles of Scotland, we find deposits of pisolitic iron-ore interbedded with the basalts. That the materials of these ferruginous masses were derived from the basaltic rocks on which they rest there can be no doubt. The actual agency which effected the concentration of the iron appears to have been that indicated by Mr. David Forbes *, namely the multiplication of organisms of a similar kind to those which have formed the well-known "lake-ores" of Sweden in recent times. This view is confirmed by the occurrence, in association with some of the beds of pisolitic ore, of masses of stratified ash, sand, conglomerate, &c., sometimes containing numerous plant-remains, which are evidently of *lacustrine* origin. Such are the deposits of Ballypalidy in Antrim, at which

suggested by His Grace, that they were entangled in a mud-stream. The discoloration of the chalk-flints, supposed to be due to the active heat, I regard as being the result rather of weathering operations. At Somma and Bagno Secco in the island of Lipari we find stratified volcanic tuffs with leaves and other plant-remains, which present a very striking resemblance to those of Ardtun, Ballypalidy, &c.

* Quart. Journ. Geol. Soc. vol. xxvi. (1870), pp. 164, 165.

place the extensive workings that have now taken place have exhibited sections which leave no room for doubt as to the true character of the beds. I have found sections of precisely similar deposits on the shores of the Sound of Ulva, and at other localities in the Hebrides. The frequency with which lakes, shallow lagoons, and pond-like hollows are formed in a district subject to volcanic eruptions—in consequence of local subsidences, through the damming up of river-courses by lava-streams, or through the formation of "pit-craters" by explosion, has been dwelt upon both by Mr. Scrope and Mr. Darwin.

(6) Local masses of unstratified volcanic dust, ashes, scoriæ and conglomerate are, by no means rarely, found intercalated with the great streams of lava.

The whole of these facts point to the conclusion that, during the period of the emission of the great lava floods which form the enormous plateaux of the Hebrides and Antrim, the surfaces over which they flowed were above the sea-level, and, further, that intervals of sufficient duration occurred between the outpourings of the lava streams to admit of the formation of those very interesting intercalated deposits, which are in every case of a terrestrial, fluviatile, or lacustrine origin.

4. *Evidences of the Former Existence of great Volcanic mountains in the district.*—In the foregoing paragraphs we have shown that we are led to the inevitable conclusion, not only that the great plateaux of the Hebrides and the north of Ireland were formed by the gradual accumulation of a long succession of lava-flows, but that, like the similar lavas of Sicily, Auvergne, and Iceland, they were actually poured out on the surface of the land.

Now, in all the cases of recently formed lavas (to which we have had such frequent occasion to refer as exhibiting so perfect an identity in character with the ancient rocks which we are describing), their extrusion has been accompanied by the piling up of ejected fragmentary and semifluid materials around the vents, so as to form those more or less conical mountain-piles which we call "volcanoes;" and it is from the summits or sides of these that the great lava streams have usually flowed.

Can we then hesitate to accept the conclusion that rocks which present such a remarkable identity in characters, even to the minutest details, must have had a similar origin?—that the formation of these ancient subaerial lavas was attended with the production of phenomena similar to those which, at so many different points of the earth's surface, we still observe to be the constant effects of volcanic action?—that, in short, within our British district there once existed volcanoes from which those great volumes of igneous materials we have been describing were ejected?

Further, when we reflect upon the fact (one patent to the most casual observer of the geology of the district) that the masses of these ancient lavas which remain for our study, notwithstanding their vastness, are nevertheless mere isolated relics, which have escaped destruction by denudation, of plateaux which must originally have covered many thousands of square miles*—that, moreover, these fragments which remain still constitute mountains nearly 2000 feet in height, entirely made up of almost horizontal lava sheets,—must we not conclude that the volcanoes from which these wide-spreading and thickly piled masses of lava were ejected could have been of no mean dimensions or insignificant character?

At what points, then, were these great volcanoes situated? Where are the relics of their vast masses, the indications of their violent action? Can it be that all traces of such great mountain-piles, belonging as they do to one of the most recent of the geological periods, have altogether disappeared? Or are we rather to conclude that denudation and other causes have so modified and disguised their characters, that their true nature is not now at first sight recognizable? These are the questions that everywhere present themselves to the geologist in the Western Highlands, and press for a solution.

In support of the opinion that, even within a comparatively recent geological period, such vast volcanoes may have entirely disappeared, while extensive fragments of the lava streams which flowed from them so conspicuously remain, it may be pointed out, first, that the former would be composed mainly of loose and fragmentary materials, which are much more easily acted upon by degrading forces than the solid rocks of the latter; secondly, that their greater elevation would facilitate their destruction; and, thirdly, that the evidence of denudation, even on the most stupendous scale, having taken place in the district since the period of the formation of these volcanoes, geologically recent though they are, is of the most unmistakable character.

But on the other hand it must be remembered that the remains of the great volumes of fluid materials which ascended through the volcanic piles, and, sending off ramifications in all directions, served to bind together the masses of fragmentary matter, must not only in themselves have constituted rocks of great solidity and permanence, but, by affording coherence to the volcanoes have retarded their denudation. Of these solidified igneous springs, which constituted the connexions between the great rivers of lava and the subterranean reservoirs of liquefied rock, it is hard, nay, impossible, to conceive the remains to have been wholly removed while any portion of the older rocks which they penetrated remained; though in many cases we can readily understand the effects of denudation to be such as to render obscure the connexion between these solidi-

* It is perhaps not possible to adduce any more striking illustration of the vast changes which have taken place in the relative position of rock-masses, and the extent to which they have been subjected to denuding agencies since a period so geologically recent as the Miocene, than that which is afforded to us in the great fault at Morvern. Here we find a mass of strata composed of Lias unconformably overlain by Upper Cretaceous, and this in turn by Miocene basalts, let down by a fault, which must have a throw of nearly 2000 feet, against the contorted gneissic rocks of the Lower Silurian. Nothing can present a greater contrast than the green terraced hills of the former, rising in Glashven to the height of 1516 feet, and the barren and rugged mountains of the latter culminating in Garbh-shlios (1638 feet). The abrupt junction of these rocks can be traced in the wild ravine of Innimore.

fied reservoirs and rivers, through the removal of all traces of the ducts which once connected them with one another, and which must have necessarily existed at higher elevations than either of them.

In the following pages I hope to be able to supply a complete and satisfactory solution of the interesting question of the *position* of the vents from which the great lava streams so conspicuous in the north-western part of the British archipelago originally flowed; and even of the *dimensions* and *features* of these old volcanoes I hope to be able to furnish some data for forming a judgment. At the same time I shall exhibit, in its outlines at least, the history of the long series of volcanic eruptions to which the rocks of this district owe their accumulation. Further, I believe that it will be possible, from these interesting examples, to deduce some important conclusions as to the modes of operation of volcanic action, especially of that by no means insignificant part of it which takes place far below the surface, and which, in the nature of things, can never be observed by us in volcanoes which are still active or but recently extinct; for in these the mountainous piles of ejected materials altogether conceal the underlying rocks. Even in the cases of the deepest ravines on the flanks of existing volcanoes (and I do not here except even the wonderful natural sections of Somma and the Val del Bove), interesting as these undoubtedly are, the insight afforded to us of the internal structure of the mountains must be at the best very partial indeed; but in the Hebrides I shall show that we have supplied to us that great geological desideratum—a number of volcanoes so dissected by the scalpel of denudation as to constitute, as it were, a series of anatomical preparations, from which we may learn directly the internal structure of the piles, and obtain bases for reasoning on the causes to which that structure owes its origin. Thus the study of these ancient volcanoes is, as I believe, calculated to throw new light upon some of the most difficult problems of physical geology.

As I have already intimated, we have, in the west of Scotland, the relics of two great and widely separated periods of volcanic action: one of these was evidently of earlier date than the deposition of the Mesozoic strata which unconformably overlie its products; the other was certainly of later date than the formation of the Secondary rocks, upon which its products are everywhere superposed, and through which they are intruded. As might be anticipated, the relations between the various products of the two volcanic series and the intermediate Secondary strata are often of the most intricate character.

For the purposes of the present argument it will be convenient to discuss, in the first instance, the characters presented by the younger series of volcanic rocks, as these, owing to their comparatively better state of preservation, often throw much light on the internal structure and the true relations of volcanic masses. Guided by the analogies of this younger series of rocks, we shall be the better prepared to decipher the more obscure, because less perfectly preserved, relics of the older series of similar products.

II. *The Tertiary Volcanoes.*

1. *Classification of the Tertiary Volcanic Rocks.*—In approaching the consideration of this part of my subject, I hasten to acknowledge the important assistance which I have received from the very valuable memoir of Prof. Zirkel, of Leipzig, entitled "Geologische Skizzen von der Westküste Schottlands" *, which made its appearance in 1871. This author, who is so well known for his important contributions to petrology, made a tour in the Hebrides in 1868, and in the memoir referred to has given an admirable sketch of all that had hitherto been done in the elucidation of the geological structure of the district, accompanied by the details of his microscopic studies of the various specimens of rocks collected by him.

Bearing in mind the backward state of petrological investigations in this country, I have in the present memoir almost uniformly followed the classification and adopted the nomenclature of Prof. Zirkel. The few instances in which I have departed from his terminology, such as, for example, in avoiding the use of the terms "porphyry" and "amygdaloid," and employing their adjective derivatives instead, will, I hope, commend themselves to all geologists. In the case of rocks not noticed by Prof. Zirkel in the memoir cited, I have endeavoured as far as possible to make my use of terms correspond with the definitions given by the same author in his very admirable 'Lehrbuch der Petrographie,' published in 1866.

In studying these rocks and minerals I have also to acknowledge the valuable assistance of Mr. David Forbes, F.R.S.; of Mr. Thomas Davies, of the British Museum; and of Mr. Rudler, of Jermyn Street.

The Tertiary volcanic rocks constitute two well-marked parallel series. Each of these series has at one end of it a highly crystalline rock, and at the other a perfect glass; while the intermediate terms constitute the most complete and insensible gradation between these two extremes. The *ultimate* chemical composition of the rocks of either series is identical in all the members of it, or rather varies between the same comparatively narrow limits. But the average composition of the rocks of the two series presents the most marked contrast when compared with one another.

These two series of igneous rocks have long been recognized by petrologists as occurring both in recent volcanoes and in association with the strata of every geological period. From the marked difference in the quantity of silica which they contain they have been designated the acid and basic series: the former is sometimes known as the felspathic, orthoclastic, or trachytic series; and the latter as the augitic, plagioclastic, or basaltic.

In the members of the acid series of igneous rocks the percentage of silica varies from 60 to 80, averaging about 70; while in the basic its limits are 45 and 55, and its average 50. In the former class of rocks the proportion of alkalies is comparatively large, and that of the alkaline earths and the oxides of iron and manganese small; but in the latter, lime, magnesia, and oxide of iron con-

* 'Zeitschr. d. deutschen geologischen Gesellschaft,' Jahrg. 1871, pp. 1–124.

stitute a very large proportion of the mass, while the quantity of soda and potash is comparatively insignificant.

The contrast between the ultimate composition of the rocks of the two series is illustrated in the following Table:—

	Acid series.			Basic series.		
	Max.	Average.	Min.	Max.	Average.	Min.
Silica	80	72	61	55	50	45
Alumina	19	15	10	18	14·5	10
Alkalies	20	7	0	8	3·5	0·5
Alkaline earths	8	2	0	29	17	8
Oxides of iron and manganese	5	2·5	0	19	14	8

In the acid series the highly crystalline form is known as granite, the glass as pitchstone or obsidian. The intermediate terms of the series have received a great number of names, only a few of which it will be necessary to notice here.

In the basic series the most highly crystalline form is known as gabbro, the glass as tachylite; and the intermediate forms are also, as in the former case, very numerous.

In the accompanying Table (p. 235) the composition of the principal rocks of these two series is illustrated; the averages are for the most part those calculated by Durocher; in the instances marked by an asterisk I have been compelled to employ averages calculated by myself from published analyses.

The Tertiary granites consist essentially of two species of felspar with quartz, and either mica or hornblende, or both of these minerals together. These granites often, but by no means uniformly, present a somewhat cavernous structure, in which case the constituent minerals are found with perfectly terminated crystals projecting into the cavities of the rock. The felspars consist of orthoclase and oligoclase, with much more rarely albite also; their crystals often present a pale brown or buff colour, owing to the partial decomposition of ferruginous materials entangled in them. When, however, the rock is quarried at some depth from the surface the felspars are usually seen to be of a beautifully white colour; while more rarely they present pink and reddish tints. The quartz is usually white, but not unfrequently smoky, and in rare cases black; it sometimes forms perfect crystals. The felspar and quartz make up the mass of the rock, which is always a highly silicated one; and the magnesian and ferruginous silicates are present only in comparatively small quantities. In the deeper and more central parts of the great granitic masses the rock is micaceous; but as we pass

Table Illustrating the Average Ultimate Chemical Composition of the Rocks of the Acid and Basic Series.

Acid Series.

	Specific gravity.			Silica.			Alumina.			Potash.			Soda.			Lime.			Magnesia.			Oxides of iron and manganese.		
	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.
Granite	2·73	2·66	2·60	78	72·8	66	18	15·3	11	9	6·4	4	2·5	1·4	0	1·5	0·7	0	2	0·9	0	2·5	1·7	0·5
Syenite-granite ...	2·75	2·68	2·63	72	69·0	64	17	15·0	12	6	4·2	3	3·5	2·8	1	4	2·2	1	4	2·6	2	5	3·2	2
Felsite *	2·70	2·65	2·60	81	74·3	68	15	13·1	11	8	4·4	2	5	2·8	0·5	3	1·2	0·5	1·5	0·6	0	5	2·8	1
Felstone	2·63	2·64	2·53	80	75·4	68	18	15·0	11	6	3·1	2	6	1·3	0	2	0·8	0	2·5	1·1	0	4·5	2·3	0·5
Pitchstone &c. ...	2·36	2·34	2·31	74	70·6	62	17	15·0	11	6	1·6	0	3	2·4	1·5	1·5	1·2	1	2	0·6	0	4	2·6	1

Basic Series.

	Specific gravity.			Silica.			Alumina.			Potash.			Soda.			Lime.			Magnesia.			Oxides of iron and manganese.		
	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.
Gabbro	3·10	2·95	2·85	54	49·0	45	17	15·0	12	1	0·3	0	4	2·5	0·5	14	9·5	6	15	9·7	7	14	11·5	8
Augitic-gabbro * .	3·90	2·90	2·75	54	49·8	45	20	16·5	14	3	1·7	0·8	6	3·9	2	11	7·9	4·5	7	5·4	4	16	13·0	8
Dolerite	3·10	2·95	2·85	55	51·0	45	16	14·0	12	1	0·2	0	5	3·4	2	13	10·0	7	9	5·5	3	18	14·7	9
Basalt..............	3·10	2·96	2·85	53	48	42	18	13·8	10	3	1·5	0·5	5	3·0	2	14	10·2	7	10	6·5	3	16	13·8	9
Tachylite *.........	2·54	2·52	2·50	56	54·3	50	18	16·0	12	4	1·8	0·5	5	4·0	3	8	7·2	6	6	2·8	0·5	13	11·2	10

towards the higher and outer parts the mica is gradually replaced by hornblende, and the rock passes through the varieties of hornblendic granite into syenite-granite. The adventitious minerals in these granites are pyrites, marcasite, chalcopyrite, garnet, apatite, and epidote. The texture of the rock varies greatly, from coarse and sometimes porphyritic varieties to others so finely granular that they might be mistaken at first sight for sandstone.

By the disappearance of the crystals of hornblende (which appear to be replaced in many instances by some easily decomposable mineral, lining the cavities of the rock) the syenite-granites pass into felsites. These exhibit every variety, from the most granitic forms, like eurite, to others which have been called *quartz-trachyte*, from which volcanic rock, indeed, they are in no way distinguishable. These felsites are usually quartziferous, and sometimes very highly so; at other times they are almost wholly made up of crystals of felspar, imbedded in an amorphous paste; and not unfrequently they exhibit the porphyritic structure.

When the felspathic rock becomes compact, as it usually does in the lava streams, it may be called felstone. The felstones of the Hebrides vary in colour from black, through various shades of green and grey, to white; but in almost all cases their surfaces acquire a white crust as the consequence of weathering action. By this circumstance, and also by the manner in which they withstand denuding influences, preserving everywhere the striæ and *roche-moutonnée* forms impressed upon them during the glacial epoch, the felstone-lava streams are strikingly distinguished from the basaltic. Both, however, exhibit the columnar structure (though with characteristic peculiarities in either case), the globular forms developed by weathering, and the amygdaloidal structure, which in both is developed to the greatest extent at the upper and under surfaces of each lava stream. The felstones appear to be highly siliceous trachytic lavas which have undergone more or less alteration; and occasionally, by weathering action, the obliterated banded and sphærulitic structures so commonly found in, and so characteristic of, quartz-trachytes*, are restored in their ancient representatives, the felstones.

When the same rock becomes glassy in structure it is pitchstone or obsidian, the former name being properly applied to the varieties with a resinous, and the latter to those with a vitreous lustre.

In the various intrusive masses and veins the several forms of highly felspathic rock are found passing into one another by the most insensible gradations.

In the basic series of rocks the place of granite is occupied by *gabbro*, a rock which, from the similarity of its mode of occurrence and behaviour to that of the former, has been called "granitone" and "granito-di-gabbro." It consists essentially of a plagioclase felspar, one or more pyroxenic minerals, and olivine—the latter mineral being so uniformly present that, according to Zirkel, it must be regarded as an essential ingredient of the rock. The felspar of this rock appears

* See Mr. Scrope "On the Geology of the Ponza Islands," Trans. Geol. Soc. 2nd ser. vol. ii. p. 195.

to be in almost every case labradorite, of white, green, or purplish tints, and often belonging to the beautifully glassy varieties. The pyroxenic ingredient is usually diallage; but this is often replaced on the one hand by hypersthene, and on the other hand by augite, in the same manner as Streng has shown to be the case with the gabbros of the Hartz. In many cases the augite wholly replaces the diallage; and this is found to be always the case as we pass to the higher and outer portions of the great intrusive masses; while occasionally, instead of augite, we find some other variety of pyroxene, such as the beautiful green coccolite. These brilliant varieties of pyroxene, with the glassy labradorite and the peculiar forms of olivine, constitute rocks of great beauty. The olivine is usually filled with innumerable microliths of chromic or titaniferous iron, by which its ordinary aspect is entirely masked; sometimes, however, it presents its usual clear pale-green tint, and at others, through partial decomposition, has assumed a reddish-brown colour. The gabbros vary in structure from aggregates of crystals, sometimes 2 inches in length, down to finely granular rocks. Among the adventitious minerals which they contain, the first place must be assigned to magnetic iron, which is often present in large quantities; pyrites, marcasite, chalcopyrite, biotite, garnet, apatite, and epidote also occur in it; while serpentine and chlorite are among the results of the incipient alteration which is often found taking place in its mass.

When the gabbro in which the diallage is wholly replaced by augite assumes a granular structure, it becomes dolerite; and when still finer grained, it passes into anamesite and basalt; finally, when the basic rock becomes glassy in structure, it is known as tachylite.

Each member of the basic series of rocks can be seen passing into the others by the most insensible gradations. Thus the side of a gabbro vein is often formed by a layer of basalt; that of a basalt vein by one of tachylite.

The parallelism between the different varieties of the acid and basic series of igneous rocks, and the similarity in their modes of occurrence, is very striking. There is one important distinction between them, however, which it is necessary to bear in mind: the crystalline acid rocks (granites) are usually among the most stable and indestructible of the materials of the globe; the crystalline basic rocks (gabbros) are, on the other hand, particularly liable to decomposition, the diallage and olivine giving rise to the formation of various serpentinous minerals.

I have not attempted to describe the interesting details of minute structure which the microscope has revealed in most of the rocks of these two series, but must refer the reader for information on this subject to the excellent memoir of Prof. Zirkel before quoted.

Besides the acid and basic rocks of Tertiary age in the Hebrides, there occur also a few examples of the intermediate forms—such as diorites and syenites among the intrusive masses, and "porphyrites" and phonolites among the lavas. But these are so small in quantity, and so local and exceptional in their mode of occurrence, as not to demand more than a passing notice in this place.

2. *Nature and Origin of the Great Volcanic Rock Masses.*—Confounded under the common name of "trap," several very important distinctions have been, in the case of these igneous rocks, to a great extent lost sight of; these it will therefore be necessary to refer to particularly.

a. *Lavas.*—These, as already noticed, constitute the great mass of the plateaux, which have been cut up by denudation into those terraced hills so characteristic of the district. They are usually composed of compact or crypto-crystalline varieties of rocks, more rarely of the glassy forms (in the case of the acid and intermediate varieties), but never of the largely crystalline or granitic forms. In very many cases they are distinguished by their amygdaloidal character; but the absence of this feature must not be regarded as an evidence that any particular rock is not to be considered a lava; and, indeed, in thick lava streams the amygdaloidal (or altered vesicular) varieties are almost wholly confined to the upper and lower portions of the mass*. The amygdaloidal lavas often exhibit evidence of their vesicles having been drawn out by the flowing of the mass, but in very various degrees in different cases. Both the basic and the acid lavas at times assume columnar characters; but in those of the former class these are much more frequently displayed, and in a more striking form. The basaltic lavas often exhibit the thick regular columns with equidistant joints, cup-and-socket articulations, and angular processes so well known as occurring at Staffa and the Giant's Causeway; in the felspathic lavas, on the other hand, the columns, when present, are usually of smaller diameter and less regular form, while they are often of great length, and never exhibit joints at regular intervals. The masses of felstone lava are seldom found extending to greater distances than ten miles from their centres of eruption; the basaltic lavas, however, have spread in vast sheets to distances of fifty or sixty miles from those centres.

b. *Intrusive Masses.*—These vary in dimension, from the thinnest veins or strings, to vast bosses constituting great mountain-groups like the Cuchullin Hills of Skye, or the deer-forest of Rum and Ardnamurchan. In their ultimate chemical composition they coincide perfectly with the rocks composing the lavas; but in the varieties of their texture and mineralogical constitution they exhibit a much wider range. Thus, while we find veins of basalt in which the rock-structure is identical with that of many of the lavas, we find also others in which the same rock passes into a glass, tachylite; while others, again, are composed of the highly crystalline or granitic gabbro rocks. Similarly, felstone veins are related to those of pitchstone and obsidian on the one hand, and to masses of felsite, syenite-granite, and granite on the other. As a general rule it may be stated that the largest intrusive masses are composed of the most highly crystalline or granitic rocks. Thus the gabbros on the one hand, and the granites on the other, constitute, for the most part,

* The manner in which this character is displayed by almost every recent lava stream is familiar to all who have visited volcanic districts, and has been alluded to by many authors.

great mountain masses; the dolerites and the felsites occur as intrusive sheets or bosses; while the basalts and felstones form narrow dykes and veins, of which the sides and the smaller offshoots pass into tachylite and pitchstone respectively. Sometimes different varieties of rock-texture are exhibited in the same mass; thus the sides of a mass of granite often pass into felsite, and a vein of gabbro is bounded by surfaces of dolerite or basalt. That these masses were actually forced through older rocks, is shown by the manner in which the latter, whether of aqueous or igneous origin, are disturbed in the neighbourhood of the larger masses of the kind; that they were, at the time of their eruption, in a fluid condition, is proved by the manner in which they have occupied even the minutest fissures of the disturbed rocks; and that this fluidity was connected with a great development of heat, is indicated by the changes to which they have given rise in the rocks with which they have come into contact.

The intrusive rocks seldom exhibit the vesicular (resulting in the amygdaloidal) structure; but they are, on the other hand, often columnar. In the case of the larger masses the columns are generally of large proportions, but indistinct character, while in the dykes and veins they are usually small and often very minute, being in all cases arranged at right angles to the surfaces of the intersected rock.

c. *Volcanic Agglomerates.*—But besides the two series of rocks which we have described as constituting by far the greater portion of the volcanic products of the Hebrides, namely the lavas and eruptive masses, there are others of a very remarkable character, which have hitherto almost wholly escaped observation. Like the two classes of rocks just described, these rocks have also been confounded under the general name of "trap." They are always found associated with the great masses of eruptive rock, and are often remarkable for the fantastic forms to which, in consequence of their peculiar modes of yielding to denudation, they give rise. On their fresh surfaces of fracture the rocks of this class often present no peculiarity which would enable us to infer their mode of origin; it is only on the surfaces of masses which have had their remarkable structure "developed" by weathering operations, that these striking features are revealed to us. In the same manner that a highly crystalline and apparently altogether unfossiliferous limestone (like that of Durness, for example) often exhibits on its weathered faces proofs that it was originally made up of a congeries of beautiful organisms, so these apparently structureless igneous rocks are by the same agency made to reassume to a certain extent their original form. The weathered surfaces of the blocks show that the rocks in question are really agglomerates, composed of angular and subangular masses of rock of all sizes, from blocks several tons in weight down to lapilli, volcanic sand and dust. Many of these fragments are shown by the same weathering process to be highly vesicular and scoriaceous, and among them not a few present the peculiar characteristics of entire or fragmentary "volcanic bombs." In many cases crystals of various volcanic minerals, either fractured or with worn angles or faces, such as commonly occur among the materials ejected from volcanic vents, are found imbedded in these agglomerates.

That these peculiar rocks are really portions of old volcanic piles, and that they are made up of the fragments actually ejected from volcanic vents, no one who has had an opportunity of studying the appearances presented by their weathered surfaces can for one moment doubt. But in the same manner that loose masses of shells and corals have been converted, through the chemical reactions set up by the infiltration of water, into crystalline and apparently structureless limestone, so these old heaps of volcanic cinders have been transformed by similar agencies into rock-masses of great solidity and hardness.

But lest any doubt should still remain as to the real origin of these remarkable rocks, I am fortunately able to adduce a kind of evidence of the same convincing character as that of fossils in the sedimentary rocks. He who would hesitate to accept as evidence of aqueous origin in a rock such physical characters as stratification, oblique lamination, and ripple-marks, could scarcely continue to doubt, if shown in its mass, groups of oysters, bored by sponges and annelids, and overgrown by serpulæ and polyzoa.

In the case of the volcanic rocks, though we cannot adduce the evidence of fossil animals and plants, we can nevertheless point to the characteristic species and varieties of minerals which they contain. Every one is aware that the vents and cones of volcanoes constitute natural chemical laboratories in which many beautifully crystallized minerals are formed which are seldom or never found except in the actual vicinity of eruptive centres. Hence such species and varieties are usually classed by mineralogists as "volcanic minerals." These minerals, as is so well known, are constantly found filling the fissures and vesicular cavities which occur in the various blocks ejected from the volcanic vent; and as has been remarked by Daubeny, Sorby, and other authors, they usually belong to different species and varieties from those which characterize the lava streams which have solidified at some distance from the volcanic vent. The agents concerned in the production of these volcanic minerals appear to be intense heat, combined with the infiltration of water under immense pressure, and the penetration of various acid gases and volatile materials.

Many of the peculiar volcanic minerals are of remarkably unstable character; and of these it would be as unreasonable to expect the preservation as that jelly-fish, lobworms, and the soft tissues of animals and plants should be found in sedimentary rocks. But the more stable species of volcanic minerals actually do occur in a "fossil state" in the midst of the volcanic agglomerates of the Hebrides; and the preservation, under favourable conditions, of their often delicate and beautiful crystals is the result of a remarkable series of operations. In the first place, by infiltration, the masses of crystals are surrounded by, and imbedded in, a mass of zeolitic minerals which is formed by the decomposition of the felspars of the lava; and thus carefully packed they escape further injury. Subsequently, on the exposure by denudation of the rock-masses, the "cotton-wool" of zeolitic materials is gradually removed: and, under favourable circumstances, the original crystals are sometimes thus again exposed, exhibiting all their pristine lustre and beauty. Among the minerals thus occurring many beautiful varieties of the epidote and garnet groups are especially conspicuous. Some of these minerals appear to have been formed in the fissures of masses of rock which were ejected from the volcanic vents; others may have originated from the action of various gases upon the materials of the lava during the "solfatara stage" of the volcano's history.

d. *Volcanic Breccias.*—The rocks of the last-mentioned class pass by insensible gradations into those which it is now our purpose to describe. Scattered through the masses of the agglomerates of scoriæ and ashes, we find blocks of stone of the most various kinds, which are evidently of foreign origin; and in some cases these become so numerous that the rock may be described as a breccia composed of fragments of foreign rocks imbedded in a matrix of volcanic ashes, sand, and lapilli.

That these angular blocks, which vary in size from masses several tons in weight down to the smallest fragments visible to the naked eye, were actually ejected from volcanic vents, we should be justified in concluding, not only from the analogy of existing volcanoes, but from the confused and irregular manner in which they lie in the masses of evidently erupted volcanic materials *. Fortunately, however, we can point to facts which are altogether conclusive as to the origin of these blocks. They are found to belong, in every case, to the particular rocks through which the volcanic vent which they surround has been opened. Thus in the island of Rum (where these volcanic breccias are admirably displayed, as we shall see hereafter), which forms the central part of an old volcano that has burst through rocks of Cambrian sandstone, the blocks in question consist exclusively of materials derived from that formation; in Mull a great volcano has originated in the midst of various Palæozoic and

* The frequency with which blocks torn from the rocks underlying a volcano are thrown from its vents during eruptions is a fact familiar to all students of volcanic geology. Alike in the old agglomerates of Somma and among the modern ejections of Vesuvius, there abound fragments of those stratified rocks in the midst of which the great fissures to which the Neapolitan volcanoes owe their origin have been opened. The so-called "lava" ornaments of Naples are made from the limestones, often more or less dolomitized, of these ejected blocks; while from the cracks and cavities of the same are derived the greater portion of those beautifully crystallized specimens which have made Somma and Vesuvius so preeminently famous among mineralogists. The blocks thrown out of the great Neapolitan volcano were, for the most part, evidently derived from the Subapennine (Tertiary) strata; but some from the Apennine (Secondary) rocks also occur. My friend Prof. Guiscardi, of the University of Naples, was, in 1856, able to give a list of no less than 112 species of fossils derived from the blocks thus ejected from the crater of Vesuvius (see his "Fossile Fauna des Vesuvs" in Roth's 'Der Vesuv und die Umgebung von Neapel,' 1857); and this list he has since increased. Near the great crater now occupied by the Lago Bracciano, I found great masses of volcanic agglomerate containing such enormous quantities of angular fragments of Subapennine limestone as to constitute "volcanic breccias" greatly resembling those of Mull which are referred to in the text.

Secondary strata, fragments of the whole of which occur in the volcanic breccias; while at Beinn Shiant, a volcanic vent having been opened in a tract made up of older lavas, easily recognizable portions of these occur in the great masses of agglomerate which constitute a portion of the relics of the volcanic cone.

In many cases such ejected blocks exhibit evidence of having been submitted to a certain amount of heat. Being often composed of materials of much more indestructible character than the consolidated ashes &c. in which they are imbedded, they are frequently left lying, like the included blocks of masses of Boulder-clay which have been destroyed by denudation, upon the surfaces of the mountains; and for these, indeed, they may, by a casual observer, be easily mistaken in some instances. Such an idea, however, is at once removed by an attentive study of the whole of the phenomena and conditions of the case.

3. *Relations of the Volcanic Rocks to one another and to the Older Deposits in the Island of Mull.*—We now turn to the consideration of the very interesting question of the manner in which the several kinds of volcanic products, which we have described in the preceding pages, are associated with one another, and of the positions which they occupy with respect to the strata of the Palæozoic and Mesozoic epochs. Owing to a peculiar combination of favourable circumstances, which will be more particularly described in the sequel, the island of Mull furnishes us with a most complete and beautiful illustration of the relations which the volcanic rocks bear to one another; and we therefore propose, in the first instance, to describe the structure of this district.

The island of Mull, with the adjacent peninsula of Morvern and various small surrounding islands, form portions of a great plateau, composed of sheets of basaltic lava piled upon one another to the depth of nearly 2000 feet. This plateau, which is now broken up by denuding agencies and traversed by numerous fiords and sounds, is, on its southern side, brought into abrupt contact with the Palæozoic rocks through the agency of a great fault, which has a throw of at least 1600 feet.

In the centre of this basaltic plateau rises a group of lofty mountains, about twelve miles in diameter, many of the peaks of which rise to heights of from 2000 to 3000 feet above the sea-level, while one of them, Beinn More, attains an altitude of no less than 3172 feet.

Nothing can be more striking than the contrast presented by the mountain-peaks of this central group of mountains and the eminences of the surrounding plateau. While the latter are everywhere characterized by those remarkable tabular and terraced forms which have suggested the name of "trap" (forms which, by constant repetition in these districts, tend to become monotonous), the former exhibit the most wonderful diversity of outlines—lofty, smooth, pyramidal masses, like Beinn Tsalla, being mingled with wildly irregular, and fantastically shaped peaks, like Beinn Buy, Creach Beinn, Beinn Varnach, Dun-da-gu, and Craig Craggen.

A very slight examination of the rocks of Mull is sufficient to explain the cause of the differences presented by the mountains of the central and outer portions of the island respectively. While the latter are made up of nearly horizontally disposed lava streams, the former consist of a number of intrusive masses composed of rocks of very various degrees of hardness, and associated with great deposits of volcanic agglomerates and breccias—the several rocks yielding, as might be anticipated, to denuding forces in very unequal degrees and in very various manners.

The positions and relations of the rocks of Mull are illustrated in the accompanying plan and sections (Pls. XXII. & XXIII.). In these an attempt has been made to exhibit the relations of the different rock-masses by employing different colours for the two great varieties of igneous rocks, while the variations in the depth of tint in either case serve to indicate their crystalline, stony, or glassy character.

Forming the basis of the great central mountain-group of Mull are masses of highly siliceous intrusive rocks. Where great valleys have deeply intersected these masses, they are seen to be composed of granite, usually of the hornblendic variety, but passing, in the deepest and most central portions of the masses, into ordinary granite with mica. But in proportion as we trace the rocks of the mass outwards and upwards, we find the granite passing by insensible gradations into felsite. Lying upon the skirts of these central bosses of granitic and felsitic rock are thick masses of felstones, disposed in regular sheets and of amygdaloidal structure, which alternate with beds of scoriæ, lapilli, and ashes, containing many included blocks of the stratified rocks of the island. While these latter undoubtedly represent the lavas and fragmentary materials ejected from a volcanic vent, the central hills of granite and felsite are no less certainly great eruptive masses; and that this is the case is proved by the fact that they give off numerous veins both into the overlying felstone lavas &c. and into the surrounding older strata, which veins are often seen to have entangled fragments of the various rocks which they traverse.

Rising through the midst of these masses of granitic and felsitic rocks, and constituting the bulk of Beinn Buy with parts of the surrounding mountains of Creach Beinn, Beinn Varr ach, and Beinn Tsalla, we find a great mass of gabbro or basic rocks from which there proceed in every direction innumerable veins, sheets, and intrusive masses of irregular form, that traverse the whole of the highly siliceous rocks in every direction. In these great intrusive masses of gabbro the pyroxenic ingredient in the deeper and more central parts appears to be diallage and hypersthene, which minerals are replaced in the peripheral portions by various forms of augite. As we trace the gabbros into the numerous veins which proceed from the central mass, they are found to graduate into dolerites, exhibiting every degree of coarseness of grain, and through these into ordinary basalt. In the latter condition the veins and dykes often proceed to great distances from the central mass, intersecting alike the lavas of the great plateaux and the various Primary and Secondary strata which underlie them (see Pl. XXIII. fig. 1).

Owing to the very different modes of weathering of the igneous rocks of the acid and basic series respectively, it is comparatively easy for the geologist to study the relations which they bear to one another. This study is conclusive as to their relative age and position. The rocks of the acid series were first extruded and consolidated; and subsequently there was forced through their midst a fluid mass of basic materials penetrating the innumerable fissures of every size which, by the upheaving force, were rent alike in the earlier-formed igneous rocks and the surrounding strata.

Overlapping the edges of the felstone-lava series we find the basaltic lavas of the great surrounding plateaux; and that these once entirely buried the former is shown by the small outlying portions of basalt which at some points still remain capping the felstones.

Finally, we must notice that all round the central masses of eruptive rocks there occur patches of volcanic agglomerate and breccias, alternating with lava-sheets and traversed by innumerable veins and dykes. These patches constitute the last remaining vestiges of the great conical piles of fragmentary materials which so frequently surmount volcanic vents. As will be hereafter shown, they belong to two different periods of eruption.

Of the rocks upon which the streams of lava which constitute so large a portion of Mull were poured out, and through which the great eruptive masses of the central portion of the island have forced a passage for themselves, we are not left in doubt. At the south-western extremity of the island the peninsula of the Ross of Mull, consisting of Lower Silurian gneiss and mica-schist, with an eruptive mass of granite (which will be shown hereafter to be of later Palæozoic age), stretches beyond the lavas of the great plateau, and is continued in the proximate island of Iona, composed of rocks supposed to be of Laurentian age. In the south-eastern part of Mull a series of old volcanic rocks, alternating with breccias, conglomerates, and sandstones (all of later Palæozoic age), is exposed by the agency of great faults; while, at a great number of different points around the coast, strata of Middle and Lower Lias age are exposed beneath the lava streams, and are seen to rest unconformably upon the several palæozoic rocks; all these older formations are covered unconformably at some points by Cretaceous rocks representing the Upper Greensand and Chalk.

Wherever we approach the great central eruptive masses, whether of granite or gabbro, the whole of the stratified rocks, both of Primary and Secondary age, are found to have suffered great disturbance and intense metamorphism—the limestones passing into saccharoid marble, the sandstones into quartzites, and the shales into indurated slaty rocks or the "Lydian stone" of many old authors.

Lastly, as already noticed, fragments of nearly the whole of the underlying rocks of the island occur imbedded among the ashes, lapilli, and scoriæ forming the volcanic agglomerates already noticed.

4. *Sections illustrating the Structure of the Island of Mull.*—In consequence of the facility with which certain of the volcanic rocks of Mull yield to disintegrating forces, owing to their extremely

jointed condition, some of the mountains in the island present splendid natural sections, which afford the geologist the clearest insight into the relations of the different rocks which constitute them. By selecting several of these fine natural sections as types, we shall best be able to illustrate clearly the somewhat complicated relations of the different volcanic rocks of the island to one another.

a. Beinn Greig (see Section, Pl. XXIII. fig. 2) is a mountain which rises near the western end of Loch Bah to the height of 1941 feet. The appearance of this mountain, as viewed from the north, is very striking, the much-jointed granite and felsite which constitute the greater part of its mass having crumbled down, leaving an almost precipitous face. The lower and internal portion of the mountain, as is well seen on its south side, in the deep ravines which divide it from Beinn-y-chat and Beinn-a-Gobhar, is composed of a well-formed typical granite, for the most part of the hornblendic kind. As we ascend the mountain this granite is found to pass by insensible gradations into a quartziferous felsite, the hornblende being replaced by easily decomposable minerals, the decay of which greatly facilitates the disintegration of the rock. Still higher the rock becomes finely crystalline or granular, the magnesian and ferruginous materials being apparently no longer separately crystallized, but diffused through the mass as colouring-matters. The porphyritic structure is locally displayed by all portions of the mass alike, from the coarsest granite to the finest-grained felsite.

When the northern face of this mountain is viewed from a little distance, the whole mass presents the appearance of being made up of a number of concentrically curved beds. This pseudo-stratified appearance is, as all geologists are aware, very frequently presented by masses of undoubted igneous origin *; whether in the present example it is to be regarded as due to the manner in which the fluid rock was extruded, or to changes which have taken place in the mass during the process of cooling, I shall not here attempt to determine.

The granite and felsite of Beinn Greig are traversed by innumerable veins. These all appear to be of the "contemporaneous" class, and to be composed of similar materials to those of the mass itself, differing for the most part only in the degree of fineness of grain, colour, &c. Usually the rock of the veins is of much finer grain than that which it traverses; and in some analogous cases the acid rock actually passes into the glassy condition, and exists as pitchstone veins traversing granite. In a few instances thin veins of almost pure quartz and others made up of crystallized felspar are found.

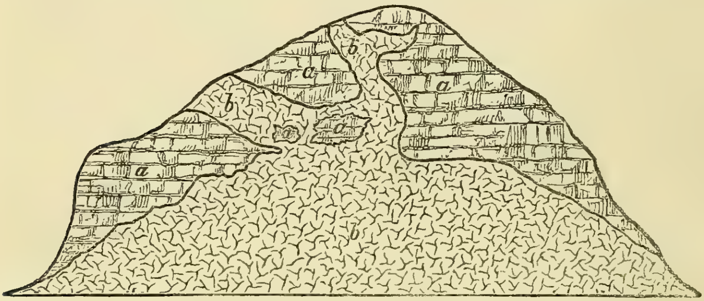
Lying upon the summit and flanks of the eruptive rocks just de-

* I may especially cite the granite of Arran, where similar features to those described as occurring in Mull were noticed by Macculloch. This concentric structure appears to be similar to that referred to by Mr. Scrope as occurring in certain of the domitic puys of Auvergne, such as Clierson and Le Grand Sarcouï (see 'The Geology and Extinct Volcanos of Central France,' 2nd edition, 1858, p. 68).

scribed, are sheets of lava of the highly acid variety (felstones), often highly vesicular and amygdaloidal in structure, which alternate with great masses of ash, lapilli, and scoriaceous fragments. The very rugged forms which these rocks assume in weathering causes them to present a marked contrast with the rocks on which they repose. They have evidently been thrust upwards to a certain extent by the great intrusive masses below them, and are seen dipping in both directions from them; on the west they are intersected by the shores of Loch-na-Kael, where their characters can be conveniently studied.

b. Beinn Uaig.—The relations of the intrusive granite and felsite to the overlying felstone lavas is, owing to the inaccessibility of many parts of the mountain, not conveniently exposed for study upon Beinn Greig. But in Beinn Uaig we have a precisely similar section in which the junction in question is beautifully illustrated. This section is represented in the woodcut, fig. 1. The granite and felsite

Fig. 1.—*Rocks forming the Summit of Beinn Uaig, Isle of Mull.*



a. Felstone lavas, with agglomerates.
b. Syenite-granite graduating into felsite.

are seen to give off great veins which traverse the masses of felstone lava and volcanic agglomerate, producing a very sensible degree of alteration in them along the surfaces of contact; and, further, these veins are seen to include masses of the traversed rock which have been caught up in them. In all these features we recognize the characteristics of intrusive granitic masses, which have been so admirably illustrated in the writings of Hutton, Playfair, Webb Seymour, and Macculloch.

c. *Craig Craggen* (Section, Pl. XXIII. fig. 3).—The valley of the Forsa or Pennygown river exposes on its western side a fine section of the mountain called Craig Craggen, which rises to the height of 1885 feet. We here find the granites and felsites presenting the same relations to the overlying felstone lavas as in the two examples before cited. As we trace the lavas up the slopes of the mountain the intercalated masses of agglomerate are found to become gradually thicker, until they constitute the larger portion of the mass, though still traversed throughout by lava sheets, and intersected by innumerable dykes. Associated with the agglomerates are numerous ejected blocks; these comprise examples of nearly all the rocks found beneath the lavas of Mull, including the Lower Silurian gneiss, quartzite, mica-schist, and slate, the Newer Palæozoic breccias, conglomerates, sandstones, and lavas, the Liassic rocks, and the Cretaceous quartzose conglomerates, grits, and sandstones.

At its northern end, as we approach the summit, the whole of the highly siliceous rocks which compose the mass of the mountain, granite, felsite, felstone lavas, and felspathic agglomerates, are seen to be penetrated indiscriminately by numerous intrusive sheets or dykes on the grandest scale, composed of various forms of gabbro, passing into dolerite and basalt, which have evidently produced a greater or less amount of alteration at the planes of contact in the rocks which they traverse. These great intrusive sheets and dykes of basic igneous rock were, from their position, evidently at one time connected with the great masses of gabbro forming Beinn Varnach and the eastern portion of Beinn Tsalla, from which they are now separated by the Forsa Glen. Owing to the manner in which these gabbro dykes resist denuding influences their course among crumbling rocks of the acid class can be easily traced by the geological observer.

The last point to be noticed with regard to Craig Craggen is that the spur known as Nid-a-shoag (the Hawk's nest) is capped by an isolated patch of ordinary basalt, which, from its amygdaloidal character is recognized as a portion of an old lava sheet; while, overlapping the felstone lavas, towards the northern foot of the mountain we find portions of the great series of basaltic lavas, which, though cut off abruptly on the shores of the Sound of Mull, are seen to be continued on the opposite side in Morvern. The relations of the several masses of rock of the basic class are such as to leave no room for doubt that the comparatively soft scoriaceous masses of this mountain owe their preservation to a covering of basaltic lavas, of which the outlier of Nid-a-shoag constitutes the last vestige; and it seems almost equally impossible to resist the inference that the lavas of the great basaltic sheets were once actually continuous with the great intrusive gabbro masses, which are composed of identical materials with them though in a different state of aggregation.

d. *Beinn More* (Section, Pl. XXIII. fig. 4).—To complete our series of illustrations of the relations which the several volcanic products of the island of Mull bear to one another, we cannot do better than notice this, the highest peak in the island. In the lower parts of this mountain and the spurs around it the granites, felsites, felstone lavas, felspathic agglomerates, with the intersecting dykes of gabbro, dolerite, and basalt may be observed presenting the relations to one another which have been already described. Resting unconformably upon these is a mass, many hundreds of feet in thickness and constituting the whole of the higher portions of the mountain, composed of basaltic scoriæ, tuffs, and ashes, alternating with lava sheets and intersected by a plexus of dykes. By the thinning-out of the masses of agglomerate the basaltic lavas come together, forming the great peninsula of the Bourg or Gribun, which is made up of lava sheets piled on one another to the depth of more than 1600 feet. It is evident that the beds forming the summit of Beinn More, which are composed of alternations of lavas and agglomerates, the latter exhibiting in the fissures of ejected blocks so many beautiful minerals of the same kind as are found in similar positions in connexion with existing volcanoes, constitute the last vestige of a volcanic cone formed during the period at which the basaltic lavas were ejected. The entire absence of ejected blocks of the stratified rocks in these later agglomerates becomes a very significant fact when we remember that, while the earlier eruptions of acid rocks broke through masses of the older strata, the later basaltic masses forced their way through the midst of the former.

Although the great mass of the lavas constituting the great plateaux are of basaltic composition, yet they vary greatly among themselves in many minor features; and among them are occasionally found sheets of clinkstone*, a rock of a more or less acid or intermediate composition. The number of these exceptional lavas is found to greatly increase as we approach their points of origin, as in passing up Beinn More. This circumstance (one presented in many existing volcanoes) is easily explained by the well-known fact that the more acid lavas as a general rule exhibit a much less perfect fluidity than those of the basic class.

5. *Proofs that the Central Mountain-group in Mull constitutes the Relic of a great Volcano.*—No one familiar with the phenomena of active or recently extinct volcanoes, illustrated as these have been by the researches of Lyell, Darwin, Von Waltershausen, Humboldt, Von Buch, and many other investigators, but more especially by Scrope, in his classical work on 'The Geology and Extinct Volcanos of Central France,' can for one moment hesitate as to the interpretation to be given to the phenomena which I have described as being presented by the rocks of the island of Mull.

The group of mountains occupying the central portion of the island is clearly the greatly denuded core of an immense volcanic pile, the great accumulations of scoriæ and lavas which formed the bulk of this mountain-mass having been to a great extent removed, and what now remains to our study being little more than the skeleton or framework of the vast pile, formed by the consolidation of the springs of liquefied rock which rose through its mass. "If," wrote the late Professor Jukes, "we could follow any stream of lava to its source in the bowels of the earth, we should probably find it changing, under varying circumstances of depth and pressure, from scoriæ or pumice to granite"†. By the study of the relations of the rocks of Mull the geologist is able to supply the most complete verification of this conclusion, and indeed to illustrate every stage of the transformation.

* The term "porphyrite" has been sometimes applied to these rocks; but they agree in every essential respect with many of the phonolitic lavas of recent volcanoes. Rocks precisely resembling those of Mull occur in the central masses of Mont Dore and the Mezen in Central France.

† Encyclopædia Britannica, Art. "Mineralogy and Geology."

Moreover the history of the accumulation of its materials, the plan of its architecture, and the succession of the changes which have taken place during its formation may be distinctly read in the ruins of this old volcanic cone.

At the commencement of the Tertiary Period the area now constituting the island of Mull formed part of an old land-surface composed of many different rocks. It is not difficult to reconstruct the geological features of the district at that period. Strata of Laurentian age were covered unconformably by highly metamorphosed Lower Silurian rocks, through the midst of which arose a great eruptive mass of granite. Lying unconformably upon the Older Palæozoic rocks were great masses of old lavas &c. belonging to the Newer Palæozoic periods, while the whole was unconformably overlain by many patches of Jurassic strata. Lastly, overlapping the whole of the rocks already noticed, and lying upon their upturned and denuded edges, were a number of tracts composed of Cretaceous rocks only recently upheaved above the sea-level.

Such were the geological features of the land upon which the grand and long-continued series of volcanic phenomena which we have to describe were displayed. This volcanic action appears to have commenced by the opening of vents from which violently escaping steam hurled aloft great volumes of felspathic ashes, lapilli, and scoriæ, mingled with numerous fragments torn from the rocks through which the explosive discharges took place. These eruptions of fragmentary matters were accompanied, at intervals, by the outflow of streams of acid or trachytic lavas now forming felstones. And, further, the rising liquid mass from which these streams were fed, to a certain extent forced upwards the rapidly accumulating deposits of ejected materials, injecting at the same time with its substance the numerous fissures which the expansive force could not fail to create in the superincumbent and surrounding rocks*. By slow consolidation under pressure the fluid matter gave rise to the formation of masses and veins of felsite and granite. Thus there was gradually built up a great volcanic pile, composed principally of igneous materials of the acid variety.

This period of the ejection of acid materials, which was doubtless one of vast duration, appears to have been followed by one of inactivity; for there is distinct evidence that before the second series of eruptions took place the first-formed cone had undergone great decay: explosions had destroyed its symmetry; subsidences had taken place in portions of its mass; and denudation had removed to a large extent its covering of agglomerates and lavas, exposing the granites and felsites of its central mass.

The second period of eruption was marked by the prevalence of

* Whether some of the granitic and felsitic hills of Mull are the centres of great masses of acid lavas, extruded in a bulky form at the surface, like the "domitic puys" of Auvergne, the central trachytic masses of Rocca Monfina, or the bosses in the midst of the crater of Astroni, it is not possible, in the present degraded condition of the Mull volcano, absolutely to determine. From the analogy of the cases we have cited and also many similar ones, however, we may reasonably infer such to have really been the case.

materials of the basic class among the products of this volcano. The liquefied materials of this period were forced through the older igneous rocks, fissuring them in every direction: those fissures which did not reach the surface would be filled by the consolidating rock and form dykes; but, doubtless, many of these great rents extended to the surface and then gave rise to those eruptions producing the "parasitic cones" so common on the flanks of many great volcanoes. The lavas of this period being possessed of so much greater fluidity, instead of being confined, like those of older date, to the neighbourhood of the volcano, flowed to enormous distances; and so vast were the volumes of material discharged from the volcano, that the lava streams accumulated to a thickness of 2000 feet. That the formation of deposits of such vast thickness occupied periods of enormous duration we may reasonably infer; and the conclusion is confirmed by the proofs of intereruptive denudation among these old lavas, and by the existence of old soils, forest-growths, river-gravels, and lacustrine deposits between them.

At the close of this second period of eruption the volcano of Mull became extinct, and has gradually fallen into that state of decay and ruin which it now presents. But, as we shall hereafter show, volcanic activity in the district did not cease with the extinction of this and the other similar great volcanic mountains of the period.

Having demonstrated the real nature of the central mountain-group in the island of Mull (namely, that it constitutes the basal wreck of a great volcanic pile), I shall proceed to show that, at a number of other points in the same district, there occur similar masses of eruptive rocks associated with volcanic agglomerates and breccias, and that these are the relics of other volcanoes, similar to, and contemporaneous with, that of Mull. After the details into which I have entered with regard to this last-mentioned example, it will not be necessary for me to do more, in describing the other similar instances, than to point out in a general manner the analogies and variations of their structure as compared with that which we have chosen as the type.

6. *The Volcano of Ardnamurchan.*—Immediately to the northward of the island of Mull stretches the peninsula of Ardnamurchan, which forms the most western portion of the mainland of Scotland. In this district we have exhibited to us, though in a much more fragmentary condition, a precisely similar series of rocks, presenting relations with one another identical with those described in the island of Mull.

Constituting the peak of Meal-nan-con and a number of adjoining heights, which stretch in a belt south-westward to near Kilchoan, we find great masses of intrusive felsite presenting many local variations, but as a whole exhibiting a striking identity with the great felsitic rocks of Mull, like which they, in places, assume a distinctly granitic character. Lying upon the eastern and southern flanks of these felsites and penetrated by numerous veins which proceed from them are numerous sheets of felstone, often of amygdaloidal structure. These are interstratified with beds of ash and scoriæ, enclosing fragments of the Lower Silurian and Jurassic rocks which constitute the foundation on which the volcanic rocks of Ardnamurchan are piled.

The whole of the western extremity of the peninsula of Ardnamurchan is constituted by masses composed of many varieties of gabbro, which form a number of wild and barren mountains. At the western extremity of the peninsula the pyroxenic ingredient of the gabbro is either diallage or hypersthene; but as we go eastward these are found to be replaced in varying degrees by other members of the pyroxene family, and the gabbro graduates into dolerite.

Of the intrusive character of this great mass of highly crystalline basic rocks, and its posteriority alike to the Secondary strata and the felstone lavas and felsites, we have the most ample proof. Along the southern side of the peninsula, on either side of the cape called Stron Beg, the strata of Lias and Infeiior Oolite are seen to be upheaved at very high angles on the flanks of the masses of gabbro; and as we approach the latter the sedimentary deposits are found to undergo the most wonderful metamorphism; sandstones are seen passing into quartzites, limestones into marble, and clay into hard shale, slaty rock and "Lydian stone." Not less striking are the effects produced by the gabbros on the earlier volcanic rocks, the felstone lavas which overlie the Secondary strata. In proximity to the gabbros, these felstone lavas are seen to have been upheaved at high angles and to have acquired a peculiar platy structure and splintery fracture, combined in many cases with the development of a probably preexisting banded coloration. Even the crystalline felsites have not escaped the general metamorphism, but exhibit peculiarities of texture and fracture near their junction with the gabbros.

Secondary strata, felstone lavas, and felsite masses are alike penetrated in all directions by innumerable veins, dykes, and sheets of gabbro, dolerite, and basalt; while, to the eastward, the vestiges of old basaltic lava-flows are seen resting indifferently upon the Lower Silurian gneiss, the Secondary strata, and the felspathic lavas of the earlier period of eruption.

Here then, in spite of the more fragmentary character which the relics have assumed in consequence of the enormous amount of denudation which they have suffered, their analogy with the rocks of Mull is unmistakable and points to precisely to the same succession of events. It is evident that in Ardnamurchan we have preserved the "sector" of a great circular volcanic pile, which, like that of Mull, consisted of an older interior mass composed of igneous rocks of the acid class, intrusive, laval, and fragmentary, which mass was pierced and enveloped by the basic products of a second period of eruption.

The manner in which, by means of denudation, the internal structure of the volcanic masses of Ardnamurchan has been laid bare to our view in sea-cliffs and deep ravines, renders this fragment of a volcano of special interest to the geologist. Here he is enabled to study in detail the results of the potent subterranean actions which went on side by side with those subaerial phenomena with which our ideas of volcanic activity are usually associated, but which do not constitute the only, nor perhaps even the principal effects of these grand outbursts. To the consideration of these subterranean phenomena I shall have to return in the sequel.

7. *The Volcano of Rum.*—Lying to the north-west of the peninsula of Ardnamurchan we find the group of the Small Isles, comprising Rum, Canna, Eigg, and Muck, with several smaller islets. The whole of these, with the exception of the first mentioned, are evidently isolated fragments of a plateau composed of basaltic lava-sheets, which are in some places seen to rest unconformably upon various Secondary strata. In the island of Rum, however, we find a great mass of eruptive crystalline rocks which have burst through the older strata; and the various igneous products, in their nature, positions, and relations, present such remarkable analogies with those of Mull and Ardnamurchan as to leave no room for doubt that in Rum also we have the basal relics of a great volcanic mountain (Section, Pl. XXIII. fig. 5).

Nothing can be more instructive than the admirable manner in which, through denudation, the mutual relations of the stratified and eruptive rocks are displayed in the island of Rum. The former consist of Cambrian sandstone with some masses of gneissose, schistose, and quartzose rocks, probably of Lower Silurian age; these occupy the north-west, north-east, and south-east sides of the island, while its interior is formed by masses of eruptive rocks, including both granites and gabbros, which rise into lofty mountains. At a distance from the igneous rocks, the Palæozoic strata exhibit their usual mineralogical characters and their normal strike and dip; but wherever they approach the great central intrusive masses they are found to be violently upheaved and often much contorted, and are further seen to have undergone a striking metamorphism, which often extends to a considerable distance from the igneous rocks; the more argillaceous or felspathic portions of the Cambrian sandstone pass into a highly micaceous black schist, and the more siliceous portions into an impure quartzite. The whole of the stratified rocks surrounding the intrusive masses of granite and gabbro are intersected in all directions by innumerable veins and dykes.

Let us now turn our attention to the igneous masses which form the central group of mountains, and upon the flanks of which the Primary strata lie on three sides of the island, having evidently been removed by denudation on the fourth side. These central mountains of Rum, as is evident to the most casual observer, are composed of two very distinct kinds of rocks, the contrast between which, owing to their different modes of weathering, is extremely striking.

To the westward, and forming the smooth dome-shaped mountain mass of Oreval (1872 feet) and its dependencies, is a great development of much-jointed highly felspathic rocks, consisting of granite passing by every gradation into felsite. These rocks are identical in all their characters with the acid rocks of Mull. They occur also in the south-east of the island of Rum, being there, however, much broken up by numerous sheets and veins of the crystalline basic rocks.

The north-eastern mountains of the central group rise into singularly wild and rugged peaks, among which are Haskeval (2667 feet), Halival (2367 feet), Scùr-na-gilean (2553 feet), and Beinn More (2505 feet). They are composed of the varieties of gabbro in which the pyroxenic constituent consists of several varieties of the augite group, but in which diallage and hypersthene only rarely occur. Precisely similar rocks are found, as we have seen, forming the outer portions of the great basic intrusive masses and the veins which proceed from them, both in Mull and Ardnamurchan. The great masses of gabbro in Rum often exhibit that pseudo-stratification so often observed in igneous rocks, and of which we have noticed such a remarkable example in the granites and felsites of Mull. They are also penetrated by numerous "contemporaneous veins."

The relations between the eruptive masses of the acid and basic classes respectively are scarcely less strikingly displayed in Rum than in Mull; we find numerous offshoots and veins proceeding from the gabbros and traversing the granites and felsites, as well as the surrounding older strata and the agglomerates and lavas.

Thus the island of Rum is for the most part made up of great intrusive masses, and of the more or less disturbed and altered sedimentary deposits through which these have been thrust. Of the overlying ejected materials (lavas, scoriæ, ashes, and breccias) only comparatively small and isolated vestiges remain; owing, however, to the clear manner in which the relations of these to the other rocks are displayed, they are well worthy of attentive study by the geologist.

On the northern flanks of the mountain of Halival we find a great mass of felstone lavas intermingled with agglomerates. But associated with these are deposits of enormous thickness, consisting of blocks of Cambrian sandstone of all sizes imbedded in a matrix of felspathic ash. The included blocks of sandstone in this volcanic breccia vary greatly in size, from masses several feet in diameter down to the smallest fragments. As we approach the gabbro masses which form the bulk of the mountain, the felstone lavas are seen to undergo analogous changes to those manifested in similar positions by the same rocks in Ardnamurchan and Mull.

Other patches of felstone lavas with accompanying agglomerates, which have escaped destruction by denudation, occur at several points on the south-eastern side of the island. On the western side, however, there are several small outliers of the ordinary columnar and basaltic lavas. These exhibit all the usual characters of the sheets forming the great plateau, and were doubtless once continuous with the other and larger outliers of the same rocks, which constitute the islands of Canna, Eigg, and Muck. At Scùr More, or

Bloodstone Hill, these rocks present some features of interest to the mineralogist, owing to the beautiful specimens of heliotrope and other minerals which are found in their amygdaloidal cavities.

But to the geologist the fact of greatest interest in connexion with these basaltic lavas is that they rest directly upon the granite and the Cambrian sandstone, thus affording a most striking proof of the unconformity which exists between the products of the two great periods of volcanic eruption, and an indication that a vast interval must have elapsed between them. This is plain from the fact, of which we have clear evidence, that rocks of the acid class were much wasted by denudation before being covered up by the ejection of basaltic materials.

It is unnecessary for me to remark on the striking manner in which the peculiar features and relations of the rocks of Mull and Ardnamurchan are, in every essential detail, repeated in those of Rum; nor is it necessary to insist upon the conclusion that, like the examples before described, these rocks must be regarded as the relics of a great volcanic pile, and the products of a similar succession of eruptions.

8. *The Volcano of Skye.*—It is doubtless a misfortune that the attempts to unravel the somewhat complicated phenomena presented by the igneous rocks of the Hebrides have hitherto, for the most part, been made in the most frequently visited island of the group, Skye. For, although the relations of the rocks of this island are sufficiently clear, when viewed in connexion with the analogies presented by the other islands; yet, considered alone, they are by no means obvious. It is not surprising therefore that observers, unacquainted with the clearer sections of Mull, Ardnamurchan, and Rum, should have been sometimes led to conflicting conclusions upon the subject.

I will in the first instance point out briefly in how exact a manner all the essential and distinctive features of the old volcanoes already described are repeated in that portion of the island of Skye which is included between Loch Sligachan and Broadford Bay on the north, and Lochs Brettle and Eichart on the south.

Nearly the whole of this district is composed of intrusive rocks which have burst through strata of Palæozoic (Cambrian and Lower Silurian) and Mesozoic (Liassic and Oolitic) age: these are seen at a number of points lying in a greatly disturbed and hightly metamorphosed condition upon the flanks of the igneous masses.

These igneous intrusive masses consist of two different kinds of crystalline rocks, granite and gabbro; and the contrasts between their modes of weathering are exhibited in their most exaggerated form in the island of Skye. The granitic masses of the Red Mountains, culminating in Beinn Glamaig (2670 feet) and Beinn-na-Cailleach (2385 feet), are as remarkable for their strikingly smooth pyramidal forms as the gabbro masses of the Cuchullin Hills and Beinn Blabheinn (both exceeding 3000 feet in height) are unrivalled for their wild, jagged, and fantastic outlines*. The granites of the Red Mountains graduate into many varieties of felsitic rocks,

* *Vide* Geikie, 'Scenery of Scotland,' pls. 2 & 4.

and are traversed by numerous "contemporaneous veins," usually of similar composition to the mass which they traverse; the gabbros of the Cuchullin Hills and Blabheinn pass insensibly into dolerites and basalts, and are also traversed by many "contemporaneous veins." Both of these intrusive rocks, in places, exhibit the pseudo-stratified appearances so commonly displayed by igneous masses.

That the rocks of basic composition were ejected subsequently to those of the acid variety, is illustrated by sections at a number of different points; and this fact was detected by the late Principal J. D. Forbes * in 1845, and by Professor Zirkel † in 1868.

As in Rum, the ejected rocks, lavas, agglomerates, and breccias form only disconnected outliers in Skye; but some of these present very interesting characters. Patches of volcanic agglomerates and breccias, including fragments of the several Primary and Secondary rocks through which this volcano has burst, are found at several points: the preservation of these is probably due to local subsidences; and a good example of them may be examined in the hill on the south of Beinn Dearg, known as Cnoc-na-Fitheach. Outliers of the felstone lavas, more or less mingled with scoriæ and ashes, occur at a number of points round the central mountain-group, and in the island of Scalpa and the peninsula of Strathaird are seen lying directly upon the various Primary and Secondary strata.

Of the great basaltic plateaux which doubtless once surrounded the old volcano of Skye on all sides, we have also only a number of fragments left. By far the largest and most important of these is the one which, stretching north-westwards, constitutes the great peninsulas of Trotternish, Vaternish, Durinish, and Minginish. This mass of lavas has been upheaved on its eastern side so as to display in a very interesting manner the Secondary rocks upon which it lies. Another small outlier of the basaltic plateaux, which has escaped from destruction by denudation, occurs in the adjacent island of Raasay, where it forms the highest point, the striking hill of Dun Can. In Applecross, however, denudation has proceeded one step further, the lava streams having been altogether removed, and thus the Secondary rocks with their included sheets of intrusive igneous rock exposed at the surface. Further, for great distances round the central mountain-group of Skye the whole of the stratified rocks are penetrated by innumerable dykes and intrusive masses both of acid and basic composition.

9. *The Volcano of St. Kilda.*—I have not yet been able to visit this remote group of islands; but from the descriptions of Martin and Macculloch it is sufficiently obvious that we have in them the relics of another of the old Tertiary volcanoes. The islands are said to consist wholly of "trap-rocks;" and the central and largest of the group is described as being formed in its eastern part of granite, and in its western part of gabbro. Macculloch, who was so competent a judge of petrological characters, informs us that these rocks were identical in every respect with those found in the island of Rum.

* Edinb. New Phil. Journ. New Ser. vol. xl. (1845-46), p. 86.
† Zeitschr d. deutschen geologischen Gesellschaft, Jahrg. 1871, p. 90.

10. *Comparison of the great Tertiary Volcanoes.*—It has been shown in the preceding pages that we have evidence of the existence during the Tertiary period of five great centres of volcanic action in the northern portion of the Hebrides—and that at each of these points a great volcanic mountain once existed, the fragmentary, but unmistakable, relics of which still remain for our study. A problem which, however, will naturally suggest itself to every mind is that of the causes which have led to the very different states of preservation of volcanoes which appear to have been formed contemporaneously. The portion of this inquiry which is of more especial interest to the geologist is that concerning the reasons of that comparatively perfect state of preservation exhibited by the volcano of Mull which renders it so admirable a key to the interpretation of the whole series of phenomena presented by the Western Isles of Scotland.

Fortunately the causes of the different extent of denudation in the several cases, and of the exceptional state of preservation of the volcano of Mull, are sufficiently obvious; and as the consideration of these leads us to some highly interesting and important conclusions, I shall now proceed to detail them.

If we compare the volcanoes of Mull and Skye, the differences alluded to, in spite of the identity of the characters and relations of the various rocks which compose them, are very striking. Thus while in the former case we observe the most wonderful interlacing of the two kinds of eruptive rock, and the outliers of the great superposed piles of fragmentary materials are still clearly to be traced, in the latter case the two great eruptive masses rise side by side, with but comparatively few examples of offshoots from the younger into the older series, and the lavas, agglomerates, and breccias which formed the mass of the volcano have almost wholly disappeared.

A careful study of the rocks of Mull shows the cause of this difference to be that the volcanic pile in this island has suffered far less from denudation than in Skye, and that in fact the existing surface in the former island presents a cross section of a volcano taken at a higher level than in the latter. Further, it can be shown that this difference is due to a remarkable central subsidence which has taken place in the case of the Mull volcano.

When we examine the fine sections of the lavas of the basaltic plateaux which are exposed along the shores of the deep fiords of Loch Scridain and Loch-na-Kael, we find that the lava sheets, instead of sloping away from the great central masses of eruptive rock, actually for many miles around dip *towards* them at angles varying from 2° or 3° up to 5°, the inclination increasing as we approach the volcano. Now, as we are certain that this was not the original position of the lava streams, we are led to the conclusion that a subsidence has taken place in the great central mass of the island, a view which is confirmed by an examination of the inclination of the whole of the lavas surrounding the volcano. Still further support to the inference is afforded by the fact that at certain points, as in the valley between Kilfinichan and Gribun, where the Cretaceous rocks underlying the lavas are suddenly cut off, we have clear evidence of the existence of faults the downthrow of which is in all cases towards the great central mass.

By a study of the section of Craig Craggen in connexion with those exposed at some other points, we are led to infer that a similar subsidence took place after the period of the eruption of the acid lavas, and before the outpouring of the basaltic lavas from the same centres commenced.

Now it is a most interesting fact that precisely similar subsidences beneath cones of comparatively recent date have been shown to exist in the case of a volcano in the Cape-Verde Islands by Mr. Darwin *, and in one in New Zealand by Mr. Heaphy †. The phenomena described in these two modern examples are perfectly analogous to those presented in the ancient volcano of Mull; indeed Mr. Scrope has, in reasoning on the causes of the phenomenon, speculated on the probability of its very general occurrence to a greater or less extent in the case of many volcanoes ‡.

According to the observations of Krug von Nidda, Iceland exhibits a precisely similar subsidence of the great volcanic centres to that which we have been describing in Mull, and on even a grander scale §.

From the relative positions of the central masses of granite and gabbro in the great Tertiary volcanoes of the Hebrides we are led to infer that changes must have taken place in the position of the axes of eruption of several of them in the same manner as has been so admirably illustrated in the case of Etna by Sir Charles Lyell (*vide* Phil. Trans. for 1858, pp. 738–744, and 'Principles of Geology' 11th ed. vol. ii. pp. 9–14).

With the consideration of the causes of the phenomenon of the central subsidence of volcanic piles, however, we are not here concerned; but its effect in the island of Mull, where it is exhibited in so marked a manner, has been the exceptional preservation of a series of rocks which afford us the clearest insight into many important matters connected with the history of these ancient volcanoes.

I have already had occasion to allude incidentally to the wild and rugged character of the scenery to which the basic crystalline rocks

* Volcanic Islands, p. 9.

† Quart. Journ. Geol. Soc. vol. xvi. (1860) p. 244.

‡ Volcanos, 2nd edit. (1872) p. 225.

§ Karsten's Archiv, vii. (1834) pp. 247–284. Recent studies of the positions and relations of the older volcanic rocks of the Lipari Islands have convinced me that similar central subsidences must have taken place in connexion with the great volcanic piles of that area. It seems not unreasonable to suppose that the deflection of the liquefied matter below a volcanic centre to new vents may very generally give rise to a certain amount of subsidence in the masses of ejected materials which, often to a very great height, have been piled about it; the great weight of the latter would assist in producing the same result. Of course such gradual and comparatively slight subsidences will not be confounded with, or thought to lend any countenance to, the theory of violent engulfment of the central parts of volcanic mountains, to which cause some geologists have felt disposed to refer the formation of their great crateral hollows.

of the Western Isles give rise, owing to their peculiar modes of weathering. Acted upon very slowly by the agents of atmospheric disintegration, the rock-surfaces assume a remarkable roughness owing to the persistence of the crystals of diallage and augite, acquiring at the same time a deep brown tint from the peroxidation of the iron; and, moreover, these surfaces, not giving rise to the formation of soil, are altogether destitute of any covering of vegetation. The lower flanks of the mountains are marked by the dome-shaped forms resulting from the passage over them of glaciers; and the grooving and striation are wonderfully preserved upon them*; but the summits of the same mountains stand up in the form of wild craggy pinnacles, many of which are altogether inaccessible. Moreover the striking features of these rugged and barren rocks are heightened by the contrasts which they present with the verdant, terraced slopes of the basaltic plateaux on the one hand, and the smooth, dome-shaped and débris-covered hills of granite on the other.

These features of the gabbro rocks are displayed in a sufficiently striking manner in Mull, especially in the wild glen between Beinn Buy and Creach Beinn, and also in Ardnamurchan and Rum; but in each of these cases the entangled portions of acid rocks give rise to the formation of streams and taluses of detritus and the consequent production of soil and vegetation, relieving the monotonous barrenness of the surfaces of these rocks. But in the island of Skye we have a considerable area which is formed almost exclusively of the gabbro rocks; and the wonderful features of the scenery to which these give rise are familiar to all who have visited the Cuchullin Hills and Blabheinn, being most remarkably displayed in the sombre glen which contains the "dark loch" of Coruiskh.

The deep impression made by this remarkable scene on the mind of Sir Walter Scott is recorded in his well-known lines in the 'Lord of the Isles':—

"Rarely human eye has known
A scene so stern as that dread lake,
With its dark ledge of barren stone.
Seems that primeval earthquake's sway
Has rent a strange and shattered way
Through the rude bosom of the hill,
And that each naked precipice,
Sable ravine, and dark abyss,
Tells of the outrage still."

But for the geologist this justly celebrated, and now tourist-haunted, locality may claim a more especial interest. For if his study of the rocks dispels, as it certainly will do, the poet's beautiful dream concerning their origin, it will be only to replace it by a far grander conception; and as he stands here, in the very centre of the cooled reservoir of an ancient volcano, his instructed imagination will revel in the reconstruction from reliable data of the wild and grand features of this old "Tierra del Fuego."

* *Vide* J. D. Forbes, Edinb. New Phil. Journ. New Ser. vol. xl. pp. 90–99 (1845–46).

11. *Dimensions of the great Tertiary Volcanoes.*—It might at first sight appear impossible to arrive at any sound conclusions upon this question, concerning, as it does, the physical features of a period so remote from the present. Nevertheless, as I hope to be able to show, so far is this from being the case, that we have several different kinds of data, foremost among which must be ranked those derived from the subsidence which we have shown to have taken place in the case of the Mull volcano, enabling us to arrive at least at an approximate estimate.

We are able in the case of each of the great Tertiary volcanoes to to arrive at some idea concerning the areas covered by their bases. The base of the volcano of Mull must have had a circumference of at least forty miles; Etna, which has a greatly truncated form, nevertheless rises to the height of 10,900 feet from a base only thirty miles in circumference*; a similar relation between the base and altitude of the great volcanoes of Sicily and Mull would lead us to infer that the elevation of the latter was at least 14,500 feet.

By a careful study of the present inclinations of the lava streams which flowed from the Mull volcano, we may obtain another approximation to the minimum possible elevation of its summit. From an examination of all the data, especially those furnished by the sections along the shores of Loch Scridain and Loch-na-Kael, and carefully availing myself of every check in making the calculations, I find that, if the rocks were restored to the positions which they occupied before the great central subsidence took place, the present summit of Beinn More, which is 3172 feet above the sea, would be raised to to an elevation of at least 6000 feet—and, further, that a central cone reconstructed on the basis thus obtained would have an elevation of more than 10,000 feet.

But this must be regarded as only the lowest possible estimate; for in making it I have totally neglected four different considerations, all tending to increase our estimate, but by what exact amounts it is impossible to state. These are:—

(1) The gradual increase of the inclination of the lava-beds on the higher slopes of the mountain.

(2) The effect of the great faults before alluded to as contributing to the central subsidence, the influence of which, though not exactly determinable, was certainly very considerable.

(3) The originally greater elevation of the surfaces on which the volcanic rocks lie. This is proved by the fact that many rocks which were certainly of terrestrial origin are now below the sea-level.

(4) The great masses of agglomerates and lavas which originally formed the summit and flanks of the mountain, but have now been removed by denudation.

In speaking, however, of the height of a volcano it must be remembered that we are dealing with a quantity subject to constant and wide variations. During a single paroxysm, hundreds, nay, even thousands, of feet of materials may be blown from the sum-

* In this estimate I of course only include the mass of rocks constituting the mountain proper, and not the lava-covered plains around it.

mit of a volcano, and in a few days, weeks, or months a new cone of different form and proportions built up. Such changes doubtless occurred over and over again in the case of the ancient volcanoes of Scotland as well as in those of more recent date.

From the area which its relics occupy, we may conclude that the volcano of Skye was not inferior in its dimensions to that of Mull; and on similar grounds we are led to infer that the volcanoes of Rum, Ardnamurchan, and St. Kilda, though somewhat smaller than these, were nevertheless mountains of great extent and elevation.

Thus we are led to the conclusion that during the Tertiary epoch there existed in the north-western part of the British Islands a range of volcanic mountains which were on the grandest scale—a fact which all who consider the wonderful extent and thickness of their accumulated lava streams will be fully prepared to admit.

12. *Series of later Volcanic Eruptions in the Hebrides resulting in the formation of "Puys."*—I shall now proceed to show that, subsequently both to the period of the eruption of the acid lavas and to that of the ejection of basic rocks, and at a time when the great volcanoes from which these flowed had become extinct and their products greatly denuded, another series of volcanic outbursts of a sporadic character took place within the district, and gave rise to the formation of numerous smaller cones with their accompanying lava streams.

The researches of Mr. Scrope in Central France, of Mr. Darwin in the volcanic islands of the Atlantic, of Hamilton and Strickland in Asia Minor, with others that might be cited, have sufficiently demonstrated that the extinction of great volcanoes is in many (if not in all) cases followed by eruptions on a minor scale, which burst out in the plains at their base and give rise to the formation of numerous small cones, usually arranged along what appear to be lines of fissure. It would seem that the volcanic forces having to a great extent expended themselves, and being insufficient to raise columns of lava to the summits of the mountains which successive eruptions have continually elevated, have nevertheless been able, before sinking into absolute quiescence, to open new vents at lower levels. To the class of smaller volcanoes thus produced it will be convenient to apply the general term "puys,"* from the name by

* It is of course impossible to draw any absolute line of demarcation between the class of subsidiary or parasitical cones which are so abundant on the flanks of many great volcanoes (on Etna there are said to be no less than 800 of them) and that of the "puys," or cones thrown up in the plains in their vicinity. As is so well shown by Mr. Scrope, in his work on Central France, the formation of such puys in a district may be going on during periods of vast duration, and the several eruptions to which they owe their origin may be separated by very wide intervals of time. They appear, however, in almost all cases to be of subsequent date to the extinction of the great central volcanic mountains, and sometimes, indeed (as in the case of the Puy de Tartaret in the Mont Dore), to have been formed in the midst of the ruinous masses of rocks to which such great volcanoes have been reduced by denudation. The course of events in connexion with the history of the decline and decay of a great volcano would appear to be

which they are known in the district rendered classical by the admirable researches and descriptions of Mr. Scrope. I shall now proceed to describe the remarkably interesting evidences which remain of the former existence of such "puys" in connexion with the great volcanoes of the Hebrides.

In the peninsula of Ardnamurchan the highest mountain, Beinn Shiant, rises to the height of 1759 feet. Its very peculiar outlines (see woodcuts figs. 2 & 3, p. 262), exhibiting neither the terraced slopes of the masses composed of superposed lava streams, nor the peculiar contours of either of the two classes of eruptive rocks, are alone sufficient to arrest the attention of the geologist and to lead him to its careful examination. And such study is amply rewarded. The mountain, which exhibits a series of grassy slopes reaching almost to its summit, is remarkable for the far-stretching and boldly shaped spurs which on all sides branch out from a common centre. On a nearer approach we find the cause of these striking features to be that each of the spurs is capped by masses of lava usually exhibiting beautifully columnar forms, while the green slopes below are composed of softer and more easily weathered rocks. The mountain rises near the line of junction of the older felspathic and basaltic lavas before described.

The lavas of Beinn Shiant are intermediate in character to the acid and basic rocks which constitute the masses of the older and great central volcanoes; they present distinctive features by which they are easily recognizable, and are remarkable alike for their great hardness and their power of resisting atmospheric denudation. They constitute rocks of great beauty, varying from aggregates of crystals of glassy felspar, through numerous porphyritic and highly crystalline varieties to compact felstones, which finally pass into pitchstones of more or less porphyritic character, these last being sometimes identical in their mineralogical features and the peculiarities of columnar structure with the rock of the well-known Scùr of Eigg. These lavas appear to be very similar in character to a dark-coloured porphyritic trachyte which occurs at Mont Dore les Bains in Auvergne*.

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generally as follows:—By constant ejections from its summit a volcano is continually increasing its height and adding to the length of the column through which fluid materials must be raised in order to produce a central eruption. In the course of this action a point will certainly be arrived at when it becomes easier for the subterranean forces to rend new fissures in the flanks of the mountain than to raise a column of lava to its elevated summit. At this stage of its history Etna now appears to have arrived, the formation of new parasitical cones on its flanks alternating with comparatively feeble ejections from its summit. But, as the bulk and solidity of a volcanic cone are continually added to by these operations, the subterranean forces will be gradually forced to seek new vents at lower levels in the plains around the mountain, and thus give rise to the formation of "puys." In Ischia, the Lipari Islands, and many other volcanic districts, we have admirable opportunities afforded to us for tracing the sequence of this very interesting series of operations.

* In the islands of Lipari and Salina we have many beautiful illustrations of lava streams, composed of dark-coloured, often nearly black, trachyte, with disseminated crystals of sanidine. These rocks are precisely similar to those

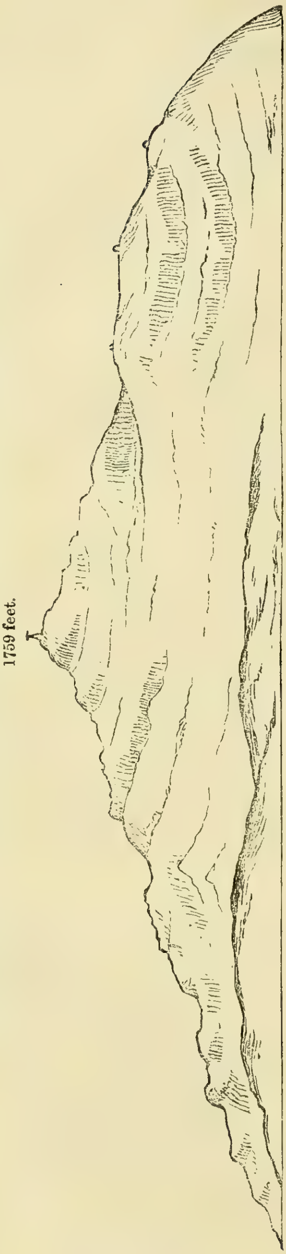

Fig. 2.—*Outline of Beinn Shiant, in Ardnamurchan, as seen from the N.N.W.*

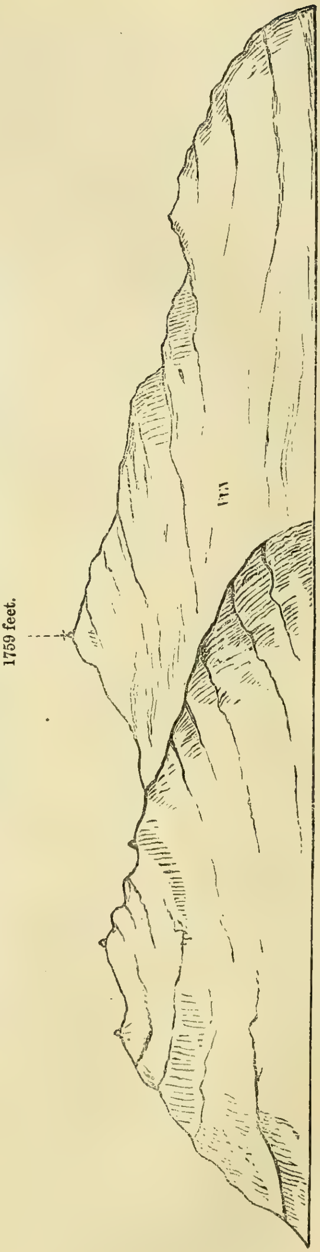

Fig. 3.—*Outline of Beinn Shiant, in Ardnamurchan, as seen from the W.*

The central and apical portion of the mountain of Beinn Shiant is formed of rocks of similar petrological character, which, however, are apparently of intrusive origin. On the northern side of the mountain these rocks form a lofty and precipitous ridge.

The masses of columnar rock evidently constitute portions of a number of lava streams which appear to have been originally in connexion with the central mass, and to have diverged in a radial manner from it. Some of these lava streams can be traced to very considerable distances.

Where the grassy slopes below the lava cappings of the spurs are cut through by streams, they are seen to be composed of volcanic agglomerates and breccias. These contain numerous angular fragments of both the felspathic and basaltic lavas of earlier Tertiary periods with some of the underlying Lower Silurian gneiss, such being the rocks upon which the mass of Beinn Shiant is built up; mingled with these are numerous fragments of felspathic scoriæ and ashes, with many fractured and worn crystals of glassy felspar included in the mass*.

Fortunately for the geologist, one of the spurs of Beinn Shiant is cut across in a sea-cliff forming the headland of Srone More or Maclean's Nose; and here we have a magnificent display of the wonderfully interesting features in the rock-masses composing this remarkable mountain. The upper part of Srone More, which rises to a height of 1050 feet, is composed of the columnar lavas already described; but the almost precipitous cliffs below are seen to be made up of nearly angular blocks of all sizes, up to 6 or 8 feet in diameter, heaped together in the wildest confusion, and presenting no appearance whatever of stratification or of the sorting of the materials according to their specific gravity.

Lastly, it is necessary to notice that the great masses of agglomerate which constitute so large a portion of Beinn Shiant, together with the older lavas and gneiss on which they are piled, are traversed in every direction by dykes and veins of every size, composed of similar rocks to those forming the lava streams—namely, trachyte and "pitchstone-porphyry."

To any one familiar with the characters presented by Arthur's

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of Beinn Shiant, and like them graduate, in consequence of the matrix in which the felspar crystals are imbedded acquiring a glassy texture, into "pitchstone-porphyry." In speaking of the Eocene acid lavas of the Hebrides, I have preferred to apply to them the term "felstone," although it must be remembered that they present no *essential* points of distinction from recent quartz-trachytes, either in chemical composition or mineralogical structure. The later lavas of Beinn Shiant and the Scùr of Eigg present still fewer points of difference from those of active volcanoes; and it would perhaps be more correct to speak of them as "trachytes" than as "porphyrites."

* The frequency with which crystals, often more or less worn and fractured, of various volcanic minerals, such as augite, biotite, the felspars, &c., are thrown out from the vents of volcanoes has been noticed by Mr. Scrope. Such crystals are found alike in the recent ejections of Stromboli, and imbedded in the tuffs connected with extinct volcanoes at Vulcano, Albano, Bracciano, Rocca Monfina, and some of the puys of Auvergne.

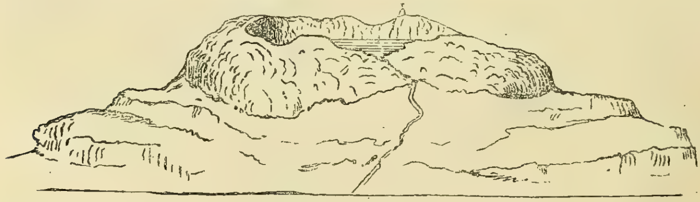
Seat, the volcanic origin of which has been so admirably illustrated by Charles Maclaren, Edward Forbes, and Archibald Geikie, the similarity of the phenomena presented by Beinn Shiant will be sufficiently striking; nor will he fail to recognize that in either case we have a much-denuded and ruined volcanic cone submitted to our study. The volcano of Beinn Shiant, however, was of far larger dimensions than that of which the ruins constitute Arthur's Seat.

Although the lava streams of Beinn Shiant are now, by denudation, reduced to more or less isolated fragments, yet such is their distinctive character that I believe there will be little difficulty, when the country is accurately mapped, in restoring the main features of this volcanic cone and of the lava streams which issued from it. Of the posteriority in date of this volcanic pile to both the felspathic and basaltic lavas of the great central volcanoes, we have the clearest evidence; for not only do its products overlie the sheets forming the great plateaux, but the fragments of the latter are included in great numbers in the agglomerates which compose it. Further, it is clear that these earlier lavas had undergone a vast amount of denudation before the outflow of those from Beinn Shiant; for the latter overlap the older basalts, and in places, where these have been wholly removed by erosion, rest directly upon the bared surfaces of Lower Silurian gneiss.

If in the case of Beinn Shiant we are unable to trace the igneous masses of this volcanic cone penetrating the older lavas and gneiss, this is solely due, as in the case of recent volcanoes, to the covering of ejected materials wholly concealing the relations of the rocks which lie below them. Fortunately, however, many examples of analogous later eruptions which have taken place within this district occur, wherein, as a result of the removal by denudation of the materials of the volcanic pile, the relations between the older lavas and the newer intrusive masses are very clearly exhibited. One of the most interesting of these we shall now proceed to describe.

At a distance of three miles to the south-west of the village of Tobermory in the island of Mull there rises, in the midst of the great plateau of basaltic lavas, a hill presenting somewhat striking features, known as Sarsta Beinn (see woodcut, fig. 4). Its height

Fig. 4.—*View of Sarsta Beinn from Stot Hill.*

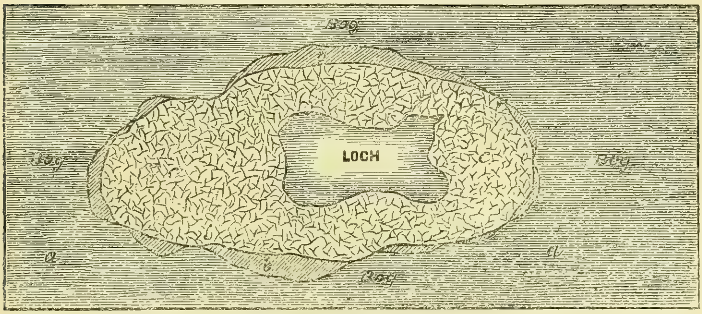


above the sea-level is apparently about 800 or 900 feet; but the peculiarity of the mode of weathering of the rock masses which compose it, as compared with the surrounding tabular basalts, makes it a rather conspicuous object. Its summit is occupied by a small loch, or mountain-tarn, which is said to be of great depth.

When we examine this rocky mass standing up so abruptly in the midst of the basaltic plateau, we find it to be composed of a dolerite of the coarsest grain, passing in its lower portions into gabbro. The rugged, rusty-brown surfaces of these rocks, which resist denudation and the growth of vegetation, form a striking contrast with the grassy tabular masses of the basaltic lavas in the midst of which they rise.

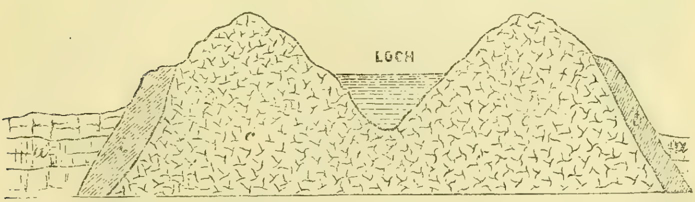
The identity in character between this rock mass and others of eruptive origin which we have before described is sufficiently obvious. That it was actually upheaved through the older basaltic lava sheets, we have the clearest and most unmistakable evidence. As shown in the plan and section (woodcuts, figs. 5 and 6), the contact between

Fig. 5.—*Plan of the Hill of Sarsta Beinn.*



a. Ordinary basalts covered by boggy ground.
b. Basalts altered by contact with the intrusive mass.
c. Great mass of coarse dolerite graduating into gabbro.

Fig. 6.—*Section of Sarsta Beinn.*



a. Basalts of the great plateaux.
b. Basalts altered by contact with the intrusive mass *c*.
c. Intrusive mass, composed of dolerite in places graduating into gabbro.

these highly crystalline rocks and the basalts in the midst of which they lie is marked by a belt of metamorphosed rock. The basalts near their junction with the intrusive dolerites and gabbro have acquired a harder texture, a splintery fracture, and a peculiar platy mode of weathering, often in concentrically curved planes. In consequence of their greater hardness, an almost entire belt of the altered and indurated basalts is found surrounding the crystalline mass on all sides. From the central mass a number of dykes and veins can be traced intersecting the surrounding older lavas.

That, subsequently to the eruption of the great sheets of basaltic lavas, a mass of basic igneous rock was upheaved in their midst at Sarsta Beinn is evident. And that this eruptive mass was surmounted by a volcanic cone from which probably lava streams flowed, no one who has studied the example of Beinn Shiant will, I think, be disposed to doubt. Indeed fragments of these lava-streams may still remain, though now forming undistinguishable portions of the great basaltic plateau. When we remember the observation of Mr. Darwin, that both in the Cape-Verde Islands and the Galapagos archipelago he found it impossible to trace the boundaries of recently erupted lava streams, " except by the size of the bushes growing upon them, or by the comparative glossiness of their surfaces, characters which a short lapse of time would be sufficient to obscure," it will not be surprising that we are not, as a rule, able to trace the separate lava streams of the Hebrides. The fact that in the case of the lavas of Beinn Shiant we are able so to do, is due solely to the fact that in them a great capacity for resisting degrading influences is combined with remarkably distinctive petrological characters.

I have described in some detail these two examples of Beinn Shiant and Sarsta Beinn on account of their great size and typical character ; but there is the clearest evidence that at a very great number of points the basalts of the great plateau were broken through by similar eruptive masses, sometimes, as in the case of Sarsta Beinn, composed of basic rocks, at others, as in Beinn Shiant, of more felspathic materials, and in others, again, of both these varieties. Few of these later eruptions appear to have been on the same grand scale as those which we have selected as types ; and many of the intruded rock masses, which now alone remain to indicate their points of origin, are of quite insignificant proportions. Thus in the little island of Eigg two such masses were detected by Professor Geikie, and I have found a third of similar character ; in the other islands also such masses are found scattered in all directions. Until, however, the whole district has been mapped in the most careful detail, it will be impossible to give a distinct view of the distribution of these latest points of eruption in the district, and to show their exact relations to the great volcanoes. Even after such survey, indeed, many of the smaller intrusive masses may escape the observation of the geologist through being concealed by peat-mosses or the vegetable covering.

Having pointed out that, even in the great mass of Beinn Shiant, the preservation of the ruins of the volcanic cone are due to very remarkable and exceptional circumstances, it will be almost unnecessary to add that the small cones which doubtless once surmounted most, if not all, of these eruptive masses, have in almost every instance been wholly swept away by denudation, and that the lavas which flowed from them have also disappeared or are now undistinguishable.

In the case of the celebrated Scùr of Eigg, however, I believe that we have a fragment of a lava stream which proceeded from one of these "puys," every other trace of which, however, has been removed. The character and relations of this interesting mass of rock have been very clearly illustrated by Prof. Geikie; and I would only suggest with regard to it that the characters of the buried conglomerate are suggestive of a mountain-ravine subject to the passage of violent floods rather than of an ordinary river-channel. It seems to me probable that this ravine was situated on the flanks of the great volcano of Rum*, then an extinct and rapidly disintegrating pile; that after the accumulation by the flooded stream of fragments of all sizes of lava and sandstone (all of which would be naturally derived from the ruins of that volcano) and the intermingling with these of uprooted trees (the *Pinites eggensis*) which grew upon its slopes, the whole was buried and sealed up in consequence of several lava streams, issuing from an (at that time) eruptive "puy," finding their way into and filling up the ravine. The course of the subsequent changes was similar to those long ago shown by Mr. Scrope to have taken place in so many instances in Auvergne; and, like these latter, they have raised up a striking monument to the power and duration of those forces which, almost unnoticed by us, sculpture the earth's surface. The history of the events connected with the formation of the Scùr of Eigg has been very clearly described and its lessons eloquently enforced by Prof. Geikie.

13. *Subterranean Phenomena of the Tertiary Volcanoes.*—In the preceding pages it has been my principal object to show that in the Hebrides we have evidence, mutilated and fragmentary it may be, but nevertheless most clear and unmistakable, of the occurrence of a series of phenomena which, alike in their character and their sequence, are identical with those exhibited by existing volcanoes. But interesting as these conclusions undoubtedly are, they are not perhaps the most important of the fruits of a geological study of the beautiful dissected volcanoes of the Highlands. Still more suggestive, from the circumstance that they enable us to correlate the familiar subaerial actions of volcanoes with others often regarded as wholly distinct in character and origin, are the phenomena presented to us when we study the connexions between the intrusive masses constituting the centres of these ancient volcanic piles, and the older stratified rocks through which they rise. To this most interesting subject I now proceed to direct attention.

The manner in which the surrounding strata are seen to be upheaved, contorted, and metamorphosed by the great eruptive crystalline masses, whether of acid or basic composition, has been already pointed out in a number of different localities. But in the case of the island of Skye, it was first shown by Dr. Macculloch, and after-

* As an example of a "puy" in Auvergne, similarly situated to that which appears to have given rise to the lavas forming the Scùr of Eigg, I may point to the Puy de Tartaret, which, rising in the Valley of Chambon, one of the great ravines cut on the flanks of Mont Dore, has poured forth a lava stream which has occupied all the lower parts of that great watercourse.

wards more clearly illustrated by Prof. Geikie, that besides the great central eruptive masses of granite there are other portions of the same rock, usually of a finer-grained character and passing into many varieties of felsite, the relations of which to the Primary and Secondary strata among which they lie is of a totally different kind. Instead of violently breaking through and disturbing them, these intrusive masses appear to form hills simply overlying the stratified rocks, but occasionally sending off veins into them and entangling portions of them in their mass; and in place of effecting a metamorphism in the sedimentary rocks extending for a great distance around, they produce only a comparatively small and local action upon them. These features, it must be confessed, seem at first sight sufficiently anomalous; and some authors have even gone so far as to describe these granites as having been poured out upon the existing surface "like ordinary trap rocks."

A careful study and comparison of all the phenomena presented by masses of this kind, numerous examples of which occur in connexion with the different volcanoes we have been describing, affords us a very simple explanation of the supposed anomalies. These masses of fine-grained granite passing into felsite are really portions proceeding from the great central masses and intruded between stratified rocks. In Skye, and also in some other cases, the overlying strata have been removed by denudation; and the intrusive rocks, which have by their hardness resisted denuding influences, now appear uncovered, and as if actually deposited upon the strata below. That the explanation now given of this phenomenon is the true one, I have been able to verify by the comparison of a very great number of cases, in which every stage of the series of operations here described as terminating in the production of the anomalous features in question, can be clearly traced. Admirable examples showing that these masses of granite and felsite were actually intruded among the stratified rocks, are seen in Raasay, Ardnamurchan, and Mull; I may especially cite the cases of Stron Beg and Craignure, situated in the two last-mentioned of these districts respectively, as illustrating the features and relations of such masses in a peculiarly interesting manner. A mass of this kind, probably originally connected with the volcano of Rum, occurs at the northern part of the island of Eigg; Professor Geikie notices the resemblance of the rock of which it is composed to the "quartziferous porphyries" of Skye and Raasay, and he justly states that the mass "appears to have risen approximately along the bedding of the Oolitic strata, and thus to form of itself a large rude bed"*.

In the very different modes of their subterranean disposition, the igneous rocks of acid and basic composition respectively present a remarkable parallel to the behaviour of the two classes of lavas to which they give rise. While the acid igneous rocks, when intruded between strata, tend to form thick lenticular masses, which are generally confined to within moderate distances from the great centres of eruption, the basaltic rocks, on the other hand, under like con-

* Quart. Journ. Geol. Soc. vol. xxvii. (1871) p. 294.

ditions, spread in vast sheets, which insert themselves along a plane of weakness between two sets of beds, and often proceed to enormous distances from the centres of eruption.

Very wonderful and striking are the relations between the great intrusive sheets of dolerite and basalt, connected with the great centres of volcanic action, and the stratified rocks which they traverse. These relations are exhibited in a very beautiful manner along the magnificent range of cliffs that forms the eastern boundary of the peninsula of Trotternish in Skye, and also in Raasay, Applecross, and the south of Mull. So remarkable is the regularity with which many of these sheets of molten rock have flowed between the same two strata for great distances, that it is not surprising they were for a long period regarded as being lava streams contemporaneous in date with the sediments among which they lie. A close examination, however, shows that these sheets of igneous material alter alike the rocks lying above and below them, and that they are altogether destitute of the vesicular character leading to the production of amygdaloids, as well as other features always presented by true lava streams. When, too, their courses are followed over considerable distances, they are found, in places, either bifurcating into separate sheets which enclose masses of the stratified rocks, or entangling fragments of these in their midst, or cutting for a time across the beds, or sending off processes and veins, or terminating abruptly in wedge-shaped masses, or breaking suddenly through the superincumbent strata, and so reaching the surface.

The rocks of which the great intrusive felspathic masses are usually composed, include many different varieties of felsite, usually more or less quartziferous, and often beautifully porphyritic in structure; these, in many places, by the appearance of scattered crystals of hornblende in their mass pass into a fine-grained syenite-granite. The intrusive sheets of basic rock consist in almost all cases of dolerite, often containing much olivine, and passing on the one hand into fine-grained gabbro, and on the other into many varieties of basalt.

Besides these larger masses, the igneous intrusions of all ages give rise to the formation of dykes and veins in prodigious numbers. Those of felspathic composition appear to be for the most part confined to within comparatively moderate distances from the eruptive centres; those of basaltic composition, on the other hand, are found proceeding to extraordinary distances from them. Prof. Geikie has even speculated, with much show of probability, on the existence of a connexion between the great basaltic dykes which traverse the whole of the rocks in the north of England and the great focus of igneous activity in the Hebrides. Basaltic dykes with such a connexion certainly traverse all the rocks in the west of Scotland in prodigious numbers; and the manner in which they sometimes, through greater relative capacity for resisting denuding forces, stand up like immense walls, and at others, by their more rapid decay, originate vast chasms, are facts which must have been observed by all who have travelled in the western Highlands. In the immediate neighbourhoods of the great volcanoes their almost infinite numbers, the complexities of their intricate interlacings, and the manner in which those of later date cut across and often laterally displace portions of the earlier ones, give rise to a series of phenomena of the most instructive and interesting character. As a general rule, the larger the dyke the more coarsely crystalline is the mass of rock which composes it; and in many cases the middle of the dyke is composed of a coarser-grained rock than the sides.

Frequent allusion has already been made to the metamorphism produced in the Primary and Secondary strata, and also in pre-existing rocks, by the passage through them of masses of igneous rock. Careful examination will serve to detect such alteration at the surfaces of contact of almost every igneous mass; but in the *degree* of this action there is the greatest diversity in different cases. Sometimes it consists of a scarcely perceptible induration extending for a distance of a few lines only from the surfaces of the igneous mass, and unattended by any change in chemical characters; but in other cases the soft sediments of the Lias, Oolite and Cretaceous formations have had every trace of their abundant fossil contents wholly obliterated, and their masses converted into rocks undistinguishable in appearance and characters from the most highly metamorphic Primary rocks, with which, indeed, they have in some cases been confounded.

A careful study of these phenomena of local metamorphism enables us to enunciate the general law which governs its action to be as follows:—The degree of metamorphism and the distance to which its action extends from the intrusive mass is usually proportioned to the mass of the latter. Thus, the maximum of change is seen in the vicinity of the great eruptive mountain masses, and the minimum near the smaller intrusive veins and dykes; while around the various intrusive sheets and bosses every intermediate degree of alteration is exhibited. Even among dykes we can often observe that the amount of induration in the strata which they traverse, and the distance to which this extends from their surfaces, are directly proportioned to their width. There are, it is true, occasional apparent exceptions to this rule; but these are in most cases capable of easy explanation. Thus masses of rock traversed by a complete plexus of veins and dykes, such as are seen at some points in Ardnamurchan, undergo a very great amount of change, their fossils being almost wholly obliterated and very decided chemical changes induced in their mass, these changes being evidently the result of the *cumulative* action of the numerous small intrusions. The establishment of this law of metamorphic action serves to confirm what, indeed, is sufficiently obvious, that the metamorphism in surrounding rocks results from the passage of heat from the intrusive masses of molten matter as these gradually pass into the solid condition.

I can scarcely conceive of any series of phenomena more striking in character, and certainly of none more interesting and suggestive to a geologist, than those presented by the wonderful complexities produced by the mutual interferences of different eruptive rock-masses, varying in dimensions from great mountain-groups down to the minutest veins and strings, exhibiting innumerable distinctions of mineralogical constitution, and belonging to three successive geological periods. Nor is it easy to imagine a more striking series of mechanical and chemical changes than those which in the surrounding strata have attended the eruption of these masses, resulting in the most extraordinary contortions and the extremest metamorphism.

Such features are admirably exhibited alike in the district of Strath in Skye, on the southern coast of Mull, and at various points around Rum, but in none in so striking a manner as in the peninsula of Ardnamurchan. Here the scalpel of denudation has revealed the intricate and curious relations of the several varieties of igneous rocks with one another and with the Primary and Secondary strata. To represent these, however imperfectly, would require a series of maps and sections on the very grandest scale; in many cases, indeed, adequate conceptions of the relations of such very intricate rock structures could only be conveyed by means of models. It is, however, to the rocks themselves that the student must be referred; and he will find in them illustrations of the characters and action of igneous intrusions which will amply repay him for the time and labour expended in their investigation *.

14. *Ages of the several Volcanic Outbursts already described.*—That the events of which we have been discussing the evidence, stupendous as they are in scale and complicated as they are in succession, all took place subsequently to the Mesozoic epoch, we have the most ample proof:—

First, in the fact of the entire absence of *contemporary* volcanic deposits among the Secondary strata. I have already alluded to the earlier misapprehensions which prevailed upon this subject, and on the manner in which these were removed by the observations of Prof. Geikie in 1865.

Secondly, in the circumstance that the volcanic masses are thrust through and among the representatives of the whole series of Secondary strata, up to and including the Upper Chalk; and that the volcanic products unconformably overlie and include numerous fragments of the whole of the Secondary rocks—these fragments having acquired their present positions either through being ejected from volcanic vents (as in the case of the breccias of Mull, Rum, &c.), or by the agency of ordinary denuding agencies opera-

* Below Mingary Castle, near Kilchoan in Ardnamurchan, a section may be observed which is interesting as throwing light on the probable mode of formation of the celebrated Puy Chopine in Auvergne, the peculiar and apparently, at first sight, anomalous characters of which have been frequently remarked upon (see Scrope's 'Geology and Extinct Volcanos of Central France,' pp. 72–76). At Mingary a mass of quartziferous porphyry has been forced between beds of Lower Lias shale, while a later-formed sheet of basalt has evidently taken advantage of the plane of weakness, constituted by their junction, to force itself between them. In the Puy Chopine a mass of the older rocks (in this case composed of granite) has been forced upwards by an extrusion of domite, while a sheet of basalt has similarly inserted itself along their line of junction.

ting in the intervals between the several outflows of lava (as in the chalk- and flint-detritus of Ardtun and Carsaig).

That, on the other hand, this remarkable series of events, even the latest of them, took place at a period very remote from the present, is proved by the enormous amount of denudation which the volcanic products have undergone.

I know of no more striking evidence of the vast duration of geological periods, than that which is afforded to us in the Hebrides, when we contrast the wonderful freshness of the contours, polished surfaces, and striæ produced during the Glacial period, with the everywhere abundant proofs of enormous denudation suffered by rocks of undoubted Tertiary age, many of these, moreover, being very conspicuous for their intense hardness and great capability of resisting weathering influences. How almost infinitesimal on such a comparison appears the time which has elapsed since the Glacial epoch, to the duration of the great Tertiary periods!

The facts adduced in the present paper show that there were three well-marked periods of igneous activity in the district, which were characterized as follows:—

First Period. The outburst in the midst of a terrestrial surface, composed of various Palæozoic and Secondary rocks, of ashes, scoriæ, and fragments of the rocks in which the vents were opened, alternating with the outflow of streams of highly felspathic lava. With these subaerial phenomena was connected the ascent of molten masses, in a manner to a great extent peculiar to rocks of acid composition, which, injecting the fissures of the surrounding and superposed rocks, consolidated into felsitic rocks in their outer portions, but in their deeper and more central portions, under different conditions of slow cooling and great pressure, assumed well-marked granitic characters.

Second Period. The extrusion from the same volcanic foci of masses of basic igneous materials, which on reaching the surface spread, after the usual manner of lavas of this class, into streams which, following one another at intervals, sometimes of long duration, gradually built up those enormous plateaux of basalt rock of which only mere fragments have escaped denudation. The same eruptions of basic rocks evidently gave rise to the formation of the mountain-masses of gabbro and the intrusion between and among the surrounding strata of innumerable and widely-spread sheets and dykes of dolerite and basalt.

Third Period. The appearance in a sporadic manner, in the neighbourhood of the grand old extinct volcanoes, of numerous minor outbursts of lava (felspathic, basaltic, or intermediate in composition), which, with the accompanying fragmentary ejections, gave rise to the formation of a series of volcanic cones, small, indeed, as compared with the vast mountain masses formed during the two preceding periods of eruption, but of which some at least were of no mean dimensions. The greater number of these would, to some extent, compensate for their inferior dimensions.

But from the facts which I have adduced in this paper it is also evident that periods of enormous duration must have separated these three epochs of intense volcanic activity. This is evidenced by the unconformable relations which the rock-masses produced during the three periods of eruption bear to one another.

The proofs of extensive denudation having taken place in the interval between the outflow of the great masses of felspathic and basaltic lavas appear to be of a very decisive character.

(1) The basaltic lavas and their accompanying piles of scoriæ, rest *directly* in many cases, as is so well seen in both Rum and Mull, not on the lavas and ashes which must have constituted the outer portions of the earlier volcanoes, but on the intrusive felsites and granites which could only have formed their interior and deeply seated portions.

(2) The felspathic lavas, &c., are seen in Mull to have undergone considerable movements and to have suffered largely from denudation, before they were buried under the overwhelming products of the period of basaltic eruptions.

(3) It appears also that the basaltic streams frequently lie in hollows eroded in the preexisting felstones. This fact is not so easily made out as those before noticed; but I believe there are distinct proofs of it in Ardnamurchan.

The evidences of erosion on a very extensive scale having taken place between the period of the eruptions of basic rocks and that of the formation of the "puys" are not so easily traced as those of the former inter-volcanic period, owing to the almost complete removal of the latest-formed volcanic deposits of the district by denudation. But in the case of the Scùr of Eigg, as so clearly explained by Prof. Geikie, and in that of Beinn Shiant, which has been described in this paper, the proofs of unconformity between the lavas of the two series are sufficiently distinct and striking.

Lastly, of the enormous changes which have taken place since the period of the formation of the "puys," we have the clearest proofs in the total removal, with rare exceptions, of the volcanic piles which doubtless once surmounted those igneous protrusions, which now alone mark the sites of the latest series of eruptions in the district.

In the almost total absence of palæontological evidence, it cannot, of course, be absolutely demonstrated that the three series of volcanic outbursts which we have described were in the case of the different centres strictly synchronous; but the remarkable uniformity of characters, in the succession of products in all the different cases, leads to the very strongest presumptions in favour of a connexion having existed between these different foci, and of the contemporaneity between the several analogous phenomena manifested at each of them.

Our means of correlating these three epochs of volanic activity during the Tertiary period, with the divisions of the same era founded on the relations which its successive faunas bear to one another and to the existing creation, must be confessed to be small; and hence the results attainable by us on this subject are to a certain extent indecisive; nevertheless it will be well in this place to bring together the whole mass of evidence as yet obtained which bears upon the question.

The beds intercalated with the earliest series, that of the felspathic lavas, have, as yet, furnished no organic remains. They are evidently, as a mass, post-Cretaceous; but I have observed some phenomena, which will be described hereafter, apparently pointing to the conclusion that volcanic activity must have commenced in the district before the Cretaceous period had altogether closed. May we not, therefore, bearing in mind these facts and also the strong proofs already detailed of unconformable relations between these felspathic lavas and the Miocene basalts, venture to refer the former, at least provisionally, to the great Eocene period?

The proofs of the Miocene age of the basalts constituting the great plateaux, both in the Hebrides and in Antrim, are as follows:—

At Ardtun in Mull, low down in the series, the following species of plants have been obtained from the pond-like hollows buried under streams of mud and lavas as before described.

Sequoia Langsdorffii, *Ad. Brongn.*
(Taxites Campbellii, *Forbes.*)
Rhamnites (?) multinervatus, *Forbes.*
—— major, *Forbes.*
Rhamnites lanceolatus, *Forbes.*
Equisetum Campbellii, *Forbes.*
Filicites (?) hebridicus, *Forbes.*
Alnites (?) McQuarrii, *Forbes.*
Corylus grosse-dentata, *Heer.*

In the plant-beds intercalated in a series of lacustrine deposits at Ballypalidy, Co. Antrim, the following have been found:—

Sequoia Du Noyeri, *Baily.*
Pinus (?) Plutonis, *Baily.*
Cupressites MacHenryi, *Baily.*
Eucalyptus oceanica, *Unger.*
Daphnogene Kanii, *Heer.*

with fragments referred, somewhat doubtfully, to the genera *Platanus?*, *Fagus*, *Podocarpus*, *Andromeda*, *Quercus*, *Rhamnus*, *Hakea*, *Celastrus*, and *Graminites*. Also the elytra of two species of beetles.

In "ash-beds" between the basalts near Shane's Castle, Lough Neagh, Co. Antrim, the following were obtained:—

Platanus aceroides, *Göpp.*
Sequoia Langsdorfii, *Ad. Brongn.*

with fragments referred to the genera *Juglans*, *Fagus*, *Laurus*, &c.*

Both Prof. Edward Forbes and Prof. Heer concur in the opinion that these floras indicate that the beds in which they occur were deposited during the Miocene period.

Concerning the age of the last of the three periods of eruption, that of the "puys," the evidence from organic remains is much more scanty. It consists only of the fossil wood (known as *Pinites eggensis*, With.) found under the lava stream of the Scùr of Eigg, upon which, of course, no conclusion can be founded. Considering, however, the proofs already adduced, from their unconformable relations, of the separation of the deposits of this period alike from those of the Miocene and the recent epochs, we can scarcely hesitate to regard them as belonging, at least approximately, to the Pliocene†.

* *Vide* Forbes, Quart. Journ. Geol. Soc. vol. vii. (1853), p. 103; W. H. Baily, *ibid.* vol. xxv. (1869), p. 357; and Tate and Holden, *ibid.* vol. xxvi. (1870), pp. 162–63.

† In venturing thus to compare the three periods of volcanic activity in the north-western parts of the British Islands with those divisions of the Tertiary epoch which Sir Charles Lyell has founded upon a comparison of the molluscan

To those familiar only with the English representatives of the three great Tertiary periods, the Eocene sands, marls, and clays, of the London and Hampshire basins, the Miocene lignitiferous beds of Bovey Tracey, and the insignificant Pliocene deposits of the Crags, the evidences of such enormous physical changes, as we have shown must have taken place in the north-western portion of these islands during the same periods, will indeed appear startling. But to remove any feelings of difficulty or doubt which may have their source in such comparisons, it is only necessary to refer to the well-ascertained facts of the geology of the Alps, where events on even a grander scale than those which we have described, can be shown to have taken place during the same periods.

15. *Connexion between the Tertiary Volcanoes of the Hebrides and those of other districts.*—It would be foreign to the objects of the present memoir to enter upon a discussion of this most interesting question. I shall therefore only state that, while we have the clearest proofs of the contemporaneity of the basalts of Antrim with those of the Inner Hebrides, we have also strong grounds for regarding the granites of Arran and the Mourne Mountains as having been erupted during the same period with those of Skye, Mull, Rum, &c.* Thus we are led to the conclusion that along a line stretching at least 400 miles from north to south, in the north-western part of the British archipelago, there rose, during a great portion of the Tertiary period, a chain of volcanoes in a state of violent but intermittent eruption. But continuing this line to the northwards, we find the proofs of volcanic action during part of the Tertiary period (and in some cases, at least, this action has not yet become extinct) in the Faroe Islands, Iceland, Jan Meyen, and Greenland. And southward the same line of volcanic vents is continued in Central France, the Iberian peninsula, the Azores, Madeira, the Canaries, Cape-Verde Islands, Ascension, St. Helena, and Tristan d'Acunha.

When we remember the proofs of the existence of widely spread terrestrial conditions during the Miocene epoch, and the interesting facts concerning the distribution of existing terrestrial species, made known to us by the labours of Edward Forbes, Unger, Heer, and others, we may well be prepared to regard these isolated masses of volcanic rocks, as has been suggested by Professor Nordenskiöld, as portions of a great ridge now for the most part submerged beneath the sea-level and constituting a boundary to the great eastern continent, similar to that which the Andes, Cordilleras, and Rocky Moun-

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faunas of certain deposits with those of recent seas, I am actuated by a feeling of the necessity of such a comparison to a due appreciation of the subject, rather than by a belief in the possibility of establishing any thing like actual *contemporaneity* between divisions based respectively on purely palæontological and physical evidence, both of which series of divisions, moreover, are incapable of very exact definition and limitation.

* My friend, Mr. Thomas Davies, has called my attention to the fact that the granite of Lundy Island offers peculiarities of structure strikingly similar to those presented by the granites of the Mourne Mountains, Arran, and the Northern Hebrides. It is possible, therefore, that in Lundy Island we have relics of another of the centres of volcanic action during the Tertiary period.

tains form to the western. The recent soundings of H.M.S. 'Challenger' have not only confirmed these conclusions, but have shown that the elevation of this old Andes of the eastern continent was not inferior to that of its existing homologue in the western, and that some of the peaks rose to the height of at least 25000 feet above the surrounding plains.

16. *General Conclusions from the relations between the Volcanic and Plutonic rocks of the Tertiary period.*—The study of the rocks of the Inner Hebrides has clearly demonstrated a fact which had been already strongly suspected by Dr. Macculloch, Prof. Geikie, and other geologists, that the granitic rocks of that area had a close connexion and were of contemporaneous age with the old lava streams so extensively developed in their neighbourhood.

We have shown how, by the more or less complete removal of its upper portions and the consequent exposure of its deeply seated rocks through denudation, a volcano may present many different aspects—from examples such as that of Mull, in which the relations of the various volcanic products can still be easily traced, to others, like that of Skye, in which these relations are by no means so clear at first sight. It will be easy to conceive a still further stage of ruin in a volcano in which, all the surrounding lavas and other erupted materials being removed, we should have left only the central core of granite or gabbro (the latter perhaps altered into various serpentinous rocks) rising in the midst of a series of stratified rocks; and in such cases there would be nothing to connect such eruptive masses with the ordinary subaerial phenomena of volcanic activity.

When we reflect on the striking similarity of the products of this series of Tertiary volcanoes, we can scarcely doubt of their connexion, or of their materials having been derived from a common reservoir. It is, under these circumstances, easy to imagine that, by the total removal of the superincumbent rocks, the consolidated contents of this old reservoir may be exposed. In such cases we might reasonably expect to find at the surface a tract of granite of wide extent, like that of Leinster.

Fortunately the same district which we are now studying affords us, in a series of igneous rocks of older date than those already described, a number of beautiful illustrations and convincing proofs of the truth of these views concerning the relations between the Volcanic and the Plutonic rocks. These we now proceed to describe.

III. *The Newer Palæozoic Volcanoes.*

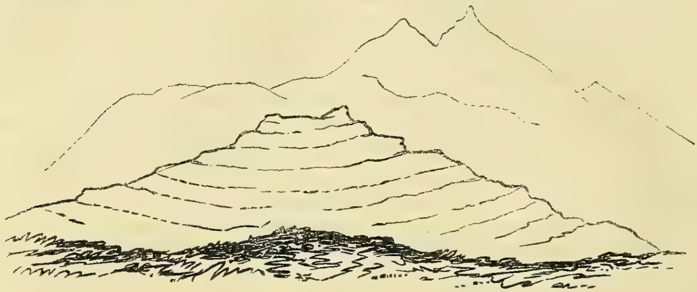
That there is evidence in the Highlands of Scotland of a great period of volcanic activity which *preceded* the deposition of the Secondary strata of the district has been already pointed out. I shall proceed to show that the eruptions of this earlier period were on a scale of at least equal magnitude with those of the Tertiary epoch just described, that like these latter they gave rise to the formation of vast plateaux composed of lava streams surrounding on all sides great volcanic mountains, and that under the action of denuding forces these plateaux have been broken up into more or less isolated fragments, while the central volcanic cones have been so worn away as to have lost many of their distinctive features. From the facts to be adduced it will clearly appear that, prior to the Mesozoic epoch, the greater part of the southern and central districts of Scotland, both north and south of the Grampians, was covered to the depth of thousands of feet by the products of igneous activity and the strata enclosed between them. But, as might be anticipated from their far greater antiquity, the lava plateaux of this earlier period are in a more fragmentary condition, and its volcanic cones in a far more ruined state than those of the Tertiary period. Aided, however, by the analogies of the latter, I hope to be able to demonstrate what were the principal characters of this earlier volcanic period, to trace the history of the succession of events which took place during its continuance; but more especially, as bearing upon the objects of the present inquiry, my endeavours will be directed to the reconstruction of those ancient physical features which resulted from these volcanic outbursts, and which to so great an extent determined the conditions under which the Mesozoic strata were deposited.

1. *Lavas of Lorn and the adjacent islands.*—In the same district of the Western Highlands with the Tertiary lavas already described, and in close proximity to them, we find another series of volcanic rocks belonging to a very different geological period. They occupy a large portion of the district of Lorn, and are also extensively developed in the south-eastern part of Mull, in Kerrera, Seil, and the smaller islands in their vicinity. By Loch Etive this volcanic tract, which extends about 22 miles from north to south and 18 miles from east to west, is divided into two very unequal portions—the smaller and northern portion extending through Benediraloch towards Loch Creran, and the larger and southern portion to the neighbourhood of Loch Awe and Loch Melfort. An examination of the boundaries and relations of this volcanic tract shows that it must be regarded as a fragmentary patch of a series of deposits once widely spread, which has been preserved from denudation, like so many other masses of rock of various ages in the Highlands of Scotland, through being let down between great faults or within vast synclinal folds. This conclusion is fully borne out, as we shall hereafter see, by the existence of small and distant isolated patches (outliers) of the same formation.

Until very recently the "trap-rocks" of Lorn were confounded with those of Tertiary age which are developed in their immediate neighbourhood. Macculloch appears to have considered that the sandstones and conglomerates which occur at their base were part of the Secondary series of the Highlands, while Prof. Nicol suggested that they might represent the Trias. In the map of Scotland published in 1861 by Sir R. Murchison and Prof. Geikie the "traps" of Lorn are indicated as being of Old Red Sandstone age.

The general features of the district occupied by these rocks, and the scenery to which they give rise are those which usually characterize tracts of rocks of volcanic origin. These are well illustrated by the annexed outline sketch of the mountain which rises at the eastern end of Glen Lonnan (woodcut, fig. 7). When compared with the great plateaux of the Tertiary lavas which have been already described, a number of points of difference, however, will be remarked. The wonderful regularity of the terraced features, so strikingly displayed by the basaltic plateaux of the Tertiary period, are to a certain

Fig. 7.—*Outline Sketch of a Mountain near Glen Lonnan, illustrating the Mode of Weathering of the Porphyrite and Felstone Lavas of Lorn.* (The granitic peaks of Beinn Cruachan are seen in the background.)



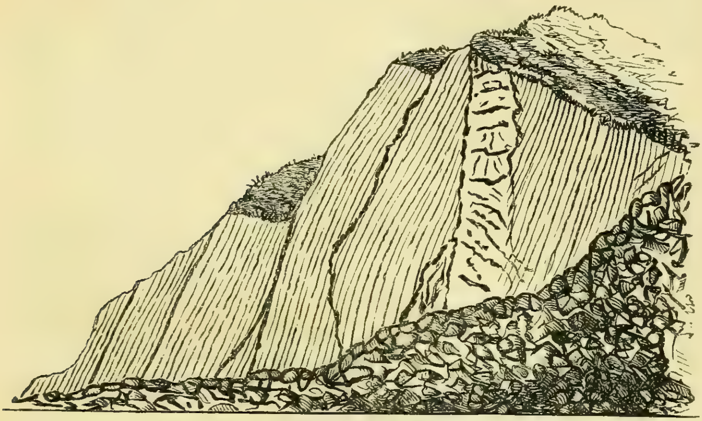
extent wanting in the piles of felspathic lavas which were poured out before the deposition of the Secondary rocks; the cause of this difference is of course to be sought in the usually greater fluidity and consequent even diffusion of the lavas of basic as compared with those of acid and intermediate composition.

2. *Characters of the Volcanic Rocks of Lorn.*—As already intimated, the great mass of these lavas is of felspathic or acid composition, and includes innumerable varieties of the rocks which were formerly known by the names of felspar-porphyry, compact felspar, clinkstone, claystone, &c. For the most part they may be regarded either as varieties of the rocks included in this country under the name of "felstone," or of the extensive class called "porphyrites" upon the Continent—the former representing the quartz-trachytes, and the latter the ordinary trachytes of modern volcanoes.

The changes which have taken place in many of these rocks subsequently to their deposition have been such, as in many cases to mask their real origin as lava streams; in this respect, however, we find the greatest variations in the same mass of rock. A close examination of the structure and relations of these rocks will, in almost every instance, furnish many interesting points of evidence bearing upon their mode of origin.

The columnar structure is by no means so common among the felspathic lavas as among those of the basaltic class; nevertheless some interesting examples of it are afforded by the rocks of Lorn. The columnar forms assumed by the acid lavas present distinctive characteristics of their own, as compared with those of the basalts. In the former class of rocks the columns are usually of smaller diameter and less regular form, while they often extend to much greater length than those of the latter class, unlike which again they are never divided into regular blocks by equidistant, curved, joint-planes. One of the best examples of the columnar structure among the old lavas

Fig. 8.—*Cliff-section, S.W. of Oban, exhibiting very fine Columnar Structure in the Porphyrite Lavas of Lorn.*



of Lorn is that exhibited in a cliff about two miles south-west of Oban, where the columns are of great length and beautifully curved (see woodcut, fig. 8); but more or less perfect examples of the same structure are exposed on the face of Beinn Lora and at other points.

Some of the volcanic rocks of Lorn present characters which, at first sight, appear not a little anomalous and puzzling; but this is a circumstance which, when we remember the metamorphic processes to which lavas, in common with all other rocks, are subject, need scarcely occasion surprise. Certain of the lavas appear after their emission to have weathered into the characteristic spheroidal and concentric forms, while others have evidently decomposed into a "wackose" condition; and in both cases the rocks which result from the re-induration of such masses, present very peculiar features, and may, in some instances, be mistaken for consolidated "trap-tuffs."

The separate lava-flows were often of enormous thickness. As a general rule the great body of each of these streams is made up of a compact, often highly porphyritic rock; but towards the upper and under surfaces of the mass, it usually assumes the amygdaloidal structure. The amygdaloidal cavities, which have evidently served as chemical laboratories in which very complex operations have been carried on, are frequently deprived of their contents by recent weathering operations; and the original structure of the rocks is thus to a great extent restored. Then is made clearly apparent the originally highly vesicular character of the upper and under portions of these ancient lava streams, the vesicles being often seen to be drawn out in the direction of the flow, while the actual surfaces of the stream exhibit the most strikingly scoriaceous aspect. The same weathering process sometimes develops in these old lavas other original structures, which had become wholly obliterated by infiltration, crystallization, and other processes taking place in the mass of the rock; and these structures would have remained altogether unsuspected but for the action of this cause. Thus some highly crystalline and porphyritic rocks, when weathered, resume their earthy or compact texture; and in certain cases structures like the sphærulites of pearlstone, which had become wholly obscured in the mass, are again revealed. Similarly many rocks of very solid appearance are seen, when the infiltrated materials are removed by weathering, to have been originally aggregates of ashy, pumiceous, and scoriaceous fragments, among which "volcanic bombs" or their fragments may not unfrequently be detected*.

3. *Relations of the Volcanic Rocks of Lorn.*—In considering this question it is important at the outset to notice two striking facts with regard to the positions of the lavas and associated beds of Lorn. In the first place they always rest directly, but unconformably, upon the Lower Silurian gneissose and schistose rocks, and never exhibit any of the fossiliferous Secondary strata at their base; in this respect they present a striking difference in their relations from the Tertiary lavas of the adjoining districts. And, secondly, they are, like the older rocks upon which they repose, penetrated in every direction by numerous dykes of dolerite and basalt; these are precisely similar to the intrusive masses associated with the Tertiary volcanic rocks—of which series, indeed, we can scarcely hesitate to regard them as forming a part.

These later dykes of dolerite and basalt, which are sometimes of great width, and often present a prismatic or columnar structure, constitute a most interesting and striking feature in the district. In consequence of their usually greater relative hardness, they frequently stand up like gigantic walls amidst the rocks of slate and felstone which once enclosed them but have now been weathered away from their sides.

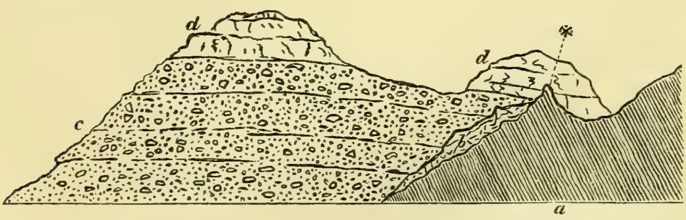
The remarkable series of volcanic rocks of Lorn is probably several thousand feet in thickness—though, its upper portions having been everywhere removed by denudation, its original limits in this respect are quite unknown to us. Its relations to the slate rocks and certain conglomerates, sandstones, and breccias appear, at first sight, to be

* That the geologist never meets with glassy lavas (obsidians, pitchstones &c.) among the older rocks will not occasion any surprise when we reflect upon the facility with which *artificial* glasses undergo devitrification. That glassy lavas were formed even in palæozoic times appears to be indicated by the fact recorded in the text that weathering sometimes reveals the characteristic *sphærulitic* structure in some of the lavas of Lorn. Many of the Newer Palæozoic "porphyrites" of Scotland are quite undistinguishable in appearance from some trachytes, such as those of Hungary. The white granular siliceous rocks into which the former are sometimes found altered, appear to be equally undistinguishable from the products of the decomposition of the latter (occasioned by the passage of acid vapours through them), and constituting the so-called "Alaunstein."

so anomalous as to have occasioned no little difficulty to the older geologists who sought to explain them ; indeed the slate rocks were found to occcur at such various levels among the series of lavas, conglomerates, and sandstones, and in such unexpected situations, as quite to baffle Macculloch and other observers who sought to illustrate their relations by horizontal sections*.

That in a district so disturbed as this has been shown to be, the strata in question should be found to be traversed by great faults will occasion no surprise ; and among rocks of such inconstant characters as these, it is, moreover, not easy to detect and follow the details of such dislocations, though their general effect may often be sufficiently obvious. Thus in the island of Kerrera a N.W. and S.E. fault, with a throw of not less than from 500 to 600 feet, is very conspicuous. It is not, however, to these dislocations, striking as their effects undoubtedly are, that the anomalous position of the rocks in question is mainly due, but rather to the fact that the volcanic and associated rocks were accumulated upon an old terrestrial surface of great irregularity, the hills and peaks of which stand up at very various levels amidst the great mass of overlying rocks. From the examination of the sections near Oban, in the island of Kerrera, and on the shores of Lochnell Bay, this relation of the several rocks becomes sufficiently clear. Sometimes, in favourable sections, peaks of the Lower Silurian slate rocks are actually seen standing up amid the overlying deposits, while in other cases hills composed of the former rock stand in such a manner amid surrounding masses composed of nearly horizontal beds of conglomerate, sandstone, and lava, that no doubt can remain that the former constituted, prior to the denudation which has sculptured the existing surface, the sides of valleys which were subsequently filled

Fig. 9.—*Section through the Highest Point of the Island of Kerrera, illustrating the Relations between the Slate Rocks and the overlying Volcanic Series of Lorn.*



a. Lower Silurian slates. *b.* Breccia composed of angular fragments of *a.* *c.* Conglomerates and sandstones. *d.* Porphyrite lava-streams. * Slates baked and altered by the enveloping lava.

with the deposits of the latter. Interesting examples of such slate hills again exposed by denudation are found at the "mythical Beregonium" (where the mass is crowned by a vitrified fort) and near the town of Oban. The accompanying section (woodcut, fig. 9)

* *Vide* Macculloch's 'Western Isles of Scotland,' vol. iii. pl. xvi. fig. 3, p. 14.

will serve to illustrate the peculiar relations of the several rocks in these cases.

The rocks on which the volcanic series of Lorn usually rests are black clay-slates, abounding in fine cubical crystals of pyrites and often traversed by numerous veins of quartz. This formation is perhaps the highest member preserved to us of that great series of Lower Silurian rocks which, bent into endless folds and greatly metamorphosed, occupies so large a portion of the Scottish Highlands. At Seil and Easdale it is extensively worked for roofing-slates; as yet, unfortunately, it has not yielded any fossils; but it exhibits in the island of Seil interbedded igneous rocks, apparently of *contemporaneous* character.

The only point at which the series of rocks so well displayed in Lorn is seen in juxtaposition with the Mesozoic sedimentary rocks and the Tertiary lavas is in the south-eastern part of Mull. Here, unfortunately, among the wonderfully disturbed and greatly metamorphosed rocks, which are exposed only in precipitous and altogether inaccessible cliffs, I have sought in vain for any simple section illustrating the relations of these three series of deposits. Nevertheless, after carefully tracing the positions of such masses as can be reached and studied, there appears to be no room for doubt that the various members of the Mesozoic series rest indifferently upon the denuded lavas of Lorn and the older rocks, and that they are themselves covered unconformably by the Tertiary volcanic rocks.

4. *Succession of Rocks in Lorn.*—The series of rocks which we have been describing has usually been represented as consisting of beds of conglomerate and sandstone at the base, overlain by a great mass of "trap" rocks. A careful examination of the district, however, proves that its structure is by no means so simple as this statement would imply. The outpouring of the great lava streams was, in part at least, contemporaneous with, as well as subsequent to, the deposition of the conglomerates and sandstones. This is proved by the alternation of the "trap" rocks with the conglomerates and sandstones, and by the fact that the materials of the latter are to a great extent derived from the former. Good examples of the alternations of the traps with the sandstones and conglomerates are to be seen near Dunolly.

At the base of the whole series of the Lorn rocks, and in immediate contact with the subjacent slates, is often found a breccia of very interesting character. It is wholly composed of perfectly angular fragments, sometimes of considerable size, of the slate and quartz rocks on which it rests; this breccia exhibits no trace of stratification or of its materials having been sorted or acted upon by water. It sometimes forms masses of considerable thickness, which appear to have been accumulated upon old terrestrial surfaces of the slate rocks by purely subaerial agencies.

The conglomerates of the Lorn series present very remarkable characters, which are familiar to all who have examined the picturesque cliffs on either side of the beautiful Bay of Oban. They are made up of blocks of very various sizes, occasionally angular but usually subangular or well-rounded, of "trappean" materials mingled with others derived from the metamorphic rocks. These blocks are so firmly cemented together by a sandy matrix, derived from the same materials, that the great joints which traverse the rock in all directions, and give rise to the bold and fantastic forms which it assumes under denudation, frequently cleanly divide the separate pebbles of which the rock is made up, even when they are composed of the hardest known materials. These conglomerates, which attain to thicknesses of hundreds of feet, exhibit great variations in the size of their materials, sometimes passing into coarse sandstone, which usually occupies lenticular patches in their midst, and at others containing blocks of very large dimensions. In the remarkable naturally isolated pillar of this conglomerate near Dunolly Castle, which is known by the name of Clach-a-choin, there is a single block of felstone, 8 feet long, 6 feet broad, and 5 feet thick; and many similar blocks of almost equal dimensions are seen at other points.

The sandstones of the Lorn series vary from very coarse grits, almost wholly made up of felspathic materials, to fine micaceous sandstones, exactly resembling those so abundant in, but by no means peculiar to the Old Red Sandstone. These sandstones are usually of a grey colour, but sometimes brownish-red. They frequently exhibit much false-bedding, and sometimes contain fragments of rock of considerable size but of flat form, such as can easily be borne along by currents of water. In many places they include bands of pebbles of very various size, and thus graduate into the conglomerates.

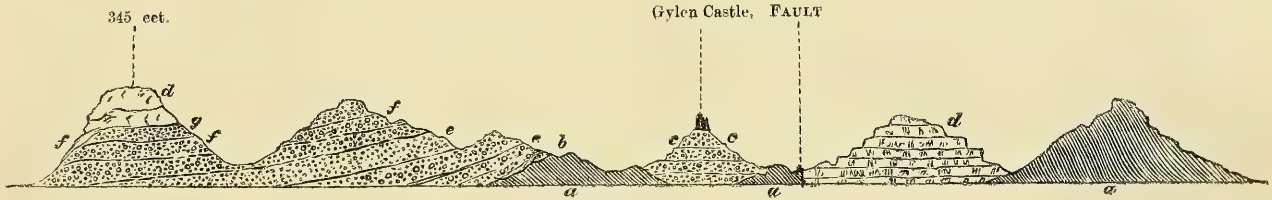
With the conglomerates, sandstones, and "traps" are interstratified a number of subordinate beds of peculiar character; of these some are composed of well-stratified materials of excessive fineness, which appear to occupy pond-like cavities in the midst of the other beds; and these seem to be made up of the fine volcanic dust so frequently ejected in great quantities from volcanic vents. In other cases we find well-stratified beds of small angular fragments of igneous material (lapilli &c.), constituting "tuffs" precisely similar to those of modern volcanoes.

As might be anticipated from the characters of these rocks, there is no appearance of a regular order of succession among them; but on the contrary the deposits are of the most local description. In order to illustrate their mode of occurrence I give a section taken along the south end of the island of Kerrera, where these strata are especially well exposed (woodcut, fig. 10, p. 284).

From the descriptions already given of the relations of the series of rocks in Lorn, it is clear that the lava streams must sometimes be found in contact with the slates, at other times with the conglomerates, and at others, again, with the sandstones. The appearance presented by each of these junctions I propose to describe in illustrative examples.

In the island of Kerrera we find a remarkably interesting example of the contact of one of the lava streams with the slate. Here a pinnacle of slate rock protruding above thick masses of sandstone and conglomerate, in the manner already described has been involved in

Fig. 10.—*Section along the South End of the Island of Kerrera, Lorn.*



a. Slate rocks (Lower Silurian), with quartz veins.
b. Breccias composed of angular fragments of Lower Silurian rocks.
c. Conglomerates, mainly composed of pebbles and blocks of Lower Silurian rocks.
d. Lavas of Lorn (felstones and porphyrites).
e. Thick beds of greenish-grey sandstone.
f. Coarse conglomerates, with many pebbles and blocks of the lavas of Lorn.
g. Very coarse grey sandstones.

a lava current. The dark-blue highly cleaved slate is changed to a soft grey rock, divided into angular fragments by numerous joints, while the brilliant crystals of iron-pyrites with which the slate is studded are converted into a black amorphous substance still filling the original cavities (see woodcut, fig. 9, p. 281).

Many examples of the contact of a lava stream with a bed of sandstone are exhibited in Lorn and the adjoining islands. The sandstone, while still exhibiting more or less clearly, under the lens, its original granular structure, has for some depth from its surface been converted into a substance of intense hardness, and the mixture of felspathic and siliceous materials of which it is composed has evidently undergone incipient fusion.

Where the lava has flowed over a bed of conglomerate, the pebbles of the latter have been frequently caught up and enveloped in the mass of vesicular and scoriaceous rock forming the base of the lava stream, in a manner which has often been described as taking place in the case of the products of recent volcanoes*.

In a road-cutting in the vicinity of Oban I found a very interesting illustration of the phenomena presented at the contact of some of the lava streams with the beds below. The section was as follows:—

(*a*) Compact dark-coloured felstone lava, which has apparently undergone considerable alteration; here and there a hollow vesicle occurs in the mass. A thickness of 15 or 20 feet of this rock is seen in the section.

(*b*) About nine inches or a foot from its base this mass of lava becomes highly vesicular or scoriaceous, the cavities being strikingly flattened and drawn out. Many burnt-looking fragments (lapilli) are caught up in this part of the lava stream.

(*c*) For a depth of about 2 feet below we have a confused mass of vesicular lava, rounded blocks of lava, pebbles of quartz, &c., all imbedded in a matrix of highly scoriaceous rock. The lower part of this mass passes in places into a sandy conglomerate; the ordinary coarse sand consisting of lava detritus constituting the matrix.

(*d*) Conglomerates, composed of pebbles of trap and of the Lower Silurian rocks, with some unmistakable volcanic bombs, and with a matrix of very coarse sand, 2 feet thick. In this bed are lenticular patches of a very fine-grained sedimentary material, probably stratified volcanic dust.

(*e*) Beds of well-stratified and finely laminated red sandstone, very similar in character to the typical rocks of the Old Red Sandstone.

The stream of lava of which (*a*) and (*b*) form the lower portion appears to be 40 or 50 feet in thickness, to be highly vesicular in its upper part, and to be covered directly by another lava stream. The appearance presented by (*b*) and (*c*) is exactly such as would be produced by a lava stream with a cindery crust which it rolls over as it flows along, in the manner so graphically described by Mr. Scrope, and passing over a mass of shallow-water deposits, the materials of which it entangles in its course.

The sandstones and conglomerates, which in places attain to a thickness of several hundreds of feet, appear to be wholly confined to the *lower* part of the volcanic series of Lorn. In its upper part

* In the island of Lipari there occur beautiful instances of lava streams of glassy character having entangled in their mass many fragments of the older rocks, that have evidently strewed the surfaces over which they flowed.

that series consists of stream after stream of lava piled one upon the other in almost endless succession; and so far as I have observed, these include between them no stratified deposits. The mode of weathering peculiar to "trap" rocks, while it often exhibits large faces of the different lava currents, causes their junction to be usually buried beneath a talus of fallen fragments. Nevertheless we are able to observe at many points, as near Loch Feochan, Loch Nell, and Glen Lonnan, that between the old lava streams there occur masses of a peculiar rock, usually of a bright red colour. At first sight these red rocks present but little resemblance to "trap-tuffs," being often extremely hard and compact in texture, through the infilling of their pores with crystalline materials. Fresh fractured surfaces, however, show that the rock is made up of angular fragments of lava, &c. (*lapilli*), quite unstratified; and here, again, weathering processes come to the aid of the geologist, and, by removing to some extent the crystallized materials from the interstices of the rock, reveal its true tufaceous structure. Occasionally too we find in the beds unmistakable fragments, and more rarely entire examples, of volcanic bombs; but these it is seldom possible to extract entire, owing to the jointed structure which they have acquired since being imbedded in the rock wherein they lie.

5. *Conditions under which the Volcanic series of Lorn was deposited.*—The highly irregular surface of the old slate rocks, with its hollows filled by breccias composed of their angular fragments, points to the existence of an old land-surface. Upon this, as we have seen, the accumulation of lava sheets and great masses of conglomerate and sandstone appears to have gone on simultaneously for a very considerable period. The stratified rocks associated with the lower lava sheets of the Lorn series are of such an extremely local and irregular character, that they do not by any means necessarily imply a subsidence of the old land-surface beneath the sea-level. On the contrary, the accumulation of large blocks of the local rocks, with alternating seams of sand of various degrees of fineness, would seem rather to indicate the action of mountain-streams subject to violent floods. The causes so clearly described by Mr. Drew* as having given rise to the formation of the great fan-shaped masses of alluvium in India (the nature and disposition of the materials of which would seem to be strikingly similar to those of the beds we are describing) appear to me to be fully competent to the production of the peculiar deposits of Lorn.

It therefore appears that the remarkable series of rocks in Lorn was accumulated along the flanks of a range of lofty volcanoes, the heaping up of conglomerates by mountain-torrents and the outpouring of lava streams, under which these were buried and preserved, going on side by side†. During the formation of the upper

* Quart. Journ. Geol. Soc. vol. xxix. p. 441.

† Mr. Scrope has clearly described the important part which is played by violent floods (resulting either from the sudden melting of snows on volcanic cones during their eruptions, or from the condensation of the enormous quantities of vapour to which they give origin) in distributing and rearranging the materials thrown out from volcanic vents.

and larger part of the Lorn series the volcanic forces appear to have been almost the sole agency concerned in the accumulation of the rocks; for these consist of subaerial lavas alternating with unstratified tuffs.

6. *Age of the Volcanic series of Lorn.*—In the entire absence of palæontological evidence, this question must be admitted to be still to a certain extent an open one. In forming a judgment concerning it, however, we have the following facts to guide us:—

(1) The very marked unconformity between these rocks and the strata of Lower Silurian age on which they lie. The latter were evidently not only deposited, but bent into great contortions and folds, and brought to their present metamorphosed condition, before the period of the formation of the former.

(2) The fact that the Mesozoic strata appear to rest upon them, and, in some instances at least, quite unconformably.

(3) The resemblance which the lava streams, of which they are so largely composed, present in their petrological characters to others on the south of the Grampians, which sometimes alternate with strata containing fishes of Old-Red-Sandstone species.

With these points of evidence before us, we can scarcely hesitate to regard the volcanic and associated rocks of Lorn as belonging to some part of the Newer Palæozoic periods; but to hazard any closer approximation to their age would probably be unsafe.

7. *The Newer Palæozoic Lavas of the Lowlands of Scotland.*—South of the Grampian Mountains very large areas of Scotland are occupied by series of old lavas, which, so far as mineral characters go, present very striking resemblances to those of Lorn which we have been describing. These rocks have been more or less fully described by many authors, and the evidences of their volcanic origin and of the conditions under which they were accumulated very ably discussed by Maclaren and Prof. A. Geikie. Moreover the districts where they are developed are now being mapped by the Geological Survey, and the relations and characters of these old lavas are being very admirably illustrated by the maps, sections, and memoirs issued by that department. Under these circumstances it will only be necessary for the purpose of the present argument to refer briefly to the general characters presented by these interesting rocks.

Nearly the whole of the hill-ranges of Central Scotland, such as the Ochils, Sidlaws, Pentland and Braid Hills, Campsie Fells, Kilpatrick Hills &c., are composed of these volcanic rocks. The preservation and present positions of the masses of these rocks which still remain, appear to have been determined by the great N.E. and S.W. faults which traverse the country. The exact positions and effects of these lines of fracture are very admirably shown on the detailed maps of the Survey, so far as it has gone.

The lavas composing these great ranges of hills, which are in some cases over 2000 feet in height, consist for the most part of rocks of a more or less felspathic character, though not usually so highly siliceous as those of the earliest Tertiary period. Like those of Lorn they commonly display in a very marked manner the porphyritic structure. Occasionally, however, streams of a more basic character, and approaching to basalts in composition, alternate with the felstone lavas. With regard to the nomenclature of these rocks great confusion and uncertainty still unfortunately prevails. By Jameson and his pupils they were distinguished as porphyries, clinkstones, compact felspars, claystones and basalts. In the earlier publications of the Geological Survey they are referred to as "felstones;" and in the later works published by that department an attempt has been made to assimilate their nomenclature to that adopted on the Continent by applying to them the terms porphyrite, melaphyre &c.

The lavas of Central Scotland, like those of Lorn, have, as a rule, undergone a far greater amount of change from chemical action than those of the Tertiary period. Consequently in many cases their mode of origin is by no means so obvious as in the case of these latter; and in some places not only have they undergone a very great amount of general alteration, but mineral veins have been formed in their mass.

Strikingly similar as the lavas of Lorn are to those of Central Scotland in their petrological characters, they nevertheless present in their relations one very marked point of contrast. While the lavas of the northern flanks of the Grampian Mountains are, with the exception of the conglomerates and sandstone near their base, only separated by thin bands of interstratified ash &c., the similar lavas of Central Scotland alternate with great masses of sedimentary rocks, conglomerates, sandstones, limestones, shales, and beds of stratified ash. While the rocks of the former appear to be the products of a series of subaerial volcanic eruptions, those of the latter are not less clearly seen to have been formed by the outburst from time to time of streams of lava, which flowed over the beds of seas or lakes in which the accumulation of stratified sediments was going on.

With regard to the age of the great lava sheets of the Scottish Lowlands we are fortunately supplied with the most satisfactory evidence. The associated contemporaneous sedimentary rocks occasionally contain fossils; and thus we are able to define the age of different parts of them as Lower, Middle, and Upper Old Red Sandstone and the lower part of the Carboniferous (Calciferous Sandstone). Some difficulties still remain, it is true, with regard to the ages of some of the isolated portions of what once constituted great plateaux of volcanic rocks covering a very large portion of Scotland. This is due to the fact that many of the fossils, especially those of the Old Red Sandstone, are very local in their mode of occurrence; but that strata belonging to all the periods enumerated are found interbedded with these ancient lavas is indisputable. Towards the latter part of the period indicated (namely, during the deposition of the Calciferous Sandstone) the lavas show a general tendency to a more basic character than those of earlier periods, and thus form a transition to the basaltic eruptions of a sporadic character by which the great series of volcanic phenomena extending through the whole of the Newer Palæozoic periods was brought to a close.

8. *The Eruptive Masses of the Grampian Mountains.*—From Peterhead, on the north-east, to the Ross of Mull, on the south-west, there occur, along the whole course of the Grampian Mountains, as is well known to all geologists, a series of masses of crystalline and igneous rocks which have evidently been protruded through the contorted and metamorphosed strata of the Lower Silurian. At an early period in the history of geology these rocks excited much attention, from their bearing upon the controversies then raging between the supporters of the Neptunian and Plutonic theories respectively. Many of the phenomena were most carefully studied, especially in Glen Tilt, where Hutton found the most beautiful illustration of his theory of the igneous origin of the granites, and where Playfair, Webb Seymour, and Macculloch by a series of patient observations contributed so much towards the establishment of the truth of that theory.

The largest and most important of the igneous masses of the Grampians are the great granitic bosses, which give rise to so many varieties of physical feature—from the lofty mountains of the Cairngorm, Beinn Nevis, and Beinn Cruachan groups, to the low, undulating, and sometimes almost level tracts of the Ross of Mull, the Moor of Rannoch, and many districts in Aberdeenshire. Where, through extensive denudation, the lower and deeper portions of these masses are exposed, they are found to be composed of an almost uniform mass of typical granite, such as is so well seen in the Ross of Mull; but where, on the other hand, they rise into lofty peaks, the granite is found to become more and more hornblendic, and then to graduate through euritic varieties into a felsite, usually more or less porphyritic in structure (porphyry of authors). The same changes are often found to take place in the characters of the rocks composing these great eruptive masses when we trace them from their central portions towards their outer margins.

The relations which exist between the great granitic masses and the stratified rocks among which they lie have been clearly described by many observers. Whenever we approach such intrusions the prevalent strike and dip of the beds in their neighbourhood appear to be more or less interfered with, and the strata are seen to be frequently affected by sudden disturbance and contortion. Moreover the uniformly metamorphosed Lower Silurian rocks are found in the neighbourhood of all these masses to have undergone further and striking changes, which are of a comparatively local character.

It is evident that these great masses of granitic rock have been forced in a fluid or semifluid condition through the strata among which they lie, and which, in their passage, they have disturbed and altered. This is confirmed by the fact that when we examine the junction of the granite and stratified rocks; we find the former sending off numerous veins into the latter, which veins often include angular fragments of the traversed rock, that have been caught up and enclosed in their substance. Moreover similar fragments, often of large size, but more or less altered on their surfaces and frequently traversed by granite veins, are found actually imbedded in the granitic masses. And, further, it appears that considerable tracts of stratified rocks, preserving all their usual characters, were actually enveloped by the fluid igneous protrusions; and thus we have often the most complex entanglements of the granitic and stratified rocks. These facts are very clearly exemplified in the fine coast-sections of the Ross of Mull, and more obscurely, owing to the want of sections, at many points in the Grampian Mountains.

But besides these great granitic masses and the veins in immediate connexion with them, the whole district for many miles around bears witness to the igneous activity to which their origin is referred. In all directions smaller masses of granite, syenite-granite, or felsite are found, either forced between, or cutting across the strata; while dykes of similar materials, passing into felstones, are found traversing the surrounding rocks, in all directions and often to great distances from the great central igneous masses. Such veins and dykes usually occur in prodigious numbers near the great granite protrusions, as is so well seen in the passes of Glencoe and Brander; but their frequency diminishes in proportion as we recede from the central intrusive masses.

The smaller intrusive masses and the dykes effect a certain amount of local metamorphism in the rocks which they traverse; but this is far more limited in extent and less striking in character than that produced by the great central granitic masses. Where, however, the stratified rocks are traversed by a complete plexus of dykes, as in Glencoe, the amount of alteration produced by them in rocks through which they pass is often very considerable.

The period at which these intrusions of igneous rocks (which are almost uniformly of acid or felspathic composition) took place we can approximately determine. No one can study the distribution of the various rocks which make up the Lower Silurian strata of the Highlands, now that the true succession of these beds has been so clearly demonstrated by the labours of Sir Roderick Murchison and Professor Geikie, without perceiving that the igneous protrusions were posterior, not only to the deposition of the Lower Silurian rocks, but also to the disturbance and metamorphism by which they have acquired their present characters. This necessary corollary to the main conclusions arrived at concerning the succession of the Lower Silurian strata was clearly recognized by the authors whom I have cited*.

On the other hand, that these granitic protrusions took place prior to the deposition of both the Secondary and Tertiary strata, is sufficiently shown by the fact that no traces of the extensive network of veins and dykes proceeding from them are in any instance found traversing these younger rocks.

Thus it appears certain that the igneous rocks of the Grampian Mountains must be referred to some part of the Newer Palæozoic periods. Pebbles of these granitic rocks are entirely absent from the conglomerates of the Old Red Sandstone, which, however, are

* Quart. Journ. Geol. Soc. vol. xvii. p. 228.

often wholly made up of fragments of Silurian strata. This absence, is very striking when, as sometimes occurs, masses of granite are now exposed in the immediate neighbourhood of the conglomerates; and it affords a strong confirmation of the age which we have assigned to the granites, by showing that at the time when the Old Red conglomerates were formed, the granites were not exposed at the surface.

Now, in the whole of the phenomena presented by the igneous masses of the Grampian Mountains, we have an exact counterpart of those which we have seen are displayed, as the result of subterranean action, in the case of the great Tertiary volcanoes of the Hebrides. In both cases we find great intrusive masses of granite, passing by insensible gradations into syenite-granite and felsite; and these, in rising through the surrounding strata, violently disturb and greatly metamorphose them. With the great bosses of igneous rock are evidently connected, in both cases, those smaller masses and dykes of similar materials, which traverse the surrounding rocks, producing in them degrees of disturbance and metamorphism proportional to their bulk.

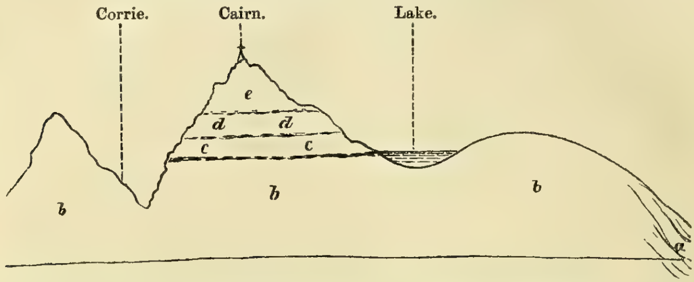
We have already seen that both north and south of the Grampian Mountains we have proofs of the former existence of extensive plateaux composed of lavas, for the most part of a felspathic character. Unmistakable evidence, both stratigraphical and palæontological, and of totally independent character in either case, has led us to the conclusion that the subaerial felstone and porphyrite lavas of Lorn, the similar subaqueous lavas of Central Scotland, and the intrusive masses of identical ultimate chemical composition in the Grampians, were all formed during the same geological periods, those constituting the latter part of the Palæozoic epoch. From the relations shown to exist between the granitic rocks and lavas of Tertiary age already described, we are thus led to see that there are strong grounds for the presumption that a connexion between these different igneous rock masses once existed, and that they all form fragments, now isolated from one another by extensive denudation, of the same great series of volcanic outbursts. I shall now proceed to adduce evidence which is, I think, sufficient to convert this strong presumption into almost absolute certainty.

9. *Relations of the Igneous Rocks of Beinn Nevis and Glencoe.*—In spite of the arguments already brought forward in support of the view that the subaqueous lavas of Central Scotland and the subaerial lavas of Lorn originally formed parts of one series of wide-spread plateaux, and that the great igneous masses of the Grampians are the relics of great centres of eruption during the same period, some may be inclined to regard it rather as a bold speculation than as an established scientific conclusion. It is a fortunate circumstance, therefore, that we are able to point to more than one relic of these volcanoes of the Newer Palæozoic period, the study of which is sufficient, I believe, to convince the most sceptical upon the subject.

Amid that broad belt of elevated ground constituting the Grampians, the peak which rises superior to all the rest is—that monarch among British mountains—Beinn Nevis. The superior elevation of this peak has resulted in the preservation of rocks elsewhere wholly removed by denudation; and the mountain group of which it forms a part is as conspicuous for the value of the evidence which it affords to the geologist, as it is for its great elevation and its strikingly picturesque features. Let us therefore ascend this mountain and study its structure.

Beinn Nevis consists of a well-marked and, to a great extent, isolated group of mountains, having a circumference of about 20 miles

Fig. 11.—*Diagrammatic Section illustrating the Relations of the Rocks forming Beinn Nevis.*



a. Lower Silurian rocks, greatly contorted and metamorphosed at their junction with the granite.
b. Coarse-grained porphyritic granite, with many "contemporaneous veins" graduating into *c.*
c. Fine-grained granite graduating into felsite.
d. Felsite sending off veins into *c.*
e. Felstone lavas and volcanic agglomerates alternating with one another.

and culminating in a peak 4406 feet above the level of the sea (woodcut, fig. 11).

The outskirts of this mountain group are composed of the gneiss, schist, quartzite and limestones of the Lower Silurian, the highly inclined strata of which are seen striking N.E. and S.W., on either side of the great intrusive mass of granite which cuts across them abruptly. From the great central granitic mass there proceed numerous offshoots, sheets, veins and dykes, composed of granite, syenite-granite, felsite, &c., which traverse the stratified rocks in all directions, penetrating between or cutting across their beds.

As we approach the central mass of igneous rocks, the regular dip and strike of the stratified rocks is found to be greatly interfered with, considerable disturbance and contortion being manifested among them. Further, in proximity to the intrusive igneous mass, the already metamorphosed Lower Silurian rocks are found to have undergone still greater alteration; the uniform flaggy masses pass into highly micaceous, chloritic, talcose, hornblendic and actinolitic schists, while the associated limestones become more highly crystalline and intermingled with serpentine.

The great mass of the central mountain-group of Beinn Nevis is composed of hornblendic granite, passing by insensible gradations into ordinary granite on the one hand, and into syenite granite on the other. The normal character of this rock is that of an aggregate of white orthoclase and oligoclase felspar with colourless quartz and hornblende, the latter being usually in part replaced by varying proportions of lepidomelan; and the whole mass is rendered beautifully porphyritic by the dissemination through it of fine crystals of orthoclase felspar of a pink colour. Locally, however, it exhibits many variations from the typical character. It is traversed, too, in every direction by veins of various size, composed usually of granite of finer grain, of euritic felsite, or of crystallized quartz and felspar. The granitic rocks constitute those great spurs, with sharp summit-ridges and steeply sloping sides, which divide the deep corries that form so striking a feature in the Beinn Nevis group.

Let us now ascend the central peak and examine its structure. Some distance above the well-known lake, which lies in a hollow upon the shoulders of the mountain, a remarkable change is found to take place in the character of the granitic mass; it becomes much finer-grained, and as we still ascend we find the hornblende and mica gradually disappearing, till in the end the rock becomes a finely granular felsite of a pale red colour, and often more or less porphyritic in structure.

The highest portion of the mountain, however, is composed of a mass of rocks of totally different character. Instead of the pale red granites, eurites, and felsites, we find dark-blue, grey, greeenish, and purplish felstones; and associated with these are enormous masses of volcanic agglomerate, composed for the most part of angular fragments of all sizes, of felspathic materials, heaped together in the wildest confusion, and compacted into masses of great solidity and hardness.

The confusion produced by the ever descending fragments which cover the upper slopes of the mountain and constitute such impressive evidence of the potency of atmospheric agencies in the work of denudation, is inimical to a complete study of the relations of the rocks forming the summit of the mountain; but an attentive examination both of these slopes and of the more accessible of the precipices surrounding the corries shows that the felstones form great sheets, sometimes exhibiting a rudely columnar structure, and that between them lie the enormous masses of volcanic agglomerate, the whole being traversed by innumerable felstone dykes.

From the same cause, namely the abundance of *débris* on the higher slopes of the mountain, the relations of the underlying felsites and granite to the great cap composed of felstones and agglomerates is not at first sight very apparent. Careful study, however, shows that the former rocks send off veins into the latter; and the abundance of the fragments of the granitic rocks, above the level at which the lavas and agglomerates commence, shows that these veins are by no means few in number.

With regard both to the felstone lavas and the associated agglomerates, the changes produced by the chemical action that has taken place in the mass has been very great. But in this, as in so many similar instances, weathering action is found to a great extent undoing the work of metamorphism, and revealing original structures that had been wholly obscured by it; thus many rocks, now of highly crystalline or compact character, are shown to have been originally composed of highly vesicular or scoriaceous materials.

The remarkable characters and relations of the rocks forming Beinn Nevis were not unnaturally the cause of much doubt and difficulty during the infancy of geological science. Almost the only attempt at their explanation hitherto made, consists in the suggestion that masses of "porphyry" had been forced through the midst of an earlier-formed mountain of granite.

But to any one who has studied the Tertiary volcanic rocks of the Hebrides nothing can be clearer than the significance of the features exhibited by Beinn Nevis. Indeed it is evidently but a repetition, on a grander scale, of many a Tertiary mountain like Beinn Uaig in Mull, which we have already described. In both alike we see the evidence that while felspathic lava streams and scoriæ were being erupted at the surface, masses of molten materials of the same composition were intruded below them, and by slow consolidation forming those bosses of felsite which pass by insensible gradations, in their lower and deeper parts, into hornblendic and ordinary granite. That both alike constituted portions of great volcanic piles is, I believe, from the facts adduced in this memoir, placed beyond dispute.

Scarcely less interesting, in their bearing upon the present inquiry, are the phenomena displayed in Glencoe. At the northern end of the celebrated pass we find the Lower Silurian strata undergoing considerable disturbance and great metamorphism; and they are also seen to be traversed by a wonderful plexus of veins, dykes, and intrusive masses composed sometimes of hornblendic granite, but more usually of numerous varieties of red felsite ("porphyry" of authors). The stratified rocks are overlain by great masses of felstone, with some beds of the so-called "brecciated porphyry" (consolidated ash, scoriæ, &c.), which are, however, by no means so abundant here as on Beinn Nevis. These felstones are traversed, like the stratified rocks upon which they rest, by an almost infinite number of veins and dykes, usually composed of felsite; and they have in many cases undergone a certain amount of alteration from heat, similar to that which we have seen taking place in the Tertiary lavas under like conditions, and resulting in the development in them of a peculiar banded structure and splintery fracture.

These felstones occupy the whole of the central parts of the pass, and weather into those striking forms which characterize the scenery of this famous spot. At the southern end of the pass there appear from underneath these altered felstones, the felsites passing into granites, and enclosing masses of often highly altered Lower Silurian strata, which constitute the great intrusive mass of the Black Mount.

Here it is evident that there has escaped destruction by denudation a portion of the lavas and associated beds which formed the outskirts of one of the great Newer Palæozoic volcanoes—the lavas of Glencoe lying in part on the disturbed and metamorphosed stratified rocks, and in part on the great eruptive masses which have produced that disturbance and metamorphism.

Besides Beinn Nevis and Glencoe there are some other points which exhibit, though in a less striking manner, relics of these doubtless once grandly developed masses of lava and fragmentary materials, which during the Newer Palæozoic periods formed those great volcanic cones of which the granitic masses of the Grampians constituted the central cores, and which rose above vast plateaux of the felspathic lavas that issued from them; of these plateaux only small and outlying fragments have, by a combination of accidents, escaped destruction by denudation. There is one fact which I have not yet noticed, but which is of a sufficiently striking character to arrest the attention of every geological observer; I allude to the very marked similarity in petrological characters between the vestiges of the lava rocks preserved in Beinn Nevis and Glencoe on the one hand, and those which make up the larger areas, as of Lorn and central Scotland on the other.

10. *Physical Features of Northern Scotland during the Newer Palæozoic periods.*—That the different deposits of the Old Red Sandstone were accumulated in lakes, has been suggested by Mr. Godwin-Austen, and supported by a variety of arguments by Prof. Ramsay. The peculiar characters of the deposits of this age in the districts referred to in this paper appear to accord perfectly with this hypothesis.

The conditions which prevailed during the earlier part of the Newer Palæozoic periods would appear to have been as follows:—In what is now the Scottish Highlands an extensive land area existed, with a number of more or less isolated lakes or inland seas. Along the line now occupied by the Grampian Mountains rose a range of great volcanic cones, while numerous intermittent eruptions took place at the bottom of the great sheets of water; the centres of eruption of some, at least, of these have been pointed out by Mr. Maclaren and Prof. Geikie. Thus while great masses of lava, with agglomerates, tuffs, and ashes, were accumulating round the great volcanoes, other enormous deposits were simultaneously formed, consisting of alternations of similar lavas with stratified rocks—the latter being composed in part of the detritus of these lavas, in part of fragmentary eruptive materials which fell into the lakes, and in part of the materials derived from the older rocks which formed their shores. A similar series of operations went on during the next succeeding period, that of the Calciferous Sandstone, though, in consequence of physical changes, lacustrine were exchanged for estuarine and terrestrial conditions.

During the whole of these periods much local subsidence must have taken place, to permit of the accumulation of such enormous thicknesses of rocks; and the resulting disturbances led to the production of those local unconformities which have been noticed by Prof. Geikie and other authors. These unconformities do not appear, however, to have the same significance which we naturally attribute to phenomena of the same kind when exhibited by rocks which have been formed under less violent conditions.

We have seen that, during the later portions of the Tertiary epoch, the eruptions from the great centres of volcanic activity were succeeded by a series of sporadic eruptions, resulting in the formation of numerous small cones or "puys;" and in this we find a close analogy with what has taken place in the case of many modern volcanoes. The great volcanoes of the Grampians, which were in activity during the Newer Palæozoic periods, also appear on their extinction to have been succeeded by the outburst of numerous "puys." "The area of the Lothians and Fife," says Prof. Geikie, "appears to have been dotted over with innumerable volcanic vents;" and these sporadic eruptions seem to have continued during a great part of the Carboniferous and Permian periods. These latest eruptions of the Palæozoic epoch consisted of materials of more or less basic character; and the wide-spreading sheets of melaphyre and similar rocks connected with them, and intruded between the older strata, have given rise to those numerous "crags" which, often crowned by old castles, form such a striking feature in Lowland scenery. The most familiar type of these later palæozoic "puys" is the well-known Arthur's Seat, near Edinburgh, the origin of which has been so well illustrated by Maclaren, Edward Forbes, and Prof. Geikie; but innumerable other beautiful examples of the same kind occur, some of which are described in the publications of the Geological Survey.

IV. *Conclusion.*

1. *Comparison of the two Great Periods of Volcanic Activity in Scotland.*—From the facts described in the present paper it appears that the British archipelago, in common with the surrounding districts, has been the theatre at two distinct periods, since the deposition of the Silurian rocks, of exhibitions of volcanic phenomena upon the very grandest scale. The first of these epochs of violent igneous activity appears to have lasted from the commencement of the Old-Red-Sandstone period down to the close of the Palæozoic era; the second, during nearly the whole of the Tertiary epoch. The interval between these two grand displays of igneous forces, namely that during which the Mesozoic strata were deposited, appears to have been one of comparative, perhaps of complete, quiescence of volcanic action. Bearing in mind the arguments of Mr. Darwin in support of "the identity of the force which elevates continents with that which occasions volcanic outbursts," it is not a little interesting to find that the periods of maximum volcanic activity, namely the Old-Red-Sandstone and the Miocene, appear to have coincided with those during which (as hown from various considerations by Professor Ramsay) a great extent of continental land prevailed in the same areas.

A comparison of the products of the volcanoes of the Newer Palæozoic and Tertiary periods respectively, leads us to the following conclusions.

During both of these periods of igneous activity, as in the case of volcanic outbursts of more recent times, the extrusion of lavas of highly felspathic composition has, as a general rule, preceded those of the basaltic varieties.

But, while in the later of these epochs, the Tertiary, we have a period characterized by the ejection of lavas and the intrusion of subterranean masses of highly silicic composition, followed after a long interval by the outburst from the same vents of highly basic igneous rocks, in the earlier of the two epochs (the Newer Palæozoic) we witness, apparently, a gradual transition during the enormous periods through which the eruptions continued, from rocks of a moderately acid to others of a moderately basic character.

The last efforts of volcanic activity in each of these epochs, as in the case of many, if not all, recent exhibitions of volcanic phenomena, have been of a sporadic character, and have resulted in the formation of numerous, but comparatively small, volcanic cones or "puys."

At the earlier epoch the range of great volcanoes was thrown up along a line ranging N.E. and S.W., coincident with the direction of the subterranean forces which, both long before and subsequent to their upheaval, appear to have determined the elevations, foldings, and great fractures of the rocks of the district. But at the later epoch the volcanoes were thrown up along quite a different line, one ranging N. and S.; and there is evidence that at the close of the Mesozoic era new axes of upheaval were originated, differing in direction from those which had prevailed during the whole of the periods from the Silurian to the Cretaceous.

But to the consideration of these general conclusions concerning the subterranean forces, and their influence in determining the characters and position of the strata, I shall have to return in the concluding division of this memoir.

2. *Influence of Volcanic Action in determining the Characters and Relations of the Secondary Rocks of Scotland.*—The importance of a clear conception of the history of the two great periods of volcanic activity, which respectively preceded and followed the deposition of the Mesozoic strata, to a complete understanding of the nature and significance of the features presented to us by the latter, is shown by the following considerations.

(1) The main features of the physical geography of the area in which the Secondary rocks which we are studying were deposited, were to a very great extent originated by that grand exhibition of volcanic activity which had only just come to a close when the formation of the latter commenced. Hence this pre-Mesozoic volcanic action had much to do in determining the nature of the rocks which supplied the materials of the Secondary sediments, and also the conditions under which they were accumulated.

(2) Constituting, as we have seen it did, a period of rest

between two epochs of the most violent volcanic activity, the Mesozoic era may well be supposed to have been characterized by the subdued efforts of those imprisoned forces which were unequal to the task of opening "safety-valves" for their violence at the surface. I shall show in the sequel that many of the anomalous characters of the Secondary rocks in this district can only be explained on the supposition that during the period of their deposition the area was subject to frequent and great oscillations of level.

(3) It is to the overwhelming masses of matter poured out by the Tertiary volcanoes that the preservation even of such small vestiges of the Secondary rocks as remain to us is wholly due. In the case of each of the patches of these strata which we are called upon to study on the west coast of Scotland, the positions and relations of its beds, and the nature and extent of its metamorphism, are the result of that complicated series of volcanic phenomena which followed their deposition.

3. *The "Geological Record" in the Scottish Highlands.*—The purposes which the Alps have served to continental geologists, have been to a great extent fulfilled in the case of British observers by the Scottish Highlands; and in either of these districts the materials for the solution of some of the most important problems of physical geology have been not unsuccessfully sought for. It was not unnatural that, in the case of both these mountain-groups, the greatly altered and highly crystalline character of the rocks which compose them should have been looked upon by the older geologists as proofs of their great antiquity. But the discovery of fossils in some of the less-altered portions of the Alpine rocks has quite revolutionized the views of geologists upon the subject of their age; and, similarly, the results of recent researches in the Scottish Highlands enable us to refer their great crystalline masses to well-known, and in some cases very recent, geological periods.

Should any one still cling to the old view that highly crystalline characters in rocks may be regarded as a criterion of antiquity, I would point to the Cuchullin Hills of Skye, which have been regarded as of Laurentian age, but which, from the clearest evidence, we have shown to belong to the Miocene period.

The early maps of the Scottish Highlands were of necessity purely *mineralogical.* The first attempt at the production of a *geological* map, that is of one in which the classification of the rocks adopted is based upon the periods of their formation, is the Sketch Map of Murchison and Geikie, published in 1861. The production of this was rendered possible by Peach's important discovery of Lower Silurian fossils in the limestone of Durness. We are now, however, in a position to show that the rocks of the Highlands, far from being of great and unknown antiquity, include representatives of a great variety of geological periods. The rocks of Lower Silurian age are of great thickness, and cover a vast extent of country; and beneath them we find two older series of strata which may, possibly, represent the Cambrian and the Laurentian. Of the existence of Upper Silurian rocks in the Highlands we have as yet no certain evidence; but the

Old Red Sandstone is admirably represented, in all its divisions, both by sedimentary and igneous products; while the Carboniferous and Permian (?) also find representatives in rocks of the latter class. As I shall show in the present memoir, we have fragmentary but almost consecutive examples of all the Mesozoic formations, from the Trias to the highest rocks of the Cretaceous series. In the Tertiary epoch we have the felspathic igneous rocks representing the Eocene period, the basaltic rocks, the Miocene, and the smaller scattered eruptions of the "puys" the Pliocene; while of the Pleistocene period the interesting glacial deposits of the Highlands supply us with a sufficient record. Thus we arrive at a basis for the construction of a true geological map of the Scottish Highlands; but the actual performance of this task is one which will demand a vast expenditure of time and effort.

4. *Light thrown on some problems of Physical Geology by the Volcanic Rocks of the Highlands.*—The admirable labours of those pioneers of Scottish geology, Hutton, Playfair, Webb Seymour, James Hall, and Macculloch, have clearly demonstrated the relations which exist between the granitic and the associated strata of the Highlands. On the other hand the researches of Scrope among the extinct volcanoes of Central France, supplemented as these have been by the observations of Darwin, Lyell, and a host of other geologists, in the most widely scattered districts, have thrown much light upon the structure of modern volcanoes and upon the nature and succession of the phenomena which accompany their formation. In the rocks of the Hebrides we find the means of connecting these two series of observations, and thus of arriving at a complete theory of the action of the igneous forces operating under different conditions.

The characteristics of *Stigmariæ* and *Sigillariæ* respectively were known to palæontologists long before the discovery of a section in the Coal-measures enabled them to be identified, in their true relations, as the roots and trunks of the same plant. Similarly physical geologists have separately studied the features of Volcanic and Plutonic rocks, which the wonderful sections of the Hebrides now warrant us in affirming to have the closest connexion—the great intrusive masses being, as it were, the roots of a tree of which the stem, branches, and leaves are represented by the dykes, lava streams, and cinder piles of great volcanic cones.

From the active volcanoes of Etna, Vesuvius, and Skaptar Jökul, the step to the ruined piles of the Mont Dore and the Cantal is an easy one: and with these last we have but little difficulty in perceiving the parallelism of the phenomena displayed by the rocks in the central mountain-group of Mull. From the condition of the volcanic rocks in Mull to that in Skye the transition is obvious, and from the latter to Beinn Nevis, and thence to the granitic bosses of Cairngorm, the Moor of Rannoch, and the Ross of Mull, can easily be made; nor will any difficulty be experienced in passing from these latter to the wide-spreading tracts of granite, such as that of Leinster.

Circumscribed though the observations of the geologist necessarily are, within the infinitesimal periods of human chronology, he may nevertheless learn to triumph over the painful limitations of time by availing himself of the opportunity which he has of studying the same series of operations at various stages of its progress, as presented in different examples. As was so well expressed by Playfair, "It is true we do not see the successive steps of this progress exemplified in the states of the same individual rock, but we see them clearly in different individuals; and the conviction thus produced, when the phenomena are sufficiently multiplied and varied, is as irresistible as if we saw the changes actually effected in the moment of observation"*.

To this mode of reasoning the geologist is continually compelled to resort. If, as I believe, it is demonstrated that in wide-spread intrusive masses of granite and gabbro or serpentinous rocks—in the more or less isolated mountain-groups of granitic and doleritic rocks—in the great volcanic mountains in varying stages of decay and destruction by denudation—and in the long lines of parasitical cones which surround them, we witness but different portions of the same grand series of phenomena, then the geologist is enabled to picture to himself the characteristics and results of volcanic activity in all its developments and under all its phases.

Thus he is led to the conclusion that the distinction between Plutonic, Trappean, and Volcanic rocks, convenient though it may be in practice, is a purely artificial one, and that the whole of these must be regarded as the products of the same igneous forces when operating under different conditions. While, on the one hand, we are led to conclude that great tracts of granite, like that of Leinster, may once have been surmounted by vast volcanic piles, we cannot, on the other hand, doubt that the subaerial volcanic phenomena of Iceland, Sicily, and the Andes are accompanied by innumerable igneous injections in subjacent strata and the formation of masses of granite, syenite, diorite, and gabbro at great depths beneath them.

EXPLANATION OF PLATES XXII. & XXIII.

In these Plates an attempt has been made to illustrate the relations of the great masses of volcanic rocks in the Hebrides to one another, and to the sedimentary deposits which they have been the means of preserving.

The sketch map on Plate XXII. is an attempt to exhibit the relations of the outcrops of the great intrusive bosses, sheets, and dykes of igneous rock to the lavas, agglomerates, and older strata in the island of Mull; but this, owing to the small scale employed, could only be accomplished in a somewhat diagrammatic manner. To display the complicated interlacings of the almost innumerable igneous intrusions of the district would require maps of great accuracy on the largest scale, and even then could only be attempted after a very detailed and minute survey of the area. Unfortunately the Inner Hebrides have not yet been surveyed by the Ordnance Department; and, although the coast-lines are well laid down on the Admiralty Charts, the geologist meets with almost

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* Illustrations of the Huttonian Theory, p. 101.

insuperable difficulties in attempting to record and correlate his observations on the interior portions of the larger islands, from the want of even tolerably accurate maps.

Although I have endeavoured to make the best possible use of all the materials which were available as a basis for my study of the position and relations of the rocks of Mull, yet nothing more could be attempted, in such a sketch map as the present, than to convey a general idea of the structure of the island. It must be remembered, in examining this map, that the forms of the outcrops of the ramifying masses of igneous rock, as there laid down, are in part determined by the surface-contours in these highly mountainous districts. Thus the outcrop of a mass of rock filling a *rectilinear* fissure, when exhibited on a mountain-side, forms a *curved* line. It is especially necessary to bear this fact in mind in seeking to realize from the map the actual relations of the great solid rock masses. Of course in a map on so small a scale, the *size* of the dykes and sheets has had to be enormously exaggerated, while only the most imperfect idea is conveyed of their vast numbers and complicated relations.

By employing strongly contrasted colours for the two great classes of igneous rock, I have endeavoured to make their relations to one another as clear as possible; while by varying the depth of tint in each case I have sought to illustrate the gradations from coarsely crystalline to granular, compact, and vitreous structures, in rocks of the same ultimate chemical composition. In the scale of colours on the map I have employed the same petrological nomenclature as is used in the memoir; it must be remembered, however, that I have been compelled to use some terms in a restricted and, to a certain extent, conventional manner—as, for instance, in applying the name "felsite" to rocks of granular and "felstone" to those of compact texture. The index of colours on Plate XXII. serves also for the sections on Plate XXIII. On the latter, however, an additional tint (pale red dotted with black) has been employed in fig. 5 for the Cambrian, which does not occur in the map.

In Plate XXIII. all the sections are constructed, as far as possible, on a true scale, the proportions, both vertical and horizontal, being the same in each instance. But this scale is in each section perfectly independent of that of the others; consequently the sections bear no relation to one another.

In the section across the island of Mull (fig. 1) a dotted line is added to show the least possible elevation of the volcano before it had undergone central subsidence and extensive denudation. The asterisks show the difference between the original and the present positions of what is now the summit of Beinn More, as explained on page 259.

The publication of the general Map of the Western Isles is postponed till the appearance of the next paper of the series, as it will serve at the same time to illustrate the relations of the volcanic rocks to one another and the positions of the scattered fragments of sedimentary deposits, from which the history of the Mesozoic periods in this district has to be reconstructed.

Discussion.

Mr. Campbell thanked the author for having taught him so much concerning the country in which he had been born and bred, and invited him to inspect models which are described in 'Frost and Fire.'

Mr. D. Forbes was gratified to find the subject of the igneous rocks of Britain taken up in so able a manner, and the subject not left entirely to continental geologists. The author was fortunate in the fact that he had occupied the same ground as that which had already been explored by Prof. Zirkel, whose work had been thus supplemented. He agreed with the author in regarding Volcanic and Plutonic rocks, from granite down to the most recent lavas, as of one and the same origin. He suggested a doubt whether the older granites belonged to so recent a period as that assigned to them by the author.

Prof. Maskelyne considered that this paper would go far towards settling the question between one half of the petrologists of the present time and the other half. He accepted the author's view as to the Tertiary origin of the granite, inconsistent though it was with the view of the age of granite maintained by the school of Richthofen. This paper exemplified the necessity of combining the observations of the geologist in the field with those of the mineralogist in his laboratory.

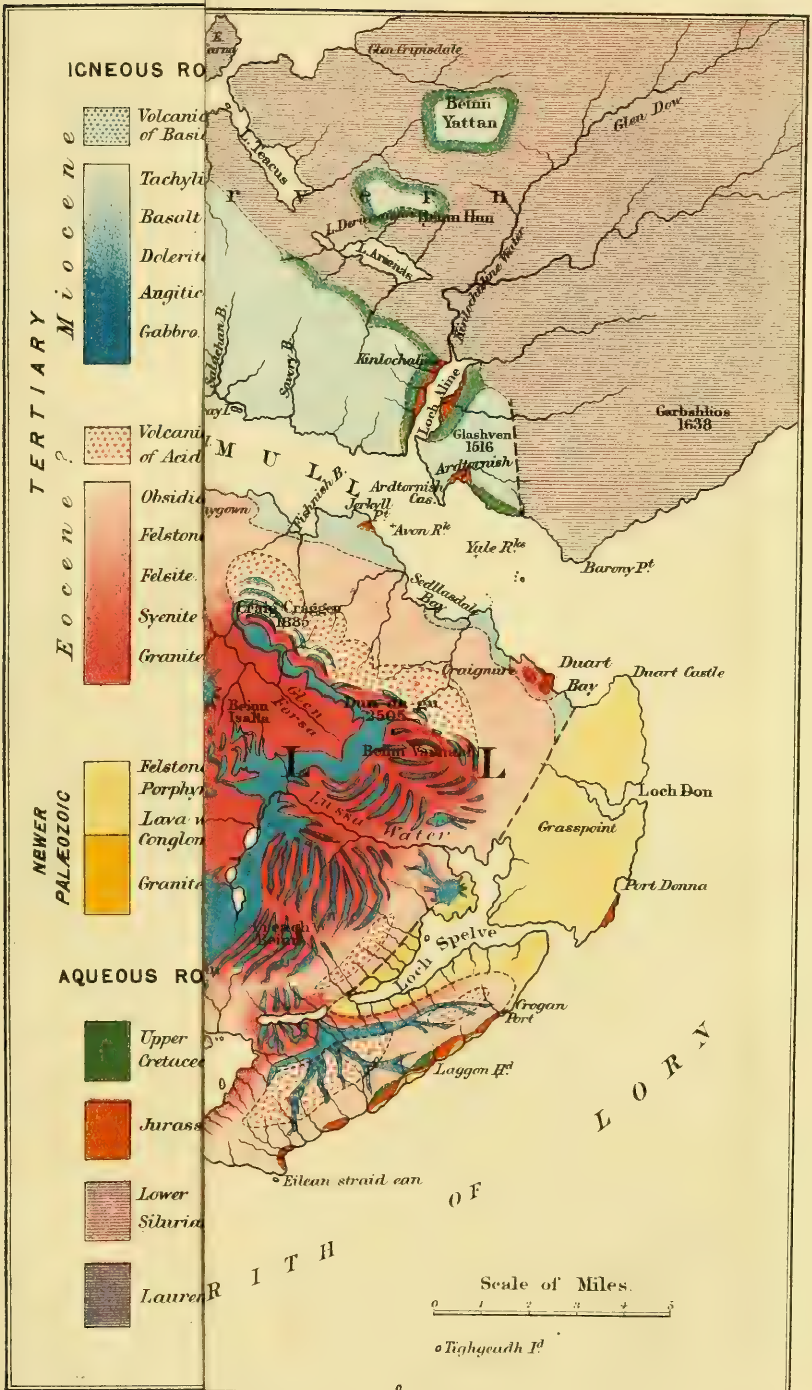
Mr. Seeley remarked on the importance of this paper as furnishing lines of departure for investigating the early physical history of the earth. He had ascertained that the old lines of volcanic activity corresponded with the agonic lines of magnetism; and the paper afforded data which would assist in drawing conclusions as to the changes in the position of the earth's axis by a comparison of these lines with those of the magnetic currents.

Mr. W. W. Smyth congratulated himself on again hearing of intrusive granitic dykes such as recalled the earlier days of the Society, and tended to dispel some accepted ideas as to metamorphism. He adduced the recent deposits of Etna and Vesuvius in illustration of the specimens exhibited by the author.

Mr. Blanford suggested that there might be in this case only one form of the existence of granite. When the gradual passage from schists into granite could be traced, there could be little doubt of its origin; and even in its eruptive form the granite might be only the result of a very complete metamorphism. He agreed with the author as to the probability of the great horizontal outflows of basalt being subaerial, and not subaqueous, and instanced analogous examples in India.

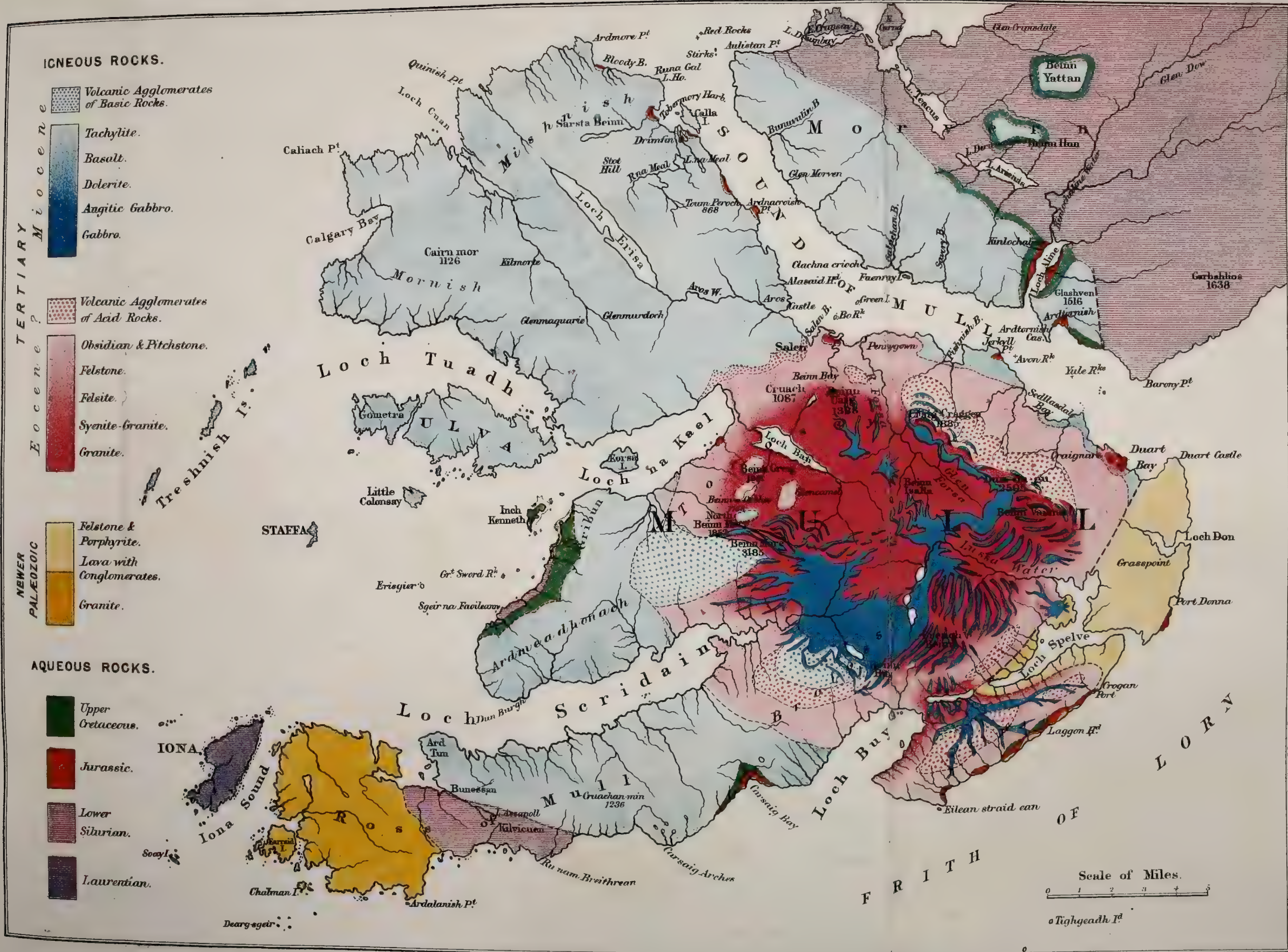
Mr. Tiddeman, referring to the great length of time alluded to by the author as represented in the volcanic rocks of Scotland, wished to call attention to the rocks in the neighbourhood of Seuir-na-Gillean in Skye, which consisted partly of basaltic lavas of Miocene age. These appeared to be tilted by the syenite of Marscou &c.; and upon both rested unconformably a great thickness of hypersthene. But furthermore, the base of this latest rock appeared to be thrown down by a fault with a displacement of some thousands of feet.

Mr. Judd, though admitting there were two sides to the question as to the origin of granite, could not regard intrusive masses of granite passing through rocks of different mineral constitution as the metamorphosed representatives of each. He briefly replied to the other points raised in the discussion.



OF MULL.

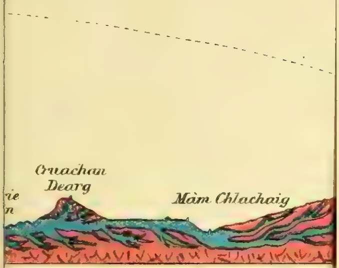
Mintern Bros lith.

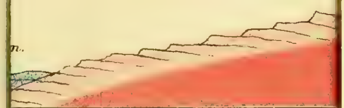


SKETCH MAP ILLUSTRATING THE STRUCTURE OF THE VOLCANO OF MULL.

Mintern Bros lith.

OUP OF MULL.





CKS IN THE ISLANDS OF

Fig. 1.

SECTION THROUGH THE CENTRAL MOUNTAIN GROUP OF MULL.

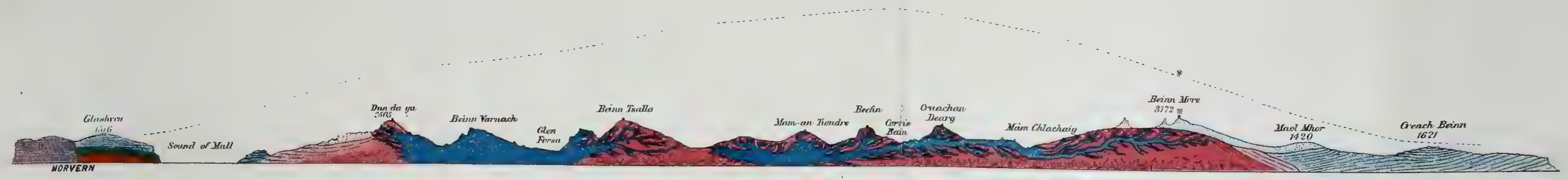


Fig. 2.

BEINN GREIG.

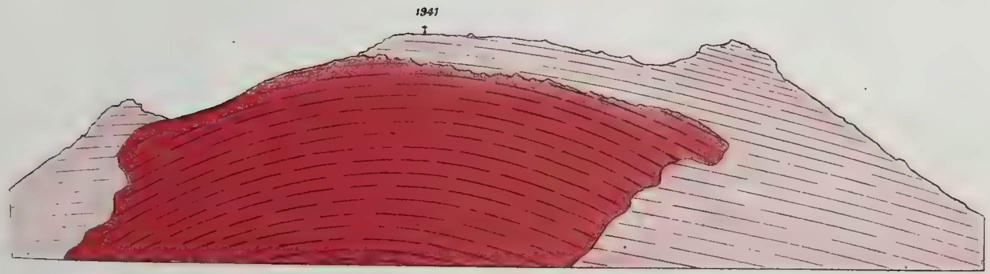


Fig. 3.

CRAIG CRAGGEN.

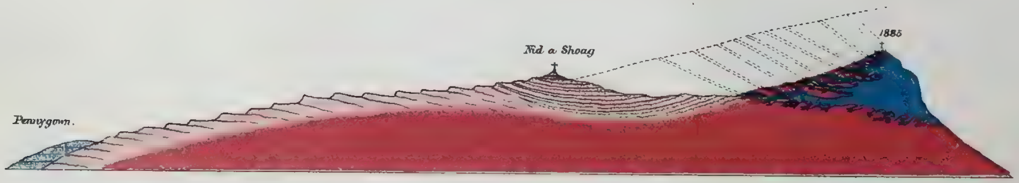


Fig. 4.

BEINN MORE.

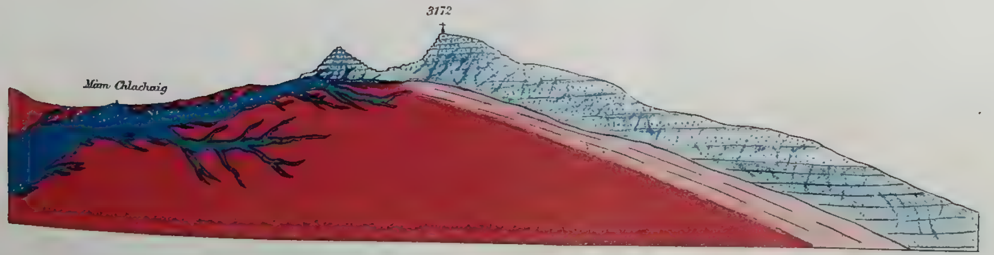


Fig. 5.

SECTION ACROSS RUM.

SECTIONS ILLUSTRATING THE RELATIONS OF THE VOLCANIC ROCKS IN THE ISLANDS OF MULL AND RUM.

Mintern Bros. lith.

24. Note *on the* Occurrence *of* Sapphires *and* Rubies in sitû *with* Corundum, *at the* Culsagee Corundum-mine, Macon County, North Carolina. By Colonel C. W. Jenks. (Read February 25, 1874.)

(Communicated by David Forbes, Esq., F.R.S., F.G.S.)

The oriental ruby and sapphire are, mineralogically considered, merely coloured crystals of corundum, which mineral species has been shown by chemical analysis to consist of the earth alumina in a crystallized state and nearly pure condition. Where these gems have been met with, they appear almost always, if not invariably, to have been discovered in the beds of rivers as waterworn pebbles; and although the existence of corundum in small quantities in granular limestone in Asia Minor and the United States has long been known, any thing like a deposit of this mineral *in sitû*, sufficiently abundant for commercial exploration, appears to have been altogether unknown, until the author's attention was directed to the occurrence of numerous fragments of corundum on the surface and in the river-beds of Macon County, North Carolina, which encouraged him to make a minute examination of this district, and resulted in the discovery, in the summer of 1871, of the deposits of corundum now known as the Culsagee Corundum Mine.

The locality of this mine is a hill, situated about nine miles east of Franklin, the principal town of Macon County, the summit of which is some 400 feet above the valley and about 2500 feet above the level of the sea; geologically it is a boss of serpentine protruded through the surrounding granite.

In the bed of the river, which runs past the south side of this hill, now commonly known as Corundum Hill, numerous waterworn pebbles of corundum, often of large size, were met with, along with small fragments of rubies and sapphires; and subsequent explorations revealed the existence of some fine nearly parallel veins containing corundum, cropping out for a length of about a mile, along the steep side of this hill in a north-east and south-west direction.

These veins all dip to the south-east, at an angle of about 45°, and, although generally only a few inches across at the surface, widen out as they descend into the body of the hill. In the deepest working, now 75 feet, the vein is seen to be 10 feet thick. The veins themselves consist of a mass of chlorite, jefferisite, and corundum, the latter forming from about a third to one half of the entire mass, and occurring as more or less well-developed crystals imbedded in the other minerals. Along with these the following mineral species were found in minor quantity:—chrysolite, anthophyllite, margarite, damourite, felspar, talc, sapphire, ruby, spinel, zircon, hornblende, staurolite, diaspore, black tourmaline, chalcedony, quartz, chromoferrite, magnetite, and two new silicates to which Professor Genth has given the names of kerrite and maconite.

The corundum is invariably crystallized, some of the crystals weighing more than 300 pounds; usually the large crystals are found to enclose plates of chlorite or jefferisite, just as if these minerals had been entangled in the very act of the crystallization of the corundum itself.

About 200 tons of corundum have already been extracted from this mine, and, after crushing, used for grinding and polishing stones, glass, and metals &c., being found far superior to emery for these purposes. Taking the sapphire as a standard at 100, the corundum from this mine was found to have an abrasive power of no less than between 90 and 97, whilst the best Naxos emery only stood at between 40 and 57.

The colour of the corundum crystals is very variable. Some are perfectly colourless and transparent, while others have all shades of yellow, green, blue (sapphire), pink and red (ruby), many of the crystals showing different colours in different parts of their substance—some of the large ones, when fractured, revealing portions coloured as rubies or sapphires, from which many gems have already been broken out and cut for setting: most of these have as yet, however, been of small size, owing to the difficulty of finding large pieces free from flaws or cleavage-planes passing through them. There can be no doubt as to these stones being the true gems; and Mr. H. C. Sorby, to whom the specimens have been submitted, declares, from their microscopic structure, that they must have been formed at an elevated temperature, and that they contain the same well-marked fluid-cavities filled with a highly expansive liquid (without doubt liquefied carbonic acid) as are seen in the sapphires from Ceylon; he also attributes the colour of the rubies and of the green sapphire to chromium, but is uncertain as to the cause of the blue of the sapphire, suggesting that it may be due to protoxide of iron or possibly to uranium; and he sees no reason for doubting these gems being quite identical with those so long known from the East.

The serpentine rock of the Corundum Hill has been analyzed by M. Th. M. Chatard with the following results:—

Silica	41·58
Alumina	0·14
Protoxide of iron	7·49
Protoxide of nickel (trace of cobalt and manganese)	0·34
Magnesia	49·28
Lime	0·11
Loss on ignition	1·72
	100·66

As several of the minerals occurring in the Culsagee Mine have been analyzed by Professor Genth, M. Chatard, and Dr. Koenig, the results obtained by these chemists are given below:—

Spinel	Sp. gr. 3·766. Fine-grained. Koenig.	Sp. gr. 3·797. Coarse-grained. Koenig.	Sp. gr. 3·695. Dark green. Genth.
Alumina	54·32	56·58	66·63
Sesquioxide of chromium	3·96	2·28	trace.
Sesquioxide of iron	11·51	9·66	1·80
Protoxide of iron	11·16	14·60	11·35
Magnesia	19·05	16·88	19·86
Oxide of copper	......	......	0·11
Oxide of nickel	......	......	0·25
	100·00	100·00	100·00

Jefferisite	Broadly foliated. Koenig.	Broadly foliated. Chatard.	Scaly. Chatard.
Silica	33·93	33·77	34·00
Alumina	17·38	17·56	20·36
Sesquioxide of iron	5·42	5·61	4·91
Protoxide of iron	0·50	0·50	0·42
Protoxide of nickel	0·35	?	0·57
Magnesia	23·43	22·48	21·71
Ignition loss	19·17	20·30	18·50
	100·18	100·22	100·47

Chlorite	Foliated dark green. Genth.	Fine scaly. Genth.
Silica	27·56	29·48
Alumina	22·75	22·22
Sesquioxide of iron	2·56	0·70
Protoxide of iron	5·43	5·30
Oxide of nickel with cobalt } Oxide of manganese }	0·30	0·11
		0·17
Magnesia	28·47	30·99
Ignition loss	13.80	11·63
	100·87	100·60

	Margarite, sp. gr. 3·087. Chatard.	Staurolite, sp. gr. 3·711. Genth.
Silica	28·80	27·91
Alumina	49·57	52·92
Sesquioxide of iron	......	6·87
Protoxide of iron	0·34	7·80
Magnesia	0·75	3·28
Lime	11·33	trace.
Ignition loss	6·64	1·59
Soda, potash and lithia	undetermined	......
		100·37

	Maconite, sp. gr. 3·827. Chatard.	Kerrite, sp. gr. 2·303. Chatard.
Silica	34·20	38·26
Alumina	21·66	11·42
Sesquioxide of iron	12·54	1·97
Protoxide of iron	0·32	0·32
Nickel with cobalt	0·13	0·22
Magnesia	14·61	26·50
Lithia	trace.	......
Soda	0·50	......
Potash	5·91	......
Ignition loss	11·90	21·28
	101·77	99·97

Discussion.

Mr. Warington W. Smyth considered the communication made by Col. Jenks as a very important and interesting one. He referred to the nature of these gems, and expressed a hope that Col. Jenks's further operations might result in the discovery of large and fine crystals.

Mr. D. Forbes remarked that much credit was due to Col. Jenks for having followed up the fragmentary evidence which he originally obtained with such good results. The origin of these gems had long been a disputed point; all those hitherto obtained have been found in a waterworn state in the beds of streams. Col. Jenks had discovered the actual home of the so-called oriental ruby and sapphire.

Prof. Tennant observed that Mr. Sheppard had years ago brought home sapphires from the same district. They were obtained from the beds of rivers.

Col. Jenks gave some further statements with regard to the depth to which the corundum-veins referred to in his paper have been worked, and stated that some of the crystals obtained from the veins could be broken across by a very slight pressure in the fingers when first taken from the vein, but that they became hard by exposure to the air.

25. *On the* RELATIONSHIP *existing between the* ECHINOTHURIDÆ, Wyville Thomson, *and the* PERISCHOECHINIDÆ, M'Coy. By R. ETHERIDGE, Jun., Esq., F.G.S. (Read March 11, 1874.)

[PLATE XXIV.]

A CONSIDERABLE degree of light has lately been thrown on the relationship existing between palæozoic and recent Echini, from materials obtained during the cruise of the 'Porcupine' in 1869.

Prof. Wyville Thomson, in his 'Depths of the Sea'*, described two new and peculiar genera of Echinoidea, *Calveria* and *Phormosoma*, which, in certain peculiarities of structure, such as the overlapping of the constituent plates of the test, appear to unite the Echini of the present seas with certain of those genera which existed during palæozoic times.

Although the structure referred to had previously been noticed, in the case of Cretaceous Echini, by the late Dr. S. P. Woodward, and in that of a Palæozoic genus by Prof. James Hall, of Albany, yet it was not until Mr. J. Young, of Glasgow, drew attention to the nature of the plates in the Carboniferous genus *Archæocidaris* that such structure had been observed in any palæozoic genus found in this country†.

Prof. W. Thomson states‡ that in the test of *Calveria* (woodcuts, figs. 1 & 2) the ambulacral and interambulacral plates, instead of abutting directly against one another, and thus forming a rigid and compact test, overlap each other, those of the ambulacra from below upwards (that is, from the mouth to the apical pole), those of the interambulacra from above downwards, or from the apical to the oral pole. The overlapping of both series of plates takes place at their inner ends, whilst the outer ends of the interambulacral plates are separated, the one from the other, by intervening membrane, thus assisting in the general mobility of the framework. At their outer extremities the interambulacral plates carry each a primary tubercle, and also overlap the outer extremities of the ambulacral plates, "so that the ambulacral areæ are essentially within the interambulacral" §. The pores of the ambulacral plates are arranged in a peculiar manner, in arcs of three, specially placed.

The second genus, *Phormosoma* (*P. placenta*, W. T.), resembles the preceding in the arrangement of the ambulacral and interambulacral plates and flexibility of peristome; but the overlapping of the plates is not carried to so great an extent as in *Calveria*, and no membranous spaces are left; so that the test is continuous, as in the normal forms of the Echinoidea. *Phormosoma* is chiefly remarkable for the peculiar characters of the under or ventral surface, where the

* 'The Depths of the Sea, an account of the General Results of the Dredging-cruise of H.M.SS. "Porcupine" and "Lightning," during the Summers of 1868, '69, '70.' London. 8vo. 1873.

† Geol. Mag. 1873, vol. x. p. 301. ‡ *Loc. cit.* p. 158. § *Loc. cit.*

Fig. 1.—*Calveria hystrix,* Wyville Thomson. (Two thirds nat. size.)*
(From Thomson's 'Depths of the Sea,' p. 156, fig. 27.)

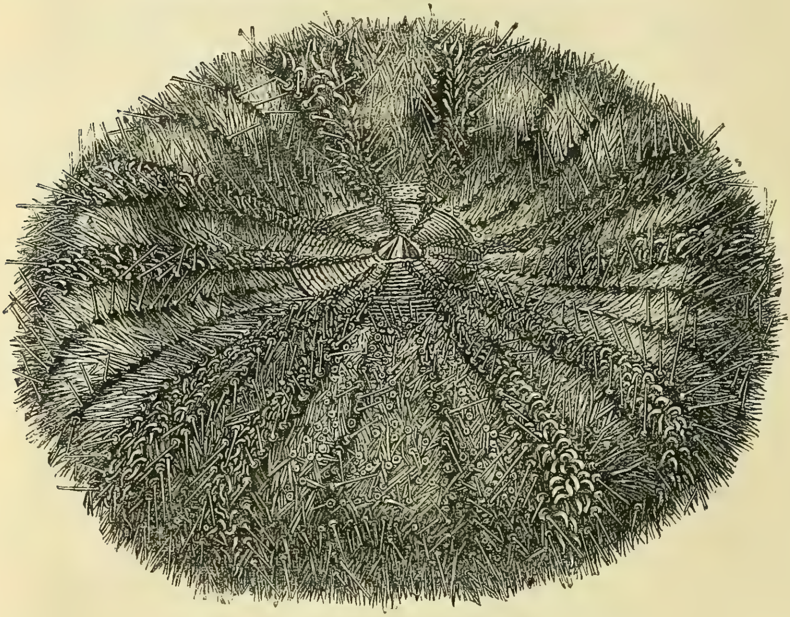
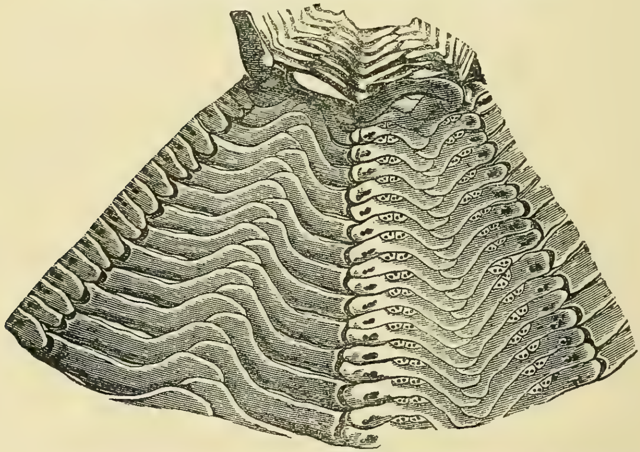


Fig. 2.—*Calveria hystrix,* Wyville Thomson*.
(From Thomson's 'Depths of the Sea,' p. 157, fig. 28.)



Inner surface of a portion of the test, showing the structure of the ambulacral and interambulacral areas.

* [We are indebted to the kindness of Messrs. Macmillan, the publishers of Prof. Wyville Thomson's work, for the loan of these engravings.—Ed. Q. J. G. S.]

distinction between the ambulacral and interambulacral areæ becomes entirely lost.

I have quoted thus largely from Prof. Wyville Thomson's work that the succeeding remarks on the fossil forms may be thoroughly understood.

The first of these, *Echinothuria*, S. P. Woodward, together with the two preceding recent genera, compose Thomson's family of the *Echinothuridæ*; and it is to the consideration of the relation of this family to the *Perischoechinidæ*, M'Coy, that I purpose to devote the remainder of these remarks.

Echinothuria was obtained some years ago by Mr. Wickham Flower from the Upper Chalk of Higham, near Rochester*, and in its principal characters agrees completely with *Calveria* and *Phormosoma*. It differs from the first named, however, in the wider interambulacral and ambulacral plates, in the smaller amount of overlapping of the same, and in the absence of membranous intervals; from the latter by having the structure of the oral and apical surfaces the same. (*Thomson.*)

So far we have examined the characters of those genera which constitute the *Echinothuridæ*; and if we now turn to the palæozoic forms of the Echinoidea we shall find an interesting repetition of many of the foregoing facts.

Palæozoic Echini are represented by a limited number of species, comprised in the following genera:—*Archæocidaris*, M'Coy, *Palæchinus*, Scouler, *Perischodomus*, M'Coy, *Lepidechinus*, Hall, *Eocidaris*, Desor, *Melonites*, D. D. Owen, *Lepidocentrus*, Müller, and *Oligoporus*, Meek & Worthen.

In 1849 Professor M'Coy† proposed the order *Perischoechinidæ*, to include palæozoic Echini possessing more than two rows of plates in each interambulacrum, as distinguished from those of Secondary, Tertiary, and living genera, where the same areæ are composed only of two rows.

This complexity of the interambulacral system was found by M'Coy to be present in the genera *Archæocidaris*, *Palæchinus*, and *Perischodomus*. Since the first enunciation of these characters sufficient information has been obtained to enable us to add the remainder of the palæozoic genera mentioned (I am not so certain of *Lepidocentrus*, Müller, and therefore do not wish these remarks to be applied to that genus with so much certainty as to the others) to M'Coy's *Perischoechinidæ*.

Mr. Young's‡ remarks on the interambulacral plates of *Archæocidaris* clearly indicate that a certain amount of overlapping took place in that genus. These, as originally pointed out by M'Coy §, are of two kinds, a pentagonal and a hexagonal series, arranged in the test in three or more rows. The larger pentagonal plates have two of the sides bevelled (Pl. XXIV. *a*, fig. 1), against which would fit the corresponding bevelled surface of the next plate, but in this case

* W. Thomson, *l. c.* p. 162.

† Annals & Mag. Nat. Hist. 1849, vol. iii.

‡ *Loc. cit.* p. 302.

§ Synopsis Carb. Foss. Ireland, p. 173.

on the lower edge. Mr. Young also observes that one of the other two sides is provided with a small groove, into which would fit the edge of a succeeding plate, and so probably prevent too great a laxity of test.

If, for a moment, we now examine the state of matters as regards *Palæchinus*, we shall find, judging from M'Coy's beautiful figures in his 'Synopsis of the Carboniferous Fossils of Ireland' (pl. 24), that the test in this genus had no overlapping plates, but was rigid, after the normal character of the Echini*.

Sufficiently good specimens of *Archæocidaris* have unfortunately not been obtained to show a series of these overlapping plates in juxtaposition; but I think a careful examination of well-preserved interambulacral plates, with their peculiar bevelled edges, cannot but prove that these edges could have served no other purpose. Confirmatory evidence of this is to be met with in a closely allied genus, *Lepidechinus*, which is described by Hall as having the "plates of the interambulacral series imbricating from the dorsal side, and the lower edges of each range overlapping those below; while the plates of the ambulacral series are imbricating in the opposite direction"†, a complete repetition of the arrangement seen in *Calveria*. [*Note.*—In the 3rd vol. 'Illinois Geol. Report, p. 552, Messrs. Meek & Worthen remark that Prof. Hall has since stated that his original description of *L. imbricatus*, the type of the genus, was not absolutely correct, but that the imbrication of all the plates is exactly the reverse of what he had supposed. He suggests that he may have been mistaken in regard to which was the dorsal and which the ventral side.]

From a consideration of these facts, and admitting that if the existence of overlapping plates be accepted in *Archæocidaris*, whilst the presence of simply abutting plates is recognized in *Palæchinus*, we have in M'Coy's *Perischoechinidæ* two types of structure—one, *Archæocidaris*, with overlapping plates, allied to Thomson's *Echinothuridæ*, the other, *Palæchinus*, with abutting plates, allied to the ordinary forms of Echini, but both still possessing their great distinctive character, viz. the increase in the number of interambulacral plates, which at once presents a clear line of demarcation between them and all recent types.

Perischodomus, *Melonites*, *Eocidaris*, and *Oligoporus* have not been shown to possess overlapping plates, although, as will be presently pointed out, from their resemblance to one of the two preceding, it is probable that some of them at least will be found to do so.

I shall now proceed to note the more intimate test-structure of the genera constituting the *Perischoechinidæ*, and show how they agree with this family on the one hand, and with the *Echinothuridæ* on the other, simply premising that they all possess the distinctive character of the former, viz. the great increase in the number of the interambulacral plates.

* Mr. W. H. Baily has also given good figures of *Palæchinus*, which show the arrangement of the interambulacral plates. See Trans. Roy. Geol. Soc. Ireland, vol. i.

† Descr. New Sp. *Crinoidea*, Prelim. Notice, Albany, 1861, p. 18.

Genus Archæocidaris, M'Coy, 1844*. Pl. XXIV. fig. 1.

(*Echinocrinus*, Agassiz, 1841. *Palæocidaris*, Desor, 1846.)

In this genus the ambulacra are narrow, and composed of two rows of small plates, of irregular form, each provided with two pores. The interambulacra are continuous from pole to pole, and are composed of three or more rows of plates, each provided with a primary tubercle. The rows of plates bordering the ambulacra are pentagonal in form, the middle row or rows hexagonal; the large oblong pentagonal plates have two of the sides bevelled from the upper surface, the opposite side being bevelled on the lower edge; one of the other two sides has a small groove into which the edge of the next plate was received †; the primary tubercles are perforated and hollow; apical disk unknown; mouth surrounded apparently by a membrane bearing numerous minute imbricated plates ‡.

Taking this genus as the type of the *Perischoechinidæ*, we have the first approach towards the structure of the *Echinothuridæ*, as typified by *Calveria*. Whether the interambulacral plates of *Archæocidaris* were imbricated from above downwards, and the ambulacral from below upwards, or *vice versâ*, must remain an open question at present, as we are not in possession of sufficiently good specimens to prove this point. In *Calveria* the peristome is covered with small plates §, and the primary tubercles, as in *Archæocidaris*, are hollow.

Archæocidaris is confined to rocks of Carboniferous age.

Genus Palæchinus (Scouler), M'Coy, 1844 ‖. Pl. XXIV. figs. 2 & 3.

The plates composing the test of this genus abut end to end in the regular way, and, so far as we know, there is no overlapping or intermediate membrane. The interambulacral areæ are composed of from five to six or eight rows of plates, those adjoining the ambulacra pentagonal as in *Archæocidaris*, the others hexagonal. The ambulacra, narrow, and sometimes slightly furrowed, are composed of two alternating rows of small plates, wider than long, each perforated by two rows of pores. The apical disk consists of five genital plates each perforated by three pores, (ovarian and seminal), the fifth being somewhat larger (madreporiform plate?), and five ocular plates, each perforated by two openings ¶.

Further, in the apical disk there are eight plates, answering to the *suranal* of the *Saleniadæ* **.

It becomes apparent that *Palæchinus* belongs to that division of the *Perischoechinidæ* which more nearly approaches the normal Echini, from which, however, it differs in two most important cha-

* Synop. Carb. Foss. Ireland, 1844, p. 173. † J. Young, *loc. cit.* p. 302.
‡ Palæontology of Illinois, vol. ii. p. 294. § W. Thomson, *l. c.* p. 157.
‖ *L. c.* p. 171. ¶ Baily, Geol. Mag. vol. ii. p. 44.
** Baily, two papers read before the Royal Geol. Soc. Ireland, March 9th and April 12th, 1864, "On the Structure of *Palæchinus*." [On the other hand Prof. de Koninck has described and figured (Geol. Mag. vii. p. 259, pl. 7. fig. 1) the apical disk of *Palæchinus* with genital plates only, four perforated by three pores, and the fifth by one pore.]

racters, viz. the triple perforation of the genital plates and the double perforation of the oculars. It has usually been considered that *Palæchinus* possessed spines only of one kind, small ones, analogous to the secondary spines of *Archæocidaris*; but Baily has shown * that both primary and secondary spines were present, the former with tubercles perforated for the passage of the *ligamentum teres* of the spine.

Palæchinus is chiefly confined to Carboniferous rocks. It is said to occur also in the Silurian.

Genus Perischodomus, M'Coy, 1849 †.

Nearly related to *Archæocidaris*, from which it is principally distinguished by the presence of primary tubercles only on the marginal interambulacral plates bordering the ambulacra. Each ambulacrum is composed of two rows of small plates, each pierced by a pair of small pores; the interambulacra are wide, and composed of five rows of plates of irregular form and shape.

Very little is known regarding this genus. It was described originally from two very imperfect specimens, consisting only of portions of the test; and I am not aware that any other specimens have since been described. With the small amount of evidence at our command it is impossible to form an opinion regarding the construction of the test; all that can be said at present is, that it is closely allied to *Archæocidaris*, although the interambulacral plates appear to be more irregular in form and size.

Perischodomus, so far as is known, is confined to Carboniferous rocks.

Genus Lepidechinus, Hall, 1861 ‡.

"The form and arrangement of the ambulacral and interambulacral series, as in *Palæchinus*, with the plates of the interambulacral series imbricating from the dorsal side, and the lower edges of each range overlapping those below, while the plates of the ambulacral areas are imbricating in the opposite direction, narrow and deeply interlocking at their joining edges, each plate pierced near the opposite extremity by two pores" §.

Of all the palæozoic genera of *Echinoidea* the present one shows in the most complete manner the imbricating character of the *Echinothuridæ*. According to Prof. Hall, the interambulacral areæ are many times as wide as the ambulacral, and contain a large number of plates of somewhat irregular form, judging from the figures ||. The imbricating nature of the plates of the test closely connects this genus with *Archæocidaris*, from which it may be distinguished by the form of the ambulacral and other plates, and probably, according to Meek and Worthen ¶, by the fact of there being no primary tubercles on

* Baily, *loc. cit.* † Annals & Mag. Nat. Hist. 1849, 2nd ser. vol. iii. p. 253.

‡ Descr. New Sp. *Crinoidea*, Prelim. Notice, Albany, 1861, p. 18; also, 20th Rep. State Cabinet N. Y. 1867, p. 295.

§ See *Note*, p. 310. || *Ibid.* pl. 9. fig. 10. ¶ Pal. Illinois, vol. ii. p. 295.

any of the interambulacral plates *on the underside* of the test, except on the marginal plates bordering the ambulacra. If we accept this statement, founded on imperfect specimens, as given by the latter authors, it must be borne in mind that *Perischodomus* has primary tubercles only on the marginal interambulacral plates; so, presuming for one moment that that genus is ultimately proved to possess imbricating plates, the two genera, *Lepidechinus* and *Perischodomus*, may perhaps be considered identical.

Lepidechinus has hitherto been found only in America, in the Chemung (Devonian) and Burlington-Limestone (sub-Carboniferous) groups.

Genus Eocidaris, Desor, 1858*.

Ambulacra composed of a double series of plates, perforated near their outer extremities by two small pores; interambulacra of five or more rows of plates, those bordering the ambulacra, as in the other genera, pentagonal, the remainder hexagonal, some of the rows of which become obsolete before reaching the poles; each interambulacral plate carries a primary tubercle, but without the usual miliary ring surrounding it.

The above characters are taken from Prof. Hall's emended description †; and from them it appears tolerably certain that this genus did not possess imbricating plates, but is distinguished from the other palæozoic genera by the absence of the ring surrounding the primary tubercles, and the decrease in the number of the rows of interambulacral plates towards the poles.

Eocidaris occurs in the Devonian, Carboniferous, and Permian formations.

Genus Melonites, D. D. Owen, 1846 ‡. Pl. XXIV. figs. 5 & 6.

Body ovoid, spherical; interambulacral plates hexagonal; ambulacral plates of two kinds—one elongated hexagonal series composed of two rows in the centre of the ambulacral areæ, elevated into a prominent ridge, giving rise to a furrow on each side at the junction of each row with the second kind of plates, which are smaller, polygonal, ranged in four vertical rows on each side the larger central rows, thus giving to each ambulacrum no less than ten rows of plates; each ambulacral plate perforated by a pair of pores, which, in the smaller polygonal plates, are said by Owen to be central, whereas, in the larger hexagonal plates, they are placed on one side, that furthest from the central ridge.

In *Melonites* we find a still further departure from the regular Echinid type, in the great development of the rows of plates in the ambulacral areæ, five times as many as those seen in *Calveria*, *Palæchinus*, or *Archæocidaris*. The apical disk in this genus presents some peculiarities worthy of notice. Both ocular and genital plates are present, as usual; but in some cases the former are without any

* Synopsis des Echinides, p. 155.
† 20th Report State Cab. New York, 1867, p. 297.
‡ American Journal, 1846, 2nd ser. vol. ii. pp. 225 *et seq.*

trace of pores, at other times a single pore may be present in two of them. The genital plates vary even more than the oculars; for in some instances three of the plates are pierced by four pores, the other two by five; again, three of the plates may carry four pores, and the other two plates three pores only*, showing how great may be the variation in this respect amongst individuals of this genus.

Genus OLIGOPORUS, Meek & Worthen, 1860†. Pl. XXIV. fig. 4.

In the size and arrangement of the plates composing its ambulacral and interambulacral areæ *Oligoporus* agrees very closely with *Melonites*, but differs from it in possessing only four rows of plates and four double rows of pores in each ambulacrum, in the place of ten. The ambulacra are deeply and doubly furrowed.

Oligoporus appears to be intermediate between *Melonites* and *Palæchinus*, possessing half the number of ambulacral plates and pores of the former, and double the number of the latter. It also agrees with the former in the deeply furrowed nature of the ambulacra‡.

Confined to Carboniferous rocks.

In the foregoing remarks some of the more general characters of the various genera have been touched upon. I have now to notice a few deductions to be drawn from them.

1. We have seen that the group *Perischoechinidæ* was established by M'Coy for the reception of those palæozoic Echini with more than two rows of plates in each interambulacrum,—a character common to all the genera previously noticed, and thereby distinguishing them from Recent and Secondary forms.

2. Certain members of the *Perischoechinidæ* possessed overlapping plates, both in the ambulacra and interambulacra, in one at least, *Lepidechinus*, on a plan similar to that seen in the recent genus *Calveria*.

3. We have no conclusive evidence of the presence of membranous interspaces in conjunction with the overlapping plates as in the *Echinothuridæ*; but the fragmentary condition in which the remains of *Archæocidaris* are usually found would lead us to the conclusion that such did exist.

4. There does not appear to have been any palæozoic genus, so far as our present knowledge goes, which exhibits the peculiar want of distinction between ambulacra and interambulacra on the ventral half of the test seen in the genus *Phormosoma*.

5. In two closely allied genera, *Melonites* and *Oligoporus*, we find an increase in the number of rows of plates in each of the ambulacra, similar to that which takes place in the interambulacra throughout the whole group.

6. Lastly, the *Perischoechinidæ* differ from recent and later Echini in an increase in the number of perforations of the ocular and genital

* Pal. Illinois, vol. ii. p. 228.

† Proc. Acad. Nat. Sciences Philad. 1860, p. 474.

‡ Pal. Illinois, vol. ii. p. 249.

plates of the apical disk: in *Palæchinus* the ocular plates are doubly perforated, the genital plates triply so; in *Melonites* the perforations appear to vary in different individuals.

In conclusion, it will be obvious that the diagnosis of the *Perischoechinidæ* must be so far modified as to include the characters of the overlapping plates of *Lepidechinus* and *Archæocidaris*, and the increase in the number of the rows of plates in the ambulacra of *Melonites* and *Oligoporus*.

It has also been pointed out that Mr. Baily has discovered primary tubercles in *Palæchinus*; how far this will affect M'Coy's division of the *Perischoechinidæ* into two families, based on the presence or absence of primary tubercles, will very much depend on the characters of these structures in some of the other genera mentioned.

[Since these remarks were written I have seen the description of another genus of this group, *Lepidesthes*, Meek & Worthen, in the 3rd vol. of their admirable 'Illinois Survey Report,' p. 522. Here the interambulacra were composed of plates imbricating from below upwards and outwards from the middle; the ambulacra were composed of ten rows of small pieces imbricating from above downwards, with two nearly central pores to each piece. The whole surface appears to have been ornamented with small granules, probably for the articulation of small spines. *Lepidesthes*, in the mode of imbrication of its plates, agrees with *Lepidechinus*, Hall, as now understood, but differs in the relative breadth of the ambulacra and interambulacra. In the presence of ten rows of plates in the former, it agrees with *Melonites*, but differs in their imbricating character. Messrs. Meek and Worthen remark that this peculiar imbrication of the plates will probably "be found to be of even more than generic importance."]

EXPLANATION OF PLATE XXIV.

Fig. 1. *Archæocidaris*, interambulacral plates, from drawings kindly supplied by Mr. J. Young, F.G.S.: *a*, bevelled edges.

2. *Palæchinus*, portion of an ambulacrum, and the bordering interambulacral plates, enlarged. (From Prof. M'Coy's figures, 'Synop. Carb. Foss. Ireland,' pl. 24.)

3. *Palæchinus*, apical disk, enlarged: *a*, genital plates, with triple perforations; *b*, ocular plates, with dual perforations. (From Mr. Baily's figure in a paper read before Roy. Geol. Soc. Ireland, March 9, 1864.)

4. *Oligoporus*, portion of an ambulacrum and bordering interambulacral plates. (After Meek & Worthen's figure, 'Illinois Geol. Rep.' ii. p. 248, fig. 28.)

5. *Melonites*, similar figure to last. (*L. c.* fig. 27.)

6. ——, apical disk: *a*, genital plates, with pores; *b*, ocular plates, without pores. (*L. c.* p. 228, fig. 22.)

7. Oral disk and teeth of a recent *Cidaris*: *a*, the five ambulacral segments, with notched and perforated plates. (From Mr. S. P. Woodward's figure, 'Geologist,' 1863, pl. 18.)

DISCUSSION.

Mr. ETHERIDGE described *Calveria* as resembling an elastic ball rather than an ordinary Sea-urchin, its calcareous plates being held in place by a flexible membrane—and as connecting the ordinary forms with *Echinothuria*, in which the plates slide over one another like armour. He remarked that the apical disks vary in each genus; in the palæozoic genera the ovarian plates have three or more and the ocular plates two perforations. The interambulacral areas in the palæozoic genera have invariably more than two rows of plates. In *Archæocidaris* the plates have bevelled edges. The chief point of the paper was its indicating that a type supposed to have been long extinct is still represented in our seas.

Mr. Seeley observed that the buccal membrane in the recent Echinoidea has overlapping plates, so that if the development of the plates usually forming the remainder of the test were arrested, forms would be obtained approaching those described in the paper. He stated that in his opinion both the Echinoderm-type and the Brachiopod-type have analogies with the Annelids, which are supported by a comparison of the multiplied poriform zones of *Melonites* with the perforated shells of Terebratula; this he thought indicative of a far-off affinity between these types.

Mr. H. Woodward stated that the author of the paper had done much towards the investigation of the Carboniferous fossils of Scotland. He had detected in the Carboniferous rocks undoubted spicules of *Synapta* and *Chirodota*, showing that the soft-bodied Echinoderms were in existence at the period of their deposition. Mr. Woodward further remarked that of the Holothuridæ some forms, such as *Psolus*, are protected by calcareous plates having perfect freedom of motion.

Mr. Gwyn Jeffreys stated that *Calveria hystrix* was dredged off the Faroe Islands, and subsequently in the Bay of Biscay. He remarked that many missing links will probably be found hereafter, and that nomenclature will be benefited thereby; thus, if *Echinothuria* and *Calveria* really belong to the same genus, one of these names may be discarded. In support of this view he stated that the palæozoic *Euomphalus* is identical, as regards the characters of the shell, with the recent *Homalogyra*. It is very desirable that zoologists and palæontologists should employ the same names.

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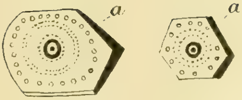

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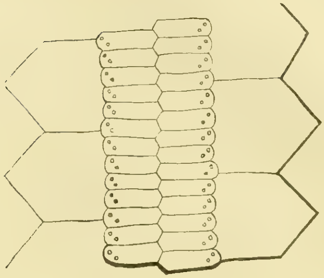

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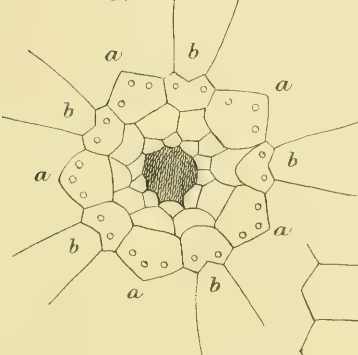

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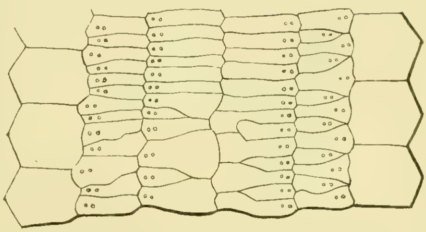

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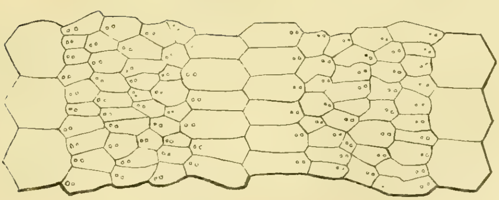

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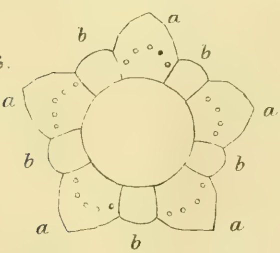

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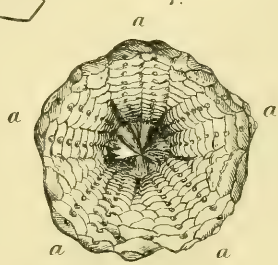

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PERISCHOECHINIDÆ.

26. *On the* Last Stage *of the* Glacial Period *in* North Britain.

By T. F. Jamieson, Esq., F.G.S. (Read May 27, 1874.)

Contents.

§ 1. *Introductory.*

In Scotland we seem to have at least three well-defined stages in the history of the Glacial period, viz. :—1st, the great early glaciation by land ice; 2nd, the period represented by the glacial marine beds, containing remains of arctic mollusca, when much of the country was covered by the sea; and, 3rd, what I shall call the time of the later glaciers. It is to the history of this last part that the following pages are chiefly devoted.

During the first stage glacial conditions seem to have attained their maximum, and the whole of Scotland appears to have been covered for a long time with snow and thick ice, as North Greenland is at the present day. An opinion has occasionally been expressed that it was the polar ice which at this time spread in a continuous mass from the arctic circle over a considerable part of the northern hemisphere, covering much of the north of Europe as well as most of Britain. I cannot say that I have met with evidence of a mass of glacier-ice from the polar regions having moved over the district with which I am acquainted. On the contrary, there are facts which seem to me inconsistent with such a notion. One of these is the occurrence of extensive beds of chalk-flints along the crest of a range of low hills running for six or seven miles inland from Peterhead.

These beds of loose flint pebbles, lying, as they do, on the very top of a range of bare exposed hills at altitudes of from 250 to 370 feet, must have inevitably been swept off by a great mass of glacier-ice moving over them from any quarter. It is true they have been carried away here and there, and cut off abruptly in certain directions, as if by the glacier-ice of the adjoining district; but for a distance of several miles they lie thickly along the very top of the ridge. Their quantity, and the extent of ground they cover, forbid us from supposing that they have been drifted from some foreign region; but assuming that they are native to the locality, it may still be said that they were not in the state of loose pebbles at the time of the ice, but may have been imbedded in strata of solid chalk, which have since been dissolved. This, however, I consider a very improbable supposition.

This ridge, although it attains the altitude of only a few hundred feet, is, nevertheless, higher than any ground immediately to the north of it; in fact it may be said to be nearly open sea between it and the North Pole.

Ever since I visited the district of Lochaber and the Parallel Roads of Glenroy in 1861–62 I have inclined to the belief that there must have been a great development of snow and ice in this country after the submergence, or second stage of the Glacial period; and an examination of the glens around Ben Nevis impressed me at that time with the belief that the glacier, and *not* the sea, was the last occupant of the surface. It also seemed to me that the recurrence of severe glacial conditions on the land after it emerged would explain many facts otherwise very difficult to account for. In subsequently examining various parts of Scotland I have kept this point specially in view; and the result has been to force upon me the conviction that the development of snow and ice during this third stage of the Glacial period must have been far greater than most geologists suppose.

§ 2. *General Features of the Surface.*

The general features of the country, even in the lower districts, do not appear to me to correspond with the notion that since the sea retired nothing but the ordinary action of the elements has modified the surface. In such a case I should expect to find level sheets of gravel, sand, and silt, containing some remains of marine fossils in a more or less perfect state; also zones of beach-pebbles mixed with some littoral shells, and deposits of a similar nature capping eminences that had been in shoal water; and, in particular, I should look for traces of estuary mud along the curves of the wider valleys, where the tide and the river had formerly met. Now in Scotland, so far as I am aware, we have absolutely no trace of any such estuary beds containing remains of animals peculiar to places of the sort, except at levels below thirty feet, and which belong, as I have elsewhere shown, to a more recent period, when glacial conditions had passed away, the shells indicating a climate rather warmer than at present. How could the glacial sea have gradually retired, or, rather, how could the land have gradually emerged, without some tidal sediment being left here and there along the valleys where a pause in the change of level took place? It is true some have thought they have discovered traces of ancient sea-margins in certain more or less horizontal banks and terraces, which, however, admit of a different explanation; but no one, so far as I remember, has been able to point out any estuary beds, containing estuary fossils, along the valleys at high levels. Why, also, should we not see some more distinct lines of old sea-cliff and sea-caves at higher altitudes, and likewise some heavy masses of blown sand and shells, like what we find on the coast at present? The beds of glacial marine clay and sand have been destroyed along the valleys to an extent inexplicable on the supposition that the sea gradually retired and nothing but ordinary subaerial action followed. In certain low districts, where this clay has nearly all disappeared, patches of it are left on eminences and places just where we might suppose it most likely to have escaped the action of glaciers; and at the mouth of some valleys (as, for example, that of the Dee at Aberdeen) we find masses of it which seem to be the denuded remains of beds that some powerful agency has swept clean out of all the rest of the valley. And some of these beds appear to have been dislodged from their original position and thrust out seawards in a confused mass, as in the banks near the Aberdeen lighthouse and powder-magazine —a result such as we might suppose would follow from a glacier moving down the valley over the beds of clay and sand, wasting them gradually beneath it, and forcing them partly before it.

Now let us consider what would be the effect of a glacier extending itself over beds of sand and clay such as had been deposited during the submergence of the country. The advance of the ice over this old sea-bottom would either destroy the marine beds, by pushing them before it and wasting them beneath it (the water flowing from the end of the glacier contributing to the effect), or it would move over them without entirely destroying them. Much would depend upon the weight of ice, its duration, the slope of the country, and also the depth and firmness of the marine strata.

Where the glacier was thick and the valley narrow and steep, the marine beds would probably be entirely cleared out. The glacier would push them bodily before it; and where it did slide over them, the pressure of the ice would work up the clay and sand into a liquid mud, which would be continually carried off by the water escaping from beneath the ice; so that the wasting of the mass would go on rapidly, and result in its entire destruction, leaving only the stones and washed gravel in front of the glacier. But where the glacier was not very thick, and the marine strata of considerable depth and firmness, I imagine the ice might slide over such a deposit without entirely destroying it. The effect would probably be to compress and wrinkle it to some degree, and to work the upper portion of it into an unstratified paste or mud mixed with stones. This would result from the grinding pressure of the ice and the want of good drainage for the water beneath it; for unless there was a current of water to carry off the mud, the material would remain beneath the glacier, although a part would no doubt be continually carried forward by adhering to its sole and travelling on along with it. The pressure of the ice pushing into beds of stratified clay and sand would, in some cases, displace them, and wrinkle them into folds, thus giving rise to beds of contorted drift.

The unstratified, unfossiliferous mass of pebbly clay which occupies so much of the surface, and is occasionally seen overlying marine beds containing arctic shells, may have been formed in the way above described. It occurs in many parts of Scotland, and has got the name of upper drift or upper boulder-clay. Much of what has been occasionally described as the upper covering of gravel and boulders I believe to be also a result of the action of the later glaciers. When these upper beds consist of marine deposits ground into mud by the action of the ice, it is evident that bits of broken shells may occasionally be found in them.

Mr. Trimmer, who devoted much attention to the superficial accumulations of England, and sought to explain them chiefly by the action of the sea and floating ice, was yet unable to overlook the remarkable fact that there is a general absence of marine remains, and of regular beds of these remains, in what he termed the Upper Erratics, not only in Norfolk, which he had specially studied, but also in every district of England, Wales, and Ireland he had examined *.

§ 3. *Disappearance of the Marine Beds.*

The general disappearance of the glacial marine beds over most of Scotland is a fact difficult to explain, except upon the supposition that there was a subsequent occupation of the ground by glaciers. The amount of submergence is on this account very difficult to determine; for the evidence of the sea's presence has been destroyed. Several geologists, influenced no doubt by the discoveries in Wales, have supposed, and perhaps rightly, that the submergence reached to a great amount, and that the former coast-line must at one time have been 2000 feet above the present, or even more. But when we ask for proof we get little that is satisfactory, the presence of far-travelled boulders at great heights being almost the only fact of any value; and this may admit of explanation by the agency of land-ice. Supposing, however, that the submergence was much less, and reached no higher than say 500 feet (which no one, I imagine, will consider an overestimate), we ought to find marine beds far more widely spread than we do. For with the exception of some of the flatter ground along the east coast, away from the mountains, and here and there over the Scottish coal-field, beds containing marine arctic fossils are unknown. As a rule, they are absent from all the Highland valleys, even at low levels, and, generally speaking, are not to be met with near hills, and from the country to the west of the Caledonian canal have not been reported at all.

In the Clyde district many shell-beds are known, but generally near the shore, and very little above the present reach of the tide. If we suppose that the glaciers again occupied the surface after the sea withdrew, it will afford a better explanation of the disappearance of the marine beds than any other I can think of. For much of Ireland and England the same hypothesis seems to be required.

In Caithness the area occupied by the dark grey drift containing marine shells probably marks the extent of ground in that quarter which escaped the action of the later glaciers. This area seems to be bounded by the hilly ground which borders the plain of Caithness to the west and south. In the latter direction it stops at the low ridge that divides the water of Dunbeath from Berriedale Glen, into which the grey shelly drift does not enter. Very likely the grey drift may have been cleared out of the lower part of Berriedale by a glacier; for some patches of it occur about the mouth of the

* Quart. Journ. Geol. Soc. vol. vii. p. 24, 1850.

glen, in the cliffs facing the sea. I regret having been prevented from tracing the outline of this peculiar fossiliferous drift of Caithness along all its western boundary; for features of interest will no doubt present themselves where the ice from the hilly ground came down upon it.

From Berriedale to Inverness, all along the eastern border of Sutherland and Ross, the later glaciers seem everywhere to have come down in great force to the present coast-line. At Ardersier, near Fort George, I came upon a small patch, a few yards in extent, of grey clay, containing arctic sea-shells. It was buried underneath, or enveloped in, a brownish unfossiliferous mass of gravel and silt, and seemed to be a remnant of some bed that had been destroyed by the action of the later glaciers. Its occurrence, however, interested me much, by showing that glacial marine deposits had once existed in that neighbourhood. Although no marine fossils were got in the cuttings for the Caledonian Canal, it is worthy of note that they have now been discovered near Fort William and Fort George, at both extremities of the great glen.

Glacial clays containing marine fossils of arctic type are scarcely known along the borders of the Moray Firth. Dr. Gordon, of Birnie, tells me the only instances he is aware of are this one at Ardersier and another at Burghead. In the interior of Nairn and Elgin they have not been found.

I met with them, however, some distance to the east of Speymouth, between Cullen and Banff, where the sea-cliffs here and there show deep masses of dark bluish clay, in which remains of arctic shells may occasionally be detected. Further eastward, at Gamrie, they again present themselves, but only to a very limited extent, having apparently been swept out of the little ravines by small glaciers descending from the neighbouring heights. Without this hypothesis it is difficult to account for the patchy manner in which these marine beds have been left there.

In the island of Arran, as has been shown by the Rev. Mr. Watson and Dr. Bryce, we have evidence of submergence to the amount of some hundreds of feet above the present sea-level; but the marine beds have all disappeared from the mountainous part of the island, and even in the lower southern extremity they have been wellnigh destroyed and overwhelmed beneath heavy masses of sand, mud and boulders—the work, as I suppose, of the later glaciers.

Long ago Dr. Scouler pointed out that certain ravines near Dublin had apparently been formed after the deposition of the shelly gravel of that district, from the fact that they are completely destitute of any vestige of this marine gravel, although it ascends to higher levels in the neighbourhood. But he was at a loss to understand on what principle of selection one set of hollows had become receptacles of this shelly drift while others had escaped (Journ. of Geol. Soc. of Dublin, vol. i. p. 266). Afterwards Mr. Oldham, in 1848, in examining this locality and confirming Dr. Scouler's observations, was struck with the same remarkable fact, that several of the glens in Wicklow contain no trace of marine beds, although shelly gravels surround them on all sides and ascend to much higher elevations; and he further states that the great boulder deposit of Wicklow is perfectly distinct from, and in all cases *subsequent to*, these marine beds (*ibid.* vol. iii. p. 302).

Mr. Darwin was the first to perceive the true meaning of such facts. After studying the similar phenomena of Wales, he pointed out, in 1842, the evidence they afford of the advance of glaciers subsequent to the deposition of the marine beds, showing that when the land had risen to nearly its present height the ice filled some of the valleys near Snowdon, and cleared out the accumulations left in them by the sea. In tracing the phenomena downwards, Mr. Darwin seems to have been unable to say where glacier-action ended and marine action began. Professor Ramsay, who followed up Darwin's observations, and confirmed them by additional details, does not bring his chief Snowdon glacier far down the valley, supposing the lower ground near the sea to be covered with marine drift which the later glaciers have not disturbed; and he looks upon the high-lying flats, at elevations of even 2000 and 2300 feet, as terraces of marine formation, marking pauses in the reelevation of the country (Old Glaciers of Wales, pp. 95–102, and map).

Judging from what I know of Scotland, I am inclined to think the later Welsh glaciers must have been far more extensive than these views would indicate, and that the Snowdon one at least must have come down to the Menai Straits. Mr. Symonds has pointed out many facts which imply the action of land-ice and snow, after the land emerged, not only in various parts of Wales, but also in the Malvern Hills.

As illustrating the nature of the climate I suppose to have prevailed during the time of the later glaciers, let me give the following example.

In the northern extremity of Aberdeenshire there is a hill called Mormond, about 800 feet high, which lies a few miles south of the town of Fraserburgh. It rises out of the low surrounding region like a great mole-heap. Many years ago I had found a good deal of evidence in the neighbouring district of the presence of the sea up to heights of nearly 500 feet, and, among other facts, had noted beds of well-rolled shingle forming the crest of certain low hills, at elevations of from 200 to 480 feet, which seemed to me to have been shoals in the sea of that period. In some of these I got remains of arctic shells. I argued, therefore, that if the sea had covered the land to the height of 480 or 500 feet, as it evidently did, it should have encircled this hill of Mormond, and formed a belt of shingle round it at a corresponding height; or if the submergence was sufficient to completely cover the hill, it ought to show a mass of gravel on the top. I accordingly spent two long summer days in the month of June examining the hill, which is a wide-spreading, heath-covered mass, some eight or nine miles in circumference, bare and brown, without a bush or tree upon it. I was disappointed and puzzled to find no rolled shingle anywhere over the whole surface of the hill, neither on the top nor on the sides of it. But along the base and skirts I came upon mounds of gravel which did not form a zone or sheet at any regular level, but were disposed in a manner I could not account for by marine action of any sort. Nowhere did they reach to the height of 400 or even 300 feet; and all the top and sides of the hill seemed completely destitute of marine deposits of any kind—no beds of gravel, shingle, sand, or silt—nothing but the angular stony rubbish of the gneiss, quartz-rock, and granite of which the hill is composed.

Mormond is somewhat of a horseshoe-form, by reason of two spurs or ridges it throws out towards Fraserburgh, which enclose a hollow in the northern bosom of the hill. This hollow contains a bed of peat, below which we find coarse grey mud, like what occurs beneath a glacier, full of stones, several of which are ice-scratched. In front of this hollow, at the distance of a mile or so towards Fraserburgh, there is a transverse ridge of gravelly débris (somewhat like a kaim), called the Sinclair Hills, the base of which is not more than 50 feet above the sea. The explanation of the matter I take to be as follows:—This hill was no doubt encircled by the sea, or may have been completely under it during the time of the submergence; but after the waters withdrew, it appears to have been covered by snow and ice, which obliterated all trace of the sea's presence, and carried down the gravelly débris to its outer edge to form the mounds we now see along the base of the hill. The hollow in its northern face was probably occupied by a glacier which stretched further out, the ridge of the Sinclair Hills marking its former termination. Some of this gravel may have been originally of marine formation, and afterwards remodelled by the glacier and by the water flowing from it. In the north-eastern part of Aberdeenshire I find traces of heavy snow beds, or small glaciers of the second order, on the flanks of hills even lower than Mormond; but in most districts these low hills have been overrun by ice from the interior of the country.

§ 4. *Moraines at Low Levels.*

One of the proofs that the glacier and not the sea has been the last occupant of the surface is the occurrence of well-preserved moraines at low levels. Now the goodness of the evidence here depends, first, upon the certainty that the masses in question are really moraines, and, secondly, upon the assurance that they have never been covered by the sea since they were formed. Differences of opinion will, no doubt, exist for some time in regard to both of these points.

When Agassiz visited Dr. Fleming at Aberdeen, in 1840, he was shown some ridges of gravel near the coast, a little to the north of that city, and pronounced them to be moraines. Fleming dissented from this opinion, on the ground that they were of more recent origin than the beds of fine clay beside them, which contain arctic shells. I think Agassiz was right as to the mounds being moraines, and that Fleming was also right, that they were a more recent deposit than the clay containing the shells. They imply, in my opinion, that the glaciers of the Dee and Don coalesced and reached the coast after the period of submergence—the left flank of the ice lying upon Belhelvie, and the right flank on the hills of Nigg. Assuming that these mounds at Aberdeen are actually moraines of the later glaciers, we ought to be able, on proceeding up the valley of the Dee, to point out the various halting-places of the glacier as it gradually retreated to the mountains. This, I think, can be done. Ten miles up the valley of the Dee we find indications of a halt, a crescent-like band of moraine-matter curving out from the base of the Hill of Fare to the Loch of Drum. At Aboyne (20 miles further up) there are indications of another halt. But the longest and most decided pause has been a little below the village of Ballater, about 40 miles from Aberdeen and 600 feet above the sea. Here there is a great assemblage of mounds on both sides of the river. On the north side they commence at the base of the hill immediately below the Pass of Ballater, and extend eastward past Tullich to Culbleen, where they cover all the ground between the river and the base of the hill, forming a great mass of hillocks and tumuli of various forms. To the eastward of Tullich they reach an elevation of about 400 feet above the river, their upper surface forming a nearly horizontal line or platform, which, however, is not quite horizontal, but slopes slightly to the eastward or down the valley. These moraine-heaps fill all the curve of the hills between Camus o' May and Tullich. The flank of the hill of Culbleen is much bared, and dotted with perched boulders. Here may be seen split blocks of red granite, which may have been broken by tumbling off the end or side of the glacier.

On the south side of the valley, along the base of Pannanich Hill, the higher part of the moraine does not take the shape of hillocks so much as it does on the north side, but forms a great bank leaning against the hill-side, like a rude platform or terrace, strewed with granite boulders, and corresponding in height with the upper level of the moraine on the opposite side of the valley. The granite of the spur of the hill to the east of Pannanich Wells is bare, and dotted with perched blocks, of which there are some fine examples. The rock itself is rounded off into pillowy masses, which are more rugged on their eastern outline; these appearances extend far above the level of the highest moraines. The granite, however, is too much weathered to show the finer glacial markings; and the same remark applies to most of the granite on Deeside. The great sheet of gravel which covers the moor of Dinnet for some miles to the east of Camus o' May has probably been spread out by the waters pouring from the end of the glacier, and issuing from beneath it, aided by occasional floods when the snow and ice thawed extensively.

Other moraines of later origin than this one below Ballater are to be found in the upper branches of the Dee—as, for example, in Glen Lui, near Derry Lodge, at an altitude of about 1600 feet, and still higher up, near the top of Glen Derry, not far from Loch Etichan, at the base of Ben Muick Dhui, probably 2000 feet above the sea. These mark the last stages of the glacier. Corresponding moraines occur in Glen Dee and in the ravines on the north side of the Cairngorm mountains.

That the glacier of the Dee actually did come far down the valley after the land emerged is also shown by a remarkably fine series of terminal moraines in the valley of the Feugh, which is a tributary of the Dee. These moraines occur at levels of 300 and 400 feet. They appear to be perfectly undisturbed, and, so far as I can judge, have never been touched by the sea since they were formed. Occurring as they do at these low levels, they afford good evidence of the advance made by the later glaciers. The Feugh takes its rise at the foot of Mount Battock (2555 feet), and, after a course of about fifteen miles, falls into the south side of the river Dee, at the village of Banchory, which is eighteen miles from Aberdeen and 150 feet above the sea. On walking up the valley of the Feugh for about a couple of miles we meet with a moraine at a place called Gellan, on the south side of the stream. This moraine must have been formed by the glacier of the Feugh after it had been joined by those of its two tributaries, the Avon and the Dye. The moraine here comes down below the level of 300 feet; and the glacier, at the time of its formation, was about thirteen miles long. Proceeding two miles further up the valley, immediately after passing the mouth of the Dye, we come to a fine moraine at a level of about 300 feet, which must have been formed by the united glaciers of the Feugh and the Avon, when the ice-stream was ten or twelve miles in length. The great size of this moraine marks a very long pause of the glacier here. The quantity of débris is enormous, especially on the south side of the valley, where it forms a range of mounds composed of gravel, sand, and rolled boulders. One of these hillocks, called the Dunimore, is about 120 feet high. In some of these ridges there is a considerable quantity of washed sand, like river-sand; others are composed of blocks and boulders of granite mixed with rough stony débris, while a few consist of a mass of boulders of all sizes up to 3 or 4 feet in length, with a mixture of disintegrated granite. All the material of the moraine on the south side of the valley seems to be derived from granite; but on the opposite side, at Whitestones, much of it consists of gneiss and crystalline schist. This accords with the distribution of the rocks, which are all granite on the south side, but mostly of gneiss on the north. It would seem, therefore, that the débris of the two sides of the valley has been kept from mingling; and this is just what a glacier would do, and not what we should expect had these mounds been heaped together by the sea. In the centre of the valley, which is here very flat, the moraine has been swept away. The river Avon, which joins the Feugh a little above this, is a small stream that also rises at the foot of Mount Battock, and flows along a deep, narrow lonely glen, or gorge, between Clochnaben (1944 feet) and Peter Hill (2023 feet). There is a fine little moraine just outside the entrance to the gorge, at an altitude of about 440 feet above the sea, forming a characteristic crescent-shaped ridge, dotted over with large granite boulders. There it lies, clear as a sunbeam, just as the glacier left it. I walked up the glen a good long way above this, until I was near the foot of Mount Battock, but observed no other moraines, which would seem to show that the glacier must have shrunk rapidly above this. Here, therefore, as in Lochaber, the glaciers seem to have retreated by stages, pausing for a long time at certain places and retiring rapidly at others. There seems to be a corresponding moraine on the Feugh, near Finzean; and I have no doubt others will be found in Glen Dye, which, however, I had not time to explore.

Terminal moraines (at least what I suppose to be so) also occur on the south side of the Grampians, in localities which imply very intense glacial conditions. Thus in Kincardineshire I observed one at Drumlithie, near the railway station there, at an altitude of 280 or 300 feet above the sea, formed apparently by the glacier of the Bervie, a small stream which takes its rise among hills of from 1500 to 1700 feet in height. When this moraine was formed, the glacier was seven or eight miles long. This moraine, I believe, is locally known as the Kaims of Candy, and seems to resemble the kaims of the south of Scotland, many of which have been described by Mr. Milne-Home, Professor Geikie, and others, and are supposed by them to be accumulations formed underneath the sea by the action of conflicting currents or tides. This kaim at Drumlithie, however, appears to me to be a terminal moraine. It consists of a long narrow mound, or series of mounds, from 20 to 30 feet high, with sides sloping at angles of 20° to 30°, curving in a crescent- or horseshoe-form, with the convexity seawards. So far as I could make out, it is composed of coarse gravelly débris, irregularly piled together. These mounds are most sharply defined at their north-eastern extremity. Outside them (*i. e.* seawards) there are traces of lower and more gently sloping mounds, all under cultivation. A narrow steep-sided mound like this, over which one can easily pitch a stone, curving along for more than a mile in a crooked manner, is not, I think, an accumulation which conflicting tides or currents would make. The action of the sea would rather level such a mound than make it. However, I shall touch upon the subject of the Kaims and Eskers further on.

In the north and west Highlands, where the mountains come near the coast, moraines of a more decided character are often to be seen close beside the sea. Those at Brora, for example, on the east coast of Sutherlandshire, are very striking, and have attracted the attention of many observers. I examined another very good example near Muir of Ord, about ten miles west of Inverness, formed apparently by the right flank of a glacier descending Glen Orrin. Along both sides of the Dornoch Firth I noticed moraine-like masses, which implied that the glacier had come well down the Firth there. The great range of gravel ridges and boulders which runs from Culloden Moor to Kildrummy*, near Nairn, consists, in my opinion,

* *Kildrummy* is a Gaelic word, and probably means the head or end of the ridge, which is very descriptive of the place.

of moraines, and shows that the later glaciers which filled the valley of the Caledonian Canal and the neighbouring glens to the westward reached the head of the Moray Firth.

Many of the moraines that attracted the attention of Agassiz in 1840 were at low levels. The most distinct and well-marked of all he saw in the British Islands were, he tells us, near Florence Court (the seat of Lord Enniskillen), in Ireland. He also mentions as good examples those on the banks of Loch Awe and Loch Etive, especially near Bunaw Ferry; all these must have been formed by the later glaciers. Buckland also pointed out a number in Scotland and England which indicate a very great advance of the ice. Dr. Hooker, in a communication to the 'Reader,' in 1865, mentioned that in the upper valley of the Tees there are huge moraines, as well developed and as clearly marked as any in the Alps or Himalayas, and that the glacier determined precisely the present course of the river and its windings. I am therefore inclined to believe that not only in the north of Scotland, but also in Ireland and much of England, the glacier, and not the sea, has been the last occupant of the surface, and that many of its peculiar features, such as the kaims, eskers, gravel terraces, and unfossiliferous upper drift, will have to be referred to the action of glaciers and freshwater currents. The valley-gravel is well explained by supposing it to have been formed during the gradual and final retreat of the glaciers; and the remarkable absence of the bones of elephants and other large quadrupeds which occur so frequently in the south of England and France is no doubt due to the later occupation of the northern regions by snow and ice.

A great many of the land-locked hollows along the bottom of hills, now occupied by peat-mosses, probably indicate the position of the last beds of snow and ice which lingered there before they finally vanished.

In places where the glaciers did not reach there were probably heavy beds of snow, which would be partly converted into ice at the bottom. These would exert a modifying influence on the surface, and also affect the drainage of the localities they occupied.

Mr. Kinahan reports a well-marked terminal moraine at a height of only 140 feet above the present sea-level, near Bantry Bay, in the extreme south-west of Ireland—a district which enjoys the mildest winter temperature in the British Islands. This moraine, he says, could never have been under water, or it would have been washed out of shape (Proc. Geol. Soc. Dublin, March 14, 1866). Facts like these have not been sufficiently weighed; for if glaciers came down to within 140 feet of the sea at Bantry Bay, what must have been their development in the northern parts of Britain?

§ 5. *Freshness of the Glacial Markings.*

The freshness of the glacial markings on the bare top of many a hill, in localities which betoken an immense development of ice, affords another argument in favour of a late extension of the glaciers;

for we can scarcely suppose that these markings would have stood the action of the weather so long as they must have done had they been imprinted in the period before the submergence. The length of time that has elapsed since then must be enormous; and yet on some hills of 2000 feet, the summits still exhibit the ice-worn surfaces left by the glaciers which overflowed them from the central heights. As no covering of earth or turf seems ever to have protected them from the weather, it is difficult to conceive how they could have escaped destruction so long had they existed before the time of the submergence.

§ 6. *Kaims, Eskers, &c.*

Many of the narrow, steep-sided, curving ridges of gravel, known in Scotland by the name of Kaims*, and in Ireland as Eskers, I believe to be deposits formed along the margin of the later glaciers. The fact of these gravel-ridges being composed of water-worn materials, often stratified, although generally in confused, irregular beds, has induced most people to think that glaciers could have nothing to do with them; and British geologists generally refer them to the agency of marine currents. But in an ice-covered country where precipices and high rocky escarpments seldom occur, and where the hills are comparatively low with gentle slopes, the deposits formed along the margin of glaciers will often be of a gravelly nature, abounding in beds of sand and rolled pebbles having a sort of stratified arrangement. Such is the case in many of the old moraines of the Vosges. A great deal of water escapes from the end of glaciers and pours off their surface during certain seasons; and a glacier many miles in length, when the snows are melting, will abound in streams of running water, which will carry along much gravel and fine sand and produce deposits of irregularly stratified stuff along the sides and at the end of the glacier.

In order to have moraines of rough rocky débris abounding in great angular blocks such as occur in alpine districts, there must be the necessary conditions, viz. alpine heights and rocky cliffs bordering the glacier. Where these occur in Scotland moraines are found of the usual alpine character; but in a region of low undulating hills it would be vain to look for such. I have no doubt the same explanation will apply to many of the Irish eskers. Assuming masses of glacier ice to have covered the mountains of Ireland and also to have occupied part of the central plain of that country, what kind of deposits might be expected to form along their margin, as they gradually melted away? Something very different no doubt from the usual character of alpine moraines. At certain seasons there would be great streams of water running along the margin of

* The word *Kaim* is in Scotland generally applied to a narrow steep-sided mound. Some derive the term from the fancied resemblance to a cock's *comb*; others suppose it to come from the Gaelic word *cam*, crooked, being often applied to a crooked or curving hill (see Dr. Jamieson's 'Scottish Dictionary'). Mr. Campbell, of Islay, derives it from *Ceum*, a path.

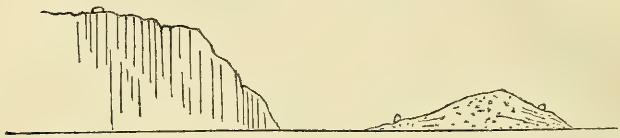
the ice, and pouring off its surface, when the winter covering of snow thawed rapidly. And when the glaciers of the Clyde valley were retreating to the high grounds of Lanarkshire, what sort of deposits might be expected to form in front of them at the time they were pausing near Carnwath or Carstairs? Would they not be something like the Kaims which Mr. Geikie has described as occurring there?

It is not to be supposed that all the ice which gathered over the central plain of Ireland and other low regions of a like nature proceeded from the hills, although glaciers descending from the mountains would, of course, contribute their proportion. For if a great thickness of snow fell, year after year, over the whole surface of the country, and lay there without melting, the bottom layers would be gradually converted into ice, the thickness of which would depend upon the depth of the superincumbent snow. In course of time, as the weight of the mass increased, motion would commence by the ice yielding in the direction of least resistance. The pressure in certain places being unequal, the ice would move (very slowly, no doubt) towards the quarter where the pressure was weakest. This, it is likely, would in most cases be the seaward opening of the chief valleys; and motion having once begun there, would be gradually propagated into the interior of the country.

I have remarked that these Kaims often lie across valleys in long sinuous lines, forming curves or segments of a circle, the concavity of which is presented to the head of the valley, and their convexity towards the sea or downward end, as in terminal moraines. Such would seem to be the case with some of those in the south of Scotland. For example, in the statistical account of the parish of Greenlaw, in Berwickshire, the writer makes mention of certain gravel ridges or Kaims, which he says are "*disposed like a horseshoe, with the hollow towards the hills.*" Some of the most notable Irish Eskers lie in lines across the vale of the Shannon, as, for example, those between Athlone and Parsonstown. Another sweeps round the northern extremity of the Slieve Bloom mountains; and Sir Richard Griffiths tells us of a large one called the Horseshoe, from its peculiar shape. These linear ridges of gravel seem to be most developed in low districts away from the mountains. In such localities the ice, being unconfined by hills, would spread out into a wide cake or sheet. The time of their formation appears to have been at the close of the glacial period, not during the submergence, but after it, when the icy masses had begun their final retreat. The material they consist of and its mode of arrangement point to streams of water flowing over the surface of the glaciers, and washing the gravelly débris into heaps along their margins. A mass of gravel reposing against the side or end of a glacier would lose its support when the ice melted away, and, falling down in a slope, would assume the form of a steep-sided mound. Glaciers are subject to oscillations, sometimes advancing, sometimes receding, according to the varying nature of the seasons. Suppose the end of a glacier to push forward into a sheet of gravel lying in front, the result would be to force it up into a mound all along the edge of the ice (see figs. 1 & 2).

Fig. 1.—*Terminal slope of a glacier, with gravelly débris resting against it.*

Fig. 2.—*Retreating glacier, leaving a Kaim or Esker.*



M. Collomb mentions that the frontal slope of terminal moraines is generally steeper than that of the other side. In the old moraines of the Vosges this is constantly the case, the frontal slope sometimes amounting to an angle of 35°. Sir Richard Griffith tells us that in the case of the Irish horseshoe Eskers one side generally slopes at an angle of 30° and the other at 10° to 15°.

If the Kaims and Eskers were formed beneath the sea by conflicting tides and currents, how comes it they are so destitute of marine fossils? No satisfactory explanation of this has been given. As most of the Irish ridges are composed of limestone gravel, there would be the less likelihood of the shells being dissolved by the percolation of water. The only shells I ever found in a Kaim were in the parish of Slains in Aberdeenshire. These were old-Crag shells (*Voluta Lamberti* and others), showing, as I conceive, that the formation of the Kaim was long posterior to the time when the mollusca lived which inhabited the shells, and therefore affording no argument that the ridge owed its shape to the action of the sea. The occurrence of these old shells, however, was so far interesting as it showed that, if the gravel of other Kaims had been originally fossiliferous, the shells in them ought not to have all disappeared. The marked absence of marine fossils in the Kaims, Eskers, and upper drift or upper boulder-clay affords a strong presumption that these deposits were not accumulated beneath the sea.

I have also a difficulty in believing that narrow crooked (sometimes even zigzag) ridges of gravel, with their sides sloping at angles of 20° to 30°, would be formed beneath the sea, or at all events could have emerged from it without being thrown down. I should think the materials could not lie at such an angle of repose beneath agitated water, and would have been levelled to some extent as they came under the influence of the waves and breakers. They could not have stood the dash of the water in stormy weather, even in comparatively sheltered places. The material of which these ridges are usually composed is of a loose incoherent nature; and the present slope of their sides is often as steep as what the sand and pebbles can lie at. Now the angle of repose of such stuff in strongly agitated water is much less than it is in air. Long narrow mounds sloping steeply on both sides could not have preserved this form when lashed by the waves and breakers; and I therefore maintain that when the movement of emergence brought them near the surface of the water they would have been levelled to the angle of repose which gravel beaches usually exhibit.

A large iceberg running aground amongst gravel might cause mounds like the Kaims, but this could take place only in water of considerable depth. Heavy packs of ice driven forcibly ashore might perhaps also give rise to similar ridges, although scarcely, I should think, of such great dimensions. But unless the mounds were formed high up on the beach beyond the extreme limit of the tide they would be levelled again by the return of the waves. If formed in this way they should also contain some littoral shells, and their curves ought, as a rule, to present the convex side to the land, and not to the sea. The sea cutting into the face of a bank may no doubt cause a steep slope on one side, but not a narrow crooked ridge, steep on both sides like a railway embankment.

The Swedish *Osar** and the American *Horsebacks* seem to resemble the Kaims and Eskers in their linear character, gravelly composition, steep sides, and want of fossils. Sir Charles Lyell, in his account of the Swedish Osar, says he met with only one instance of shells occurring in them, viz. in the top of a ridge near the Castle of Upsala; but as the species he mentions consist of edible mollusca (mussels, cockles, and periwinkles), there may be a doubt as to whether their presence in this very exceptional instance has not been due to some accidental cause. Agassiz, in his description of the glacial phenomena of Maine, says the *horsebacks* "are unquestionably of a moraine nature, and yet they are not moraines in the ordinary sense of the term." Some of these horsebacks run from north to south; but occasionally they trend from east to west. "This," he says, "is the case where a morainic accumulation of loose materials may have been pushed forward along the margin, in front of an extensive sheet of ice moving southward, and then left unchanged by the subsequent retreat northward of the whole mass. I conceive that such horsebacks running east and west may be compared to terminal moraines, which, as is is well known, owe their origin to oscillations of the front end of a glacier pushing forward a mass of loose materials, thus throwing it up into a transverse ridge, and then melting away to some point further back." (Agassiz in the Atlantic Monthly, Feb. & March, 1867). He makes no mention of any marine fossils occurring in these horseback ridges, and does not seem to think that the sea was concerned in their formation. I may also mention that some of these American ridges occur in the region of

* Under the name of *Osar* it would seem that deposits of more than one kind have been described, perhaps of different ages and various modes of formation.

the freshwater drift of the Western States, where we can scarcely suppose the sea to have operated.

As the later glaciers in Britain and Ireland in many cases must have moved over sand and gravel previously accumulated by the sea, it is evident that their marginal deposits would be influenced by this circumstance; for the gravel and pebbles in front of them might have been originally waterworn by the waves, and some marine shells might thus be occasionally found in them. The occurrence of such remains in a few Eskers I would therefore consider to be no material objection to my mode of accounting for them. In reference to the waterworn and pebbly character which many of these glacial accumulations present, it may be useful to bear in mind that deposits of similar materials are common in Switzerland, and that even the famous blocks of Monthey lie amongst stratified sand and gravel.

§ 7. *Gravel Terraces.*

The terraced banks of sand and gravel that occur along the sides of our Scottish rivers seem to me to have been formed during the close of the glacial period. Some geologists have attributed them to marine action, and have considered them to be ancient sea-margins. I myself, at one time, endeavoured to account for many of these gravel accumulations by the off-rushing action of the sea during movements of upheaval at the time the land was gradually emerging from the sea of the glacial period, which we know covered much of Great Britain. But I have become convinced that this explanation is not the right one, and I now incline to think they are almost all freshwater and glacial deposits.

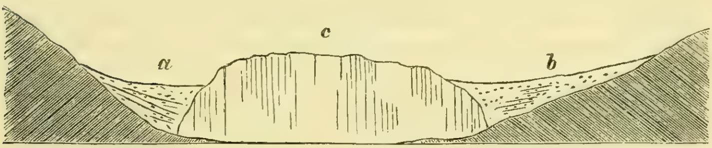
Not a single marine fossil has been found in them. Not a trace of old estuary mud occurs along the higher reaches of our rivers in connexion with them. Now it seems to me that if the sea had occupied a valley after the glaciers finally left it we ought to find some marine fossils and estuary beds here and there along the valley. The absence of all organic remains, terrestrial as well as marine, in these terraces and valley-gravels, agrees better with the supposition that Scotland was at the time covered with snow and ice. Moreover these river-terraces are not horizontal, as they ought to be if they were sea-margins; for as a rule they slope seawards, like the bed of the present rivers *. They occasionally contain large heavy boulders, 3 to 4 feet in diameter or more, and are associated with elongated mounds and confused hillocks of coarse gravel of a more morainic character. I am of opinion, as I have expressed in former papers, that these deposits have been for the most part accumulated during the gradual retreat and melting of the later glaciers. That such terraces and mounds can be formed without the presence of the sea is very well shown by the similar deposits that occur in the valleys of the Pyrenees, the Himalaya, and other mountain-chains in

* For a good account of some Scottish terraces, see a paper on the Old River-terraces of the Earn and Teith, by the Rev. Thos. Brown. Trans. of Royal Society of Edinburgh, vol. xxvi., 1870.

the interior of continents, where we have reason to believe no sea has entered since the glacial period.

I have fancied that some of these terraces may have originated in the following manner. Suppose the channel of one of our Highland rivers to be occupied by a retreating glacier when the climate was gradually growing milder. During warm seasons, when much snow was melting, gravel, sand, and other débris would be washed down the hill-sides and lodge against the flank of the glacier. The rivulets and streams would at such times come down from the neighbouring heights, carrying with them much matter of this sort. At present it all finds its way into the bed of the river; but when the channel was occupied by a glacier this débris would be arrested by the mass of ice and lodge in the depression between the glacier and the hill (fig. 3). This hollow would therefore be gradually filled up and might be traversed at times by streams of water. When the glacier melted, the mass of stuff resting against it would lose its support and fall down in a steep slope, thus giving rise to the terraced banks we now find (fig. 4).

Fig. 3.—*Section of valley with glacier in retreat.*



c. Glacier. *a* & *b.* Gravelly débris lodging between the glacier and the sides of the valley.

Fig. 4.—*Section of valley after disappearance of glacier.*

a, b. Gravel terraces.

It is a mistake, therefore, to refer all these gravel terraces and platforms of stratified material to the action of the sea, as geologists have sometimes done, forgetting that the sea is by no means essential to their formation. The total absence of marine fossils ought to caution us against such hasty inferences. Extensive beds of stratified gravel, sand, and silt seem to have been formed in all countries that were formerly occupied by glaciers.

I conceive that in many of the valleys the bed of the stream might be wholly occupied by ice, the rivers being frozen nearly from top to bottom—and that, on the approach of summer, a great quantity of snow would be melted before the ice in the central trough of the valley broke up, so that heavy floods of turbid water would be let loose over the surface of the frozen rivers and thus rise to great heights along their banks. The thick solid ice occupying the bed of the stream would take longer to melt, but would gradually break up, rising to the surface in great masses, and bringing with it stones and pebbles from the bottom. These masses of ice would float down the stream, dropping the boulders here and there as they dissolved. When the Straits of Dover were dry land and the rivers wandered away down far below the present coast-line, it is probable that during the winter season the Seine, the Somme, the Thames, &c. would be completely frozen along what are now the lower reaches of these rivers, and at the break up of the snow in summer these frozen masses would cause the river-floods to rise to heights which now appear very marvellous.

Mr. Prestwich has discussed this subject in an excellent manner in the 'Philosophical Transactions' for 1864, p. 286; and I would only suggest that he has perhaps not sufficiently allowed for the unmelted ice in the bottom of the valley, forcing the floods to reach a height they could not otherwise do.

The underground ice of Siberia may have been buried in this way by the rivers flooding it and flinging down beds of mud on it before it had time to melt and become detached from the bottom.

§ 8. *Comparative Glaciation of East and West Coasts.*

I have often been struck with the remarkable intensity of the glacial action displayed on the rocks of the west side of Scotland compared with the east, and in a former paper * I threw out the suggestion that the precipitation of snow along the west Highlands had probably much exceeded what fell on the eastern slope of the island, just as takes place now in regard to the rainfall. Thanks to the Meteorological Society of Scotland, we have now accurate data concerning the rain; and Mr. Buchan's excellent papers on the subject show us what an immense excess there is in the quantity that falls on the west side of the country compared with the east. There are several stations in the west Highlands where the annual rainfall exceeds 100 inches, whereas along the east coast it ranges generally from 25 to 30; and it is interesting to note that the glaciation of the rocks corresponds in intensity with the present excess of the rainfall, showing that the precipitation of snow had been similarly distributed; and is it not the case generally that the marks of ancient glaciers are most decided where the rainfall is now heaviest?

The prevailing wind in Scotland is the south-west, which, sweeping up the moisture from the Atlantic, is cooled as it rises over the mountain-tops of the west coast and throws down its burden in copious showers on those hills, so that before it reaches the eastern side of the island it is a comparatively dry wind. This is well seen

* Quart. Journ. Geol. Soc. xix. p. 258, 1863.

along the line of the Caledonian Canal. Fort William (at its south-west extremity) is one of the wettest places in Scotland, while Culloden (at the north-east end) is one of the driest—86 inches of rain falling at the one, to 25 at the other; while in the Glen Quoich, near the summit level of the canal, 102 inches are recorded in the course of a year.

Can we doubt that in the Glacial period a similar inequality must have existed in the fall of snow? and must not the glaciers fed by three times the quantity of snow have been much heavier and more erosive than those in the eastern valleys? Braemar, at the head of the river Dee, in Aberdeenshire, although embosomed among the highest mountains in Scotland, has a rainfall of only 33 inches in the year, while some of the Argyleshire glens have more than a hundred.

The absence of erratic phenomena along the Ural chain and Siberia generally may perhaps be traced to the well-known dryness of the air and lack of snow in that region.

Many of the singular features in the glaciation of the British Islands seem to be due to excessive falls of snow along the western hills and valleys, in the localities probably where the heaviest rains now occur. The phenomena of the Parallel Roads of Glen Roy, for example, if we are to explain them by the agency of glaciers, require us to suppose that the ice was much more developed on Ben Nevis and the region to the west of the Caledonian Canal than in the hilly district around the sources of the Spey. But the mountain-ridge that lies between Loch Laggan and Loch Spey is quite as lofty as the hills which encircle Loch Arkaig, if not more so—four of the summits exceeding 3000 feet, and one of them being no less than 3700. Yet it is evident the glaciers proceeding from this ridge were much smaller and waned sooner than those that blocked the mouths of Glen Gluoy and Glen Spean; otherwise they would have occupied the watersheds or cols and also the top of Glen Roy at the time the terraces show that these places were clear of ice. Now what we know regarding the rainfall of the district harmonizes remarkably with these results. We have the records of three gauges in the neighbourhood of Ben Nevis and Loch Arkaig—namely, one at Fort William, another at Glen Quoich, and a third at Inverie near Loch Nevis; and the annual rainfall at each of these places is 86, 102, and 82 inches respectively, being an average of 90 inches in the year, whereas at Laggan, near the head of the Spey, the annual amount of rain is only 46 inches, or just about half of this.

Again, there seems reason to believe that the upper reach of the Moray Firth was at one time occupied by a large glacier composed of the united ice-streams issuing from all the glens of Ross-shire and Inverness, which now pour their waters into the Moray and Dornoch Firths. This great glacier seems not only to have occupied the top of the Moray Firth, but to have spread eastward past Nairn and Elgin to near Speymouth, as if the glaciers descending from the district lying to the east of Inverness (now remarkable for its dry climate and small amount of rain) were comparatively so small as to be overborne and pressed aside by the heavier ice issuing from the western glens. The absence of marine fossils in the drift of Elgin and Nairn favours the supposition that this glacier may have existed even after the time of the submergence. A belt of gravel and boulders, forming kaim-like ridges, which may be traced from the neighbourhood of Inverness eastward along the base of the gneiss hills of Nairn and Elgin to near Speymouth, may perhaps mark the southern edge of this great glacier. It is cut through and partly washed away by the rivers that now cross its path ; but although some have regarded it as an old sea-terrace, no marine fossils have have ever been found in it to substantiate that opinion. Now the climate of the country to the east of Inverness is at present one of the driest in Scotland, the yearly fall of rain at Culloden and Nairn being only 24 inches, while in the western glens of Ross and Inverness the rainfall is very heavy. If, therefore, we suppose the fall of snow to have been similarly proportioned, it would help to explain how it came to pass that the western glaciers were so large as to overpower and press aside those of the eastern district. The transport of boulders and denudation of the surface over the low grounds of Morayshire imply the action of some great force passing from W. to E., such as would arise from the flank of a glacier moving down the Moray Firth as I have supposed.

Consider, again, the wonderful facts connected with the glaciation of Ireland made known lately by Messrs. Kinahan and Close, and by Mr. Campbell, of Islay ; do they not imply an excessive snowfall along the western heights of that island, and, it may be, a comparatively high elevation of all the western side of the country ? And the dispersion of the boulders of Shap granite from Wastdale Crag in the north of England would admit of a clearer explanation if we supposed that the region of the lakes, now so noted for its immense rainfall, was formerly distinguished by a like excess of snow.

I incline to think that the Glacial period, in this country at least, was distinguished by enormous falls of snow as well as by a low temperature. If we might suppose that during summer the elephant, rhinoceros, and other wild animals browsed along the borders of the ice-covered region, it seems likely that they would be sometimes caught in the early storms of approaching winter, when these happened sooner than usual, and thus get bewildered and smothered in the heavy snowdrift. Their short-legged heavy carcasses would ill fit them for wading through deep wreaths of snow ; and this would account for the frequent occurrence of their remains in comparison with those of the lighter and fleeter animals. When these large heavy beasts lost themselves amongst the snow and sunk in it, they would be covered up until the summer thaw came, which would float off their carcasses and carry them down the rivers, lodging them in the silt and gravel along their course.

§ 9. *Conclusion.*

This last phase of the Glacial period was therefore no time of mere local glaciers lingering among some of the higher mountains, but the return of a great ice-sheet which spread over nearly the whole of Scotland and Ireland and also the greater part of England. But the ice seems not to have been so thick and extensive as it was in the early glaciation—nor so enduring; for it has failed to destroy all the beds of clay and sand containing arctic shells which the sea left behind it, whereas in Scotland we find that the ice of the former period cleaned off every thing down to the hard rock. I would suppose that all the mountain-ranges of Scotland and Wales were coated with thick ice, which reached the coast in most places, likewise the hilly ground of the north of England, including the Pennine ridge along its whole length as far at least as Derby. In the lower districts of England further south, there would probably be extensive snow-beds, more or less converted into ice at the bottom. During the summer thaws these would send out great streams of muddy water, occasioning those superficial deposits of brick-earth, warp, and loess which are so widely spread to the southward. Beds of gravel would be lodged where the force of the current was stronger, and when the thaw was unusually rapid. That there must have been heavy beds of consolidated snow even in the extreme south of England, I infer from the fact that I find traces of such in my own neighbourhood, in the low eastern part of Aberdeenshire, on the flanks of hills only a few hundred feet in height. In the low ground in front of these places there is generally a land-locked hollow or shallow basin occupied by peat.

This second ice-sheet gradually shrank into smaller and smaller compass, separating by degrees into valley-glaciers, which paused for a time here and there in their retreat, leaving Kaims and Eskers in the low grounds and more distinct moraines in the mountain-glens. At times the ice seems to have receded rapidly over a wide area without leaving any marginal deposits. In these places the surface is more or less covered with a sheet of coarse earth or mud mixed with stones, which formed the bed or lair of the ice. During such times there probably occurred a succession of warmer seasons, causing a considerable thaw, when vast bodies of water would flow down the valleys, spreading out much gravel, sand, and silt along their course. But it is important to observe that no great submergence of the country again occurred, nothing but that slight depression which is marked by the estuary beds and raised beaches a little above the present coast-line.

The last great modification of the surface has been subaerial, and not submarine. Glaciers, frost, and rain have done the work, not the waves of the sea.

Discussion.

Mr. Jeffreys considered that the author's remarks relating to the beds containing Arctic species of Mollusca were not quite correct. *Pecten islandicus* has been found in the drift of Scotland, but not in the seas at present surrounding that country. At depths of 30 or 40 fathoms many Arctic shells in a semifossil state have been dredged, although they do not now live in those waters. *Mya trun-*

cata, a species which lives in very shallow water, has been found in much deeper water in a semifossil state. At Fort William there is a bed containing Arctic species of shells 7 or 8 feet above the level of the sea. Arctic shells of deep-water species have occurred 200 feet above the sea. Different conditions have existed at different parts of the same seas, altering the character of the Mollusca. The raising of the sea-beds above the level proper to enable certain Mollusca to flourish, would cause them to become extinct.

Dr. Carpenter mentioned that cold water may be thrown up into very small depths under certain circumstances. Near Halifax, N.S., the surface-water is tolerably warm, but at no great depth the temperature falls to 35° F. In this case the rotation of the earth causes the cold water from the north to surge up on its western coast. The North Sea is a shallow sea, with a shoal in the middle, and having off the coast of Norway a deep channel which conveys the cold Arctic undercurrent; hence the east side is 10° F. colder than the west side. Local peculiarities of disturbance of temperature may thus occur within short distances.

Prof. Ramsay remarked that the author was not dealing with wide ocean-deposits, but with ice coming down to the sea from the land. He had described certain changes—a great Glacial period, a period of submergence, and a second minor Glacial period.

Mr. Prestwich maintained that temperature was a most important question in connexion with the subject of Mr. Jamieson's paper. The shells of the Glacial deposits, however, were mostly littoral, and therefore dependent upon the local temperature. The subject was one of much interest; but the paper was somewhat speculative, and he should like to see all the evidence upon which the opinions expressed were founded.

27. REMARKS *on* FOSSILS *from* OBERBURG, STYRIA. By A. W. WATERS, Esq., F.G.S. (Read January 21, 1874.)

The Eocene occurs in Styria only in a small district in the south, in the neighbourhood of Oberburg. These beds are followed by extensive deposits of later Tertiaries, which attain their fullest development in the central part of the country. It was these latter beds (the "Neogen" of the Austrians) which were studied by Sedgwick and Murchison, and described in their classical paper on the Eastern Alps, the occurrence of the Eocene being then unknown to them.

But since the researches of these two geologists, who have done so much for Alpine geology, the occurrence of a Nummulitic deposit containing a rich store of well-preserved Anthozoa has been made known to geologists and palæontologists through the publication of a monograph by the late Professor von Reuss, "Die fossilen Foraminiferen, Anthozoen, und Bryozoen," Denkschriften der Akademie der Wissenschaften in Wien,1864.

From this monograph it is not a difficult task to determine the corals which I collected this summer during a short stay in Oberburg.

Since the publication of the above, the geological relationships of the district have been fully discussed by Stur in his "Geologie der Steiermark."

There are two points, about ten miles distant, which have yielded the richest harvest; these are Gradischneg and Neustift; and the fossils found in each are designated in Stur's list. Since I have found several fossils in both places which had only been found in one of the localities, I have thought it well to make out a corrected copy of Stur's catalogue.

Corrected List of the Fossils from the Nummulitic Formation of Oberburg (O) and Neustift (N), Styria.

Natica crassatina, *Lam.* O, N.
—— obesa, *Brongn.* O.
—— perusta, *Brongn.* O.
Delphinula scobina, *Brongn.* O, N.
Fusus subcarinatus, *Lam.* O.
Turritella oberburgensis, *Rss.*
—— asperula, *Brongn.* O.
Cerithium trochleare, *Lam.* O.
Diastoma costellata, *Lam.* O.
Panopæa, sp. N.
Venus Aglauræ, *Brongn.* O, N.
Crassatella tumida, *Lam.* O, N.
Cardium, sp. O, N.
Pecten Gravesi, D'Arch. O.
Perna Sandbergeri, *Desh.* O.
Ostrea, sp.
Turritella incisa, Brongn. N.
Melobesia, sp.
Lithothamnium nummuliticum, *Gümb.* O, N.
Verneuilina oberburgensis, *Freyer.* N, O.
Clavulina triquetra, *Rss.* O, N.
Spiroloculina striatella, *Rss.* N.
—— Morloti, *Rss.* N.
—— Freyeri, *Rss.* N.
Triloculina trigonula, *Lam.* N.
—— oblonga, *Montagu.* N.
—— granulata, *Rss.* N.
Quinqueloculina hiantula, *Rss.* N.
Vertebralina sulcata, *Rss.* N.
Discorbina obtusa, *D'Orb.* N.
Truncatulina variabilis, *D'Orb.* N.
Rotalia formosa, *Rss.* N, O.

Polystomella latidorsata, *Rss.* N.
Lagena, sp. N.
Operculina irregularis, *Rss.* N, O.
Nummulites mamillatus, D'Arch. N, O.
—— *striatus*, D'Orb. N, O.
Amphistegina, sp. N, O.
Tinoporus vesicularis. O, N.
Trochosmilia subcurvata, *Rss.* O, N.
Cyathomorpha conglobata, *Rss.* O.
—— explanata, *Rss.* O, N.
Calamophyllia fasciculata, *Rss.* O, N.
Rhizangia Hörnesi, *Rss.* Repenscheg.
Dimorphophyllia oxylopha, *Rss.* O.
—— lobata, *Rss.* O.
Mycetophyllia interrupta, *Rss.* O.
—— multistellata, *Rss.* O.
Leptoria eocænica, *Rss.* O.
Cœloria ? cerebriformis, *Rss.* O.
Hydnophora longicollis, *Rss.* O, N.
—— sp. N.
Stylophora annulata, *Rss.* O, N.
Stylocœnia lobato-rotundata, *M.-E. & H.* O, N.
—— taurinensis, *M.-E. & H.* O, N.
Dictyarea elegans, *Leym.* O.
Favia dædalea, *Rss.* O, N.
Heliastræa eminens, *Rss.* O, N.
Heliastræa Boueana, *Rss.* O, N.
Astræa Morloti, *Rss.* O, N.
Thamnastræa leptopetala, *Rss.* O, N.
Pseudastræa columnaris, *Rss.* O.
Podabacia prisca, *Rss.* O, N.
Dendrophyllia nodosa, *Rss.* O, N.
Astræopora compressa, *Rss.* O, N.
Dendracis Haidingeri, *Rss.* O, N.
Actinacis Rollei, *Rss.* N.
Porites nummuliticus, *Rss.* N, O.
Litharæa lobata, *Rss.* N.
Alveopora rudis, *Rss.* N.
Millepora depauperata, *Rss.* N, O.
—— cylindrica, *Rss.* O.
Membranipora subæqualis, *Rss.* O.
—— formosa, *Rss.* O, N.
—— Münsteri, *Rss.* N.
—— angulosa, *Rss.* O, N.
—— leptostoma, *Rss.* O.
Lepralia Reussi, *D'Orb.* N.
—— rudis, *Rss.* N.
—— megalota, *Rss.* N.
—— multiradiata, *Rss.* O.
Eschara papillosa, *Rss.* N.
—— membranacea, *Rss.* N.
Defrancia cumulata, *Mich.* sp. N.
Heteropora stellulata, *Rss.* O.

Fossils or localities in italics indicate that they are additions to Stur's list.

Reuss mentioned, besides the *Nummulites variolarius*, two Nummulites which he does not determine, but thinks resemble *N. garansensis* and *intermedius*. Of these three, I find the first (*variolarius*) is not a Nummulite but an *Amphistegina*; the other two are *N. striatus* and *mamillatus*. I have also found a *Lagena*, and have no doubt a more extended examination might add still more to the list of the Foraminifera. I have further found *Tinoporus vesicularis*, P. & J., and *Entalophora attenuata*, Rss.; and I find there are several of the Bryozoa from Gradischneg which have not been mentioned, but of which I have not had time to make a list. One of the Pectens is *Pecten Gravesi*. Besides *Turritella oberburgensis* I have *T. incisa*.

Stur mentions the occurrence of *Lithothamnium nummuliticum*, (Gümbel); but a form I cut through much resembling it is a *Melobesia* (Rosanoff).

The coralliferous beds occur only in the immediate neighbourhood of Oberburg and Neustift; but the Prassberg beds, an arenaceous limestone, have been found over a much more extended district, and of considerable thickness. They overlie the Oberburg beds, and have been joined with them into one series, which passes by the name of "Oberburg- und Prassberg-Schichten." This contains fragments of Pectens, which Stur says are undeterminable. Some I collected remind me of *Pecten Faujasii* and *quinquecostatus*. Above this we get the Wurzenegg beds, with plant-remains and fish-teeth; then follow strata of the same age as those of Eibiswald and Sotzka, which occur so well developed in Central Styria.

Reuss found ten species of Anthozoa the same as those from Castel Gomberto; and as the Mollusca bear out the same conclusion, the beds must at present be regarded as parallel. It would seem that the Oberburg beds are not the youngest Nummulitic beds, as they should probably be correlated with the Lucasana beds of Hantken, as developed in Hungary, which are overlain by the Tchihatcheffi-Schichten of western Hungary. These last come to light again near Vienna, at Stockerau. The Lucasana beds contain a large number of corals very similar to those of Oberburg; Reuss considered them the equivalent of the Castel-Gomberto beds; but the exact correspondence has been disputed by Hantken.

The Eocene beds were evidently deposited in a large bay extending from Neustift to St. Florian (near Schönstein) and as far as Prassberg. Since their deposition these beds have been raised to a height of over 2000 feet.

Discussion.

Prof. Duncan commented on the sad loss which science had lately sustained in the death of Prof. Reuss, from whose labours he had received much assistance, and with whom he had long been in the most kindly relations. He had been disposed to place these beds among the Upper Eocene or Oligocene beds; but the discovery of Nummulites in them might cause them to be placed on the lower horizon.

28. *On the* Gault *of* Folkestone. By F. G. H. Price, Esq., F.G.S. (Read April 29, 1874.)

[Plate XXV.]

In this paper I have not made any attempt to correlate the Gault of Folkestone with beds of similar age in other parts of England or of the Continent, but simply to describe the Gault as seen at Folkestone, and to give a list of its fossils.

Not having had time to examine the Gault in other parts of England, I am not in a position at present to state whether these divisions will hold good over extended areas.

Upon some future occasion I hope to place before this Society a more general paper upon the Gault, correlating the various beds.

The Geological Magazine for April, 1868 (vol. v. No. 4), contains a most valuable paper entitled the "Albian or Gault of Folkestone," by Mr. Charles E. De Rance, of the Geological Survey. In this paper Mr. De Rance divides the Gault into eleven zones, all of which are well marked and have been recognized more or less by all geologists and fossil-collectors who have visited the district.

Provisional names have been assigned to these beds, indicative either of their colour, position, or fossil contents.

Having investigated the whole of the Gault at Copt Point and in Eastweir Bay, which lies about one mile to the eastward of Folkestone harbour, where it may be seen resting upon the Folkestone-beds of the Lower Greensand or Upper Neocomian, and found that, for the most part, Mr. De Rance's division into zones or beds holds good, I consider that we cannot do better than adopt his order of dividing the Gault into the various beds which I propose describing in this paper, setting forth one or two points on which I disagree.

It is exceedingly difficult for any one who has not thoroughly investigated the Gault *in situ* to be able to discern the various beds as they lie on the beach in Eastweir Bay. In consequence of the slipping of the Chalk above, the Gault has been pressed out and faulted in great confusion, many of the beds being mixed up together.

The lithological characteristics once familiar to the investigator, he will plainly see how utterly impossible it would be for any one to attempt taking accurate measurements of the beds as they are there placed. They are not merely mixed, but are much expanded in comparison with what they are at Copt Point, where the only accurate measurements can be obtained, the Gault at that place being *in situ*, and capped by the Upper Greensand.

The Gault of Eastweir Bay is always moving, and in very wet weather may almost be seen to move, as the quantity of water percolating through the Chalk to the Gault, where it meets with an obstacle, causes the Chalk above to press out these lower beds. I do not think the day is very remote when we shall have to record a considerable slip of the upper beds over this slippery floor into Eastweir Bay.

Copt Point is described by Dr. Fitton* as being 130 feet above the level of the sea, and by Mr. Mr. De Rance as 128 ft. 5 in.

In the autumn of 1873 I endeavoured to take accurate measurements of the Gault at Copt Point and at the Pelter†, a local name given to a part of Eastweir Bay where the upper beds occur *in situ*.

I took my line of measurements from the seam of nodules of sulphuret of iron, the base of the Gault, which is found about 4 feet above a hard seam of sandstone, the zone of *Ammonites mammillatus*, the top of the Upper Neocomian, the intervening four feet consisting of light sands.

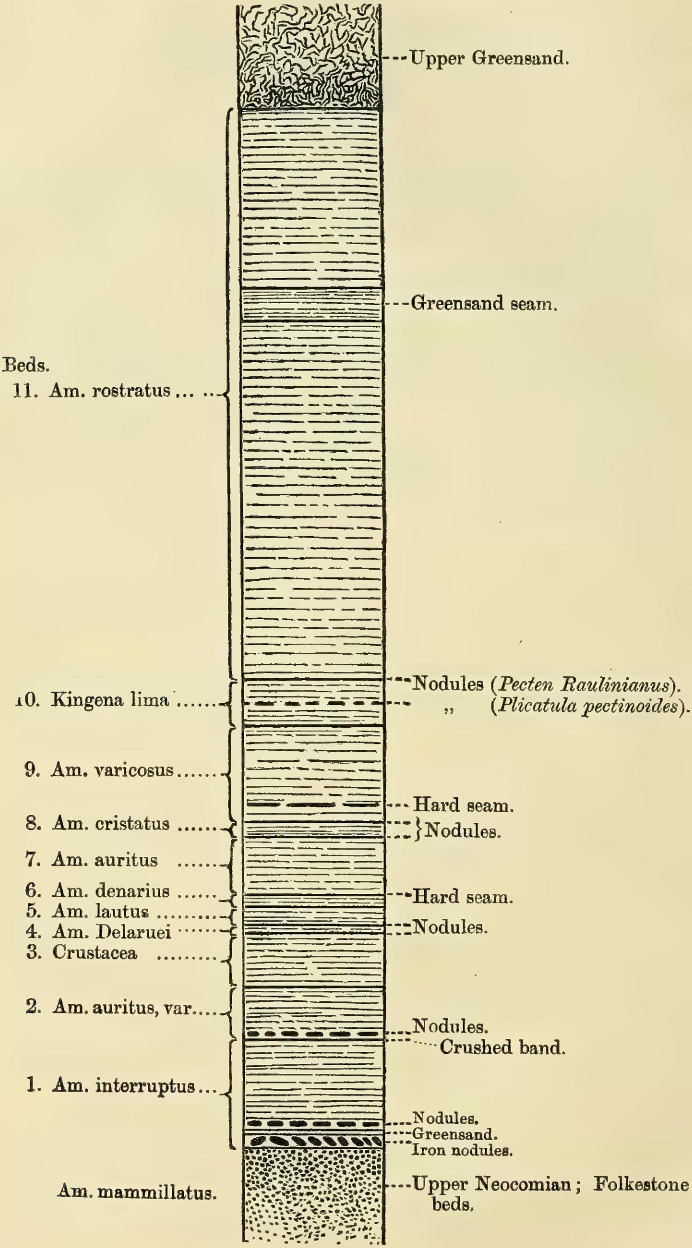
From the sulphuret-of-iron band up to the base of the Upper Greensand I found to be 99 feet 4 inches.

The Gault is divided into two groups or divisions, *i. e.* the Upper and Lower Gault, separated by a passage-bed; and these divisions may be again subdivided into ten well-defined zones, seven being below and three above the nodule- or passage-bed, as shown in the following diagram section (fig. 1, p. 344).

* Trans. Geol. Soc. vol. iv. part 2, 2nd series.

† A brig of this name was wrecked here, which gives the local name "Pelter" to this part of the bay.

Fig. 1.—*Diagram Section of the Gault at Copt Point.*



(Scale 18 feet to 1 inch.)

Bed I.

The junction-bed separating the Folkestone-beds of the Lower Greensand from the Gault consists of a line of nodules of sulphuret of iron, which is about 1 foot 3 inches in thickness. This is succeeded by a band of dark greensand, containing two lines of phosphatic nodules, in which nodules *Ammonites interruptus* and pieces of wood bored by *Pholadidea sanctæ-crucis*, Pictet et Camp., are found; many of the fragments of Ammonites, *Inocerami*, &c. which are plentiful in this band are sprinkled over with small spicules or crystals of selenite. In no other band throughout the Gault has this ever been observed. The dark greensand seam goes off suddenly into Gault, with a line of phosphatic nodules traversing it. These nodules of phosphate of lime arise, I presume, from the decomposition of the remains of mollusca, fish, saurians, &c.

The fossils of this junction-bed are usually in the condition of rolled casts, and of a fragmentary nature. The following are some of the most ordinary forms met with:—

Palæocorystes Stokesii, *Mant.*
Inoceramus concentricus, *Park.*
Nucula pectinata, *Sow.*
Pecten, sp.
Pholadidea sanctæ-crucis, *Pict. et Camp.*, in wood.
Teredo-tubes.
Trigonia Fittoni, *Desh.*
Dentalium decussatum, *Sow.*
Pyrula, sp.
Ammonites interruptus, *Brug.*
Hamites attenuatus, *Sow.*
H. rotundus, *Sow.*
Belemnites minimus, *List.*
Nautilus, sp.
Vertebræ of saurians and fish.

Mr. Gardner has obtained a species of *Hippurites* and *Buccinum gaultinum* from this bed.

The above-mentioned fossils are mostly found more or less incrusted with phosphate.

Upon many pieces of Ammonites, nearly all of which are *Ammonites interruptus*, I have found specimens of *Plicatula pectinoides*, *Pecten quinquecostatus*, *Trochosmilia sulcata*, and a species of *Nucula* allied to *obtusa*, all with the shell on, apparently indicating that they were contemporary with the formation of the bed, which appears to have been derived from some deposit now destroyed.

Whilst examining this bed last October at Copt Point, I met with a piece of *Ammonites Roissyanus*, D'Orb., *in situ*, imbedded in phosphate; this is a very rare Ammonite to meet with at all, and especially in the Lower Gault, as it belongs to the *Cristati*, or crested group of Ammonites, which are characteristic of the Upper Gault.

I also found a fragment of a very large smooth Ammonite, deeply grooved, which I cannot at present assign to any species.

The total thickness of this bed from the top of the Upper Neocomian beds, *i. e.* the Folkestone-beds of the Lower Greensand, to a hard seam of nodules and crushed band of fossils is 10 feet 1 inch.

This bed may be considered the zone of *Ammonites interruptus*, Brug., as that well-known and varied form occurs in this bed and in no other, excepting in the band immediately above, which is only 1 inch in thickness.

The following are the synonyma of *Ammonites interruptus*, Bruguière, 1792:—*Ammonites serratus*, Parkinson; *A. dentatus*, Sow.; *A. noricus*, De Haan; *A. dentatus*, Fitton; *A. Deluci*, D'Orb.; *A. Chabreyanus*, Renevier; *A. Benettianus*, Sow.

Bed II.

may be considered the bottom bed of the Gault, commencing with a band of crushed fossils one inch in thickness, which has a line of phosphatic nodules running through it.

The clay of this bed is of a very dark colour, in fact, very nearly approaching to black when moist, and is somewhat hard.

It is remarkable for the deep rich colour of its fossils, and for its containing several species peculiar to it.

At a distance of three inches upwards from the last-mentioned band, a line of selenite in large pieces occurs; this mineral is not met with in any other part of the Gault, and only in the position here indicated in bed II.

One foot above the selenite a line of phosphatic nodules occurs; the space between these two is the horizon of *Aporrhais calcarata*, D'Orb., which beautiful little Gasteropod is not met with elsewhere in the Gault. *Turrilites elegans* and *Ancyloceras spinigerum* likewise occur in this horizon and are not again seen.

The following species are peculiar to this bed:—

Fusus Itierianus, *D'Orb.*
Cerithium trimonile, *Mich.*
Narica cancellata, *Chemn.*
Corbula gaultina, *Pict. et Camp.*
Myacites, sp.
Pectunculus, sp.
Nucula De Rancei, *Price.*
Pollicipes rigidus, *Sow.*

and a variety of *Ammonites auritus* having long tubercles, which may perhaps be a distinct species.

The total thickness of this bed, measured to the base of the "light bed" No. III., is 4 feet 2 inches.

The rich colour on the shells of the fossils from this zone is, no doubt, due to the very large percentage of iron in the form of oxides, and to the comparatively small percentage of carbonate of lime met with in the clay of this bed.

My friend Mr. W. H. Hudleston, to whom my best thanks are due, has given me the following analysis of the clay of bed II.:—

"The Gault of this bed consists of a grey marly clay; constituent particles extremely fine and close; nothing granular observed except a few specks of pyrites and a considerable amount of organic matter. Dried at 100 C. it contains

		per cent.
	Water and organic matter	8·25
	Carbonate of lime	8·61
	Silica, silicates, oxides of iron*, pyrites &c.	81·93
Not actually estimated	Chloride of sodium (consid.) Carbonate of magnesia (traces) Sulphuric acid Phosphoric acid (traces)	1·21
		100·00

"This differs principally from the upper bed in containing less carbonate of lime, and less phosphoric acid, but much more iron and more organic matter."

Bed III.

Known as the "light bed," or "crab-bed," from the fact of many of the Crustaceans found in the Gault being derived from it.

It may be readily recognized from any other by its light fawn-coloured clay, which exhibits a striking contrast to the very dark colour of the bed last described.

Its thickness is 4 feet 6 inches, being measured from the top of bed II. to a line of nodules containing many rolled fossils with the shell preserved on them, carapaces of *Palæocorystes Stokesii* and *P. Broderipii*, Hamites and bones of saurians and fishes.

A remarkably fine type of *Inoceramus concentricus* occurs in this line of nodules.

Tabular masses of ironstone occur in various parts of this bed, being of the same light fawn-colour as the clay. Similar ironstone also occurs in bed V. It contains many of the fossils common to the bed, *Corbula elegans* being met with in it in large numbers.

For the following analysis of this ironstone I am indebted to Mr. W. H. Hudleston:—

"A clay ironstone free from grit. The bulk of the mass consists of pulverulent carbonate of lime, ferrous carbonate, extremely fine particles of clay &c. with about 2 per cent of pyrites. Dried at 100 C.:—

Amount of metallic iron (principally as protoxide)	29·40
Add for iron in combination with sulphur (say)	1·00
Total metallic iron	30·40"

Bed IV.

This is a narrow band which was apparently overlooked by Mr. De Rance, or not considered by him of sufficient importance to be constituted into a separate bed. It is measured from the line of nodules containing the carapaces of Crustaceans before named, to a line of phosphatic nodules and rolled casts of fossils. Imbedded in many of the fragments of phosphate a very small species of *Hoploparia* is met with, which species is not found in any other part of the Gault.

* Metallic iron 4·25 per cent.

The total thickness of this bed is four inches; in colour it is slightly darker than the preceding bed No. III. and not mottled like the clay of bed No. V.

Comparatively few fossils are met with in this bed; the following may be regarded as peculiar to it:—

Ammonites Delaruei, D'Orb., a form belonging to the group *Cristati*, which may be considered characteristic of the Upper Gault as the groups *Dentati* and *Tuberculati* are of the Lower. *Ammonites cornutus*, Pictet, and *Ammonites Roissyanus*, D'Orb., are the only other forms belonging to the group *Cristati* that I have met with in the Lower Gault; and as only these three forms have been found in the Lower Gault, the *Cristati* group of Ammonites may still be considered characteristic of the Upper division.

An Ammonite possessed of very long spines or tubercles, which may be classed as a variety of *Ammonites tuberculatus*, Sow., M. C.; a small species of *Natica*, which will be subsequently described in this paper as *Natica obliqua*; and *Fusus gaultinus*.

The conditions under which this bed was formed appear to have been especially favourable to the development of *Dentalium decussatum*, remarkably fine specimens of which occur between these lines of nodules.

I submitted one of the nodules from the last-described band (in fact, one containing a specimen of the small *Hoploparia*) to my friend Mr. Hudleston, who has reported to me the following results:—

"This is a mixture of carbonate of lime with phosphate of lime and iron, some clay, organic matter, and pyrites.

"The amount of phosphoric anhydride in the sample dried at 100 C. is

25·53 per cent = 55·60 tricalcic phosphate."

Bed V.

This bed may consistently be termed the "coral bed," on account of the quantity of corals which it contains.

Its thickness is 1 foot 6 inches. The clay is of a dark colour, spotted to within a few inches of the top with light fawn-coloured markings.

It is measured from the line of nodules containing the fossil casts up to a line where the clay becomes more strongly mottled.

This bed is considered by Mr. De Rance to be the zone of *Nautilus Clementinus*; but as that fossil is by no means peculiar to it, and makes its first appearance in bed III., and has been met with in every bed up to and in bed XI., I do no not think we can specialize it as the zone of *Nautilus Clementinus*, but rather as the zone of *Ammonites lautus*, as the typical form of this species makes its first appearance in it.

The following fossils appear to be peculiar to this bed:—

Astarte Dupiniana, *D'Orb.*
Cerithium Dupinianum, *D'Orb.*
—— subspinosum? *Desh.*
Turritella, two sp. undetermined.
Solarium albense, *D'Orb.*
—— moniliferum, *Mich.*

The following eight forms make their first appearance in this bed:—

Cardita rotundata, *Pictet.*
—— tenuicosta, *Sow., G. T.*
Nucula Vibrayeana, *D'Orb.*
Avellana inflata, *D'Orb.*
Actæon affinis, *D'Orb.*
Bellerophina minuta, *Sow., M. C.*
Solarium conoideum, *Sow.*
Phasianella ervyna, *D'Orb.*

Resin is also found in this bed. Mr. Hudleston tells me such substances, like the Highgate resin, are viewed by Dana as a kind of copalite. This resin is wholly volatile, burning with a highly luminous flame and fragrant odour. It is not appreciably soluble in alcohol.

Bed VI.

This bed, commonly styled the "mottled bed," is of small vertical thickness, being only one foot. It is measured from the top of bed V. to a hard seam. The clay is darker than that of the preceding bed, and is mottled throughout with lightish-coloured markings.

It may be considered the zone of *Ammonites denarius*, Sow., M. C., as that fossil is frequently met with in it and is of rare occurrence in any other bed. The following six forms are peculiar to this zone:—

Homolopsis Edwardsii, *Bell.*
Necrocarcinus Bechei, *Deslong.*
Fusus elegans, *D'Orb.*
Scalaria gastyna, *D'Orb.*
Turrilites Hugardianus, *D'Orb.*
Ammonites cornutus, *Pictet* (a small variety).

Bed VII.

The top bed of the Lower Gault is measured from the hard seam constituting the limit of bed VI. up to the first line of nodules forming the base of the junction-bed. It is 6 feet 2 inches in thickness, and is usually called the "dark bed" from its very dark colour, although it is not so dark as bed II., neither do the fossils bear so rich a colour as they do in the latter.

This bed is highly fossiliferous, containing as many as 67 species; it is especially rich in Gasteropoda, and possesses six species peculiar to it, namely:—

Nucula albensis, *D'Orb.*
Aporrhais Parkinsoni, *Sow.*
Fusus indecisus, *D'Orb.*
Avellana Dupiniana? *D'Orb.*
Cerithium tectum, *D'Orb.*
—— Phillipsi? *Leym.*

There are likewise three well-marked forms which make their first appearance and are abundant in this bed, and pass up into the junction-bed above, where they only occur sparsely. These are:—

Nucula bivirgata, *Fitton.*
—— ornatissima, *D'Orb.*
Buccinum gaultinum, *D'Orb.*

Of the last-named fossil I have thought it well to give figures (Pl. XXV. figs. 1 & 2), as that given by D'Orbigny in his 'Paléontologie Française,' tom. ii. pl. 233, is of so fragmentary a character as to be difficult to identify with the fine specimens met with in this bed.

Ammonites auritus and a variety of the same occur in large quantities, from which circumstance it may be well to describe this as the zone of *Ammonites auritus*.

The genus *Cerithium* is well represented in the Lower Division, in which (ranging from bed No. II. up to this bed) as many as 16 different species have been met with. Of these 10 appear not to have been described. I have only enumerated 10 species in my table; of the remaining six I have only found single specimens, and have therefore deferred noting them until more data shall have been obtained. This group will form an excellent subject for a monograph at a future time.

Bed VIII.

This constitutes the junction-bed or "passage" between the Upper and Lower Gault, and is measured from the first line of nodules before cited as forming the top of bed VII. to a second line of nodules. It has a total thickness of 10 inches, and is well known by the name of the "nodule bed."

This passage-bed, for such it really is, contains many species belonging to both the Upper and Lower Gault, and marks the total extinction of many Lower-Gault forms, no less than the introduction of others which took their place.

Few species of Gasteropoda, which are so plentiful in the top beds of the lower division, pass into this junction-bed; they are here generally found in the form of casts or much enveloped in phosphate. Several Ammonites belonging to the various groups are found here. The characteristic species is *Ammonites Beudanti*, which is not found in any other part of the Gault. It may be well to mention that this well-marked form obtains largely in the zone of *Ammonites mammillatus* in the Upper Neocomian or Folkestone-beds of the Lower Greensand.

The nodules of this zone, like the nodules at the base of the Gault in bed I., contain for the most part a *remanié* group of fossils.

The Lower Gault appears to have been especially favourable to the life and development of the Gasteropoda; for as many as 46 species have been obtained (as may be observed in the accompanying table) from those beds; and they reached their maximum of development in bed VII. Nine of these species extend into the nodule-bed No. VIII., there being but two species peculiar to it.

Out of the 11 species of Gasteropoda found in the Upper Gault, 6 appear to have survived from the Lower, and 5 are peculiar to the Upper, thus showing that the conditions of the Upper-Gault sea were unfavourable to the continuance of the more delicate forms of life, or, if they were continued, that the chemical constituents of the sediments deposited during the formation of these marls were unfavourable to the preservation of specimens.

Out of 73 species of Lamellibranchiata that I have met with in the whole deposit, 39 become extinct in the lower division, or in bed VIII.; 4 are peculiar to that bed, and 16 to the Upper Gault; whereas only 14 species are continued from the lower beds.

Taking the whole of the fauna of the Gault, of which I have collected as many as 240 species, marking their particular horizon on the table of genera and species at the end of this paper, it will be seen that 124 forms become extinct in bed No. VIII., and 39 forms are continued into the Upper Gault. Bed VIII., besides containing the limit-fauna, possesses as many as 18 species which are peculiar to it. 59 new forms occur in the Upper Gault, making their first appearance either in No. VIII. or in a higher zone.

The following is a list of fossils which may be considered peculiar to bed VIII.:—

Bathycyathus Sowerbyi, *Edw. & H.*
Vermicularia, sp.
Avicula, sp.
Cucullæa glabra, *Park.*
Cyprina quadrata, *D' Orb.*
Mytilus Galliennei, *D' Orb.*
Pholas, n. sp.
—— Rhodani, *Pict. et Camp.*
Scalaria gaultina, *D' Orb.*
Murex calcar, *Sow.*
Ammonites splendens, *Sow.* (a variety).
—— Beudanti, *Brongn.*
—— Brongniartianus? *Pictet.*
—— Itierianus, *D' Orb.*
—— Selliguinus, *Brongn.*
Pachyrhizodus glyphodus, *Blake & Mackie.*
Ptychodus, sp.
Fish-jaw and fish-teeth, undescribed.

In addition to the above a variety of *Ammonites tuberculatus*, Sow. is met with.

This bed may be considered the zone of *Ammonites cristatus*.

Bed IX.

This bed, forming the base of the Upper Gault, is measured from the line of nodules at the top of the last-described bed to a line of nodules containing vast quantities of crushed forms of *Inoceramus sulcatus*; its total thickness is 9 feet $4\frac{1}{2}$ inches.

Inoceramus sulcatus is the most characteristic fossil of this bed, which is everywhere marked with its silvery impressions. This species has never been met with in the Lower Gault at all, with the exception of a rolled cast recorded* as being found by Mr. Etheridge some years ago in the junction-bed I. In the middle junction-bed, No. VIII., it appears frequently, and occurs in good condition; but it reaches its maximum of development in the bed now under consideration, beyond which it does not pass. At a distance of one foot above the nodule-bed there occurs a seam of very hard marly Gault, which is filled with specimens of this fossil.

A hybrid form of this *Inoceramus* is met with in this zone, half of the shell resembling *I. sulcatus*, and half *I. concentricus*. It was named *Inoceramus subsulcatus* by the Rev. Thomas Wiltshire†, and is figured by Pictet et Roux, Grès Verts, pl. 42. fig. 1.

Ammonites varicosus, Sow., is another fossil met with in great abundance in this zone, and is decidedly the characteristic Ammonite of the bed; it makes its first appearance in the line of

* Memoirs of the Geological Survey, 'The Geology of the country between Folkestone and Rye.'

† "On the chalk of Hunstanton," by the Rev. Thomas Wiltshire, Quart. Journ. Geol. Soc. vol. xxv. p. 190 (1869).

nodules below, and passes up into bed X, where, however, it is not frequently found. I would suggest that bed IX. be considered the zone of *Ammonites varicosus.*

The geologist will at all times when working in the Gault readily be able to fix his position, and know that when he discovers these two most characteristic fossils he is upon the base of the Upper Gault.

A variety of *Ammonites lautus* occurs in this zone, ranging from the nodule-bed, where it is found in the form of casts, up to a hard seam near the top, but never having been noted as passing above that horizon. This Ammonite belonging to the group *Dentati,* forms another exception to the rule of the Upper Gault being restricted exclusively to Ammonites of the group *Cristati.*

Just below the hard seam at the top of this zone, *Ammonites rostratus,* Sow.=*Ammonites inflatus* of D'Orbigny, makes its first appearance. It extends thence up to the top of the Gault.

Pholadomya fabrina, D'Orb., is only met with *in situ* in this bed; it certainly is found in the nodule-bed No. VIII., but then only in the form of rolled casts. No other fossils, so far as I have as yet been able to ascertain, can be considered to be peculiar to this zone; but the two following well-known Upper-Gault forms make their first appearance in it:—

Pleurotomaria Gibbsii, *Sow. M.C.* Scaphites æqualis, *Sow.*

Bed X.

Commences at the crushed band of *Inoceramus sulcatus,* and extends upwards to a line of phosphatic nodules containing specimens of *Pecten Raulinianus,* D'Orb., 5 feet 1 inch above the top of bed IX.

The Gault of this zone is homogeneous, hard, and of a pale cold grey colour, poor in organic remains, and partakes more of the character of marl than clay, as does the whole of the Gault of the upper division, which contains as much as 26 per cent. of carbonate of lime—a fact sufficient of itself to account for the shells of the fossils being so seldom preserved.

At a distance of 2 feet 8 inches above bed IX. a line of phosphatic nodules is met with, in which *Plicatula pectinoides* occurs in good condition and in large quantities.

At the base of this bed *Rostellaria maxima* *, the largest known *Rostellaria* from the Gault, was procured.

Between the last-mentioned seam of phosphatic nodules and the line of nodules containing *Pecten Raulinianus,* forming the base of bed XI., the clay, which has a thickness of 2 feet 5 inches, is much mottled. *Pentacrinus Fittoni* occurs in masses, whereas in all other parts of the Gault it is only found in fragments. *Cidaris gaultina* is only met with between these two lines of nodules.

Many pieces of bones of Chelonians and fishes are obtained from the same horizon.

Upon two separate occasions Griffiths has discovered in this zone,

* See Geol. Mag. March 1873, vol. x. pl. vi.

between the two lines of nodules, crushed bodies which have been supposed by some to be the eggs of a species of turtle; they are more or less round, possessing the texture of egg-shells. Mr. J. S. Gardner has two specimens in his collection; and I have one, which I showed to Mr. J. W. Hulke, who reported that he did not think it was a Chelonian egg at all, but that of a crocodile, and that in the coarse pitting of the shell it most resembles that of *Crocodilus biporcatus*.

The following fossils may be considered peculiar to this bed:—

Goniaster, sp.
Kingena lima, *D'Orb.*
Hinnites, sp.
Astarte, sp. (*A. omalioides*, J. S. Gardn. MS.).

Many teeth and dorsal spines of *Hybodus*, and teeth of *Otodus appendiculatus*, are found in it.

From the frequency of occurrence of *Kingena lima*, D'Orb., in this zone, I adopt the conclusion arrived at by Mr. De Rance, and propose to name the bed the zone of *Kingena lima*.

Bed XI.

This bed consists of a marl of a cold pale grey colour, traversed by a series of partings, the smooth portions between which are coated over with a smear of oxide of iron. Some difficulty was experienced in finding the whole of this bed *in situ*, though equal in thickness to more than half the Gault. We therefore measured from the seam of phosphatic nodules containing *Pecten Raulinianus*, the base of bed XI., up to the base of the dark greensand seam which traverses this bed, and found that it had a thickness of 35 feet 6 inches. This measurement was taken in that part of Eastweir Bay, eastward of Copt Point, known as the Pelter.

As the upper portion of the greensand seam was wanting at this point, it having slipped off together with the upper part of the bed, we went slightly to the east of Copt Point, and southwards of Martello Tower No. 3, where the top of the Gault is *in situ*, capped by the Upper Greensand. We found the base of the greensand seam by excavating a trench down the cliff-side; we then took measurements of this seam (which, I may mention, Griffiths calls the "Middle Greensand," by no means an inappropriate term), and found that it had a thickness of 3 feet 3 inches. From the top of this seam to the base of the Upper Greensand was found to measure 17 feet 6 inches, thus giving a thickness of 56 feet 3 inches for bed XI., and a total thickness for the whole deposit of 99 feet 4 inches.

In this greensand large quantities of nodules occur in lines, which may be pyriform sponges; also a small species of *Inoceramus* (perhaps a young form of *concentricus*), *Aporrhais Orbignyana*, *Trochocyathus conulus*, *Pecten orbicularis*, *Belemnites ultimus*, *Ammmonites Goodhalli*, *Avicula gryphæoides*, *Pollicipes* —— ?, and *Plicatula sigillina*, fixed to Ammonites, an Ammonite allied to *A. lautus*, *Drephanephorus canaliculatus*, *Ichthyosaurus campylodon*, &c.

The Gault immediately above this greensand seam is of the same marly character as that below, only much mixed with grains of sand for the first few feet.

The bed No. XI. contains but few fossils which are entitled to be regarded as peculiar to it; they are as follows:—*Ostrea frons, Ptychoceras, Hylospongia* of Sollas, only met with just below the greensand seam; *Inoceramus Crispii,* a large smooth species, and *Ammonites varians* ? occurring above the greensand seam.

Ammonites rostratus is found of large size in this zone, often having *Plicatula sigillina* adhering to it. I have frequently met with this Ammonite measuring as much as 12 inches in diameter. *Ammonites Goodhalli* likewise attains a very large diameter.

Belemnites are rarely found at all above the greensand seam.

For the following analysis of the Gault of bed XI. I am indebted to Mr. W. H. Hudleston, who has taken considerable time and trouble in working it out for me.

"It consists of a pale grey marl, the particles in a minute state of subdivision. The bulk of the mass is a mixture of chalk and clay; a very few, and extremely small, quartz grains, and, after treatment with acid, one or two translucent greenish grains were observed; also small crystals and fragments of pyrites.

"Dried at 100° C. this sample contains:—

	per cent.
Water and organic matter	6·75
Carbonate of lime	26·45
Clay-sand and silica, oxides of iron, pyrites, &c. ..	65·95
Chloride of sodium, Sulphate of lime, Carbonate of magnesia } found, but not estimated ..	·81
Phosphoric acid	·04
	100·00

Metallic iron 2·55 per cent."

There is an enormous field open in the Gault to the palæontologist; and it is to be hoped that the day is not far distant when the large quantity of material obtained and still to be obtained from the Gault in various parts of England, more especially at Folkestone, will be exhausted, and some valuable monographs will be prepared for the Palæontographical Society.

The data the palæontologist has at present to fall back upon are principally works, very able in their way, which have been produced by foreign geologists upon foreign species. Those few scattered specimens from the Gault that have been figured by English authors have been mostly from very imperfect specimens.

Besides the fossils here enumerated, there are many forms which it is difficult at present to assign to any genus.

I may add that there are many fish-remains (which occur mostly in the upper division) wholly undescribed. The species of the class Cephalopoda require entirely reworking out, more particularly the Hamites, which have been described by Messrs. Sowerby, Pictet, and others from fragments, and the specimens procured from Folkestone are frequently quite perfect; thus any one undertaking the task of producing a monograph upon this genus would have fewer difficulties to contend with than those authors who have already described them from imperfect data.

On some New Species of Gault fossils.

The first species I have to describe is well known to collectors of Gault fossils, and has been, if I mistake not, erroneously considered *Ringinella lacryma*, D'Orb. Pal. Fr. pl. 167. figs. 21–23, which species is never found in this country. Upon close examination and comparison with the figures of *R. lacryma*, D'Orb., and of *Avellana lacryma*, in Pictet et Campiche, Pal. Suisse, Environs de Sainte-Croix, p. 198, 2nd part, it does not agree, inasmuch as the specimens I have had to refer to in the collection of the Museum of Practical Geology and my own cabinet are of uniform size and smaller than those figured by the before-named palæontologists, besides other differences, to which I shall presently allude.

The following is the description :—

Shell ovate, thick. Spire formed of a regular angle composed of convex whorls usually five in number ; body-whorl occupying three fourths of the whole shell ; sutures somewhat canaliculated. Two folds on the columella ; aperture narrow. Outer lip thickened and reflected, emarginate and denticulated on the inside. Shell ornamented by fine horizontal lines composed of small ovate punctures, with spaces between of about three fourths of a millimetre in breadth ; these spaces are quite smooth, having usually from 15 to 20 lines on the body-whorl. The spaces between the punctate lines become broader in the middle of the body-whorl ; in some instances they acquire their greatest breadth at the posterior portion of the body-whorl.

Length of shell 10 millims. ; breadth of shell 6 millims.

This fossil is frequently met with in beds VII., VI., IV., and III. in the Lower Gault of Folkestone ; I propose to name it *Avellana pulchella*. The genus *Avellana*, D'Orbigny, synonymous with *Ringinella*, D'Orb., is divided into two sections by MM. Pictet et Campiche, in 'Pal. Suisse, Environs de Sainte-Croix,' the first section being composed of elongated forms with prominent spires, and the second section of globose forms with short spires.

Of these the following are recorded as having been found in the Gault of England :—

First section.

1. Avellana inflata, D'Orb. pl. 168. figs. 1–4.

= *Auricula inflata*, Fitton, 1836, Trans. Geol. Soc. vol. iv. pl. 11. fig. 11.

= *Cinulia inflata*, S. P. Woodward, Manual of Moll. p. 314.

2. Avellana Clementina, D'Orb. Pal. Franç. pl. 168.

Second section.

3. AVELLANA INCRASSATA, D'Orb. Pal. Franç. Crét. p. 168.
 = *Auricula incrassata*, Mantell, 1822, Sussex, pl. 19. fig. 33.
 = *Auricula incrassata*, Sow. Min. Conch. pl. 163. figs. 1–3.
 = *Ringicula incrassata*, Geinitz, Grundriss der Versteinerungskunde, p. 337, pl. 16. figs. 3 & 4.

4. AVELLANA DUPINIANA ?, D'Orb. Pal. Franç. Crét. pl. 169.

5. AVELLANA PULCHELLA, F. G. H. Price. (Pl. XXV. figs. 4 & 5.)

Besides the above, with the exception of *Avellana pulchella*, the following are found in the Gault of France and Switzerland:—

6. AVELLANA LACRYMA, D'Orb. Pal. Franç. Crét. pl. 167.
 = *Tornatella lacryma*, Mich. 1834, Mag. de Zool. cl. v. pl. 33.
 = *T. affinis*, Leymerie, 1842, Mém. de la Soc. Géol. t. v. p. 31.
 = *Auricula acuminata*, Deshayes, 1842; Leymerie, Mém. de la Soc. Géol. p. 12, pl. 16. fig. 1.

7. AVELLANA VALDENSIS, Pictet et Campiche, Pal. Suisse, Environs de Sainte-Croix.

8. AVELLANA ALPINA, Pictet et Roux, Moll. des Grès verts, p. 172.

9. AVELLANA SUBINCRASSATA, D'Orb. Prodr., & Pal. Franç. Crét. pl. 168 (not Sowerby).

10. AVELLANA HUGARDIANA, D'Orb. Pal. Franç. Cret. pl. 168.

11. AVELLANA BANDONIANA, Cotteau, 1854, Moll. Foss. de l'Yonne.

12. AVELLANA OVULA, D'Orb. Pal. Franç. Cret. pl. 169.

Avellana pulchella approaches very near to *Avellana alpina*, Pict. et Roux, but does not possess such a long spire, and differs from it in ornamentation or sculpture; inasmuch as that of *A. alpina* is composed of slightly elevated ridges with little square punctures, whereas in *A. pulchella* the ridges are not raised but simply marked with small ovate punctures.

It will be seen from the above note that this shell differs essentially from any of the figured species of *Avellana*, although possessing certain affinities, inasmuch as the size, ornamentation, the thick reflected outer lip, the denticulation on the inside of the outer lip, &c. are not found embodied in any other species.

NATICA OBLIQUA, F. G. H. Price *. (Pl. XXV. fig. 3.)

Shell globose, glossy and almost smooth; the lines of growth very fine, with indications of longitudinal striæ. Spire very short and

* The following is a list of the *Naticæ* known from the Gault, with their synonyms:—

NATICA CLEMENTINA, D'Orb. Pal. Franç. Crét. t. ii. p. 154, pl. 172. fig. 4.
 = *Littorina pungens*, Leymerie.

depressed. Aperture oblique, ovate, the length being nearly double the width. Inner and outer lips nearly parallel. Outer lip thin; the inner lip, which is somewhat reflected over the umbilicus, is callous and broader at its upper part, where it forms an angle at the point where it joins the body-whorl.

Umbilicus shallow and open.

	millims.
Length of shell	12
Breadth of shell	10
Length of aperture	9
Breadth of aperture	4½

This shell has only been met with in bed IV. of the Lower Gault, Folkestone.

A large *Nucula* occurs in the Gault of bed II., which is not met with elsewhere; this I have always considered to be a new and undescribed species, since I carefully examined the figure and description given by D'Orbigny of *Nucula ovata* in the Pal. Franç. Crét. tom. iii. p. 173, purporting to be Mantell's species. I then found that he has mistaken the large species, which is peculiar to bed II. at Folkestone, for what has always been taken as the typical form of *Nucula ovata*, Mantell, which has a range throughout the Lower Gault.

These two separate species are constant in form, and differ as much the one from the other as it is possible for two *Nuculæ* to do. If this large form, which is figured by D'Orbigny, be taken as the *Nucula ovata* of Mantell, then that which has hitherto been considered *Nucula ovata* by all English palæontologists, and which is found throughout the Gault of the south-east of England, and does not appear to occur at all in France (that is to say, it has not been described by D'Orbigny), is a separate and distinct species. But this latter fossil is the typical English Gault form of *Nucula ovata*, and was named, described, and badly figured by Dr. Mantell

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NATICA GAULTINA, D'Orb. Pal. Franç. Crét. t. ii. p. 156, pl. 173. figs. 3 & 4.

= *Ampullaria canaliculata*, Mantell, 1822, Geol. of Sussex, pl. 19. fig. 13, p. 87.

= *Natica canaliculata*, Fitton, 1836, Tr. Geol. Soc. ser. 2, vol. iv. pl. 11. fig. 12.

The above two species are common in the Gault of England. *Natica Clementina* is met with in beds VI. and VII. of the Lower Gault; whereas *N. gaultina* has a wider range, being first found in the zone of *Ammonites interruptus* at the base of the Gault, and passing all through the various beds up to the top.

There are four other species obtained from the Gault of France, which have not been recorded as occurring in the English Gault. They are:—

NATICA DUPINII, Leymerie, 1842, Mém. de la Soc. Géol. t. v. p. 13, pl. 16. fig. 7.

NATICA EXCAVATA, Michelin, 1836, Mém. de la Soc. Géol. t. iii. pl. 12. fig. 4.

NATICA ERVYNA, D'Orbigny, Pal. Franç. Crét. t. ii. p. 159, pl. 173. fig. 7.

NATICA RAULINIANA, D'Orbigny, Pal. Franç. Crét. t. ii. p. 160, pl. 174. fig. 1.

in his Geology of Sussex, pl. xix. f. 26, 27, in the year 1822, and also badly figured by Phillips in his 'Yorkshire' in 1829; whereas the *Nucula ovata* erroneously described as that of Mantell in the Pal. Franç. Crét. t. iii. p. 173, was published in the year 1843 by D'Orbigny, twenty-one years later *.

Therefore, following the rules of priority, the *Nucula ovata* of Mantell, figured and described in his 'Geology of Sussex,' must stand good as a species, and the *Nucula ovata* of D'Orbigny must receive a new specific name, as, in my conviction, he made an error in considering it to be identical with that of Mantell.

Below I give a description of this larger form of *Nucula*, which I propose to name *Nucula DeRancei*.

NUCULA DERANCEI, F. G. H. Price. (Pl. XXV. fig. 7.)

Shell ovate, inequilateral, inflated, thick, nacreous, ornamented with delicate concentric striæ; ventral portion furnished with more or less concentric laminæ. Anterior portion of dorsal margin short and angular; posterior long, sloping from umbones to posterior margin. Lunule indistinct; lip of ventral margin very thick; muscular impressions well-marked and callous.

	millims.
Length of shell................	31
Height of shell................	20

This well-marked shell, differing from all other *Nuculæ* in form and size, is only met with in the lower part of bed II., not even extending into the horizon of *Aporrhais calcarata*.

Table of Species of Gault Fossils from Folkestone.

Genera and Species.	Junction.	Lower Gault.						Junction.	Upper Gault.		
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
PLANTÆ.											
Pinites hexagonus, *Carruthers*	...	...	...	...	...	...	...	...	*		
AMORPHOZOA.											
Hylospongia, *Sollas*	...	...	...	...	...	...	...	...	...	...	*
Pyriform sponges	...	...	...	...	...	...	...	...	...	...	*
ZOOPHYTA.											
Bathycyathus Sowerbyi, *Edw. & H.*	...	...	...	...	...	...	...	*			
Cyclocyathus Fittoni, *M.-Edw.*	...	*	...	...	...	...	*	*	*		
Smilotrochus elongatus, *Duncan*	...	...	...	*	*	...	...	...	...	...	*
—— insignis, *Duncan*	...	...	...	*	*						
Trochosmilia sulcata, *Edw. & H.*	...	...	...	...	*	...	...	...	*		
Trochocyathus conulus, *Edw. & H.*	*	...	...	...	...	...	...	...	...	...	*
—— Harveyanus (var. of), *M.-Edw.*	...	*	...	...	...	*	*				

* There is a very fair figure of *Nucula ovata*, Mant., in the 'Tabular view of characteristic British Fossils.'

Genera and Species.	Junction.	Lower Gault.						Junction.	Upper Gault.		
	I.	II.	III.	IV.	V.	VI.	VII.	VIII	IX.	X.	XI.
Echinodermata.											
Cidaris gaultina, *Forbes*	...	...	...	...	...	...	...	...	...	*	
Hemiaster asterias, *Forbes*	*	*	*	...	...	...	...	...	...	*	*
—— minimus, *Ag.*	...	...	...	...	...	...	...	...	...	*	*
Pseudodiadema, sp.	...	*									
—— Wiltshirii ?, *Wright*	...	*	...	...	...	...	...	*	...	*	
Goniaster, sp.	...	...	...	...	...	...	...	...	...	*	
Pentacrinus Fittoni, *Aust.*	...	...	...	...	...	*	*	...	*	*	*
Articulata.											
Serpula articulata, *Sow.*	...	...	...	...	...	...	...	...	*	*	*
—— plexus, *Sow.*	...	...	...	...	...	...	...	...	...	...	*
Vermicularia, sp.	...	...	...	...	...	...	...	*			
Cirripedia.											
Pollicipes lævis, *Sow.*	...	...	...	...	...	...	*	*	*		
—— rigidus, *Sow.*	...	*									
—— unguis, *Sow.*	*	...	...	...	...	...	...	...	...	*	
——, sp.	...	...	...	...	...	...	...	...	...	*	
Crustacea.											
Alpheus ?, sp.	...	...	*								
Diaulax Carteriana, *Bell*	...	...	...	...	...	...	...	...	...	...	*
Etyus Martini, *Mantell*	...	...	...	*	...	...	*	...	...	*	
Homolopsis Edwardsii, *Bell*	...	...	...	...	...	*					
Hoploparia longimana, *Sow.*	...	*	...	...	...	...	...	...	...	*	
——, sp.	...	*	...	...	...	...	...	...	...	*	
——, sp. (minima, *MS.*)	...	...	...	*							
Necrocarcinus Bechii, *Deslong.*	...	...	...	...	...	*					
Palæocorystes Broderipii, *Mant.*	...	...	*	*	...	*	*				
—— Stokesii, *Mant.*	...	...	*	*	...	...	*	...	*	*	
Brachiopoda.											
Kingena lima, *D'Orb.*	...	...	...	...	...	...	...	...	...	*	
Terebratula biplicata, *Sow.*	...	...	...	...	...	...	...	*	*	*	*
——, sp.	...	...	...	...	...	...	...	...	...	*	
Lamellibranchiata Monomyaria.											
Anomia, sp.	*	*	...	...	...	*	...	...	...	...	*
——, sp.	...	...	...	...	*						
Avicula, sp.	...	...	...	...	...	...	...	*	*	*	
—— cenomanensis, *D'Orb.*	...	...	...	...	...	...	...	...	...	...	*
——, sp.	...	...	...	*	...	...	...	*			
—— gryphæoides, *Sow.*	...	...	...	...	...	...	...	...	...	...	*
Exogyra conica, *Sow.*	...	*	...	...	...	...	*	*	...	...	*
Gervillia solenoides, *Defrance*	...	...	*	*	*	*	*	*			
Hinnites, sp.	...	...	...	...	...	...	...	...	...	*	
Inoceramus concentricus, *Park.*	*	*	*	*	*	*	*	*	*	*	*
—— Crispii, *Mantell*	...	...	...	...	...	...	...	...	...	...	*
—— sulcatus, *Park.*	*?	...	...	...	...	...	...	*	*		
—— subsulcatus, *Wiltshire*	...	...	...	...	...	...	...	...	*		
——, sp.	...	...	...	...	...	...	...	...	...	...	*
Lima globosa, *Sow. M. C.*	...	*	...	...	...	...	...	...	*		
—— parallela, *Sow. M. C.*	...	*	...	...	...	...	*	...	*		
Pecten Beaveri, *Sow. M. C.*	...	...	...	...	...	...	...	...	...	*	
—— orbicularis, *Sow. M. C.*	*	...	...	...	...	...	...	...	...	...	*
—— quinquecostatus, *Sow. M. C.*	*	*	...	...	...	...	*	...	...	*	

Genera and Species.	Junction.	Lower Gault.						Junction.	Upper Gault.		
	I.	II.	III.	IV.	V.	VI.	VII.	VIII	IX.	X.	XI.
Pecten Raulinianus, *D'Orb.* ...	...	...	...	...	...	...	...	*	...	...	*
—— ——, allied to	*										
——, sp.	...	...	...	...	...	...	...	...	*		
——, sp.	*	...	...	...	...	...	...	*			
—— rhotomagensis?, *D'Orb.* .	...	*	*								
Perna Rauliniana?, *D'Orb.* ...	*										
Pinna tetragona, *Sow. M. C.*...	...	*	*	*	...	*					
——, sp.	...	...	...	...	*	*					
Plicatula pectinoides, *Sow. M. C.*	*	*	*	...	...	*	...	*	...	*	*
—— sigillina, *Wood*	...	...	...	...	...	...	...	...	...	...	*
Ostrea canaliculata, *D'Orb.* ...	...	...	...	...	...	...	...	*	...	*	*
—— frons, *Park.*	...	...	...	...	...	...	...	...	...	...	*
LAMELLIBRANCHIATA DIMYARIA.											
Arca nana, *D'Orb.*	...	*	...	...	...	...	*	*			
—— Hugardiana, *D'Orb.*	...	...	*	...	...	...	...	...	...	*	*
Astarte Dupiniana, *D'Orb.* ...	...	...	...	...	*						
——, sp. (omalioides, *Gardner, MS.*)	...	...	...	...	...	...	...	...	...	*	*
Cardita rotundata, *Pict.*	...	...	...	...	*	...	*	*			
—— tenuicosta, *Sow. G. T.* ...	...	...	...	...	*	...	*	*	*	...	*
Corbula elegans, *Sow. M. C.*...	...	...	*	...	...	*	...	...	*		
—— gaultina, *Pict. et Camp.* .	...	*									
Cucullæa carinata, *Sow. M. C.*	...	*	...	...	...	...	...	*	*	*	
—— glabra, *Park.*	...	...	...	...	...	...	...	*			
Cyprina quadrata, *D'Orb.*	...	...	...	...	...	...	...	*			
Leda solea (allied to), *D'Orb.* .	...	*	*	...	*	...	*				
Lucina tenera, *Pict. et Camp.* .	...	*									
—— sculpta, *Phil.*	...	...	...	...	...	*					
Lyonsia?	...	...	...	...	...	...	*				
Myacites plicatus, *Sow.*	...	*									
Mytilus Galliennei, *D'Orb.* ...	...	...	*	...	...	...	...	*			
Nucula albensis, *D'Orb.*	...	...	...	...	...	...	*				
—— arduennensis, *D'Orb.* ...	...	...	...	...	*						
—— bivirgata, *Fitton, G. T.*...	...	...	...	...	...	...	*	*			
—— De Rancei, *Price*	...	*									
—— impressa, *Sow. M. C.* ...	...	...	...	...	...	*	*				
—— Mariæ, *D'Orb.*	...	*	...	*	*	*					
—— ornatissima, *D'Orb.*	...	...	...	...	...	...	*	*			
—— ovata, *Mantell*	*	*	*	*	*	*	*	*	*	*	*
—— obtusa, *Sow. G. T.*	...	*	...	...	...	...	*	*			
—— pectinata, *Sow. M. C.* ...	*	*	*	*	*	*	*	*	*	*	*
—— subrecurva, *Phil.*	...	...	...	*	*						
—— Vibrayeana, *D'Orb.*	...	...	...	...	*	...	*	*			
Pectunculus, sp.	...	*									
——, sp.	...	...	...	...	...	*					
Pholas rhodani, *Pict. et Camp.*	...	...	...	...	...	..	...	*			
—— sanctæ crucis, *Pict. et Camp.*	...	*	...	...	...	...	...	*			
——, sp. nov.	...	...	...	...	...	...	...	*			
Pholadomya fabrina, *D'Orb.*...	...	...	...	...	...	...	...	*	*		
Thracia simplex?, *D'Orb.*	...	*	...	...	...	...	*				
Tellina phaseolina, *Pict. et Camp.*	...	*	...	...	...	*					
——, sp.	...	...	*	...	...	...	*				
Teredo (tube of)	*	...	...	...	...	...	...	*			

Genera and Species.	Junction.	Lower Gault.						Junction.	Upper Gault.		
	I.	II.	III.	IV.	V.	VI.	VII.	VIII	IX.	X.	XI.
Thetis Sowerbyi, *Römer*	...	...	...	*	...	*	*				
Trigonia Fittoni, *Desh.*	*										
—— —— (var.)	*										
ENCEPHALA.											
GASTEROPODA.											
Siphonostomata.											
Aporrhais calcarata, *Sow.*	...	*									
—— Orbignyana, *Pict. et Roux*	*	*	*	*	*	*	*	...	*	*	*
—— Parkinsoni, *Sow. M. C.*	...	...	...	...	...	...	*				
Rostellaria carinata, *Mantell*	...	*	...	...	*	*	*	*	*		
—— carinella, *D' Orb.*	...	...	...	...	...	*	*				
—— cingulata, *S. P. Woodward*	...	...	...	...	...	*	*	*			
—— elongata ?, *Sow.*	...	...	...	...	...	*	*				
——, sp. (Griffithi, *Gardner, MS.*)	...	...	...	...	...	*	*				
—— maxima, *Price*	...	...	...	...	...	...	...	...	...	*	
Pteroceras bicarinatum, *D' Orb.*	...	*	*								
Fusus elegans, *D' Orb.*	...	...	...	...	...	*					
—— Itierianus, *D' Orb.*	...	*									
—— indecisus, *D' Orb.*	...	...	...	...	*	...	*				
—— gaultinus, *D' Orb.*	...	...	...	...	*						
——, nov. sp.	...	...	...	...	...	...	*				
Murex bilineatus ?, *Pictet*	...	...	...	...	...	...	...	*	*		
—— calcar, *Sow.*	...	...	...	...	...	...	...	*			
Pyrula Smithii, *Sow. G. T.*	*										
Buccinum gaultinum, *D' Orb.*	...	...	...	...	...	...	*	*			
Holostomata.											
Narica cancellata, *Chemn.*	...	*									
Natica Clementina, *D' Orb.*	...	...	...	*	*	*	*				
—— gaultina, *D' Orb.*	...	*	...	...	*	...	*	*	...	*	*
—— obliqua, *Price*	...	...	...	*							
—— ? an operculum	...	...	...	...	*						
Cerithium Dupinianum, *D' Orb.*	...	...	...	...	*						
—— ervynum, *D' Orb.*, no loc.											
—— Phillipsii ?, *Leym.*	...	...	...	...	...	...	*				
—— subspinosum ?, *Desh.*	...	...	...	...	*						
—— tectum, *D' Orb.*	...	...	...	...	...	...	*				
—— trimonile, *Mich.*	...	*									
——, sp.	...	*	*								
——, sp.	...	*									
——, sp.	...	...	...	...	...	...	*				
——, sp.	...	...	...	...	...	*					
Scalaria Clementina, *D' Orb.*	...	*	...	...	...	...	...	*			
—— Dupiniana, *D' Orb.*	...	...	...	*	...	...	*	...	...	...	*
—— gastyna, *D' Orb.*	...	...	...	...	...	*					
—— gaultina, *D' Orb.*	...	...	...	...	...	...	...	*			
Turritella granulata, *Sow.*	...	...	*	...	...	...	*				
Solarium albense, *D' Orb.*	...	...	...	*	*						
—— conoideum, *Sow.*	...	...	...	...	*	*	*	*			
—— dentatum, *D' Orb.*	...	...	...	...	...	...	...	...	*		
—— moniliferum, *Mich.*	...	...	...	*	*						
—— ornatum, *Sow.*	...	...	*	...	...	*	*	*	*	*	*
Rissoina incerta, *D' Orb.*	...	*	...	*	*	*					

Genera and Species.	Junction.	Lower Gault.						Junction.	Upper Gault.		
	I.	II.	III.	IV.	V.	VI.	VII.	VIII	IX.	X.	XI.
Phasianella ervyna, *D' Orb.*	...	...	...	...	*	*					
Turbo Brunneri ?, *Pict. et Camp.*	...	...	...	...	...	...	...	...	*		
Pleurotomaria Gibbsii, *Sow.*	...	...	...	...	...	...	...	...	*	*	
Acmæa tenuicosta, *D' Orb.*	...	*	...	...	*	*	*	*			
Dentalium decussatum, *Sow.* = ellipticum ?, *Sow.*	...	*	...	*	*	...	...	*	*	...	*
Avellana Dupiniana ?, *D' Orb.*	...	...	...	...	...	...	*				
—— inflata, *D' Orb.*	...	...	...	...	*	*	*				
—— pulchella, *Price*	...	...	*	*	*	*	*				
Actæon affinis, *D' Orb*	...	...	...	...	*	*					
Bellerophina minuta, *Sow. M. C.*	...	...	...	...	*	*	*				
CEPHALOPODA.											
Ammonites auritus, *Sow. M. C.*	...	*	...	...	...	*	*	*			
—— ——, a var.	...	...	*	...	*	*	*				
—— ——, a var. spined	...	*									
—— Beudantii, *Brong*	...	...	...	...	...	...	...	*			
—— Brongniartianus ?, *Pictet.*	*	...	...	...	...	...	...	*			
—— Bouchardianus, *D' Orb*	...	...	...	...	...	...	...	*	*		
—— cristatus, *Deluc*	...	...	...	...	...	...	...	*	*		
—— cornutus, *Pictet*	...	...	...	...	...	*	...	*			
—— Delaruei, *D' Orb.*	...	...	...	*							
—— denarius, *Sow. M. C.*	...	...	*	...	*	*	*	...	*		
—— Deshayesii, *Leym*	...	*									
—— Goodhallii, *Sow.*	...	...	...	...	...	...	...	...	...	...	*
—— interruptus, *Brug* / —— ——, var. Benettianus, *Sow*	*										
—— Itierianus, *D' Orb*	...	...	...	...	...	...	...	*			
—— lautus, *Sow. M. C.*	...	...	...	...	*	*	*	*			
—— ——, var.	...	...	...	...	...	...	...	*	*	...	
—— Mayorianus, *D' Orb.*	...	...	...	...	...	...	...	...	...	*	*
—— Roissyanus, *D' Orb.*	*										
—— rostratus, *Sow.*, = inflatus, *D' Orb*	...	...	...	...	...	...	...	...	*	*	*
—— Selliguinus ?, *Brongn.*	...	...	...	...	...	...	...	*			
—— splendens, *Sow. M. C.*	...	*	...	...	...	...	*	*			
—— ——, var., grooved	...	...	...	...	...	...	...	*			
—— tuberculatus, *Sow*	...	...	...	...	*	...	...	*			
—— ——, var. ?, very long spines	...	...	...	*							
—— varicosus, *Sow.*	...	...	...	...	...	...	...	*	*	*	
—— varians ?, *Sow.*	...	...	...	...	...	...	...	...	...	...	*
——, sp.	...	...	...	...	...	...	...	...	...	...	*
——, sp.	...	...	*	*							
——, sp.	...	...	...	*							
——, sp.	...	...	...	...	...	...	*				
——, sp.	...	...	...	*							
Ancyloceras spinigerum, *Sow.*	...	*									
Baculites, sp.	...	...	...	...	...	*	*				
Belemnites attenuatus, *Sow.*	...	...	...	...	*	*	*	*			
—— minimus, *Lister*	*	*	...	...	...	*	*	*	*		
—— ——, with phragmocone	...	...	...	...	*	*	*				
—— ultimus, *D' Orb*	*	*	...	...	*	*	*	*	...	...	*
—— ——, with phragmocone	...	...	...	...	...	...	*				
Crioceras Astierianum, *D' Orb.*	*										

Genera and Species.	Junction.	Lower Gault.						Junction.	Upper Gault.		
	I.	II.	III.	IV.	V.	VI.	VII.	VIII	IX.	X.	XI.
Hamites armatus, *Sow.*	...	...	...	...	...	...	...	...	...	...	*
—— attenuatus, *Sow*	...	...	*	...	*	*					
—— elegans, *D' Orb.*	...	*									
—— maximus, *Sow.*	...	...	...	...	...	...	*	*			
—— rotundus, *Sow.*	*										
Nautilus Bouchardianus, *D' Orb.*	*	...	...	...	...	...	...	*			
—— Clementinus	*	...	*	...	*	*	*	*	*		
——, sp.	...	...	...	...	...	...	...	...	...	*	
——, sp.	...	...	...	...	...	...	...	*			
Rhynchoteuthis quinquecarinatus ?, *Pict. et Camp.*	...	...	...	...	...	...	...	...	*		
Ptychoceras, sp.	...	...	...	...	...	...	...	...	...	...	*
Scaphites æqualis, *Sow.*	...	...	...	...	...	...	...	...	*	*	*
Turrilites elegans, *D' Orb.*	...	*									
—— Hugardianus, *D' Orb*	...	...	...	...	...	*					
——, sp.	...	...	...	...	...	...	...	...	*		
——, sp.	...	...	...	...	...	...	...	...	...	...	*
Toxoceras, sp.	...	...	...	...	...	...	...	...	...	*	*
Pisces.											
Drepanephorus canaliculatus, *Eg.*	...	...	...	...	...	...	...	...	...	...	*
Edaphodon Sedgwicki ?, *Ag.*	...	...	...	...	...	...	...	*			
Fish: ear-bones, scales, vertebræ, &c.	*	*	...	*	*	...	*	*	*	*	*
——: jaw (undescribed)	...	...	...	...	...	...	*				
——: ,, (undescribed)	...	...	...	...	...	...	...	*			
——: tooth (undescribed)	...	...	...	...	...	...	...	*	*		
——: ,, (undescribed)	...	...	...	...	...	...	...	...	*		
Hybodus, teeth and dorsal spine	...	...	...	...	...	...	...	...	...	*	*
Ischyodus brevirostris, *Ag.*	...	...	...	...	...	...	...	*			
Otodus appendiculatus, *Ag.*	...	*	...	...	...	*	...	...	...	*	*
—— ——, large	...	...	*								
Pachyrhizodus glyphodus, *Blake & Mackie*	...	...	...	...	...	...	...	*			
Pisodus ?, palate	...	...	...	...	...	*					
Ptychodus, sp.	...	...	...	...	...	...	...	*			
Saurocephalus lanciformis, *Harlan*	...	...	...	...	...	...	...	*	...	*	*
Reptilia &c.											
Chelonian bones	...	...	...	...	...	...	...	...	*	*	*
Crocodilian ? egg	...	...	...	...	...	...	...	...	...	*	
Ichthyosaurian vertebræ	*										
Plesiosaurian vertebræ	*	...	...	...	...	...	...	*	...	...	*
Polyptychodon interruptus, *Owen*	...	...	...	...	...	...	*	...	*		
Pterodactylus, sp.	...	...	...	*	...	...	...	*			
Rhinochelys (lower jaw), *Seeley*	...	...	...	...	...	...	...	...	...	...	*
Pearl	...	...	...	*							
Quartz pebbles	...	...	...	...	...	...	*	...	...	...	*

The following are additional species in the collection of Mr. J. S. Gardner, F.G.S., for which I have no localities :—

Opis, sp. Emarginula, sp. Neæra sabaudiana ?

Table of Beds of the Gault at Folkestone.

No. of Bed.	Nature of Bed.	Measured from	Measured up to the	Thickness of Beds. feet	in.	Zones.	Characteristic Fossils.
XI.	Pale, cold grey marl, with a seam of greensand 3 feet 3 in. thick running through it.	A line of nodules containing *Pecten Raulinianus.*	Upper Greensand.	56	3	*Ammonites rostratus.*	*Inoceramus Crispii, Pecten Raulinianus, Ammonites Goodhallii, A. rostratus, A. varians.*
X.	Hard marl of a pale grey colour.	The crushed band of *Inoceramus sulcatus.*	Line of nodules containing *Pecten Raulinianus.*	5	1	*Kingena lima.*	*Cidaris gaultina, Hemiaster minimus, Kingena lima, Terebratula biplicata, Pentacrinus Fittoni, Plicatula pectinoides, Ammonites rostratus.*
IX.	Pale grey marly clay.	Second line of nodules in bed VIII.	*Inoceramus - sulcatus* cast-bed.	9	4½	*Ammonites varicosus.*	*Inoceramus sulcatus, I. subsulcatus, Ammonites varicosus, A. rostratus.*
VIII.	Clay darker than above, containing two lines of nodules and *remanié* fossils.	First line of nodules at the top of bed VII.	Second line of nodules.	0	9½	*Ammonites cristatus.*	*Pholas sanctæ crucis, Mytilus Galliennei, Cucullæa glabra, Cyprina quadrata, Ammonites Beudanti, A. cristatus.*
VII.	Dark clay, highly fossiliferous.	Hard seam at top of bed VI.	First line of nodules.	6	2	*Ammonites auritus.*	*Nucula bivirgata, N. ornatissima, Aporrhais Parkinsoni, Fusus indecisus, Pteroceras bicarinatum.*

VI.	Mottled with lightish marking on dark clay.	Top of coral-bed V.	Hard seam, top of bed.	1	0	*Ammonites denarius.*	*Necrocarcinus Bechei*, *Turrilites Hugardianus*, *Ammonites cornutus* (small var.), *A. denarius.*
V.	Spotted with light markings on darkish ground.	Line of nodules containing rolled casts in phosphate.	Line where the clay becomes more mottled.	1	6	*Ammonites lautus.*	*Smilotrochus elongatus*, *S. insignis*, *Solarium moniliferum*, *Phasianella ervyna*, *Ammonites lautus.*
IV.	Slightly lighter than the above, not mottled.	Line of nodules, with backs of crabs &c.	Line of phosphatic nodules and rolled casts.	0	4	*Ammonites Delaruei.*	*Natica obliqua*, *Dentalium decussatum*, *Fusus gaultinus*, *Ammonites Delaruei*, *Avellana pulchella.*
III.	Light fawn-coloured clay.	Top of black bed II.	Line of nodules, containing backs of crabs &c.	4	6	Crustaceans.	*Palæocorystes Stokesii*, *P. Broderipii*, *Leda* allied to *solea*, *Pinna tetragona*, *Hamites attenuatus.*
II.	Very dark clay; fossils bearing high colours.	Band of crushed fossils above the zone of *Ammonites interruptus.*	Base of light bed III.	4	3	*Ammonites auritus*, var.	*Pollicipes rigidus*, *Pectunculus*, *Lucina tenera*, *Corbula gaultina*, *Arca nana*, *Nucula pectinata*, *Cerithium trimonile*, *Fusus Itierianus*, *Aporrhais calcarata*, *Ammonites auritus*, var.
I.	Dark clay, dark greensand, and iron nodules.	Nodules of sulphuret of iron, top of Neocomian beds.	Band of crushed fossils &c.	10	1	*Ammonites interruptus.*	*Ammonites interruptus*, *Crioceras Astierianum*, *Hamites rotundus.*
			Total thickness	99	4		
		Lower Greensand............	Folkestone beds			*Ammonites mammillatus.*	

EXPLANATION OF PLATE XXV.

Fig. 1. *Buccinum gaultinum*, D'Orb. (large specimen, decorticated).
2. —— —— (small specimen, with shell preserved).
3. *Natica obliqua*, Price, enlarged.
4. *Avellana pulchella*, Price, front view, enlarged.
5. —— ——, back view, enlarged.
6. *Nucula ovata*, Mantell.
7. —— *De Rancei*, Price.

Discussion*.

The Rev. T. Wiltshire remarked that the various beds were frequently divided by lines of nodules, especially towards the bottom, and that these nodules had definite forms in the different belts, in some being all rounded, in others radiate. He thought it was very desirable to ascertain the reason of this. With regard to *Ammonites rostratus*, he stated that its aperture was beaked in the young as well as in the adult state, and remarked that information as to its mode of growth, and especially whether the successive beaks were absorbed, would be of much interest. He also referred to the unexplained fact that a bed at the base of the Gault contains both shells and casts.

Mr. Carruthers referred to the discovery in the Gault of Folkestone, by Messrs. Gardner and Price, of cones belonging to two species of *Sequoia*, and, associated with these, some species of *Pinus*, two of which were to be referred to a group of that genus at present found associated with the two existing species of *Sequoia* on the mountains of western North America. These *Sequoiæ* from the Gault are the oldest known representatives of the genus; and it is remarkable that they should be thus early associated with species of the same group of Pines which is now represented only in the same country where the *Sequoiæ* also grow. Mr. Carruthers believed this to be the earliest trace of the geographical distribution of plants which now exist on the surface of the earth.

Mr. Topley remarked that the lithological and stratigraphical break between the Gault and the Neocomian is less marked than is generally supposed. At a place near Folkestone the lithological difference is so small that it becomes difficult to say where the one ends and the other begins. At Folkestone the highest beds of the Neocomian are false-bedded sands; and, contrary to what might be expected, these sands are the most constant of the series, always occurring where the Neocomian is represented below the Gault. As the Gault is traced westwards we come to places where it is difficult to discern any difference between it and the Neocomian. He stated that Prof. Way had found the exterior of the nodules to contain more phosphate of lime than the interior, which seemed to indicate that the phosphate came from without.

Mr. Charlesworth doubted whether the fossil egg, if that of a Crocodile, could be that of a living species. With regard to the

* This discussion also relates to Mr. Meyer's paper "On the Cretaceous Rocks of Beer Head."

forms of nodules, he remarked that in the Crag the nodules round the fang-like bases of sharks' teeth were more or less globular; and he did not think that the form of nodules has any relation to that of the nucleus around which they may have been aggregated.

Mr. Hawkins Johnson considered the nodules to be due to organic structures, probably sponges, which had grown upon a hard bottom, and afterwards been affected by its mineral constituents.

Mr. Teal inquired whether the nodules at the base of the Gault had been rolled.

Mr. Seeley, having examined the supposed Crocodile's egg, declared that from its form it could not be that of a Crocodile, and he did not think it was that of a Turtle. It might possibly be the egg of an *Ichthyosaurus* or *Plesiosaurus*. He stated that he had found nodules of different forms scattered indiscriminately in the Gault, and that his investigations led him to believe that all these nodules had been subjected to wear and tear before coming into their present position. The subdivisions of the Gault recognized at Folkestone would not, he thought, be represented elsewhere; for their mineral characters were found to change greatly towards the west, the Gault itself becoming more sandy and micaceous as it approaches the granitic rocks. He believed that the Blackdown beds represented both the Greensand and the Gault.

Prof. Hughes thought that we should take as the base of the Lower Cretaceous Series the first marine beds which succeed the freshwater deposits of the S.E. of England and rest on the Trias and older rocks in the S.W. He considered them to be deposits formed during a considerable period, as successive parts of an irregular land-surface were being depressed below the sea; so that a shore deposit might be formed at Blackdown while fine sand or clay was being thrown down further out to sea over that part of the south-east of England which had already been submerged to a considerable depth.

Prof. Ramsay observed that the value of such detailed sections, in a palæontological point of view, was very great; and with respect to the physical relations of the Gault and Upper Greensand, he stated that in some parts of England there is lithologically no clear line of demarcation between the two formations; and, in like manner, in some other areas there is no very definite boundary line between the Upper Greensand and the Chalk. He then drew attention to the views originally advanced by Mr. Godwin-Austen, who showed that in this part of the world all these Upper Cretaceous formations were deposited over a great continental area that was being slowly submerged, so that while the Upper Greensand began to be deposited in the sea in one area much of the land still stood above water, and as it got depressed these Greensand strata were gradually deposited on the sinking land. For this reason the two ends, so to speak, of a long section of the Greensand will be of somewhat different age; and while the end nearest the land was being deposited as sand, further out at sea true Chalk was being formed; and thus much of the Upper Greensand may be considered to have been formed contemporaneously with much of the Lower Chalk under different local conditions of proximity of land and depth of water.

Mr. Blake believed that the animal of *Ammonites rostratus* might have lived outside its shell.

Mr. Price stated that he did not wish to imply that the divisions indicated in his paper would hold good over wide areas. He added that bones of Turtle were not unfrequent in the Gault.

Mr. Meyer said that the division between the Gault and Greensand was not distinct. The Beer stone deposited in a hollow to the westward exhibited a change of texture. The upper beds of the Lower Greensand of Folkestone represent a lower horizon of the Lower Greensand at Guildford.

G.H Ford & C.L. Griesbach. Mintern Bros. imp

GAULT FOSSILS.

29. *On the* Cretaceous Rocks *of* Beer Head *and the adjacent* Cliff-sections, *and on the* Relative Horizons *therein of the* Warminster *and* Blackdown Fossiliferous Deposits. By C. J. A. Meyer, Esq., F.G.S. (Read April 29, 1874.)

The Cretaceous rocks which cap the higher ground over a considerable portion of the south-east of Devonshire, and from the partial destruction of which vast beds of gravel have accumulated over the same area, are exposed on the coast-line between Seaton and the west of Sidmouth in numerous fine cliff-sections. The strata thus exposed, while resembling in great measure the various corresponding deposits of other parts of England, possess at the same time a certain *facies* of their own which renders their correlation in part a matter of uncertainty. I purpose to offer in this paper a description of certain of these cliff-sections, to point out the various petrological and palæontological subdivisions of the strata therein exposed, and to leave to the consideration of others the chief point of interest which I have been as yet unable to determine, namely the age of the lowermost deposit.

This paper probably contains little which is not already to be found in the writings of previous observers. But so far as it is the result of independent observation, it may not be without its value.

Reference to Previous Descriptions.

The following papers, to some of which I shall have occasion to refer, are amongst the principal contributions to the literature of the subject:—

De La Beche, Sir H. T. (1822). "Remarks on the Geology of the South Coast of England," &c. Trans. Geol. Soc. ser. 2, vol. i. pp. 40 & 95.

De La Beche, Sir H. T. (1826). "On the Chalk and Sands beneath it (usually termed Greensand) in the vicinity of Lyme Regis," &c. Trans. Geol. Soc. ser. 2, vol. ii. p. 109.

Fitton, Dr. W. H. (1836). "On the Strata between the Chalk and the Oxford Oolite in the South-east of England." Trans. Geol. Soc. ser. 2, vol. iv. p. 233 &c.

De La Beche, Sir H. T. (1839). Ordn. Surv. 'Report on the Geology of Cornwall, Devon, and West Somerset,' p. 237.

Godwin-Austen, R. A. C. (1842). "On the Geology of the South-east of Devonshire." Trans. Geol. Soc. ser. 2, vol. vi. p. 433.

Hutchinson, P. O. (1843). 'The Geology of Sidmouth and of South-eastern Devon.' 8vo. Sidmouth.

Renevier, M. E. (1856). Bull. Soc. Vaudoise Sc. Nat. v. pp. 51, 52.

Whitaker, W. (1870). "On the Chalk of the Southern Part of Devon and Dorset." Quart. Journ. Geol. Soc. vol. xxvii. p. 93.

The Cretaceous rocks in their range westward from the Isle of Wight repose successively on the abraded surface of older and yet older deposits. The Oolitic, the Liassic, the Triassic, and Old-Red-Sandstone strata support in turn the overlying Cretaceous series. In passing westward these Cretaceous rocks diminish steadily, yet at the same time unequally, in thickness. They change slightly, also, both in mineral character and in their fossil contents. From Lyme Regis westward to Axmouth, and from Beer Head again westwards to their last exposure on the coast at Peak Hill, near Sidmouth, the base of the series rises gradually higher in the cliff-sections.

In the face of this prevailing rise of the Cretaceous series to the westward, the Chalk-cliffs of Beer Head, the most westerly chalk promontory in England, owe their preservation in great measure to a local synclinal or trough-like arrangement of the strata.

Many writers on the geology of Devonshire have attributed the present trough-like arrangement of these strata to subsidence since their original deposition. It is not clear, however, that this view is correct; and it may, perhaps, be worth considering presently whether this seeming subsidence is not due in part to an original inequality of the ocean-bed. For the moment I must pass on to other matters.

I. *Cretaceous Rocks represented in the Cliff-Sections of South Devonshire.*

The Cretaceous rocks of the Beer-Head district include the following principal subdivisions:—

Upper Chalk (in part)?
Middle Chalk.
Lower Chalk.
Chalk Marl.
Chloritic Marl.
Upper Greensand.
Gault.
(?)

These broader and generally recognized divisions are split up naturally into many minor beds, either by variation in mineral composition or by the prevalence of a special fauna.

In describing these minor beds, or groups of strata, it may be most convenient to take them in their natural or ascending order, and for facility of reference to number them throughout consecutively.

Description of the minor Subdivisions of the Cretaceous Strata as seen in the Beer-Head and adjacent Sections* (fig. 1).

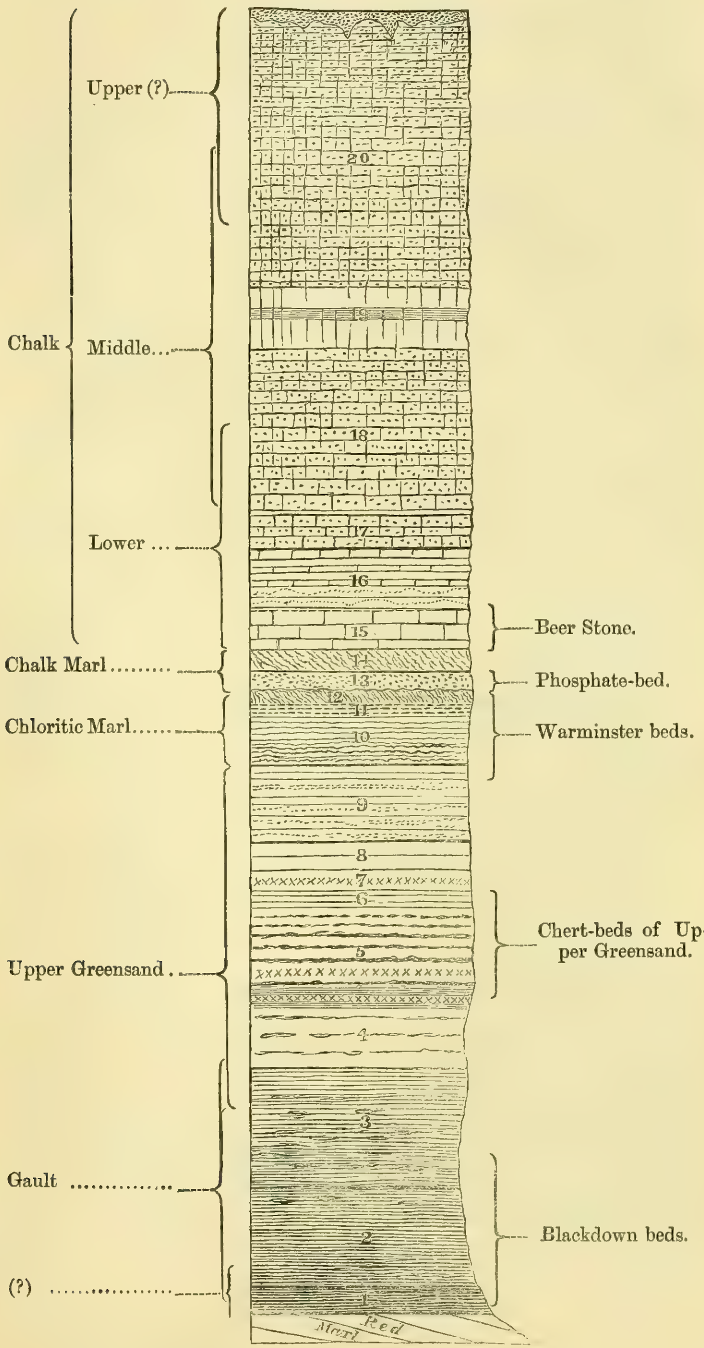
Bed 1.—Greenish sandy argillaceous strata. Including often, near its base, a grit-bed of minute subangular pebbles, or fragments of the underlying rocks.

Thickness variable, usually a few feet only: 3 ft. at White Cliff, $3\frac{1}{2}$ ft. at Dunscombe, $2\frac{1}{2}$ feet at Salcombe Hill.

Prevailing fossil—*Exogyra conica* (small var.).

* The sections here referred to as adjacent sections are:—those of White Cliff and Beer; the Southdown Undercliff, or landslip of 1789; the cliffs at Branscombe Mouth, Weston Mouth, Dunscombe, Salcombe, and Sidmouth.

Fig. 1.—*General Section.* Scale 48 ft. to the inch.



Fossils :—

Exogyra conica, *Sow.* (small var.)	Peak Hill.	Salcombe.	Weston.
Vermicularia concava, *Sow.*	Salcombe.		
Arca carinata, *Sow*	White Cliff.		
Trigonia, sp.	Axmouth.		

This, the well-nigh universal base-bed of the Devon Cretaceous series, is, from its somewhat retentive character, usually the most difficult to examine *in situ.* It may be seen in part at White Cliff, and here and there along the cliffs from Branscombe westward to Peak Hill. It is present also, in much the same condition, at the base of the Blackdown strata at Punchey Down, near Collumpton, and again, further westward, at Haldon.

Bed 2.—Argillaceous sand, with abundance of green earth. Varies in colour from dark greyish to pale brownish green, apparently according to its condition of moisture. Fossiliferous semi-indurated nodules occur near the top of this bed at White Cliff and in places to the westward, and have much resemblance to the "Cow-stones" of Lyme Regis.

Thickness variable: 15 ft. at White Cliff, 25 ft. at Dunscombe, 25 ft. at Salcombe Hill, 20 ft. at High Peak.

Fossils, in places, numerous.

May be seen at White Cliff and in the cliff-sections between Branscombe and High Peak to the west of Sidmouth.

Fossils of bed 2:—

Madrepora (?)	Salcombe.		
Bryozoa (?)	Peak Hill.		
Silicified wood	”		
Epiaster Murchisoniæ, *Mant.*	Axmouth.		
Hemipneustes Greenovii, *Forbes*	”	Peak Hill.	White Cliff.
Fusus quadratus, *Sow.*	Peak Hill.		
Rostellaria Parkinsoni, *Sow.*	”		
Anomia, sp.	”		
Exogyra conica, *Sow.*	”	Salcombe, &c.	
—— undata, *Sow.*	Axmouth.		
Pecten Millerii, *Sow.*	Peak Hill.		
—— orbicularis (small var.)	”	White Cliff.	
Arca carinata, *Sow*	”	Axmouth.	
Cardium Hillanum, *Sow.*	”	White Cliff.	
Cyprina cuneata, *Sow.*	”	Salcombe.	
Inoceramus sulcatus, *Sow.*	”	Axmouth.	
Lucina orbicularis, *Sow*	”	White Cliff.	
Mactra angulata, *Sow.*	”		
Nucula impressa, *Sow.*	”		
—— lineata, *Sow.*	”		
Pectunculus umbonatus, *Sow.*	Dunscombe.	White Cliff.	
Tellina striatula, *Sow*	Peak Hill.		
—— (*or* Psammobia)	”		
Thetis major, *Sow.*	”		
Trigonia (allied to Coquandiana, *D' Orb.*)	”		
—— spectabilis, *Sow*	White Cliff.	Beer Head.	
——, sp.	Dunscombe.	Axmouth.	
——, sp.	Axmouth.		
Venus immersa, *Sow.*	”		
Vermicularia polygonalis, *Sow.*	”		
—— concava, *Sow*	Salcombe.	Peak Hill.	

At White Cliff these fossils occur only as casts and impressions in the indurated nodules. At Branscombe some of them are more perfect. At Peak Hill, where the condition of the bed is slightly different, many of the species occur precisely as at Black down, the shell itself having been replaced by chalcedony.

De La Beche* has recorded many other species as having been obtained from this bed at White Cliff; and he was also one of the first to point out their resemblance to the Blackdown fauna.

Bed 3.—Buff-coloured and greyish marly sands, with large, rounded, and spongiform concretions.

Thickness variable: 40 ft. at White Cliff, 30 ft. at Branscombe, 25 ft. at Dunscombe, 20 ft. at Salcombe.

Fossils scarce.

Fossils :—

Exogyra conica, *Sow.*	White Cliff.	
—— lævigata, *Sow.*	,,	Branscombe, &c.
Pecten orbicularis, *Sow.* (var.)	,,	Axmouth.

This bed may be seen at White Cliff and in all the sections from Branscombe westward to High Peak.

Bed 4.—Light-coloured, yellowish, and slightly marly sands, with irregular concretions.

Thickness about 20 ft.: 25 ft. at White Cliff (?), 20 ft. at Beer Head, 25 ft. at Dunscombe.

Prevailing fossils—*Exogyra columba*, Lam., and *Janira quadricostata*, Sow.

A shingle-bed or layer of *sandstone pebbles*, mingled with the broken valves of *Pecten* and *Exogyra*, occurs in the upper part of these sands at White Cliff. Near Branscombe and at Weston Mouth the broken shells occur without the pebbles.

The White-Cliff section of this portion of the series gives, in descending order :—

(*a*) Argillaceous sand	1 foot.
(*b*) Dark, greyish, sandy clay, with pyrites	1½ ,,
(*c*) Greenish grey sand, crowded with sandstone-pebbles and broken shells	2 feet †.
(*d*) Sands with irregular concretions	20 ,,
Total	25 feet.

Fossils :—

Exogyra columba, *Lam.*
Janira quadricostata, *Sow.*
Pecten orbicularis, *Sow.*
Pecten elongatus, *Lam.*
Vermicularia umbonata, *Sow.*

Bed 5.—Light-coloured sand, with chert in nodules or layers, usually more or less tabular.

Thickness variable: 25 ft. at White Cliff, 20 ft. at Beer Head, 20 ft. at Branscombe, 8 ft. at Weston Mouth, 7 ft. at Dunscombe.

* Trans. Geol. Soc. ser. 2. vol. ii. p. 114.

† This shingle-bed has been thought by some geologists to mark the upper limit of the Gault.

Characteristic fossils—*Exogyra columba*, Lam., and *Janira quadricostata*, Sow.

The diminution in the thickness of these strata to the westward is so considerable that I have thought it advisable to give the sections. They are, in descending order, as follows:—

		ft.	in.
White Cliff	Sand, with chert in layers	12	0
	Bed of sandstone-pebbles, with broken shells	3	6
	Sand, with chert	7	0
Beer Head	Sand, with chert in layers	6	0
	Broken-shell bed	1	0
	Sand, with chert	11	0
Weston	Sand and chert (shattered)	6	0
	Broken shells	0	8
	Chert: an almost continuous layer	1	0
Dunscombe	Chert in sand (shattered)	7	0

At Axmouth the chert and sand about it is crowded with sponge-spicules.

Bed 6.—Light-coloured sand (in places almost white) passing into sandstone.

Thickness variable: 1 ft. at White Cliff, 2 ft. 6 in. at Beer Head, 1 ft. at Branscombe, 6 in. at Weston.

Fossil—*Exogyra digitata*, Sow.

Bed 7.—Sandstone-pebbles, with fragments of large *Ostreæ*.

Thickness 0 ft. at White Cliff, 2 ft. at Beer Head, 1 ft. at Branscombe, (?) at Weston.

Bed 8.—Buff-coloured-sand beds, irregular in structure, with zones of sandstone pebbles.

Thickness variable: 5 ft. at White Cliff, 10 ft. at Beer Head, (?) at Branscombe, 5 ft. at Weston Mouth, 2 ft. at Dunscombe.

Characteristic fossils—*Exogyra digitata*, Sow., and *Orbitolina concava*, Lam.

Fossils:—

Orbitolina concava, *Lam.*	Axmouth. Weston. Beer Head. Branscombe.
Exogyra digitata, *Sow.*	Axmouth. Weston. Beer Head.
Rhynchonella Schlœnbachi, *Dav.*	Weston.
Spines of Cidaris	Dunscombe.

Bed 9.—Buff-coloured saccharine-looking sandstone, with fine green grains. Includes layers of quartzose grit.

Thickness variable: 5 ft. at White Cliff, 20 ft. at Beer Head, 15 ft. at Branscombe, 8 ft. at Weston, 4 ft. at Dunscombe.

Fossils:—

Rhynchonella Schlœnbachi, *Dav.*	Spines of Cidaris.
Ditto (fragments).	Small fish-teeth.

Bed 10.—Rubbly, yellowish, quartzose sands, in chalky paste.

Thickness variable: 6 ft. at White Cliff, 15 ft. at Beer Head, 10 ft. at Branscombe, 5 ft. at Weston Mouth, 4 ft. at Dunscombe.

Characteristic fossils—*Siphonia*, sp., *Nautilus lævigatus*, D'Orb.
Fossils :—

(*Note.*—Abbreviations as to localities:—Ax. = Axmouth, BH. = Beer Head, Br. = Branscombe, D. = Dunscombe, WC. = White Cliff, W. = Weston.)

Astrea (?)	D.
Bryozoa (several species)	D. BH.
Siphonia, sp.	D. Br. BH. Ax.
Ananchytes subglobosus, *Leske*	BH. Ax.
Cottaldia Benettiæ, *König*	BH.
Discoidea subuculus, *Klein*	D. BH.
Echinoconus (Galerites) castaneus, *Brongn.* (small var.) (?)	D.
Pyrina ovulum, *Ag.*	BH.
—— Prattii, *Forbes*	BH.
Salenia petalifera, *Desm.*	BH.
Ammonites Mantelli, *Sow.*	Ax.
Nautilus lævigatus, *D'Orb.*	Ax. D.
Fusus, sp.	D.
Pleurotomaria Mailleana, *D'Orb.*	D.
Pterocera, sp.	D.
——, sp.	D.
Rostellaria Mailleana, *D'Orb.*	D.
Trochus, sp.	D.
Turritella Bauga, *D'Orb.*	D.
Caprotina, sp.	D.
Gastrochæna, sp.	D. BH.
Inoceramus latus, *Mant.*	BH. Ax.
Opis, sp.	D.
Trigonia sulcataria, *Lam.*	D.
—— tenuisulcata, *Dujard.*	D. W.
——, sp.	D.
—— abrupta, *Buch.*	D.
Perna (or Avicula) ?	D.
Lima ornata, *D'Orb.*	D.
—— semiornata, *D'Orb.*	D.
—— semisulcata, *Goldf.*	D.
Janira quinquecostata, *Sow.*	D.
Mytilus striato-costatus, *D'Orb.*	Ax.
Ostrea (allied to O. Normaniana, *D'Orb.*)	Ax. BH.
—— carinata, *Sow.*	D.
—— diluviana, *Linn.*	D. Ax.
Pecten asper, *Lam.*	D.
Rhynchonella dimidiata, *Sow.*	BH.
—— gallina, *Brongn.*	WC.
—— convexa, *Sow.*	D.
—— Schlœnbachi, *Dav.*	BH.
Terebratella pectita, *Sow.*	D. BH.

Bed 11.—Yellowish quartzose sand, with fine green grains, in a chalky paste, semicrystalline.

Thickness variable: 2 ft. at White Cliff, 3 ft. at Beer Head, 2 ft. at Branscombe, 6 in. at Weston Mouth, 2 ft. at Dunscombe.

Characteristic fossils—Crustacean (*Callianassa* ?), *Exogyra columba* (small var.), and *Terebratella pectita*, Sow.

Fossils :—

Crustacean (Callianassa ?	BH.
Bryozoa (many species)	D. BH.

Ananchytes subglobosus, *Leske*	D.
—— lævis, *Deluc*	BH.
Discoidea subuculus, *Klein*	BH.
Goniophorus lunulatus, *Ag.*	D.
Micraster, sp.	BH.
Pseudodiadema Michelini, *Ag.*	BH.
—— variolare, *Brongn.*	BH.
Trochus, sp.	D.
Caprotina, sp.	D.
Exogyra columba, *Lam.* (small var.)	W.
Lima, sp.	D.
—— ornata, *D'Orb.*	D.
Janira quinquecostata, *Sow.*	BH.
——, sp.	BH.
Pecten rhotomagensis, *D'Orb.*	D.
—— Puzosianus, *Math*	BH.
—— asper, *Lam*	BH.
Trigonia, sp. (allied to T. sinuata, *Park.*)	D.
Rhynchonella dimidiata, *Sow.*	D.
—— grasiana, *D'Orb.*	D. BH.
—— Schlœnbachi, *Dav.*	BH.
Terebratella pectita, *Sow.*	D.
Terebratula rugulosa, *Morris*	D.

Bed 12.—Compact, nodular, rubbly bed, with green grains and quartz grains, in a chalky paste.

Thickness variable: 1 ft. at White Cliff, 2 ft. at Beer Head, 2 ft. at Weston, 2½ ft. at Dunscombe.

Characteristic fossils—*Catopygus carinatus* and *Ammonites varians*.

The top of this bed usually presents an uneven surface at its junction with the next above, the junction of the two being also marked in places by a ferruginous line.

May be seen at White Cliff and in all sections from Beer Head westward to top of Dunscombe cliff.

Fossils:—

Bryozoa (many species)	D. BH. Ax.
Scyphia (species)	D. BH.
Spongia (several species)	D. BH. Ax.
[These are mostly coated with green matter, and more or less covered with *Serpulæ* and the attached valves of *Crania* and *Plicatula*.]	
Ananchytes subglobosus, *Leske*	BH. &c.
Catopygus carinatus, *Goldf.*	BH. &c.
Discoidea subuculus, *Klein*	BH. D.
Echinoconus (Galerites) castaneus, *Brongn.*	D.
Nucleolites lacunosus, *Goldf.*	D.
Pyrina Desmoulinsii, *D'Arch.*	D.
—— Prattii, *Forbes*	BH.
—— ovulum, *Ag.*	BH.
Salenia gibba, *Ag.*	BH.
—— petalifera, *Desm.*	BH.
Spatangus bufo, *Brongn.*	BH.
—— lævis, *Deluc*	D.
Ammonites Mantelli, *Sow*	Ax.
—— Coupei, *Brongn*	Ax.
—— varians, *Sow.*	WC. D.
Nautilus Largilliartianus, *D'Orb*	Ax. D.
—— Fittoni, *Sharpe*	Ax.
—— lævigatus, *D'Orb.*	Ax.

Scaphites æqualis, *Sow.*	WC.
Turrilites costatus, *Lam.*	D.
—— Bechei, *Sow.*	Ax.
Avellana cassis, *D'Orb.*	D.
Fusus, sp.	D.
Natica, sp.	D.
Neritopsis, sp.	D.
Pleurotomaria, sp.	Ax.
—— perspectiva, *Sow.*	Ax. D.
—— cassisiana, *D'Orb.*	Ax.
Pterocera, sp.	BH. D.
Solarium ornatum, *Sow.*	Ax.
Trochus cirrus, *Woodw.*	D.
Cardium (allied to C. Hillanum, *Sow.*)	WC.
—— Mailleanum, *D'Orb.*	WC.
—— (Unicardium) ringmeriense, *Mant.*	D.
Lucina turoniensis, *D'Orb.*	D.
Trigonia abrupta (?), *Buch*	D.
—— crenulata, (?) *Lam.*	D.
—— sulcataria, *Lam.*	D.
—— (allied to T. sinuata, *Park.*)	Ax.
Anomia, sp.	BH.
Exogyra columba, *Lam.* (small var.)	Br. W.
Janira quinquecostata, *Sow.*	D.
Lima (allied to L. intermedia, *D'Orb.*)	D.
——, sp.	Ax.
—— ornata, *D'Orb.*	Ax.
——, sp.	Ax. D.
Mytilus ligeriensis, *D'Orb.*	Ax.
—— Guerangeri, *D'Orb.*	D.
Ostrea carinata, *Lam.*	D.
—— (allied to O. normaniana, *D'Orb.*)	WC.
Pecten asper, *Lam.*	BH. Ax. D.
Crania cenomanensis (?), *D'Orb.*	Ax. D.
Megerlia lima, *Defr.*	BH. D.
Thecidium, sp.	D. Br.
Terebratella pectita, *Sow.*	D.
Trigonosemus incertus, *Dav.*	BH. D.
Terebratula ovata, *Sow.*	BH.
—— rugulosa, *Morris*	BH.
—— squamosa, *Mant.*	D.
—— obesa, *Sow.*	Ax.
Rhynchonella dimidiata, *Sow.*	BH. D.
—— convexa, *Sow.*	BH. D.
—— Grasiana, *D'Orb.*	BH.
—— Mantelliana, *Sow.*	BH.
—— Wiestii, *Quen.*	BH.
—— Schlœnbachi, *Dav.*	WC.

Bed 13.—Greyish or brownish chalk, with green grains, quartz grains and *phosphatic nodules*.

Thickness variable: 4 ft. at White Cliff, 5 ft. at Beer Head, 4 ft. at Weston Mouth, 2½ ft. at Dunscombe.

Characteristic fossils—*Discoidea cylindrica*, Lam., and *Rhynchonella Mantelliana*, Sow.

May be seen at White Cliff and in sections from Beer Head westward to top of cliff east of Salcombe.

Fossils:—

Astrea (?)	BH.

Micrabacia coronula, *Goldf.*	Br.
Bryozoa	BH.
Sponge-nodules (phosphatic)	BH. Ax.
Cidaris (spines and plates)	Br.
Discoidea cylindrica, *Lam.*	Ax.
—— subuculus, *Klein*	Ax. Br. BH.
Echinocyphus difficilis, *Ag.*	BH.
Pseudodiadema variolare, *Brongn.*	BH.
Belemnitella	BH.
Ammonites Mantelli, *Sow.*	Ax. D.
—— rhotomagensis, *Defr.*	Ax. BH.
—— navicularis, *Sow.*	WC.
——, sp.	BH.
Scaphites obliquus, *Sow.*	Ax.
Turrilites tuberculatus, *Bosc.*	BH.
—— Bechei	Ax.
Arca Mailleana, *D'Orb.*	BH.
Lucina turoniensis, *D'Orb.*	BH.
Janira quinquecostata, *Sow.*	Br.
Plicatula spinosa, *Mant.*	D.
—— ventricosa, *Goldf.*	D.
—— hippuritarum, *D'Orb.*	Br.
Rhynchonella dimidiata, *Sow.*	WC.
—— Grasiana, *D'Orb.*	D.
—— Mantelliana, *Sow.*	BH. D. WC.
Terebratula ovata, *Sow.*	BH. D.
Megerlia lima, *Defr.*	D.

Note.—Many of the fossils of this bed seem to have been deposited in the condition of casts; and some at least of these may have been derived from a partial wearing away of the Chloritic Marl.

Bed 14.—Hard nodular chalk, with fine quartz grains.

Thickness variable: 4 ft. at White Cliff, 5 ft. at Beer Head, 2½ ft. at Dunscombe.

May be seen at White Cliff, Beer, Beer Head, and sections westward to Dunscombe.

Fossils :—

Discoidea subuculus, *Leske*	BH. D.
Cardiaster (allied to C. rostratus, *Forbes*)	BH.
Ammonites Mantelli, *Sow.*	BH.
Rhynchonella Mantelliana, *Sow.*	Beer.
—— limbata, var. robusta, *Tate*	Ax.

Bed 15.—Creamy white or yellowish sandy chalk, semicrystalline. (The Beer Stone of the Beer quarries.)

Thickness variable: 5 ft. at White Cliff, 10 ft. at Beer quarries, 6 ft. at Beer Head, 2 ft. at Dunscombe.

Characteristic fossil—*Inoceramus mytiloides,* Sow.

May be seen in part from White Cliff westward to Dunscombe.

Fossils :—

Ananchytes subglobosus, *Leske*	Br. BH.
Discoidea subuculus, *Klein*	Ax. BH.
Echinoconus (Galerites) castaneus, *Brongn.*	BH.
Inoceramus mytiloides, *Sow.*	BH. Beer.
Lima simplex, *D'Orb.*	Br.

Bed 16.—Hard, nodular, sandy chalk, without flints; semi-crystalline in structure. (The Bastard Freestone of the Beer quarries.)

Thickness variable: 8 ft. at White Cliff, 14 ft. at Beer quarries, 14 ft. at Beer Head, 3 ft. at Dunscombe.

Prevailing fossil—*Inoceramus mytiloides*, Sow.

May be seen in part at White Cliff, in the Beer quarries, and in face of cliffs to west of Beer Head. Passes out in top of cliff to east of Salcombe Mouth.

Fossils:—

Ananchytes subglobosus, *Leske*	BH.
Cidaris, sp.	BH.
Discoidea subuculus, *Klein*	BH. BQ.
Echinocyphus difficilis, *Ag.*	BH.
Echinoconus (Galerites) castaneus, *Brongn.*	BH.
Micraster cor-bovis, *Forbes*	Ax.
Salenia umbrella, *Ag.*	BH.
Inoceramus Brongniarti, *Sow.*	Br.
—— mytiloides, *Sow*	Br. Ax.
Rhynchonella plicatilis, *Sow.*, var	Beer.
—— Cuvieri, *Brongn.*	Beer.

Bed 17.—Marly and, in places, nodular chalk, with flints. Chalk veined with bands of pale grey or yellow. Flints finger-like, dispersed. At base a zone of large flints.

Thickness about 10 ft.

Characteristic fossils—*Inoceramus mytiloides*, Sow., and *Micraster cor-bovis*, Forbes.

This portion of the chalk with flints may be seen at White Cliff, Beer, Beer Head, Branscombe, and Weston. It passes out near the top of cliff to east of Dunscombe.

Fossils:—

Ananchytes subglobosus, *Leske*	BH.
Cidaris (allied to C. clavigera, *Mant.*, spines and portions of)	Br.
Discoidea subuculus, *Klein*	BH.
Echinoconus (Galerites) subrotundus, *Mantell.*	Ax.
Micraster cor-bovis, *Forbes*	Ax.
Pseudodiadema Michelini, *Ag.*	Ax. BH.
Salenia petalifera, *Desm.*	BH.
Encrinite (portions of)	Br.
Oreaster (portions of)	Br.
Inoceramus Brongniarti, *Sow.*	Axm. Br.
—— mytiloides, *Sow*	Br.
Rhynchonella Cuvieri, *Brongn.*	W.
Terebratula semiglobosa (var. subundata), *Sow.*	BH.

Bed 18.—Chalk with numerous flints, mostly in layers. Chalk more or less nodular.

Thickness about 40 ft.

Characteristic fossils—*Holaster planus*, Mant., and *Inoceramus Brongniarti*, Sow.

Occupies a considerable part of sections at White Cliff, Beer, Beer

Head, and Branscombe. Passes out at top of cliff to east of Branscombe.

Fossils :—

Holaster planus, *Mant.*	BH.
Inoceramus Brongniarti, *Sow.*	BH.
Ostrea vesicularis, *Lam.*	BH.
Terebratula semiglobosa, *Sow.*	WC.
Rhynchonella Cuvieri, *Brongn.*	BH.

Bed 19.—Hard chalk without flints.

Thickness about 15 ft.

Characteristic fossil—*Inoceramus Cuvieri,* Sow.

A greyish marly-looking band, of about 3 ft. thickness, occurs above the middle of this bed. Occupies part of cliffs at White Cliff, Beer, and Beer Head. Runs out near top of cliff to east of Branscombe Mouth.

Fossils :—

Discoidea (allied to D. minima, *Ag.*)	BH.
Inoceramus Cuvieri, *Sow.*	WC.
Spondylus, sp.	B.
Terebratulina gracilis, *Schloth.*	B. BH.
—— Martiniana, *D'Orb.*	BH.
—— striata, *Wahl.*	BH.
Rhynchonella plicatilis, *Sow.*	BH.

Bed 20.—White chalk with numerous flints.

Thickness about 60 ft. at Beer Head.

Characteristic fossils—*Galerites albo-galerus,* Lam.; *Micraster cor-anguinum,* Gmel.; *Terebratula carnea,* Sow.

Occupies upper part of cliffs about Beer and part of Beer Head.

Fossils :—

Galerites albo-galerus, *Lam.*	WC.
Micraster cor-anguinum, *Gmel.*	BH.
Spondylus spinosus, *Sow.*	WC.
Ostrea	WC.
Crania ignabergensis, *Retz.*	WC.
Terebratula carnea, *Sow.*	WC.
Terebratulina gracilis, *Schloth.*	WC. BH.
—— striata, *Wahl.*	WC.

In the foregoing description many minor details, including purely local variations in the mineral condition of the deposits, have been necessarily omitted. The lists of fossils, also, include such species only as I have observed *in situ* in the beds described. These lists are consequently incomplete, and in some cases, as I am well aware, do not include one half the species obtainable.

II. *Classification of the Deposits.*

In attempting to classify these various deposits one meets with considerable difficulty. There is in the first place no well-marked base-line to the Devon Cretaceous system, the lowest beds, both lithologically and palæontologically, answering almost equally well to Upper Greensand, Gault, or Lower Greensand. Then, again, the upper limit of the series is almost equally ill-defined.

Subject therefore to correction as to the age, or precise geological horizon, of the highest and lowest deposits, the grouping of the beds enumerated in the previous pages should probably be as follows:—

Beds 1 to 3 may represent collectively either Gault, or Gault and Lower Greensand (in part). They represent also, without question, the so-called "Greensand" of Blackdown.

Beds 4 to 9 inclusive are clearly Upper Greensand.

Beds 10 to 12, although attaining in the Beer-Head district a most unusual thickness, must be referred collectively to the so-called "Chloritic Marl" of the Isle of Wight.

These beds (10 to 12), in their mineral character especially, have much in common with the higher beds of the Greensand of Warminster. They include, also, amongst their fossils the greater portion of those usually quoted as Warminster species. There is little doubt, therefore, that the fossiliferous portion of the so-called "Upper Greensand" of Warminster is, properly speaking, "Chloritic Marl" instead of "Upper Greensand" as usually stated. And this point is of some importance.

Bed 13 represents the base-bed of the Chalk Marl, or that part of the Chalk Marl which, in so many localities, contains lumps and nodules of phosphatic matter.

In most of the Devon sections, as, indeed, in numerous other localities, beds 12 and 13 are distinctly separated. That is to say, the Chalk Marl (bed 13) rests on an uneven surface of the Chloritic Marl (bed 12). This, again, is a fact of much importance in its bearing on cretaceous geology, and one to which I propose to refer again in a separate paper.

Beds 14 to 17 represent apparently the Chalk Marl (in part) and the Lower Chalk (in part) of our more eastern counties. It is impossible, however, to say with certainty how much belongs to either.

Beds 18 and 19, as shown by their fossils, fall in, I think, undoubtedly between the Lower and the Upper Chalk, and are so placed, provisionally, in Table II.

Bed 20 is possibly Upper Chalk (in part). I cannot vouch, however, for its exact horizon.

III. *Relation of the Cretaceous Rocks of the Beer-Head district to those of certain other localities.*

This paper being intended simply as a general description, I have not thought it necessary to encumber it with special sections. In the absence of such sections, however, it may be as well to trace out briefly the relations of the more variable strata of the district under consideration to those of better-known localities. And here arises, once again, the question of the age of the lower deposits.

The age of the beds 1 to 3, which form the lower and most argillaceous portion of the Devon Cretaceous strata, has been at various times very variously estimated.

Sir Henry de la Beche in 1826 * and again in 1839 † appears to have classified these strata with the Upper Greensand.

Dr. Fitton in 1836 ‡ makes them Lower Greensand.

Mr. Godwin-Austen in 1842 § described them as possibly "a sandy condition of the Gault."

In 1863 ||, and again in 1866 ¶, I attempted to show, partly on palæontological, partly on stratigraphical evidence, that these strata belonged to the top of the Lower Greensand rather than to the Gault or Upper Greensand. It is fair to say, however, that the palæontological evidence then chiefly relied on has proved far from trustworthy.

Mr. Etheridge, to whose opinion as a palæontologist every one may well bow submissively, places these beds on the horizon of the Gault, mainly, I believe, on the evidence of the Black-Ven section. At the present moment I am almost prepared to agree to his opinion. The sandy-argillaceous strata near the base of the Black-Ven section contain unquestionably a large number of Gault fossils; and there is full evidence of the continuance of similar strata to the westward; but, still, are these strata entirely Gault?

True Gault, such as one knows so well in the Isle of Wight, is to be seen near Punfield, in Swanage Bay, where it is underlain by a considerable thickness of the Lower Greensand. It is traceable as Gault along the coast-line as far westward as Mewps Bay. At Lulworth Cove it is to be seen no longer as Gault, which, in its argillaceous condition, has either thinned out or given place to dark greenish sandy strata with zones of large concretionary nodules.

These beds contain Gault fossils in abundance, and (what is well worthy of notice) pass upwards insensibly into Upper Greensand, and downwards into ferruginous sands of the Lower Greensand.

In the altered condition of the Gault as present at Lulworth, one finds, therefore, an approach already to the condition of the so-called Gault as seen at Black Ven. And there is no doubt whatever that Gault in such condition is present both at Black Ven and in the sections to the westward. But is this all? I think it possible that Lower Greensand, which, as we have seen at Lulworth, actually accompanies the Gault to its extinction as a clay-bed, may form a part also of the still doubtful strata to the westward. As to the correctness of this supposition, it is only fair to say I have no evidence whatever.

The Upper Greensand proper of the Beer-Head district (beds 4 to 9 in Table II.) exhibits to some extent a purely local development. The zones of sandstone pebbles or "shingle-beds" described by Mr. Godwin-Austen in 1842 **, for instance, and which form so marked

* Trans. Geol. Soc. ser. 2, vol. ii.
† Ord. Surv. Report, p. 237.
‡ Trans. Geol. Soc. ser. 2, vol. iv. p. 233.
§ *Ibid.* vol. vi. p. 449.
|| Geologist, vol. vi. p. 50.
¶ Geol. Mag. vol. iii. p. 13.
** Trans. Geol. Soc. ser. 2, vol. vi. p. 449.

a feature in the Beer-Head and other sections, are in great measure local. The recurrence of these shingle-beds throughout the several sections in the district, and their limitation to distinct and definite horizons, would seem, however, to indicate some special periods of disturbance. It is at least worth notice that the horizon of one of them is marked as far eastward as Lulworth by a layer of phosphatic nodules. These pebbles, in the Devon sections, are formed entirely of sandstone, and, as long since also suggested by Mr. Godwin-Austen *, would seem to have resulted from the destruction of Portland strata.

The sand-beds 6 and 8 of the Branscombe and Weston sections are also in so far peculiar to the Devon Upper Greensand, that they are scarcely represented either at Lulworth or in the Isle of Wight. It would appear, however, that both these beds exist to the westward, *Orbitolina concava*, Lam., and *Exogyra digitata*, Sow., their characteristic and common fossils, being present in the Haldon Hills †, in the Irish Greensand ‡, and, I believe, also in the greensand of Normandy.

The Chert-beds of the Devon "Upper Greensand," although greatly varying in thickness, are traceable continuously from the Dunscombe Cliffs to the Isle of Wight. From the Blackdown Hills they have been in great part denuded.

The Chloritic Marl of the Beer-Head section is remarkable (as already stated) on account of its unusual development, the beds 10 to 12 of Table II., which from their fauna and mineral character certainly represent the chloritic marl, having in the Beer-Head undercliff a thickness collectively of not less than 20 feet. It is true that this thickness is exceptional, and that the beds diminish rapidly to the east and west of the Beer basin. Yet their presence in such local force is worth notice as illustrating the variable character of this division.

Judging from appearances, the Chloritic Marl of many of our coast-sections would seem to have been a deposit of slow accumulation. Indeed one may observe in it, in places, an almost entire change of fossils within the thickness of only a few inches. Such being the case, an occasional thickening of the strata, as at Beer Head, and possibly at Warminster, is far from unlikely.

In tracing these beds eastward, the threefold subdivision of the strata, as seen between Beer Head and Branscombe, becomes less and less apparent. It may be seen, however, although somewhat obscurely, in Pinhay Cliffs near Lyme Regis, at White Nore in the Isle of Purbeck, and more clearly in cliffs just east of Punfield Cove. At Chard and Chardstock the threefold subdivision of the strata has been well described by Mr. Davidson (Mon. Pal. Soc. vol. viii. p. 114), the beds IV., V., and VI. of the section therein given answering extremely well to beds 10, 11, 12 of the Beer-Head strata. Curiously enough, this section of Mr. Davidson's appears to have been taken by many continental geologists as a measure of the whole of the English Upper Greensand.

* Proc. Geol. Soc. vol. iv. p. 197. † Trans. Geol. Soc. ser. 2. vol. vi. p. 452.
‡ Quart. Journ. Geol. Soc. vol. xxi. p. 35.

The base-bed of the Chalk Marl (bed 13) with its phosphatic nodules, which is fairly represented in the Beer-Head district, is also traceable more or less continuously to the eastward. Sometimes, indeed, it *almost* merges into the Chloritic Marl; yet even then it is always traceable. Its upper bed, however (bed 14), and the succeeding representatives of the Lower and Upper Chalk (beds 15 to 20) are, on account of their local peculiarities of structure, far from easy to correlate with the thicker masses to the eastward. This difficulty of correlation is also increased considerably by the present ambiguity of the terms Upper and Lower Chalk. The term Upper Chalk, in its ordinary, text-book acceptation, appears hitherto to have signified chalk with flints. And this acceptation of the term would have been perhaps as good as any other if flints occurred only above a given horizon. That such is not the case is sufficiently evident. The chalk of Yorkshire, for example, contains flints on a lower geological horizon than that of Sussex or of Hampshire. Now it is evident, as shown by its fossils, that the chalk of the Dorset and Devon sections contains flints at an exceptionally low geological horizon. Mr. Whitaker, in a recent communication to the Geological Society (Quart. Journ. Geol. Soc. vol. xxvii.) has pointed out this fact very clearly where (pp. 95 & 96) he refers to the presence of flints in the Chalk Marl itself. It is clear, therefore, that the beds above the Chalk Marl in the Devon sections are, from their exceptional character, exceedingly difficult to correlate with their true equivalents to the eastward.

Taking bed 13 as the true base-bed of the Chalk Marl, bed 14 must at the least be added to that division.

Beds 15 and 16, which include the Beer Stone, will then fall in the Lower Chalk. And in this point I fully agree with Mr. Whitaker. But I believe the lower part of the chalk with flints (beds 17 and part of 18) of the Beer section to be also Lower Chalk, as compared with that of Surrey and the Isle of Wight, and that, as above stated, the flints are here below their ordinary level *. It is bed 17 which caps the cliffs to east and west of Branscombe, and which, by a partial thinning-out of the intermediate strata, is brought down in places so nearly on the Upper Greensand.

The succeeding portions of the chalk of the Beer district (beds 18–20) I have had too little opportunity of studying to describe with confidence. I may say, however, that the zones of fossils are fairly marked, and that these appear to indicate the presence of a considerable portion of the higher chalk.

On comparing the Devon cretaceous system with that of the north-east of Ireland as described by Mr. Ralph Tate (Quart. Journ. Geol. Soc. vol. xxi. p. 15), one can hardly resist the supposition that the two series were originally connected. There is at the same time, however, so marked a difference in the distribution of their respective faunas, that one must question either their former actual connexion or the horizons at present assigned to the Irish strata.

* *Vide* a paper on the Surrey Chalk, by Caleb Evans, Esq., F.G.S. (Proc. Geologists' Association for 1870).

These cretaceous rocks of Ireland have been referred by Mr. Tate to two formations—"the Hibernian Greensand, and the Upper Chalk," the term "Hibernian Greensand" being applied to the cretaceous beds underlying the Upper Chalk of Ireland.

The Hibernian series, says Mr. Tate, "forms three lithological zones, each with its own suite of organic remains." For their full description, however, I must refer the reader to the original paper.

Now, of these three zones, the lowest, or "Glauconitic Sands" of Tate, apparently represents to some extent the beds 1 to 3 of the Devon sections.

The succeeding "grey marls and sandstones with chert" clearly represent the true Upper Greensand, in part (beds 4 & 5), of the Devon sections.

The "chloritic sands and sandstones" forming the upper part of the Hibernian Greensand would seem by some of their fossils to represent the beds immediately beneath the Chloritic Marl (beds 6 to 9) of the Devon sections. They contain, however, apparently a singular mixture of species, and are consequently not easy to correlate. And the same must be said, I think, with respect to the so-called Upper Chalk.

IV. *Conclusion.*

Taken as a whole, then, and in spite of the as yet doubtful age of the lowest and highest deposits, the Beer-Head and contiguous sections of the Devon Cretaceous strata present collectively a highly important section. One may observe here, as probably nowhere else in one continuous section, the true relation of the fossiliferous Blackdown strata to those of Warminster, and, what is at least almost equally important, the relation of both of these beds to that of the true Upper Greensand of the Isle of Wight.

The "Blackdown beds" in these sections underlie most clearly the true Upper Greensand, and hold (apparently) the *position* of the Gault or of the Gault and Upper Neocomian in part.

The "Warminster beds," on the contrary, are seen to cap the Upper Greensand, and are therefore in reality Chloritic Marl.

If, then, the above should prove to be a correct reading of these Devon sections, it cannot but affect to some extent the use of the term Upper Greensand; and I submit that such term should be applied exclusively, as far as possible, to beds between the Gault and the Chloritic Marl, and that the Chloritic Marl should be considered a distinct division.

Table I.—*Showing the Distribution and Range of the Fossils enumerated in this Paper.*

Note. + denotes that a species is abundant, – that it is less abundant, and o that it is rare.

	? Gault. =Blackdown beds.			Upper Greensand.						Chlor. Marl =Warminster beds.			Chalk Marl.		Chalk. Lower.			Chalk. Middle.		Chalk. Upper.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
Foraminifera.																				
Orbitolina concava, *Lam.*								+												
Porifera.																				
Various species										–	o	+	–							
Scyphia (several species)										+		–								
Siphonia, sp.										+										
Zoophyta.																				
Micrabacia coronula, *Goldf.*													+	–						
Echinodermata.																				
Ananchytes subglobosus, *Leske*										–	–	+	o	o	–	–	o			
—— lævis, *Deluc*											–	–								
Cardiaster (allied to C. rostratus, *Forbes*)														o						
Catopygus carinatus, *Goldf.*												+								
Cidaris, sp.													–							
——, sp.																o				
—— (allied to C. clavigera, *Mant.*)																	+			
Cottaldia Benettiæ, *König*										–										
Discoidea subuculus, *Klein*										–	o	+	+	–	–	–	o			
—— cylindrica, *Lam.*													+							

Echinoconus (Galerites) castaneus, *Brongn.*												+			–	–				
—— (——) —— (var.)										–										
—— (——) subrotundus, *Mant.*																	–			
Echinocyphus difficilis, *Ag.*													–			–				
Epiaster Murchisoniæ, *Mant.*		–																		
Galerites albo-galerus, *Lam.*																				–
Goniophorus lunulatus, *Ag.*											o									
Hemipneustes Greenovii, *Forbes*		–																		
Holaster planus, *Mant.*																		–		
Micraster, sp.											o									
—— cor-bovis, *Forbes*																–	–			
—— cor-anguinum, *Gmel.*																				–
Nucleolites lacunosus, *Goldf.*												–								
Pseudodiadema variolare, *Brongn.*											–		–							
—— Michelini, *Ag.*											–						–			
Pyrina ovulum, *Ag.* (?)										–		–		?	?					
—— Prattii, *Forbes*										–		–								
—— Desmoulinsii, *D'Arch.*												+								
Salenia gibba, *Ag.*												–								
—— petalifera, *Desm.*										–		+					?			
—— umbrella, *Ag.*																–				
Spatangus bufo (?), *Brongn.*												o								
Brachiopoda.																				
Crania cenomanensis (?), *D'Orb.*												–								
—— ignabergensis, *Retz.*																				–
Magas Geinitzi (?), *Schlönb.*										o										
Megerlia lima, *Defr.*												–	–							
Terebratulina gracilis, *Schloth.*																		–	+	+
—— Martiniana, *D'Orb.*																			o	
—— striata, *Wahlb.*																			–	–
Terebratella pectita, *Sow.*										–	+	–								
Terebratula carnea, *Sow.*																				–

TABLE I. (*continued*).

	?	Gault. =Blackdown beds.		Upper Greensand.						Chlor. Marl =Warminster beds.			Chalk Marl.		Chalk. Lower.			Chalk. Middle.		Chalk. Upper.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
Terebratula ovata, *Sow.*											—	+	—							
—— obesa, *Sow.*												—								
—— rugulosa, *Morr.*											—	—								
—— squamosa, *Mant.*												o								
—— semiglobosa, *Sow.*																		—		
—— subundata, var., *Sow.*																	—			
Thecidium, sp.												o								
Trigonosemus incertus, *Dav.*												o								
Rhynchonella convexa, *Sow.*										—		+	—							
—— Cuvieri, *Brongn.*																—	+	o		
—— dimidiata, *Sow.*										—	—	+	—							
——, var. (gallina, *Brongn.*)										—	—									
—— Grasiana, *D'Orb.*										—	—	+	o							
—— limbata, var. robusta, *Tate*														o						
—— Mantelliana, *Sow.*												—	+	—						
—— plicatilis, *Sow.*																			—	--
—— ——, var.																—	—			
—— Schlœnbachi, *Dav.*								o	—	+	—	—								
—— Wiestii, *Quenst.*												o								
CONCHIFERA.																				
Anomia, sp.		o																		
——, sp.												—								
Caprotina, sp.										—	—									
Exogyra columba, *Lam.*				+	—															

—— —— (small var.)											+	—								
—— conica, *Sow.*		—	+	—	○															
—— —— (small var.)	—	—																		
—— digitata, *Sow.*						+	—	+												
—— lævigata, *Sow.*			+																	
—— undata, *Sow.*		—																		
Inoceramus Brongniarti, *Sow.*																—	—			
—— Cuvieri, *Sow.*																			—	
—— latus, *Mant.*										—										
—— mytiloides, *Sow.*															—	+	+			
—— sulcatus, *Sow.*		—																		
Janira quadricostata, *Sow.*				+	+															
—— quinquecostata, *Sow.*										—	—	+	—							
—— (allied to atava, *Röm.*)											—									
Lima, sp.											—	—								
—— (allied to L. intermedia, *D'Orb.*)												—								
—— ornata, *D'Orb.*										—	—	+								
—— semiornata, *D'Orb.*										—										
—— semisulcata, *D'Orb.*										—										
—— simplex, *D'Orb.*															—					
Mytilus Guerangeri, *D'Orb.*												○								
—— ligeriensis, *D'Orb.*												—								
—— striato-costatus, *D'Orb.*										—										
Ostrea (allied to Normaniana)										○		—								
—— carinata, *Sow.*										—		—								
—— diluviana, *Linn.*										—										
—— vesicularis, *Lam.*																		—		
Pecten asper, *Lam.*										—	—	—								
—— elongatus, *Lam.*				—																
—— Milleri, *Sow.*		—																		
—— orbicularis, *Sow.*				—	○															
—— —— (small var.)	—	+	—																	
—— Puzosianus, *Math.*											○									

TABLE I. (*continued*).

	?	Gault. =Blackdown beds.		Upper Greensand.						Chlor. Marl =Warminster beds.			Chalk Marl.		Chalk. Lower.			Middle.		Upper.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
Pecten rhotomagensis, *D'Orb.*	......	......	......	......	......	......	......	......	......	......	–									
Plicatula spinosa, *Mant.*	......	......	......	......	......	......	......	......	......	......	......	......	+	–						
—— ventricosa, *Goldf.*	......	......	......	......	......	......	......	......	......	......	......	......	–							
—— hippuritarum, *D'Orb.*	......	......	......	......	......	......	......	......	......	......	......	......	–							
Spondylus spinosus, *Sow.*	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	–
——, sp.	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	o	
Arca carinata, *Sow.*	......	–																		
—— Mailleana, *D'Orb.*	......	......	......	......	......	......	......	......	......	......	......	–	–							
Cardium Hillanum, *Sow.*	......	+																		
—— —— (sp. allied to)	......	......	......	......	......	......	......	......	......	......	......	–								
—— Mailleanum, *D'Orb.*	......	......	......	......	......	......	......	......	......	......	......	+								
—— ringmeriense?, *Mant.*?	......	......	......	......	......	......	......	......	......	......	......	+	–							
Cyprina cuneata, *Sow.*	......	+																		
Gastrochæna, sp.	......	......	......	......	......	......	......	......	......	+										
Lucina orbicularis, *Sow.*	......	+																		
—— turoniensis, *D'Orb.*	......	......	......	......	......	......	......	......	......	......	......	+	–							
Mactra angulata, *Sow.*	......	+																		
Nucula impressa, *Sow.*	......	–																		
—— lineata, *Sow.*	......	–																		
Opis, sp.	......	......	......	......	......	......	......	......	......	–										
Pectunculus umbonatus, *Sow.*	......	+																		
Psammobia, sp.	......	–																		
Tellina striatula, *Sow.*	......	–																		
Thetis major, *Sow.*	......	+																		
Trigonia (allied to T. Coquandiana, *D'Orb.*)	......	–																		

——, sp.		—																		
—— abrupta, *Buch.*										—		—								
——, sp.	—	—																		
——, sp. (allied to T. sinuata, *Park.*)										—	—	—								
—— spectabilis, *Sow.*	—	+																		
—— sulcataria, *Lam.*										—		—								
—— tenuisulcata, *Dujard.*										—										
—— crenulata (?), *Lam.*												—								
Venus immersa, *Sow.*		—																		
GASTEROPODA.																				
Avellana cassis, *D'Orb.*												—								
Fusus quadratus, *Sow.*		—																		
——, sp.										—		—								
Natica, sp.												—								
Neritopsis, sp.												—								
Pleurotomaria cassisiana, *D'Orb.*												—								
—— Mailleana, *D'Orb.*										—		o								
—— perspectiva, *Sow.*												—								
——, sp.												—								
Pteroceras, sp.										—		+								
Rostellaria Mailleana, *D'Orb.*										—										
—— Parkinsoni, *Sow.*		—																		
Solarium ornatum, *Sow.*												—								
Trochus, sp.										—										
——, sp.											—									
—— cirrus, *Woodw.*												—								
Turbo Guerangeri, *D'Orb.*												o								
Turritella, sp.										—										
Vermicularia concava, *Sow.*	—	—	—																	
—— umbonata, *Sow.*				—																
—— polygonalis, *Sow.*		—																		

TABLE I. (*continued*).

	? =Blackdown beds.	Gault.		Upper Greensand.						Chlor. Marl =Warminster beds.			Chalk Marl.		Chalk. Lower.			Middle.		Up-per.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
CEPHALOPODA.																				
Ammonites Coupei, *Brongn.*	...	...	...	...	...	...	...	...	...	...	...	—								
—— Mantelli, *Sow.*	...	...	...	...	...	...	...	...	...	—	...	+	—	—						
—— navicularis, *Sow.*	...	...	...	...	...	...	...	...	...	...	...	...	—							
—— rhotomagensis, *Defr.*	...	...	...	...	...	...	...	...	...	...	...	...	—							
—— varians, *Sow*	...	...	...	...	...	...	...	...	...	...	...	+								
——, sp.	...	...	...	...	...	...	...	...	...	—	...	—								
Belemnitella	...	...	...	...	...	...	...	...	...	...	...	...	+							
Nautilus Fittoni, *Sharpe*	...	...	...	...	...	...	...	...	...	...	...	+								
—— Largilliartianus, *D'Orb.*	...	...	...	...	...	...	...	...	...	...	...	—								
—— lævigatus, *D'Orb*	...	...	...	...	...	...	...	...	...	—	...	—								
Scaphites æqualis, *Sow.*	...	...	...	...	...	...	...	...	...	...	...	+	—							
—— obliquus, *Sow.*	...	...	...	...	...	...	...	...	...	...	...	...	—							
Turrilites Bechei, *Sow.*	...	...	...	...	...	...	...	...	...	...	...	—	—							
—— costatus, *Lam.*	...	...	...	...	...	...	...	...	...	...	...	—								
—— tuberculatus, *Bosc.*	...	...	...	...	...	...	...	...	...	...	...	...	—							
CRUSTACEA.																				
Callianassa?	...	...	...	...	...	...	...	...	...	...	—									
PISCES.																				
Lamna, sp. (teeth of)	...	...	...	...	...	...	...	...	—											

Table II.—*Illustrating the Succession of the Cretaceous Strata near Beer Head, Devon.*

Divisions.		No. of Bed.	Minor Divisions.	Approximate Thickness.	Zones of Fossils.
				ft.	
Chalk.	Upper (?)	20.	White chalk, with flints	70	Micraster cor-anguinum.
	Middle.	19.	Chalk, without flints	15	Terebratula carnea. Inoceramus Cuvieri. Terebratula semiglobosa.
	Lower.	18.	Hard chalk, with flints in layers.	40	Inoceramus Brongniarti. Holaster planus.
		17.	Marly chalk. Flints finger-like, dispersed.	10	Inoceramus mytiloides. Micraster cor-bovis.
		16.	Nodular sandy chalk, without flints; semicrystalline.	14	Rhynchonella Cuvieri.
		15.	Cream-coloured sandy chalk; semicrystalline.	10	Inoceramus mytiloides.
	Chalk Marl.	14.	Hard nodular chalk, with quartz grains.	5	Discoidea subuculus.
		13.	Greyish nodular chalk, with quartz grains, green grains, and *Phosphatic Nodules.*	5	Ammonites Mantelli. Discoidea cylindrica. Rhynchonella Mantelliana.
Chloritic Marl. (Warminster beds.)		12.	Compact nodular bed, with green grains and quartz grains in a chalky paste.	2	Ammonites rhotomagensis. Scaphites æqualis. Holaster subglobosus. Catopygus carinatus.
		11.	Yellowish quartzose grit in a chalky paste.	3	Rhynchonella dimidiata. Terebratula pectita. Exogyra columba (small var.).
		10.	Rubbly, yellowish, quartzose grit in a chalky paste.	15	Siphonia. Nautilus lævigatus. Discoidea subuculus.
	Upper Greensand.	9.	Buff-coloured sandstone and grit-beds, with fine green grains.	20	
		8.	Buff-coloured sands	10	Orbitolina concava. Exogyra digitata, *Sow.*
		7.	Shingle-bed of sandstone-pebbles.	2	
		6.	Light-coloured sand and sandstone.	$2\frac{1}{2}$	Exogyra digitata, *Sow.*
		5.	Chert-beds, in light-coloured sand.	20	Exogyra columba. Janira quadricostata.
Gault. (Blackdown beds.)		4.	Yellowish marly sands, with irregular concretions.	20	Exogyra columba. Janira quadricostata. Pecten orbicularis.
		3.	Greyish marly sand, with nodular concretions.	30	Exogyra conica. ,, lævigata.
		2.	Sands, with green earth (argillaceous).	25	Blackdown fauna. Inoceramus sulcatus, *Sow.*
	?	1.	Greenish-grey sands and grit-bed.	$3\frac{1}{2}$	Exogyra conica (small var.).

TABLE II.—*Illustrating the Succession of the Cretaceous Strata near Beer Head, Devon.*

Divisions.	No. of Bed.	Minor Divisions.	Approximate Thickness.	Zones of Fossils.
Chalk. Upper (?)			ft.	
	20.	White chalk, with flints	70	Micraster cor-anguinum.
Middle.	19.	Chalk, without flints	15	Terebratula carnea. Inoceramus Cuvieri. Terebratula semiglobosa.
Lower.	18.	Hard chalk, with flints in layers.	40	Inoceramus Brongniarti. Holaster planus.
	17.	Marly chalk. Flints finger-like, dispersed.	10	Inoceramus mytiloides. Micraster cor-bovis.
	16.	Nodular sandy chalk, without flints; semicrystalline.	14	Rhynchonella Cuvieri.
	15.	Cream-coloured sandy chalk; semicrystalline.	10	Inoceramus mytiloides.
Chalk Marl.	14.	Hard nodular chalk, with quartz grains.	5	Discoidea subuculus.
	13.	Greyish nodular chalk, with quartz grains, green grains, and *Phosphatic Nodules.*	5	Ammonites Mantelli. Discoidea cylindrica. Rhynchonella Mantelliana.
Chloritic Marl. (Warminster beds.)	12.	Compact nodular bed, with green grains and quartz grains in a chalky paste.	2	Ammonites rhotomagensis. Scaphites æqualis. Holaster subglobosus. Catopygus carinatus.
	11.	Yellowish quartzose grit in a chalky paste.	3	Rhynchonella dimidiata. Terebratula pectita. Exogyra columba (small var.).
	10.	Rubbly, yellowish, quartzose grit in a chalky paste.	15	Siphonia. Nautilus lævigatus. Discoidea subuculus.
Upper Greensand.	9.	Buff-coloured sandstone and grit-beds, with fine green grains.	20	
	8.	Buff-coloured sands	10	Orbitolina concava. Exogyra digitata, *Sow.*
	7.	Shingle-bed of sandstone-pebbles.	2	
	6.	Light-coloured sand and sandstone.	$2\frac{1}{2}$	Exogyra digitata, *Sow.*
	5.	Chert-beds, in light-coloured sand.	20	Exogyra columba. Janira quadricostata.
Gault. (Blackdown beds.)	4.	Yellowish marly sands, with irregular concretions.	20	Exogyra columba. Janira quadricostata. Pecten orbicularis.
	3.	Greyish marly sand, with nodular concretions.	30	Exogyra conica. " lævigata.
	2.	Sands, with green earth (argillaceous).	25	Blackdown fauna. Inoceramus sulcatus, *Sow.*
?	1.	Greenish-grey sands and grit-bed.	$3\frac{1}{2}$	Exogyra conica (small var.).

30. Note *on the* Carboniferous Conglomerates *of the* Eastern Part *of the* Basin *of the* Eden. By J. G. Goodchild, Esq., H.M. Geological Survey of England and Wales. (Read March 25, 1874.)

(Communicated by H. W. Bristow, Esq., F.R.S., F.G.S., by permission of the Director-General of the Geological Surveys of the United Kingdom.)

Professor Phillips has pointed out, in his 'Geology of Yorkshire,' that the Mountain-Limestone between the northern border of the Lake-district and the river Eden includes a group of red sandstones, alternating with limestones in the lower part of the series.

They were referred to by him as the "Alternating Limestone and Red Sandstone Series," and were considered to be the passage-beds between the true basement series, or Upper Old Red, and the principal mass of the Mountain-Limestone which forms the comparatively high ground between the basins of the rivers Lune and Eden.

This middle group is fairly exhibited about three miles to the south of Kirkby Stephen, at Ash Fell, where the different members of the whole series may be examined in the quarries and natural sections laid bare in the immediate neighbourhood (fig. 1).

The general sequence in descending order is as follows:—

"*a.*" Principal mass of the Carboniferous Limestone, including a few thin beds of stained sandstone and shale between thick masses of limestone, and having a total thickness of not less than 1000 feet, between Ash Fell and Kirkby Stephen.

"*b.*" Obliquely laminated, soft, red sandstones, here and there very calcareous, generally containing many traces of Coal-measure plants, and frequently assuming a conglomeratic character in consequence of the presence of a few pebbles of milky quartz, and the occurrence of lenticular fragments of now decomposed shale on some of the faces of bedding.

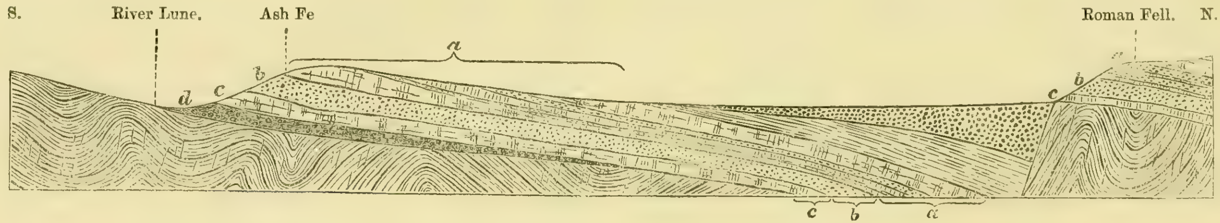
These beds alternate with thin shales, which are usually very full of fossils where calcareous, and with beds of limestone of variable thickness and different degrees of purity.

Near the top of the series these limestones are usually encrinital and crystalline; others are rather earthy and have interlaminated sandy bands; while those nearer the base, although generally pure in the mass, have courses of quartz pebbles up to an inch in diameter on some of the bedding planes.

Here and there amongst the quartz pebbles may be detected pieces of pinkish felspar or fragments of slaty rock, probably of Silurian origin, which suggest by their usually subangular character that the associated quartz was rolled into pebbles ere it began to be drifted into its present position.

The total thickness of this series at Ash Fell is about 500 feet; but the interbedded limestones thin rapidly in a north-westerly direction, so that near Shap the total thickness cannot be much more than 300 feet, which is mostly made up of sandstones more or

Fig. 1.—*Diagram Section from the Howgill Fells to Roman Fell.*



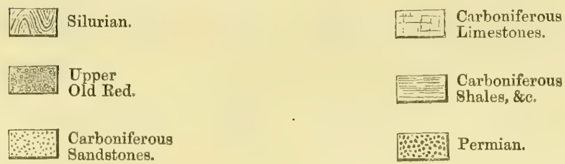
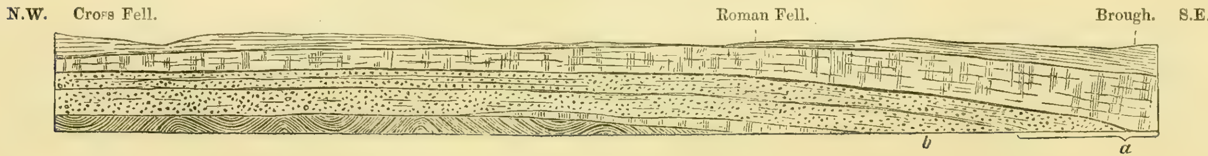


Fig. 2.—*Diagram Section along the Cross-Fell Escarpment.*



less conglomeratic, and subordinate beds of limestone, which are similar in lithological character to those in the Ash-Fell sections.

Some sandstones about the middle of this series may be seen in the railway-cutting in the village of Shap.

"*c*." The Sandstone series is succeeded by a variable thickness of limestone, which cannot be less than 500 or 600 feet near Ash Fell.

The beds are not usually so pure as those of the upper series ; but this lower group is nowhere split up by beds of sandstone or shale. Near the base it becomes thinner-bedded and passes down by almost insensible gradations into the next series.

"*d*." This group in its upper part consists of shales, with thin impure limestones here and there containing grains of quartz, and passes down through calcareous beds of a more decidedly conglomeratic character into a series of apple-green quartz conglomerates and chocolate and grey shales.

These, in their turn, are succeeded without any clear line of demarcation by the Drift-like series of red conglomerates, sandstones, and shales which forms the lower part of the Carboniferous basement-beds here, and has always been considered the equivalent of the Upper Old Red of other parts of the kingdom.

This basement-series is exceedingly variable in thickness and mineral character; and, so far as it has yet been proved, it seems to be mainly composed of locally derived materials.

These are the beds which are seen at intervals along the northern border of the Lake-district between the Silurian rocks and the limestone scars of the Carboniferous series. They are very well exposed in Birk Beck, between Tebay and Shap Wells.

Between Poola Bridge, at the foot of Ullswater, and the village of Dacre are thick masses of roughly stratified conglomerates belonging to this basement-series. It is these beds which form the striking conical hills known as Great Mell Fell and Little Mell Fell, as well as others of the same outline between the foot of Ullswater and the outcrop of the Carboniferous Limestone to the north.

A thickness of several hundred feet of limestone belonging to group "*c*" comes on above the conglomerates in the river-Eamont sections north of Ullswater; and it is not until we reach Yanwath, about two miles to the south of Penrith, that we find the Ash-Fell beds in full force.

Groups "*b*," "*c*," and "*d*" form much of the valley-ground skirting the north-eastern border of the Lake-district; and the generally north-easterly dip of the beds causes these lower groups to pass beneath the higher members of the Carboniferous series and the Permian rocks up to the great lines of disturbance at the foot of the Pennine escarpment, where they are again thrown up to the surface by faults which have several thousand feet of downthrow on the south side.

About a mile and a half to the east of Ash Fell a north-easterly line of disturbance cuts off the Ash-Fell beds on the east, and throws in limestones belonging to the series "*a*."

The strike of the beds on the western side of the faults continues nearly parallel to the lines of disturbance from near Ash Fell, northward along the foot of Stainmoor, to the Cross-Fell escarpment (fig. 2, p. 395); so that limestones belonging to the higher part of "*a*" are not lost sight of for any great distance, but may be traced round to the perfectly clear section in the scars above Brough, where the principal bed of this series is recognized as the Melmerby-Scar Limestone.

This is the bed which forms, with the Whin Sill, the more striking and picturesque features of the Carboniferous rocks on the upcast side of the Pennine faults.

A little to the west of Brough the generally north-easterly dip of the beds on the north side of the lines of disturbance brings up from beneath the Melmerby-Scar Limestone a series of sandstones of various degrees of coarseness interbedded with shales and beds of impure limestone.

These are clearly seen to overlie a group of conglomerates, gannister-like sandstones with Coal-measure plants, and subordinate beds of sandy limestone containing many courses of well-rolled pebbles of quartz.

This conglomeratic series is succeeded by a mass of grey limestone, the thickness of which cannot be made out in the typical sections.

These beds, from the Melmerby-Scar Limestone downwards, correspond so closely in lithological character and geological position with the beds seen south of Kirkby Stephen that there is little room left for doubt as to their identity.

The sandstone and impure limestone series next below the Melmerby-Scar Limestone probably represents the lower part of group "*a*," which was described as being split up by thin beds of sandstone and shale.

It must be admitted that the interbedded limestones in this sandstone group in the escarpment are rarely found to be thicker than 25 or 30 feet, while those on what is supposed to be the same horizon south of Kirkby Stephen have a thickness of from 100 to 150 feet between the partings of sandstone.

As there is a distance of a little more than eight miles between the two lines of outcrop, few geologists accustomed to follow individual beds over long distances will feel inclined to lay much stress on the difference in thickness of the limestones in the two sections, when the thinning can be shown to be at the rate of only 15 feet in a mile. As an additional argument in favour of the identity, at least in part, of the escarpment-sandstone and thin limestone series with the limestone group "*a*" south of Kirkby Stephen, it may be mentioned that the thin beds of sandstone observed in the limestone series "*a*" north of Ash Fell are found to thicken and the associated beds of limestone to diminish in thickness, and become still further split up by sandstones and shales, as they are followed in a north-westerly direction towards Penrith.

If it were possible to follow these beds under the Permians still further to the north-west, we should probably find that the limestones had become quite subordinate to the sandstone series, and that there would be little, if any, noticeable difference, except that of colour, between these beds and the rocks below the Melmerby-Scar limestone at the eastern end of the Cross-Fell escarpment.

The conglomerate series next in order, notwithstanding its superficial resemblance in lithological character to the conglomerates of the basement-series, as seen at the foot of Ullswater, is distinguished from them by its including thin beds of limestone; and we should probably not err in referring this part of the series to beds about the horizon of the Ash-Fell beds "*b*."

The mass of grey limestone on which the conglomerates lie occupies the relative position of the limestone group "*c*," beneath the Ash-Fell beds, and probably is wholly or in part identical with it.

The base of the series is not clearly seen in the typical section in the escarpment; but, as in an adjoining section the conglomerates are clearly seen to be at no great distance from the floor of Silurian rocks upon which the Carboniferous beds lie, there cannot be any great thickness of this lower limestone.

Perhaps the only other distinction of any note between the beds seen in the escarpment and those along their southern outcrop about Ash Fell lies in the fact that the very well-marked red tint which is seen in the Ash-Fell sandstones is nearly or quite absent in the beds under the Melmerby-Scar limestone.

But as other sandstones higher in the series, which are red on the downthrown side of the great faults, are clearly seen to be of their natural colour on the upthrown side, it is inferred that the staining is due to Permian influence; and the mere absence of the red tint is therefore not a distinction of any value.

In my opinion this marked absence of staining in the Carboniferous beds on the escarpment sides of the great lines of disturbance is due to a considerable upheaval in late geological times, the plain upon which the Permian rocks once rested being now only in part represented by the tops of the highest fells on the north side of the Pennine faults.

Perhaps there is no place along the Cross-Fell escarpment where this group of sandstones and conglomerates can be so well examined, and its relation to the beds above and below so clearly made out, as on Roman Fell and in the scars to the south-east of it.

Along other parts of the escarpment, much of the lower slopes along which these beds mostly occur is obscured by drift and by fallen blocks from the scars above.

It will therefore be convenient to speak of the whole series between the base of the Melmerby-Scar limestone and the top of the lowest thick limestone as the Roman-Fell beds.

This group will therefore include not only the supposed representatives of the Ash-Fell beds "*b*," but also the lower part of the Limestone series, indicated by the letter "*a*" in the diagram section at Ash Fell (fig. 1).

In following the outcrop of the Roman-Fell beds towards Cumberland, the conglomeratic beds from the middle of the group downwards are found to increase much in thickness, and the included stones to become so much larger that there is little difficulty in finding masses of quartz nine inches or a foot in diameter in some of the coarser beds.

The upper part of the group, between the conglomerates and the Melmerby-Scar limestone, does not seem so changeable: except that the interbedded limestones are thinner and usually of a lesser degree of purity, and that coals set in to the north, there is but little difference between these beds under Cross Fell and their eastward extension as seen near Brough.

As has already been remarked of some of the limestones associated with the Ash-Fell beds on the south side of the great faults, the beds above and below the Roman-Fell series become much thinner in a north-westerly direction, so that under Cross Fell the Melmerby-Scar limestone is little more than half as thick as the same bed at Brough; and there is reason for believing that the lower limestone, which is seen under the Roman-Fell beds near Brough, dies away completely before we reach Cumberland.

The exact point where it does so cannot be indicated until a more detailed examination of the ground has been made.

So far as the writer has been able to make out in his holiday rambles, there does not appear to be any undoubted equivalent of the true Carboniferous basement-series along the escarpment, although it is possible that those beds may be feebly represented in places by the lower part of the conglomerates.

The tendency to become coarser in a north-westerly direction is not so marked along the southern outcrop of the Ash-Fell beds, so far as they have yet been traced into the basin of the Eden; but at a short distance west of Penrith some sandstone beds, which must be very near this horizon, are quite as coarse as any millstone grit, and in themselves could not be distinguished from it.

Over a considerable area to the east and north of the Silurian rocks of the Lake-district one of the results of the Geological Survey has been to prove that, as a rule, the limestones of the Carboniferous series increase in thickness towards the south-east, and that, on the other hand, the purely drifted deposits come on in greater force, and generally tend to increase in coarseness, in proportion as they are followed towards the north-west.

As this rule can thus be shown to be one of wide application in the higher parts of the series, one may infer that these lower beds form no exception, but that the whole of the lower part of the Carboniferous series tends to assume more and more of a littoral character as it is followed towards the north-west, and that any of the limestones which can be shown to have died away along the escarpment will not be found to reappear along the northern outcrops of the local base of the carboniferous rocks, but that these Roman-Fell beds over large areas will be found to rest directly upon the older rocks wherever there are no intervening patches of "Old Red."

We should perhaps not be far wrong in considering that these Roman Fell beds are about the horizon of the Calciferous Sandstone series of the south of Scotland. If one may judge by the published descriptions, there is a close agreement between them both in lithological character and in their position in the Carboniferous series*.

From what has been stated it would therefore appear that certain beds, which can be shown to occur about the middle of the Carboniferous Limestone in one part of Westmoreland, develop into coarse conglomerates, which are locally undistinguishable from much of the true basement series, and have been described, by authors who have not had opportunities of tracing out the true position of these beds in the Carboniferous series, as undoubted Old Red Sandstone.

Discussion.

Prof. Hughes confirmed the observations of Mr. Goodchild, and showed their importance as bearing upon inquiries into the changes of the land which furnished, and of the currents which arranged, the materials of the beds described.

Prof. Ramsay remarked that the author was entitled to much praise for the manner in which he had worked out the minor details of the Carboniferous system. The Cross-Fell conglomerates had been called Old Red Sandstone; they are now placed in the Lower Carboniferous, but no distinct line of demarcation can be determined. Prof. Ramsay remarked on the distribution of deposits of the Carboniferous series in Britain, and referred especially to the Carboniferous Limestone. In the south of Pembroke and Glamorganshire this formation is 2500 or 3000 feet thick; in the Devonshire area 100 feet, and in the north of Glamorganshire 500–600 feet represent the whole of the Mountain-Limestone; in Coalbrook Dale, again, its thickness is only about 100 feet, in North Wales 800 feet, in Anglesea 500 feet. In advancing towards Palæozoic districts, where old land existed, the limestone becomes thin, whilst it becomes thick in the deep-water areas,—in Derbyshire 3000–4000 feet, falling off to less than 1000 feet in Cumberland, where it is split up by sandstones; and this is still more strikingly the case in Scotland, where 100 feet of limestone is a rarity. He thought the existence of coral reefs in the Mountain-Limestone doubtful.

Mr. Tiddeman remarked that the Mountain-Limestone was 3000 or 4000 feet thick in the Lake-district, and in the Pennine Chain, at a distance of 15 miles, only 600 feet.

* The writer wishes it to be stated that he had independently arrived at this conclusion before he heard that Mr. James Geikie held similar views regarding these Roman-Fell beds.

31. *On the* OCCURRENCE *of* THANET BEDS *and of* CRAG *at* SUDBURY, SUFFOLK. By WILLIAM WHITAKER, B.A. (Lond.), F.G.S., of the Geological Survey of England. (Read June 10, 1874.)

(Communicated by permission of the Director-General of the Geological Surveys of the United Kingdom.)

1. THANET BEDS.

THE newer Tertiary deposits of the Eastern Counties have had such a power of fascination over geologists that the older beds have been left almost unnoticed: indeed since the description of a few sections in Mr. Prestwich's essays on the Lower London Tertiaries, which have now been published 20 years and more, I know of but one paper (and this probably known to very few geologists)* that gives us any information about that series in the district in question, whereas the number of papers that treat of Crag and Drift is legion. It has therefore been an agreeable surprise to me to find, in the course of my Geological Survey work, that there are fine sections of the older Tertiary beds in Suffolk and the neighbouring part of Essex; and it was with some astonishment that I saw one of the finest sets of sections in the London Basin round the town of Sudbury, on the border of those two counties.

These sections convinced me that the lowest member of the Lower London Tertiaries, the Thanet Beds, crops out along part of the northern edge of the Tertiary district, an occurrence of which I had a very slight suspicion from other sections near Ipswich.

Mr. Prestwich has, indeed, doubtfully referred some of the sands of the northern outcrop to this division, though without describing any section; but he does not notice the particular part where it is now to be seen in many large and clear pits, and the following notes are all that can be gleaned from his elaborate papers:—

"In north Essex the zone of outcrop of these sands usually occurs on the slope of hills, and they therefore form a very narrow belt, which is further frequently so obscured by drift that they do not constitute any marked feature in the district. Owing to this cause and the want of sections, their structure there remains uncertain. Their thickness may be from 30 to 50 feet" †; and in a foot-note is added the remark that the Thanet Sands, if present, probably commence (on the west) somewhere near Bishop's Stortford. Again, in a later paper, "I am doubtful whether the Thanet Sands range thus far north. If they do, they must be represented by the bed of sand which is to be seen reposing on the Chalk in a few pits between Bishop Stortford and Newport" ‡.

Since the above was written a great improvement in the matter of sections has taken place, so that I have had the advantage of

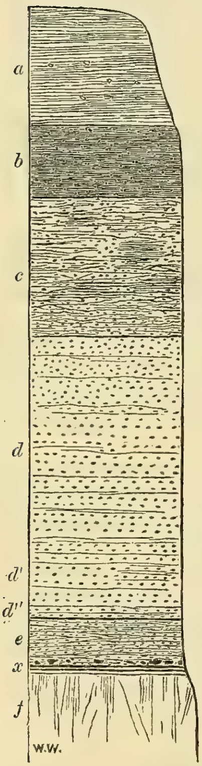
* J. B. Phear, "On the Geology of some parts of Suffolk, particularly of the Valley of the Gipping," Trans. Camb. Phil. Soc. ix. p. 431 (1856).
† Quart. Journ. Geol. Soc. viii. p. 241 (1852). ‡ *Ibid.* vol. x. p. 92 (1854).

further and better evidence. The sands above referred to must in great part belong to the Reading Beds, as there is no thickness of even 20 feet of Thanet Sand to be seen in North Essex; but I think it can be shown from an examination of the pits at Sudbury that there is really an outcrop of Thanet Sand—though I believe it does not reach so far westward as Stortford, unless the bed of clayey greensand that comes on above the Chalk there should belong to this division of the Lower London Tertiaries.

Details of the various sections will be given in the proper place (a Geological-Survey Memoir); but it has been thought better to lay a statement of the facts (trifling though they be) before the Society than to keep them hidden away for perhaps some years. It will be

Section of the Lower Tertiary Beds at the Great Chalk-pit, Balingdon. 1873.

(Scale 8 feet to an inch.)



		feet.
	a. London Clay, brown and dark grey, with "race." No basement-bed.	
Reading Beds.	*b.* Blackish, rather sandy clay, and clayey sand	3
	c. Pale greenish-grey, red-mottled, bedded sandy clay, the upper part redder...	6
Thanet Sand.	*d.* Buff and pale grey, fine, soft, and somewhat clayey sand, bedded and firm. The bottom 3 feet or so (*d'*) pinkish, that tint being stronger at the lowest half foot (*d''*) ...... about	12
	e. Clayey greensand, very bright-coloured at top, with a few green-coated flints at the bottom, and here and there some higher up. This bed is noticed by W. Smith, in his 'Geological Map of Essex' (1820), as "Greensand, called Devil's Dung," a name still kept in the locality .... about	2
	f. Chalk. A thin bed of tabular flint (of alternate black and white layers) at top (*x*). Other flints rare (? = the "Margate Chalk" of Kent). The top flint bed is noticed by W. Smith, in his 'Geological Map of Suffolk' (1819) thus:—"Chalk, covered with a Floor of Stratified Flint."	

enough here to notice the one great section where all the beds from the London Clay to the Chalk may be seen. This is in a pit on the right slope of the valley of the Stour, just south of Balingdon, the Essex suburb of Sudbury, which is worked down to the level of the river, laying bare the set of beds shown in the figure, drawn on the same scale as various analogous figures in the Memoir on the London Basin*.

No fossils have been found in the beds that I have classed as Thanet Sand, except some pieces of Foraminifera, by Dr. Holden; the reasons for this classification are purely lithological, and as follows:—

1. The likeness of the sand, in fineness, compactness, and colour to that which occurs in the same position in West Kent.

2. The persistence of these characters in all the sections, and the absence of false-bedding of pebbles and of red-mottling, tending to show that the sand belongs to the Thanet Beds rather than to the more varying Reading Series.

3. The fact that the greensand at the bottom is like the "base-bed" of the Thanet Sand; and the occurrence immediately beneath it of a layer of tabular flint, as is very usual where that bed caps the Chalk.

Westward from Sudbury I have traced this sand for more than three miles; but eastward it is soon hidden by Drift, after being shown in many sections on the outskirts of the town. The greensand over the Chalk, near Ipswich, is much like that at Sudbury; so perhaps the progress of the Geological Survey may establish the occurrence of the Thanet Beds in that direction.

In the northern band here noticed this division seems to be present at the expense of the overlying Reading Beds, which are remarkably thin at Sudbury; and this outcrop most likely joins on underground to that in South Essex and Kent, many of the deep wells in the tract between seeming to pass through the Thanet Sand.

2. Crag.

The pits that give evidence of the occurrence of Crag have been opened only during the last few years, and are all on the left, or Suffolk, side of the Stour, at the northern and eastern edge of Sudbury, the three best sections being close together, on the hill within a quarter of a mile N.E. of St. Peter's Church.

The general section of these is as follows:—

A small patch of Drift.
Crag. Ferruginous dark reddish-brown sand, with layers of ironstone, slightly false-bedded; in parts a light-coloured grit with broken shells; thin layers of flint-pebbles, phosphatic nodules, and phosphatized bones in the lower part; and at the bottom a marked bed of the same, up to a foot or more thick. The whole as much as 10 feet in a hollow, elsewhere as much as 7 feet.
Thanet Sand; the lower pinkish bed, and the green base-bed.
Chalk.

In the furthest pit, Mr. Webb's, the shells are mostly broken up, and many specimens of *Purpura lapillus*, var. *crispata*, with one valve of a small *Anomia ephippium*, were all that could be found in any thing like a perfect state; but in the nearest pit, Mr. Harding's,

* Memoirs of the Geological Survey, iv. (1872).

all the fossils were in the state of casts and impressions in one of the layers of ironstone, which yielded the following:—

Nassa elongata.	Mya arenaria.
Natica occlusa.	Mytilus edulis.
Trophon antiquus (lower whorls).	Pecten opercularis.
Cardium Parkinsoni.	Tellina.
Mactra.	Pollicipes.
Modiola modiolus.	Balanophyllia.

From their unsatisfactory state these fossils are of little value in deciding the age of the bed; indeed Mr. Etheridge assures me that it is hard in most cases to assign the specific names with any certainty, and consequently it is open to suggest that the bed might be a fossiliferous member of the Glacial Drift. The reasons, however, for referring it to the Crag are as follows:—

1. That no fossiliferous Glacial Drift is known within a very great distance, much greater than the distance of the Crag tract (on the east).

2. That no layer of phosphatic nodules is known to occur at the base of the Drift, whilst the presence of such a layer at the base of the Crag is very usual.

3. That the bed is unlike the well-developed Drift of the neighbourhood, whilst it is like some of the less fossiliferous beds of the Red Crag.

As might be expected, this small patch belongs to the upper and wider-spread division, the Red Crag *, and not to the lower and rarer White (or Coralline) Crag. Its chief interest consists in the distance from any yet known masses, it being some miles westward of all other exposures. Perhaps Crag may yet be found still further westward; for my colleague Mr. Penning showed me a section near Stoke (west of Clare) where, between a mass of Drift sand and the Chalk, was a bed of angular flints and flint-pebbles, in which I found one very small piece of phosphatized bone, and on the top of which we were told a mass of shells had once been found. We have since seen some of these, which turn out to be *Purpura lapillus*, the common Sudbury shell.

The level of the Crag is, I believe, far higher at Sudbury than in any other part of the Eastern Counties. I fear that the layer of phosphatic nodules at the bottom is here too thin, too irregular, and too much mixed with flint-pebbles to be of economical value.

P.S.—Since the above was written Mr. Penning and myself have found traces of the bottom bed of the Crag southwards of Thaxted, in Essex, in the shape of a few small phosphatic nodules and a piece of phosphatized bone in a very thin layer of gravel at the bottom of Drift sand and lying on London Clay. [April 1874.]

A few days after this paper was read [June], when with my colleague Mr. Bennett, I found Thanet Sand a little north of Hadleigh, and south of that town some nodules of ironstone in sand (resting on London Clay), which were crowded with casts of shells,

* Mr. S. V. Wood, Jun., thinks it most likely to belong to the higher part (Chillesford beds) of this division.

the most common being *Cardium angustatum*, a species hitherto found in Crag only, as I am informed by Mr. S. V. Wood, who has kindly examined my Sudbury fossils, which he regards as belonging to the Crag rather than to the Drift.

Discussion.

Mr. Prestwich said that he was quite prepared to accept Mr. Whitaker's interpretation of the beds referred to the Thanet Sand.

Rev. Mr. Timins remarked that the presence of ironstone did not prove the beds in which it occurs to belong to the Red Crag.

Mr. Gwyn Jeffreys said that the limits of the Red Crag were not easy to determine, and that the casts of shells obtained in the beds near Sudbury were not sufficient to prove the exact position to which they should be referred, although they represented Crag species.

Mr. Seeley stated that he had seen fine sections of Thanet Sands fully 20 feet thick at Hadleigh sixteen years ago. They contained sharks' teeth. The sands were capped with pebbles, and above these with London Clay. The Reading Beds either almost thin out to the north or are changed to sands at Hadleigh. This would give the Thanet Sands a more northern extension.

Mr. Charlesworth inquired as to the number of species that could be identified with true Red-Crag fossils. He thought that the presence of phosphatic nodules was confirmatory of the beds belonging to either the Red or the Mammaliferous Crag.

Mr. Godwin-Austen remarked that the occurrence of Thanet Sands at Sudbury was a fact of much geological interest.

Prof. Ramsay considered that freshwater conditions generally succeed marine, and that the submergence of the Chalk areas was followed by upheaval of land.

Prof. Hughes thought that the base of the Thanet Sands could not represent a land-surface, but that there had been land in the neighbourhood, which gave rise to fluviatile conditions.

Mr. Whitaker, in reply, said that the beds at Hadleigh, referred to by Mr. Seeley, belonged to the basement-bed of the London Clay, being above the Reading Beds. He maintained that the balance of probabilities was in favour of the beds referred by him to the Red Crag being of that age rather than Drift.

32. *On the* Character *of the* Diamantiferous Rock *of* South Africa.

By Prof. N. Story-Maskelyne, F.R.S., Keeper, and Dr. W. Flight, Assistant, of the Mineral Department, British Museum. (Read June 10, 1874.)

Introductory Note.

The character of the rock in which the diamonds are found in South Africa, in the various diggings of Du Toit's Pan, Bultfontein, (the Old) De Beer's, and the Colesberg Kopje or New Rush, is essentially the same.

In some observations I made to the Society on the occasion of a notice of Mr. Dunn's on the subject of the rocks of the Diamond-fields, I gave a brief account of the minerals of which the particular rock in question appeared to be composed. I had at that time only optical, crystallographic, and pyrognostic features to go upon. Since then these minerals have been carefully selected and separated, and have been analyzed in the Laboratory of the Mineral Department by the careful and accurate hand of my colleague Dr. Flight; and the results that gentleman has obtained confirm in almost every particular the forecast I gave to the Society regarding these minerals.

The specimens of rock examined by us came from various depths—from near the surface down to 180 feet (in the case of one mass from the Colesberg Kopje).

Their general character is that of a soft and somewhat pulverulent ground-mass, composed of a mineral soapy to the touch and of a light yellowish colour in the upper, and of an olive-green to bluish-grey colour in the lower regions of the excavations. In this ground-mass are seen interspersed fragments of shale more or less altered and a micaceous-looking mineral which sometimes rises into an important constituent of the rock. It is a mineral of the vermiculite group. Crystals of a fine bright green colour of a ferriferous enstatite (bronzite) are not infrequent; and a hornblendic mineral is occasionally met with, apparently rather as an accidental than as a constituent ingredient: it closely resembles the mineral known as smaragdite. Garnet is also frequently but sparsely met with. Ilmenite also is present, generally in rather greater abundance than the garnet. A more important mineral, however, than these as a constituent of the rock, since it occurs in much larger and more generally diffused fragments, is a kind of bronzite of a paler buff tint, and in this respect, as in the size of its crystals, differing from the former bronzite, which owes its brilliant green to a small amount of nickel, and exists uniformly in small prismatic crystals not larger than a canary seed. A diallage much altered, but recognizable by its optical as well as by its mineral characters, is present to some amount in the rock of Du Toit's Pan.

Opaline silica, occasionally in the form of hyalite and sometimes resembling hornstone, is disseminated through the greater part of these rock-masses; and calcite has penetrated them everywhere, in some cases even surrounding and, as it were, cementing the diamonds in their rocky setting.

The analyses of the several minerals composing the rocks are given below, with the localities from which they were taken. They will be seen to exhibit this undoubtedly once igneous rock in the light of a bronzite rock converted (except where the remains of crystals have still survived the process of metamorphism) into a hydrated magnesium silicate, which has the chemical character of a hydrated bronzite. It is possible that the steatite-like magma in which the other minerals and shale fragments are contained may have, in fact, originated in an augitic mineral once more plentiful, but of which part of the calcium and the silica have been separated as opaline silica and calcite.

It is, however, not very probable that a separation of ingredients in this way from a decomposed augite would leave a hydrated bronzite with so definite a character as is the base of this rock. It is far more probable that the calcite is an infiltered ingredient, and that the silica has been imported by the agency of water, probably thermal, and possibly associated with the secondary results of the volcanic outburst to which the columnar pipes filled with these rocks, and of which they were first shown by Dr. Cohen to have been probably the volcanic throats, were due.

It would seem that the diamonds are more plentifully, if not almost exclusively, found in the neighbourhood of dykes of diorite that intersect the hydrated rock or occur near it in the horizontal strata through which the igneous rocks have been projected. This is the view taken by Mr. William Nevill, whose experience on the diamond-fields is the more valuable from his having carried with him to South Africa some mineralogical experience. At Bultfontein, where the diamantiferous rock is in contact with a narrow dyke of diorite, small diamonds, numerous and remarkable for the absence of colour in them, occur in the immediate neighbourhood of the diorite. At the "diggings" of Du Toit's Pan, on the other hand, where the diamond-bearing rock intervenes between the diorite and the horizontal strata of shale, large yellow diamonds, accompanied by a few white ones, were found. In the old De Beer, again, diamonds were found in a rock that abutted on a large boss-like mass of a much more coarse-grained diorite. The same thing was true of the rich deposits of diamonds found at the so-called New Rush or Colesberg Kopje.

The distinctive character of the diamonds met with in these different localities would seem to point to a source in each case not very remote from the place where they are found, a confirmation of which is further to be seen in the sharp and unabraded character of the edges of the crystals, while the fact that so many diamonds have undergone fracture and in fact are found as fragments, would not be inconsistent with such a view.

The presence, in intruded masses, of diorite, and the crushed and broken appearance so often presented by the metamorphosed enstatite rock containing the diamonds—the fragmentary nature of so many of these stones, while at the same time they offer no evidence of attrition—the eroded lines carried on their octahedral faces by so many of the diamonds, indicating (as shown by Gustav Rose) the probability of their having been exposed to an incipient combustion,—these facts, added to the brecciated character of many of the rocky masses containing fragments of carbonaceous shale, all seem to point to a great disturbance of the original enstatite rock. This rock, probably at some depth below the present surface, and possibly at the places of its contact with carbonaceous shales, was probably the original home of the diamond—the alterations that have ensued from its shattering, at a period subsequent to its becoming solidified, having aided in effecting the hydration that has so largely changed it from an enstatite rock into a mixture of enstatite with a hydrated enstatite, a combination which, both in its composition and structure, recalls vividly to the mind the similar mixture of the former mineral with the so-called pseudophite in which it occurs at Zdar in Moravia.—N. S. M.

I. Rock of Bultfontein.

The ground-mass of this rock is formed of a drab-coloured mineral, which appears to be quite broken into fragments that are cemented by calcite in bar-like forms, much resembling crystals of felspar. This contains a good deal of the bright green bronzite which will be hereafter noticed, while garnet, always surrounded by crystals of a kind of vermiculite, is more abundant than in the varieties of these rocks from other localities. There is also a paler-coloured bronzite (see No. 4); and the whole rock appears to have undergone more than ordinary change.

This rock has the following composition:—

		Oxygen Ratios.	
Lime carbonate	59·625		
Magnesia carbonate	4·972		
Iron carbonate	3·016		
Silicic acid	20·700		11·04
Alumina	0·553		
Iron protoxide	4·296	0·95	3·27
Magnesia	5·799	2·32	
Lime	0·524		
Water	undetermined		
	99·485		

Treatment with potash removed only a small portion (2·996 per cent.), which consisted chiefly of silicic acid; some portion of this constituent was most probably protected by the carbonates from the action of the alkali. The rock consists, it will be seen, of nearly 68 per cent. of carbonate and a few per cent. of opaline silica, the remaining constituent being a hydrated ferro-magnesian silicate, very similar to that which will be described as occurring in the drab-coloured rock from New Rush.

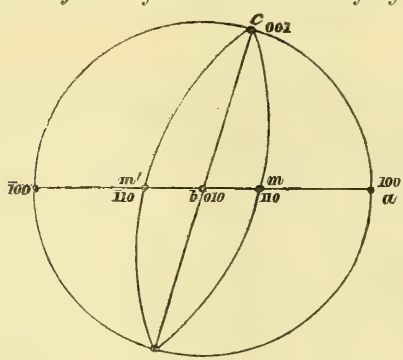
II. Specimens from Du Toit's Pan.

The drab-coloured mineral, or hydrated bronzite, again forms the ground-mass of the rock. Through it is disseminated a considerable amount of a vermiculite mineral, which often takes upon the surface-layers a fine bluish green-colour like that of clinochlore, the whole mass in some cases having this colour. Besides these there occur small imperfect crystals of the bright green bronzite, garnet, and ilmenite, while fragments of brownish-white zircon and crystals of a hornblendic mineral, with much the aspect of smaragdite, are authentically stated to come from this locality, with grossular garnet and brilliant little black tourmalines. One diamond crystal in the British Museum is *in situ* in a mass of this rock, singularly gneiss-like in appearance, the mica-like mineral really consisting of the mineral resembling vermiculite, which we now proceed to describe.

1. *Vaalite.*

The mineral resembling vermiculite occurs in hexagonal prisms, the angles of which are nearly 60° and 120°. Several measurements gave a mean angle of 59° 50′. The crystals are clinorhombic, the

Fig. 1.—*Projection of Vaalite on Plane of Symmetry.*



angle (y) of the oblique axes being very near 103° 30′. The faces measured were those of the forms *c* (001), *a* (100), *m* (110), *b* (010).

$$
\begin{aligned}
100,\ 001 &= 76^\circ\ 30' \\
110,\ \bar{1}10 &= 59\ 50 \\
110,\ 001 &= 83\ 20, \text{ calc. } 83^\circ\ 19' \\
001,\ 010 &= 90
\end{aligned}
$$

The plane *c* offers a very facile cleavage, far less ready cleavages following the directions of the faces *m*.

The normal of the face 001 is actually, or very nearly, coincident with the mean line of the optic axes, which are inclined at so very small an angle as to give a stauroscopic figure almost identical with that of a uniaxial crystal.

In parallel light, however, the cleavage-plane exhibits principal sections parallel and perpendicular to the edge *c*, *a*; and a slight opening of the cross perpendicularly to that edge can be detected, so that the optic axes would lie in the plane of symmetry. The crystal is negative. It hardly exhibits any dichroism for light traversing the principal cleavage-plane perpendicularly.

When heated on platinum-foil a little piece expanded to about six times its original thickness; after it has been reduced to powder it does not expand at all. By long boiling in strong hydrochloric acid it gradually expands, and loses constitutional water at about 110° C. Heated for many hours at 100° C., it apparently underwent no constitutional change.

The powder dried for an hour and a half at 100° C. lost no weight. In one portion the loss of weight at higher temperatures was ascertained; in another the total amount of water present was directly determined. The results are as follow:—

	per cent.
During half an hour at 125°–130° C.	1·309
" half an hour at 125–130	0·205
" one hour at 130	0·025
" half an hour at 150	0·231
" half an hour at 150	0·179
	1·949
Water evolved at a low red heat	9·717

All water which passes off at temperatures about 100° C. has been regarded as constitutional water.

The mineral has the following composition:—

			Oxygen Ratios.	
Silicic acid........	40·833		21·777	10
Alumina	9·801	4·562 }	6·616	3
Iron peroxide	6·844	2·054 }		
Chromium oxide ..	trace.			
Magnesia	31·338		12·535	6
Soda	0·670			
Water	9·717		8·636	4
Carbonic acid	trace.			
	99·203			

The above ratios correspond with the formula

$$R_2O_3, SiO_2+2(3MgO, 2SiO_2, 2H_2O).$$

On comparing the atomic ratios obtained from the analysis of this mineral with those given in Prof. Cooke's recently published memoir on the Vermiculites*, as those of Jefferisite and Hallite† respectively,

* J. P. Cooke, 'Proc. Amer. Ac. Arts and Sciences,' December, 1873. 'Phil. Mag.,' April, 1874.

† The choice of the name of this mineral is unfortunate, as it is already in use as a synonym for the aluminite (Websterite) of Halle.

it will be seen that they do not coincide with those of either of these minerals.

	RO.	R_2O_3.	SiO_2.	H_2O.
Jefferisite	12	6	15	18
Hallite	12	2	9	12
Vaalite	12	2	10	8

As we can see no grounds for identifying the mineral under description with either of the above, we propose to call it Vaalite, from the Vaal river, and to consider it to be an outlying member of the vermiculite family.

Analyses are given in the paper of Prof. Cooke of two varieties of Hallite, a green and a yellow, which vary very slightly in composition, and are only distinguished by the fact of the green variety containing somewhat more than 1 per cent. (1·13 per cent.) of iron protoxide, and the yellow variety 0·32 per cent. This would lead to the assumption that the development of colour is due to the presence of a small amount of iron in the lower state of oxidation. The drab vaalite is accompanied, as has already been stated, by a few flakes of a fine blue tint; and it was considered important to determine whether these contained iron protoxide. They were boiled with strong acid in an atmosphere of carbonic acid, and tested with gold solution, when a precipitation of metal equivalent to 4·282 per cent. of iron protoxide took place.

2. *Bronzite.*

Small bright green crystals, with something of an emerald tint, are among the minerals that occur in the diamantiferous rocks of Du Toit's Pan; and they are at the same time a permanent ingredient, more particularly in the neighbourhood of the garnet, at Bultfontein, and occur more or less sparsely in the rock of Colesberg Kopje.

These crystals resemble very closely those of the bronzite of the meteorite of Breitenbach, but are less rich in crystallographic planes; in fact they are nearly confined to those of the prism and of the faces of the form 100. The prism-angle is about 87° 20′, and the principal sections are parallel and perpendicular to the zone 001. The crystal is undoubtedly prismatic.

It was dried at 120° C., and analyzed with the following results:—

		Oxygen Ratios.	
Silicic acid	55·908		29·817
Alumina	2·638		
Chromium oxide	0·539		
Iron protoxide	4·991	1·109	15·073
Nickel oxide	trace		
Magnesia	34·912	13·964	
Lime	0·457		
Water	not determined		
	99·445		

With the exception of the enstatite of Aloysthal, in Moravia, analyzed by Von Hauer, this bronzite is distinguished for containing less iron oxide than any specimen as yet examined.

Although the mineral was dried at 120° C., a little water was still retained; but its amount was not determined.

A portion of the powdered mineral was treated with a mixture of equal volumes of strong hydrochloric acid and water at 100° C. during twenty hours, and subsequently with potash. Rather more than a quarter of the material was dissolved, as shown below:—

		Oxygen Ratios.	
Silicic acid	15·445		8·23
Alumina	0·648		
Iron oxide, with a trace of chromium oxide	1·505	0·33	3·80
Magnesia	8·685	3·47	
	26·283		

The action of the acid, therefore, was that of a solvent only.

3. *Smaragdite.*

Brilliant greyish-green fragments of crystals are met with among the minerals in the rock of Du Toit's Pan. They consist chiefly of the planes of a prism with the angle, as determined by the goniometer, of about 123° 15′, which is that of a mineral of the hornblende type.

Acid had no action upon this mineral beyond removing the adhering carbonate. After having been dried for several hours at 120° C., it was analyzed with the following result:—

		Oxygen Ratios.	
Silicic acid	52·967		28·25
Alumina, with a little chromium oxide	1·939		
Iron protoxide	4·522	1·005	
Lime	20·475	5·85	13·85
Magnesia	17·487	6·995	
Soda, with trace of potash	1·772		
Water	0·577		
	99·739		

III. Rock-specimens from New Rush, or Colesberg Kopje.

The aspect of the rocks from New Rush appears to vary considerably with the depth. In the higher parts and down to 70 or 80 feet the prevailing tint is a drab yellow; at greater depths it assumes a bluer tint, and consists largely of a breccia containing fragments of the shales through which the rock has been intruded, with occasional fragments of igneous rocks.

In selecting material for the investigation of this much metamorphosed rock, those varieties were taken in which the metamorphosis appears to be the least complete, while they still retained characteristic features of the diamantiferous deposit.

Among these a small specimen offered special advantages for the investigation. Its first aspect is that of a piece of serpentine of dark greenish hue pervaded by porphyritic-looking spots, many of which possess crystalline outline, and, at first sight, somewhat resemble the crystals of olivine in an augitic lava rich in that mineral. The minerals that make up this rock are, first, the dark greenish base, secondly the once crystalline greenish-grey substance scattered through it, crystals of the mineral we have called vaalite, rarely garnet, and interspersed calcite, which pervades the whole mass.

A thin section of this rock, seen in the microscope, exhibits, besides the very metamorphosed crystals before alluded to, a groundmass containing crystals of a similar kind, only much smaller, an irregular granular mixture of what appears to be the same mineral, mingled throughout with nearly opaque minute irregularly formed particles that sometimes seem to present crystalline outline. The last-mentioned microscopic grains are of a deep olive-yellow to olive-green; and of one the crystalline outline gave normal angles of 57° to 59° 30′ for the measurements of two prism-planes upon a third plane that appeared to be a pinacoid, which might be taken to represent the inclination of the plane 101 on the cleavage-plane 100 of olivine. It would be the angle *g′m* of Descloizeaux, of which the value of the normal angle would be 59° 37′. The mineral is too much metamorphosed to present any optical characters, so that it is impossible to confirm this conclusion by their aid. If, however, this olive-green ingredient be olivine, it is present only in absolutely microscopic particles, the bulk of the rock being the mineral which fills the place once occupied by crystallized bronzite, while throughout the whole the interstices are filled with infiltrated calcite.

The measurement of the angles afforded by the outlines of what were once bronzite crystals offers the usual difficulties where the observations are not controlled by optical characters; a distinct prism-angle of 87° to 87° 30′ in one very symmetrical section would correspond fairly well with the angle of the Breitenbach bronzite, viz. 110, $\bar{1}10 = 88°$ 16′.

4. *Altered Bronzite.*

The metamorphosed bronzite-like mineral was carefully picked and examined. It contained no carbonic acid, and when boiled with potash gave up a very small amount of silicic acid. The composition of the mineral is as follows:—

			Oxygen Ratios.
Silicic acid	53·462		28·513 4
Alumina	0·948		
Iron protoxide	8·768	1·947	
Magnesia	25·925	10·369	13·039 2
Lime	2·534	0·723	
Water	8·363		7·434 1
	100·000		

The oxygen ratios correspond very nearly, it will be observed, with the formula $2(RO\,SiO_2)H_2O$, or that of a bronzite, two equivalents of which are combined with one equivalent of water.

The darker matrix could not be separated from the above mineral, which, as has been stated, filled very small cavities in many parts; nor could all the vaalite be removed. The specimen employed for analysis, which was more or less mixed with these substances, had the following composition:—

Silicic acid	39·732
Alumina	2·309
Iron protoxide	9·690
Magnesia	24·419
Lime	10·162
Carbonic acid	6·556
Water	7·547
	100·415

It may be assumed that the lime and carbonic acid are present as carbonate of lime, which is distinctly recognizable under the microscope. A small amount of alumina invariably accompanies bronzite, whether as unchanged crystal or in the hydrated form; so that it is difficult to base calculations as to the amount of vaalite present on the amount of this oxide. If, however, we regard the whole of the alumina as present in the form of that mineral and assume that the excess thus taken compensates for the iron oxide which must necessarily accompany it, we obtain, after subtracting the oxygen ratios of the constituents of vaalite, the following residual oxygen ratios given in column I.:—

	I.	II.
Silicic acid	17·610	17·6
Protoxide	9·769	9·6
Water	5·265	5·2

In column II. of the above Table are given the oxygen ratios of a mixture of nine equivalents of the hydrated bronzite and two equivalents of serpentine, of which mixture it is assumed the matrix of this rock consists.

Among the minerals thus incompletely decomposed in the rocks of New Rush, beside the hydrated bronzite already described, there exists, in considerable quantities, a fibrous transparent mineral, irregular in its outline, but exhibiting an augitic cleavage, of a pale brownish colour, possessing in some lights a violet tinge.

Between the fibres of this mineral there are occasionally seen minute bars of the brown vaalite; but it seems tolerably free from calcite. This variety of vermiculite is occasionally associated with a yellow wax-like substance, which is probably opal. The mineral of which we are speaking is one that was described by one of us at the reading of Mr. Dunn's paper, from its microscopic and optical characters, as enstatite. It is in fact a ferriferous enstatite or bronzite, as the following analysis will show. From the impossibility of separating the minerals mixed with even the most compact specimens that could be selected, the analysis of such specimens was followed by treatment with potash.

The percentage composition was as follows:—

		Oxygen Ratios.	
Silicic acid........	66·915		35·68
Alumina	0·970		
Chromium oxide ..	0·251		
Iron protoxide	7·778	1·72	9·95
Magnesia	19·785	7·91	
Lime	1·115	0·32	
Water	not determined		
	96·814		

A quantity of the powdered mineral was treated with an excess of potash during three hours at 100° C., when constituents amounting to 41·614 per cent. were removed. They were:—

Silicic acid	34·566
Alumina	1·152
Magnesia*	1·724
Water (calculated)	3·186
	40·628

The oxygen ratios of the insoluble portion indicate, as will be seen below, the composition of a bronzite for the other constituent mineral of this rock.

		Oxygen Ratios.	
Silicic acid........	32·349		17·25
Iron protoxide	7·778	1·72	8·94
Magnesia	18·061	7·22	
	58·188		

The matrix of the striated mineral was then examined with the following results:—

Silicic acid	74·776
Alumina	0·411
Chromium oxide	0·946
Iron protoxide	6·964
Magnesia...........................	7·221
Lime	0·609
Water	5·135
Lime carbonate	3·173
	99·235

* The insoluble part was washed out with dilute acetic acid towards the end of the process, in order to prevent the passage of fine particles through the filter.

When treated with potash, 55·345 per cent. were dissolved. The residue was somewhat richer in silicic acid than was that of the enclosed mineral; and this may have been due to insufficient digestion with alkali. The silicate appears to contain more iron oxide in this case, the oxygen ratios of iron protoxide to magnesia being 1 : 2 here, and 1 : 4 in the former instance.

The portion insoluble in potash, amounting to 44·655 per cent., was of a dull olive-colour and exceedingly hard. Moistened with a few drops of cold water, it immediately swelled up to twice or three times its bulk and crumbled to powder, the action in every way resembling that observed in the slaking of lime. Treated with a mixture of one part of strong hydrochloric acid (spec. grav. = 1·16) and two parts of water in the cold during about two hours, 14·267 per cent. (or about one third of the material employed) were dissolved. A comparison of the percentages of iron protoxide and magnesia dissolved by the acid (I.), with those of the same bases in the residue from the potash treatment (II.), shows the action of the acid to have been that of a solvent.

	I.	II.
Iron protoxide	4·955	6·964
Magnesia	4·356	7·225

If we regard the matrix as made up, in addition to calcite, of a hydrated bronzite of the form already described, and an opal having the composition

Silicic acid	95·766
Water	4·234
	100·000

and regard the free silicic acid occurring in the striated mineral as an opal of the same composition, this striated mineral may be regarded as made up of

Bronzite	43·850
Hydrated bronzite	24·017
Opaline silica	30·895
Alumina	0·970
Chromium oxide	0·251
	99·983

The lithological character of the rock, even down to a depth of 180 feet from the Dempster Claim, is precisely the same as that before described. The base of the rock consists of the same ingredients as that described above, the mass of it being the hydrated bronzite. The rock is further very full of fragments of the shale, which has been altered but still contains carbon; indeed the character of the rock is almost that of a breccia, in which these masses of shale are cemented by hydrated bronzite containing the vaalite and the bright green bronzite, with ilmenite and the other minerals associated with it.

33. *On the* Remains *of* Labyrinthodonta *from the* Keuper Sandstone *of* Warwick, *preserved in the* Warwick Museum. By L. C. Miall, Esq. (Read May 13, 1874.)

(Communicated by Prof. Huxley, F.R.S., F.G.S.)

[Plates XXVI.–XXVIII.]

A collection of Labyrinthodont remains from the Keuper Sandstone of Warwick has been intrusted to me for description by the Council of the Warwickshire Natural History and Archæological Society. It includes all the material acquired by the Warwick Museum since 1842, the date of publication of Professor Owen's well-known memoir "On Species of *Labyrinthodon* from Warwickshire"*, which contained figures of all the fossils accumulated up to that time. I now propose to describe the additional collection, and afterwards to review Prof. Owen's determinations. It may thus be possible to combine in one paper all the information on the subject at present accessible. The Warwick Museum is fortunate enough to possess nearly all the fragments of Triassic Labyrinthodonts hitherto found in this country.

Nothing contained in this paper will, I hope, imply unconsciousness on the part of the writer of the vast superiority of the distinguished anatomist and palæontologist, one of whose minor works covers part of the ground now to be traversed. The interval between 1842 and 1874 is the period within which all that is most important for the elucidation of the structure of the Labyrinthodonts has been accomplished. The writings of Von Meyer, Plieninger, Quenstedt, Burmeister, Huxley, and Hancock, all subsequent to 1842, now constitute the chief body of the literature of the subject. In endeavouring to interpret the fragmentary remains of the Warwickshire Labyrinthodonts we shall necessarily rely upon decisions arrived at by naturalists whose material for comparison was so much more extensive and perfect than that at Prof. Owen's command. Reasons will be given in the following pages for unsettling some of that author's determinations. In particular, an impartial reconsideration of the five species founded by Prof. Owen seems necessary for the true correlation of the Triassic Labyrinthodonts of England and Germany. The progress of every branch of knowledge calls for such revision of long-respected conclusions with unwelcome frequency.

The Warwick specimens, whether owing to the hardness of the matrix, or to the conditions of fossilization, are singularly fragmentary. In this respect they present difficulties from which the fortunate describers of the nearly entire crania found in the shales and sandstones of Württemberg were exempt. Though fragmentary, the fossils now under consideration are free from distortion, and often show details of structure with beautiful clearness. No pains

* Trans. Geol. Soc. 2nd series, vol. vi.

have been spared by the Honorary Curators of the Geological Collection at Warwick to render every feature apparent.

1. Mastodonsaurus pachygnathus, Owen—interorbital tract. Coton End, 1867. Pl. XXVI. fig. 1 A.

This fragment comprises the frontal, with parts of the prefrontal, postfrontal, and parietal ossifications of each side. The anterior margin of the right orbit and the internal margins of both orbits are shown. The surface displays the characteristic sculpture of *Mastodonsaurus,* besides the posterior or interorbital portion of the symmetrical mucous canals (*m.g.*) which form the lyra. A narrow, sharp-cut furrow, occasionally interrupted, occupies the middle line. The parietal foramen is visible on the broken posterior end (*p.f.*); the section, accidentally made by fracture, shows that the foramen is much more contracted on the subcutaneous surface than below.

The sutures are nearly obliterated; but enough of them may be distinguished to prove that the frontal bounds a considerable part of the inner orbital margin. Such an arrangement is uncommon in the Labyrinthodonta; it occurs, however, in *Mastodonsaurus* and *Capitosaurus.* It will be seen in a subsequent part of this paper that something turns upon the character of the prefrontal. This is clearly seen to have a sharply concave orbital border, bevelled to an edge on both sides. The lower surface is quite smooth, and exhibits no foramen or other marked feature. The greatest thickness does not exceed $\frac{1}{4}$ inch.

The inferior surface of the coronal bones is rarely seen; indeed I am not aware that it has been exposed in any of the German examples of *Mastodonsaurus.* It is therefore interesting to find the underside of the present fossil clear of matrix, and detached from the bones of the palatal tract. The inferior surface is nearly even, and quite smooth over the greater part of its extent. It has already been stated that part of the orbital margin is bevelled on the lower as on the upper surface. The angulation is most apparent upon the prefrontal bone, and disappears on the underside of the postfrontal. A pair of longitudinal ridges, $\frac{7}{8}$ inch apart, and $\frac{1}{8}$ inch high, is seen upon the underside of the parietals. They subside and diverge forwards, not reaching a line drawn to join the centres of the orbits. These ridges are longitudinally striated, especially in their posterior extent. Similar ridges exist in other Labyrinthodonts, such as the Carboniferous *Loxomma.* They have probably served for the attachment of vertically placed cartilages, which may represent orbito-sphenoids.

This fragment does not perfectly agree with *Mastodonsaurus giganteus,* Jäger *. There is a row of pits between the internal orbital margin and the frontal mucous canal. The interorbital space is much narrower than in the large skull of *M. giganteus* from Gaildorf. Difference of size proves nothing in the case of a single example; but if I have restored the orbit correctly, its length in proportion to the width of the interorbital space is considerably less in the Warwick *Mastodonsaurus* than in *M. giganteus.* In other

* =*M. Jægeri,* Alberti.

words, the proportions as well as the dimensions differ. The present fossil will probably prove to be specifically identical with some of the remains named *Labyrinthodon* (*Mastodonsaurus*) *pachygnathus* by Prof. Owen; but that species is as yet inadequately defined.

Measurements :—	in.
Width of interorbital space in the narrowest part....	$1\frac{1}{8}$
Length of orbit (restored), about	$2\frac{1}{2}$
Greatest thickness	$\frac{1}{4}$
Measurements of *M. giganteus* (for comparison):—	
Width of interorbital space in the narrowest part	$2\frac{3}{8}$
Length of orbit, about.........................	6

2. Mastodonsaurus pachygnathus, Ow.—part of postero-external orbital margin. Coton End, 1872. Pl. XXVI. fig. 1 B.

The sculpture, as well as the proportions, of this fragment connect it with *Mastodonsaurus*. I am not quite sure of its position in the skull. The concave and bevelled margin, *ab*, must have bounded the orbit; yet it cannot belong to the anterior or prefrontal part of the orbit, as the underside shows no bevelling. We may pretty confidently assign it to the outer wall, in which case the suture, *c*, represents the junction of the postorbital with the jugal, and *dd'* the malar mucous canal (*Backenfurche* of Burmeister). The bone is stouter than the preceding fragment, and the sculpture is deeper.

Measurements :—	in.
Greatest thickness (near the orbital edge)	$\frac{5}{16}$
Width of maxillary groove	$\frac{5}{8}$

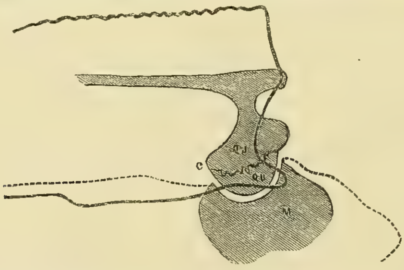
3. Mastodonsaurus pachygnathus, Owen—postero-external angle of skull (left side). Pl. XXVII. figs. 1 A, 1 B, and woodcut fig. 1.

This fragment comprises part of the roof of the temporal fossa and the greater part of the articulation for the mandible. These portions of the skull are respectively represented by a strong process directed horizontally inwards from the postero-inferior angle, and by an expanded plate. The plate is gently convex above, and shows the usual sculpture of a subcutaneous cranial surface; the lower side is nearly smooth. The greatest thickness is at the postero-inferior angle. The inferior border is thinned off to an edge ; it is somewhat undulated, descending gradually from behind so as to overlap the outer surface of the mandible, and then gradually rising in front. Behind, where it is rather more depressed than further forwards, the plate makes, with a horizontal transverse line, an angle of about 60°, measured as rectilinear. It is mainly formed by the quadrato-jugal (*Q J.*); but a portion of the supratemporal (*S T*) remains attached to the postero-superior angle, and a fragment of the jugal is present in front. I am not sure whether the fossil includes any part of the maxilla. The supratemporal and jugal are coarticulated by means of extended sutures, which overlap considerably the quadrato-jugal. On the under surface numerous vascular foramina appear, especially in the angle between the articular process and the quadrato-jugal plate.

The articular process (*Art.*) is very strong, its broken inner face being $\frac{7}{8}$ inch by $\frac{5}{8}$ inch. The lower and posterior surfaces are contributed by the quadrate (*Q*); and the suture between this and the quadrato-jugal can be made out without much difficulty. In its lower half the process presents roughly the form of a semicylinder placed transversely, with the convex surface downwards. The antero-posterior measurement of the semicylinder is rather less near the middle than at either of the two ends; its lower, or articular, surface is therefore somewhat saddle-shaped. Above the lower convex part of the articular process, and on the posterior surface, is a rounded protuberance (*pr*), about $\frac{5}{8}$ inch in transverse width, and not quite so wide in the vertical direction. This also is furnished by the quadrate. It rises nearly $\frac{3}{8}$ inch from the vertical surface to which it is attached, and lies directly above the narrowed part of the saddle-shaped articular surface. Above the prominence a thin vertical plate, lying in the angle between the articular process and the expanded subcutaneous part of the quadrato-jugal, connects the two firmly together. It thins off to an edge internally, and is there deeply arcuated, forming the external border of an opening in the posterior wall of the temporal fossa, through which an *apertor oris*, or some analogous muscle, arising from within the temporal fossa, and inserted into the post-articular process of the mandible, may have passed. In front of the semicylindrical articular surface a thin expansion of the quadrato-jugal partly conceals the quadrate, descending upon it lower at the sides than in the middle of the articular surface. An articular cartilage probably commenced where the descending edge of the quadrato-jugal terminates.

Measurements :—	in.
Greatest length of fragment	4
Greatest width	3
Greatest thickness of plate	$\frac{7}{16}$
Articular process, transversely, about	1
Articular process, longitudinally, about	$\frac{5}{8}$

Fig. 1.—*Section of the mandibular articulation of* Mastodonsaurus. (The bones supposed to be cut through are shaded.)



The continuous line represents the contour of the upper jaw, and the broken line that of the mandible (M). The zigzag line (*c*) shows the junction of the quadrate (QU) and quadrato-jugal (Q J).

4. Mastodonsaurus pachygnathus, Owen—postero-external angle of skull (right side). Warwick, 1864. Pl. XXVII. fig. 2.

This fragment is bounded on all sides by lines of fracture. The upper surface is much obscured by matrix; the part visible displays a boldly sculptured pattern. The lower surface is smooth. Upon it portions of an extremely jagged suture, which divides the bone into two nearly equal parts, may be traced. These are probably the quadrato-jugal and jugal ossifications; part of a third bone (supra-temporal?) may be indistinctly seen in the angle between the other two. At the postero-external corner a hook-like fragment projects inwards and downwards. This is evidently part of the articular process described in the account of the preceding fossil.

The greatest thickness (towards the posterior end) is $\frac{5}{16}$ inch.

5. Mastodonsaurus—portion of occipital border. Warwick, 1864. Pl. XXVI. figs. 2 A, 2 B, 2 C.

The next fossil to be described comprises the epiotic and portions of adjacent bones of the left side of the skull. Some of the margins are rounded, as if by attrition; but the fossil, though very imperfect, is for the rest in good condition. I believe it to belong to *Mastodonsaurus*, though no other examples of the genus present the same view of the same parts, so as to permit an accurate comparison. The large notch, or auditory fossa, upon the posterior border is eminently characteristic of the Labyrinthodont skull. Its horizontal outline is, in the present case, nearly semicircular. In none of the German specimens of *Mastodonsaurus* is the fossa exhibited without considerable distortion; but the Warwick fossil affords an excellent view of its boundaries and form. Nevertheless the difficulties of interpretation, arising chiefly from our ignorance of the soft parts, are considerable. The inner wall of the fossa is formed by the epiotic (*Ep*). Its original surface has been broken away from the upper half. The lower half recedes inwards and forwards; it is irregular in form, and appears to have served for muscular attachment. A broken vertical section of the epiotic, internal to the fossa, is upwards of half an inch thick. The bone slightly diminishes in thickness forwards. Upon the internal wall of the fossa it passes down to a depth of nearly an inch from the superior surface. Beneath the epiotic plate, an ascending process of the exoccipital bounds, if I mistake not, the inner side of the fossa. This ascending process runs out to a nearly vertical edge behind; it increases in thickness forwards, giving strong support to the superior wall of the cranium. Below, it is terminated by fracture; it may have been continued downwards as a ridge leading to the condyle. The large skull of *Mastodonsaurus* from Gaildorf gives evidence as to the existence of such a ridge. On the inner side of this exoccipital buttress, and in the angle between it and the epiotic, is a deep pit, the analogue, possibly, of the posterior temporal fossa in the Crocodilian skull*. Behind this pit the occipital buttress is smooth and gently convex.

* A similar pit exists in *Capitosaurus*. See Quenstedt, Mastodonsaurier &c., tab. ii. fig. 3.

The outer wall of the auditory fossa is constituted by a somewhat similar vertical buttress, the connexions of which are not quite clear. The internal face of this buttress, which forms the outer boundary of the fossa, is furnished by the supratemporal (*S T*) above, and by the postero-external expansion of the pterygoid below. The fragment of the pterygoid which remains has been displaced nearly an inch forwards. The supratemporal extends over the whole of the upper part of the surface now under description, and joins the epiotic in the anterior angle of the fossa. The inferior surface of this buttress has suffered injury. When perfect, it probably consisted of a laterally compressed vertical mass, which connected the superior part of the cranial vault with the pterygoid. The outer surface of this buttress is quite smooth, and doubtless served for muscular attachment. It is concave from above downwards, and slightly convex from before backwards. This surface formed part of the temporal fossa, being overarched in this part of its extent by the supratemporal and quadrato-jugal. The fractured upper and outer edge of the fossil shows where the overarching expansion has been broken off. No. 3 nearly represents the complementary portion of the skull as far as the postero-external angle, but belongs to the other side.

On the upper surface of the fossil, which is sculptured much as in *Mastodonsaurus*, the sutures bounding the epiotic, squamosal, and supratemporal can be clearly seen. A corner of the parietal is also shown. The backward extension, or horn, of the epiotic is nearly smooth; it has lost the extremity. The auditory fossa passes almost insensibly into the upper surface on its anterior and external sides. Internally, the broken edge of the epiotic rises abruptly.

The under surface reveals nothing of consequence, in addition to the details already mentioned, except part of the upper wall of an irregular cavity in advance of the auditory fossa. Beyond a general reference of this cavity to the acoustic chamber it would be unsafe to go at present.

6. Mastodonsaurus pachygnathus, Owen—part of right ramus of mandible. Coton End, 1856. Pl. XXVI. figs. 3 A, 3 B.

The first of a numerous and highly interesting series of Labyrinthodont mandibles, which I shall describe, comprises the posterior third or so of a right ramus. The outer plate, so far as it extends, is in excellent preservation, though its inner surface, which forms part of the wall of the alveolar canal, is obscured by matrix; the inner plate is almost entirely gone. The articular cavity has been injured, but not seriously, while the postarticular process, which yields useful characters in this order, is almost perfect.

The external surface of the angular bone exhibits a remarkably bold sculpture, which radiates from a point upon the inferior border of the ramus, about 5 inches distant from its posterior extremity. Near the centre of radiation it consists of deep and irregular pits, which become elongated, especially in front, as they recede from the centre. The upper half of the external surface is furnished by the articular element. It is comparatively smooth from the condyle forwards, being overlapped to a considerable extent by the lateral expansion of the skull (see woodcut, fig. 1). A shallow mucous canal (*h. g.*) bounds the sculptured tract above; it has a horizontal direction, and nearly coincides with the suture between the angular and articular bones. A much deeper and better defined mucous canal (*d. g.*), about half an inch wide, and nearly semicircular in section, curves downwards and forwards from behind the condyle to near the centre of radiation of the subcutaneous sculpture. At about this point it turns inwards, as if to cross the inferior border, but loses itself without impressing the smooth internal surface of the ramus. Into this descending canal the horizontal canal previously described opens. The angulari-articular suture crosses the descending canal nearly at the same point (that is, in the middle of its course), curving thence upwards, and terminating in the fractured extremity of the large and strong postarticular process. Above the suture, in the part of the ramus behind the descending canal, is a small triangular patch of sculpture; beneath it, the narrow space between the canal and the rounded postero-inferior border of the ramus is quite smooth. A number of vascular foramina appear upon the external surface of the ramus, especially in the neighbourhood of the mucous canals. Three of these, situate upon the lower, or angular, portion of the descending canal, open upwards and backwards; while those upon the articular portion of the same canal, and upon the horizontal canal, look forwards and downwards.

The ramus terminates behind in a smooth and rounded edge, which curves gently and continuously upwards from the lower end of the descending canal to the tip of the postarticular process.

The top of the ramus is occupied by a coronoid ridge, which is about 4 inches long, and about a quarter of an inch high. It passes behind into the anterior of two transverse ascending processes which bound the articular cavity; towards the broken anterior end of the fossil it gradually sinks into a groove. This groove was probably occupied by the dentary bone, which also filled part of the angle now seen between the coronoid ridge and the smooth outer surface of the top of the ramus. The surface of the ridge is smooth, except for longitudinal striæ. Other examples of *Mastodonsaurus* show that the dentary bone extended backwards nearly as far as the centre of radiation of sculpture upon the angular bone, and terminated in a point.

The condyle and postarticular process are those of *Mastodonsaurus*, though much smaller than in *M. giganteus*. Though not quite perfect, the present fossil exhibits some important features more clearly than any of the Stuttgard specimens. The articular cavity (*Art*) is saddle-shaped, being concave from before backwards, and convex from side to side. The inner half or so of the original surface has been broken away. Two transverse ridges define the cavity. Of these the posterior is the higher, and extends completely across; the anterior bounds only the inner half of the cavity. The articular surface rests in part upon a strong internal buttress. The broken mass which represents this buttress now extends for an inch beyond the middle line of the ramus; when perfect, it extended upwards of an inch further inwards. Below the articular cavity the sides of the buttress retreat gradually, so that it is broadest above. The postarticular process (*Pt. Art.*) is very Crocodilian in character, and agrees with no Labyrinthodont genus except *Mastodonsaurus*. It is an inch and three quarters long, and when perfect may have been a quarter of an inch longer. On the outer side it rises to a sharp and irregular edge, which falls rapidly backwards. The inner surface is smooth; it is concave from before backwards, variable, but on the whole convex from above downwards. In front it passes gradually into the under surface of the articular buttress. The junction of the articular and angular elements may be traced, though not without difficulty, for a short distance upon this the inner surface of the fossil. A fracture enables us to see that the plane of the suture passed nearly vertically through the internal articular buttress, and that the surface of junction was very extensive. In this part of the ramus the articular bone is securely wedged between the V-shaped plates of the angular. The whole of the articular cavity and the superior surface of the postarticular process lie above the suture, and were therefore furnished by the articular bone.

The internal cavity, or alveolar canal, of the mandible was of large size; but its extent cannot be accurately determined, owing to the removal by fracture of its inner wall. A small portion of this inner wall, contributed by the articular bone, remains attached to the upper border of the fossil in front, forming the inner boundary of the previously mentioned groove for the dentary bone. Here it seems to be united by suture to the outer plate of the articular bone. To complete this part of the ramus, the fragment of the inner wall must be produced downwards and backwards into a vertical plate, the upper half or more being contributed by the articular, the remainder by the angular bone. The restored vertical plate would converge behind towards the outer wall of the alveolar canal, leaving a long, narrow gap along the upper edge of the ramus. I suppose that this gap was occupied by a slip from the dentary bone; but there is no direct evidence that such was the case. The internal wall of the ramus would be continued to join a broken edge now visible on the inner and upper surface of the angulari-articular suture beneath the articular cavity. Were the ramus entire, a large internal mandibular foramen would appear in the inner plate, about 6 inches from the posterior extremity.

This mandible is considerably smaller than that of *Mastodonsaurus giganteus*. Its dimensions agree, so far as can be seen, with those of the four fragments of *M. pachygnathus* already described in this paper.

Measurements:—	in.
Length of fragment of ramus	$8\frac{3}{8}$
Greatest depth	$2\frac{1}{2}$
Length of coronoid ridge	4
Length of articular cavity	$\frac{5}{8}$
Length of postarticular process (broken)	$1\frac{3}{4}$

7. Labyrinthodon leptognathus, Owen—parts of mandibular rami. Coton End, 1873.

In this slab are imbedded a fragment from the middle of a left ramus, and the anterior extremity of a right ramus of a mandible specifically identical with that figured by Prof. Owen as *Labyrinthodon leptognathus* *. I see no reason to doubt its specific identity with the portion of the muzzle to which the same name is given †; but confirmation by a microscopical comparison of the teeth is desirable. The present fossil contributes nothing of importance to our knowledge of the species. A sculptured tract, belonging to the angular bone, and situate in advance of the centre of radiation, shows that the ridges, though very distinct, are closer and smaller than in any of the species of *Mastodonsaurus*. Over the small patch which remains they are remarkably continuous, and appear to increase by intercalation, not by anastomosis. The broken posterior end of the larger fragment proves that about the middle of the ramus the alveolar canal was $\frac{7}{8}$ in. deep and half as wide. The bases of two tusks appear in their usual position, near the anterior extremity of the ramus; and the row of serial teeth is continued outside them, nearly or quite up to the symphysis ‡.

8. Diadetognathus varvicensis, nov. sp.—posterior part of left ramus of mandible. Coton End, 1872. Pl. XXVII. figs. 3 A, 3 B.

After prolonged examination and comparison, I find myself compelled to regard this, and the three fragments next to be described, as belonging to a new genus and species. It is to be regretted that the characters as yet made out should be so imperfect; they are, however, irreconcilable with those of any form previously described.

The present fossil nearly corresponds as to size and extent with the right ramus of *Mastodonsaurus*, described above (No. 6, p. 422); the subcutaneous sculpture and the smooth tract above it, where the mandible is overlapped by the quadrato-jugal, have the same general character. At the same time differences are perceived, some of which seem to be of generic value. With respect to the external surface, it is readily seen that the sculpture upon the angular bone is more rounded than in *Mastodonsaurus pachygnathus*; the descending mucous canal (*d. g.*) is much less defined, and the surface behind it, instead of being diversified by a triangular patch of sculpture, is nearly smooth. On the inner side of the ramus, a considerable part of the splenial plate, which is furnished by the articular and angular bones, is preserved. An internal mandibular foramen can be distinguished, the posterior edge of which is $5\frac{3}{8}$ in. distant from the extremity of the postarticular process, while its lower edge descends within $\frac{3}{8}$ in. of the inferior border of the ramus. The in-

* Trans. Geol. Soc. 2nd series, vol. vi. pl. xliv. figs. 7–9.

† *Loc. cit.* pl. xliii. figs. 1–3.

‡ The fragment described by Prof. Owen did not exhibit this character. "Owing to the circumstance of the anterior part of the jaw having been broken, it cannot be determined whether any of the smaller or serial teeth were continued external to the large anterior tusks &c."—*Loc. cit.* p. 522.

ternal or splenial plate has suffered injury, and it is impossible to trace all the details satisfactorily. The course of the angulari-articular suture, in particular, is uncertain. But one interesting fact is clear. The strong internal buttress, which in *Mastodonsaurus* supports the inwardly produced part of the condyle, is entirely wanting in the present fossil, which presents in its place a smooth vertical plate, slightly concave from above downwards, and differing in no respect from the adjacent splenial tract. The superior, or dentary, surface of the ramus presents equally striking characteristics. There is a postarticular process (*Pt.Art.*) about 2 in. long when perfect. Its upper surface is triangular, the base being adjacent to the condyle, and the apex occupying the posterior extremity of the ramus. The process does not fall away on its inner side, as in *Mastodonsaurus*, but is bounded, like the external margin, by a ridge of bone; it presents, consequently, upon its upper surface a cup enclosed by three ridges, of which the anterior (the ascending condylar process) is the highest. The outer ridge is convex upwards; behind, it descends upon the external surface of the ramus, and terminates without quite reaching the extremity of the postarticular process. The inner ridge is concave from before backwards, and extends further back than the other. The cavity enclosed by these ridges bears much resemblance to a true articular cavity; and I have hesitated as to whether such might not be its true character. Two considerations, both influential, oppose this view. First, displacement of the quadrate either backwards, forwards, or inwards would be easy; secondly, the homologous part of the mandible in *Mastodonsaurus*, *Trematosaurus*, and several other Labyrinthodont genera is not articular but postarticular. What I take for the true articular cavity of *Diadetognathus* is the space immediately in front of the ascending condylar process (*Art.*). The posterior wall of this space is formed by the anterior face of the ascending condylar process, which is about $\frac{1}{2}$ in. high; it is concave forwards at its base, while above it inclines very slightly forwards. Transversely it is nearly straight, so that on the whole the cavity has the form of a segment of a cylinder, or more exactly, of the impression of such a solid figure. The surface is so placed as to resist backward and nearly horizontal pressure. In front of the articular surface is seen the commencement of two ridges of bone, both of which are furnished by the articular element. The outer ridge passes straight forwards, gradually expanding in width until, at a distance of 4 in. from the ascending condylar process, it is $\frac{3}{4}$ in. broad. It is at first convex upwards; but $\frac{3}{4}$ in. from the ascending condylar process a groove appears upon its upper surface. The groove increases in width with the ridge, and ultimately occupies nearly the whole of its transverse extent. It may have received the posterior and unopposed part of the maxillary series of the teeth. The inner of the two ridges diverges inwards, and ends by fracture almost immediately. It was originally continuous with a similar ridge which now projects inwards from the upper edge of the articular bone, above the internal mandibular foramen. It is better seen in the following fossil (No. 9). These two ridges are the upper edges of the outer and inner wall of the alveolar canal. They are separated, for a length of about $3\frac{1}{2}$ in., by an elongated oval space upwards of $\frac{1}{2}$ in. wide in its widest part. Towards the fore part of the fossil the dentary bone overlies the upper and outer surfaces of the external wall of the ramus. It terminates behind in an elongated pointed slip, which is confined to the outer surface; the apex was originally about $\frac{1}{2}$ in. distant from the ascending condylar process. Upon the upper surface of the dentary bone the bases, or cavities, of about seventeen teeth are visible. Such as admit of measurement are about $\frac{1}{4}$ in. from side to side, and $\frac{1}{8}$ in. in the antero-posterior direction. They are therefore much compressed in the direction of the axis of the ramus. In form and size they seem to resemble the teeth of *Capitosaurus*; but a detailed microscopic examination is necessary to elucidate their structure and relationship *.

Diadetognathus is sufficiently distinguished from *Mastodonsaurus* by the characters of its mandibular articulation as given above. In *Capitosaurus* we may note, among other differences, that the ascending condylar process is concave backwards, instead of forwards as in *Diadetognathus*, while there is a well-developed internal articular process. *Trematosaurus* differs essentially in the postarticular process, *Labyrinthodon* in the form and size of the teeth. The data for a full and accurate comparison with the last-mentioned genus do not as yet exist.

Measurements :—	in.
Length of fragment of ramus	$8\frac{3}{4}$
Greatest depth	$2\frac{1}{4}$
Length of postarticular process	$1\frac{3}{4}$
Distance of centre of radiation of sculpture from posterior extremity	$4\frac{1}{8}$
Distance of internal mandibular foramen from posterior extremity	$5\frac{1}{8}$
Height of ascending condylar process	$\frac{3}{8}$
Width of ascending condylar process	$1\frac{1}{16}$

9. Diadetognathus varvicensis—fragment of right ramus of mandible.

Both ends are broken off. The external surface shows the radiating structure upon the angular bone as in the last specimen; and the termination of the descending groove is seen upon the inferior border. Above the angular element, for a distance of nearly $1\frac{3}{4}$ in., the external dentary process of the articular bone (that destined for the support of the dentary piece) still remains in position. The inner aspect shows a smooth splenial plate and part of the border of the internal mandibular foramen. The suture between the articular and angular pieces can be traced upon the internal surface from the posterior extremity of the internal mandibular foramen backwards to near the broken end of the ramus. At first it lies nearly halfway between the upper and lower borders; about 1 in. behind the foramen it takes an upward course; and it descends again somewhat abruptly behind.

* See Addendum, p. 434.

The upper surface of the fragment shows the two longitudinal ridges of the articular bone. Of these, the internal still remains for $3\frac{3}{8}$ in.: its upper border is thick and rounded in front, where it overhangs the internal mandibular foramen; but behind it is bevelled off to an edge upon its inner side. The fragment of the external ridge is only $1\frac{5}{8}$ in. in length, corresponding in position to the anterior half of the inner ridge. Its upper surface exhibits irregular longitudinal ridges and striations. The two ridges converge in front, nearly touching where they are broken off; but behind they are separated by a distance of about $\frac{1}{2}$ in. The anterior broken end of the fragment shows that the section of the alveolar canal, at about the level of the foramen, is nearly elliptical, the external plate being strongly curved inwards in its upper half. In both the foregoing examples of *Diadetognathus*, as also in the mandible of *Mastodonsaurus pachygnathus*, an aperture exists upon the upper surface of the ramus, between the two parallel and vertical plates of the articular bone. The upper edges of these plates bear traces of union with overlying bone or cartilage; but no element of the mandible can be proved to have completed the gap. It is possible that a slip from the dentary, internal to that which is preserved in the fossil No. 7, and diverging from it, may have overlain the articular bone as far back as the condyle; but there is no evidence that such was the case.

This fragment entirely agrees with No. 7, and must be referred to the same species.

10. Diadetognathus varvicensis—fragment of left ramus of mandible. Coton End, 1872.

The chief interest of this fossil lies in the row of mandibular teeth. Eighteen of these are more or less perfectly preserved; and there are spaces for eight more. As in the previous fragment, the teeth are much compressed in an antero-posterior direction. They are lodged in an alveolus of the dentary bone. As usual in Labyrinthodonts, the outer wall of the alveolus rises higher than the inner, the difference in height amounting in the present case to $\frac{1}{4}$ in. The teeth are firmly attached both to the floor and the sides of the alveolus, so that, where they have fallen out, ridges corresponding to the spaces between the dentinal folds project from the whole width of the alveolar groove (outer wall, floor, and inner wall). The base of the tooth is a parallelopiped, whose transverse width is about twice the longitudinal measurement. From the level of the inner alveolar parapet, upwards, the tooth tapers and grows more and more conical. Its sides are ornamented with vertical striæ, easily visible to the naked eye. The largest tooth yet standing is $\frac{3}{8}$ in. high. It may have lost about $\frac{1}{3}$ of its original height; and as the bases of some other teeth are much larger than that of the one selected for measurement, it appears that an unbroken tooth may easily have attained an inch in height. A detached fragment, imbedded in the matrix between two standing teeth, shows the true crown. This is sharply two-edged, and much longer and more slender than usual. It is to be hoped that the authorities of the

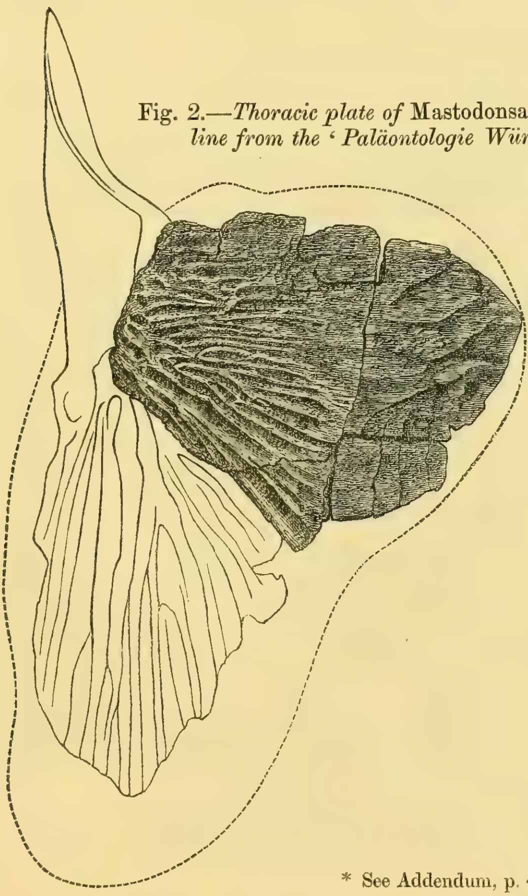
Warwick Museum will permit sections to be taken of one or more of these teeth *.

Nothing in the bony part of the fossil calls for special attention. An indistinct sculpture, consisting of elongated and separated grooves, appears upon the angular bone. The fragment seems to be considerably in advance of the centre of radiation, and to belong to the fore part of the jaw. A deep and wide groove marks the junction of the dentary and angular elements upon the outer side of the ramus.

11. Diadetognathus varvicensis—fragment of jaw with teeth. Coton End, 1872.

About twelve teeth, broken off at their bases, may be made out. The specimen yields no fresh information; and its state of preservation is such that I am not even sure whether it belongs to the maxilla or the mandible.

Fig. 2.—*Thoracic plate of* Mastodonsaurus, *with outline from the 'Paläontologie Württembergs.'*



* See Addendum, p. 434.

12. Mastodonsaurus giganteus, Jäger—part of left lateral thoracic plate. Warwick (*Dr. Lloyd*). Fig. 2.

This agrees so well, both in dimensions and sculpture, with the Württemberg fossil figured by Von Meyer and Plieninger* that I have referred it to the same species. The thin, expanded, and non-sculptured outer margin of the plate is well displayed by our example. If the specific determination is correct, the dotted outline of the Paläontologie Württembergs requires to be carried further out.

Measurements:—	in.
Greatest width (imperfect)	$9\frac{1}{4}$
Greatest width of sculptured tract	6
Thickness at the inner side, about	$\frac{3}{4}$

In the Warwick collection there are also six fragments of bones belonging to the limbs. Some of these, in all probability, are Labyrinthodont; but in the absence of evidence derived either from their association with determinable remains or from comparison with parts so authenticated, it is safer to withhold description for the present.

I shall not presume to pass a general opinion upon Prof. Owen's two Memoirs, "The Labyrinthodons of Wirtemberg and Warwickshire" and "On Species of Labyrinthodon from Warwickshire"†. The new material accumulated since 1842, in England, and especially in Germany, renders it possible to amend the determinations of particular bones; and to this task I shall, as far as possible, confine myself.

Plate 43. figs. 1–3, p. 516. *Labyrinthodon leptognathus*, Owen.

So long ago as 1844 Von Meyer gave excellent reasons for regarding this fragment of the fore part of the skull as distinct from *Mastodonsaurus*, or any other Labyrinthodont then described‡. It is only one fourth of the size of the corresponding part of the large skull of *Mastodonsaurus giganteus*, from Gaildorf; the palatal surface is more completely closed by bone, the maxillary teeth are hardly smaller absolutely, and are therefore relatively much larger than in *Mastodonsaurus*; and there is a tusk in the maxillary series. The mucous canals, visible on the upper surface, are similar to those of *Mastodonsaurus*, but not identical. There is a transverse row of small vomerine teeth, as in *Metopias*, and a longitudinal row internal to the posterior nasal aperture, as in *Trematosaurus*. Both series occur in the palate of *Mastodonsaurus* §. This fossil is the type of a distinct genus and species, for which the name of *Labyrinthodon leptognathus*, Owen, may be retained.

Plate 43. fig. 11. p. 530.

This fragment is described as the anterior frontal of *Labyrinthodon pachygnathus*. The deep pit, in what is taken for the orbital plate,

* Paläontologie Württembergs, t. iv. figs. 1 & 2.
† Geol. Trans. 2nd series, vol. vi. pp. 503–543 (1842).
‡ Paläontologie Württembergs, p. 36.
§ See Von Meyer's 'Saurier des Muschelkalkes,' t. 61. fig. 5, and t. 64. fig. 16.

is compared to "a smaller foramen in the corresponding part of the smooth orbital plate in the anterior frontal of the crocodile." But it is the lachrymal, not the prefrontal, which, in the Crocodilia, is thus excavated. The prefrontal of *Mastodonsaurus*, to which genus the present bone might conjecturally be referred on account of its proportions and surface-ornament, has been shown, in the earlier part of this paper, to have a thin, bevelled orbital margin. I have little doubt that the supposed anterior frontal belongs to the occipital tract, and that the pit represents a foramen for the passage of a large vessel, perhaps the carotid artery. In *Capitosaurus* such foramina upon the occipital surface are clearly seen*. The bone cannot, as yet, be accurately identified with *Mastodonsaurus pachygnathus*, to which species, however, it may be provisionally referred.

Plate 44. figs. 8, 9. *Labyrinthodon leptognathus*, Owen.

The mandibles, so determined by Professor Owen, may well have belonged to the cranial fragment which furnishes the type of the genus and species. The teeth have not, I believe, been microscopically compared.

Plate 43. figs. 4–11; Plate 44. figs. 1–3. *Labyrinthodon pachygnathus*, Owen.

In the preceding part of this paper reasons have been given for the belief in a smaller species of *Mastodonsaurus*, for which the name of *pachygnathus* may be retained. The two species differ in size, in the proportion of the orbit to the interorbital space, in the form of the auditory fossa, and in the character of the external surface of the mandibular ramus. As is the case with nearly all the Warwick Labyrinthodonts, the remains are so fragmentary as to preclude an entirely satisfactory definition of the species. There seems reason for including under one name all the fossils here enumerated.

Plate 45.

Of the seven objects represented in this plate there is probably not one which belongs to a Labyrinthodont. Certainly not one of them can be identified with any part of an indubitable Labyrinthodont specimen. The vertebræ (figs. 1–8) are too elongate in the antero-posterior direction, and they want the neuro-central suture. The "episternum" (figs. 9, 10) has no resemblance to any ossification in the *Labyrinthodont* skeleton. The ilium (figs. 16, 17) is probably reptilian. Of the head of the femur (fig. 18) I can say nothing, except that it is too globose for the articular end of any of the bones of the extremities of the well-established genera in this order. The criticisms offered by Von Meyer† and by Prof. Huxley‡ should be attentively considered by all who would study, in detail, Prof. Owen's Memoir or the Warwick Collection.

* Quenstedt, Mastodonsaurier &c., t. iii. fig. 16.
† Paläontologie Württembergs, p. 36.
‡ Quart. Journ. Geol. Soc. vol. xxvi. p. 47.

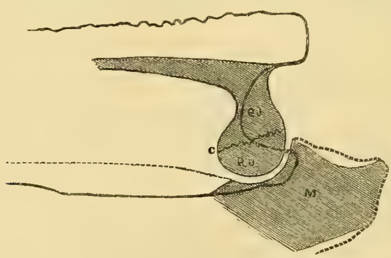
Plate 46. figs. 1–5.

The remarkable relic represented in fig. 1 has been the basis of speculation of great ingenuity. Reasons have been given elsewhere* for reconsidering the question. The collection of limb-bones, upon which so much stress is laid, does not exhibit a single Labyrinthodont feature, while the vertebræ and rhomboidal sculptured scale associated therewith, far from confirming Prof. Owen's interpretation, would almost suffice to condemn it. This fossil, like the vertebræ, ilium, head of femur, and "episternum" already referred to, would not, in 1841, have been even provisionally referred to *Labyrinthodon*, had the knowledge which we now possess of the German Triassic Labyrinthodonts been in existence, or had it been suspected that the Keuper Sandstone of Warwick might contain remains of true reptiles.

Plate 46. figs. 6, 7. "*Labyrinthodon pachygnathus*" (*Diadetognathus*?).

The notch in the left side of the principal mass of bones corresponds with the mandibular articulation. This cavity will be better understood if the bone is compared with the same part of *Mastodonsaurus pachygnathus* (No. 3). Differences will be readily perceived, such as the absence in the present fossil of the tubercle above the trochlea of the quadrate, and the greater extension of the quadrato-jugal behind the glenoid cavity. On the other hand, this fragment of the skull agrees remarkably well with the mandibular ramus of *Diadetognathus varvicensis*, and I believe that it belongs to that

Fig. 3.—*Section of the mandibular articulation of* Diadetognathus. (Explanation as before, see fig. 1, p. 420.)



species. The sculpture has the same general character as in *Diadetognathus*; but, in the absence of more distinctive features, this would not suffice to indicate the genus. The notch near the right-hand bottom corner of the figure probably marks the position of the auditory fossa. A suture, dividing the quadrato-jugal from the supratemporal, intersects the fossil from top to bottom, when placed in the figured position. The upper (anterior) part of the suture lies

* British Association Report, 1873, p. 243.

in the mucous canal as far as about the centre of the fragment. It is continued thence to the internal angle of the auditory notch.

The two adjacent pieces have apparently been detached from each other, their opposed ends being originally continuous. Thus united, the fragment would seem to represent the epiotic and some adjoining bones; but the means of comparison are inadequate, and I cannot be sure that this is the true interpretation.

Plate 47.

Casts only of this interesting jaw are preserved. Microscopical examination of the teeth is therefore impossible. The casts do not exhibit the condyle or postarticular process, which would probably have yielded distinctive characters. The fossil cannot, I believe, be certainly identified with *Mastodonsaurus giganteus,* Jäger, which differs in its sculpturing.

We are now in a position to sum up the species of Labyrinthodonts hitherto discovered in the Keuper Sandstone of Warwick. Prof. Owen's list* runs thus:—"*Labyrinthodon Jægeri, L. pachygnathus, L. leptognathus, L. ventricosus, L. scutulatus.*"

Of these species *L. ventricosus* is based upon a slight modification of tooth-structure. The position in the skull of the tooth examined is unknown; and no part of the skeleton has been identified. There is, I believe, no ground for affirming the distinctness of this species. *L. scutulatus* has not been proved to be Labyrinthodont; and there are reasons of weight against such a determination. We have found it necessary to revert to Jäger's genus *Mastodonsaurus,* retaining at the same time Prof. Owen's quite distinct genus *Labyrinthodon.* Adding the new genus and species (*Diadetognathus varvicensis*), we get the following list:—

1. Mastodonsaurus, Jäger.

1. *M. giganteus,* Jäger, = *M. Jægeri,* Alberti.
2. *M. pachygnathus,* Owen.

2. Labyrinthodon, Owen.

1. *L. leptognathus,* Owen.

3. Diadetognathus, Miall.

1. *D. varvicensis,* Miall.

(*Addendum,* May 1874.)

5 A. Mastodonsaurus ?—epiotic and parts of adjacent bones. Blakedown Hill. Pl. XXVII. figs. 4 A, 4 B.

This fossil comprises the epiotic of the right side, nearly all the supraoccipital, and portions of the squamosal and parietal. The subcutaneous sculpture is very like that of *Mastodonsaurus*; but the

* Geol. Trans. 2nd series, vol. vi. p. 543.

fragment cannot be determined with certainty. The epiotic is produced outwards and backwards into a thin expansion, with a rounded or spatulate outline. The sutures run in narrow continuous grooves. On the underside, part of the cerebral surface is exposed. Broken surfaces indicate the thick vertical walls which bounded the brain-case behind and on one side. A strong descending ridge passes from the lateral wall along the epiotic process, subsiding towards the edge. Part of the passage for the spinal cord is probably indicated by a smooth surface internal to the inner end of the posterior vertical wall. Like many other fossils in this collection, the present fragment can only be fully understood when future discoveries have brought other and more perfect examples to light.

Among a collection of Keuper Labyrinthodonts, forwarded for examination by the Rev. P. B. Brodie, I find a second example of these bones, nearly corresponding, as to extent, with the fossil in the Warwick Museum. The backward projection of the epiotic is broken off. The bones are somewhat larger and much thicker than in the fossil from Blakedown Hill. The sculpturing is coarser, but not quite so well defined. It is impossible as yet to pronounce as to the species of either fossil. In all probability both are referable to the same species; but even this is not quite certain.

Transverse Sections of Labyrinthodont Teeth. Pl. XXVIII.

By permission of the Curators of the Warwick Museum two contiguous teeth, from a mandible of *Diadetognathus*, have been cut to show the microscopic structure. Mr. Thomas Atthey kindly made the preparation; and to his skill we are indebted for a large and beautiful section.

The tooth of *Diadetognathus* differs from that of any other Labyrinthodont genus. It is much compressed, antero-posteriorly, at the base; so that its section is a rectangle, with the long sides perpendicular to the axis of the jaw. Above, the tooth gradually becomes conical. The external surface exhibits numerous striæ, but no conspicuous ridges.

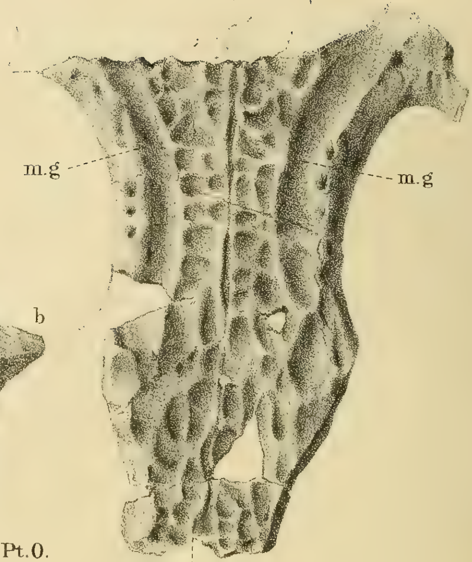
The section is made near the base of the tooth. The dentine is much folded; but there are many intricacies of arrangement, which no folding, however complicated, can explain. No pulp-cavity is visible *.

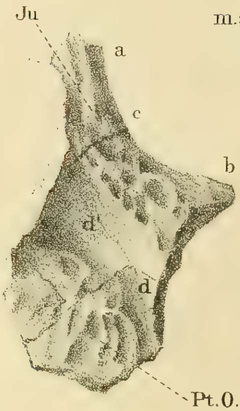
Capitosaurus, to judge from a very rough figure given by Quenstedt, is the genus nearest to *Diadetognathus* in respect of dental structure; but the resemblance is not close.

No tusk of *Diadetognathus*, similar to those which occur at intervals among the serial teeth of nearly every Labyrinthodont genus, has yet been discovered. When the fore part of the muzzle shall present itself, we may expect to find palatal, vomerine, or mandibular tusks.

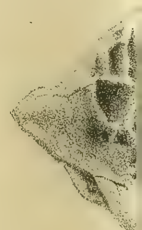
* It must be borne in mind that no opportunity has yet occurred of examining the upper part of the tooth.

1.A.

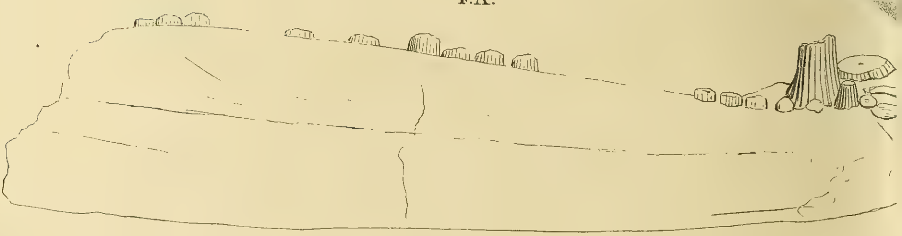




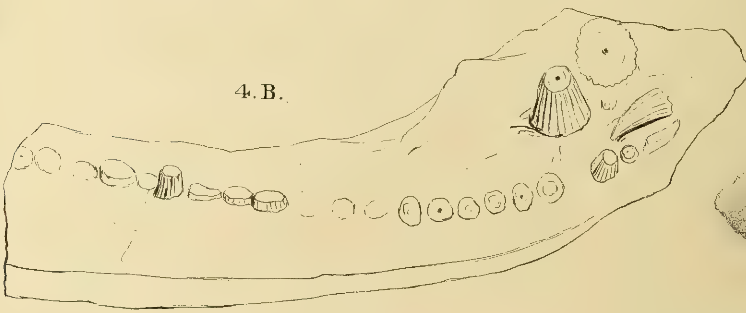
1.B.



4.A.



4.B.



G.H Ford.

TRIASSIC LABYRINTHC

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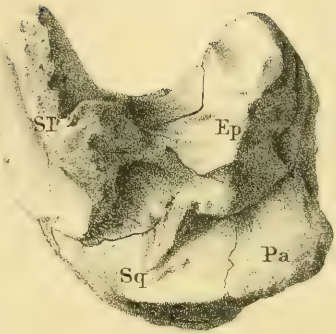

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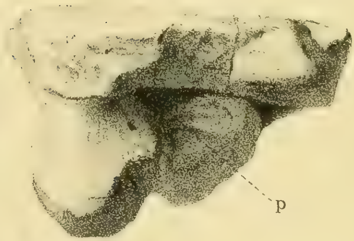

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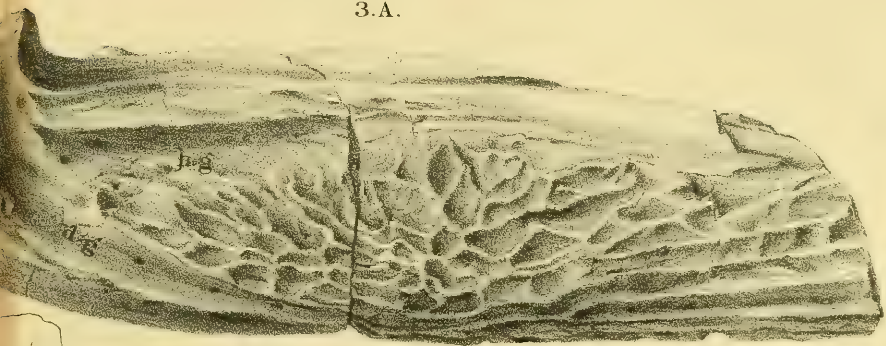

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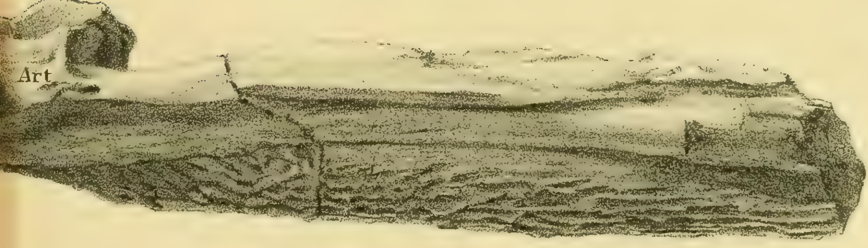

NTA, (WARWICKSHIRE.)

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TRIASSIC LABYRINTHODONTA, (WARWICKSHIRE.)

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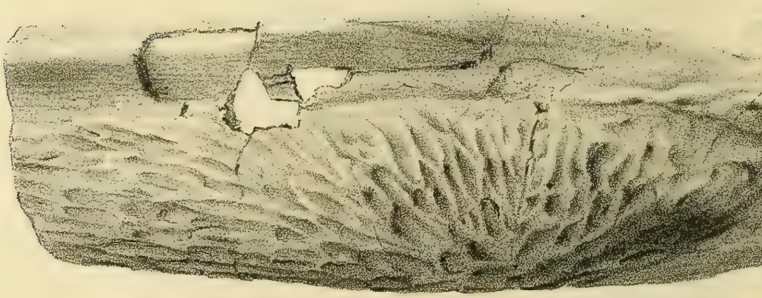

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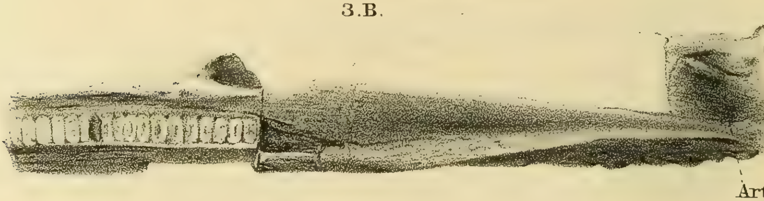

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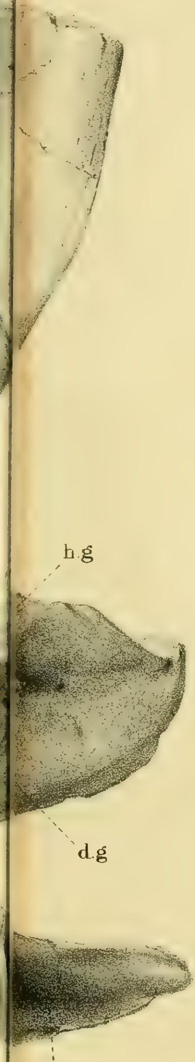

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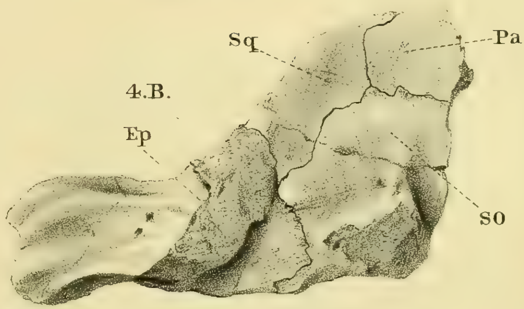

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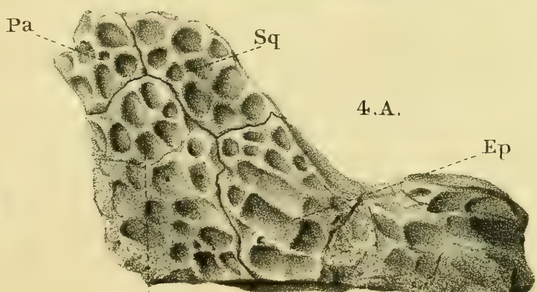

)NTA (WARWICKSHIRE)

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G H Ford

Mintern Bros. imp

TRIASSIC LABYRINTHODONTA (WARWICKSHIRE)

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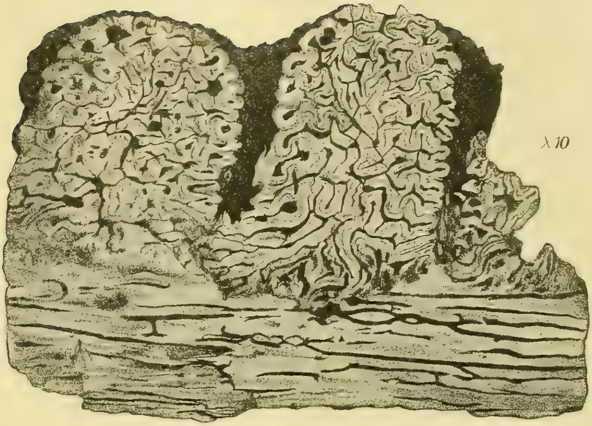

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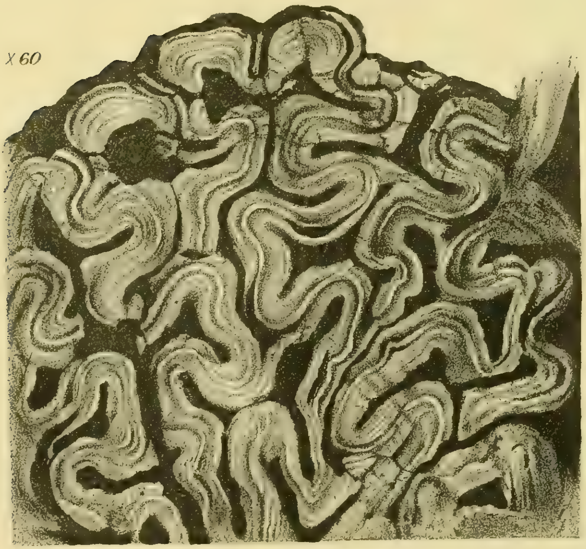

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Mintern Bros. imp.

DIADETOGNATHUS.
(Tooth-sections)

EXPLANATION OF THE PLATES.

Plate XXVI.

Fig. 1. *Mastodonsaurus pachygnathus*, Owen. Orbital region. The restored outline of the orbit is indicated by a dotted line. A. Interorbital tract: *m.g.* Mucous grooves, forming part of the lyra; *p.f.* Parietal foramen. B. Postero-external boundary of orbit: *a b.* Orbital margin; *c.* Suture; *dd'.* Malar mucous groove; *Pt. O.* Postorbital; *Ju.* Jugal.

2. *Mastodonsaurus.* Portion of occipital border; left side. A. Superior surface: *Occ.* Occipital border; *Ep.* Epiotic; *S T.* Supratemporal; *Sq.* Squamosal; *Pa.* Parietal; *a. f.* Auditory fossa. B. Inferior surface. C. Posterior surface: *p.* Pit beneath epiotic plate.

3. —— *pachygnathus*, Owen. Posterior part of right ramus of mandible. A. Side view: *h.g.* Horizontal mucous groove; *d.g.* Descending mucous groove. B. The same, seen from above: *Art.* Articular cavity; *Pt. Art.* Postarticular cavity.

4. —— ——, Owen. Outline of anterior part of right ramus of mandible. A. Side view (from 'Trans. Geol. Soc.' 2nd ser. vol. vi. pl. 44. fig. 1). B. The same, seen from above (ibid. fig. 3).

Plate XXVII.

Fig. 1. *Mastodonsaurus pachygnathus*, Owen. Postero-external angle of skull, left side. A. Posterior aspect: *Art.* Articular surface of quadrate; *Pr.* Protuberance. B. Inferior aspect: *Q.* Quadrate; *Q J.* Quadrato-jugal; *S T.* Supratemporal.

2. —— ——, Owen. Postero-external angle of skull, right side, inferior aspect. *Q J.* Quadrato-jugal; *S T.* Supratemporal; *Ju.* Jugal.

3. *Diadetognathus varvicensis*, Miall. Part of left ramus of mandible. A. Side view: *h.g.* Horizontal mucous groove; *d.g.* Descending mucous groove. B. The same, seen from above: *Art.* Articular cavity; *Pt. Art.* Postarticular process.

4. *Mastodonsaurus?* Epiotic and adjacent bones. A. Superior surface; the dotted line represents the supposed position of the occipital border: *Ep.* Epiotic; *S O.* Supraoccipital; *Sq.* Squamosal; *Pa.* Parietal. B. The same; inferior surface.

(*All the above figures are two thirds the natural size.*)

Plate XXVIII.

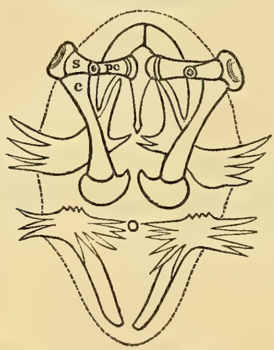
Fig. 1. Teeth of *Diadetognathus Varvicensis*, magnified 10 diameters.

2. Portion of tooth of the same, magnified 60 diameters.

34. NOTE *on some of the* GENERIC MODIFICATIONS *of the* PLESIOSAURIAN PECTORAL ARCH. By HARRY G. SEELEY, Esq., F.L.S., F.G.S. (Read May 13, 1874.)

IN not having a sternum the Plesiosauria differ from the Crocodilia and from all the Lacertian orders of Reptiles. Serpents with limbs being as yet undiscovered, the only true Reptilia which admit of comparison with Plesiosaurs in the pectoral bones are the Chelonians. And even here, at first sight, the resemblance is not so evident as to command attention; for the shapes of the plastron-bones in embryonic Tortoises are more suggestive of the pectoral and pelvic girdles of Plesiosaurians than are the internal chelonian bones which support the limbs, since in Plesiosaurs these osteological elements are expanded shields which cover much of the abdominal surface. When, however, the embryonic pectoral arch of such a Chelonian as the *Chelone mydas** (fig. 1) is critically looked at, only

Fig. 1.—*Pectoral Arch and Bones of Plastron of* Chelone mydas. (After Parker.)



c. Coracoid. *pc.* Precoracoid. *s.* Scapula.

unimportant osteological modification is needed to change its characters to those of a Plesiosaur.

The chelonian coracoid bones (*c*) are rod-like; but their extension is entirely posterior to the articulation for the humerus: the bones approximate somewhat posteriorly, are somewhat concave on their outer margin, and terminate in cartilages of a shoe-shaped form, which are so extended inward that their toe-like terminations meet in the median line. Then, from the humeral articulation the two precoracoids (*pc*) extend inward towards the median line; they are inclined very slightly forward, and join either by their cartilages or intervening connective tissue.

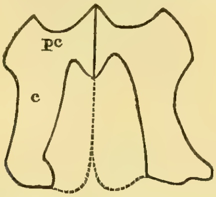
If, now, a line be drawn to join the median points of meeting of

* Mr. Parker, "Shoulder-girdle" (Ray Society), pl. xii. fig. 1.

the precoracoids and coracoids, and a thin film of ossified connective tissue extend over the interspace between them and unite these bones respectively on each side of the animal, a pair of coracoid bones will be constituted similar in form, position, and relation to those which characterize the Plesiosauria, the only difference being that in Plesiosaurs the precoracoid is connate with the coracoid, as in the Ostrich and many Lizards; while in Chelonians it is connate with the scapula (*s*): but much importance cannot be attached to the condition of the precoracoid, since no one will contend that Plesiosaurs are either Lizards or Tortoises; while among Amphibians the precoracoid is a distinct bone, so placed that it might combine indifferently with coracoid or scapula.

It is a noteworthy fact, familiar to all who collect Plesiosaurian coracoids from soft strata, that the whole of this triangular interspace between the precoracoid and coracoid parts, which I covered in the Turtle with an imaginary thin ossification, is liable to be broken away in extricating the fossil; and then there remains only a curious bone forked from the humeral articular surface, which closely resembles the precoraco-coracoid portion of the chelonian pectoral arch just described, and in which only the precoracoid parts similarly meet each other in the median line. A beautiful example of such a specimen from the Kimmeridge Clay, presented by J. C. Mansell-Pleydell, Esq., is exhibited in the British Museum (fig. 2)*.

Fig. 2.—*Coracoids of* Muræenosaurus.



Showing connation of coracoid (*c*) and precoracoid (*pc*).

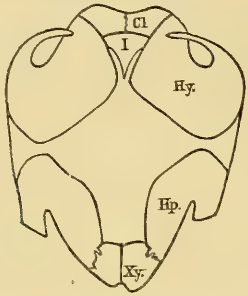
Such a specimen goes far to justify an interpretation of the Plesiosaurian coracoids as the combined coracoid and precoracoid bones.

The Chelonian, however, has the form of its pectoral and pelvic arches modified by the enormous amount of potential epiphysial ossification which characterizes the subclass. The epipleural cartilages of the Crocodile and the small epipleural bones of *Hatteria* and of Birds are, among Chelonians, changed by potential growth into ossifications, in comparison with which the original pleural elements are small; while they so grow and unite that an epipleural skeleton is formed, encased not in muscles as in most other animals, but in representatives of muscles, now converted, in most Chelonians, into horny scutes corresponding with muscles in their extension.

* It is at present standing over the remains of *Megalosaurus*, without osteological determination, and is placed upside down.

On the chelonian ventral surface (fig. 3) potential growth has in the same way repeated, in the connective tissue, the girdle-ossifications, which were subjected most energetically to the intermittent pressure of movement, by which all ossifications are originated, extended, and

Fig. 3.—*Plastron of Embryonic* Testudo. (After Owen.)



Cl. Clavicle of authors (potential precoracoid). *I.* Interclavicle. *Hy.* Hyosternal. *Hp.* Hyposternal. *Xy.* Xyphisternal.

moulded. Thus the hyposternal and xyphisternal bones (*Hp*, *Xy*) reproduce the pubes and ischia in the region of the posterior abdominal ribs; and in certain Chelonians those pelvic bones become as firmly united to the elements of the plastron beneath them as the epiphyses of a mammalian limb-bone to the shaft in old age. In the same way the coracoids are potentially represented by the hyosternal bones on which they rest (*Hy.*). The precoracoids are potentially represented by the pair of bones which have been variously named the clavicles or episternal bones (*Cl*). The chelonian interclavicle or entosternal bone (*I*) has no prototype in the chelonian pectoral girdle, and is probably the interclavicular element pressed into the external skeleton by the precoracoids, though it might even have been generated kinetically as a consequence of the alternate pressure and tension of those ossifications against each other consequent on locomotion, if there were any reason for supposing the interclavicle absent.

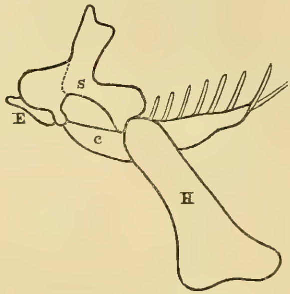
These remarks upon the chelonian plastron and appendicular girdles seem the more necessary, because the Plesiosauria show no sign whatever of an accumulation of organic energy in their organization which could not be manifested in extension of the vertebral column; and we look in those animals for no such elements as characterize the chelonian plastron, precisely because we find empirically that the energy of organization, due to movement of the vertebral column, expended itself in adding new segments to the body; while the development of the chelonian plastron is equally in harmony with the specialization of locomotive energy in the limbs: but since the girdle-bones of Plesiosaurs occupy similar positions to the pieces of the chelonian plastron, and the similarity of the limbs implies not dissimilar functions for the abdominal region in the marine groups of both types, I attribute the better ossification of the pectoral girdle in Plesiosaurs, as contrasted with Chelonians, to the larger amount of organic energy brought to bear upon the bones in consequence of their external position, and the absence of an epipleural skeleton. The structural differences of the limbs from those of Chelonians, in view of their capacity for work, are only a matter of detail.

The other important constituent element of the articular surface for the humerus is the scapula. In Chelonians this bone is a slender rod directed upward to the side of the vertebral column, being thus unlike that of a Plesiosaur in disposition even more than in form—since in Plesiosaurs the bones are invariably directed forward in approximately the same plane with the coracoids, converging anteriorly. This consideration led Cuvier to doubt the determination which named them scapulæ. But considering the enormous number of vertebræ in the cervical region of Plesiosaurs, as compared with Chelonians, I would suggest that potential growth, carrying the vertebræ further and further forward, would probably take the free ends of the scapulæ onward too, till those bones came to occupy their singular position anterior to the coracoids. This supposition perhaps receives some support from scapula and coracoid being approximately in the same plane (though a different one) in Lizards, and by the slightly anterior direction that the scapula occasionally takes.

These two bones are the essential parts of the Plesiosaurian pectoral arch; and if clavicles or interclavicle exist, their presence is exceptional, and only a generic difference.

In 1865 I figured and described, under the name of *Plesiosaurus cliduchus*, an animal in which the scapula appeared to carry, on its outer and anterior margin, a bone holding the same position as the clavicle in *Ichthyosaurus*. A clavicle being needed to complete the resemblance between the two types, I at the time identified the process as the clavicular bone. Owing to conditions of fossilization, I believe the Woodwardian specimen was delusive, and that what appeared to be a separate clavicle was only a thin process of the scapula, broken and partly displaced so as to show a sharp line of division from the thicker part of the scapula, against which it abuts nearly at right angles. Prof. Owen in 1839 (Brit. Assoc. Report, 1840, p. 56), and later, in the 'Anatomy of the Vertebrates' (1866, vol. i. p. 171), stated that the Plesiosaurian "scapula develops an acromial process representing the clavicle;" but I do not think Prof. Owen and I intended the same interpretation; for in the same author's 'Palæontology' (1861, 2nd edit., p. 247) a figure is given of the scapula, which does not seem to be in accord with any figure or published description of the genus. This figure is reproduced in the 'Anatomy of the Vertebrates' (vol. ii. p. 52). I have seen no skeleton of *Plesiosaurus* which will justify such a scapula as Prof. Owen figures (fig. 4, p. 440); and probably the broad portion of the bone, which is represented as extending dorsally and backward over the ribs, bearing upon it the number 51, should have been directed anteriorly along the interclavicle; so that the bone might be more intelligible were it revolved through half a circle.

Fig. 4.—*Pectoral Arch and Humerus of* Plesiosaurus, *as restored by Prof. Owen.*

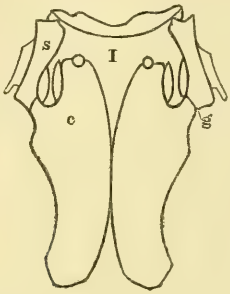


E. Episternum. S. Scapula. *c.* Coracoid. H. Humerus.

Prof. Huxley (' Anatomy of Vertebrated Animals ') apparently regards the Plesiosaurian pectoral arch as a constant quantity, since the species are said to differ in little more than the proportions of the head to the trunk, and the relative length and degree of excavation of the centra of the vertebræ. The scapula finds its affinities in the Lacertilia, the ventral part of the bone in *Plesiosaurus* being supposed to correspond to the glenoid part of the scapula of *Iguana*, while the mass of the Lizard-scapula is supposed to be represented by the lateral portion of the scapula of *Plesiosaurus*. I should not attach more than epiphysial importance to the glenoid ossifications in Lizards, seeing how largely epiphyses are developed in the order, and therefore believe that no part of the Plesiosaurian scapula corresponds to the glenoid ossification adjoining the scapula and coracoid bones in some Lizards. The two chief objections to Prof. Huxley's view are, that in Plesiosaurs there is no evidence of more than one ossification in the scapula; while the preglenoid part of the bone in Lizards is commonly in intimate relation with the clavicle, which on the hypothesis would not be the case in Plesiosaurs. The lateral part of the scapula is of such varying size, that I prefer to suppose it moulded from the scapula in the several species by muscular developmont.

At page 210 of the same work Prof. Huxley gives a diagram of the Plesiosaurian pectoral girdle (see fig. 5), based, as I learn by letter, on "what he imagines to be sufficient evidence." The chief point in which I dissent from that figure is the treatment of the interclavicle; but granting that, as Prof. Huxley remarks, the bone is not always perfectly ossified, no specimen hitherto described, or, as far as I know, exhibited in any Museum, shows the characters of the five-rayed mass named by Prof. Huxley "*a*, clavicles and interclavicle?" (fig. 5, *I*).

Fig. 5.—*Pectoral Arch of* Plesiosaurus, *as restored by Prof. Huxley.*



s. Scapula. *I.* Interclavicle and clavicles. *g.* Glenoid cavity. *c.* Coracoid.

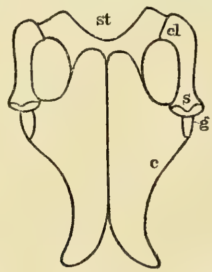
Another interpretation lately given is that of Prof. E. D. Cope, who, in his splendid memoir "On the Extinct Reptilia &c. of North America" (Trans. Am. Phil. Soc., vol. xiv. pt. 1. p. 51, pl. 2), conjectures that the bones which I have here named scapulæ should be called "clavicles or procoracoids;" and consequently, in restoring the skeleton, an imaginary scapula is introduced, which he supposes should extend dorsally over the ribs after the pattern of Prof. Owen's diagram. Prof. Cope's genus *Elasmosaurus*, in which this structure is represented in a restoration (pl. 1), is formed so entirely on the Plesiosaurian type, that I think the laws of osteological correlation warrant us in affirming that, since no trace of such structure exists in any European Plesiosaur, no such bone will ever be found in *Elasmosaurus*. The above hypothesis alone could have induced that distinguished naturalist to name the scapulæ clavicles; it may also have induced him to draw the limits of the glenoid cavities for the humeri entirely in the coracoid bones, excluding therefrom these elements of the scapular arch, because it would be contrary to analogy for them to enter into the glenoid cavity if the scapulæ are supposed to be clavicles. I am convinced that clavicles form no part of the ossified mass figured by Prof. Cope. If it were asked what becomes of the clavicles? the same question might be repeated with regard to those bones in Crocodiles; and if the so-called clavicles of Chelonians are, as I believe, only potential representatives of the precoracoids, there would be no need to account for clavicular bones, even to complete the osteological analogy with the chelonian pectoral arch. If Mr. Parker's nomenclature were accepted, we should be led, starting with a chelonian comparison, to look for the clavicles rather in relation with the interclavicle than with the scapulæ.

Professor Phillips, whose loss we have lately had to deplore, appears, in his 'Geology of Oxford,' to have mistaken the bones of the pectoral arch in *Plesiosaurus* for those of the pelvic arch: bones which have all the characters of coracoids are named pubic bones, while the scapula is identified with the ischium. These determinations seem to me attributable to the occurrence in the Oxford Clay of unsuspected generic modifications, and to a Teleosaurian theory of the affinities of *Plesiosaurus*, by which alone it became possible to regard the pectoral as the pelvic girdle. I allude especially to the fig. 116, p. 310 (Geology of Oxford), which represents, I think, the pectoral arch of a new genus with the posterior end turned forwards. The forms of these bones are exactly paralleled by pectoral bones of undescribed genera of Plesiosauria from the great Pelolithic Period of Oxford to Kimmeridge Clay. The fact that no ilium was found by Professor Phillips is similarly explained. Diagram 180, p. 379, marked "ischium," appears to me to be a left scapula; diagram 179, p. 378, named "coracoid of *Plesiosaurus*," is the right ischium; diagram 177, called "ischial bones of *Plesiosaurus*," appears to me to represent the scapulæ of a new genus.

The English Plesiosauria hitherto indicated have been arranged in the genera *Plesiosaurus*, *Pliosaurus*, *Polyptychodon*, *Stereosaurus* (which is a genus instituted for the stiff-backed Plesiosaurs of the Cambridge Greensand), *Placodus*, and *Tanystrophæus**. Very little is known as yet of most of these, especially of the pectoral arch; so that I prefer to limit this note to the genus *Plesiosaurus* as it is usually understood.

Plesiosaurs may be divided into those which are furnished with a separate interclavicle and those in which that bone has no separate existence. Of the first family, the Plesiosauridæ, the type should be *Plesiosaurus dolichodeirus* of Conybeare; but none of the specimens so named in the British Museum gives certain evidence about its pectoral bones. Of the pectoral bones of other Plesiosaurs, Conybeare gave, in 1824, a restoration which has not since been materially improved upon (fig. 6), chiefly made from specimens said to be

Fig. 6.—*Pectoral Arch of* Plesiosaurus, *restored by Conybeare.*



st. Sternum. *cl.* Clavicle. *s.* Scapula. *c.* Coracoid. *g.* Glenoid cavity.

in the Oxford Museum, but which seem to have long been mislaid. Conybeare correctly identified the coracoids, and accurately placed the interclavicle (sternum) anterior to them, so that its hinder part is overlapped and hidden by the coracoids. The scapula correctly formed part of the humeral articular surface behind; and in front it overlapped a lateral wing of the interclavicle. The scapula in this spe-

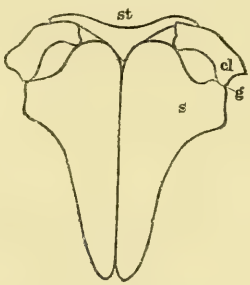
* The last two genera are from the Rhætic beds,—*Placodus* in the collection of Mr. C. Moore, of Bath, *Tanystrophæus* in that of Mr. James Plant, of Leicester.

cimen appears to be transversely divided; and Conybeare lettered the anterior piece (the piece which meets the interclavicle) as the lateral clavicular bone. Conybeare's figure and interpretation were both adopted by Cuvier, except that the bone named clavicle and scapula is regarded by Cuvier as so singularly placed that its homology needed investigation.

The author of the article "Plesiosaurus," in the 'Penny Cyclopædia,' in reproducing Conybeare's figure, named the whole bone clavicle, and supposes that the upward and backward process of the bone (not seen in the figure) is alone to be named scapula.

In 1834 Mr. Hawkins printed his memoirs of Ichthyosauri and Plesiosauri, and gave therein a restoration or diagram of the pectoral bones, professing to be chiefly drawn from the specimen which he named *Plesiosaurus triatarsostinus* (a species with three conspicuously large bones in the tarsus), which Prof. Owen, for the inadequate reason that there may be one or two more small bones in the tarsus, proposed to change to *Pl. Hawkinsii*. Mr. Hawkins's name has fair claim to retain its place; for to Mr. Hawkins belonged the merit of recognizing the species, which Dr. Buckland, who was likely to have been well advised, in 1836 confounded with *Pl. dolichodeirus* in his 'Bridgwater Treatise,' a name which it still retains in the last edition of that work. But in the pectoral restoration (fig. 7) Mr. Hawkins was less happy; for, naming the interclavicle sternum as others had done (and as it theoretically might be), he regarded the scapulæ as clavicles, as Prof. Owen subsequently did, while the coracoids are named scapulæ. I am not sure whether Prof. Owen's description of the scapula in this species is supported by evidence; for the second specimen in the British Museum, named *Pl. Hawkinsii*, in which an approximation to such a structure is seen, certainly might be separated as another species. These species being regarded as the types of the genus *Plesiosaurus*, the definition of the genus depends upon the accuracy of these osseous determinations, if generic characters are to be drawn from the pectoral arch; but the girdle-bones are obscure in *Pl. dolichodeirus*, and the scapulæ are not sufficiently excavated to determine the forms of the bones in *Pl. triatar-*

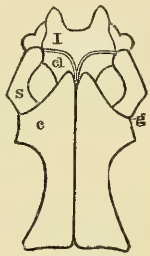
Fig. 7.—*Pectoral Arch of* Plesiosaurus, *as restored by Hawkins.*



st. Sternum. *cl.* Clavicle. *s.* Scapula. *g.* Glenoid cavity.

sostinus, Hawkins, though analogy would make it not improbable that they have the form ascribed to them by Prof. Owen. This doubt existing, the type of the pectoral bones of the genus *Plesiosaurus* may be taken from the fine specimen contained in Case 6 of Room III., North Gallery, British Museum, at present named *Pl. Hawkinsii*, and which may appropriately be left so named. The entire animal is about 6 feet 6 inches long, and has the arrangement of pectoral bones which I here figure reduced (fig. 8).

Fig. 8.—*Pectoral Arch of* Plesiosaurus, *restored from Specimen in the British Museum.*



I. Interclavicle. *cl.* Clavicle. *s.* Scapula. *c.* Coracoid. *g.* Glenoid cavity.

The interclavicle, which is very small in *Pl. triatarsostinus*, only just emerging in front of the coracoids, in this species is seen to be of large size and unusual antero-posterior extent (I). This large bone extends behind the coracoids, much as the interclavicle extends behind the hyosternal bones of Chelonians, and posteriorly shows indications of a median cleft. A groove, or perhaps a suture, diverging, extends therefrom forward and outward, most clearly seen on the left side of the animal. If this mark indicates separate ossifications, which were distinct in early life and have become anchylosed with the interclavicle in mature growth, those ossifications would probably represent the hitherto missing clavicular bones. Similar elements, not well defined, appear to occupy corresponding positions in the large pectoral arch of the animal in the British Museum, named by Prof. Owen *Pl. laticeps*, MS. If these marks do not indicate the union of clavicle and interclavicle, then, in *Plesiosaurus*, clavicles have no existence.

I proceed now to describe and define the pectoral characteristics of the genus *Plesiosaurus*.

PLESIOSAURUS. (Fig. 8.)

The coracoid bones are longer than broad, chiefly placed behind the articulations for the humeri, but also extending anterior to them, contracting in breadth. Part of the curved anterior margin contributes, with the interclavicle and a scapula, to form on each side a moderately large foramen. The coracoid unites with the scapula, by suture, to form the articulation for the humerus.

The scapulæ are very narrow, concave on the inner border, and straight on the outer border, which makes a sharp angle with the lateral vertical part of the bone, which, arising in front, widens from before backward, in a long narrow ⊲-shape, to the articulation, where it is often prolonged as a spur over and above the proximal end of the humerus. The scapulæ converge anteriorly, but are divided from each other by nearly the whole width of the interclavicle, on the extreme lateral wings of which they rest.

The interclavicle is large, often as long as broad, and apparently may include in its posterior part a pair of subordinate ossifications. It is of modified V-shape, being concave in front, with concave sides, which, converging posteriorly, are prolonged behind the coracoids in a sharp point; the lateral wings are much expanded.

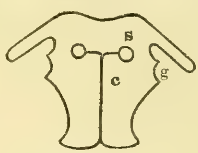
The other British animals usually referred to the genus *Plesiosaurus*, which do not conform to this type, are shown, by their pectoral girdles, to belong to the Elasmosauridæ, typified by Prof. Cope's genus *Elasmosaurus*, in which the interclavicular bone is entirely wanting. At present I am able to define three new English genera which seem to agree in this negative character of wanting an interclavicle; they are:—*Eretmosaurus*, founded on the *Plesiosaurus rugosus*, of Owen, from the Lias, in the British Museum; *Colymbosaurus*, to be indicated by *Plesiosaurus megadeirus*, of the Kimmeridge Clay, in the Woodwardian Museum and in that belonging to Marshall Fisher, Esq., of Ely; and *Murænosaurus*, from the Oxford Clay, indicated by a new species in the collection of C. E. Leeds, Esq.

I have seen indications of several other genera, which may hereafter be defined; and probably, when other parts of the skeleton are critically examined, the number will be increased.

Eretmosaurus, g. n. (Fig. 9.)

Prof. Owen has had drawn, with more than usual clearness, in the 'Monograph of Lias Plesiosaurs,' the chief characters of *Pl. ru-*

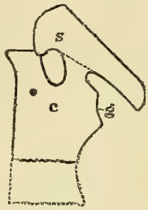
Fig. 9.—*Pectoral Arch of* Eretmosaurus, *restored from Specimen in the British Museum.*



s. Scapula. *c.* Coracoid. *g.* Glenoid cavity.

gosus; but as the pectoral bones are badly preserved in that specimen from the Lias of Leicestershire, it is only after some study that I venture to express ideas of their forms and relations. There may be a little doubt as to whether a distinct interclavicular ossification ever existed; but if such a bone were present, which another specimen disinclines me to believe, then the bone has entirely lost its individuality in the mature animal, and is blended with the scapulæ, just as the scapular bones in the region between the small precoracoid foramen and the glenoid cavity become united with the coracoids into one bone. Important light is thrown on this pectoral arch by an isolated anchylosed scapula and distally imperfect precoraco-coracoid bone, also from the Lias, clearly belonging to the same genus, though probably referable to another species (fig. 10). The

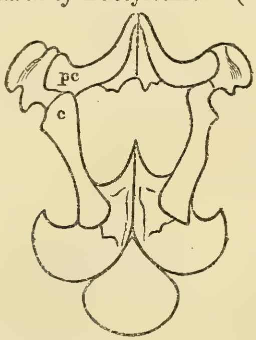
Fig. 10.—*Left Side of Pectoral Arch of* Eretmosaurus.



s. Scapula. *c.* Coracoid. *g.* Glenoid cavity.

coracoid portion of this mass is extremely thin, but thickens at the median line of the body of the animal, as is usual. The articular surface for the humerus shows no indication of being formed by more than one bone, so perfectly are the scapula and coracoid blended. On a line with the anterior margin of the articular surface, and nearer the median line than the precoracoid foramen, is a small vertical perforation, which I suppose to be homologous with the foramen similarly placed in the coracoid of Lizards, Crocodiles, and many Dinosaurs, and to be similarly definitive of the limits of the precoracoid and coracoid elements of the bones, and to indicate that in some amphibian ancestral race the precoracoids were as distinct from the coracoids as they are in the Cape frog (*Dactylethra*), which has a pectoral region not altogether incomparable with that of some members of the Plesiosaurian order (see fig. 11). The ante-

Fig. 11.—*Pectoral Arch of* Dactylethra. (After W. K. Parker.)



pc. Precoracoid. *c.* Coracoid.

rior margin of the precoracoid portion of the bone is truncated in the median line, though a suture there extends between it and the scapula. The anterior and inner margin of the scapula similarly terminates in an edge which gave attachment to cartilage, showing, I think, that the anterior median portion of the pectoral arch was occupied not by an interclavicle, but by a common cartilage, at the expense of which the scapular ossifications extended till they met in the median line.

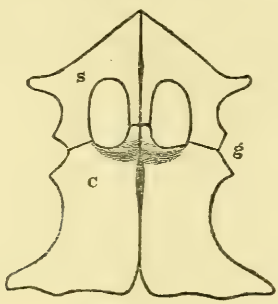
The scapula is remarkable chiefly for the length of the acromial process (which is directed outward), for the straight antero-lateral margin which the bone thus obtains, for the expansion of its anterior end, and for the small foramen which it combines with the coracoid to enclose.

These characters are supported by others in all parts of the skeleton: thus the pubic bones have a prepubic process directed anteriorly, like that seen in Chelonians; and Prof. Owen describes and figures distinct olecranon and patella bones. The caudal vertebræ give no indication of chevron bones.

Colymbosaurus, g. n. (Fig. 12.)

The coracoid bones are oblong, widening at the posterior angles, and not extending anterior to the humeral articulation, except

Fig. 12.—*Pectoral Arch of* Colymbosaurus, *from a Specimen in the Museum at Ely.*



s. Scapula. *c.* Coracoid. *g.* Glenoid cavity.

slightly in the median line of the body, and not cupped deeply to form the foramen between the scapula and coracoid.

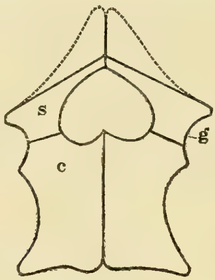
The scapula is of extraordinary form; the two bones meet in the median line of the body, meet the coracoids behind by a narrow union, and enclose the greater part of a large foramen; the anterior margins of the bones are straight, converge at about an angle of 90°; the posterior end of the straight side is prolonged into a blunt process, between which and the humeral articulation the side of the bone is concave.

These Plesiosaurians all have very long slender necks, and closely approximate to the *Elasmosaurus* of Cope, with which I hesitate to identify it till we know more details of the structure of the American animal. The species are found in the Oxford Clay, Ampthill Clay, and Kimmeridge Clay.

MURÆNOSAURUS. (Fig. 13.)

Both pelvic and pectoral arches are characterized by the bones having no median antero-posterior osseous union. Thus, instead of

Fig. 13.—*Pectoral Arch of* Murænosaurus.



s. Scapula. *c.* Coracoid. *g.* Glenoid cavity.

two obturator foramina, this genus has but one. In the same way there is but one foramen enclosed between the scapulæ and coracoids. The scapulæ converge in front with straight anterior margins, which make a right angle with enormous lateral processes, which differ from those of all other Plesiosaurians in being prolonged forward.

With these characters are associated a union of the neural arches of vertebræ, only comparable to that seen in Serpents and Iguanoid Lizards, but with semicylindrical zygapophysial facets; while the chevron bones join tubercles at the base of the centrum instead of articulating between two centrums; and the ulna and radius, and tibia and fibula, are distinct in form from those of other genera. The type of the genus is *Murænosaurus Leedsii,* Seeley, Q. J. G. S. vol. xxx. p. 197. I should place the *Plesiosaurus Oxoniensis* and *Pl. Manselli* in a subgenus of *Murænosaurus.* The species are found in the Oxford Clay, Ampthill Clay, and Kimmeridge Clay.

RHOMALEOSAURUS, g. n.

One genus, found in the Alum shale of the Upper Lias at Whitby, is represented by the fine species in the Museum of the Royal Dublin Society, which has been named, by Mr. Baily and Dr. Carte, *Plesiosaurus Cramptoni.* This type has given no evidence of its sternal bones; but its other characters differ so far from those usual in *Plesiosaurus,* that it may be placed in a genus by itself, to be named *Rhomaleosaurus.*

The cervical vertebræ are nearly as short, from back to front, as in *Pliosaurus*; and the cervical rib is articulated with the centrum by two facets, as is the case with the early cervical vertebræ of *Pliosaurus.* The ulna and fibula have not the usual reniform shape, but are short and broad, and resemble the radius and tibia in being slightly constricted. No mention is made of chevron bones in the caudal vertebræ. There are only six bones, in two rows, in the carpus and in the tarsus, and only four digits in each limb. The premaxillary bones appear to extend backward so as to divide the nasal bones; and the lower jaw is unusually deep at the coronoid bone. The double articulation for the cervical rib probably indicated relationship to the Pliosauridæ rather than to either of the families that I have discussed; but it is seen in isolated vertebræ from the Lias, contained in the British Museum.

I cannot but consider it a matter for regret that, although so large a number of species have been found in the Cambridge Upper Greensand and other Cretaceous strata, we are still ignorant of all those parts of the body which would warrant us in placing them in genera. One is thus unable to pronounce any opinion on the evolution of modifications of the Plesiosaurian girdle in relation to time. And the only general conclusion at which I have arrived is that Plesiosauria, in common with all similar groups, show, in the newer rocks as compared with the older ones, a greater amount of ossific energy, probably coincident with higher organization, which manifests itself in more perfect ossification of the bones, elongation of processes, and blending of subordinate with the principal ossific centres.

35. *About* Polar Glaciation *&c.* By J. F. Campbell, Esq., F.G.S. (Read April 15, 1874.)

Introduction.

In order to be concise and comprehensible, and to assign a reason for venturing to address this Society upon so large a theme, I must refer to former work. In 1865 and 1867 I published and enlarged a book called 'Frost and Fire.' In it I aimed at showing, by description and by designs, that certain forms are as letters inscribed on the outside of the globe to record part of its history.

Example. A volcanic crater and a water-course differ in form, as do the letters O, S, Δ. Both sets of forms convey meaning to those who have learned to read. A record of volcanic action is written on the moon in black and white, and can be read by any one who has seen Naples and its volcanoes, old and new. In November 1873 no record of aqueous or other "denudation" had been written upon the upper cone of Vesuvius, whose igneous outside form was remade in 1872, and grew upon the older mountain-top after 1842. But a deep inscription is scored in water-courses and deltas within and without the cone and crater of Monte Nuovo, which grew in 1538, during one scattering discharge of a fountain of hot vapours, fluids, and solids. That particular gun has not fired since. A deeper "water-mark" is on the older "Astroni," which was a volcano, and now is a wooded preserve for game, and upon "Somma." If we measure the relative depth of these water-marks upon two volcanic surfaces newly made in 1872 and in 1538, a scale of depth may be constructed by which to estimate the age of Astroni and Somma, by "denudation" of their igneous surfaces. No such water-marks are seen upon older and bigger cones and craters in the moon, which cannot be reached, but which can be seen.

It is recorded on the outside of these two worlds by certain forms, that it has rained little since 1872 at Naples, that it has rained a great deal there since 1538, that it has rained a great deal more there since the unknown date of the last eruption of Astroni and Somma. There is no record of glacial denudation at Naples. There is no record of any denudation on the mountains in the moon, which seems to have no atmosphere and no clouds. I strove to learn this natural alphabet of form; I copied natural forms, and gave illustrations; and I used printers' signs as symbols to convey my meaning shortly. In the book quoted, A is like the shape of mountain peaks; Y or V the section of a water-course; S, windings; Δ, fan-shaped deposits of drift, washed out of a water-course and called a "delta." ⌒ expresses the rounded outline of a glaciated hill country; ◡ hollows made or widened by glacial erosion. Water-courses of all sorts and sizes are alike, and record the same kind of aqueous denudation everywhere. "Ice-marks" of all kinds differ from "water-marks;" and both differ from marks of volcanic action and of subterranean disturbance. Probably few have read the book; so I give this explanation of my own drift in writing on the subject.

In May and November 1873, at pp. 198 and 545 of the Journal of this Society, you did me the honour to print notes on the Glaciation of Ireland, and of the Hebrides. These and this paper are sequels to 'Frost and Fire.' In July 1873, I left England to look at a new country; and after travelling 150 days, I returned in December. At your Meeting on the 7th of January 1874, I heard able papers read upon the glaciation of the lake-districts, and upon the confluence of glaciers in parts of England and Wales, and a discussion in which the existence of an older glacial period was alluded to. I then offered to give you the results of my last observations in Europe and Asia in a written form. I now give you results of work done between 1840 and 1874, referring to my former writings for details and explanations.

(1) *Geography.* The observations, of which some account is given in the writings quoted, were made in Europe and in America. In Europe they were made in Scandinavia, Finland, and Russia, in Germany and Switzerland, in Greece, Italy, Sicily, and Spain, in the British Isles, Färö, and Iceland. In America they were made from Hamilton Inlet in Labrador, to St. Louis and Washington. In 1873 I coasted Norway, rounded the North Cape, and coasted the Polar basin and the White Sea to Archangel. I crossed Russia to the Caspian, crossed that sea to Petrovsk, and travelled through the Caucasus to the Black Sea. I visited the Crimea, Odessa, Constantinople, and Syra, and rounded the south cape of Europe. I went to Corfu, Brindisi, Naples, Rome, Florence, Pisa, Spezzia, Sestri, Genoa, Nice, Cannes, and Paris, copying and studying form and superficial geology everywhere.

During more than thirty three years I have been carefully observing and describing glacial and other phenomena, within an area which includes 36 degrees of latitude and 140 degrees of longitude. I reckon from the North Cape, 71° 11′ 3″, to the Straits of Gibraltar, from Camara on the Volga, 50° E., to St. Louis on the Mississippi, 90° W. It is a very small bit of the world's outside after all; and I have little to add to knowledge previously gathered by my teachers.

(2) *Conclusion.* From personal observation and reading I had arrived at certain conclusions, which are stated in my paper on the Glaciation of Ireland (Q. J. G. S. 1873, p. 218, § xviii.). I believed that the majority of the Geological Society had arrived at similar conclusions; but I seem to have gone further than other Members. I was convinced by my facts and evidence that during the growth and decay, the waxing and waning, of the last of a series of glacial periods, small and large glaciers existed in the British Isles, that many there joined to make small and large "local systems," that many local systems joined in low grounds whilst the glacial period was waxing till the United Kingdom and the shallows about these islands

were united in bonds of thick ice from the Land's End to John o'Groat's. I had come to believe that the Scandinavian ice-system, which now has shrunk and broken up, once grew and united till it equalled and exceeded the dimensions of Greenland ice, and then crossed the German Ocean and joined the mainland to the islands, as the Humboldt Glacier now joins small islands to Greenland, wading far out in shallow seas. In America, from lat. 45° to 39°, I had seen icebergs afloat and marks on shore, which a great man, now lost to science, Professor Agassiz, attributed to a general solid polar glacier. When I started questions for solution at p. 548 of the Journal, I was inclined to follow that able leader. Then I set off in search of facts, imitating those who have taught that travel is needful for geological study.

(3) *Hypothesis.* If a polar glacier reached Washington at least, and was part of a "cap" which also overran Scotland and Ireland, then, as I surmised, that polar system must have flowed, or waded, or floated over the plains of Europe, down to the latitudes of Washington and St. Louis,—in Europe say to 40°, 39°, or 38° N. lat. That being my hypothesis, these are my facts, old and new, which seem to bear upon polar glaciation and confluent glaciers, and the marks which are now attributed to a glacial period or to a series of glacial periods.

(4) *Norway &c.* In coasting Norway once again I saw much to confirm my opinion. I saw the coast clearly, and sketched day and night while I could keep awake, from July 26 to August 7, when I landed at Vardö. Sea-marks, water-courses, and signs of volcanic action abound. Lateral pressure has bent and broken the earth's crust. A whole country has been first crumpled, and afterwards raised bodily from the sea, and bent like a bow. But I hold that hills and hollows in that country have been shaped chiefly by the "glacial erosion" to which Professor Ramsay long ago, and Mr. Clifton Ward in his late paper, attributes the rock-basins which hold lakes, and are filled with drift in certain parts of the lake-district, which he has so well surveyed and mapped (see figs. 1 & 2). So far as it goes, Mr. Ward's paper amounts to a demonstration of the truth of one proposition, which I noted. "The hollows which contain these lakes were formed by glacial erosion." I hold the converse of the second proposition, which I also noted. "The valleys, of which these lake-basins are part, are *not* due to glacial erosion." I have gone further than this author, and hope that he will follow. I seek to prove that a great many hollows of curved section, however they originated, owe their present form to the glacial erosion, which also produced hollows in them, in which water lodges; and that many hills and ridges of curved section between these furrows owe their forms to the same grinding-engines which shaped "Tors" and "Roches Moutonnées" of smaller size*.

* It still is very often denied, even by geologists, that glaciers wear rocks under them. A glacier near Cape Desolation, in Greenland, about the latitude of Christiania in Norway, is about 800 feet deep where it enters the sea, in a firth

Fig. 1.—*Svart-Iis Glaciers, Norway.* (The edge of the largest Ice-tract in Europe.)

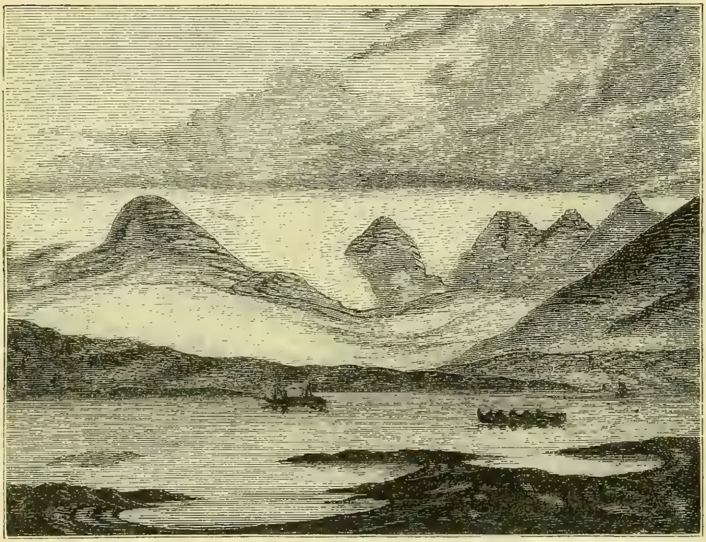
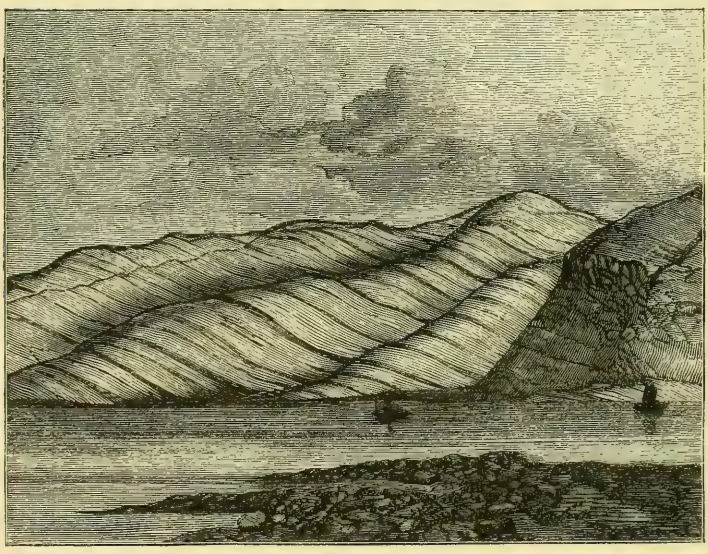


Fig. 2.—*Glacier Work, Norway.*



(5) *The Polar Basin.* According to Mr. Skanke, English and Russian consular agent at Vardö, which port is frequented by Sea-horsemen and Whalers, "Parry Island"* is the most northern in Spitzbergen, and is made of gneiss. He gave me a specimen. The most northern island reached in Novaya Zemlia is in long. 66° E., and about 77° N. lat. Consul Skanke gave me a specimen, brought thence by Captain Mack, which contains a large coral. Bear Island, near lat. 75° and north of Norway, is rich in fossils which are taken to indicate a warm climate. Judging by form and information I concluded that some hills and islands, about the mouth of Kolafjord, and at the entrance to the White Sea, are patches and outliers of stratified, unaltered, undisturbed beds, resting unconformably upon far older, greatly inclined, disturbed, crystalline, altered beds, which have been "denuded" and ground into the shape of Russian Lapland. I find, on referring to the geological map of Europe, that my inference was correct, so far as the nature of these rocks is concerned.

At Yeredick the rock is gneiss, the dip nearly vertical, the strike N.W. S.E., the direction of glaciation N. and S., magnetic. In neighbouring hills I saw faults which I take to be postglacial. A smart earthquake was felt near Kola in February 1873. At other places on the coast the rocks are gneiss, with veins of pink granite, like rocks which I have seen in the Hebrides and in Labrador. Generally the coast of Russian Lapland is made of old, hard, contorted, fractured rocks ground into curves. On the east side of the White-Sea straits the beds are nearly flat, and seem to be little altered. Limestone is there burned, and it is taken to Archangel†.

(6) *Rise of Land.* I spent five days on Vardö Island, which is in the Polar basin. I found on the sea-beach subangular and rounded stones. I found bits of metamorphic slate, broken from overhanging beds of rock, in the bay. These dip at an angle of 45° and strike N. S. Bays and hollows and ridges are on the strike; but deep "Gjàs" cross at right angles. The general form of the island is that of glaciation. Up to about 30 feet is the "Storm beach" with larger and more angular stones on it, cast up in a ridge which sweeps in a crescent round the bay. Up to about 60 feet the raised beach is a repetition of the actual beach, but grass-grown. On it are large round blocks of granite. No granite is near *in situ*. The highest

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about three miles wide. Photographs were taken there by Mr. Bradford, which which were shown at the Meeting. No moraines are on the surface; but under the ice at the side of this glacier are large boulders, and fine débris in contact with rounded rocks. All glaciers move at slow rates, varying with circumstances. A cubic foot of this ice must weigh about 55 lb. Therefore the pressure on the bed of this glacier is nearly twenty tons per square foot. If a train wears wheels and rails, and a carriage its drag and the road—if stones and sand rolled by rivers and the sea wear rocks, it seems evident that stones and sand must be crushed and ground, and must crush, break, and wear rocks under the great pressure of moving glaciers. Practically, all glacier-rivers are thick with débris worn from rocks. As glaciers wear rocks, then icebergs driven by currents must also do the same, under water, when they touch the bottom.

* The Parry Islands of maps are to the north of America.

† Since my return I have read Murchison's 'Russia,' vol. i. 1845. The rocks referred to are marked Devonian.

beach in this hollow is about 100 feet above the present sea-level, and partially covered with peat. Rolled stones and stones packed by water are close to the highest point in this island at 200 feet. The summit is 220 feet above the sea, and consists of red altered sandstone, very hard and ringing to a blow. The east coast is full of great rifts, in which waves dash and growl.

Peat beds on the raised beaches are brown and dusty, with a considerable vegetation growing on them. Rock surfaces are unmistakably wave-worn; amongst the stones on the old beach I found granite, gneiss, and red sandstone, with fossils in the shape of concentric rings, like the rock of Vardö. I also found rolled brown pumice stones exactly like those which I found in Tiree. These were abundant: but the nearest volcano is a long way off; so they have floated far, and mark the equatorial drift from the Hebrides to Vardö on the way to Novaya Zemlia.

(7) *Result.* Vardö Island, at the end of a long promontory and in the Polar basin, was first ground into shape by ice, as I suppose. It has been submerged and wave-worn since; and as it rose, drift upon it was rolled and packed by the sea, which carried light drift, and may have carried granite on rafts from anywhere. It may have brought gneiss from Parry Island or from Russian Lapland, pumice from Spitzbergen or Iceland. Then peat grew; and now people live there, and fish and roam about in the Polar basin hunting and sealing and making money. Meantime the waves are breaking the exposed side of the island into rifts and cliffs. So I read the forms on the island, without trying to make out the age of the rocks.

Since my return Consul Shanke, of Vardö, has sent me the meteorological journal of a crew of Walrus-hunters, who were frozen-in north of Novaya Zemlia. They went in June 1872; and the journal ends May 12th, 1873. The men who kept the journal, father and son, died. The survivors got home to Tromsö in December 1873. No one else has wintered there, so far as I am informed.

(8) *Ocean-currents and their effect.* Captain Mack named the most northern island in Novaya Zemlia "Castanje ö" or "Mimosa," because he there picked up "chestnuts" or "Mimosa" beans. These brown nuts prove ocean circulation, as I have shown in 'Frost and Fire,' vol. i. p. 483. They are tropical growths carried to frozen lands. The island must be about lat. 77° N., long. 66° E.

To that point the equatorial current now reaches; and there the warm water must plunge under water, which after a certain temperature gets lighter as it gets colder, till it floats ready to freeze. Solid ice was lighter than sea-water off Labrador as 9 is to 10 by bulk. In Spitzbergen the "chestnuts" get to 20° E., 77° N.; and the warm water of the equatorial current then goes under the ice to warm the sea-creatures who live at the bottom. The fortress of Vardö and the church at Vadsö are built in coral sand; it is therefore possible that fossil corals may have lived under similar conditions. Numbers of whales come into the fjord; thirty-two were slain by one small steamer in 1873 before August 6th. Fish of many kinds abound. There is plenty of life in the Arctic basin now to make fossil-beds with corals in them. At Yeredik, about 70° N., I found a luxuriant vegetation on shore—the wild corn of Iceland, "Baldur's flower," the cotton-grass, the "Indian tea" of Labrador, and many bright wild flowers. Geraniums and cacti live in pots in the houses; and canaries live through the winter in warm rooms. The winter's darkness does not kill; therefore the poles need not be changed theoretically in order to account for Arctic fossils. The hills are clothed with firs and birches where there is soil enough for them to stand in. Peat is common; so materials for coal grow now. About lat. 69° N., harbours near the mouth of Kola fjord never freeze. They are sheltered from the eastern drift and remain open all winter. A few miles further east, at the Seven Isles, the harbours are blocked every winter. On the 10th June, 1873, they were still blocked; on the 15th of August snow patches lay on the beach, but no ice was anywhere near on sea or land: it had all drifted away.

(9) *Result.* The warm equatorial current now affects climate in the Polar basin to lat. 80° in Spitzbergen and to long. 66° E. in Novaya Zemlia. The cold Arctic current affects the coasts of Greenland, Labrador and North America, and carries floating ice down to lat. 37° N., long. 47° W.* That which the sea actually does for climate now, the sea may have done when the fossils of the Arctic basin lived, and when land now dry was submerged. Arctic currents are part of polar glaciation, which is the subject of this paper.

(10) On the former trip (described, 'Frost and Fire,' vol. ii. p. 503) I crossed from the Polar Basin about 70° N. to the Gulf of Bothnia, and searched between 25° and 30° E. long., through Finland to St. Petersburg and Berlin. I found all known marks of extensive glaciation continuous as far south as 55° or thereabouts. In 'Frost and Fire' (vol. ii. pp. 3–17) I have described the marks on which I rely. I found No. 7 "Hollows" ⌣ holding lakes and bogs, No. 9 "Tors" ⌢ between the hollows. I found "Drift" upon rounded hills and in rounded hollows, on ridges and in grooves, polished striated rocks under drift, and scratched polished stones upon the polished rocks. I found "thirteen wandering blocks" (great masses of a peculiar Finnish rock which is much used in St. Petersburg, carried southwards and left on sandy plains) along the shores of the Baltic and in the neighbourhood of Berlin. I found most of these marks in Devonshire down to lat. 50° 30′ N.†, and in Ireland as far west as long. 10° W. The Alps and Pyrenees carry European glaciation as far south as 45° N., but not continuously, so far as I know.

(11) *Russian Lapland.* In 1873 I found the shores of the Polar basin between 35° and 40° E. long. universally glaciated at about 70° N. lat. The hills are all rounded, and their sky-line is studded with great "perched blocks." Rounded hollows ⌣ are glaciated and partially filled with boulders, with boulder-clay and drift, with lakes and bogs; all the marks upon which glacialists

* 'Frost and Fire,' vol. ii. p. 247. † *Ibid.* chap. 42, p. 220.

·ely abound. Rivers have made little or no impression upon the rocks, and commonly flow over drift. Thus in Russian Lapland as in Finland and Scandinavia, from Stavanger to Kola, the action of very heavy ice is proved by conspicuous marks. The record is continuous from Kola to Cape Clear, to near the Land's End and to Berlin, and to lat. 50° N. in one direction.

(12) *Rise of land.* A series of raised beaches follows the whole northern and western coast thus far, and marks a late unequal rise of land in this great tract of country. Shells *in situ* confirm the proof by form, which is everywhere conspicuous. Amongst these marks sea-caves at considerable elevations are numerous.

(13) *Result.* If ever a solid "ice cap" radiated from the Pole, and reached to Washington, and to the south of Ireland and to Berlin, these glacial marks on the edge of the Polar basin along an arc of 15° about the circle of 70° N. may be work done by the "ice cap" when it was shrinking northwards to leave isolated local systems in Greenland, Iceland, and Scandinavia. Something ground these regions of Northern Europe. An Arctic current like that which now coasts Greenland and Labrador seems to me insufficient to account for the work done. The new facts tell in favour of the Polar glaciation for which Agassiz contended. His theory had not come to the front when Sir Roderick Murchison travelled in Russia. In his 'Geology of Russia' (vol. i. p. 331) Sir Roderick mentions the discovery of recent sea-shells on the right bank of the Vaga. The town of Tromsö in Norway stands on peat, which rests on clay, in which are recent sea-shells in the position which living shells of the same kinds now hold in the mud. I saw them in 1873 in drains. In both cases the shells are overlain by "Drift."

(14) *The White Sea.* The entrance to the White Sea is not much wider than the Straits of Dover. The shores are not higher than the French and English coasts; and the eastern shore is a cliff with a beach on which large stones are strewed. I have sketches; they show stratified beds capped by drift on which fir forests grow.

From Kola to Kandalatz a series of lake-basins extends from north to south. These forms support the ice-cap theory. The existence of beds of soft rock on both sides of these harbours does not support a theory of Polar glaciation by solid ice. I have surmised that these shallow narrows may possibly represent an old river-course, widened by sea-currents and by the action of waves. About Archangel the shores of the White Sea are low and flat; and the country appears to be drift, chiefly fine mud in the delta of the Dwina. The sea is silting up. I found a great many large polished striated boulders of very hard rock, many like those which I saw on the shores of the Polar basin. According to the geological map and my own observations these must be of northern origin, unless they came down from the Ural mountains.

(15) *Archangel to Astrakhan.* Having seen rocks and boulders about 70° N. from 25° to 40° E., I followed southwards between

40° and 50° E. from the White Sea to the Caspian over Russia, with this result:—

In the entrance to the White Sea at the mouth of the Dwina, and along its banks, I found beds of newer formations little disturbed and covered with Boulder-clay and drift. I found numerous polished and striated boulders of far older and harder rocks, like those of Russian Lapland, in the drift as far as I followed the Dwina. Then we landed and drove 500 versts (about 330 miles). A little north of lat. 60° N. I came upon a tract like the country of drift-hills which I saw about Knopio in Finland amongst lakes, and in the archipelago of the Baltic along the Swedish coast. From long. 15° to 40° E. about lat. 60° N. is a range of low drift-hills. Where I passed through them along the Vaga in 1873 the breadth of this range is about 30 miles. The hills are about 800 feet high at most. They have peculiar moraine-like forms. Amongst them are detached cones and short boat-shaped ridges through which the Vaga winds northwards. Sections made by the river and by its feeders, and surfaces in fields and roads, show that these mounds are chiefly made of sand, gravel, and large stones. Most of the stones are rolled; but many are glaciated; all seem to have been carried from a region of older rocks over these plains of newer formations, on which Boulder-clay and drift are so thickly spread that solid rock is rarely seen. I saw no rock in driving through these drift-hills *.

A Russian Engineer Officer told me that a range of low hills extends nearly to the Ural Mountains eastwards. I know that they reach Sweden westwards about lat. 60° N.; I have passed them thrice.

(16) *Result.* If the range of drift-hills near Turin, about lat. 45° N., be the moraine of confluent Alpine glaciers, which Professor Ramsay taught me, and I am willing to believe, then these drift-hills, forming a large arc about the circle of 60° N., may be the moraine of that polar glacier for which Agassiz contended. I will not attempt to account for them; but I have seen them in Finland and in Russia and in the Baltic.

(17) Further south, nearer to Vologda, we passed a conical mound of drift about 100 feet high in the midst of a plain. Possibly this may be sepulchral. Tombs at Kertch are as large. On it I found specimens of the gneiss which I had followed from Lapland over about 10°. Between 60° and 55° N. lat. on the route to Yaroslav, Moscow, and Nijnii Novgorod, I found numerous boulders of kinds which I thus followed along 15 degrees of latitude. I was told by travellers that similar stones abound westwards near the sources of the Volga. I saw numerous low hills of drift about Moscow; but railway travelling by night is not conducive to geological study. I suspect that another range of drift will be found about 55° N. in Russia.

* Murchison's 'Russia,' vol. i. p. 176. "The road which leads from Ust Vaga to Usting runs for some miles at a short distance from the Dwina, and the great thickness of the drift-sands which here encumber the surface prevented our seeing the fundamental rocks." It is a great satisfaction to find my observations, independently made, confirmed by a great authority like Murchison.

(18) *The Volga.* South of lat. 55° N. and east of Nijnii, I did not see one of the northern boulders which I was hunting southwards. The southern limit of northern boulders on the geological map of Murchison and his comrades, published in 1845, is marked by a line which passes Nijnii Novgorod, where I saw the last of them in 1873.

The Volga is more than 2400 miles long, and falls 633 feet from its source to the Caspian. The right bank is commonly the highest, and gives a section of the country nearly as long as the river.

At Yaroslav the right bank is more than 100 feet high, while the left is low as far as it is visible from the terrace.

At Nijnii Novgorod the right bank is nearly 200 feet high, and is made of thick beds of stratified gravel, which are noticed in Murchison's 'Russia.' The left bank is low as far as visible from the terrace. At Saratov the right bank is 360 feet high by my barometer. It is scarped and undercut; and landslips result. The river is shallow and three miles wide; and the left or meadow-bank is a low plain, with a flat horizon distant more than twenty miles. On a very fine clear day I could see no rising ground eastwards from the scarped hill above Saratov, which is part of the country into which the Volga cuts *. I watched this bank while I was awake during the voyage of six days to Astrakhan, and I did not see one glacial boulder to be sure of. This part of Central Europe is covered by thick beds of fine drift, by stratified sands, gravels, and earth, which rest on stratified rocks which have been little disturbed since they were deposited. I have sketches to show the work of rain and rivulets, and of the big river, and the structure of the high bank.

Below Saratov beds of rock appear to be made of the same kinds of mud which rivers now carry from the Urals, and from Western Russia into the Caspian. At some places beds of different colours alternate. The cliff bank is striped horizontally, and scored vertically by water-courses, and has a strange appearance. I suppose that the mud varied in colour as the eastern or western branches were flooded. They have different colours now.

(19) *Result.* In America I lost the train of northern boulders about lat. 39° N., and found the fine drift which colours the Mississippi and extends to the Gulf of Mexico. In Germany I lost the northern boulders about 55°, 16 degrees further north.

I lost northern boulders in Russia about 56° N. at Nijnii Novgorod, and followed gravel and mud to the Caucasus and lat. 41° N. The latitudes vary; the drifts are alike. A Russian officer familiar with Siberia told me that great blocks of granite are planted amongst mounds of shells in sandy plains in the steppes of Northern Asia. He had been railway-surveying. All these facts support the idea of polar glaciation down to 70° and to 60° at least in Europe, to

* Why that river flowing southwards is working westwards is a question foreign to the subject of this paper; but the Arctic current may explain the fact.

some unknown limit in Asia, and to 32° N. in America. Whether ice flowed, or waded, or floated, it is needed to account for the transport of large stones from north to south in Europe, Asia, and America. The bed of the Volga proves that river-ice is not a sufficient cause.

From 60° to 40° N. in Europe all the drift that I saw might have been spread by water. But the drift gets finer as it gets further from the Arctic basin. It may all be of northern origin, glacial at first, sorted by water afterwards.

(20) *The Caspian.* As all the world knows, the Caspian has no outlet and is lower than the ocean, though many large rivers, including the Volga, flow into it. The waste is by evaporation; and much rain falls in Persia about the high land at the southern end of the Caspian. The water is salt, but not nearly so salt as the ocean. Far out from the mouth of the Volga for about forty miles the water is very shallow, and the bottom mud. The delta ends and the lake deepens suddenly. Lake-steamers wait at the bank for shallower river-steamers. The water is thick and dirty for a long way south. Opposite to the end of the Caucasus the basin deepens greatly; and thereabouts are naphtha springs and volcanic phenomena on shore. Manifestly the Caspian, like the White Sea, is silting up with fine mud, washed off Europe and Asia and their beds of old drift. Fish of many kinds abound and are caught in the Volga. I saw many sorts, none quite like any fish previously seen by me. "Herrings" for example are more like Bream for shape. The "Sterlet" has no bones. Since the canal was cut to join the Volga and Dwina the Sterlet has got to the White Sea. Sturgeon and Bellugu salted fill barges and are sent over Russia. The New-Red Caspian formation now forming will have many fossil fishes in it with ancient tails and bony plates outside.

(21) *The Caucasus. Hypothesis.* As ice and drift got so far in the Old and New World, I supposed that glacial phenomena of the Alps would recur in the Caucasus. These are my observations:—

From the Caspian to the Sea of Azov the range is roughly about 800 miles long. The highest peaks, Kasbeg and Elbrouz, are said to be over 16,000 and 18,000 feet high.

(22) *The Pass of Dariel.* In crossing the range from north to south from Vladikavkas to Tiflis, the road passes the foot of Kasbeg, which the natives call the "Sword of God." The road is as easy as the Simplon. It mounts along the banks of a considerable stream through a deep gorge which gives a cross section of the range.

On the 3rd of October I saw the Peak of Kasbeg and the range from the north for more than 150 miles.

Approaching it we drove over undulating plains of clay and passed a lot of large stones. Elsewhere I should have called them glacial erratics; but I could find no scratches. In the evening I walked to the right bank of the river, and found a great ridge of clay which I took for a moraine; but even here I could find no scratched stones. I believe it to be part of a delta. I sketched and inspected brick-pits, and reluctantly gave up my Caucasian glacial hypothesis, which had been rudely shaken before between Petrovsk and Vladikavkas.

October 4th. We drove up a beautiful gorge with well-marked terraces of rolled stones at the mouth of it, and with many very large stones scattered about; but I saw nothing glacial in the gorge. The rocks at first were limestone, with springs of clear water. The limestone, which is much bent, so far as I could make out from the carriage, overlies unconformably a series of beds dipping northwards at a high angle.

I noted in succession "shales," "flags," "slates," "mica-schist." Through all these beds the river has cut narrow gates of the usual square pattern, while the side streams have cut the usual V-shaped furrows. Up to 750 feet the road went over river-pebbles and gravels, with an occasional fallen stone, as big as a house, near cliffs.

Then we got to igneous rock and to strata dipping north as before. At Kasbeg Station, 2620 feet above Vladikavkas, we stopped, and I sketched a high mountain-glen without a single glacial mark in it that I could recognize. The water in the river was cold, but certainly not a glacier-stream like those which I have seen in the Alps, in Iceland, and in Norway.

October 5th. I sketched Kasbeg, which is a tall pyramid of rock on which a considerable quantity of new snow lay, but so as to show the rock and its structure. I saw nothing like a glacier from below. We drove past Sionski Gori, which is all spires and pinnacles like the rocks above Romsdal in Norway. At one place near the station of Kobi is a bed of basalt (fig. 3, *a*) with bent pillars; it is nearly horizontal and unconformable to the rest of the strata, which have the same northern dip. Rock-crystal is found and sold to travellers. Near the top of the pass water is coloured red and yellow by mineral springs. Close to the top is a bed of limestone unconformable and nearly horizontal. From this runs a spring which deposits a yellow stuff which I took for a wreath of old snow. It is like the Sprudel deposit, and forms on grass and stones and every thing, in layers like the stuff which forms about the Geysirs in Iceland. At the summit my aneroid marked 22·800, 7·700 lower than at the Caspian, which gives about 6930 feet. The height is said to be 8000 feet. From the top we trotted merrily down into Asia, passing quartz-flags much shattered, and got into a different climate and country. It was green, with lots of hay. A plant with red leaves grew in clumps and made the hill-side like a garden on a lawn. The rivers ran clear.

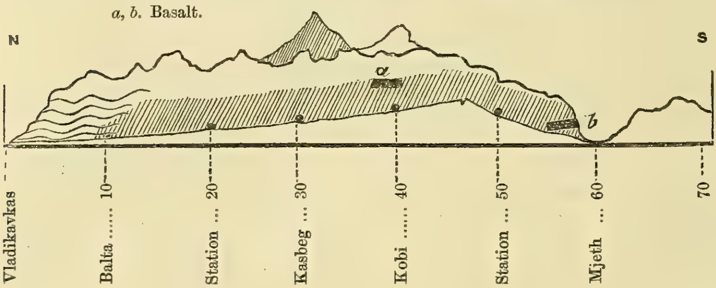
We had got from the arid rainless country to a watered land. We trotted rapidly down to 24·700, where we reached a village and a clear river, and stopped. For some distance down the first pitch the rocks have the same northerly dip. Near the river is a bed of basalt (fig. 3, *b*) which crops out along the hill-side. The pillars are very large and crossed by joints or flows of the old lava. Near this are beds of stone like the rock of Gulbrandsdal in Norway (Silurian?). Pebbles in the river are blue, with white crossing veins. The basalt seems horizontal and unconformable.

Oct. 6th. Lower down we got to the same northerly dip and followed it along the strike and again across it nearly to Tiflis. The northerly dip appeared persistent from Balta to Mjeth, for nearly fifty miles; and the sequence extends southwards from newer to older rocks. My observations were confirmed by a Russian officer.

A mere traveller bent upon copying general forms could not see geological details from the jolting springless carts which carried him rapidly through the Caucasus in four days, allowing scant time for drawing at stations. From Mjeth the road is on the strike for a long distance. Near Tiflis the beds are much folded, the folds are parallel to the main range, and the rocks are like folded beds of the coal-formation which I have seen in the Alleghany Mountains. I have drawn a rude section to fit the page (fig. 3), scale twenty miles to the inch horizontally, exaggerated vertically. The extreme height of Kasbeg would be expressed by about $\frac{1}{60}$ of an inch.

Fig. 3.—*Section through the Dariel Pass.*

(Horizontal scale 20 miles to 1 inch; vertical scale greatly exaggerated.)



The outlines of the mountains are due to weathering. Except large stones, I could find no trace of glacial action in the whole journey of 202 versts (about $133\frac{1}{2}$ miles). Short of Tzalkan, not far from Tiflis, we saw a lake ("Bazaleti"); near it is a conical mound like a moraine. I saw, or thought I saw, some scratched stones amongst a great many rolled stones, and I believed the lake to be glacial. After a careful search in the valley lower down, all the large stones that I could find were smooth water-worn pebbles taken out of the clay, and out of great beds of rolled stones which there make large hills. I noticed ploughing with fourteen and eighteen oxen hereabouts. October 7, got to Tiflis*.

* Since my return I have read Dr. Lyell's book, and find that we noticed many of the same things in the Pass of Dariel, such as the springs, the flowers, the oxen, &c. Klaproth, quoted in a note, mentions the rocks which I noticed. Keith Johnstone's Geological Map of Europe colours the Caucasus as Tertiary and Crystalline.

Montpereux, 'Voyage autour du Caucase,' 6 vols. octavo, and Atlas, 1843. In this work is a section which includes the Pass of Dariel from Vladikavkas to Tiflis. It confirms what I have said as to the dip and sequence of rocks, and marks the lake of "Bazaleti" on its pebble-beds.

(23) *Daghestan* (the mountain-country) is on the north side at the Caspian end of the Caucasus. The rocks are chiefly the folded limestones which we crossed in the pass of Dariel afterwards, and apparently some of the dark shales on which they rest unconformably. The limestones are very like beds which appear in the right bank of the Volga. The long folds are parallel to the main range. One bed of dark earthy shale contains large globular concretions. We come to it repeatedly in Daghestan in deep watercourses. Another bed consists of large hard rolled pebbles in a matrix.

From the nature of the country, the clearness of the air, and the absence of vegetation, the structure of Daghestan is easily seen. The edges of the flags and schists and igneous rocks which we afterwards passed near Kasbeg seem to form the crests of the whole range, and furnish the boulders and pebbles which the largest rivers roll down to the plains.

(24) *West-end.* From Tiflis to Poti on the south side of the range, and along the shores of the Black Sea, the structure seen near Tiflis appears to extend into the Crimea along the northern shores of the Black Sea.

The lower hills are made of folded beds of newer stratified rocks, the higher hills of the edges of harder beds upheaved. I will not attempt to guess at the age of the rocks; but some appeared like Mountain-Limestones, the Coal-measures, and superincumbent strata. Coal has been found in the Caucasus, and is worked north of the Sea of Azov and south of the Black Sea.

In any case a great thickness of old sedimentary beds have been tilted up on edge, and a great thickness of newer beds have been crumpled and folded like dough; and the key to Southern-Russian geology is in the Caucasus, in the Gate of Asia, in the pass of Dariel. The general disturbance may be found to coincide with the geological disturbance which upheaved the Alps and other chains. Between lat. 30° and 40° N. there is a marvellous coincidence in the general direction of mountain-ranges in Europe and Asia.

(25) *Denudation.* Such is a rude outline of the geology which I thought I saw while rapidly travelling through the Caucasus. The shapes of the hills and hollows, which I studied and drew, clearly are due to aqueous denudation (see fig. 4).

If ever glaciers worked in the range, their traces have been almost entirely obliterated. Very little rain now falls in Daghestan or anywhere on the northern slopes. The rivers which drain the range are small. Houses have flat roofs; dresses are not contrived

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In the map, Daghestan, which was conquered about eight years ago, is not coloured.

Koch's Geological Map, 1850, does not colour Daghestan. The Dariel Pass from north to south is coloured "Tertiäres," "Secondäres Gestein," and "Thon-Schiefer." Kasbeg, and the opposite mountain, are coloured Volcanic, including therein "Basalt and Trachyte."

I have also read Mr. Freshfield's book, and his paper published by the Geographical Society, to which I refer below.

for rain; roads made by Russian engineers have no gutters, few bridges, and no provision against floods. Nevertheless the whole range for 800 miles is deeply furrowed by water-courses which are plainly water-work, as furrows are on and in the crater of Monte Nuovo. They make a pattern like the branch of a fir-tree, or a fern, with the fine points towards the main range. While driving and riding westwards for a distance of 512 versts (about 338 miles) from Petrovsk to Vladikavkas, along the folds of limestone and the strike, a rise and fall of a couple of thousand feet was a common incident. We crossed a lofty plateau, scrambled down watercourses of gradually increasing size, till we got to some rivulet or main river flowing northwards; but only four bridges are on the road. Having crossed a river, we climbed to another scarped plateau, and entered by some queer rift or water-gate, as into a fortress. Then for eight or ten miles we rode along a different, upland, grassy country till we got to the edge of it, and plunged down into another arid gorge. I could find no signs of glaciers even on these remnants of the old surface, through which the water has dug a couple of thousand feet or more, as it appeared to me.

Each of these plateaux is like an island inhabited by people who, like Hebrideans of old, made war upon each other till they were conquered. Twenty-five languages are spoken in the Caucasus. Through this country the Russians hunted Schamyl till he was surrounded upon the Plateau of Gunib. His lower town was fired into from the opposite plateau over a water-course some miles wide, and a couple of thousand feet deep. By observation, I made the bridge 3230 feet above the Caspian, Gunib 4230, the upper town 5130, and the upper edge of the plateau 5715. The Russians scaled a cliff to get to Gunib from the west side; now they have made a tunnel through it and a practicable road down the mountain-side to Karadagh. The descent to the next river was equal to the ascent, 2485 feet. Speaking generally, there are no lakes. In all Daghestan only one is known. It is on one of the plateaux, and is about a couple of miles long. At the foot no stream escapes. The water evaporates or oozes through a dam of angular gravel, which may be a terminal moraine. At the head of the lake I found a small median moraine nearly smothered in the delta of a tiny streamlet. The lake is deep and clear, and full of trout; I believe that they were put there by Russians. I could find no glaciated rocks anywhere about the lake. The moraine is the only mark of glaciation that I could identify in the whole range while travelling from end to end. The air was so clear that I often saw a wall of mountains for more than a hundred miles at a glance. I swept it often with a good glass. I saw new snow in plenty, and got to new snow several times, but I could see no blue glacier. The country has been admirably mapped. The officers at Tiflis only told me of two small glaciers, which are to the north of the two highest peaks; and these are marked. On the southern side of the range, I saw one other small lake, as I have said. From lat. 40° to 45° N., long. 50° to 35° E., I could not find one rounded hill or hollow, one scratched rock or

Fig. 4.—*Waterwork in the Caucasus.*

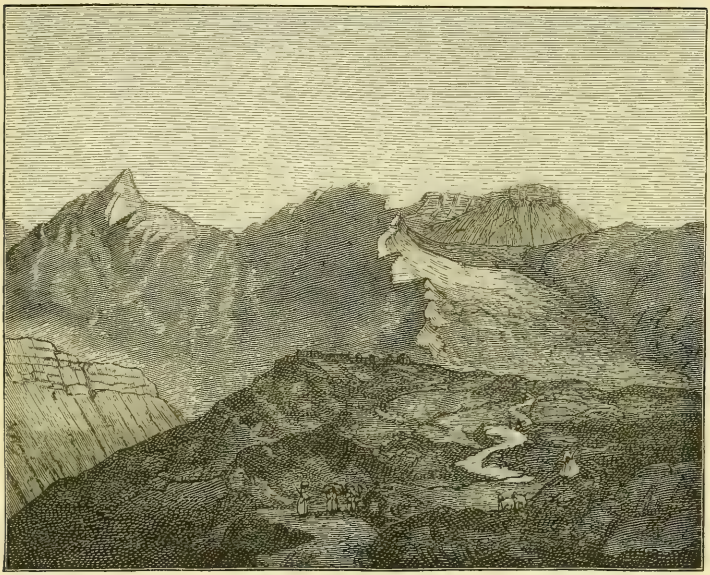
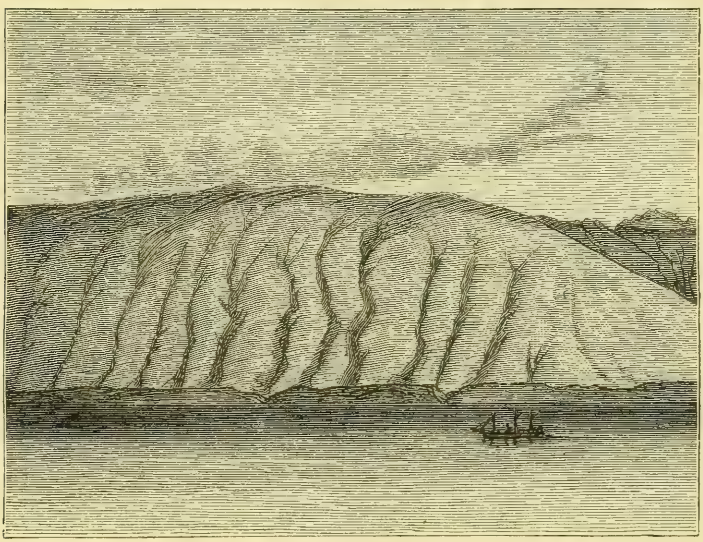


Fig. 5.—*Caucasus: Shores of the Black Sea showing Waterwork.*



stone, one perched block, one lake-basin certainly due to glacial erosion, a glacier or the trace of one. The work of running water is plain as on a railway embankment after a heavy fall. The highest hills are jagged sierras, the lower hills pyramidal or scarped. The valleys of all sizes are shaped like **V** or like **Y** (fig. 5). The tail of the **Y** is often a deep drain like those which I have described in 'Frost and Fire.' One I guessed at 500 to 600 feet deep. It is scarcely wide enough for a couple of loaded horses to pass, and it is all water-work. It is called "the tunnel of Karadagh," and is the drain for a great tract of country, and the road used by its inhabitants. When I rode through it there was hardly water enough in the river to fill a London main pipe, and passengers were numerous. Passages of the same kind abound in Daghestan, and generally are defended by villages and used as gates. Familiar with glacial marks, and fresh from Norway and Lapland, where they abound, the contrast between glacial and aqueous denudations was very striking.

(26) *Rise of land.* As I have said, the fall of the Volga from source to delta is given at 633 feet. Above Petrovsk, on the Caspian, is a sloping deposit of large rolled stones and sand, which fills up a hollow between an isolated hill and the first range of the Caucasus. No river is near to account for this, which I suppose to be a "raised sea-margin." It seems to bound the northern plains, which fade into the Caspian. The isthmus at Petrovsk, and the drift-slopes along the northern range, are more than 500 feet above the Caspian and the plains of mud which separate it from the Black Sea. If water stood at the levels marked by raised sea-margins in Scandinavia and in the Caucasus, the Caspian, the Black and White Seas, and the Baltic would be joined, and most of Europe would be sunk. Looking to the drift-section on the high right bank of the Volga, I think it probable that all these European plains were in fact submerged at a late geological period. I found terraces of large rolled stones elsewhere in the Caucasus at higher levels; but some I attributed to the action of rivers*.

(27) *Result.* If Europe was in fact submerged, the circulation of ocean-currents in the Atlantic is pertinent to the distribution of northern polar drift in Russia.

(28) *Hypothesis.* I thought it possible that northern drift might be found in the low gap which contains the sea of Azov and the Straits of Zenikali, lat. 45° N. Icebergs do, in fact, reach lat. 37° N. in the Atlantic now; and the Crimean winter is severe enough to make ice-rafts. Northern drift and large boulders reach 39° N. in America.

(29) *Fact.* Arrived at Kertch, I saw numerous conical mounds placed singly or in groups and ranged in rows along the low sky-line. I was told by different people on board the steamer, and on shore, that these mounds were "natural," that they were "volcanic,"

* At page 297 of his great work, Murchison devotes a section to the relics of a great former eastern Mediterranean Sea which covered these regions and deposited the older and newer Caspian rocks, which are marked upon his map.

that they were made of "conglomerate." I began to think that they might be "glacial." They are in fact sepulchral. Hewn-stone tombs, as big as small churches, are buried under mounds of earth. Many have been opened, and treasures of art have been taken from the "Kourgans" of Kertch. I sought "drift" in the Crimea and found none. I found naphtha-springs, which are volcanic. They abound, and the naphtha is used as fuel on board steam-boats.

(30) *The Black Sea.* The northern shores of the Black Sea differ materially from the sea-coasts further north. Between Poti and Odessa there are no deep-sea lochs or fjords like those of Scotland and Norway. There are few bays or indentations, very few harbours or islands. No sinking of mountains would change the character of the coast in these respects. The coasts appear to have risen, unless the water-level has fallen. There is no appreciable tide; but where land is low, the beach suggests that it is always ebb and a perpetual spring-tide. Salt lakes abound. These seem to result from the formation of bars at the mouths of rivers, bays, and inlets, now ebbed nearly dry. All the plains and islands that I saw looked like alluvial flats left high and dry. The lofty Crimean coast seemed to be a sea-cliff, broken out of a small bit of the Caucasus and made of like materials. I attributed the difference in this coast-line to the absence of that glacial erosion to which I attribute "rock-grooves" as well as "lake-basins," ridges left as well as furrows made, in Scotland and Norway.

(31) *Bosphorus.* I was assured that miniature arctic and equatorial currents flow in and out through the Bosphorus; and I fully believed what I was told. A passenger assured me that he felt, and that I ought to feel, the difference in temperature on opposite sides of the steamer as we entered from the Black Sea. I saw vessels at anchor heading opposite ways, and vessels under weigh dodging the stream. I was ready to believe, but I wanted proof.

Oct. 31st. I got a boat and crossed to Asia from Constantinople, and found the surface-temperature 65° from shore to shore. I found eddies in plenty, but no opposite surface-currents. With southerly winds warmer water comes in from the sea of Marmora, according to the Turkish boatmen. I went to a high hill-top, on the Asian side, and found nothing glacial anywhere about the Bosphorus. I sought drift, and found none that could not be explained by the action of water on the hills. What I saw from the hill might have been a bit of a great river. It was like Niagara below the falls, the St. Lawrence near Montreal, the Rhine near Bonn, the Volga near Saratov, or the Danube near Vienna; a stream flowing through a wide plain with a few hills in it, all seamed by water-courses. If the Bosphorus-hollow were now filled to the height of the right bank of the Volga at Saratov (360 feet), the Black Sea would be forced back into the Caspian, and the perpetual ebb would be changed to high water. I am strongly of opinion that the Bosphorus is, in fact, a drain cut by running water in very late geological times, and that the Black-Sea level has been lowered by the cutting of the drain.

(32) *Greek Archipelago.* Amongst the Greek islands I saw forms due to volcanic action. I saw volcanic cones in a latitude in which volcanic rocks and active volcanoes abound from Persia to Sicily; but everywhere I saw water-courses on the hill-sides and wave-marks at the sea-margin. About the South Cape, November 3rd, I saw none of the glacial marks which I had seen at the North Cape on the 4th of August, 1873, and in America, near Washington and St. Louis in 1864.

(33) *Italy.* At Naples I saw volcanoes old and new, and climbed Vesuvius for the second time after an interval of thirty-two years. I saw lakes in volcanic craters at Naples and near Rome, and water-courses everywhere, but I saw no sign of a lake-basin or valley due to glacial erosion in Italy. I climbed the hills above Genoa and looked down into large watercourses like those of the Caucasus. I saw nothing that I could identify as glacial work about Nice, Cannes, and the hills behind that sunny coast, with its palm-trees and cacti. The last polar glacial marks that I saw in Europe were at Nijnii Novgorod, about lat. 56° N.

(34) *Result.* My observations support the extension of polar glaciation to lat. 56° N. in the east of Europe, to 55° in Germany, to nearly 50° in Britain, to 39° in America. The Alpine and Pyrerean systems I now suppose to have been separate local systems. The absence of glaciation in the Caucasus I cannot explain by anything but ocean circulation and atmospheric causes.

(35) *Volcanic Phenomena.* The enormous disturbance of stratified rocks along ranges of mountains like the Caucasus, and the Balkans, and the Alps, I can only account for by the shrinking of the earth's mass and lateral crushing of the crust. The varnish on a globe is thicker in proportion and is disturbed when the globe shrinks or expands. The undisturbed condition of the northern regions of Europe, and the enormous development of igneous rocks south of the Caucasus can only be explained, as I suppose, by something like a fracture equal to the length of the range, which is chiefly made of sedimentary beds lifted like the lid of a box.

(36) *Sea-beds.* I wish to disclaim the notion, which I never entertained, that all valleys are "big ice-scratches," and that all hollows are due to glacial erosion. Forces which heaved up the earth's sedimentary crust in the Himalayas, in the Caucasus, in the Crimea, Balkan, Alps, and Pyrenees, which also folded the beds of the Coal-formation and threw them into basins and troughs, synclinal as well as anticlinal curves—forces which are raising and sinking whole countries now, are sufficient to account for ocean-beds and for the Caspian and other basins. But denudation alone accounts for drift, and for the materials of sedimentary rocks. I seem to have passed through a sedimentary series nearly forty miles thick in the Pass of Dariel. The earth's surface has been ground down to the extent of the sum of sedimentary beds. Glacial drift, wherever found, proves glacial erosion, equal to the mass of drift whatever that may be. The masses of drift which I have seen in Europe and in America prove glaciation on something approaching the scale for which Agassiz contended.

(37) *Conclusion.* I hold with Mr. Clifton Ward and with Professor Ramsay, who stated the theory long ago, that certain lake-basins are "due to glacial erosion," and also that many valleys and many hills between them are chiefly due to the same engines which also formed glacial drift*. I have endeavoured to explain what I mean by "denudation" and "ice-marks," and to describe what have I seen in the writings which I have quoted above. To them I must beg to refer for details, and for justification of my venturing to address you on polar glaciation. I cannot yet see my way to a general ice-cap reaching nearly to the equator.

(38) *Travelling.* Allow me to say, in conclusion, that throughout Russia I was treated kindly, courteously, and hospitably. I was asked for my passport only on arriving at Archangel, and on starting from Odessa. I had no difficulties or adventures. I endured few hardships, and enjoyed magnificent, bright, calm, hot weather for five months.

Tho best months for travelling along the route are those which I selected. The best months for the Caucasus are September, October, November, and part of December.

The Russians wish travellers to explore; and I believe that English geologists will be especially welcome visitors. Many officers especially mentioned the Alpine Club, and hoped to see more of its members.

(39) Since my return, while writing this paper, I have read Mr. Freshfield's paper in vol. xxxix. of the 'Transactions of the Geographical Society,' and his book, 'Caucasus and Bashan,' Longmans, 1869. Our facts may seem to be at variance as to Caucasian glaciers; but they may be reconciled. Mr. Freshfield and his comrades climbed; I did not. He saw the white side of the shield, I the yellow. He travelled along the ridge from Kasbeg to Elbrouz, at the rainy end; I travelled chiefly at the rainless eastern end of the Caucasus. He travelled in June and July. I passed Kasbeg in October after summer, before winter snows. In his book, and in my journal, Kasbeg, seen from the Station, is depicted as a pyramid of rock, thinly covered with snow. Possibly the unmelted snows may have led Mr. Freshfield to an enlarged estimate of the size of the formidable glaciers on which he climbed during the adventurous journey which he so well describes. His largest glacier was only 500 yards wide. In Daghestan valleys are often filled with great masses of drift, the accumulations of many confluent deltas into which the streams have cut deeply. Had I seen there unusual waving alluvial deposits covered with thick snow, while standing upon a glacier myself, I should have noted them as larger glaciers. I did, in fact, set them down for moraines when I first saw them. I made a careful sketch of one such deposit from the plateau above Gunib, believing it to be glacial. It was only after riding over a great many similar deposits, and after passing Kasbeg and the ridge, that I was driven from my Caucasian glacial hypothesis. Between Tiflis and Poti, Petrovsk and Vladikavkas, I saw no glacier stream. At Soukhum Kali on the

* See footnote on p. 452.

Black Sea, where I landed, I could find no boulders in a stream which comes from near Elbrouz; and I could see none from the steamer along the whole coast to Kertch. The glaciers trodden by Mr. Freshfield I could not possibly see; for they are on the north side of the range between Kasbeg and Elbrouz. They are marked on the Russian map. We saw different regions, and the same region under very different aspects, and we need not fall out like the knights of old who quarrelled about the gold and silver shield. What the Russians know of their country is on their Caucasian map.

Postscript.—April 27, 1874.

Mr. Belt, whose very interesting book * proves his accuracy in observing nature, describes (pp. 248–263) marks which he took for proofs of the action of land-glaciers about lat. 14° N. in Nicaragua. He says, "The evidences of glacial action between Depilto and Ocotal were, with one exception, as clear as in any Welsh or Highland valley." The exception was scratched rocks. The lowest marks noted were still 2000 feet above the sea. Believing, as he does, in "evolution," and in cold which locked up water enough on land to lower the whole surface of the ocean 1000 feet at least, Mr. Belt supposes that tropical life survived the cold in wet low grounds left dry by evaporation. These ancient low lands now are at the bottom of the salt sea, beneath 1000 feet of melted ice which turned to fresh water.

Professor Agassiz and his followers go much further. After this paper on polar glaciation was sent in, a copy of 'The New York Tribune' of December 30, 1873, was sent to me by some person unknown. On the 15th of April I spoke of the newspaper. It contains "A series of six lectures by Professor Agassiz," which seem to have been printed from short-hand notes. It is stated that the first of the series was delivered Feb. 5, 1867, before the Cooper Institute at New York, after the author's return from South America.

It is stated as proved that glaciers covered the whole of temperate North America, as well as "*the whole of Europe*." In Maine the ice was 12,000 to 13,000 feet thick; and further south glacier marks were identified. The author concluded at last that the valley of the Amazon, about the equator, was filled by a vast glacier which came down from the Andes and went into the Atlantic, the ice, perhaps, then covering the sea to such an extent that it is a question whether any open water was left at the equator then, as it is a question whether there now is open water at the Pole. But Agassiz found no scratched rocks in the valley of the Amazon. He is reported to have said, "and if this be so, you see at once how this intense cold must have modified the surface of the globe to the extent of excluding life from the surface * * *, and preparing the surface of the earth for the new creatures which

* The Naturalist in Nicaragua. By Thomas Belt. Murray: 1874.

now exist upon it." He pointed his argument directly at the theory of evolution which "is cut at the root by this winter which put an end to all living beings on the surface of the globe (*applause*)."

Any thing said by Professor Agassiz deserves that grave consideration and respect which is due to the memory of a very distinguished man. These lectures, which were much and deservedly applauded, contain an epitome of nearly all that has been denied and accepted by glacialists and geologists within the last 40 years.

Agassiz, those who worked with him, those who followed them, and those who went on separate paths to their own conclusions about glaciation, have all begun with the Swiss glaciers, which are so well described in these lectures. By reasoning from admitted facts a few have convinced themselves of the recurrence of glacial periods due to astronomical causes. The complete smothering of the whole earth in a crust of ice many thousands of feet thick periodically, and the consequent periodical destruction of all life on the earth's surface, is one of those advanced glacial theories which few accept, but which cannot be ignored by geologists. The facts on which theories are founded may be tested; and I have endeavoured to state the result of my own observations as to Polar glaciation. They go to prove that the whole of Europe "was *not* covered by a polar glacier."

P.S.—May 1, 1874.—*Caucasian Glaciers.*

Professor Abich, of Tiflis, an eminent geologist, published in 1870 part of a work on Caucasian glaciers of which I have not got the sequel. The pamphlet, which was lent to me in the end of April, contains two views and a section of the Devdoraki glacier. It is to the N.W. of Kasbeg, in the shadow, and high up. It is mentioned by Mr. Freshfield. It bursts periodically and sends a wet avalanche of rubbish into the pass. In 1867 it threatened to burst again, and damaged the post-road; therefore it was again surveyed by Professor Abich, who surveyed it in 1861. The conditions of its growth appear to be these. The top of Kasbeg is more than 16,000 feet high. A very steep cone of more than 6000 feet sheds avalanches which knead themselves into *névé,* and produce glaciers of pure ice with "dirt bands," which flow and tear and regelate according to their ascertained laws of motion. One "of 2nd order" named "of Stephen Zminda" ends at 9504 feet above the sea opposite to the Station. The largest ends at 7374 feet above the sea. In 1867 one branch of this had broken and fallen into the other, which had grown much since last surveyed. It was about 350 yards wide, about a couple of miles long, and about 300 feet deep at the end, according to estimate. The end could not be measured, because of falling stones. The surface was found to be moving at increased rates, faster than the whole glacier, which is on a slope of 17°. The views show that the sides of the valley are deeply furrowed by V-shaped water-courses. The drainage of this system of "corries" flows into the Tarek at right angles, four kilometres below the Station, which is opposite to the peak of Kasbeg. From the peak to the junction is hardly five miles on the map.

The glacier-stream there in October 1873 was a rill lost amongst a great heap of *débris*, a couple of hundred feet high at least, which seems to have crossed the valley at some time, so as to block the main streams and form a lake above the dam. This small glacier is marked on the Russian map, scale 10 versts to the inch. Thirteen small glaciers are also marked on it. All these are on the north side of the ridge, in the shadow, high up, and to the west of Kasbeg, where the range is highest and nearest to the Black Sea. The largest glacier, which is mentioned by Mr. Freshfield, and was described by Klaproth long ago, is mapped as five miles long. Probably the present dearth of large glaciers in this lofty region is due to its inland position. South-west winds are dried before they reach the Caucasus, and nearly drained before they reach the eastern end, where evaporation is in excess.

Between the Caucasus and Ararat, whose latitude corresponds to the present limit of Atlantic drift-ice, are numerous large sheets of water in low grounds. I have not seen them. They have nothing to do with the drainage of the Caucasian highlands. That gathers uniform main streams, on which are no lake-basins like those of the Alps and Scandinavia. Of these streams two flow into the Caspian and evaporate, two join the Mediterranean.

Professor Abich writes very cautiously about tracks of glaciers in a glacial period. He founds his opinion upon certain conspicuous stones, which I also noticed while travelling once along the road, and upon much local knowledge gained by himself, and by officers, surveyors, and engineers who conquered and mapped the country and made the roads. They are making railroads now. The region is subject to earthquakes and torrents. Professor Abich describes a case in which stones from 200 to 300 feet in circumference were shaken down, and moved more than 12 kilometres from a "cirque" in Ararat by a single *débâcle* of snow, ice, water, and mud during an earthquake in 1840. A glacier now descends from the top of Ararat to a level of 9000 feet, in the cirque at the head of the valley, in which the delta of this sudden mud torrent now has the shape and semblance of a "moraine."

These great Ararat "erratics" are equalled in size by only one Caucasian block, named the Stone of Jermolov, which is 3531 feet above the sea, near Lars, in the pass of Dariel, five miles below the broken moraine-dam above mentioned. I took it to be a fallen stone when I sketched it; but it has been identified with granite nearer to the base of Kasbeg, whose top is 10 miles from Lars on the map. This erratic is equalled in size by a stone on the Unter-Aar glacier, under which nine of us slept on the 15th of September, 1841. That is slowly moving on the glacier, and must have gone more than two miles by 1874. Therefore ice or mud may have carried the stone of Jermolov five or six miles down hill (10,000 feet) to its present place. These Caucasian stones are equalled in size by blocks on the Jura, in Russia, in Lapland, in Scotland and Ireland, and in America, which have somehow crossed deep valleys and arms of the sea where mud torrents are out of the question. Professor Abich concludes, with hesitation, that a Kasbeg glacier carried this erratic so far (five or six miles) down the course of the Tarek. The pass is a V-shaped valley of erosion with many large branches. The main stem is about 40 miles long, three or four thousand feet deep, and at the bottom it is little wider than the water-course. It is very unlike any glaciated valley that I have seen. The drainage of this whole "basin" escapes through a narrow rock-gorge three or four thousand feet deep; I could see no ice-marks in it; Professor Abich did. Every delta must bear some proportion to the mass eroded. In this case the wedges, which have somehow been carried out of the solid, have been somehow crumbled and rolled and carried through the gorge. The *débris*, or part of it, is spread in a fan-shape outside of the narrow gap. The Tarek is cutting into the delta, and washing the mud into the Caspian Sea. Professor Abich notes a bed of blue clay with "*Mytilus polymorphus*" (a freshwater bivalve), and sandy clays, low down in the delta-section, and large stones, granite, schist, trachyte, &c., of which a few only are scratched, which have somehow been rolled or carried from the Kasbeg region, and now rest on the delta or are buried in it, far outside the gap, down to a level of 1860 feet above the sea. These stones are exceptional. The country is chiefly mud and shingle. He concludes, with hesitation, that a Kasbeg glacier came out of the gap, split on the delta, and carried stones to the right and left to places which are about 35 miles from the gap, according to the Russian survey (of 10 versts to the inch).

The low country suggests arrangement of mud in water.

If, as I have supposed, the plains of Europe were submerged, or if a lake was at the base of the Caucasus when the shells lived, then ice-rafts like those which now grow in the sea near Kertch would suffice for the dispersion of stones carried part of the way by a glacier and by sudden floods towards the Tarek delta where they rest. Floods might account for most of them, as I suppose.

But supposing that part of this exceptional delta is a buried moraine of very unusual form and structure, and that one Caucasian glacier did extend 35 miles beyond the gap, and 5000 feet lower than glaciers do now, to a level of 1800 feet or 1000 feet, that does not affect my argument about "polar glaciation." I saw no large erratics elsewhere about the base of the Caucasus, none in other gorges. I saw nothing between Nijnii Novgorod and Vladikavkas to suggest that all Europe had been covered by the polar ice flood, which was 13,000 feet thick in the latitude of the Caucasus in North America, which reached the equator, and was as wide as the world.

I have seen no track of that glacier in crossing meridians between the Volga and the Mississippi; but I did see the Arctic current at work in "drift" latitudes. I found scratched granite boulders in Russia, 700 miles from the nearest possible source. But to prove the "ice-cap" I ought to have found them 900 miles further, in

Daghestan, and about the base of Kasbeg, 8000 feet up, where the "mountain-ignoring" cap, 13,000 feet deep, flowed over the Caucasian dam.

Somebody ought to find polar drift in Persia, and India, and Ceylon, in Turkey, Syria and Arabia, in Greece and Egypt, and about the sources of the Nile. I found Finnish granite in Northern Germany. To support the ice-cap, samples of northern drift ought to be found in the Rhine valley and in France, high up on the shoulders of the Alps and Pyrenees, in Italy and Spain, in Northern Africa and down to Coomassie. European polar drift ought to spread at the Equator between the meridians which cross Scandinavia and the Ural Mountains.

I found glaciated stones near St. Louis which must have travelled at least 800 miles southwards in America. To prove the "ice-cap" somebody ought to find specimens of northern rocks upon the shoulders of the Rocky and Alleghany Mountains, and all the way to the Amazon in continuous streams, forming the moraines of the Mississippi-valley glacier, which must have existed when the Amazon glacier reached the sea. But even if all that is found, if the severed "boulder" on the top of Adam's Peak in Ceylon turns out to be an "erratic," it has to be proved that it was not carried part of the way by polar currents and ice rafts like those which exist, which reach 37° in the Atlantic, and coincide with drift-latitudes on both shores of the Atlantic basin.

Summary. — Evaporation and condensation, atmospheric and oceanic circulation are caused by unequal local temperatures. Rivers and land-glaciers alike result from atmospheric circulation, and from local condensation, and they flow for the same reasons at different rates. The existing Arctic current is part of ocean circulation, caused by unequal polar and equatorial temperatures. That current is a conspicuous fact. It is far larger and more powerful than any existing river or ice flow on land. It is more than three thousand miles long, and it is very broad; it moves vast fragments of the largest existing land-glaciers, and great sheets of thick polar sea-ice, at great speed. It lowers the perpetual snow-limit where it flows, and it there modifies climate and all that depends on climate. Within an area equal to that of India, in Greenland it increases local condensation, and snow-flakes, and snow-falls, and ice flows and rivers; and so it increases local denudation on shore while it works on the shallows. Ice rafts in the ocean-stream carry drift southwards; and the water which drags these loaded rafts over shallows and makes them drop boulders, also rolls and packs mud and shingle and builds a delta in the sea. This kind of polar "glaciation" and deposition of "drift," caused directly and indirectly by one of the northern polar currents, cannot be denied. The agent is a true cause at work; and the work ought to be like that which I saw in Russia in 1873.

Where a sedimentary rock exists there water has been; and the drift-plains of Russia are spread upon sedimentary series little disturbed. That part of the earth's crust has been up and down many times without breaking much. If glacial periods, due to astronomical or other causes, have in fact increased evaporation and condensation, ice-flows, and rivers to any given extent, then polar currents must have gained power during these periods, because movements in air and ocean result from unequal local temperatures, on which also depend the local growth of ice on land.

Problem. — Are the clear traces of ancient glaciation which abound caused directly and indirectly by polar currents like those which exist and modify climate, and which must have existed ever since there was an ocean to circulate upon a revolving round world warmed by the sun? Or, secondly, are these marks made by polar ice-flows which do not exist, whose existence has been inferred from these marks?

I have contributed my store of facts. Those Members of the Society who care for this inquiry can form opinions upon all the facts known to them. If all the knowledge of the Society could be brought to bear on a point by a debate and a vote, we might advance geology by expressing a joint opinion upon the nature and extent of that ancient polar glaciation which is abundantly proved by acknowledged facts.

Postscript dated Salt Lake City, August 12, 1874.

I have now crossed the glacial current of the Atlantic and the Rocky Mountains, and I have skirted the back of this range southwards on the eastern side for 200 miles, seeking for Mississipi moraines. As in Europe, so in America, I have found scratched rocks and northern drift carried far south, but on certain meridians only; I have found ancient sea-margins, or something very like them, on both sides of the Rocky Mountains and at corresponding levels. I have seen ancient lake-margins corresponding to the wearing done by the rivers which flow out of the lakes. I have seen lakes drained and lakes filled up, and all known signs of atmospheric action in great abundance and on a large scale.

This salt lake is the equivalent of the Caspian, in latitude and in lack of outlet. As at the Caspian, so here, the mountains are waterworn and burrowed by "cañons," but a conspicuous old-level water-line is on the hills at a level which would give the lake an outlet. Lakes through which waters flood into this salt lake are sweet like the mountain-streams. The rocks about it are freestone and coal formation, &c. The people here suppose that this salt lake is sea-water at 4340 feet above the sea, and a mark of the elevation of the whole country. I attribute the spread of northern drift on American and on Russian plains to ancient arctic currents.

There is nothing to indicate any glacial action at all between Chicago and Salt Lake. In rising from 726 feet above the sea to 8242 feet (the highest point on the railroad), and in descending to 4340 feet, I could see no single mark of ice-action in the region. For 164° of longitude, about lat. 40° N, from the Volga to this place, I have found nothing to support the idea that solid ice extended from the pole to the equator, and acted as smaller glaciers do on rocks under and about them. But on "Pike's Peak," which is 14,000 feet above the sea, I found weathered marks of local glaciers, which carried granite to the plains for some fifteen miles, and 8000 feet down hill. In latitude and altitude and size these nearly corresponded to the Caucasian glaciers about Elbrouz and Kasbeg which still exist. The glacial traces which I have found in America seem to indicate the transfer of oceans with their systems of circulation from one part of the world to another, by the elevation or depression of land. I have found nothing to indicate an ice-cap in these latitudes thus far on my way round the world.

Discussion.

Mr. Belt stated that he had been over much of the same ground as the author, but had come to quite opposite conclusions. He agreed with Mr. Campbell that boulders only come down to a certain point, but he considered that the very plains themselves are proofs of glacial action. He thought that the absence of boulders is only a proof that there was no chain behind which could supply the requisite rock ; and in this case the only signs of the existence of a polar ice-cap would be due to the blocking up of the drainage by it, resulting in the formation of the plains of Siberia.

Prof. Ramsay thought that the ideas put forward by the author were in accordance with those of previous writers ; but he considered that he exaggerated the power of ice in the shape of icebergs to effect changes. The question was whether there were ice-caps moving towards the equator, or whether the configuration of the mountain-regions might have produced the observed effects. He expressed himself satisfied that the present configuration would account, at least to a great extent, for the changes which have taken place. The boulders found on the great plain of Russia might have been conveyed either directly by glaciers, or by icebergs broken off the ice-cap itself. Boulders have been seen 40 miles north of the Caucasus, proving the existence there of great ancient glaciers. The absence of boulders on the plains of Siberia was, he thought, to be accounted for by the absence to the north of Siberia of high land from which such boulders could be carried.

Mr. Drew thought that sufficient consideration had not been given to the relative levels of the old and new glaciers. In Cashmere he had observed a difference of 5000–6000 feet.

Prof. Hughes thought that the theory of ice-caps spreading in both hemispheres from the poles to near the equator hardly deserved discussion, seeing that no facts which could not be otherwise explained had been adduced in support of it, whilst it involved great physical difficulties, and was quite inconsistent with the continuity of the forms of life from pre- to postglacial times. The question before them seemed to be whether a smaller general drifting from northern circumpolar regions, either of land or floating ice, would better account for the phenomena observed by the author than a dispersion of boulder-bearing ice in all directions from local centres, especially in the case before them from North Scandinavia. He always understood that the boulders of N. Germany and W. Russia could be traced to that mountain-district, and that there was proof that the ice travelled to the north as well as to the south. Unless, therefore, the author showed that some of the boulders could have been derived only from circumpolar regions, he could not see the necessity of calling in any thing more than changes of level of various parts of the northern hemisphere along well-known lines of elevation and depression to explain all the phenomena observed. He questioned the accuracy of the view that glacial conditions prevailed at the same time over the whole of even one hemisphere, and, referring to the observations of Mr. Drew, pointed out that, if the glaciers of any mountain-region were shown to have once descended from 3000 to 6000 feet lower than the present ice-foot, it was only necessary to raise that chain from 3000 to 6000 feet to make the glaciers descend to their ancient level again.

Mr. Whitaker thought that the broad points of the paper had been lost sight of. The rounded configuration of rocks in Norway he regarded as clearly of glacial origin, but as the effect rather of a great extension of glaciers than of a true polar ice-cap. In Britain the glacial drift towards its southern limit is almost wholly marine, and certainly not due to the action of land-ice; so that it is distinctly opposed to the notion of the southern extension of the ice-cap. He could not believe in the existence of such a cap extending as far as the equator.

Mr. Topley thought that Mr. Campbell's views as to permanent areas of glaciation and non-glaciation due to cold and warm currents did not suffice to explain the facts; nor did he think that a warm current could have passed over the plains of Russia. He remarked that there is no drift in the south of Europe, and that a line running nearly in the latitude of Dover would mark the southern limit of the drift.

Mr. Prestwich said that he felt much interested in Mr. Campbell's paper, and recognized that the difficulty in this case lay in determining the boundary between the action of land- and sea-ice. He thought that the existence of a Gulf-stream traversing eastern Europe was not proved. In the eastern, and possibly even in the southern, counties of Great Britain there is evidence of submergence in glacial times; and marine drifts also exist in Brittany. If northern France were submerged, ingress might be afforded to warmer water.

Mr. Blanford considered that the difference in the faunas of the Black Sea and of the Caspian was so great as to furnish a strong objection to there having been a branch of the Gulf-stream passing on towards Siberia at so late a geological period, as this must have brought about a closer resemblance between the faunas. He objected to blocks found at a considerable distance from mountains being regarded as true ice-borne boulders unless they were striated or polished, seeing that blocks three or four feet in diameter might be seen in Persia, which had been carried five miles or more by the water of insignificant streams. In Persia the country, although greatly elevated above the sea-level, is covered with drift; but he had found no signs of striation on the pebbles, nor had he been able to detect glacial markings on extensive plateaux more than 6000 feet above the sea, with peaks rising to 12000 feet and even more. In his opinion the ice-sheets were entirely local.

Mr. Evans remarked that the question of glaciation had always been a puzzle. He thought that the notion of great ice-caps simultaneously covering the northern and southern hemispheres could not be maintained, since it involved the destruction and new creation of the entire fauna and flora. If the boulders referred to by Mr. Campbell were of northern origin, there must have been a flow of water from north to south, possibly in a great bay bounded by the Ural Mountains on the east. It seemed to him difficult to conceive how a current from the Atlantic could have passed over the high lands of Turkey and the Carpathians. He thought the question as to the glaciation of the Caucasus of much interest. It was difficult to conceive how so vast a denudation as that described could have occurred without either heavy rains or glaciers; but no rains occur there at present. An alteration of level, however, would of course affect the temperature and rainfall.

Mr. Campbell, in reply, stated that he had seen it given as Prof. Agassiz's opinion that the ice-caps had extinguished all life. He remarked that the boulders have travelled at least 500 miles from their original bed over level ground.

36. Notes *on the* Upper Engadine *and the* Italian Valleys *of* Monte Rosa, *and their* Relation *to the* Glacier-erosion Theory *of* Lake-basins. By the Rev. T. G. Bonney, M.A., F.G.S., Fellow and Tutor of St. John's College, Cambridge. (Read May 27, 1874.)

This paper may be regarded as a continuation of two which I have already had the honour to communicate to the Geological Society*; and with a view of preventing misapprehension, I think it will be well to state clearly what I am seeking to demonstrate, and the mode in which I am endeavouring to effect my purpose.

As I have already stated, I am unable to accept the theory which was put forward by Professor Ramsay in a paper communicated to this Society†, a theory which attributes the existence of the various Alpine lake-basins mainly to the erosive action of the glaciers by which they were once occupied. I do not deny the possibility of *some* lake-basins being the result of glacial erosion, or of others being considerably modified by it; the position which I am endeavouring to maintain is that none of the greater Alpine lake-basins has been primarily so formed, or indeed has undergone any important secondary modification. I will add that all the opportunities which I have had of examination of lake-basins in this and other countries have suggested to me serious doubts as to the excavating power of glaciers; and, notwithstanding the weighty arguments which have been advanced in favour of this theory in more northern regions‡, I am still disposed to believe, from what I have seen, that it is only under very exceptional circumstances that they can in any proper sense of the word *excavate* a rock-basin.

The principle which has directed my mode of operation has been the following:—If a key is to be a master-key to a number of locks, it must open them all; so if a theory is to be accepted as a general one, we must apply it to as many instances as possible.

In order then to test this theory of glacier erosion, I have, year by year, travelled over different portions of the Alps (as well as other mountain-regions) constantly endeavouring to apply this and other theories to the physiography of the country, and to ascertain which appears to satisfy best the difficulties of each problem.

It seemed to me that, viewing the nature of the theory, it could be better tested in this way than by any minute examination of a single district. When any advantage appeared likely to accrue I have done this; but, as the fact of the passage and the general direction of the flow of the glaciers over certain regions are not disputed, I have not thought it worth while to burden either this communication or my note-book with the results of minor observations, especially when they led to no important conclusions.

* Quart. Journ. Geol. Soc. vol. xxvii. p. 312, and vol. xxix. p. 382.

† *Ibid.* vol. xviii. p. 185.

‡ See especially Mr. J. Geikie's new work, 'The Great Ice Age.'

Thus I have said but little about direction of striæ, &c., because, as a rule, the bolder configuration of the *terrain* was sufficient, without the confirmatory evidence of minor marking, to indicate to an educated eye the path of the ice-streams,—and little about the stratigraphy of the country (although that was often carefully noted), because, as a rule, owing to its many disturbances, the evidence furnished by it was neither favourable nor unfavourable to Professor Ramsay's theory or to my own.

The observations in this communication concern principally (1) the district of the Upper Engadine and of the Val Bregaglia with the Lake of Como, and (2) the Italian valleys of Monte Rosa including the Lake of Orta. I had already travelled more than once over the greater part of these regions, together with that of the other Italian lakes; but, during the summer of 1873, I devoted myself to a more minute reexamination of these, because, from previous experience, I knew them to be among the most important.

I assume throughout this communication:—

1. That gorges and V-shaped valleys are mainly cut by "rain and rivers."

2. That valleys or basins excavated or materially modified by glaciers must have a trough-like form, that of a broad U.

3. That, except in those cases where there is a sudden change from a hard to a soft rock, the contours of a valley, whose form has been much modified by a glacier, would remain approximately uniform—viz. that if a lake-basin has been cut by a glacier, the valley above must also be more or less U-shaped.

I commence with the Engadine district, where, unfortunately, owing to the unusual lateness of the summer, my results in one or two cases were less complete than I had hoped to make them.

In the Upper Engadine are several small lakes—one group on the Bernina Pass, the other in that singular trough which forms the head of the Inn, and has for many centuries been one of the great highways of Europe across the Alps, that of the Maloya Pass.

The former of these consists of two lakes, the Lago Bianco and the Lago Nero, with a third unimportant tarn, situated at a height of about 7300′ above the sea, nearly on the summit of the Bernina Pass (7658′). The Lago Bianco is about $1\frac{1}{2}$ mile long and $\frac{1}{4}$ mile broad; the Lago Nero is very much smaller, some 300 yards long. The former discharges its waters towards the Adda, the latter towards the Inn.

The configuration of the ground in which these lakes lie is very remarkable. It is a rather broad upland trough, about two miles and a quarter long, running NW. and SE., dominated on the south-western side by the steep precipitous buttresses of the Piz Cambrena, the summit of which is 11,835′ above the sea, on the other by rocky hills rising a few hundred feet above the lakes; the south-eastern end broadens out into a hummocky plateau, no part of which is more than about a hundred yards above the water. The torrent from the Lago Bianco passes over some marshy ground, once part of the lake, and descends the steep head of the Val di Pila, while the carriage-road, hugging the northern side of the above trough, crosses a slight depression (7658′), and zigzags rapidly down into the cirque-like head of the Val Agone. It needs but a glance into these valleys to show that their physical features are anterior to the epoch of the glaciers which have undoubtedly descended them. The Cambrena glacier, still a fine ice-stream, united to smaller glaciers which yet cling to the steep sides of the mountain, once descended on to the trough along which the Bernina road now runs, and sent forth glaciers on the one side along the Vals Agone and Pila (covering doubtless all the intervening buttress), on the other towards Pontresina.

Exactly in the path of this, and where the ice-streams from the Cambrena, at the foot of its steep slopes, would be arrested by the opposite ridges (which perhaps had also their glaciers), lie these lakes. Though discharging their waters to different seas, only a low barrier of ice-worn rock, nowhere more than a few feet above the water, separates them*. This is exactly the place where the erosive action of a glacier would be most intense; and I should be inclined to attribute these shallow lakelets mainly to this cause. At the same time I observed that an important feature in the Lago Bianco, namely a projecting elbow on the northern side, is formed by a V-shaped glen, down which a considerable stream now comes. The whole of this region, however, is one where a minute examination is likely to be useful; this I hope to give on a future occasion, when the ground is not (as it was on the occasion of my last visit) masked with snow and the lake with ice; and I should not now have mentioned it, had I not considered it one which, so far as it goes, is favourable to the glacier-erosion theory.

Proceeding now to the second group of lakes, those which form the principal sources of the Inn, we are again struck by the singular configuration of the ground. As we ascend the valley a level plain extends for several miles by the side of the Inn, being very probably a silted-up lake, until, a short distance above the well-known village of Samaden, this plain slightly bifurcates, one arm extending a very short distance along the Flatzbach (the torrent descending from Pontresina), the other also soon stopping at the foot of a rocky step in the floor of the main trough, which runs very uniformly in a S.W. to N.E. direction. The height of this abrupt step is about 400′; and above it the valley extends with remarkable uniformity of level† till, at the Maloya Kulm, the edge of the abrupt descent into Italy is reached. This trough, about ten miles long, is now occupied by three lakes, which, however, were once only two in number, the present Silser See and Silvaplana See having formed one long lake, which extended from close to the edge of the Maloya Pass to

* Ball states (Alpine Guide, § 36, k) that in one place it does not exceed 3 feet above the ordinary level of the water; and that the Lago Bianco sometimes overflows into the Lago Nero. The greater part of it appeared to me not to exceed 15 feet.

† As is shown by the following levels:—Maloya Kulm, 5942′; Silser See, 5892′; Sils, 5896′; Silvaplana See, 5886′; St.-Moritzer See, 5797′. The height of Samaden above the sea is 5600′.

Campfer. Between Campfer and the head of the St.-Moritzer See is a rocky plain, and the river in places has low cliffs at its side, so that the upper lake occupies a true rock-basin; the lower one is also enclosed by a rounded ridge of schistose rock, through a narrow gorge in which the water escapes in a rapid torrent.

At first sight these lakes seem very favourable to the theory of glacier-erosion; but on closer examination several grave difficulties suggest themselves. Confining our attention for the present to the lower lake (St. Moritz) we notice:—

1. The gorge corresponds roughly in direction with the axis of the valley (S.W. to N.E.); but the longer axis of the lake lies about W.S.W. to E.N.E., the little glen through which the waters pass to enter the gorge branching off about two thirds of the way down the lake; the remaining one third of the lake-basin is formed by the union of three small glens, down each of which a stream descends, the first a mere streamlet from the barrier ridge, the second and largest descending from the Statzer See (a small sheet of water on the low shoulder of the mountain between Pontresina and St. Moritz), and the third from the side of the main (Surlei) ridge.

2. The northern bank of the lake (on which stands the village of St. Moritz) is very steep, actually precipitous at places; and this extends to some distance beyond the gorge *.

Let us then suppose for a moment that a glacier excavated this lake-basin. This glacier must either have been an offshoot from the old Pontresina glacier which overlapped the shoulder mentioned above and descended by the Statzer See, or it must have flowed down from the flank of the Piz Surlei, or it must have come down the main valley from the Maloya Pass.

Doubtless a great glacier did descend over Pontresina; and it is possible that it may have overlapped at some period of its existence in the direction of St. Moritz †; but it seems inconceivable, unless we attribute far more plasticity to ice than is usually conceded, that it can have sent off an offshoot at right angles to its main direction of flow which would have had sufficient power to excavate these hard rocks. Furthermore a glacier has certainly descended the main (Inn) valley; is it likely that it would have been thrust back so far by this intruder? With regard to the second hypothesis, it is evident that no important glacier has descended from this part of the Piz Surlei. If then we adopt the glacier-erosion hypothesis, we are driven to attribute the lake to the Inn glacier, of whose former passage down this part of the valley there is sufficient evidence. But in this case how are we to explain the abrupt termination of the rock-basin? The rocks about the gorge mentioned above would be in the "Stoss-

* Between this cliff and the present margin of the lake is a narrow strip of level meadow-land; but it is quite evident that the level of the lake has gradually been lowered, so that this ridge is one side of the true basin.

† The rocks just in this part have been much affected by subsequent weathering, which has to a considerable extent obliterated the glacial contours. The evidence on the whole seemed more favourable than opposed to an overlapping.

seite," and so should slope gently upwards from the water. Again, the whole fall of the valley from the Maloya Kulm to the St.-Moritzer See, a distance of nearly ten miles, is only 145′, and from the head of the Silser See, which extends almost to the Kulm, barely 100′, a fall of about 1 in 500, which could not give much excavating power. In a word, though the lake is a true rock-basin, the physical features of this district in no way lend themselves to a theory of glacier erosion; they rather seem to be preglacial in their age, and to have been only very superficially modified by ice-action.

We proceed now to the head of the Silser See, which, as being obviously the most important part of the district, I examined very carefully. The present head of the lake is a marshy plain, surrounded by alluvial terraces, which are about 20′ high, and often rest on rock. The results of my observations were as follows:—

1. The watershed of the Maloya Pass is formed by a low rocky iceworn barrier which falls down in fine precipices to the Val Bregaglia.

2. The various glens which come down to the Silser See show signs of local glacier-action down to very near the water's edge; but all their principal physical features appear to be anterior to the glacial epoch.

3. The principal affluents to the main Inn Glacier must formerly have been from the Val Fex and the Val Fedoz, the general directions of which make angles of about 70° with the axis of the Inn valley; yet there is no recess of the opposite shore to correspond with the entrance of these; and they cannot have materially deepened the lake, because the *débris* from them has converted it in the one case into dry land, in the other has made a considerable delta.

4. In the rocky barrier spoken of above is a gorge which shows that the lake, or the glacier occupying its place, formerly discharged its waters into the Val Bregaglia.

5. There are numerous perched blocks on this barrier and several moraines, some being very large. These extend from the base of the Pizzo della Margna in a general direction of W. 20° N. to close to the barrier. One of the largest forms the present actual water-parting. On the southern side of this are some marshy flats interrupted by moraines, the waters of which are discharged by the gorge (4).

6. Many of the blocks, perched on the barrier and in the moraines, are a fine porphyritic granite. I found no more erratics of this kind after reaching the first glen from the Piz Lunghino. They come from the Val Forno, the floor of which valley is nearly on the level of the Maloya Pass, and descends very rapidly into the head of the Val Bregaglia. The rocks near the Maloya-Kulm Hotel are also glaciated by ice that has moved from the Val Forno.

7. The glaciers about the head of the lake are all connected with the existing valley-system. That from the Val Forno actually swept over and, as it were, rested an elbow on the top of the Pass. The glen under the Piz Lunghino, which joins the lake a short way

down its western shore, bears the marks of a glacier that has descended it; and, in a word, looking down the lake, the rocks are rounded by the glaciers which once descended from the several mountain-sides; but there is nothing to suggest any scooping action, no great modification of the outline of the lake corresponding to the entrance of a glacier valley, while the existence of one or two promontories is difficult to explain on any theory of glacial erosion.

I think, therefore, we are justified in concluding:—

That this lake-basin has no immediate connexion with any of the lateral valleys.

That it once extended to within a few dozen yards of the summit of the pass, and that some of its drainage was discharged into the Val Bregaglia.

That the lake-basin (and the above-named gorge) is anterior to a period when the Forno glacier was of enormous thickness.

That, considering the slight descent of this uppermost trough of the Inn valley, no glacier formed on the north side of the Maloya Pass could have excavated the Silser See.

Hence that the basin and all the other physical features of the head of the Inn valley are anterior to the glacial epoch, and have not been much altered during it or since.

The first thousand feet of descent from the Maloya Pass into the Val Bregaglia is very steep, its head almost meriting the title of a cirque. The descent after that is generally gradual, with the exception of a sudden fall between Casaccia and Vico Soprano, corresponding with the entrance of the Albigna torrent. The usual signs of glacial action, perched blocks, roches moutonnées, and large moraines, may be detected at intervals all the way down to Chiavenna. Among the blocks porphyritic granite and coarse gneiss are conspicuous, evidently brought down by the tributary glaciers from the left bank; the rock in the bed of the valley consists of mica-schist (in one place so fissile as to be quarried for roofing-slates) and hornblendic schists. The valley is generally narrow, and V-shaped; and the ice-marks may be seen sometimes only a short distance above the torrent. They are very conspicuous after passing Piuro, near the opening of the valley, just above Chiavenna, where the roches moutonnées are magnificent, and the characteristic ice-marks may be traced within some twenty feet above the river. One example, on the left bank, about a mile from Chiavenna, is very interesting. A steep knoll of rock, some 40′ high, is divided by a narrow gap from a cliff some 50′ high, which forms part of the range rising on the left bank of the valley. The lowest part of this gap is perhaps 30 yards above the (Mera) torrent. The rock is a dark (serpentinous?) schist; the whole of the knoll and cliff are magnificently glaciated, the striæ on the latter being very conspicuous. This place, therefore, shows (1) that the base of the old Bregaglia glacier was here at no great height above the present stream; (2) that this gap was either excavated by it or anterior to it. As I cannot conceive the possibility of a glacier cutting out such a gap, I am forced to conclude that the principal features of the scene are preglacial, and that the glacier has only slightly modified them.

Just below Chiavenna the true basin of the Lake of Como begins, at the union of the Mera and the Lira (which latter is orographically the principal valley); for a broad level strath extends all the way down to the waters of the Lago de Mezzola, and Chiavenna itself is less than 350 feet above the level of the lake. Ice-worn rocks may be traced on the mountain-sides from at least 2000′ above, down to the very edge of the meadows.

Is it not then rather perplexing that these glaciers of the Lira and the Mera, which singly have only slightly modified the valleys in which they flowed, should, on their union, have been suddenly gifted with such great excavating power as to scoop out from hard schist (micaceous and hornblendic) and granite the open valley above the Lago di Como? And if they have done this, how are we to explain the comparatively slight effect produced by the junction of the broad Val Telline, which must have brought down an immense affluent of ice. About two fifths of the present Lake of Como lies in mica-schists, the remainder (including its two arms) in sedimentary rocks, following one another in ascending order, and (according to Von Hauer) members of the Silurian (?), Trias, and Rhætic formations. The strata, as a rule, dip towards the S., often at a high angle; but there are one or two rolls, as near Balbaniello and the Val Intelvi, till at last (in the Como arm) they roll gradually up and down, and finally dip sharply away from the fault which brings the Nagelflue conglomerates against them.

This arm of the Como lake has always seemed to me difficult to explain on any theory of glacier erosion; the low promontory of Bellagio, unless the valley were previously well defined, seems inadequate to split a glacier into two such divergent arms; and its form does not suggest that it has been exposed to any such tremendous pressure as it would have undergone if this had been the case. This Como arm, it is well known, has no outlet, and is chiefly cut off from the plain of Lombardy by a low range of hills composed to a large extent of Nagelflue, the pebbles being mostly metamorphic rock, quartzites, schists, and the porphyritic gneissic and granitoid rocks common in the Val Bregaglia, generally well rolled, not usually exceeding about a foot in diameter. They lie in a grey sandy matrix like Molasse, with sandy bands. The occurrence of the gneissic and granitoid pebbles is important, as showing that the valley of the Lira was defined at a very early period.

This range of hills is very peculiar in shape. It is a sharp ridge with steep slopes on both sides, its tops in places being almost an *arête*. The old glacier has indeed passed over it; for on my ascent to the tower (Castello Baradello) which is perched on the crest, I saw, in a face of rock near S. Carpofaro, that the pebbles had been planed level with the matrix, and a few of them yet retained striæ. Moreover in several other places the characteristic contours of ice-worn rocks could yet be recognized, and perched blocks could be seen dotted here and there; indeed a large one (of the usual granitoid rock) serves as a foundation-stone for the tower. Here, then, in the very path of the glacier, we have these ridgy hills, which the ice has but superficially moulded. How, then, could it excavate the lake-basin? The contours also of the ground all round the head of the lake seemed to be wholly uninfluenced by any great ice-stream acting from the lake. I could therefore come to no other conclusion than that the glacier in its passage has but slightly altered the physical features of the district, which all spoke of the usual subaerial agencies.

I must now call attention to a point perhaps of some importance. From the former head of the lake, near Chiavenna, to its end at Lecco, is about thirty-four miles. The fall is considerably less than 300 feet; how much, it is difficult to say exactly. Suppose, then, that all which is at the present time under water is the result of glacial excavation, and that the slopes of the valley above lake-level are mainly (as I think all who know the district will admit) the result of river and subaerial denudation; it follows that the stream had a fall of considerably less than 1 in 600. I doubt whether this would be sufficient for eroding a valley of this character in such hard rocks.

Again, the height of Chiavenna is 1040 feet above the sea; the deepest soundings in the lake are 1341 feet, or 642 below the sea; and the height of the hills above Como is about 900 feet. To what are we to attribute an excavating-power so enormous? A more unfavourable position for the exercise of any erosive action on the part of a glacier could hardly be conceived. On the other hand, supposing this enormous basin to have been hollowed out by ice, ought not the rocks all around to bear the most marked indications of the passage of this powerful agent? ought not those ridges of hills above Como, which lie right in its path, to have had their sharp summits planed flat? or did the glacier, when it had crawled up their steep slopes, tumble, like an exhausted caterpillar, helpless down the other side?

I pass now to what are often called the Italian valleys of Monte Rosa. Here my first care was to examine the Lake of Orta, which resembles the Como arm in being separated from the Italian plain by a low ridge, and in discharging its waters from its northern end. These hills are a quartzose felsite; and the eastern bank of the lake consists chiefly of schists. The most conspicuous of the felsite hills, that on which the Torre de Baccione stands, has a little valley on each side, of which the eastern has formed a distinct delta. From this point the lake is enclosed by a generally steep bank or terrace, perhaps 100 feet high, above which rather steep slopes rise up to the plateau on which stands the village of Gozzano. A glacier has evidently passed over this barrier, as moraine heaps of great perched blocks of granite, gneiss, and schists are strewn about. In the slope above the lake, stratified drift is seen; it is considerably below the moraines; and perched blocks lie on the surface of the bank all about. If these have not been washed out of some upper layer of soil or rolled from above, the glacier must have passed over this drift.

Now, if we suppose the Lago di Orta to have been excavated by a glacier, we must account, as in the case of the western arm of Como, for the ridgy outline of the felsite hills, which could not have resisted so great a grinding force. We must determine which was the direction of the glacier in order to see how far it would be likely to exercise a scooping force.

It either descended by the Val Strona, or was an offshoot from the great Ticino glacier, coming up the valley down which the Strona torrent now descends, and which appears like a prolongation of the valley of the Lake of Orta. The difficulties in the former view will be seen when I speak of the Val Strona. If the latter is correct, we have to account for this extraordinary offshoot, for its ascent up some 500 feet, and for its then scooping out the lake-basin.

From the northern extremity of the Lago di Orta, I ascended to the head of the Val Strona and crossed to Vogogna, in the Val d'Ossola, and then drove to Ponte Grande, in the Val Anzasca. Hence I crossed to Fobello and descended the Val Mastalone to its junction at Varallo with the Val Sesia, ascended that valley to its head, crossed over to Gressonay, in the Val de Lys, and thence to the head of the Val d'Ayas, from which I reached Zermatt by the Schwartz-Thor. The results of this journey, which occupied a week, may be summed up very shortly; but they have, I conceive, an important bearing on the point at issue.

The Val Strona is everywhere a narrow V-shaped valley, in places almost a gorge. There is abundant evidence that a glacier has descended it; but without materially altering the characteristic outlines of a valley formed by rain and rivers. The Val Anzasca is also a narrow V-valley, commonly with a gorge at the bottom; yet a glacier has evidently descended it while its form was much as now, and the ice-marks may here and there be detected at no great height above the stream.

The Val Mastalone is throughout of the above form, everywhere narrow, in most places a mere glen with little or no level land by the side of the stream; yet in places the ice-marks may be detected only a few feet above the water, as for example about 12 kilometres above Varallo. The main valley of the Sesia above that town generally resembles that of the Val Mastalone, except that there is often, though not always, a small strip of level land by the stream. It has been filled by a glacier, which has left some of its most conspicuous traces on an ice-worn mound of rock at Scopello, perhaps 300 feet high, on one side of which goes the road, on the other the river.

Among the magnificent scenery at the head of this valley, under the cliffs of Monte Rosa, I was again and again struck with the absence of any relation between the principal features of the scenery and the direction of motion of the glaciers. Surely here, if anywhere, the projecting buttresses of rock, which at times almost bar the valley, should have been ground away by the enormous pressure to which they have been subjected; but though rounded and worn smooth, they still remain as *barriers*, suggesting irresistibly the conclusion that they are older than, and have not been much affected by, the vast ice-stream which has passed above them.

The portions of the Val de Lys and Val d'Ayas which I examined did not offer any fresh evidence of importance, except that the singularly steep head of the latter is very difficult to explain on any theory of glacier-erosion.

Assuming, then, that glaciers can excavate such rock-basins as that of Orta and of Como, which is 1900 feet deep, how are we to explain their impotent action on the felsite rocks that bar the one, and on the conglomerate and Molasse that bar the other? how to explain the absence of all approach to lake-basins in those other valleys through which the ice-streams must have descended from a yet longer period, the absence of any but comparatively superficial effects over all the rest of the district? No alteration in the mineral character of the strata can account for it. The Lake of Como begins in crystalline schists, and passes without much marked change in width and depth through various sedimentary rocks. The Lake of Orta also appears to lie in rocks no softer than those of Val Strona and Val Sesia. Did time allow, I might appeal to other evidence on the Lago Maggiore and the Lago di Lugano, the form of which appears to me wholly inexplicable on any theory of glacier erosion; but I think I have done enough to show that, even if this be retained as the explanation of some of the upland tarns in the Alps, it is wholly inadequate to explain the great basins of the Italian lakes. These and their valleys appear to be much older than the ice-age, and to have been but little modified during the period of maximum extension of the glaciers.

The theory which I propounded on a former occasion*, of irregular movements of upheaval and subsidence along lines athwart the valleys, can be applied to these lakes. There is nothing in the stratigraphy of the district opposed to it; so far as the evidence goes, it is rather favourable to it. The anomalous form of the Lake of Lugano, the position of the deepest parts of the Lake of Como †, the variation in the level of its floor, all agree very well with such a theory; as does the slight slope that we must assign to the preglacial valley, compared with the fall of the other neighbouring valleys. The extraordinary extension of the old Como lake up the Val Telline also agrees very well with this, and induces us to suppose that the existence of these lakes is due to the relative subsidence of a district included roughly between one line drawn through Chiavenna from east to west, and another through Lecco, Como, and Arona. This subsidence became less going westward; but it may have affected an area some distance further to the east.

Discussion.

Mr. Drew differed from the author, and thought that glaciers coming from different directions might have produced single results at certain points.

* Quart. Journ. Geol. Soc. vol. xxix. p. 382.

† See an important paper by Mr. Ball, Geol. Mag. vol. viii. p. 359.

Prof. RAMSAY was glad to find that the author was gradually coming round towards his own views, as he now admitted that glaciers may have excavated some lake-basins. He argued that the valleys originated before they were covered with a thick coating of ice; but he maintained that at its origin the ice would have great weight and excavating power.

Rev. J. F. BLAKE thought that if the slope of the bottom of the glacier changed, its excavating power would be increased.

Mr. KOCH had sounded many lakes, and found great circular cavities, which he thought could hardly be due to ice-action. In winter glaciers move very slightly, and would be able to perform very little work.

Mr. BONNEY, in reply, remarked that he had in no way come round to Professor Ramsay's views; for he had never denied that certain tarns might be the result of ice-action. Ice-denudation is different from aqueous denudation. A glacier planes and could not cut out a notch. He said that he could only admit the smaller lakelets in special positions as the result of glacier-action. He did not think there was satisfactory evidence of the existence of an ice-sheet all over Switzerland. He urged that it is not always safe to argue from small phenomena to large ones.

37. *The* Steppes *of* Siberia. By Thomas Belt, F.G.S.

(Read June 24, 1874.)

1. Introduction.

Many writers have described the great steppes or "tundras" of Siberia, and told of their vast extent and monotonous aspect, where the traveller, day after day, sees the nearly level plains extending to the horizon in long low undulations, succeeding each other like the gentle heaving of the surface of an otherwise calm ocean. From the western base of the Ourals they spread right across the northern extremity of Asia, nearly to Kamtschatka, unbroken, excepting where the rivers have cut deep channels, or where some ridges of rock rise through the level expanse of sand and loam.

Last October I journeyed across the south-west corner of these vast plains for more than one thousand miles, from Ekaterinburg, on the eastern slope of the Ourals, to Byanool, a small town 360 miles south-east of Omsk; and although compared with the whole area of the great steppes this part forms but a small portion, I saw enough to impress me with the idea of their enormous extent, and to excite my curiosity to try to discover the cause of this continental expanse of sand and loam. I lost no opportunity of examining natural sections of the ground; and fortunately these were not scarce, as the rivers had everywhere cut deeply into the sandy strata. I propose in the present paper to give a description of the strata composing the steppes, to offer a theory to account for their origin, and to seek to apply it to other parts of the earth's surface.

Description of the Strata.—About 60 miles east of Ekaterinburg we had left the slope of the Ourals behind us and entered upon a sandy and nearly level country, the commencement of the great Siberian steppes. The sandy soil, in some parts covered with extensive pine forests, continued as far as Shadrinsky, 180 miles east-south-east of Ekaterinburg; but beyond that town it was of a more loamy character. Large shallow lakes were numerous; and much of the land in cultivation was of a peaty character. Around all the lakes were extensive tracts of peaty ground, proving that they had at one time been much larger and had been contracted by the growth of vegetation around their borders.

At Ischim we crossed a tributary of the Irtisch. It runs in an alluvial plain 4 miles wide, on each side of which the steppe strata rise to a height of about 80 feet above the river (fig. 1). They are composed entirely of loose sand, amongst which I could find no shells or other organisms. In some parts the sands are false-bedded; and next the surface they are more loamy than deeper down. They contained no pebbles.

From Ischim to Omsk, about 160 miles in a direct line, the plains continue with monotonous uniformity. At Omsk the strata exposed in the river-bank are about 60 feet thick, as shown in fig. 2. The lowest bed exposed is a finely laminated silt, which, in drying, sets to an almost stony consistency, but immediately disintegrates when placed in water; the bottom of this bed is not seen. Above it lies a bed of laminated sand, mostly clean, but in some parts mixed with silt; in others it is false-bedded. It is nearly similar to that near Ischim, excepting that I found in it some lines of small pebbles and broken and worn shells of *Cyrena fluminalis*. None of the pebbles were larger than a small cherry.

From Omsk to Pavlodav, a distance of 253 miles, our course lay up the right bank of the Irtisch, and the sections everywhere showed a similar arrangement of the beds of sand and silt as had been exposed at Omsk. At one point, about 100 miles from Omsk, I noticed that the lines of pebbles were getting more numerous and a little larger, some occurring as big as a walnut. In none of these sections was the bottom of the steppe strata seen, nor of course the bed-rock on which they rested, until I reached the town of Pavlodav, in lat. 52° 20′ N., where, on the river-bank, I found the whole of the strata cut through down to the bed-rock (fig. 3). This rock (No. 6 in fig. 3) was magnesian limestone, which at the top was crushed and broken, and seemed to graduate from broken rock through broken rock mixed with fine silt, into fine silt, in which were numerous blocks of the bed-rock. The bed of silt was unlaminated, and about 6 feet thick; in its upper half it did not contain any pieces of the bed-rock. It was followed by 15 feet of clean coarse sand, laminated, and in some parts false-bedded. It contained thin layers of small gravel; and at the point marked × in section there was a line of subangular pebbles, some of which were as large as a man's fist. This bed was followed by 8 feet of light-coloured sandy silt, and the whole capped by 20 feet of stratified reddish-brown sand containing lines of small gravel.

At Pavlodav we crossed the river and the alluvial plain, which is 6 miles wide and was covered with hay; we then struck across the country to the south-south-west. After leaving the river there were no natural sections of the

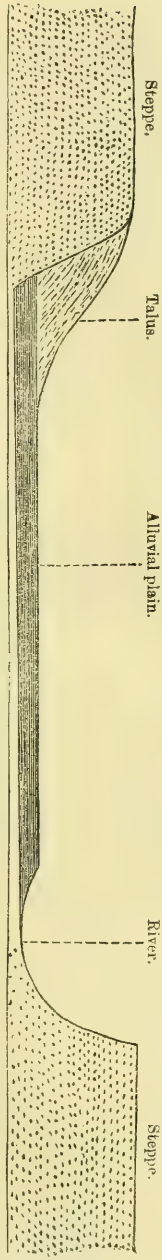


Fig. 1.—*Section across the Valley at Ischim.* (Alluvial plain shortened.)

Fig. 2.—*Section of Strata at Omsk.*

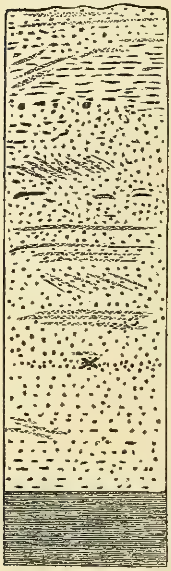
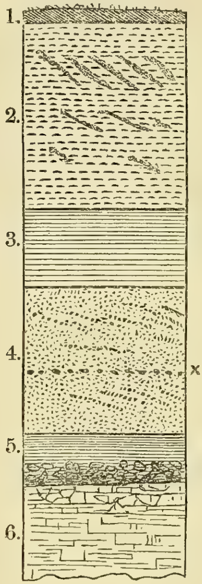


Fig. 3.—*Section of Strata at Pavlodav.*



1. 1 foot surface-soil.
2. 20 feet stratified, reddish-brown sand, with lines of small gravel.
3. 8 feet light-coloured sandy silt.
4. 15 feet coarse clean sand, with lines of small pebbles, and one line of coarser pebbles at ×.
5. 6 feet clayey unlaminated silt, with fragments of bed-rock in lower half.
6. Magnesian limestone, much crushed and broken at top.

strata exposed; but 20 miles south of Pavlodav I noticed that the surface soil contained many small subangular pebbles; and having already determined that the sand and pebbles had come from the south, towards which I was travelling, I was on the look-out for larger stones. The country was now of a more undulating character, and there were many shallow salt lakes. When 60 miles from Pavlodav, in the middle of the night, the wheel of the tarantass, for the first time in a journey of nearly 1000 miles, jolted over a stone; and on getting out I found there were many angular pieces of quartz lying on the surface, from 3 to 4 inches in diameter.

After this the stones increased in number and size; and 20 miles further south the surface-soil was full of large angular boulders of quartz, some of which were 8 feet across. Many large tabular masses of quartz rock looked as if *in situ*; but several of them had been quarried to build the enclosures of the government station, and they were seen to have rested in and on a sandy clay containing few other stones. There was nothing about these boulders or the clay in which they rested to suggest that they were moraine accumulations; they were distributed over a nearly level plain, as if they had been dropped from floating ice.

Beyond this point, southwards, the bed-rock often comes to the surface in ridges and low hills of highly metamorphosed crystalline rocks, separated by level plains composed of a sandy clay, with numerous small angular stones, invariably of the rocks seen *in situ* in the immediate neighbourhood; the fragments distributed over the plains were entirely unworn. Where excavations had been made they were seen to be much more numerous on the surface than below. The ridges and hills were covered with shattered fragments of the rocks of which they were composed; nowhere were there any signs that they had ever supported glaciers, though probably they had been exposed to the action of intense frost. If we suppose that the plains had been covered with water forming shallow lakes, the distribution of the angular fragments over their surface can be easily accounted for, as these lakes would be frozen over in winter, and on the ice breaking up in the spring it would carry away fragments of rocks from the surrounding ridges and drop them in various parts of the lakes. I have reason to believe this cause sufficient, as I have seen it in operation in the lakes of North America, and described it in a paper read before this Society in 1864.

The country beyond this to the southward, although still called the Kirghese steppes, had lost its level character, and some of the ridges of crystalline rocks rose to heights of at least 2000 feet, none of which showed any signs of glaciation, excepting that the surface had been shattered by intense frost. The true plains may be said to end on this meridian about lat. 51° N.; whilst to the north-east they extend diagonally across Siberia for 3000 miles. Over this enormous range of country their internal constitution seems to be the same as that of the plains I traversed; at Samarova, however, on the same meridian as Ischim, but 345 miles further north, Erman states that the yellow talcose clay of which the plains consist rests on another filled with large fragments of rock, and says it must be assumed

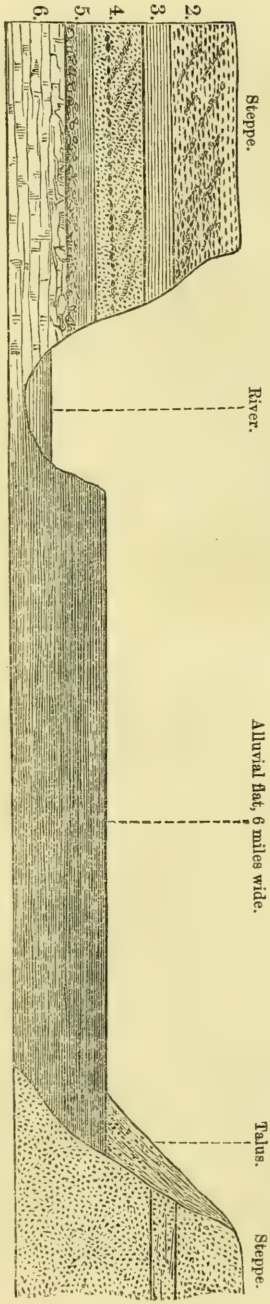


Fig. 4.—*General Section of River-valley at Pavlodav.* (Vertical scale much exaggerated.)

that west of the meridian of Samarova the blocks lie exposed on the surface, whilst eastward they are completely covered by the great deposit of clay; two thousand miles to the eastward of this point, at Yakutsk, he states that the strata of the steppes consist of loam, fine sand, and magnetic sand. In the deepest parts twigs and leaves of trees are found; the alluvial plain of the Lena also consists of similar deposits and the spoils of willow-banks. "Everywhere," he says, "throughout these immense alluvial deposits there are now lying the bones of antediluvian quadrupeds along with vegetable remains." At Pavlodav I obtained teeth of the Mammoth and *Rhinoceros tichorinus* from M. Hermann Paulson, who had made a large collection of the bones of Mammalia from the banks of the Irtisch. He told me they were exposed in sections of the steppe-sands after freshets in the spring, when portions of the banks were carried away; this information agrees with the position of the mammalian remains assigned by the traveller Pallas, who states that they do not occur in the marshes or low lands, but in the precipices of the river-banks, in what I have called the steppe-sands. It is interesting to find that they are found in the same position as the *Cyrena fluminalis*. Further to the north, around the coast of the Polar sea, within the Arctic circle, the carcasses of mammoths have been found along with marine shells, proving, I think, a small rise of the coast since they were deposited.

2. Theory of the Origin of the Steppes.

It is an interesting question, and one not easily answered, what spread out these vast level sheets of sand and loam over the whole northern base of Asia? For weeks, as I was driven over them and saw day after day the sun rise on a level horizon and set again on the far-stretching plains, I puzzled myself with it. I ultimately arrived at a solution which, I believe, meets all the requirements of the case; and to obtain its acceptance by geologists, I think it will be best to describe the steps by which I was led to it.

I soon saw that the plains had no relation to the present river-system: the rivers simply cut through them; and there are no defined river-basins, bounded by rocks of greater age, in which they might have been deposited. My next idea was that the sands must be marine; and I find that this is the explanation of their formation given by the celebrated geologist Prof. Bernhard von Cotta, who visited the Altai in 1868. He states that the absence of the entire series of rocks between the Permian and the Diluvial leads to the conclusion that during the whole of this long period the region was dry land, and that during the Diluvial period it was covered with water up to the foot of the mountains. He says "at this time an ocean, extending from the Glacial Sea to the Ural, the Altai and the Caspian and Black Seas, seems to have been a boundary between Europe and the south and east of Asia. The absence of traces of glaciers, and, indeed, generally of any vestiges of a glacial period, such as are so frequently observed in Europe, may be accounted for by the supposition that a current of warm sea-water passing from the Mediterranean to the Glacial sea took its course along the then existing Altaic coast. The Mammoths, remains of which have been found in some of the caves of the Altai, may have lived upon large flat islands rising out of the Diluvial sea"*. I have given Prof. Cotta's theory, but may remark that the supposition of the Mammoths having lived on islands is not necessary, as, if the area was once occupied by the ocean, the Mammoths might follow its retreating coast as the land was gradually elevated. I believe that the absence of sea-shells is fatal to the marine theory: I searched diligently for them and could find none; and excepting in the extreme north, around the present coast, I believe none have been found by other observers. The mollusca exist all over the present ocean; they abound around Greenland, even within a short distance of the foot of the great glaciers. I do not contend that the presence of shells of *Cyrena fluminalis* is a proof that the waters in which the sands were deposited were not marine, as they might have been (and, I believe, were) brought down to the area by streams from the south; but their preservation in the sands proves that marine shells did not exist there, or their remains would also be found. I have visited most of the coasts of the world, and dredged in northern waters, and everywhere found marine mollusks to abound; and I believe that the absence of sea-shells in any Tertiary or Post-tertiary strata, excepting in some muddy deposits in which they could not well live, is a proof that these strata were not deposited in the great ocean. Utterly improbable is it that, according to von Cotta's theory, a warm sea-current flowing to the pole passed over this area. All our experience of the existing ocean proves that such a warm current would have teemed with marine life.

Rejecting the theory of a marine submergence, I next took into consideration the possibility of a barrier having existed to the north that dammed back the drainage of the country and produced an immense lake in which the sands were spread out. I found it difficult to conceive of any rise of land to the north that could have formed such a barrier; and it is also to be remarked that there is evidence in the marine shells of the northern border that it stood lower, and not higher, than it now does. If there was now a rise of the northern boundary of the continent, would the drainage of the country be pounded back? or would not the rivers cut down their channels and still keep open their outlets to the sea?

Before reaching Pavlodav I had come to the conclusion that it was probably an overflow of polar ice that had blocked up the drainage of the country; and when I reached that town and at last got a sight of the ancient bed-rock over which the ice must have moved if it existed, and saw the crushed and shattered surface and the fragments pushed up into the overlying silt, I no longer hesitated to adopt the theory; for the appearances presented in the river-cliff were just such as might be expected to be produced at the foot of an ice-flow advancing against the slope of the continent.

* Quart. Journ. Geol. Soc. 1869.

Let us see if such a barrier would account for the formation of the steppes. Siberia is a great continental basin, surrounded on three sides by the mountain-chains of the Oural, the Altai, and the Stannovoi; and the only outlets of its drainage are to the north. If an overflow of ice took place from the north, the waters of all the rivers would be pounded back. As the ice advanced southwards it would grind against the bed-rocks, and the water issuing from below it would wash out sand and silt. Where ranges rose above it, boulders would be carried southward; and those noticed by Erman at Samarova were probably brought from the northern end of the Ourals. At its culmination I do not think it reached much further south than Pavlodav, as the steppe-sands thin out rapidly, and there is no sign of glaciation on the surface of the exposed rocks fifty miles to the south. The edge of the ice would mark the commencement of a great lake into which would run all the streams from the south and all the water from the melting ice. At its greatest elevation I believe the overflow of this lake must have run through the depression between the southern termination of the Ourals and the western end of the Altai to the Aral and Caspian Seas.

During the slow retreat of the ice the water would follow its receding margin; and every portion of the growing steppe would at one time or the other form part of the shore of the great lake.

Around this shore, and on the banks of the rivers flowing into the lake, I believe the great mammalia lived; and as the water moved northward they followed its margin; and their remains are thus found dispersed over the whole area of the steppes. Their frozen carcasses found along with sea-shells in the far north prove that they lived up to the close of the Glacial period, whilst their bones, in caves far to the south in the Altai, probably mark their range at the time of its greatest intensity.

I have shown that the ranges to the north of Pavlodav exhibit no signs of ever having supported glaciers. If we glance at a map of Asia we shall see that currents of air coming from the south would, before they reached Siberia, have to cross the high mountains of India and Central Asia, where they could not fail to part with their moisture; so that the precipitation in Siberia was probably not greater, but less, in the Glacial period than it is now. Whence then came the ice that blocked up the drainage of Siberia? I believe it was an overflow from the polar basin, which was filled with ice that poured into it from the northern extremities of America, Greenland, and Europe, and which was further heaped up towards the pole by precipitation from moisture-bearing currents of air that travelled far north, through Behring's Straits and past Spitzbergen.

3. Application of the Theory to other parts of the Earth's Surface.

Eight years ago, in a paper on the Glacial period in North America, I suggested that certain phenomena thought to prove that there had been a great submergence of the country in the Glacial period might be explained by the theory that ice coming down from the north had dammed up the valley of the St. Lawrence, and changed it into a great freshwater lake. I also showed that stratified beds of sand and gravel, without marine shells, might have been, and probably were, formed by ice flowing down the principal valleys and causing glacial lakes in the lateral ones, in which the sands and gravels were deposited. I at the same time urged that the absence of marine remains in these deposits should make us pause before we come to the conclusion that they were formed by the sea.

I certainly neither at that time nor until my visit to Siberia had any idea that the theory was of such wide application; but it will be seen that what I have now advanced is only an extension of the earlier theory, and that I was prepared to accept it more readily than I might otherwise have done.

The theory of the blocking up by ice of the drainage of countries in the Glacial period, and the formation of large and small lakes, will, I believe, explain the existence of many stratified deposits that are supposed to prove the great submergence of the land below the waters of the ocean. Thus, if the ice once filled the beds of the German Ocean and the Irish Sea, all our rivers running to the west and to the east must have at one time been dammed back by it. Similarly every lateral valley in the north of England and in Scotland was at one time or another occupied by a glacial lake; and thus, I believe, the stratified sands, often false-bedded, that lie above the Boulder-clay were formed. In many cases the barrier-ice seems to have been suddenly removed or broken through, and the escaping rush of water has cut down through the sands and left them in long ridges or isolated mounds.

Again, the ice that descended from the mountains of Scandinavia must have dammed back all the rivers of Northern Europe; and I think that a great part of Central Europe must at that time have been occupied by great freshwater lakes over which floated icebergs.

It is with some diffidence that I put forward these views, as I know they are opposed to those held by most geologists; but I am sure they will credit me with a desire to arrive at a true explanation, and admit that the arguments I have advanced show, at least, that the grounds on which it is held that a great part of the northern hemisphere was depressed below the level of the ocean in the Glacial period require reconsideration.

Discussion.

Mr. Drew thought that the deposits had a lacustrine aspect. Their nearest parallel was to be found in the great plain of India, the origin of which was not quite clear, although it had perhaps originated as a delta. He did not think that the ground had been covered by an ice-cap.

Mr. Hulke believed that the author's view as to the origin of the deposits was correct. He thought that the plains of Hungary were of a similar nature, their freshwater deposits having been formed in consequence of the stoppage of the Danube, changing what had been a dry plain into a vast lake. The effects described by the author might have been produced by a rise of land in the north.

Prof. Ansted remarked that the extent of the country under consideration might be estimated roughly at 3,000,000 square miles, and asked whether this was to be regarded as the area of a freshwater lake. If so, whence did the water come and where did it go? He thought such a phenomenon of very unlikely occurrence.

Mr. Belt, in reply, said that he was glad to find that the marine theory had had no supporters. He maintained as a fact that if a barrier were placed across the country, the numerous rivers would soon flood its whole surface.

38. Descriptions *of* Species *of* Chætetes *from the* Lower Silurian Rocks *of* North America. By H. Alleyne Nicholson, M.D., D.Sc., F.R.S.E., F.G.S., Professor of Biology in the College of Physical Science, Newcastle-on-Tyne. (Read June 24, 1874.)

[Plates XXIX. & XXX.]

The Lower Silurian rocks of North America have yielded a very large number of small corals, which have been ordinarily referred by palæontologists to one or other of the three genera *Chætetes*, *Monticulipora*, and *Stenopora*. Before considering these, however, it would seem advisable to very briefly discuss the value of the above-mentioned generic divisions, the boundaries of which are by no means yet satisfactorily defined.

The genus *Stenopora* is defined by Lonsdale as follows:—"A ramose, spherical, or amorphous tubular polypidom; tubes polygonal or cylindrical, radiated from a centre or an imaginary axis, contracted at irregular distances, but in planes parallel to the surface of the specimen; tubular mouths closed at final periods of growth; ridge bounding the mouths granulated or tuberculated; additional tubes interpolated." (Lonsdale in Strzelecki's 'Physical Description of New South Wales and Van Diemen's Land,' p. 262, 1845.)

The chief features in the above description which are relied upon as characterizing the genus are the constriction of the corallites at irregular intervals in planes parallel with the surface, the granulation or tuberculation of the ridges bounding the calices, and the interpolation of the young tubes between the old by lateral gemmation, so that a fracture exposes the outer walls of the tubes. Mural pores of course are absent, as in the whole family of the *Chætetinæ*. Lonsdale's definition, as above given, is accepted in all its essential details by M'Coy (Brit. Pal. Foss. p. 24), who describes several species under this head. Milne-Edwards and Haime, in the Introduction to the 'British Fossil Corals' (p. lxi), accept the genus *Stenopora*, defining it simply as "very similar to *Chætetes*, but having small styliform processes at the angles of the calices." They thus do not notice the characters relied upon by Lonsdale and M'Coy as separating *Stenopora* and *Chætetes*, whilst they introduce a feature not mentioned by either of these observers. In other words, they break up Lonsdale's genus into two portions, one of which, typified by *S. spinigera*, Lonsd., they retain under *Stenopora*; whilst the other, comprising all the species enumerated by M'Coy, King, Geinitz, and Howse, they place under *Chætetes* and *Favosites*. The type species, *S. spinigera*, I have never seen; but it appears to me that the characters relied upon by Lonsdale and M'Coy as separating *Stenopora* and *Chætetes* are clearly insufficient for this purpose, and that Milne-Edwards and Haime are therefore fully justified in the course they adopted. As far, at any rate, as our American examples are concerned, though the occurrence of *Stenopora fibrosa* has been often quoted, I have vainly sought for any specimens which I could refer to this genus. The periodically constricted tubes, contracted in planes parallel with the surface, do not form a feature in any of our specimens. The existence of tubercles and granules on the bounding-ridges of the calices can be observed in undoubted species of *Chætetes* (*Monticulipora*), such as *C. Jamesi*, Nich., and *C. Ortoni*, Nich. A Devonian species, *C. monilifera*, Nich., though in other respects agreeing entirely with *Chætetes*, carries a series of vertical spines which project above the surface from all the angles of the calices; and I have observed the same feature in an undescribed species from the Trenton Limestone. Lastly, all the forms which I have examined from the Silurian and Devonian rocks of America, with the single exception of a large lobate form from the Trenton Limestone, have the outer walls of the corallites exposed by a rough fracture, and may thus be supposed to increase by lateral budding. Taking this character alone, therefore, they would all have to be referred to the genus *Stenopora*, though in other respects not agreeing with it, but with *Chætetes* or *Monticulipora*.

The genera *Chætetes*, Fischer, and *Monticulipora*, D'Orbigny, save in one point to be discussed immediately, are identical with one another, and may be briefly defined as including ramose, frondescent, massive, or incrusting corals, composed of closely aggregated, polygonal, circular or subcircular corallites, which are traversed by well-developed tabulæ, and which may or may not be separated by very minute intermediate tubuli. No mural pores. Septa absent or quite rudimentary.

The point by which it has been attempted to separate *Chætetes* and *Monticulipora* is the mode of increase of the coral, which is stated to be by fission in *Chætetes* and by lateral gemmation in *Monticulipora*, the corallum in the two genera being in other respects precisely similar. It seems to me, however, that it is a pity to attempt to found a generic distinction upon this point alone, and for the following reasons:—In the first place, even if other objections were removed, and the distinction could be shown to be constant, it might be doubted if this character alone should be regarded as of more than subgeneric value. Secondly, the character is one under the best of circumstances difficult of determination, as shown by the fact that very eminent palæontologists have come to precisely opposite conclusions as to the mode of growth of the corallum of the same species. Thus Lonsdale regards *Chætetes petropolitanus* as increasing fissiparously, and places it accordingly; whereas Milne-Edwards and Haime regard the same species as increasing by gemmation, and refer it to *Monticulipora*. Thirdly, in a great many specimens of all the species the distinction in question is one which it is impossible to apply; and in some cases this is true of all the examples. Thus, in the exceedingly thin incrusting species the mode of growth cannot be satisfactorily determined; and one meets with numerous examples of the ramose, frondescent, or massive forms of which the same is true. It is, however, a pity to separate two genera by a single character which does not admit of general observation and application. Lastly, if this distinction be admitted, it will become a question whether the limits of Lonsdale's genus *Stenopora* should not be extended so as to receive the forms generally referred to *Monticulipora*.

The presence of "monticules" or "mamelons," from which the name *Monticulipora* was derived, cannot be relied upon, since these elevations are sometimes wanting, and, besides, vary very materially in their nature even in the cases where they present themselves.

The genus *Nebulipora*, M'Coy, would seem to have been rightly included by Edwards and Haime under *Monticulipora*, since the only available distinction is the presence of mural pores, and M'Coy is unable to speak with any certainty as to the existence of these openings in the forms upon which his genus is founded.

For the reasons above given I shall in this communication place all the corals under consideration in the genus *Chætetes*, irrespective of their mode of increase, which is in many instances unknown. The specimens from which my descriptions are taken have been partly collected by myself from the Hudson-River group of Canada; but most of them have been kindly furnished to me from the Cincinnati group by Mr. James and Prof. Orton, and from the Trenton Limestone by Mr. G. J. Hinde. I shall also not only describe those species which are actually new, but I shall likewise give a brief account of some of the previously recorded species, the well-preserved specimens in my possession in many cases enabling me to adduce new facts of interest and importance.

A completely satisfactory subdivision of the genus *Chætetes* (including *Monticulipora*) is at present not possible; but the genus may be conveniently broken up, according to the form of the corallum, into the ramose, frondescent, massive, and incrusting species.

I. Ramose Species.

This group includes those forms in which the corallum is ramose or dendroid, the corallites disposed in a radiating manner round an imaginary axis. The corallum is rooted at the base, and the extremities of the branches are rounded. Some of the forms of this group are slender and regularly divided; but others are more or less swollen or tumid and irregularly branched, becoming sometimes almost lobate, and thus passing into one of the sections of the massive group.

1. Chætetes Dalei, Edw. & H. Pl. XXIX. figs. 1, 1 *a*.

Chætetes Dalei, Edwards & Haime, Pol. Foss. des Terr. Paléoz. pl. 19. fig. 6.

Corallum branching, the branches cylindrical or elliptical, dividing dichotomously at short intervals; the diameter of the branches on an average from 3 to 4 lines, but sometimes only from 1 to 2 lines. Calices in general from six to eight in the space of 1 line, polygonal, with moderately thin walls. A greater or less number of smaller calices, usually in the form of very minute circular tubuli, situated at the angles of the larger corallites. Surface covered with conical, rarely transversely elongated eminences or tubercles, which sometimes attain a height of over half a line, and which are placed at intervals of from half a line to nearly 1 line apart. These tubercles are covered with corallites which are not larger than the average; and their summits may be partially compact or furnished with corallites of smaller size than usual.

At least two variations appear to be included under this species. In some forms, which may probably be regarded as the most typical, the eminences of the surface are very prominent, and the normal or average corallites are separated by a great number of extraordinarily minute cylindrical corallites, which vary from three to six or more placed round each of the larger tubes, which thus acquire a more or less circular form. In another variety the surface-tubercles are usually not so pronounced, and the corallites are for the most part nearly equal in size. Even in these examples, however, there are occasional excessively minute corallites at the points where the larger ones meet, though this is never a conspicuous feature as it is in the preceding variety.

Locality and Formation. Common in the Cincinnati group (Hudson-River formation), near Cincinnati, Ohio.

2. Chætetes rugosus, Edw. & H. Pl. XXIX. fig. 2.

Chætetes rugosus, Edwards & Haime, Pol. Foss. des Terr. Pal. pl. 20. fig. 6.

Branches cylindrical or flattened, from 2 to 3 lines in diameter, dividing dichotomously at short intervals. Corallites polygonal or subcircular, the average ones about six or eight in the space of 1 line, separated by numerous exceedingly minute circular tubes. Surface exhibiting numerous elevations, which have a height of from one quarter of a line to half a line, and are transversely elongated, so as to constitute so many discontinuous transverse ridges. These ridges vary in length, but they do not extend round the stems, and they are usually sharp-edged and placed about half a line apart. The corallites on the ridges are not larger than those on the other parts of the coral.

This species differs from *C. Dalei* in little except in the fact that the tubercles are elongated in a direction at right angles to the axis of the branches. It may be only a pronounced variety of *C. Dalei*.

Locality and Formation. Common in the Cincinnati group, near Cincinnati, Ohio.

3. Chætetes approximatus, Nich. Pl. XXIX. figs. 3, 3 *a*.

Corallum consisting of cylindrical stems, dividing dichotomously, and having a diameter of about 2 or $2\frac{1}{2}$ lines. Corallites thick-walled, though not excessively so, subcircular or polygonal, eight or ten in the space of 1 line, sometimes with excessively minute corallites interspersed amongst the larger ones, though these are never abundant and may be absent over considerable spaces. Surface exhibiting a number of small, somewhat transversely elongated tubercles, placed in diagonal lines at distances of half a line apart transversely and two thirds of a line measured vertically. The tubercles are very slightly elevated above the general surface, and are either solid at their summits, or carry a few excessively small cylindrical tubuli with or without two or three of the average-sized corallites.

This species is closely allied to *C. Dalei*, from which it is distinguished by its slightly smaller calices, by the fact that the tubercles are not conical and prominent and are not covered with corallites of the ordinary size, whilst the very minute intermediate tubuli are either absent or are present in very small numbers.

Locality and Formation. Cincinnati group, near Cincinnati, Ohio. Collected by Mr. U. P. James.

4. Chætetes attritus, Nich. Pl. XXIX. figs. 4, 4 *a*.

Corallum composed of subcylindrical branches, having a diameter of from 5 to 7 lines, and dividing at short intervals. Corallites with thin walls, polygonal, from eight to ten in the space of 1 line, subequal, some being smaller than the others, but not excessively so. No very minute intermediate tubuli interspersed among the larger corallites. Surface with numerous, very close-set, quadrangular or conical solid eminences or tubercles, each placed at the junction of from four to six corallites. These tubercles are from four to five in the space of 1 line, and are apparently quite compact, carrying neither the average corallites nor minute tubuli.

This species is distinguished from all the preceding by its thin-walled corallites, the absence of excessively minute tubuli placed round the larger tubes, and the minute, crowded, solid tubercles which stud the surface. At first sight examples of this species look as if they had been more or less weathered and worn; but a closer examination does not bear out this view.

Locality and Formation. Cincinnati group, near Cincinnati, Ohio. Collected by Mr. U. P. James.

5. Chætetes pulchellus, Edw. & H. Pl. XXIX. figs. 5–5 *b*.

Chætetes pulchellus, Edwards & Haime, Pol. Foss. des Terr. Paléoz. p. 271.

Monticulipora pulchella, Edw. & H. Brit. Foss. Corals, pl. 62. figs. 5–5 *b*.

Corallum variable in form, usually of subcylindrical branches, which have a diameter of from 2 to 6 lines, sometimes forming flattened and expanded subpalmate fronds, sometimes inosculating. Corallites thin-walled, polygonal, unequal in size, about eight of the average ones occupying the space of 1 line. Surface exhibiting rounded or somewhat stellate groups of larger corallites, of which two or three occupy the space of half a line, and which sometimes have very minute intermediate tubuli between them. These groups of larger corallites generally comprise from five to seven individuals, and they are placed about 1 line apart; they are very slightly or not at all elevated above the general surface, so that there are no conspicuous tubercles.

The characters of this species are so well marked as to render its recognition very easy, even in small fragments.

Locality and Formation. Cincinnati group, near Cincinnati, Ohio.

6. Chætetes Fletcheri, Edw. & H. Pl. XXIX. figs. 6, 6 *a*.

Chætetes Fletcheri, Edwards & Haime, Pol. Foss. des Terr. Paléoz. p. 271.

Chætetes lycoperdon, Hall (ex parte), Pal. N. Y. vol. ii. pl. 17. figs. 1 *g–i* (cæt. excl.); also Pal. N. Y. vol. i. pl. 24. fig. 1 *g* (cæt. excl.)?

Monticulipora Fletcheri, Edw. & Haime, Brit. Foss. Corals, pl. 62. figs. 3, 3 *a*.

Corallum ramose, branches from 1½ to 3 lines in diameter, cylindrical or subcylindrical, often irregularly swollen at intervals, dividing dichotomously usually at considerable intervals. Corallites with moderately thick walls, the average ones of unequal sizes, about eight in the space of 1 line, and having very minute tubuli sparingly interspersed amongst them. Surface smooth, destitute of tubercles, but occasionally showing groups of corallites which are very slightly larger than the average.

The examples of this species which I possess from the Clinton group (Upper Silurian) agree entirely with the description given by Edwards and Haime, being smooth, and simply having a moderate number of very minute tubes irregularly intercalated amongst the ordinary corallites, these latter varying slightly in their dimensions. On the other hand, the Lower-Silurian examples which I have referred to this species, though also smooth, and also having minute tubuli sparsely interspersed amongst the larger corallites, exhibit distinct groups of corallites which are of rather larger size than the average, and which are not set upon distinct elevations. They thus approach *C. pulchellus*, from which they are hardly distinguishable except by the fact that the groups of large-sized corallites are not nearly so conspicuous, the individual corallites which compose them being only very slightly above the average size. On the contrary, in *C. pulchellus* the groups of large-sized corallites are very conspicuous, as the corallites composing them are nearly or quite twice as large as the ordinary ones. Perhaps the Lower-Silurian forms here regarded as referable to *C. Fletcheri* may constitute a distinct variety either of this or of *C. pulchellus.*

Locality and Formation. Common in the Hudson-River group of the Province of Ontario, and in the Cincinnati group, near Cincinnati, Ohio; also in the Clinton group (Upper Silurian) at Dundas, Ontario.

7. Chætetes gracilis, James. Pl. XXIX. figs. 7, 7 *a*.

Chætetes gracilis, James, Catalogue of the Fossils of the Cincinnati Group, 1871 (named, but not figured or described).

Corallum dendroid, the branches cylindrical or subcylindrical, from less than 1 line to 2 lines or more in diameter, dividing dichotomously at short intervals. Corallites very small and crowded, from ten to twelve in the space of 1 line, thick-walled, opening obliquely on the surface by oval or circular calices, between which are placed excessively minute circular tubuli. The surface exhibits no elevations or tubercles, but is entirely smooth; and there are also no groups of larger-sized corallites, the ordinary corallites being all nearly of a size.

This species is allied to *C. Fletcheri*, Edw. & H., from which it is distinguished by the thick-walled nearly equal corallites, and the oblique and very small calices, the dimensions of which are much more minute than in the latter form. My description is drawn from type specimens furnished by Mr. U. P. James.

Locality and Formation. Cincinnati group, near Cincinnati, Ohio.

8. Chætetes delicatulus, Nich. Pl. XXIX. figs. 8, 8 *a*, 8 *b*.

Corallum very slender and delicate, ramose, composed of cylindrical stems, terminating in rounded, sometimes thickened extremities, and apparently springing in some cases from a horizontal footstalk. Stems sometimes apparently simple, more commonly branched dichotomously, the division taking place at acute angles; diameter of the stems and branches from one quarter of a line to half a line, rarely reaching two thirds of a line. Corallites very oblique to the surface, opening by oval apertures, the length of which corresponds with the axis of the stem and exceeds the breadth. Calices in diagonal rows, about eight in 1 line measured longitudinally, and from twelve to fourteen in the same space measured diagonally. When perfect and unworn, the lower lip of the calices is thin and prominent. The calices are all of equal size; and the surface is destitute of monticules or tubercles.

This is one of the commonest fossils of the Hudson-River formation, both in Canada and in the United States. From its very minute size, I am left somewhat uncertain as to the true position of this abundant little fossil. It is, I think, certainly the form which has generally been quoted as a slender variety of *Stenopora fibrosa*; but even if this species were to be retained, our examples could not be placed under it. It is likewise apparently one of the forms which has been figured by Hall under the name of *Chætetes lycoperdon* (Pal. N. Y. vol. i. pl. 24. fig. 1 *k*, cæt. excl.). It is most closely allied to *Chætetes gracilis*, James; but it is readily separated by the absence of minute tubuli interspersed amongst the larger corallites, by the much greater obliquity of the corallites and their much thinner walls, and by the uniformly slender habit and stunted growth. From *C. Fletcheri*, Edw. & H., it is also distinguished by the uniformity of the size of the corallites and their oblique direction.

Of the fossils of the later rocks, *C. delicatulus* runs a considerable chance of being confounded with *Helopora fragilis*, Hall, which it much resembles superficially. It is, however, readily distinguished by its almost always being branched, by the form of the calices, and by the fact that the calices are not arranged between longitudinal elevated lines.

Locality and Formation. Common in the Hudson-River group of Canada almost everywhere; also in the Cincinnati group, near Cincinnati; also in the Trenton Limestone.

9. Chætetes ? nodulosus, Nich. Pl. XXIX. figs. 9, 9 *a*.

Corallum dendroid, minute, of small cylindrical stems, which branch dichotomously at intervals of 2 lines, and have a diameter of from two thirds of a line to 1 line. Corallites prismatic or hexagonal, directed somewhat obliquely to the surface, of two sizes. Larger corallites opening by subcircular or oval apertures, the long diameter of which coincides with the axis of the stems; from six to eight in the space of 1 line measured vertically. Smaller corallites in the form of exceedingly minute circular tubuli interspersed amongst the larger tubes. Surface exhibiting numerous minute, sometimes conical, sometimes transversely elongated elevations or tubercles, which are placed at distances of about half a line apart, and give to the surface a characteristic nodulose appearance.

This very distinct species is more nearly allied to *C. Dalei* than to any other; but it is very readily separated by its much more slender and graceful proportions, and the much smaller size of the proportionally remote tubercles. One specimen, indeed, which can hardly be referred elsewhere, exhibits on transverse section about twelve very distinct radiating septa meeting in the centre of the corallites. Though all the other examples possess tabulæ and have all the characters of *Chætetes*, this raises the suspicion that possibly the form may require, on more extended investigation, to be removed from *Chætetes*.

Locality and Formation. Cincinnati group, near Cincinnati, Ohio. Collected by Mr. U. P. James.

10. Chætetes Jamesi, Nich. Pl. XXIX. figs. 10–10 *b*.

Corallum of cylindrical or subcylindrical hollow branches, the diameter of which is from 3 to 5 lines; or of somewhat lobate and subpalmate masses, the extremities of which are rounded. Branches in the ramose forms dividing dichotomously at irregular intervals, irregularly thickened and nodulose. Corallites oval or circular in section, of unequal sizes. The larger corallites about six in the space of 1 line, with very thick walls, the margins of the round or subpolygonal calices being obscurely tuberculated or granulated. The larger corallites are separated by extremely minute cylindrical tubuli, the number of which varies in different parts of the corallum. The surface exhibits no eminences or tubercles, or groups of large-sized corallites; but typical specimens exhibit at irregular intervals stellate spaces, which are either solid or minutely punctate, and have a diameter of two thirds of a line.

This species is related to *Chætetes tumidus*, Phill., of the Carboniferous rocks, especially in the rounded, thick-walled corallites, separated by minute intermediate tubes. I have, however, compared it with specimens of the latter, and find it to be clearly distinguished by the larger size and much thicker walls of the corallites, the generally greater number of the minute intermediate tubules, the tuberculated margins of the calices, and the existence of the curious stellate, solid or porous interspaces. The value of this last character is diminished by the fact that some specimens, otherwise the same, do not exhibit these spaces in a conspicuous manner. The tuberculated margins of the calices, though this feature can only be detected with the use of a high magnifying-power, remind one of the species generally considered as belonging to the genus *Stenopora.*

Locality and Formation. Not rare in the Cincinnati group, near Cincinnati, Ohio. Collected by Mr. U. P. James.

11. CHÆTETES RHOMBICUS, Nich. Pl. XXIX. figs. 11–11*b*.

Corallum ramose, the branches solid or hollow, subcylindrical, from 4 to 5 lines in diameter, terminating in acutely pointed, or at other times swollen and bulbous, extremities. Corallites with very thin walls, about eight or ten in the space of one line, variable in form and arrangement. In parts of the corallum the calices are regularly hexagonal; but over the greater portion of the surface they are obliquely rhombic, and are arranged in regular diagonal rows, the direction of which, however, changes within short distances, giving to the corallum a most peculiar appearance. In any given portion of the surface in which this arrangement obtains, the calices are disposed in a double series of diagonals, the one set crossing the branch more or less transversely, whilst those of the other set have a direction more or less corresponding with the axis of the stem. The corallites are nearly equal in size; and there are no very minute tubuli interspersed amongst the average tubes. Occasionally a corallite may be slightly larger than the average; but the surface exhibits no tubercles, or regular groups of large-sized corallites.

The present species is related in some degree to *Chætetes* (*Monticulipora*) *Bowerbanki*, Edw. & H.; but it differs altogether in its mode of growth, especially when young, whilst the calices are only about half as large.

Locality and Formation. Cincinnati group, near Cincinnati, Ohio. Collected by Mr. U. P. James.

II. FRONDESCENT AND PALMATE SPECIES.

The species of this group of the genus *Chætetes* have a corallum which forms a flattened or undulated, often palmate or subpalmate expansion, of small thickness, but often attaining a considerable width and height. The corallum is composed primitively of two layers of corallites, the bases of which are in contact, and which are directed in opposite directions from a common calcareous membrane. The corallum is rooted at the base, with which exception the entire surface is covered by the calices on both sides. In old examples, additional strata of corallites may be superimposed upon the two primitive layers.

12. Chætetes mammulatus, Edw. & H. Pl. XXX. figs. 3, 3 *a*.

Chœtetes mammulatus, Edwards & Haime, Pol. Foss. des Terr. Paléoz. pl. xix. fig. 1.

Corallum forming irregular expansions of very considerable size, sometimes palmate or lobate, carrying the polypes on both sides, and from 2 to 4 lines in thickness. Surface covered with well-marked tuberosities, the prominence of which varies in different specimens, but which are covered with calices slightly larger than the average, occasionally with a few intercalated tubes of minute size. The tubercles are somewhat irregularly arranged in diagonal lines, and are placed at intervals of from half a line to more than one line apart. The corallites are subequal, polygonal, with thin walls, from eight to ten in the space of one line. Very rarely, and quite as an exceptional thing, one or two very minute tubules may be intercalated at the angles of the larger corallites.

This species represents *C. Dalei* in the ramose group, but is distinguished by its much less prominent tubercles and its mode of growth. It is further distinguished by the small, thin-walled, polygonal corallites, the absence of exceedingly minute intermediate tubuli, and the fact that the surface-tubercles are covered with calices which in general are rather above the average size. Our numerous specimens are all broad undulating expansions of comparatively small thickness, and thus depart somewhat from the typical form of the species.

Locality and Formation. Common in the Cincinnati group, near Cincinnati, Ohio. Collected by Prof. Edward Orton and Mr. U. P. James.

13. Chætetes frondosus, D'Orb. (?). Pl. XXX. figs. 2–2 *b*.

Chœtetes frondosus, Edwards & Haime, Pol. Foss. des Terr. Paléoz. pl. xix. fig. 5.

I am not at all satisfied that the specimens which have been placed in my hands with this name are really identical with D'Orbigny's species, from which they seem to differ in some important points. I am, however, unable at this moment to refer to D'Orbigny's description of the species, and I shall therefore describe our examples provisionally under the above title. If they should prove to be new, the name of *Chœtetes ohioensis* might be applied to them. The characters exhibited by our specimens are as follows:—Corallum forming erect, flattened, undulating expansions, polypiferous on both sides, of unknown but considerable height, and varying from less than 1 line to 3 lines in thickness. Calices oval or subcircular, from eight to ten in the space of one line, almost half their own diameter apart, separated by a great number of exceedingly minute tubuli, which render the spaces between the average corallites minutely porous. Surface with stellate spaces, which are sometimes slightly elevated above the surface as very low, rounded tubercles, but which are more commonly level with the general surface, and which, instead of bearing average or large-sized corallites, are entirely occupied by very minute tubuli similar to those which separate the ordinary calices.

Some of the thinner examples included under this head have a resemblance to *Monticulipora pavonia*, D'Orbigny; but their characters appear to be quite different.

Locality and Formation. Common in the Cincinnati group, near Cincinnati, Ohio. Collected by Prof. Edward Orton and Mr. U. P. James.

14. Chætetes? clathratulus, James. Pl. XXX. figs. 1–1 *b*.

Stictopora clathratula, James, Catalogue of the Fossils of the Cincinnati Group, 1871 (named, but not figured or described).

Corallum forming a thin undulating expansion of considerable size, and about half a line, less or more, in thickness. The corallum evidently grew in an erect position, as it consists of two layers of corallites, which have their bases fixed to a common membrane, and open on opposite sides of the corallum. The corallites are thus about one quarter of a line in height, and they are slightly oblique to the central lamina and also to the surface on which they open. The calices are somewhat oblique, the lower lip very slightly prominent, the walls moderately thick. About ten of the calices occupy the space of one line, their size being nearly equal throughout, and their general form being oval. The calices are arranged in regularly decussating diagonal lines, which cross the corallum from side to side in two intersecting directions. Surface with low, rounded, obscure elevations, arranged in diagonal rows at intervals of from one line to a line and a half, and occupied by cells which, as a rule, are neither larger nor smaller than the average. The ordinary corallites never have minute tubes interspersed amongst them; but there are often some small corallites on the elevations.

This beautiful fossil might be taken at first sight for a *Ptilodictya*, though it appears to be clearly not of this nature. I have, however, been unable to make out the presence of tabulæ, and am therefore uncertain what its true affinities may be. In the form of the calices, in its mode of growth, and in the presence of low tubercles more especially, it resembles a *Chætetes*, and I have provisionally referred it to this genus. The largest specimen in my possession is an undulated expansion, broken on all sides, about 3 inches long by 2½ inches wide, and about ½ a line thick. My description is drawn from type specimens presented to me by Mr. U. P. James.

Locality and Formation. Cincinnati group, near Cincinnati, Ohio.

III. Massive and Discoid Species.

Corallum fixed or free, massive, discoidal, hemispherical, spherical, or irregular in shape. The typical forms of this group have the under surface of the corallum covered by an epitheca; and these must have had a free existence, as the under surface of the corallum is more or less deeply concave; others are fixed to some foreign object; and the mode of existence of other examples is unknown.

15. CHÆTETES PETROPOLITANUS, Pander. Pl. XXX. figs. 5–5 *c*, 6, 7, 8.

Favosites petropolitanus, Pander, Russ. Reiche, pl. 1. figs. 6, 7, 10, 11.

Favosites lycopodites, Vanuxem, Geol. New York, 3rd part, p. 46, fig. 3.

Chætetes petropolitanus, Lonsdale, in Murch. Vern. & Keys. Russ. & Ural, vol. i. pl. A. fig. 10.

Chætetes lycoperdon, Hall (ex parte), Pal. N. Y. vol. i. pl. 23. fig. 1, and pl. 24. figs. 1 *a–h*, also vol. ii. pl. 17. figs. 1 *a–f*.

Monticulipora petropolitana, Edw. & Haime, Brit. Foss. Corals, p. 264.

Chætetes petropolitanus, Meek & Worthen, Geol. Illinois, vol. iii. pl. 2. figs. 8 *a*, *b*.

(Only the more important portion of the synonymy of this species is here given.)

"Corallum in general free; its basal plate flat or concave, and completely covered with a concentrically wrinkled epitheca. Upper surface regularly convex, in general hemispherical, and presenting obtuse tuberosities about 1 line broad and varying very much in height. In some specimens these tubercles appear to have been worn away, and their existence is indicated only by the presence of small groups of large calices, with thick walls; the calices are rather unequal in size, generally polygonal, sometimes almost circular; the largest are about one fifth of a line in diameter; the walls are not perforated; the tabulæ are horizontal, complete, and placed at about one twelfth of a line from each other. Some vestiges of septa are often visible. Young specimens are flat and discoidal." (Edwards & Haime, Brit. Foss. Corals, p. 265.)

The Trenton Limestone and Hudson-River group yield a great many examples which correspond with the above description in essential respects—some altogether so, but others with more or less striking variations. In *form* this species is protean, being more or less discoidal when young, but being in its adult state subspherical, hemispherical, subpyriform, lobate, mushroom-shaped, or shaped somewhat like a cardinal's hat. The surface is sometimes mammillated with obtuse tubercles or elevations of different sizes and variable height; but quite commonly it is perfectly smooth, especially in the smaller examples. Often no definite groups of large-sized corallites can be recognized; but at other times such are present. In all the specimens that have come under my notice the calices are polygonal or subpolygonal, generally about ten in the space of one line, sometimes fewer, without any very minute tubuli intercalated amongst them.

Besides the typical free-living examples of this species, with a concave base and concentrically wrinkled epitheca, the Cincinnati group yields a number of small, hemispherical, subspherical, smooth or nodulated masses, which agree in other respects with the free forms, but which are attached parasitically to foreign bodies, and which therefore do not possess a concave under surface. I am, however, unable to decide whether this of itself should be regarded as a character of specific value, though it would seem not to be so.

Locality and Formation. Common, and very variable in form, in the Trenton Limestone of Belleville, Peterborough, and other localities in Ontario. Abundant in the Hudson-River group of Ontario. Less frequent in the Cincinnati group of Ohio.

16. Chætetes discoideus, James. Pl. XXX. figs. 4–4 *d*.

Chætetes discoideus, James, Catalogue of Fossils of the Cincinnati group, 1871 (named, but not figured or described).

Corallum free, discoid, plano-convex, sharp-edged, from 5 to 8 lines in diameter, and about 1 line in greatest thickness. Under surface concave, covered with a very thin, smooth, and not regularly striated epitheca, which usually exhibits two or three concentric wrinkles. In general, the epitheca is so delicate as to reveal clearly through its substance the bases of the superjacent corallites. Upper surface gently convex, not exhibiting any tubercles or elevations of any kind. Corallites subequal; calices with moderately thin walls, polygonal, from eight to ten in the space of one line. No groups of larger-sized corallites, nor any very minute intermediate tubuli.

I do not feel altogether certain that this form is distinct from the young of *Chætetes petropolitanus*. It is, however, a common form, and is very constant in its dimensions. Apart from its discoidal plano-convex form, it is distinguished by its great tenuity (comparatively speaking), the sharp thin edges of the disk, the absence of surface-tuberosities or groups of large-sized corallites, and the extreme thinness of the epitheca, which is transparent and is not regularly striated concentrically. But for one character, I should have been disposed to have placed this species under *Chætetes (Nebulipora) lens*, M'Coy; and that is the absence in our examples of any groups of large-sized corallites, whereas their presence is a marked feature in the latter. The underside of *C. discoideus* resembles *Lichenalia calycula*, James; but it may be distinguished by the absence of radiating striæ, and by other characters as well. The above description of the species is drawn from type specimens forwarded to me by Mr. U. P. James.

Locality and Formation. Cincinnati group, near Cincinnati, Ohio.

IV. Incrusting Species.

In this group the corallum is parasitic, and forms a thin crust composed of a single layer of short corallites, which are attached by their bases to some foreign object, such as the shell of a Brachiopod, the epitheca of a coral, or the column of a Crinoid.

17. Chætetes papillatus, M'Coy. Pl. XXIX. figs. 12–12 *b*.

Nebulipora papillata, M'Coy, Brit. Pal. Foss. p. 24, pl. 1 C. fig. 5.
Chœtetes tuberculatus, Edw. & Haime, Pol. Foss. des Terr. Paléoz. pl. 19. figs. 3, 3 *a*.
Monticulipora papillata, Edw. & Haime, Brit. Foss. Corals, pl. 62. figs. 4, 4 *a*.

Corallum forming an exceedingly thin crust, usually not more than half a line in thickness, growing upon Brachiopods and other foreign objects. Surface exhibiting rounded tuberosities, sometimes very slightly elevated, placed about their own diameter apart, and occupied by corallites of a larger size than the average. Corallites polygonal, thin-walled, somewhat variable in size, not having very minute tubuli interspersed amongst them. About eight or ten of the average corallites in the space of one line. Width of the tubercles one line or a little more.

Our specimens agree well with the description given by Mr. M'Coy of *Nebulipora papillata*; but they differ somewhat from that given by Edwards & Haime. Thus the tubercles in our examples are rounded, not to any marked extent elongated or compressed; and the large corallites occupying these eminences are from five to six in one line (instead of being one-third of a line in width).

The tubercles are not uncommonly perforated by regular and large circular perforations, which have a diameter of about half a line, and appear to be the mouths of vertical tubes. I have, however, noticed similar perforations in several other species of *Chœtetes*; and they are probably extraneous to the coral itself.

Locality and Formation. Cincinnati group, near Cincinnati, Ohio.

18. Chætetes corticans, Nich. Pl. XXIX. figs. 13, 13 *a*, 14.

Corallum forming a thin crust, growing parasitically upon foreign bodies, and having a thickness of less than one quarter of a line, or, when in superimposed layers, attaining a thickness of half a line. Surface exhibiting a number of long, narrow, compressed tubercles, which are all drawn out in one direction, and which, whilst carrying average-sized corallites on their sides, appear to be compact at their summits. The long diameter of these tubercles varies from two thirds of a line to two lines, their width not exceeding half a line, and their height being variable. They are arranged in irregularly diagonal lines, and are placed at intervals apart of from half a line to two thirds of a line. The corallites are thin-walled, polygonal, subequal, from eight to ten in the space of one line, without any intermediate minute tubuli. There are also no groups of large-sized corallites.

This species is allied to *C. papillatus*, M'Coy, but appears to be sufficiently distinguished by the long, narrow tubercles, which do not carry any large-sized corallites. The specimens which I have seen are found coating *Orthocerata*, and forming thin but extended crusts. In some examples the tubercles are depressed, and appear to be solid throughout; but in other cases they are elevated, and carry corallites of the ordinary size on their lateral aspects.

Locality and Formation. Cincinnati group, near Cincinnati, Ohio.

19. Chætetes Ortoni, Nich. Pl. XXIX. figs. 15–15 *b*.

Corallum forming exceedingly thin crusts, not more than from one sixth to one eighth of a line in thickness, attached parasitically to submarine objects. Crusts usually constituting small circular expansions, or irregular and indefinite in form. Surface exhibiting numerous, minute, rounded or obtusely conical eminences, which are placed at intervals apart of half a line, more or less. The tubercles are somewhat compact at their summits, and carry upon their sides corallites which are little or not at all larger than the average. The corallites are somewhat oblique to the surface, moderately thick-walled, subequal, without any minute intercalated tubuli. Calices small, subpolygonal or oval, from ten to twelve in the space of one line; their margins thick and surmounted by minute and crowded miliary granules, which are rounded and not spinous, and which are placed almost in contact with one another.

In appearance, this species, but for its extreme thinness, and the small close-set surface-tubercles, might be confounded with *C. papillatus.* On examination with a high power, however, it is readily distinguished from all the known incrusting species of *Chætetes* by the fine and close granulation of the margins of the calices, giving to the surface quite a peculiar appearance. All the specimens I have seen of this singular species are parasitic upon *Strophomena alternata*; and I am informed by Mr. James that it is rarely found attached to any thing else. In spite of the granulated margins of the calices, it appears to be a genuine *Chætetes*, and I see no reason for removing it from this genus.

I have named the species after my friend Prof. Edward Orton, of the Geological Survey of Ohio, from whom, as well as from Mr. U. P. James, I have received the specimens from which the above description is drawn.

Locality and Formation. Cincinnati group, near Cincinnati, Ohio.

EXPLANATION OF THE PLATES.

Plate XXIX.

Fig. 1. Fragment of *Chætetes Dalei*, Edw. & H., of the natural size. (In this, as in all the following figures of *Chætetes* which are not enlarged, the calices have been omitted for the sake of clearness, and only the general form of the corallum is shown, together with any superficial prominences which may be present.)

1 *a*. A portion of the preceding, enlarged, showing the very minute intermediate tubuli.

2. Fragment of *Chætetes rugosus*, Edw. & H., of the natural size.

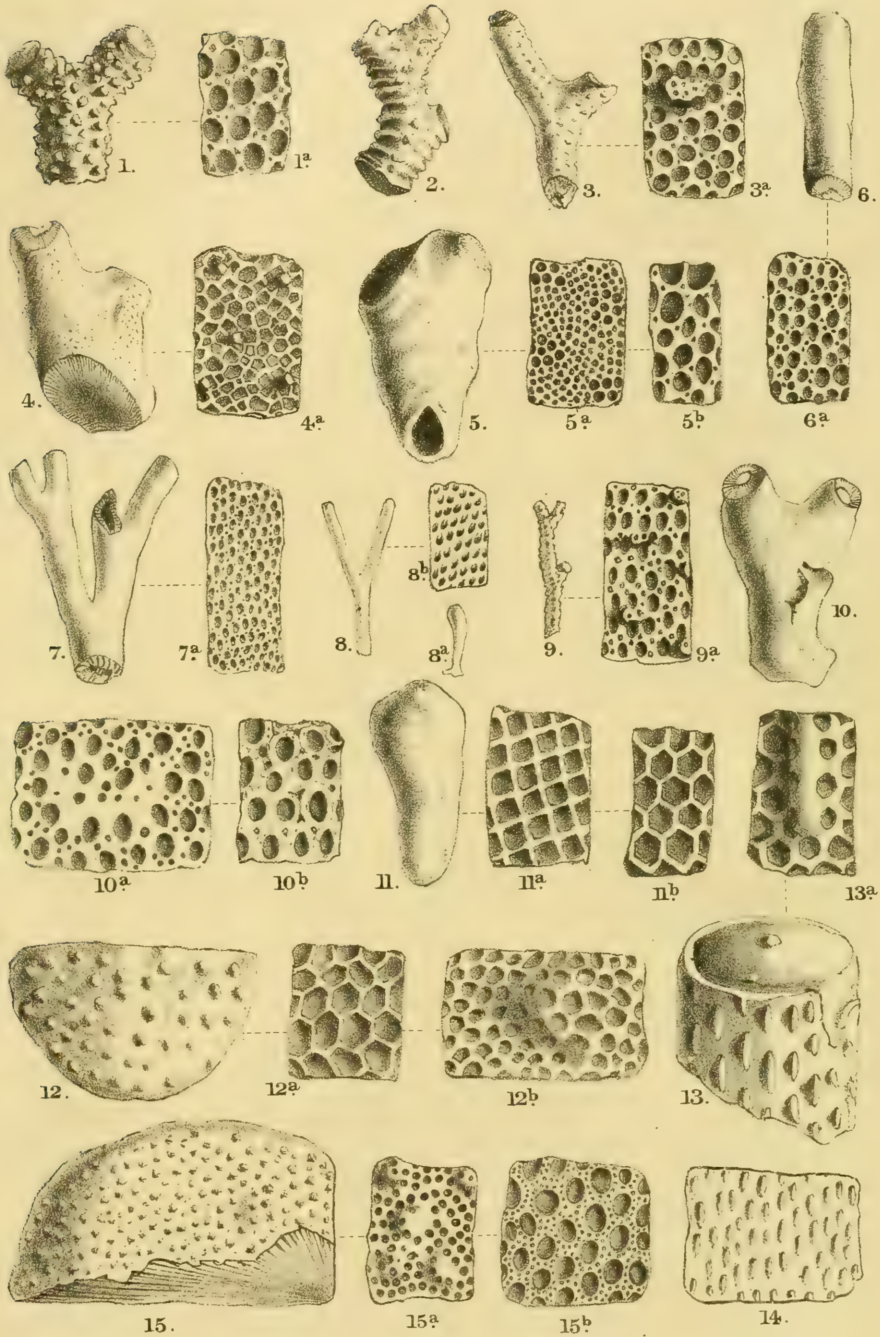
3. Fragment of *Chætetes approximatus*, Nich., of the natural size, showing the small tubercles.

3 *a*. A portion of the preceding, enlarged, showing a surface-tubercle and very minute tubuli between the average corallites. Few specimens, however, exhibit as many of these intermediate tubuli.

Fig. 4. Fragment of *Chætetes attritus*, Nich., of the natural size.
4 *a*. Portion of the same enlarged, showing the calices and the small solid tubercles.
5. A fragment of *Chætetes pulchellus*, Edw. & H., of the natural size.
5 *a*. Portion of the same, enlarged, to show the groups of larger corallites.
5 *b*. Portion, still further enlarged, showing the few minute intermediate tubuli.
6. Fragment of *Chætetes Fletcheri*, Edw. & H., of the natural size.
6 *a*. Portion of the same, enlarged.
7. Fragment of *Chætetes gracilis*, James, of the natural size.
7 *a*. Fragment of the same, enlarged, showing the small crowded calices and very minute intermediate tubuli.
8. Fragment of *Chætetes delicatulus*, Nich., of the natural size.
8 *a*. Fragment of the same, showing a stem which terminates in a rounded swollen extremity, and apparently springs from a horizontal foot-stalk, of the natural size.
8 *b*. Portion of fig. 8, enlarged.
9. Fragment of a large individual of *Chætetes? nodulosus*, Nich., of the natural size.
9 *a*. Portion of the same, enlarged.
10. Fragment of *Chætetes Jamesi*, Nich., of the natural size.
10 *a*. Portion of the same, enlarged, showing one of the stellate spaces.
10 *b*. Another portion of the same, still further enlarged, showing the thick-walled calices and their granulated borders.
11. Fragment of *Chætetes rhombicus*, Nich., of the natural size.
11 *a*. Portion of the same where the cells are rhombic and arranged in diagonal rows, enlarged.
11 *b*. Another portion of the same, where the cells are hexagonal, enlarged.
12. *Chætetes papillatus*, M'Coy, growing upon a *Strophomena*, of the natural size.
12 *a*. A few cells of the same, highly magnified.
12 *b*. A portion of the same, not so greatly enlarged, showing one of the tubercles.
13. *Chætetes corticans*, Nich., growing on an *Orthoceras*, of the natural size.
13 *a*. Portion of the same, enlarged, showing one of the tubercles.
14. Fragment of another specimen of *C. corticans*, in which the tubercles are smaller and not so pronounced, growing on a large *Orthoceras*, of the natural size.
15. *Chætetes Ortoni*, Nich., growing on *Strophomena alternata*, of the natural size.
15 *a*. Portion of the same, enlarged, showing the tubercles.
15 *b*. Portion of the same, enlarged further, showing the granulated margins of the calices.

Plate XXX.

Fig. 1. Fragment of *Chætetes? clathratulus*, James, enlarged, showing the diagonal arrangement of the cells and the tubercles.
1 *a*. Section of the same, enlarged, showing the two strata of tubes springing from a common lamina.
1 *b*. Portion of the same, enlarged still further.
2. Fragment of *Chætetes frondosus*, D'Orb. (?), of the natural size, showing the stellate spaces.
2 *a*. Section of the same, enlarged, showing the two strata of corallites arising from a common membrane.
2 *b*. Portion of the same, enlarged, showing the calices and a stellate space.
3. Fragment of *Chætetes mammulatus*, Edw. & H., natural size.
3 *a*. Portion of the same, enlarged.
4. Upper surface of *Chætetes discoideus*, James, natural size.
4 *a*. Under surface of the same, natural size.
4 *b*. Profile view of the same, natural size.
4 *c*. Portion of the upper surface of the same, enlarged.
4 *d*. Portion of the lower surface of the same, enlarged.



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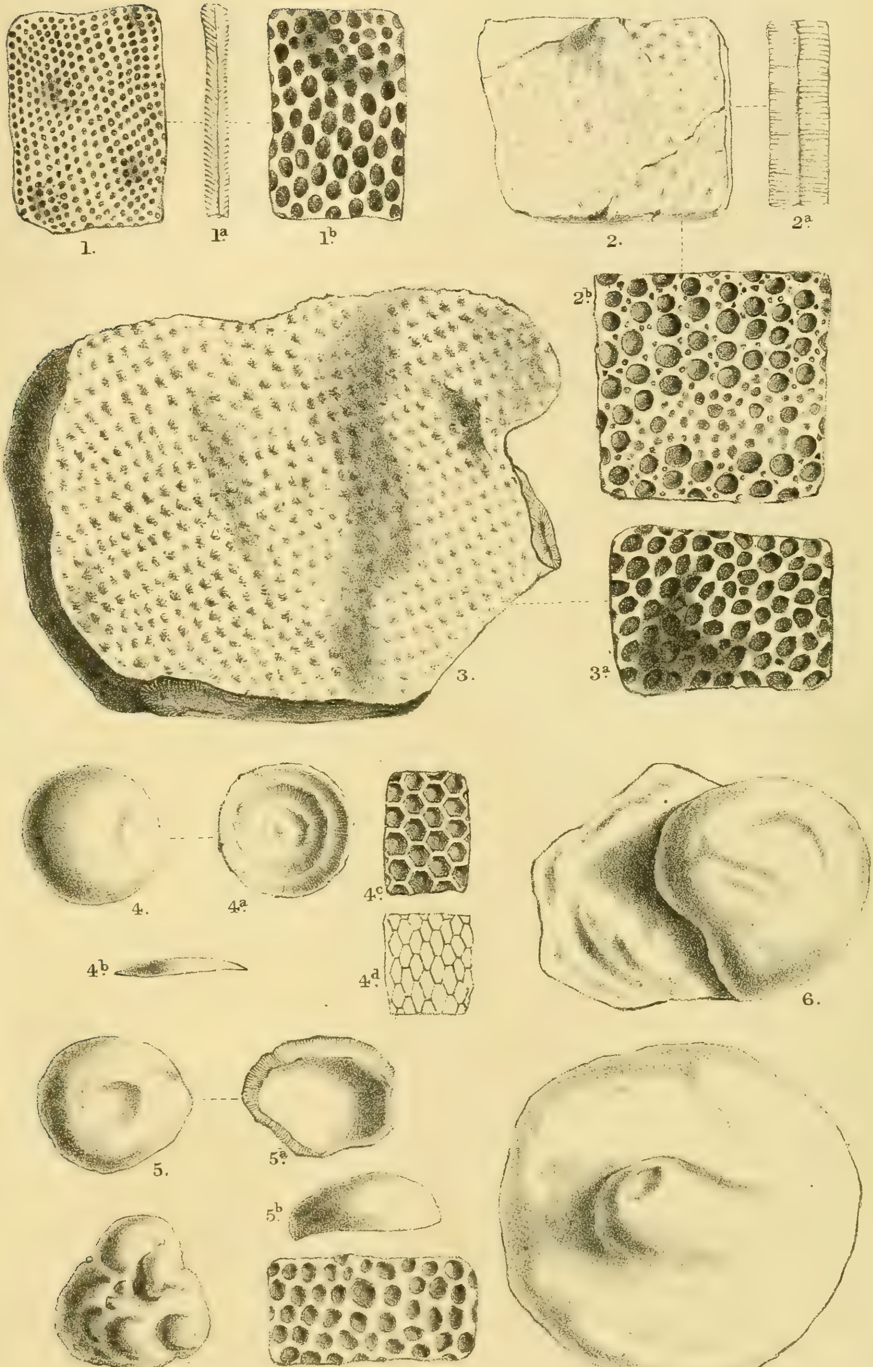

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AMERICAN CHÆTETES.

Fig. 5. Upper surface of a young specimen of *Chætetes petropolitanus*, Pander, of the natural size.

5 *a.* Under surface of the same, natural size.

5 *b.* Profile of the same, natural size.

5 *c.* Portion of the surface of the same, enlarged.

6. A specimen of *Chætetes petropolitanus* (?) attached to a Brachiopod, natural size.

7. Another specimen of the same (?), forming an apparently unattached nodulated mass, of the natural size.

8. A flattened specimen of the same (?), having the form of a cardinal's hat, of the natural size.

39. NOTE *on a* REPTILIAN TIBIA *and* HUMERUS (*probably of* Hylæosaurus) *from the* WEALDEN FORMATION *in the* ISLE OF WIGHT. By J. W. HULKE, Esq., F.R.S., F.G.S. (Read June 10, 1874.)

[PLATE XXXI.]

I AM indebted to Dr. Wilkins, of Newport, who has already so frequently afforded me valuable materials for the study of the fossil Reptilian fauna of the Isle of Wight, for the opportunity of bringing two very remarkable limb-bones before this Society. They were obtained several years ago, in Brixton Bay, by a fisherman since dead. The soft and brittle state of their tissues, the complete substitution throughout them of the red oxide of iron for the pyrites with which bones in this locality are usually impregnated, their envelopment in a concretionary matrix of this oxide and clay, and their incrustation with recent zoophytes and algæ concur in making it very probable that they had been long exposed to the waves and winds upon the shore between high- and low-water marks before they were discovered. The horizon of their *gisement* cannot be fixed more nearly than somewhere in the mottled purple and grey clays, therefore in the beds west of Cowleaze Chine, below the *Hypsilophodon*-bed. It is not even known that they were found lying so close together as to justify the inference from juxtaposition that they originally formed part of one skeleton. Dr. Wilkins informed me, when I first saw them in 1870, that he believed they were so associated when discovered; and the close agreement of their general facies, of their texture, of their mineralization, of the matrix about them, and of their algal and zoophytic crusts concur in rendering this extremely probable, and dispose me to regard them as members of one individual.

Remarkable shortness relatively to their bulk, singularly dwarfed shafts, and as notably expanded articular extremities characterize both bones.

Tibia (Pl. XXXI. figs. 1 & 2).—The general resemblance of this bone to the tibiæ of such typical Dinosaurs as *Iguanodon Mantelli* and *Megalosaurus Bucklandi* leaves no doubt of its place in the skeleton; but its proportions make it impossible to mistake it for the tibia of either of these Sauria.

Its total length is 16 inches.

The proximal end is so very massive that it greatly overhangs the slender shaft. An inner and an outer condyle, the latter separated behind by a wide, deep, roundish notch from a stout præcnemial process, are obscurely mapped on the upper or articular surface. Its antero-internal surface, and the præcnemial process into which the former is prolonged outwards, are rough as if for the attachment of muscles and ligaments; and a rather strong tuberosity marks the junction of the internal and anterior portions. The long diameter of this end, passing through the inner condyle and the base of the præcnemial process, measures about 7 inches; and when the back of the condyles rests upon a flat surface it includes with this surface an angle of about 35°; and it crosses the long axis of the distal end at an angle which in this specimen I estimate roughly at about 118°. Below the knee the tibia contracts quickly to a very short and slender shaft, in its unexpanded part not more than $2\frac{1}{2}$ to 3 inches long, and with a minimum girth of 7·5 inches, the girth of the proximal articular end measuring 21·5 inches. The cross section of the shaft is subtrigonal. The cortex of this part is compact, externally smooth, and finely grained. No large medullary canal is present, as in *Iguanodon Mantelli*, but a moderately fine cancellated tissue nearly fills the interior.

Downwards, the shaft expanding and becoming flattened, merges into the broad triangular ankle end, one angle or malleolus of which is antero-internal, the other postero-external, while the surfaces are respectively directed outwards and forwards, and backwards and inwards. The antero-external surface is undivided and nearly plane, while the postero-internal surface is broken by an angulated ridge into a smaller inner and a wider outer part. The under surface of this end is pulley-shaped, having a long, narrow, postero-external and a shorter, wider, antero-internal division. Its broad, shallow, trochlear groove ascends upon the posterior surface, external to the angulated ridge lately mentioned; and opposite to it, on the anterior surface, is a prominent tubercle. This trochlear part, with its anterior tubercle, is evidently homologous with the *Iguanodon's* separate astragalus. The condition of the specimen does not allow me to say whether this representative of the astragalus and the distal end of the tibia had become confluent during life, or whether they have simply become undistinguishably blended by post-mortem pressure and mineralization. The fact that the inner division of this trochlea stops short of the antero-internal angle or inner malleolus, and is not now coextensive with the entire under surface of this part of the tibia, is suggestive of a post-mortem displacement, and, if so, of the absence of a genuine bony anchylosis.

The proportions of this tibia are, within my knowledge, only repeated in the tibiæ of *Hylæosaurus* and *Polacanthus Foxii*. The materials for comparison are limited to a single example of each; and the account of the tibia of the latter in the Rev. W. Fox's narrative of his discovery of a great part of the skeleton of this remarkable armour-clad Saurian, communicated by him to the British Association in 1866, as also the short memorandum, with a sketch of a few of the bones, which appeared in the 'Illustrated London News' of that year, are rather "Preliminary Notices," which scarcely claim to afford the details so necessary to the anatomist who cannot study the actual specimen.

Table of Measurements.

	inches.
Length of tibia, including distal epiphysis or astragalus	16
Long diameter of proximal end	7
Girth of ditto	21·5
Girth of shaft	7·5
Long diameter of distal end	8·25

Mr. Fox (*loc. cit.*) described the tibia and fibula of *Polacanthus* as being 13 inches long, with broad ends, like those of *Hylæosaurus*, the diameters of the distal end $7\frac{1}{2}$ and $3\frac{1}{2}$ inches. I am not certain whether the larger of these latter numbers applies to the breadth of the tibia alone, or includes the still connected fibula, and also whether 13 inches is the length of the tibia, or of this with its lower epiphysis or astragalus. The extensive ossification of the tendons made it probable that the skeleton was that of a fully grown individual. Mr. Fox has verbally informed me that the bones of his *Polacanthus* have a coarse texture, and that the femur is devoid of a medullary canal. The impression which I retain from a cursory view of Mr. Fox's tibia two years ago is of a much less bulky bone than this specimen.

The tibia of *Hylæosaurus* obtained by Dr. Mantell at Bolney, now in the British Museum, probably represents the size of the adult shin-bone of this Saurian, if it actually formed part of the same skeleton with the associated scapulæ; for these (if their much larger size, greater massiveness, and stronger features than those in the well-known Tilgate-forest slab are trustworthy criteria) very likely belonged to an old fully grown individual. Its length is the same as that of Dr. Wilkins's specimen. Its proximal end is similarly massive, and its distal end is as remarkably expanded; the shaft also is strongly twisted. The condyles are better marked, and the lower end, owing to the disassociation of the astragalus, has the usual Dinosaurian notch instead of the distal trochlea of Dr. Wilkins's bone. With these close resemblances I prefer to refer this tibia to the same genus, though there are differences of detail which may possibly denote another species than Mantell's, possibly also may merely be the expression of differences of age or sex.

Humerus (Pl. XXXI. figs. 3 & 4).—The bone which I regard as a left humerus shows in an extreme degree the dwarfing of the shaft, the expansion of the extremities, and the massiveness relatively to length exhibited by the tibia. The total length is 16·5 inches, the breadth of the proximal end 8 inches, and that of the distal end rather under 7 inches. The shaft is as short as that of the tibia. The girth of the proximal end is 20 inches, that of the distal end is 18·5 inches, and that of the shaft 9 inches. The proximal border, very thick and rounded, swells out at about 3 inches distance from its ulnar end, and assumes a roughly trigonal convex form, the outer limit of which falls where the proximal and radial borders meet. The base of this sessile articular caput falls in the ventral lip of the proximal border; and its rounded dorsal apex marks the stoutest part of the border, where its thickness reaches 3·6 inches. The radial border, at first thinner than the proximal, descends straight for the space of 3 inches, and then expands into a knob-like swelling, from which it abruptly declines, ending in a ridge which is lost on the ventral or anterior surface of the short and slender shaft above the radial tuberosity. The ulnar or posterior border is strongly concave. The ventral or anterior surface of the expanded proximal part is very hollow transversely, having the shape of a wide trough.

The dorsal surface of the same part is transversely sinuous, being laterally hollow, and rendered centrally convex by a stout ridge-like continuation of the shaft, which, expanding upwards, largely supports the sessile, trigonal, articular caput. The distal end has less perfectly preserved its form. A trochlear groove, wide and shallow distally, prolonged also as a wide shallow trough on the dorsal surface of the shaft, and deep and notch-like ventrally, very distinctly mark out an ulnar and a radial condyle. The latter is ventrally surmounted by a tuberosity, the perfect form of which is now lost. The short and slender shaft has a roughly trigonal cross section; it is most convex dorsally, where one of the rounded angles falls, and less so laterally and at its ventral surface. The shaft is smooth, while the rest of the surface of the bone, especially towards the articular extremities, is very rough.

If, disregarding the hint derivable from the very probable association of this bone with the tibia just described, we look around amongst the contemporary Sauria of the Wealden formation for the owner of such a humerus, we find *Iguanodon Mantelli* and *Megalosaurus Bucklandi* immediately excluded, because their humeri are well known and very different. There remain for our scrutiny the *Streptospondyli* (*S. major* and *S. recentior*), Owen, the (Wealden) *Cetiosauri*, Owen, *Polacanthus Foxii*, and *Hylæosaurus* of Mantell. Of these, *Streptospondylus major* has still a doubtful individuality. Prof. Melville, if I mistake not, long since suggested, with much probability, that the vertebræ, then and still the only evidence on which this species was founded, belonged to the cervical and pectoral series of *Iguanodon Mantelli*; and although this may not be conceded, the individuality of *S. major* has not, I think, been so demonstrated as to render it impossible that these vertebræ may actually belong to one of the Sauria included in the genus *Cetiosaurus* as exemplified in the Wealden fauna—for instance to *C. brevis*, Owen, *Streptospondylus recentior*, Owen, *Ornithopsis Hulkii*, Seeley. *Eucamerotus*, mihi, has, as I have pointed out in a former paper, strong formal resemblances, as regards its vertebræ, to those of *Cetiosaurus oxoniensis*; but the texture of these bones is very different. Until recently only vertebræ had been found; but last autumn portions of limb-bones were recovered by the Rev. W. Fox and by myself; and as these have the same large-celled texture as the vertebræ, it is presumable that the humerus is similarly constituted, which this humerus is not. With these Sauria, and with the *Cetiosaurus brevis*, Owen, of the Wealden, and also with *Pelorosaurus* no comparison can be instituted. Turning to *Hylæosaurus* and to *Polacanthus Foxii*, the fore limb of the latter was missing from Mr. Fox's find, and no part of its shoulder-girdle has been recognized; but in the scapula of the former we observe an extraordinary massiveness of its articular end, and the large characteristic transverse crest—conditions which harmonize well with the great expansion of the proximal end of this humerus. This obvious suitability, coupled with the strong resemblances of the tibiæ, constitute better grounds for referring the humerus also to *Hylæosaurus* than to any of its contemporaries. I need hardly say that the bone which Mantell originally regarded as the humerus of *Hylæosaurus* was shown by Prof. Owen to be its tibia. There is also in the National Collection a bone labelled "Humerus of *Hylæosaurus*;" but both extremities are so mutilated that the determination is more than doubtful; if correct, the bone must have belonged to a very immature individual.

Supposing that Dr. Wilkins's specimen should prove to be the genuine humerus of *Hylæosaurus*, it is evident, on the assumption that it and the tibia belonged to one individual, that the proportions of the fore and hind limbs must have been very different from those which obtain in *Iguanodon* and *Megalosaurus*, in both which the fore limbs are, relatively to the hind limbs, remarkably reduced.

EXPLANATION OF PLATE XXXI.

Reptilian Tibia and Humerus.

Fig. 1. Front view of tibia: *pr.* proximal, *d.* distal end; *o. m.* outer malleolus; *i. m.* inner malleolus; *prc.* præcnemial crest.
2. Back view of the same tibia.
3. Oblique view of ventral surface of humerus: *c.* capitulum; *r.* radial condyle; *d.* deltoid border.
4. Dorsal surface of the same.

Fig. 3.

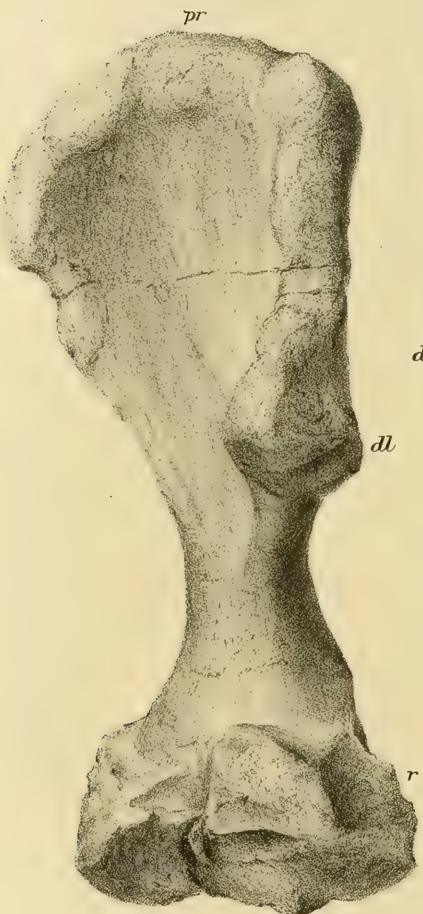
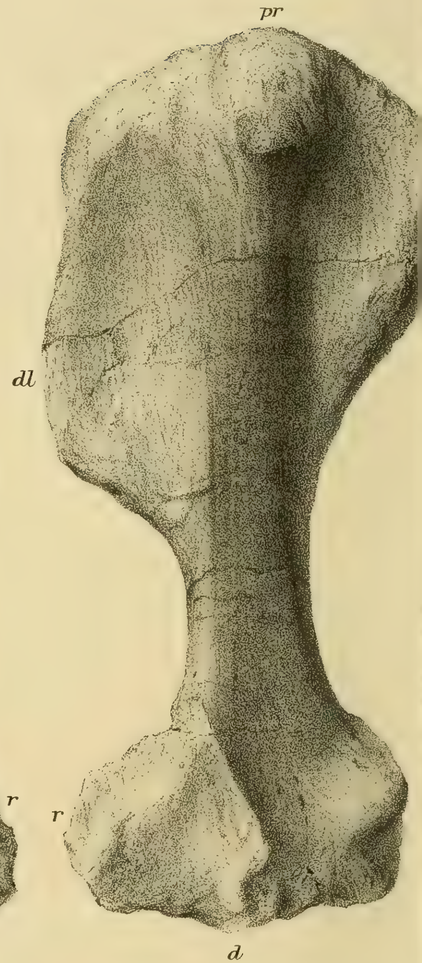


Fig. 4.



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TIBIA AND HUMERUS

Fig. 2. Fig. 1.

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US OF HYLÆOSAURUS ?(× $\frac{2}{7}$.)

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TIBIA AND HUMERUS OF HYLÆOSAURUS ? ($\times \frac{2}{7}$)

40. Note *on a* Modified Form *of* Dinosaurian Ilium, *hitherto reputed* Scapula. By J. W. Hulke, Esq., F.R.S., F.G.S. (Read June 10, 1874.)

[Plate XXXII.]

The subject of this note is a bone the true place of which in the skeleton, I suggest, with much deference to the opinions of the eminent authorities who have described it, has been misapprehended. If the interpretation I suggest should prove correct, it will indicate an altogether new genus, perhaps even a new order.

The oldest known example originally formed part of Dr. Mantell's collection. Subsequently it was purchased by the British Museum, where, labelled "Scapula of an unknown Reptile," it is exhibited amongst the Megalosaurian remains. Dr. Mantell originally referred it to his then newly discovered *Iguanodon*, but not without a caution. He described it in the following terms:—

"A scapula or omoplate 18 inches long, associated with bones or teeth of *Iguanodon*, and probably referable to that animal, presents, like the coracoid, some important modifications of the usual lacertian type. This bone is of an elongated form, and differs considerably from the omoplate of the Monitors and Iguanas. It somewhat resembles the scapula of the *Scink*, and it throws off a long tripartite apophysis, which is imperfect in the only specimen hitherto discovered; this process probably afforded support to a cartilaginous arch, as in the recent lizards. But although, from circumstances, I entertain but little doubt that the coracoid and omoplate above described belong to the Iguanodon, it is so hazardous in palæontological inquiries to affirm as certain what is merely probable, and so many impediments to accurate inductions have been occasioned by hasty and positive determination of a tooth or bone from imperfect analogies, that I deem it necessary to repeat that these specimens were not found in juxtaposition with other parts of the skeleton of the Iguanodon, but were merely imbedded in the same mass of rock." (Phil. Trans. 1841, p. 138.)

This opinion was adopted by Prof. Owen:—

"The scapula," he wrote (in 1841), "has not hitherto been discovered so associated with other unequivocal portions of the skeleton of the *Iguanodon* as to permit the characteristics of this bone to be confidently recognized. The bone (No. 194, omoplate of *Iguanodon*, Mantellian Catalogue) agrees with the undoubted scapula of the Hylæosaur and with that of certain lacertians, especially of the genus *Scincus* (Dr. Mantell has pointed out this resemblance in his Memoir in the 'Phil. Trans.' 1841), in the production of a long and slender pointed process continued nearly at right angles with the body of the bone from the anterior part of the articular surface for the coracoid; but it differs from the scapula of the Hylæosaur in the presence of two short processes given off from the lower part of the base of this long process, and in the absence of the thick and strong transverse acromial ridge which overhangs the glenoid depression, and in the deeper concavity of the posterior margin of the ascending plate or body of the bone. This part, in its shape, relative length and breadth, is intermediate between the crocodilian and lacertian type of the scapula, at least as exemplified in the Monitors and Iguanas. The Scincs and Chameleons in the more crocodilian proportions of their scapulæ resemble the Hylæosaur and the great species of extinct Saurians, most probably the *Iguanodon*, to which the present bone belongs." ("Reports on British Fossil Reptiles," in Brit. Assoc. Rep. 1841, p. 133.)

Having subsequently discovered a scapula of a different shape, the coracoid border of which he saw to be adapted to that of an unequivocal *Iguanodon* coracoid, and having verified his new acquisition by identifying it with a pair of bones in the type slab of the Maidstone *Iguanodon*, Mantell abandoned his original reference of the first scapula to this herbivorous Saurian, but he continued to regard it as a scapula. In his 'Fossils of the British Museum,' 1851, at pp. 282, 283, he reproduced from the 'Phil. Trans.' 1841 his first description of it, under the new title "Scapula of an unknown Reptile."

Mantell's determination of the genuine *Iguanodon* scapula was soon confirmed by Mr. G. B. Holmes's valuable discovery, near Horsham, of an *Iguanodon* scapula in union with its coracoid. These bones were described and figured by Prof. Owen in his monograph on the *Iguanodon* in the 'Memoirs of the Palæont. Soc.,' issued in 1855. In the following year, in a monograph on *Megalosaurus*, in the same Society's Memoirs, Prof. Owen, "with a full sense of the inadequacy of our present evidence for the precise determination of its scapula," assigned to this Dinosaur a more perfect example of Mantell's first scapula, discovered at Stammerham by G. B. Holmes, Esq.

This second specimen is thus described:—"The body of the bone is an oblong flattened plate proportionally broader and stouter than in *Iguanodon*, with the base rounded, not truncate as in *Hylæosaurus*, and with the anterior border at first, as it descends, straight, and then concave, not convex as in *Hylæosaurus*. The body of the scapula decreases in breadth as it approaches the articular end, near which there is continued from the anterior border a long and slender process at least three fourths the length of the entire bone, but the precise proportions of which cannot be determined in this specimen, because the extremity of the process is broken off. Near the base of the process a tuberous projection is developed, which touches the anterior end of the articular end of the scapula, circumscribing an elliptical vacuity, probably for the transmission of vessels. The thickened articular extremity shows indications of a division into two surfaces, one for the coracoid, the other for the humerus."

The figure of this specimen (tab. v. fig. 1) is explained to be one fourth of the natural size. Mr. Holmes writes to me that this is an error; it is accurately drawn from exact measurements.

To me the 'Scapula of an unknown Reptile' was an enigma from the time I first began to study the Dinosauria; for on the supposition that it belonged to *Megalosaurus*, which its place in the National

Collection and in Prof. Owen's monograph on this Saurian scarcely allowed me to doubt, I could not perceive how such a bone could be united to that which Cuvier and Owen had taught me to regard as its coracoid.

The first light reached me from Prof. Huxley's valuable paper on the "Classification of the Dinosauria," read at a Meeting of our Society, 10th Nov., 1869, in which the previously reputed coracoid of *Megalosaurus* was shown to be its ilium, and the forms of the genuine coracoid and scapula were made known (*cf.* Prof. J. Phillips's letter of July 1, 1869, here given). I now knew certainly that the "scapula of an unknown reptile," relegated from *Iguanodon* to *Megalosaurus* did not enter into the shoulder-girdle of the latter. At one time I conjectured it might be an os pubis, in its spatulate form having some resemblance to that of the crocodile; but becoming better acquainted with Dinosaurian ilia I began to suspect that it might be a modified form of ilium, and on comparing it with the ilia of *Iguanodon Mantelli* and of *Hypsilophodon Foxii* I was gratified to find its leading features repeated in these. In my following autumn holiday (1870) I saw in Dr. Wilkins's collection two previously unrecognized bones obviously identical with Mantell's type "scapula of an unknown reptile." Wholly stripped of their matrix, so that they could be viewed from every side, they illustrated some points in their structure better than the only two previously known specimens, and substantiated, I thought, my surmise that the reputed scapula was an ilium. Dr. Wilkins has lately very courteously afforded me an opportunity of studying these bones at my leisure, and he kindly permits me to exhibit them this evening.

The smaller bone (Pl. XXXII. fig. 1) formally repeats Mantell's and Holmes's specimens. Its glenoid (or acetabular) end is in some of its details much more complete than theirs; but a considerable part of the body is missing; it has been broken off at the distance of one inch above the upper root of the long anterior process, which has been likened to a connate clavicle. From the level of this process upwards the front and back margins of the body converge gently, with a corresponding decrease of width of the body, as far as this has been preserved. The anterior border is thin and sharp, the posterior border is thicker. The greatest thickness of the body, where broken across, is ·7 inch. Towards the glenoid (or acetabular) end the body widens out and it thickens. The terminal aspect of this end is chiefly occupied by an arched, hollow, smooth, articular surface (fig. 1, *a*, & fig. 2), the chord of which forms nearly a right angle with the axis of the expanded blade or body of the bone, and in its now mutilated condition measures about 3·5 inches. In the direction of its short diameter, or transversely, this articular surface measures at its anterior extremity 1 inch, which increases to 1·5 inch at its posterior end; and in this direction the surface is slightly concave. The uninterrupted smoothness of this arched surface throughout its whole extent unmistakably indicates that the whole formed one part of a joint in which another bone played freely as a ball in a socket. At each end this arc is terminated by a process, of which the anterior (*p*) is small (in the specimen it is mutilated; but in the larger bone it is a thin compressed lip, which projects strongly downwards and forwards), while the posterior is stout and blunt. This latter process (*i*) forms the posterior inferior angle of the bone, and it is its stoutest part. Its truncated terminal aspect looks downwards and backwards, and has the characteristic rugosity of a synchondrosis.

The long slender upper process (*Spp*) given off from the anterior margin of the body measures along its upper surface 7 inches, and about 1 inch less along its under surface; the free end is missing. From its base to the free end it makes a gentle double curve, its upper outline being first convex, then concave. The cross section of this process is roughly trihedral; its under surface is marked with coarse longitudinal grooves. At 4·3 inches from its free end it bears a small process, now mutilated, separated by a wide subcircular notch from that which limits anteriorly the large articular arc. This little process is clearly the anterior of the two small projections at the under surface of the long slender process which tend to convert the notch between them into a closed ring in Mantell's specimen. The two remaining surfaces of the long slender process (one upper, the other lateral) are smooth. From their union, near the base of the process, a ridge (*r*) passes backwards at the distance of 1 inch above the articular arc, concentrically with it, which, gradually widening and becoming less conspicuous, is lost near the posterior inferior angle of the bone.

Dr. Wilkins's second specimen is from a much larger individual; a much greater portion of the body and smaller piece of the long anterior process are preserved (Pl. XXXII. figs. 3 & 4). The smooth (enarthrodial) arch (*a*) at the lower end of the body is flattened and distorted by pressure; its chord now measures 7·5 inches. In front it ends in a sharp compressed lip, which projects strongly downwards and forwards; and behind it terminates in a low massive hummock, which, unprotected by matrix, is worn smooth. A splintered, mutilated projection, which, as in the smaller specimen, the long slender process detaches, near its base, from its under surface, inclines downwards, and tends to close the notch which separates it from the articular arc, and to convert it into a foramen (*p*).

Of the long slender process (*Spp*) only about 6 inches remain. Its cross esction is an oblong, the long axis of which is nearly vertical to that of the same section of the body of the bone. The upper surface is gently convex transversely, and it is smooth; the under surface is longitudinally grooved and rough. The greater relative breadth of the body near the lower articular end, and the obtuse angle which the long slender process makes with the body, are matters in which this differs conspicuously from the smaller specimen. Perhaps, if both bones were complete, these dissimilarities might appear less.

If now we test these four specimens—Mantell's type in the British Museum, Mr. G. B. Holmes's, figured by Prof. Owen in the Fossil Reptilia of the Wealden Formation, and Dr. Wilkins's two, exhibited this evening—by the scapular hypothesis originally propounded by Dr. Mantell, and adopted by Prof. Owen and the Rev.

W. Fox, the large, smooth articular arc (a) at the lower end of the body must be, in its entirety, the scapular share of the glenoid fossa, because it alone, as Dr. Wilkins's smaller specimen demonstrates, affords evidence of having formed part of a freely movable joint, and it bears no mark of a subdivision into a glenoid and a coracoid portion. The "appearance of a subdivision of the thickened articular end into two surfaces, one for the humerus, the other for the coracoid," which Prof. Owen observed in Mr. Holmes's specimen*, if descriptive of this articular arc, was perhaps due to a post-mortem distortion; but there is the possibility that Prof. Owen considered the whole of this arc as the coracoid division, and the stout buttress which posteriorly limits it, as that against which the humerus rested.

Assuming, then, as proved, that the large, arched articular surface in its entirety represents (on the scapular hypothesis) the scapular part of the glenoid fossa for the humerus, its entirety and diarthrodial nature being placed beyond doubt by Dr. Wilkins's specimens, the coracoid attachment must be sought in front of it. Dr. Mantell (unless I misunderstand him) supposed that one or both of the small projections from the under surface of the long slender process gave attachment to the coracoid bone; but these, even if complemented by the long slender process, appear very inadequate for the firm attachment of a bone which contributes about an equal share with the scapula to the shoulder-joint, and has with it to bear very considerable pressures; besides, in *Iguanodon Mantelli*, *Hypsilophodon Foxii*, *Megalosaurus Bucklandi*, *Hylæosaurus Conybeari*, and *Scelidosaurus Harrisoni* (the only British Dinosaurs of which scapulæ in union with coracoids have, so far as my knowledge reaches, as yet been found) the coracoid border of the scapula is so much longer, relatively to the humeral border, than these two little projections are to the arch behind them, that it is hardly possible to conceive that they can be the functional equivalents of the coracoid border of the scapula as we know it in the Dinosaurs just mentioned. But conceding that they are corresponding parts, what explanation can be given of the stout posterior inferior angle of the body which limits the smooth articular arc behind? Its truncated terminal surface, directed downwards and backwards, bears, in Dr. Wilkins's smaller specimen, the stamp of a firm cartilaginous union with some other bone. But what bone is there united with the scapula behind the glenoid fossa?

There remains only the suggested resemblance of the long, slender, anterior process detached from the anterior margin of the body near its lower end, to certain processes found in *Hylæosaurus*, and in some existing Lacertians, notably in *Scincus*.

The part of the Hylæosaurian scapula to which Prof. Owen compares this long slender process is described by him in these terms:— "On the outer side of the scapula two broad convex ridges descend and converge to form the beginning of a thick and strong spine at fourteen inches distance from the base; this then expands into a

* Brit. Foss. Rept., *Megalosaurus*, p. 14.

thick acromial ridge, which extends transversely, and is continued forwards as a long subprismatic process from the anterior angle of the head of the scapula. This process, which appears likewise to be present in the scapula of *Iguanodon*, perhaps also in *Megalosaurus*, is broken off in the present specimen about four inches from the neck of the scapula, with which it forms a right angle"*.

It is not stated from what specimen this description is taken. Only four are, I believe, yet known; and these are all in the British Museum. Two of them are the immature pair in the Tilgate-Forest slab, which has been so often figured; and in these the crest crossing the outer surface above the humeral and coracoid borders is but slightly developed, and it ends in front very slightly in advance of that part of the coracoid border which is still joined to the coracoid bone. I fail to perceive here any indication of a "long subprismatic process" continued forwards from "the thick (transverse) acromial ridge;" nor do I find any thing answering to this description in the two other scapulæ, which, from their much larger size and massiveness, belonged to a much older and probably mature individual. Of one only the articular end, very mutilated, is preserved; the other (No. 584, Mantellian Catalogue; No. 2584, Brit. Mus. MS. Catal.) is a magnificent specimen, almost complete. It wants only the anterior inferior angle, formed by the junction of the anterior and the lower or coracoid border. The fracture which has severed this missing piece passes vertically, in the same plane, through the coracoid border and the anterior termination of the transverse crest, where it merges into this just in front of the wide, and here shallow, groove which separates the crest and this articular border. This scapula also yields no evidence that its crest was produced forwards in the shape of a slender process beyond the coracoid border. In the absence of any evidence of the existence of a long slender anteriorly projecting process, the resemblance of the "*scapula of an unknown reptile*" to that of *Hylæosaurus* in respect of such a process seems to me to be wanting in proof, and untenable.

Upon a close comparison of the long slender process with the processes detached from the anterior border of the scapula in certain extant lizards, such differences discover themselves as seem to me to disprove their identity. There is no skeleton of *Scincus* in the British Museum, or in that of the Royal College of Surgeons; and my knowledge of its scapula is derived from the figure in Cuvier's 'Ossemens Fossiles.' In this figure the process, passing off from the anterior border of the neck of the scapula, is represented as bending upwards and forwards nearly parallel with this border, a direction quite different from that of the process in any of the specimens of the unknown reptile's scapula, and one which has an obvious relation to the process detached from the front of the coracoid bone, to the end of which it is linked by a cartilaginous loop. The shape of the scapular process in *Scincus* is, I believe, also dif-

* Report on British Fossil Reptiles in Brit. Assoc. Report, 1841, p. 117; and Brit. Foss. Rept. of the Wealden Formations—Monograph *Hylæosaurus*, where this extract is reproduced.

ferent. As in other lizards, it and the coracoid processes are compressed flat blades, the thin edges of which are adapted to the attachment of the membrane which fills the unossified spaces between them; whereas the long, slender anterior process of the unknown reptile's scapula is subcylindrical, and, where compressed, this is in the opposite direction to that of the scapular processes of living lizards. Here, too, I suggest, the comparison fails.

The difficulties of the scapular hypothesis appear to me insurmountable. On the other hand, upon a comparison of these reputed scapulæ with a typical Dinosaurian ilium, *e. g.* of *Iguanodon Mantelli*, the essential correspondence of all their several parts is so evident as to render irresistible the conviction that they are identical members of the skeleton: *a* is the acetabulum, *p* its pubic process, *i* its ischial process; *Sp* the long, upper, anterior, slender process, is the suprapubic process so largely developed in *Iguanodon Mantelli*; and *b* is the expanded part or body of the ilium; the notch (*n*) corresponds to that beneath the small anterior process in existing lizards, beneath which the nerves and vessels wind which are destined for the front and upper surfaces of the hip-joint and thigh. The most obvious differences of these ilia from that of *Iguanodon* are the angle which the axis of their body makes with that of the long, slender process, and the absence of any distinct stamp of a sacral attachment.

In the three smaller ilia which have been mentioned in this note, viz. Dr. Mantell's, Mr. G. B. Holmes's, and Dr. Wilkins's smaller specimen, the long, slender process makes nearly a right angle with the axis of the body; in Dr. Wilkins's larger specimen this angle is more obtuse, whereas in *Iguanodon* the body and the long, slender suprapubic process are most extended in nearly the same line. As the ilium forms the upper part of the acetabulum, the axis of its body, which is nearly vertical to the chord of the acetabular arc, is highly inclined or nearly vertical to the vertebral column, and the ilium would therefore necessarily be connected with fewer sacral vertebræ than in typical Dinosaurs—dispositions resembling those which obtain in existing lizards, where, as is well known, the number of sacral vertebræ is two, and the slant of the ilium is considerable, notably in *Hatteria*, in which it includes, with the vertebral column, an angle of about 80° (Dr. Günther), and in *Chamæleon*, in which the ilium depends nearly vertically from the sacrum. These, it is worth notice, exhibit some closer skeletal resemblances to Dinosauria than do other existing lizards.

As regards the absence of distinct marks of attachment to the sacrum from both the lateral surfaces of the body, I would speak cautiously. Only one surface of Dr. Mantell's and Mr. Holmes's specimens is exposed; and Mr. Beccles writes me that one surface of his specimen of this bone is backed with plaster of Paris. In neither of Dr. Wilkins's bones do I find these marks; but in each the upper end of the body is missing, and they may have been present here, where we find them in existing lizards.

The Rev. W. Fox, to whom I turned for some information on this point, (singularly enough, on the day my letter reached him) found a very perfect example of the bone; and he most obligingly carefully removed the matrix from both surfaces to look for a sacral impression, but did not find any. Its absence is, I think, his chief reason for regarding the bone as a scapula. Should the absence of any indication of a firm cartilaginous union with the coalesced sacral transverse processes be confirmed, the absence will not disprove the iliac nature of the bone; for the ilium may have been simply attached by strong fibrous bands passing ligamentously between it and the vertebral column, as in the Enaliosauria. Whichever mode of attachment obtained, its extent was manifestly much less than in typical Dinosaurians; and this is a modification of sufficient importance to place the possessors of such ilia outside all the known genera of Dinosauria, and, perhaps, outside this order.

In conclusion I would tender my warm thanks to Mr. G. B. Holmes, the Rev. W. Fox, and Mr. Beccles for kindly affording me information respecting the specimens of this bone in their collections, and to Dr. Wilkins especially, for the interest he has shown and the aid he has afforded me in this inquiry. I feel, also, that an apology is due to the Society for trespassing upon its time whilst some difficulties to the acceptance of the interpretation I offer remain unsolved; my excuse is my hope that some of our Fellows may, during the recess, recognize specimens of these ilia which may be lying unknown in private collections, and seize the opportunity to confirm or modify my conclusions.

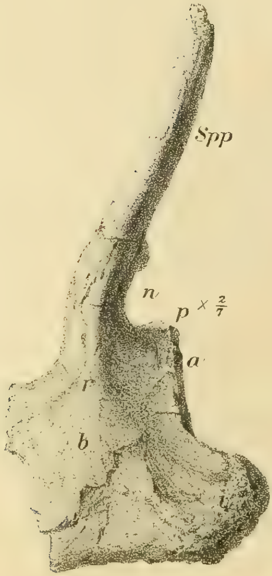
EXPLANATION OF PLATE XXXII.

Modified Dinosaurian Ilia in the Collection of Dr. Wilkins, Newport.

Figs. 1 & 2. Smaller specimen. 1. Outer surface, $\frac{2}{3}$ nat. size: *a.* articular arc; *p.* pubic process; *i.* ischial process; *Spp.* suprapræpubic process; *r.* ridge directed backwards from *Spp*, concentric with *a*; *b.* body; *n.* notch. 2. Direct view of articular arc, $\frac{1}{2}$ nat. size (fig. 1, *a*).

3 & 4. Larger specimen, $\frac{2}{3}$ nat. size. 3. The outer surface. 4. The inner surface. Letters *a, p, i, Spp, b, n,* represent the same parts as in figs. 1 & 2.

Fig. 1.



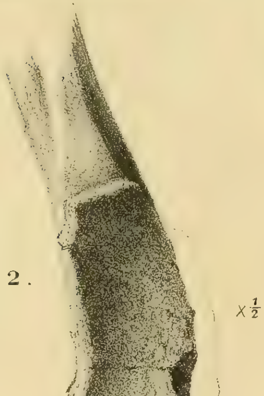


Fig. 2.

Fig. 3.

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DINOS

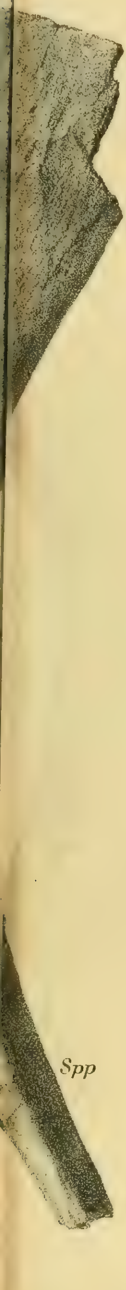
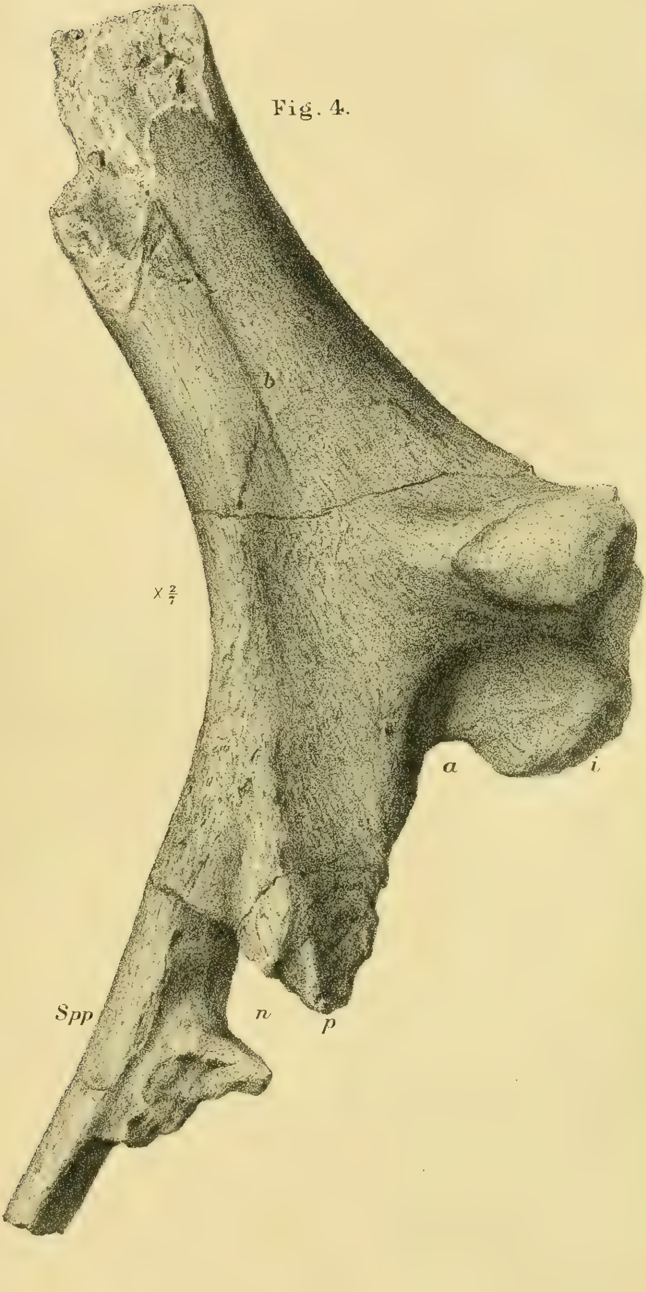


Fig. 4.



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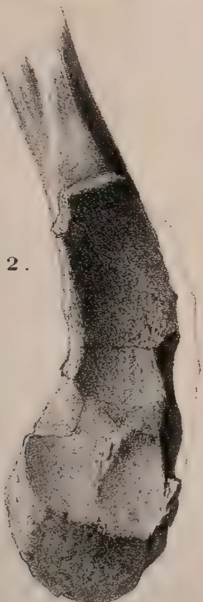
RIAN ILIUM.

Fig. 1.

Fig. 3.

Fig. 4.

Fig. 2.



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DINOSAURIAN ILIUM.

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