XXVIII.—*On the Geology of the South-east of Devonshire.*

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[Read 1834, 1836, 1837, 1839, 1840*.]

Plates XLI., XLII.

CONTENTS.

Introduction.

THE range of Dartmoor, independent of geological considerations, forms the most natural division of the county of Devon ; and the following pages relate only to the

* In this memoir are given in a condensed form the substance of the following papers :—1. An Account of the raised Beach at Hope's Nose, read Nov. 19th, 1834. See Proceedings, vol. ii. p. 102. 2. On the part of Devonshire between the Exe and Berry Head and the coast and Dartmoor; read May 25, 1836. Proceedings, vol. ii. p. 414. 3. On the Geology of the South-east of Devonshire; read Dec. 13, 1837. Proceedings, vol. ii. p. 584. 4. On the Structure of South Devon; read April 24, 1839. Proceedings, vol. iii. p. 123. 5. On the Bone Caves of Devonshire; read March 25, 1840. Proceedings, vol. iii. p. 286.

southern portion, but which includes perhaps a greater number of distinct formations; presents them under circumstances more favourable for their study; and illustrates more points of geological interest than any other tract of equal extent in England. The object of the memoir is to describe, 1st, The several sedimentary formations; their mutual relations, and organic remains. 2nd, The igneous rocks. 3rd, General conditions; the amount of successive change and local disturbance.

General View of the Deposits of South Devon.

1. *Actual Period.* (Map, Pl. XLI.)

§ 1. *Estuary deposits.*—Along the south coast of England, from the district where the older rocks first show themselves, all the rivers pour their waters into salt or brackish tidal estuaries, some of which are of considerable size; and it is necessary to notice them and certain points connected with such bodies of water, to enable the reader to appreciate the evidence from which we infer that the estuaries were at a former period more considerable, and that other valleys were once estuaries which have now ceased to be so. The rocks which bound the terminal valley of the Teign are, in the lower part, sandstones and conglomerates of the new red series; and, in the upper, inferior rocks; the length of the estuary being about five miles, but its breadth when full is less than one. At low-water this space presents long banks of sand and of mud, black and fetid, from the abundance of decomposing vegetable matter, but between the banks a few streams of fresh water find their way: at high tide the whole area is submerged, and the water reaches the base of a line of low cliffs on each side. Such also are the features of the estuary of the Exe and of others to the westward.

The species of mollusca living in these estuaries are few. The common Mytilus occurs only near the openings with the sea. *Cardium edule*, *Mactra compressa*, *Venus verrucosa* and *V. reflexa*, ascend much higher, and are very numerous; and many curious instances may be observed of the power which some marine animals acquire of adapting themselves to alternate change. When tides are low, and the volume of the Teign considerable, the banks in which these mollusks live are covered by fresh water; yet the animals do not perish. A short distance above West Teignmouth are some sandstone beds, which are tenanted by a colony of the *Pholas dactylus*, and from which remarkably fine specimens may be procured; yet at low-tide the beds are covered by a stream of fresh water, which flows over them from the land. In like manner, the Teredines, which entirely destroyed the piles of Teignmouth Bridge, were constantly exposed to fresh water for several hours. But though the marine conchifera can thus accommodate themselves to change, the Uniones and other fluviatile shells never, that I am aware, descend into the estuary; so that there is always a considerable area which affords no testacea, a circumstance which may account for the paucity of such remains in valleys now abandoned by the sea.

§ 2. *River sand and gravel.*—The production of river sand and gravel, and the forms of fluviatile pebbles as distinguishable from marine shingle, are facts familiar to most observers. It is likewise well known that all streams which take their rise in upland regions have their channels strewed with blocks; yet the power of transport which the rivers of South Devon occasionally exert will probably appear incredible to the casual visitor ; but whoever is interested in such inquiries will be able to collect much information in the upper parts of the courses of the Erme, the Dart, and the Teign.

§ 3. *Marine beds.*—The accumulations in progress over the bed of the sea vary in character with the depth of the water ; coarse materials being seldom found beyond the ten-fathom line ; from that to forty, the sands decrease in coarseness, and deeper still is only mud or ooze. We know from soundings that in some places the teeth of certain fishes, and that in others certain shells, are peculiar to particular banks,—a grouping of individuals of the same species, of which we find such frequent instances in regular deposits, particularly in the crag. If therefore at the present time very different suites of organic remains are being buried in the contemporaneous accumulations of even inconsiderable areas, we seem hardly warranted in making the use we now do of the fossil forms of the older formations. If also we confine our observations to the natural productions of that small portion of the coast of the south-west of England which belongs to the district here described, it will be found to present peculiarities which must of necessity be perpetuated.

In the south-western parts of England the fern tribe bears a larger proportion to the rest of the vegetation than elsewhere ; thus in the valley of the Dart, above Ashburton, the *Osmunda regalis* occurs in greater abundance than in the whole of the rest of England. It is equally common in certain valleys of the south and west of Ireland. This remarkable fern could not be carried down into the present sea by any streams east of the Teign.

The teeth of the hake occur in great numbers on certain banks at the opening of the Channel, but from the known range of this Mediterranean fish, its remains will be limited to our south-west shores : in the same manner, about twenty-five other species common in the Mediterranean seldom range further east than the waters of West Bay. So also the testacea which will in future ages characterize these same deposits will contain as many as seventy species common in the Mediterranean ; or in the same manner as the faluns of Touraine differ from the contemporaneous crag of England in the more southern character of its shells, so will the actual deposits off the coasts of Devon and Cornwall differ from those of the Northern and German seas*.

The following list contains such living shells as are peculiar to the coasts of South Devon and Cornwall, together with such as are common there, but comparatively rare on the eastern and northern coasts ; the numerical proportion of certain species being, I conceive, in comparisons of this sort, of greater value than the rare occurrence of any particular shell.

The letters M. P. T. B. mark that the species occurs in the Mediterranean, or fossil in the pliocene deposits of Italy or Sicily, in the faluns of Touraine, or near Bordeaux.

Spirula australis, *Lamk. Anim. sans Vert.*
Bulla aperta, *Linn. Syst. Nat.* M.
—— cylindracea, *Pennant, Brit. Zool.* M., B.
Bulla hydatis, *Linn.* M.
—— lignaria, *Linn.* M., T., B.
Ianthina fragilis, *Lamk.*

* See the notice of Mr. Lyell's paper on the Faluns of Touraine, Proceedings Geol. Soc., vol. iii. p. 437.

Turritella exoleta, *Lamk.*
——— truncata, *Linn.*
Natica glaucina, *Lamk.* T., B., It., Sic.
——— nitida, *Fleming.*
Phasianella pallida, *Flem.* (Turbo, *Mont.*)
Turbo albus, *Penn.*
——— cimex, *Linn.* M.
——— costatus, *Turton.* M., It., Sic.
——— lacteus, *Linn.* M.
——— pullus, *Linn.* M.
——— reticulatus, *Montagu.*
——— striatulus, *Linn.* M.
Trochus cinereus, *Da Costa.* M.
——— erythroleucos, *Turton.* M., T., It., Sic.
——— magus, *Linn.* M.
——— papillosus, *Da C.*
Scalaria communis, *Lamk.* M., It., Sic.
——— Turtoni, *Turton.*
Cerithium costatum, *Flem.*
——— reticulatum, *Mont.* (C. lima.) M.
Buccinum lineatum, *Da C.*
——— macula, *Mont.* Med., T., It.
Murex erinaceus, *Linn.* M., T., It., Sic.
——— purpureus, *Mont.* Med., T., B., It.
——— trunculus, *Linn.* M., T., Sic.
——— septangularis, *Mont.*, *F. Duj.* T.
——— turricula, *Mont.*, *F. Duj.* T.
Fusus costatus, *Flem.*
Sigaretus haliotoideus, *Lamk.* B., It., Sic.
——— tentaculatus, *Mont.*
Marginella alba, *Lamk.*
Tornatella tornatilis. (T. fasciata, *Lamk.*)
Velutina otis, *Leach.* M.
——— stylifera, *Turt.*
Haliotis tuberculata, *Linn.*
Calyptræa sinensis, *Lamk.* M., T., B. (C. muricata, *Bast.*)
Pileopsis ungarica, *Lamk.* M., T., B.
Emarginula fissura, *Lamk.* M., T.
Fissurella græca, *Lamk.* M., T. (neglecta.)
Dentalium dentalis, *Linn.* M., It., Sic.
——— entalis, *Linn.* M., T., B., It., Sic.
——— several other species.
Anomia cepa, *Linn.*
——— electrica, *Linn.*
——— fornicata, *Lamk.*
Pecten Jacobæus, *Penn.* M., P.
Pecten lineatus, *Da C.*
——— maximus, *Penn.*
——— obsoletus, *Penn.*
——— tumidus, *Turt. Conchol. Dict.*
Arca barbata, *Linn.* M., T., B., It., Sic.
——— lactea, *Linn.*
——— Noæ, *Linn.* M., T. (biangula, *Bast.*)
Pectunculus glycimeris, *Lamk.* M., T., B. (P. pulvinatus, *Bast.*)
——— pilosus, *Lamk.* M., T.
Modiola barbata, *Lamk.*
——— discrepans, *Lamk.* B.
Lithodomus lithophagus. *Cuv.*
Pinna ingens, *Penn.* M.
——— fragilis, *Penn.* (P. pectinata, *Linn.*)
——— papyracea, *Turt.*
Isocardia cor, *Lamk.* B.
Donax complanata, *Mont.*
——— denticulata, *Linn.*
Tellina crassa, *Penn.* T.
——— donacina, *Linn.* M., T., Sic.
——— fragilis, *Linn.* M., T., It., Sic.
——— lineata, *Turt.*
——— rubra, *Da C.*
——— tenuis, *Da C.* B.
Lucina arcuata, *Mont.*
——— divaricata, *Lamk.* Eo., Mio., & Plio.
——— lactea, *Lamk.* M., T., B., Sic.
——— pisiformis, *Flem.*
——— radula, *Lamk.*
Amphidesma truncatum. (Mactra truncatum, *Turt.* Mactra, *Mont.*)
——— convexum, *Turt.*
——— declive, *Turt.* (Anatina declivis.)
Mactra Binghami, *Turt.*
——— glauca, *Born.*
——— triangula, *Brocchi.* (M. solida, *var.*) M., T., It., Sic.
Astarte Damnoniensis, *Sow.*
Venus cassina, *Linn.* B., T.
——— decussata, *Linn.*
——— dysera, *Linn.* Med., T., B., It., Sic.
——— fasciata, *Donovan*, V. paphia, *Linn.* M.
——— gallina, *Linn.* M., T. (V. cothurnix, *Duj.*)
——— pallida?
Cytherea chione, *Lamk.* M., T.
——— exoleta, *Lamk.* M., B.

Venerupis Irus, *Lamk.*
Corbula nucleus, *Lamk.* (*Syn.* C. rugosa, *Bast.*) according to Lamk. M.
——— striata, *Lamk.* B.
Pandora rostrata, *Lamk.* M., It.
Thracia pubescens, *Leach.* M., Sic.
Mya arenaria, *Linn.*
Lutraria rugosa, *Lamk.*
Psammobia vespertina, *Lamk.* M.
Solecurtus, *De Blain.* { Solen antiquatus, *Linn.* B. / —— coarctatus. Med.
Solecurtus strigilatus, *Linn.* M., B., T., Sic.
Solen ensis, *Linn.*, *Penn.* Sic.
—— legumen, *Linn.*, *Penn.* Med., B., T.
—— purpureus, *Turton.*
—— siliqua, *Linn.*, *Penn.*
Panopæa Aldrovandi (Mya glycimeris), *Mén. de la Gr.* M.
Gastrochæna hians, *Brocchi.* (Mya dubia, *Penn.*) M., B., It.
———— modiolina, *Lam.* It., Sic.

2. *Period prior to the most recent changes of relative level of land and water, and of climate.*

§ 1. *Surface-soil.*—Throughout South Devon the surface-mould partakes of the nature of the subjacent rock. The map (Pl. XLI.) illustrating this memoir will sufficiently show how many formations, composed of very different constituents, are closely associated within its limited area, so that perhaps no other district affords better opportunities for observing the influence of soil on natural vegetation, or indicates more clearly the requirements of particular plants. Geology in its application suggests various considerations, which the labourer in the pure science has too much neglected; and very many more consequences flow from the original arrangement of the mineral masses of a district than at first appear.

On the slopes of the hills of the slate district of South Devon, and immediately beneath the superficial soil, the edges of the laminæ of the slate are disturbed in a very remarkable manner, and frequently to the depth of several feet. In general, they present a simple curve, but occasionally they are most curiously contorted as in fig. 1, which represents a portion of a section at Goodrington, near Ashburton. In every case the curve is directed outwards. By the action of frost on the exposed edges of inclined slate rocks the laminæ separate, earthy matter is carried in between them, and thus the space they required is gradually increased. I have no doubt that in a similar process we have the true explanation of the appearance above described; and though it would be hazardous to say that it may not have resulted from long-continued action of the actual frosts, yet when we consider the great extent to which this separation of the leaves of the slate has been carried, and the very inconsiderable depth to which frost at present penetrates in this part of England, we seem to require a period with a lower temperature and the action of deeper searching cold.

Fig. 1.

In some places, as in most valley sections, and above the raised marine beds of the modern period, are thick accumulations of angular fragments, brought down from the high grounds immediately above. These beds are not similar to those which in rocky districts occur at the base of cliffs and precipitous slopes; and the shape of the fragments (usually composed of flat shaly limestone as at Hope), as well as the angles presented by the surface of the accumulations, which are too small to favour the descent of fragments of even much rounder forms, oppose such an origin. The transferring of earthy matter from the sides of hills into their valleys is continually going on, and to an extent much greater than is usually supposed, but the accumulations which result from this process consist only of minutely subdivided materials; whilst those of the fragmentary beds, above noticed, seem to have required for their conveyance some agent of greater power than any at present in operation. The condition of the materials and their strictly local character sufficiently evince, that no denuding forces can have acted here; yet these accumulations rest on bare surfaces without the intervention of any mould, nor is there any mould or earthy matter mixed up with them; and it is only since they were collected, that we find proofs of disintegration by the action of meteoric agents, and traces of animal and vegetable life, of which the superficial mould is the mixed product.

Changes of Elevation and Depression.

§ 2. *Submerged forest-ground.*—Beneath the waters of a considerable portion of Tor Bay is a tract in portions of which, exposed at neap-tides, stumps of trees of large growth project above the surface, and after gales of wind have removed the sand, they are found to be firmly fixed by their roots in the soil below. This fact has been often mentioned. Leland in his Itinerary says, "Fisschar men hath divers times taken up with ther nettes in Torre Bay musens of hartes, wherby men judge that yn tymes paste it hath been forest ground," and it is also noticed by De Luc*. At Broad Sands in the same bay, a similar deposit is well exhibited between high and low water marks, passing on one side beneath the shingle of the beach, and on the other beneath the sands of the bay; and certain black beds, but for the occurrence of freshwater shells (*Cyclades*, *Paludinæ*), might easily be mistaken for an accumulation of sea-weed; the bones of deer and oxen are also readily found. These beds exactly resemble those peaty and decayed vegetable accumulations formed everywhere in low situations. Both at the Tor Abbey and Broad Sands they rest on lacustrine mud, which at the latter place contains the shells of the *Paludina impura* in great abundance; at Goodrington are likewise traces of lacustrine marl.

§ 3. *Ancient alluvia.*—An ancient forestial condition, such as even history informs us all this country presented, would necessarily occasion a greater condensation of aqueous vapour and more copious streams than now flow through this part of the county; but there are phænomena in South Devon on much too exten-

* Geol. Travels, English Trans., vol. ii. p. 303, 1811.

sive a scale to be thus accounted for. There is not perhaps a single valley through which a river, or even a brook, at present takes its course, along which alluvia are not found at elevations such as the existing streams in their most swollen states never have attained. The valleys of the Dart and the Teign afford frequent instances.

Since 1834, when I gave an account of some of the recent changes to be observed in South Devon*, facts of this kind have accumulated so rapidly, and are so generally admitted, that at present it seems necessary to give only a general indication of the nature of the evidence and of some of the localities where such phænomena may be conveniently observed.

In the valley near Chagford, and beneath the cultivated fields on each side of the stream, are thick accumulations of granitic sand and pebbles, and from their elevation and extent they prove the action of a river far more considerable than the present one. If we take the course of the Teign downwards, and attend to the sections which its banks afford, we see similar deposits of great thickness presenting that peculiar arrangement so characteristic of fluviatile action, and rising high above the reach of present floods. These deposits can be traced spreading out at the junctions of the valleys which open into that of the Teign. Another instance of the total inadequacy of the power of the present stream to produce the phænomena to be observed in its vicinity, occurs in the valley of the Lemon (a small tributary to the Teign), and particularly in that portion of it from Bickington to Holbeam Mill. The steep banks of the stream, and several good sections exposed in artificial openings in the fields show, that accumulations of the same character as those above described, occupy the whole broad expanse of level ground, and indicate the former existence of a river of corresponding width. Above Holne Bridge, north-west of Ashburton, the valley of the Dart presents similar phænomena on a wide scale †; and from this point nearly to Totness there is continuous evidence of a like kind, the neighbourhood of Staverton in particular affording most instructive instances on both sides of the river. The flat meadows about Totness are occasionally covered by the waters of the Dart, but these floods strew no coarse materials over their surface, as the fine silt and sand composing the soil sufficiently prove; so that the thick subjacent accumulation of blocks and gravel must be referred to a former condition of the river.

§ 4. *Ancient lacustrine deposits.*—Though the ancient alluvia of the Dart and Teign show that in several places their waters once spread over considerable areas, yet the only expanse which deserves to be distinguished as an ancient lake is that portion of the valley of the Teign which extends from Bovey to Kingsteignton.

The uppermost part of the series of deposits which occupies this basin, so far as the level and unintersected nature of the district exhibits, is what the clay-diggers call "the head," and it consists in some places of horizontal layers of sand, as in the upper and middle parts of the valley; coarse beds, which are often thirty feet thick, occur chiefly along the N.E. side, and it is from beneath these, that most of the pipe-clay is now raised. Good sections may be seen on each side of the lower road to Chudleigh. (Pl. XLII. fig. 8, B.) The appearances which indicate that this "head" is of fluviatile or lacustrine origin are the sub-

* See Proceedings Geol. Soc., vol. ii. p. 102.

† Mr. De la Beche, in his Report on Devon and Cornwall, gives at p. 411 a section taken at this place.

angular and flattened, rather than rounded, forms of the materials, their arrangement, and those directions of the banks of sand (which is such as may be observed in estuaries), which were caused by the currents produced in the lake by streams discharging at the same points at which they now enter the valley. The estuary of the Teign, but for artificial embankments and a wear, would even at present extend nearly as far as Teign Bridge, for the foundations of the present structure are on a level with the sea at Teignmouth. From Teign Bridge to the upper part of the valley near Bovey, there is a rise of just eighty feet; so that before that elevation took place, of which there are such numerous proofs, the whole of this basin must have been placed beneath the level of the sea.

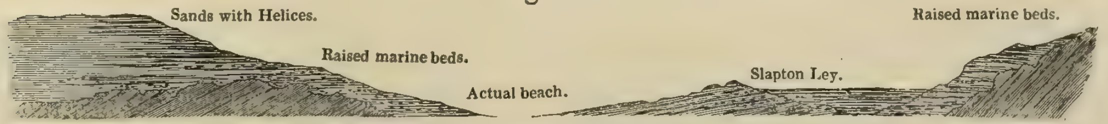
The bones of the wild boar, the ox, and the red deer are found in the superficial sands of the Bovey valley, and beds of peat have often been discovered beneath the "head" in openings made in search for clay-beds. The bones of this lacustrine accumulation are black, with a smooth polished surface, resembling those which are now found in the beds of rivers or ponds, and are very unlike remains from breccias and caves, which are either white or slightly stained with red, and are corroded on the surface, as if they had been long exposed to the atmosphere.

§ 5. *Raised estuaries.*—The general features of some of the valleys as they approach the sea, suggest that they were formerly estuaries, though at present only very inconsiderable streams of water flow through them; thus the broad level deposits of the valley of the Axe could hardly have been accumulated by any shiftings and expansions of the present river. Next to the eastward, the valley of the Otter presents for several miles inland a flat extent of meadow bounded by vertical cliffs (§ 1. p. 434). In some places, as from Datton Mill towards Newton, the stream flows at the base of cliffs consisting of compact beds of new red sandstone; through the greater part of its course, however, it does not approach them, but occupies a deep channel along the central line of the valley; these vertical cliffs therefore cannot possibly have been produced by any causes in present operation, and clearly indicate the extent of the former estuary. On the eastern side of the valley, below Datton Mill, is a remarkably good section, presenting three feet of silt, resting on a considerable thickness of sea-sand, the whole being placed on the coarse gravel of the district.

In the upper part of the estuary of the Exe, from Topsham to Alphington, and particularly along the western side, is a flat expanse of land, high above the present water level, but which must have been accumulated under salt or brackish water; the beds abounding with existing British species of Mactra, Tellina, Cardium, &c. These shells are found in the nursery-grounds of Messrs. Pince, as high up the valley as north of the main road leading from Alphington into Exeter. The great width of the body of water which formerly occupied this valley, is easily observed in still higher parts of its course.

The tract at the mouth of the Exe, known as the Warren, consists, on the sea side, of lines of sand-hills or dunes of some elevation, resting on a broad bank of sand and shingle of purely marine origin. This bank belongs to the time when the valley had a lower level, or was constantly submerged, and when the sea reached the base of the cliffs on the western side of the mouth of the river, and produced the range of cliffs running inland from Warren Point. As at the mouth of the Taw, where we have a like order of things on a rather larger scale, there is no real line of separation between the blown-sands and the subjacent coarse beds, which contain marine shells, so, at the mouth of the Exe, we have a passage upwards from beds purely marine into others of a fluvio-marine character, graduating into such as swarm with the shells of two or three species of Helix. At Slapton Ley, Swanpool, and other places, are also raised marine beds passing into lacustrine ones, full of freshwater shells, which occasionally contain layers of freshwater fishes, the remains of those which from time to time are destroyed by irruptions of the sea, as in 1824 and 1836.

Fig. 2.



Raised Estuary Deposits.

§ 6. *Raised marine beds.*—A raised beech is seen a little on the inside of the point of land known as Hope's Nose, which forms the eastern limit of Tor Bay. From the rocks below, or from the sea, it has the appearance of a series of horizontal and parallel beds; and the view, fig. 3, taken from the east, shows the mass as it rests on the highly inclined edges of the limestone. (See also Pl. XLII. fig. 1.)

Fig. 3.

Raised Beach at Hope's Nose.

The distance between the usual line of high water and the lowest part of this deposit is thirty-one feet; and the thickness of the compact stratified portion is seventeen feet. How far the beach extends upwards and inland, it is difficult to determine, as it is covered by an accumulation of shaly limestone derived from the hill above; but as, at an elevation of about sixty feet, there is a bed of sharp quartzose sea-sand beneath the superficial debris, and as the point of land, previous to its elevation, must have presented a shelving coast, the marine beds would thin off gradually, and the greatest amount of elevation may be taken at about seventy feet.

This deposit is not an uniform mass throughout: in the lowest part it is coarse, and contains blocks of considerable size, and the shells of a large oyster occur in considerable numbers: higher up it becomes an exceedingly hard, fine-grained, and compact sandstone; the shells in this portion are abundant and well preserved, being *Patella vulgata*, *Murex erinaceus*, *Turbo littoreus*, *Turritella terebra* (*Flem.*), *Serpulæ*, *Cardium edule*, *C. tuberculatum*, *Modiola vulgaris*, *Pecten maximus*, *P. varius*, *Cyprina Islandica*, *Venerupis decussata*, and *Ostrea edulis*. The materials of these beds are such as the rocks in the immediate vicinity might supply; but chalk flints also occur, which are not to be found, that I am aware, on any beach within the Bay.

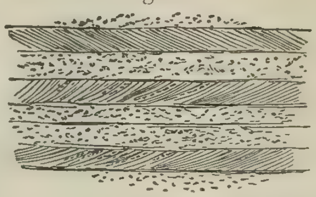
A similar marine deposit occurs on the Thatcher, a small insulated rock situated about a quarter of a mile south-west of Hope's Nose; and it is rich in shells, particularly the *Turritella terebra* (Flem.).

The circumstance to which the preservation of this evidence of so great a change of relative level is owing, is the hard nature of the limestone rock on which the marine beds rest, and with which they are co-extensive. From this, and also the abrupt manner in which they are cut off, these detached beds may be taken as fair illustrations of the amount of elevation, but not of their original horizontal extent.

Near Brixham, both within the Bay and between Berry Head and Sharkham Point, are similar deposits, which contain portions of the iron-lode of that place, rounded into pebbles. At one spot the hæmatite has reunited into a compact mass, and includes occasionally patches of sea-sand and shells.

Similar proofs of recent elevation occur at intervals along the southern coast, wherever the hardness of the rocks has enabled the deposit to resist the washing of the sea; as near the mouth of the Dart, and at Slapton, where it rests on new red sandstone. These beds, like those of Hope's Nose, contain chalk flints, though none are to be found along the present line of beach.

Fig. 4.



Recent marine deposits diagonally laminated.

All the above deposits exhibit instances of that diagonal lamination so common in some of the older arenaceous formations, particularly in the new red sandstone of South Devon (fig. 4.). The beds also are seldom horizontal, except where the surface on which they rest happens to have been so; if otherwise, they partake of the slope, and dip at various angles towards the sea. In one instance, on the north coast of Devon, I observed an inclination of as much as 35°.

To those who are aware how rich the waters of the neighbouring sea, and of Tor Bay in particular, are in testacea, the list above given will appear exceedingly meagre; but in this respect the Devonshire deposits agree with those of the same period in other localities. Not only are all the forms which have been already noticed, and which may be considered as the present characteristics of our south-western coasts, entirely wanting, but we miss all those other shells which any beach, at the present day, would readily supply. This is only negative evidence, but it suggests that the period of these raised deposits may have been one less favourable than the present to the development of marine life,—owing, perhaps, to a lower temperature; such as the broken up or detrital edges of the slate rocks would also indicate.

Tertiary Deposits.

Period marked by Extinct Animal Forms. (Map, Pl. XLI.)

§ 1. *Gravel.*—This term would probably be applied to many accumulations within the district here described, which, though they may have been produced by a similar condition of things, yet belong to very distinct periods; it is used, in the present instance, to designate those deposits which have been found to contain certain mammalian remains.

All the valleys of South Devon, from the Exe eastward as far as Lyme inclusive, have afforded the tusks, bones and teeth of the elephant and rhinoceros. The deposits which contain these remains, though not stratified, have a very distinct horizontal arrangement, consisting of gravel, with irregular layers of sand, and they afford sections similar to those which estuary or fluviatile accumulations usually present. They occur invariably in low situations, proving that, prior to the occupation of the country by the animals in question, the several valleys were as deep as they now are, that the process of excavation had been completed, and that the surface exhibited the same outline as at present.

This period may be contemporaneous with, or immediately subsequent to, that of the occupation of the ossiferous caves; and in the latter case it would be synchronous with that inundation which seems to be requisite to account for all the appearances presented by the ossiferous fissures, and which will be presently mentioned.

Comparing the remains of the large Pachyderms found in caves with those of the gravel beds, the latter appear to have generally belonged to old, full-grown animals, whilst collections from Kent's Cavern show that the animals were mostly young.

Referable also to this period are those accumulations which, at the western base of Haldon, either fill the wide fissures in the lime rocks, or are collected in depressions on their uneven surfaces; the latter containing the remains of all the animals found in the fissures, as may be constantly seen at the great quarry near Chudleigh, whenever the workmen remove the "head" to get at the surface of the limestone*.

§ 2. *Ossiferous caves and fissures.*—The phænomena of ossiferous caves, fissures and breccias have been usually classed together, but they appear to me to be really distinct, both as to time and the circumstances which produced them.

Their natural order appears to be, 1st, the caves which have been inhabited by animals; as Kent's Hole, Anstis, and Yealmpton, described by Col. Mudge†. 2ndly, a complex group, including all those breccias or superficial collections of angular fragments usually found in the neighbourhood of calcareous strata, frequently associated with the bones of animals, and which seem also to have required the aid of moving water to have reached their present positions; and 3rdly, the large fissures in lime-rocks, as those of Chudleigh and Plymouth, now filled to their mouths with ossiferous breccias, but often expanded into chambers containing masses of mud, bones and debris, the forms and positions of the accumulations clearly pointing to the vertical fissure through which they were introduced. Confirmation of this process of filling is afforded by many limestone caverns which have not been found to contain any remains of animals; such caves having the character of fissures, and must not be confounded with the inhabited ones. In filling the fissures the transporting power of currents of water is required, which

* The collection of bones of extinct animals found in a depression in the limestone of the Hoe, and which Dr. Moore brought before the Geological Section of the meeting of the British Association at Plymouth in 1841, were most probably from a similar superficial accumulation.—(*Note,* 1841.)

† Geol. Proceedings, vol. ii. p. 399, 1836.

could move along from exposed surfaces all loose materials, bones, and land-shells, and which would naturally fall into such open chasms. Nor is this action of flowing water a mere assumption; whoever will examine the collection of materials in these great open joints and fractures will be satisfied that they could have been filled only in the manner here suggested; there being in every case an admixture of materials from a distance, and it is a remarkable fact that these have been derived from rocks *in situ*, north of the places in which we find them. Thus the breccias of Chudleigh contain granite and altered rocks from the sides of Dartmoor, and the same phænomenon occurs at Yealmpton and Plymouth.

The first class of caves, such as those near Torquay and others, belong to the time when the country was the actual habitation of certain forms of animals now extinct or foreign; the second class contain the evidences of some subsequent event, which apparently happened at the close of that period.

The well-known Kent's Hole, near Torquay, is a large cavern in a compact limestone, and consists of one large chamber, with several minor ones communicating by narrow passages, all parts being of easy access. A stalagmitic crust, which appears to have covered all the lower part of the cave before it was broken up in the search after remains, is still very thick in some places, and it is a curious fact that the deposition of stalagmite has been subsequent to the introduction of the clay, for I have frequently worked through the entire thickness of the latter and found it resting on the bare limestone. No increase to the stalagmite is now being made. The mass of bones which this cave contained was very great, and must have required a considerable lapse of time for its collection; there are appearances also about many of these remains which seem to indicate that they had been long exposed to the air before they were included in the clay. Nearly all the specimens I possess from this cave bear the marks of teeth, and mixed with them are quantities of the fæces of animals which must have fed largely on bone. Human remains and works of art, such as arrow-heads and knives of flint, occur in all parts of the cave and throughout the entire thickness of the clay: and no distinction founded on condition, distribution, or relative position can be observed, whereby the human can be separated from the other reliquiæ.

The obvious inference from this fact is at variance with the opinions generally received, and the circumstance of the Paviland Cave will doubtless be adduced as a solution of the difficulty. The two cases have nevertheless nothing in common. In the Paviland Cave the bones of the skeleton were together, in their mutual relations, and the several implements in close juxta-position; in the other they are as above described, and there is not a single appearance which can suggest that the cave has been used as a place of sepulture.

The bones of the cave must have been gradually collected; the clay may either have been carried in at some given period, or else have been added from time to time by floods; in the latter case there would be an alternation of layers of bones with seams of clay, but we find no arrangement of the kind, and I think it more probable that their confused mixture has resulted from some one event.

The osseous remains found in Kent's Cave belong principally to the elephant, rhinoceros, ox, deer, horse, bear, hyæna, and a feline animal of large size*.

This and other similar caves, both in England and on the continent of Europe, as the celebrated Kirkdale

* The following observations respecting the animals which occupied osseous caves were read March 25, 1840.

Cave, described by Dr. Buckland, are supposed to have been the dens of hyænas. There can be little doubt that the bones found in these caves have been collected by animals of prey, and as all the forms we find in them are such as we are acquainted with at the present day, the argument from analogy is the most obvious. If we take as our guide the habits of existing species of hyænas, we find little or nothing to warrant the conclusion that they have been the active agents in conveying the cave-bones into the places where we at present find them. These animals, now much better known than formerly, neither hunt after living prey nor live together in packs, still less in caves*; nor have they courage to attack any formidable animal; on the contrary, such is not the position of the genus in the natural order to which it belongs; they prefer the putrid flesh and bones of such animals as they find in their nightly prowlings. The instance quoted by Dr. Buckland, on the authority of Burchell, in support of the supposition that these ancient hyænas were hunting animals, is now well known to have rested on the false classification of the *Hyæna venatica* of Burchell† with the true hyænas, an animal in important parts of its structure related to the genus *Canis*, and with which it has many similar habits; but even granting that these ancient hyænas might have acted in concert, and thus attacked such large animals as the elephant and rhinoceros and subdued them, they could never have conveyed their bodies over the surface of a rocky limestone district; and on the authority of Knox we may assert, that they never attempt to do so—whatever an hyæna meets with he devours greedily on the spot.

Lions and panthers, on the other hand, pursue only living prey, which at one spring they lay prostrate beneath them, and securing it in their jaws, and bearing its weight on their powerful shoulders, they retreat with it to their caves. Cuvier notices the extraordinary strength and rapidity of the movements of the larger Felidæ. In Asia there is no animal which they are afraid to attack; the African lions constantly carry away oxen and animals of great bulk. With respect to their usual abodes, we have the authority of all African travellers and hunters, that chasms, caves, overhanging ledges of rocks, and similarly protected places are their haunts, and the spots to which they carry their prey.

Large Felidæ existed in South Devon, in other parts of England, and Northern Europe during the geological period we are now considering; their remains occur in the Oreston breccia and in Kent's Cave. Dr. Buckland has figured both a canine and a molar tooth from Kirkdale. " Ces dents," says Cuvier, " n'ont rien de différent de celles d'un lion, même pour la grandeur." (Oss. Foss., 3rd edit. t. iv. p. 455.)

I conclude, from the known habits and powers of the only ten genera we have to consider, that the various animals were dragged into the caverns by powerful Felinæ, who used these places as dens during a long period of time; that when the larger Carnivora had satiated their hunger or were absent, the caves were visited by hyænas (who lived then as now on the abandoned prey of others), by whom the bones were picked, gnawed, splintered, and scattered. The hyænas who frequented the caves would in this manner be exposed, even more frequently than any other animals, to fall a prey, and accordingly their skulls are found pierced by the canine tooth of a large animal; and in these instances their remains would be devoured by their own species: that such was the case, the bones of the hyænas sufficiently show.

The occurrence of human remains and works of art in Kent's Cave deserves some further notice, such a statement being very liable either to be questioned, as at variance with a favourite theory, or to be so accounted for as to present no difficulty in the way of the theory. There is no *à priori* reason why man and the several animals whose remains occur in caves and in gravel should not have lived here at

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* " Les hyènes se tiennent solitaires dans les parties montagneuses."—Cuv. Oss. Foss., 3rd edit. t. iv. p. 387.

† " Il est évident que cette hyène [*H. venatica*] doit former un sous-genre dans le genre des chiens, qu'il liera plus intimement à celui des hyènes."—Cuv. Oss. Foss., edit. 1825, t. iv. p. 387; Règne Animal, vol. i.; Swainson, Class. of Quadrupeds, p. 131.

some remote time, just as closely allied species now do in other regions: that some of the fossil species may differ slightly from existing ones does not affect the question, as the man of that period may have differed as much, or belonged to a more southern type. Few, I imagine, who are acquainted with the facts which the labours of MM. Schmerling, Marcel de Serres, and others have established, entertain any doubts as to the fact that the bones of man have been found in caves; what I wish to state distinctly is, that they occur in Kent's Cave under precisely the same conditions as the bones of all the other animals. The value of such a statement must rest on the care with which a collector may have explored; I must therefore state that my own researches were constantly conducted in parts of the cave which had never been disturbed, and in every instance the bones were procured from beneath a thick covering of stalagmite; so far then, the bones and works of man must have been introduced into the cave before the flooring of stalagmite had been formed. It may be suggested, that this cave was used as a place of sepulture by some early inhabitants of this country, and that bones of the other animals occupied the lower parts of the cave when such sepulture took place.

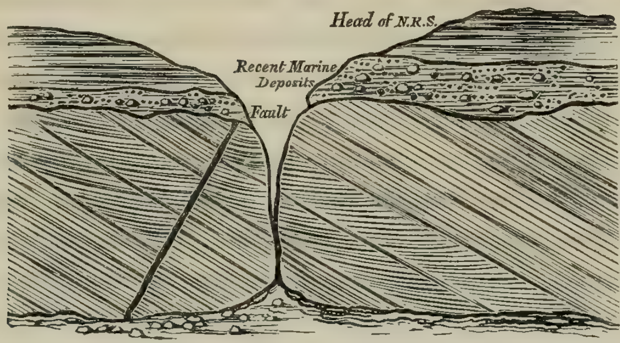
In this case our researches should expose the human skeletons entire, as in the Paviland Cave; or at least the bones should occur in some sort of mutual relation to each other, but no such thing has ever been observed by any explorer in Kent's Hole; so that as far as the evidence from this cave is to be our guide (and which is all that we should look to), there is no ground why we should separate man from that period, and those accidents, when and by which the cave was filled.

The favourite habitats of beasts of prey, in a wild state, are warm and dry situations; and at the time when, as we may fairly assume, the country was thickly covered with forests and swamps—the range of the horse, the ox, and the large Pachyderms,—we cannot well imagine spots better suited to Carnivora than the great tabular masses of limestone, with their caves and crevices, which the surface of South Devon presented. It would be to such spots that they would retreat with their prey. So that in the lapse of time the surfaces would be strewed with the teeth and harder portions of every animal of the country and period; just as, according to all accounts, the vicinity of the haunts of the large Carnivora is at the present day. Any subsequent inundation, such as that which other considerations have established, would carry forward with it all the animal remains, and leave them, together with detached blocks of limestone, mud, sand, and foreign rocks, in every open chasm and depression.

In support of this there are evident marks about most of the bones from the osseous breccias, that they had long been exposed to the air before they were buried in the clay. Had all the various animals whose bones have been collected, fallen into these chasms, portions of each animal should occur, and in nearly their proper relations; but there has never been observed the slightest tendency to such a condition. Very little personal search among these masses of breccia will be sufficient to convince any observer, that casualties of this sort cannot account for the scattered fragments of bone he may discover in them. Animals may have so perished; but such cases must be considered exceptions to the process by which the fissures were filled.

§ 3. *Surface-accumulations at higher levels.*—Over most parts of the district here described, particularly within the combes of the new red sandstone series, are thick accumulations of local debris, as if during the formation of the valleys the finer particles had been removed and the coarser alone left. In the Dawlish valley, associated with materials from the new red conglomerate strata, are others derived from the cretaceous series, the whole mass being upwards of forty feet thick (Pl. XLII. fig. 5.). Similar accumulations are scattered over the whole of that part of Devon which intervenes between the Haldons and Blackdowns; and those in the valley of the Otter present as great an admixture as the deposits of Dawlish; but proceeding eastward, as in the valley of the Sid, Salcombe, Weston, and Branscombe, the collection consists of chalk-flints, flint-breccia and sandstone, and materials from the harder beds of the greensand. These accumulations are not confined to valleys, but invest the slopes and crown the summits of many minor ridges, as those which lead up to the Haldons. In thus classing together the accumulations on the high grounds with those in the bottoms of valleys, it is not implied that they are exactly of the same geological age, or referable to some particular period of dispersion, but that they are the results of those agents, which, for a long period, must have been in operation over this district, and produced the actual configuration of surface.

Fig. 5.



New Red Sandstone.

Section near Dawlish of regenerated new red sand resting on a recent marine deposit.

The above cut represents a road-section near the summit of the hill west of Dawlish. A bed of marine debris rests on the uneven surface of the new red sandstone, and above it, is a thick mass of regenerated new red sand, in regular layers, but without a single pebble of chert or flint, and the uppermost mass is another thick bed of debris.

In the cliffs east of Dawlish is a similar thick deposit of pure, regenerated new red sand, resting on a bed of materials from the chalk and greensand series.

§ 4. *Uppermost beds of Haldon.*—The outline of the Haldon and Blackdown hills, viewed from any point which commands their range, is strikingly horizontal, and their upper surfaces present table-lands, from which deep combes and valleys, descending to the level of the sea, have been excavated through various formations. The uppermost deposits, of inconsiderable thickness in both ranges, correspond; but in the nature and condition of their materials they are very distinct from what occurs immediately beneath them. The line of contact presents an irregular surface, similar to that exhibited where the subjacent beds rest on chalk or greensand.

This superficial accumulation consists principally of flints, but it contains in places, and rather plentifully, fragments of red porphyry, altered slates, black schorly granite and quartz, from Dartmoor; all the latter being rounded, like marine shingle, and the whole mass having an exceedingly water-worn character. (Pl. XLII.

fig. 8 A.) The proportion which the crystalline rocks of the upper Blackdown beds bear to the rest, is less than in the equivalent ones of Haldon, but the pebbles are mineralogically identical, and undoubtedly have been derived from the same quarter.

In these beds we seem to have the last operation in the order of events, before the excavation of the deep valleys of the district commenced.

A bed of considerable thickness, composed chiefly of angular chalk flints, but containing in its lower portions large tabular and angular blocks of chert and sandstone, mixed with sand, is found on Blackdown and its ramifications, resting occasionally on chalk, but more generally, as on Haldon and Milber Down (Pl. XLI.), on greensand. This accumulation lies on a very uneven surface, as is well exhibited along the coast-section generally, both east and west of Sidmouth ; the depressions which produce this rugged outline being either troughs, or deep, inverted cones. In 1836 I examined one of the latter, which had been just emptied of the flints it had contained. The strata in which it occurred, were of very compact sandstone, and the sides of the pit, which was circular, exhibited deep concentric grooves, such as would be produced by the circular motion of the materials within. Similar pits have been often noticed over the surface of the chalk, and they are very common in this neighbourhood. They have been attributed to the erosive action of acidulous waters ; but as they are not confined to calcareous beds, extending here into arenaceous strata, such an explanation can hardly be received as a general mode of operation, and we must have recourse to the mechanical action of hard substances set in motion by water, in the same manner as pits and basins are now constantly produced along the coast and in rapid rivers. This mass of purely cretaceous materials, the flints, coated by a black substance, being intermixed with abundance of strong clay, is very distinct as an accumulation from the overlying water-worn flints and pebbles of older rocks ; but it corresponds exactly with those beds which in many places constitute the lowest tertiary deposits, where they rest on chalk. In the Bovey valley a similar accumulation is subjacent to the pipeclay beds.

Other portions of the tertiary series apparently once extended here. Scattered largely over the surface of all this district, and mixed with the debris on the hills, are blocks of a breccia, composed of angular fragments of chalk flints, cemented together by an exceedingly hard, siliceous paste. This breccia affords proof of a long post-cretaceous period of tranquil deposition, and of a subsequent one of destruction, of both of which it is the sole remaining indication. Besides the breccia, there are large slabs, composed partly of similar materials, and in part (taking the blocks according to their thickness) of a compact, fine-grained sandstone, some blocks containing only an occasional flint, but some none at all, in which cases they are mineralogical grey-wether sandstones ; and may probably be the equivalents of those siliceous masses, warranting, a presumption at least, that tertiary deposits once extended wherever this breccia now occurs; for the blocks are so angular that they cannot be supposed to have been conveyed from a distance. The breccia, with its accompanying sandstones, occurs on the Blackdowns; it is very abundant in the valleys about Sidmouth; it has been worn into rounded boulders and pebbles in the great valley of the Exe; it is found again in tabular masses on the Haldons, below the accumulation of more rounded materials (p. 448), and in similar angular blocks beneath the pipeclay. A very large block serves as a foot-bridge over a water-course near Kingsteignton*.

Secondary Deposits. (Map, Pl. XLI. Sect. Pl. XLII. Figs. 1, 2, 3, 5, 8 A.)

§ 1. *Chalk.*—There are the following proofs that the chalk extended over portions of South Devon, from which it has been since removed: 1st, in the abundance of chalk-flints, uninjured by transport or attrition, which crown the greensand hills of Haldon (fig. 8 A.); and 2ndly, in the circumstance that the high lands along the line of coast, from the Exe westward, present a very uniform elevation, the dip of the beds being in the same direction, and at such angles, that, proceeding from west to east, we encounter a constantly ascending series, and find the various divisions smoothed off, as they rise to the general surface-line of the country.

The chalk in the valley of Beer offers the same artificial divisions which it does in the South Downs, the only difference worth noticing being, that the cretaceous series generally in its extension westward must have presented, when complete, a gradually decreasing thickness. With the slight difference of a rather larger proportion of siliceous particles, the chalk seems to have preserved its general appearance as far westward as the small overlying mass on Maynard Hill, where it is very remarkable on account of its great abundance of the remains of Radiaria. Blocks of chalk may be found among the debris as far west as Peak Hill, near Sidmouth, and the thick capping of angular flints on the greensand of Haldon, as before stated, and on that of the Bovey valley, indicate that the formation once extended thus far.

Certain white granular beds, worn into deep furrows on the upper surface, which surmount the greensand at Staple Hill, near Stover, and contain the spines of a *Cidaris*, may perhaps represent chalk. (Pl. XLII. fig. 2.)

§ 2. *Greensand.*—The greensand of the S.E. parts of Devon may be considered as belonging to the great mass of Blackdown, so well described and illustrated in Dr. Fitton's memoir†. An interesting fact, which appears to have escaped observation, is the occurrence of a shingle bed in the lower part of the deposit, and well seen in the capping of greensand on Salcombe Hill, near Sidmouth. The pebbles consist of

* See an account of similar blocks in Dorsetshire in the Memoir of Dr. Buckland and Mr. De la Beche on Weymouth, Geol. Trans., 2nd Series, vol. iv. p. 4.

† Geol. Trans., 2nd Series, vol. iv. p. 235.

compact sandstone, containing green earth, and are totally unlike any of the older English strata; but they are exactly such as occur on the beach near Swanage, and derived from the harder beds of the greensand. I was unable to find a specimen containing organic remains. If, as most geologists, I feel confident, will admit, these pebbles have been derived from greensand beds, just as pebbles of the hard compact sandstones of the raised marine beds on the actual coast may be included in strata now being formed, we have proof that portions of the greensand series had become consolidated, and having been exposed to destruction, had contributed materials to the shingle beds in question; or if this mass of shingle has been derived from some older formation, as for instance, from some beds of the oolitic series, the mineralogical agreement between the shingle and the overlying sand would follow as a natural consequence, just as the recomposed tertiary greensand beds cannot be distinguished from the parent subcretaceous strata. Exogyræ and Serpulæ adhere to the pebbles. A host of the Blackdown fossils given in Dr. Fitton's tables * are found in the branches of the formation which extend to the sea-coast. East of Sidmouth large branched corals are very abundant, and a gigantic, undescribed Ostrea.

The next mass westward is that of High Peak, and traces of the deposit perhaps occur on the Woodbury Hills, near the Belvidere.

The greensand of Haldon differs a little from that of the Blackdowns. The lower beds, which rest on new red sandstone (fig. 8 A.) and carbonaceous rocks, consist of clay and yellow sand, with fragments of shells, or else of a pebbly conglomerate, made up of portions of the carbonaceous series, with shells and large corals†. This conglomerate may be found along the western slopes of Little Haldon. Sands with abundance of green earth, layers of whetstone, and beds of shells of considerable horizontal extent and thickness, converted into red or transparent chalcedony, form the middle portion. Above these are sands with no green earth and lines of chert. A very distinct vegetation everywhere marks the line of junction.

To the westward of the Haldons the greensand has not been described by former observers, yet it occurs in situations which make it exceedingly interesting, and renders a detailed description the more necessary, as it illustrates some of the disturbances which the district has experienced.

One great mass is that of Milber Down, near Newton Bushel, where, owing to the thick accumulation of sand and flints which forms the upper surface, and the few places in which unequivocal stratified beds are exposed beneath, the tract has been usually considered a portion of the Bovey basin. The Milber beds are identical with those of Haldon, and but for the roads, which in Haldon have exposed artificial sections, proof of undisturbed greensand would be as difficult on one eminence as on the other. Along the edges of the waste of Milber, as in the descent to Haccombe, however, are beds of true greensand, with included layers of chert and whetstone, covered with characteristic fossils. From that place the

* Geol. Trans., 2nd Series, vol. iv. part 2. p. 239.

† Mr. Lonsdale I find refers these to Ehrenberg's genus Cyathina.

deposit ranges over the summits of the hills above Coffinswell, passes into the valley a little below Kingskerswell, and then rises into the opposite hills; near Aller Mills it contains beds of yellow ochre, with sand and light-coloured clay—an association very like that at Shotover; and it crowns the hills above Woolborough. On the other side of Newton it forms very compact beds a little beyond White Hill, beneath clay and debris, and also at Ringslade. From Staple Hill (fig. 2.) to the Ashburton road the greensand acquires considerable breadth, the strata dip at a high angle, and appear broken: intermediate between the greensand and the "head" are the white beds, which may perhaps represent chalk.

The *Trigoniæ* which occur in the arenaceous beds at Staple Hill, prove the deposit to belong without any doubt to the greensand.

Crossing over to the opposite side of the valley, similar beds are well exposed by Bellamarsh. On each side of the road leading down to Combe Farm, we have an artificial section, fig. 6, showing the base of the deposit, resting on carbonaceous shales, and containing fragments of culmiferous grit, also Exogyræ, *Pecten quinquecostatus*, &c. in great abundance.

Fig. 6.

Greensand resting on Carbonaceous Shale, near Combe Farm.

Below Ponswine Farm the formation presents fine-grained beds with green earth and numerous characteristic fossils. The deep cutting for the new road affords a good section, showing the thick capping of debris resting on the furrowed surface of the greensand: in this section are lines of chert, and some very remarkable beds almost entirely composed of Orbitolites.

The greensand along all this course occupies the slopes of the hills which form the Bovey valley, and it rests on new red, carbonaceous, and transition strata, perhaps upon granite, as near Letford Bridge, on the road to Lustleigh.

Pipeclay occurs towards the base of the greensand in Great and Little Haldon *, and attempts have been made to work it near the western extremity of Great Haldon. In a deep water-course below Woolborough, pipeclay beds alternate with sand, and an alteration of the road near Ford presented an interesting section of similar clay-beds alternating with greensand.

A small outlying patch of greensand occurs near Larcombe Bridge, below Ideford, a connecting link between the Haldon deposits and those of the Bovey valley.

* It is the bed in the section presented by a well, carried through the entire thickness of the deposit by Sir Robert Newman, quoted by Mr. De la Beche, Report, p. 247.

Scattered over the surface of the soil about Lindridge, near Ideford, are large blocks of a compact siliceous rock, containing much green earth, and many well-preserved greensand fossils; they also include rounded pebbles from the harder beds of the carbonaceous series. These blocks occur only at this particular spot, which is just below the point where a mass of trap (certainly of subsequent date to the new red sandstone) is hid by the greensand of Haldon; they are unlike any of the beds to be found in place on either of the Haldons; and judging from the change which the trap has effected in beds of new red sandstone, these masses present just such a character as would have been produced by the igneous rock had it come in contact with the lower greensand, which probably was the case.

The greensand beds of the Haldons and the Bovey valley are very far from containing the same number of species of shells as the Blackdown; I have, however, collected the following species:—

Exogyra halyotoïdea, *Sow. Min. Con.*
——— conica, *Sow. ibid.*
Pecten asper, *Lam. Anim. sans Vertèb.*
——— quinquecostatus, *Sow. Min. Con.*
——— quadricostatus, *Sow. ibid.*
——— Stutchburianus, *Sow. Geol. Trans.* 2 Ser. vol. iv.
Lima semisulcata, *Sow. ibid.*
——— proboscidia, *Sow.* Ponswine.
Inoceramus concentricus, *Parkin. Geol. Trans.* 1 Ser. vol. v. Ponswine; Staple Hill.
——— gryphæoides, *Sow. Min. Con.*
——— mytiloides, *Mant. Geol. South Downs.*
Gervillia aviculoides, *Sow. Min. Con.*
——— solenoides, *Defrance, Dict. Sci. Nat.*
Trigonia aliformis, *Sow. Min. Con.*
——— spectabilis, *Sow. ibid.*
——— scabra, *Lam. Envir. de Paris.*
——— dædalia, *Park. Org. Rem.*
——— excentrica, *Park. ibid.*
Pectunculus umbonatus, *Sow. Min. Con.*
Pectunculus sublævis, *Sow. Min. Con.*
Cucullæa carinata, *Sow. ibid.*
——— glabra, *Sow. ibid.*
——— fibrosa, *Sow. ibid.*
Cardium Hillanum, *Sow. ibid.*
——— proboscideum, *Sow. ibid.*
Venus angulata, *Sow. ibid.*
——— gigantea.
——— lineolata, *Sow. Min. Con.*
——— caperata, *Sow. ibid.*
——— sublævis, *Sow. Geol. Trans.* 2 Ser. vol. iv.
Tellina inæqualis, *Sow. Min. Con.*
——— striatula, *Sow. ibid.*
Mya læviuscula, *Sow. Geol. Trans.* 2 Ser. vol. iv.
——— mandibula, *Sow. Min. Con.*

Auricula incrassata, r. *Sow. ibid.*
Littorina pungens, *Sow. Geol. Trans.* 2 Ser. vol. iv.
Turritella, n.s., r.

Serpula filiformis, *Sow.** *Geol. Trans.* 2 Ser. vol. iv.

Remarkable differences are observable in the above suite, when compared with that contained in the rich fossiliferous sand of the hills about Sidmouth, not only in the species but in the condition in which they occur. At the latter place, as already described, are beds of shingle, with Serpulæ and large oysters, apparently in the very places they occupied when living, surmounted by beds with the various Blackdown species enumerated by Dr. Fitton, facts which would indicate an increasing depth of

* The corals of the greensand of England have not been described: none are enumerated in Dr. Fitton's valuable table. Large branched Cyathophylla abound in the greensand of Sidmouth; they are numerous in that of Haldon, together with *Astrea elegans, A. escharoides, Retepora clathrata, Eschara.*

water over that particular spot. The mollusca so abundant there, are altogether wanting in the Haldon beds, which contain conchifera of littoral habits, mostly broken and water-worn. Nor, in a very large collection have I a single specimen with the valves united, and very few even perfect.

The greensand beds of the Bovey valley, owing to their covered condition, have as yet afforded fossils from only a few localities, indicated in the foregoing table, and the species are few in number. The Orbitolites, which occur sparingly on Haldon, are exceedingly numerous in beds below Lindridge Hill, forming by themselves layers of some thickness; the same beds contain Orbiculæ.

§ 3. *The New Red Sandstone.*—This formation presents, in a direction from east to west (see map, Pl. XLI.), the following obvious divisions :—

1st, Marls, containing gypsum in the lines of deposition ; and extending as far as Sidmouth.

2ndly, Sandstones, as between Sidmouth and Dawlish.

3rdly, Shingle and conglomerate.

It is almost unnecessary to observe, that these divisions are not separated by any distinct lines, but that they gradually pass into each other. In general the conglomerate increases in coarseness towards the western edge of the deposit.

This formation has been so fully described in the "Outlines of the Geology of England and Wales," Chapter IV., that a few observations as to the mode of its accumulation is all that it seems to require here.

The rocks which supplied materials for the formation of the conglomerate, are mostly such as are found in the immediate district, consisting of slate, limestone, porphyry, carbonaceous grit, greenstone-trap, and altered shales. Some of the blocks are much water-worn, as the limestones generally towards the edge of the deposit; but taken within its area, as in the cliffs of Teignmouth, they are subangular. It will be found too, that along the boundary-line the conglomerate partakes of the nature of the rocks in the immediate vicinity; as for instance, limestone blocks predominate in the beds facing Marychurch, Barton, Kingskerswell, &c., a circumstance in strict accordance with what was noticed respecting the present sea-beach. In some more central places, on the other hand, the body of water which distributed these conglomerates appears to have set in a constant direction; for the blocks of porphyry, which, from similarity of character, must have been derived from one source, have a linear arrangement, as may be seen along the Haldons, especially up the Combe Valley; and, tracing this line down to the sea, we find them occupying the whole vertical thickness of a lofty cliff east of Teignmouth. From the inspection of a very large collection of specimens, I feel confident that these blocks have been derived from the great sheet of porphyritic matter, of which portions still remain, *in situ*, at the north extremity of Great Haldon and other places ; so that we are moreover informed as to the direction in which the materials moved, and the prevailing set of the water which transported them, just in the same manner as we now find oolitic rocks travelling eastward, and mixing with the chalk-flint shingle of the coast of Sussex, but know, that we never meet with a single fragment of that series mixed with the older materials on the beaches or bed of the sea to the west. If the conjecture be correct as to the source from which the porphyritic blocks were derived, from the known fact that they occur in particular places throughout the entire thickness of the deposit, as in the cliff already noticed, we arrive at another unavoidable inference, —that some portion of the porphyritic mass was not covered up, but was so situated as to be exposed to constant destruction throughout the red sandstone period; whilst it will be seen, in the notice of this porphyry, that in other places, after having supplied some materials, it became buried under the sandstone. We thus appear to have ascertained, for one point at least, the limit of the waters of that particular period. Other considerations would seem to point out, that in some places the existing limits are nearly the original ones, such as the gradually decreasing thickness of the sandstone beds westward; the local character of the deposit in some places already noticed; the manner in which it terminates abruptly at the base of limestone cliffs, as near Wotton; and where it follows depressions caused by old disturbances in the slate rocks, as at Bowbridge.

This formation is distinctly stratified throughout, and it is well known that from Babbacombe to Sidmouth, a distance of twenty miles, the sea-cliffs are entirely composed of it, and that it finally disappears beneath newer formations a little beyond Axmouth, about nine miles farther east. Along all this line the strata dip at a slight angle towards the S.S.E.; in one place only, on the south side of the Teign, is the inclination reversed, and for a short space the beds are horizontal. Now if we suppose, as has been done, that the order of conglomerates, sandstones and marls is constant throughout this formation, the one carried beneath the other with the same relative dimensions that may be observed in any given section, and if we attempt to estimate the total thickness of the deposit, deduced from the mean angle of its dip, we obtain a result which at once shows that such a supposition must be erroneous, viz. a thickness of little less than five miles for the deposit at Axmouth.

There is no reason why the divisions of the new red sandstone should be considered as members of an ascending series, although the sandstones seem to overlie the conglomerates, and in turn to be covered by the marls, as, in so doing, we tacitly admit a mode of accumulation very different from that which is at present effected by large bodies of water. Successive additions now take place, as we have seen (p. 435), over every part of the bed of the sea simultaneously, wherever particles of matter are carried; and the distribution of the conglomerates, sandstones and marls, the finer sediment occurring at the greatest distance from the western boundary of the formation, show us the manner in which the deposition of the whole series could proceed contemporaneously.

If we take the coarseness of the conglomerate as a measure of the forces which produced it, and compare it with the effects of the action of the waves of the actual sea upon the very same mineral masses, we shall see no reason to call in the aid "of a stormy and disturbed period, agitated by perpetual convulsions." Such a state of things could never have existed. All the laws by which the stability of large masses of water are maintained must have been in operation during every period,—waves, propagated by whatever cause, must have had their limits confined by the same laws as regulate them now; nor is a contrary supposition at all necessary, as no masses occur in the new red conglomerate which exceed in size such as, during every gale, are removed by the waves on our own coasts. The largest porphyritic blocks which fall from the cliffs east of Teignmouth are soon transported away; and the conglomerate of the raised marine beds of Hope's Nose is as coarse as any that occurs in the new red conglomerate series: beds of conglomerate, of whatever age, indicate the action of breakers and an inconsiderable depth of water.

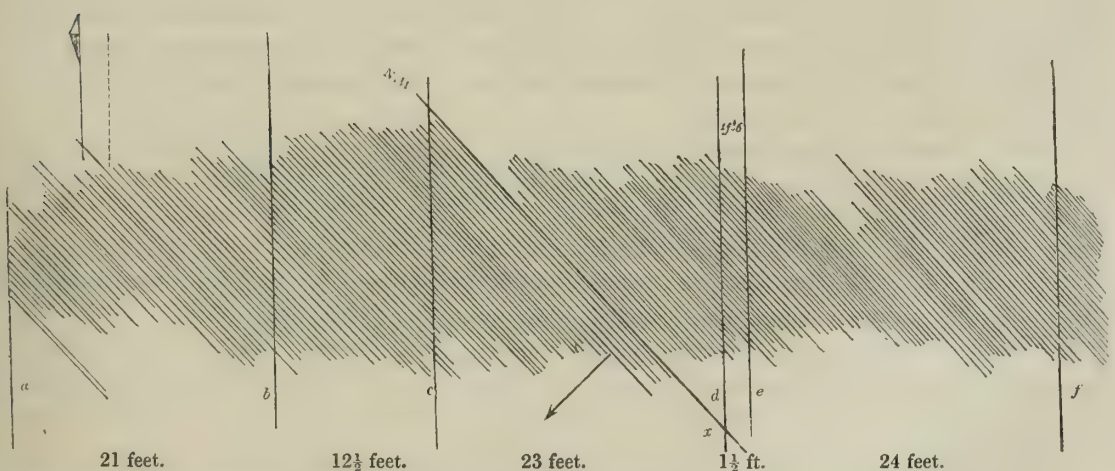
The arenaceous beds of this series, as west of Sidmouth, present ripple-markings on their upper surfaces, and this beneath 200 feet of the deposit in a vertical line. It has been supposed that these markings may be produced under any depth of water, but perhaps erroneously, from the well-known tranquillity which prevails over the bed of the sea, even at the inconsiderable depths to which divers have descended; the castings of worms are also beautifully preserved over the same slabs of sandstone,—a circumstance, coupled with the former, which would seem to indicate that a gradual encroachment of the sea, or a slow subsidence of its bed, accompanied the accumulation of the deposit in this part of England.

The bright red colour of the formation, particularly the South Devon portion of it, has not been satisfactorily accounted for. The colouring metals are iron and manganese, but the latter only in a small proportion; and it may be some help towards the solution of this point to mention, that wherever limestone blocks and pebbles occur (as about Teignmouth), the materials which surround them are not coloured. Now either the whole mass was red throughout, and the colour of the portions in contact with the limestone subsequently discharged, or the colour must have been at some time subsequent to the accumulation of the deposit imparted to all the mass, except to such portions as happened to be in contact with fragments of limestone; the latter supposition seems most reasonable. If we examine the coloured portions, we observe that each particle is coated with a thin pellicle of peroxide of iron: now as this could not have been held in solution by the water which collected the materials, we must suppose that the conditions under which they were subsequently placed, favoured the conversion of the iron contained in the abraded porphyritic rocks, and at first only mechanically disseminated throughout the mass, into colouring matter for the whole of it, with the exception already noticed.

A jointed structure, the joints having a constant direction, is not distinctly marked throughout all portions of this formation, and the nature of the deposit does not admit of its being observed as easily as in some other rocks; yet lines belonging to a system of joints may occasionally be traced even among the conglomerates, as beneath the Ness at Teignmouth.

Near Sidmouth these divisional lines are particularly well marked, and may serve as a general illustration.

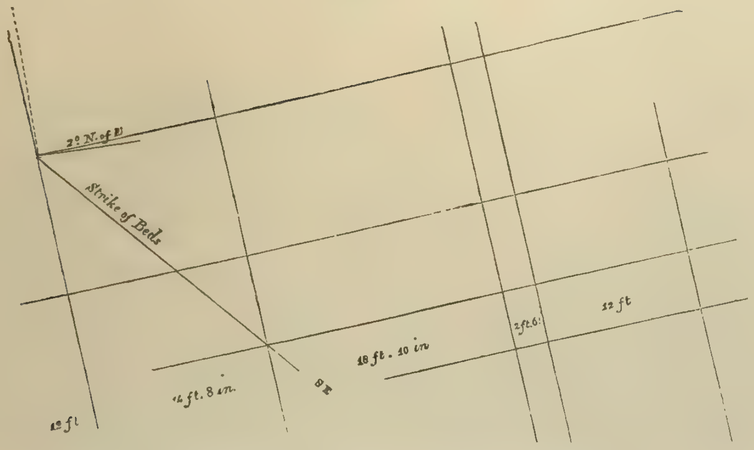
Fig. 7.



Jointed and Cleavage Structure, New Red Sandstone near Sidmouth.

The above diagram represents a ground-plan of rocks of fine-grained fissile sandstone, exposed at low water, and exhibits six lines of joints (a to f), ranging 1° 30′ west of true north, at intervals of 21 ft., 12 ft. 6 in., 23 ft., 1 ft. 6 in., and 24 ft. The strike of the beds is marked by a seam of sulphate of lime x, running N.W. and S.E., and the other lines parallel to this are those of the partings of the laminæ.

Fig. 8.



Jointed structure, New Red Sandstone near Sidmouth.

Fig. 8. represents the north and south joints, at the intervals of 12 ft., 14 ft. 8 in., 18 ft. 10 in., 2 ft. 6 in., and 12 ft. These two plans, taken only a short distance apart, give the divisional structure of the deposit. Now the dip of the beds is N.E., but from the direction of the coast at this particular place, the east inclination only is seen, and consequently only one set of joints, viz. the north and south, can have their vertical course observed. It fortunately happens that every one of these north and south lines can be traced to the foot of the cliffs, and are there seen to meet other lines which traverse the entire thickness of the deposit. The direction of these lines is from vertical to 8° or 10° E.; it necessarily happens, therefore, that such lines, if prolonged, must approximate or cross, which accounts for the various distances observed upon the beach between the north and south lines. Hence it is evident that the new red sandstone is structurally composed of octohedral masses, having their major axes much extended through the thickness of the deposit. At the point where fig. 7. was taken, there is a subsidence of a few inches to the west.

Guided by analogy, geologists have concluded that the jointed structure of sedimentary rocks has been superinduced by the agency of heat, and if the divisional lines of the new red sandstone have been so produced, the same agent would account for the other phænomena. The depression of the new red sandstone so as to admit of the accumulation above it of the whole of the cretaceous and tertiary series, placed it under conditions of temperature quite adequate for the purpose; for, from the decomposition of the water which the rocks would naturally contain, the oxygen would enter into combination with the iron, so abundant in the deposit, and form a peroxide, except where, the same causes producing a decomposition of the surface of the limestone fragments, a carbonate of iron would result; the *quantity* of the carbonic acid overcoming the stronger affinity of the iron for the oxygen.

At the southern extremity of Great Haldon, near Ugbrook, also in the valley of the Teign, the neighbourhood of Torbay, and everywhere along its western outline, the new red series rests on the edges of the older carbonaceous or graywacke rocks. About Newton, between Berry and Torquay, and between Newton and Totness (Bowbridge), conglomerates and sandstones of this age fill deep valleys, as if the slate rocks had presented great inequalities of surface before the newer formation was superimposed.

Their association with the porphyry of Exeter, &c., will be noticed under the head of the Igneous Rocks (*posteà*, p. 470).

The absence of organic remains in this deposit is very general, nor has any exception yet been noticed in the great mass which occurs in South Devon, though it presents every variety of mineralogical character. An abundance of peroxide of iron has been stated to be unfavourable to their preservation, but in many places, as near Exminster, the deposit presents thick beds of yellow sands, which are equally deficient in animal reliquiæ. The fossil castings of worms, already noticed, to be seen near Sidmouth, Exeter, and other places, are the only indications that animals of any sort existed; but to this we may add, that the upper surfaces of the slabs of sandstone in the cliffs west of Sidmouth present straight irregularly branched bodies, and sometimes of considerable size, composed of fine-grained, compact sandstone. They can be easily removed from the slab in which they lie; and if of vegetable origin, no structure is preserved, as in the fossil wood of the greensand.

Carbonaceous Deposits. (Map, Pl. XLI. Sect. Pl. XLII. Figs. 2, 3, 6, and 8.)

In a communication to the Geological Section of the British Association, at the Meeting in August 1836*, Prof. Sedgwick and Mr. Murchison first separated from the older rocks of the West of England certain deposits which constitute an extensive portion of North Devon, presenting a very peculiar mineralogical character, and to which, from the abundance of terrestrial vegetation contained in a particular portion, they gave the name of culm deposits. In a paper I read to the Geological Society in March 1836†, I noticed certain conglomerate and sandstone strata, exhibited in Ugbrooke Park, near Chudleigh, and other adjacent places, and which I erroneously supposed to be included in the transition series. In the autumn of the same year, I pointed out these deposits to Prof. Sedgwick, who considered them as a portion of the culmiferous beds of the centre of the county.

The first point of interest connected with the carbonaceous series in South Devon is the position of certain deposits in the neighbourhood of Newton Bushel, and of those in Ugbrooke Park above alluded to. Rydon Hill (Pl. XLII. fig. 2.), near Newton, consists, in its upper portion, of black shales and conglomerates, containing much disseminated carbonaceous matter and occasional vegetable remains; so that in general aspect and character the deposit differs widely from the slate series of the district. It has a very limited range, and has been accumulated on an uneven and abraded surface of older rocks. Figs. 9. and 10. (see next page) represent this unconformable position as exhibited in quarries near Newton. On the right of the road

* See Report of the British Association for 1836, Notices of the Sectional Meetings, p. 95.

† See Proceedings, vol. ii. p. 414.

to Totness the carbonaceous beds occur on the east side of the great mass of Conator limestone; and on the opposite side they abut against a vertical wall of limestone, acquiring considerable thickness, and in the lower portion present the same alternations of carbonaceous shales with siliceous bands as the culm series of North Devon. The pebbles of the conglomerate beds are mostly siliceous, and may have

Fig. 9.

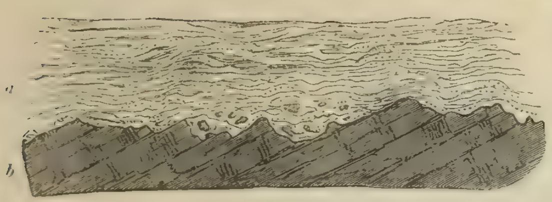


Fig. 10.

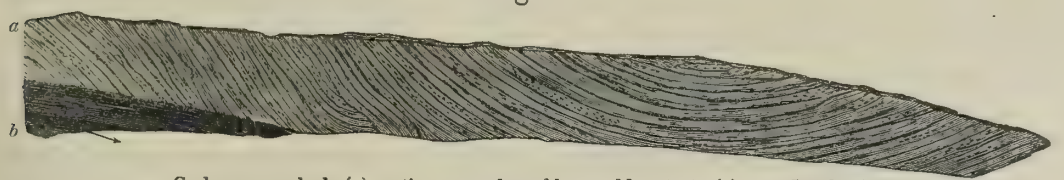
Unconformable position of the carbonaceous deposits (*a*) to the older rocks (*b*) near Newton.

been derived from the quartz veins of the older slates; but in the section represented by Fig. 9. the lowest beds are seen to contain blocks of limestone derived from the subjacent rock, and mostly angular or but slightly water-worn. The unconformable position of this mass can also be observed along the road from East Ogwell to Newton, and in the valley near Bradley House.

The rocks of Ugbrooke Park closely resemble those of Rydon Hill, consisting of the same black earthy shales, coarse sandstones, and siliceous conglomerates; but their superficial extent is much greater. They moreover contain pebbles of green porphyry, and of a black flinty rock like Lydian stone; but in the numerous beds of this conglomerate which I have examined, I have never detected a fragment of granite. Their position, like that of the Rydon deposit, is unconformable, as may be seen south of the Lewell stream, near the Chudleigh Rock, and in the sections represented in Pl. XLII. fig. 6, fig. 8, E. Vegetable remains may be found in the sandstone quarry, by the road leading from Chudleigh to Whapple-well, and in Ugbrooke Park generally; impressions of large Calamites occur also in the Orchard-well valley, but not sufficiently well preserved for the determination of the species. We may safely conclude, that these deposits are of the age of some portion of the true coal-measures of the other parts of England.

The culm series of Professor Sedgwick and Mr. Murchison undoubtedly passes round the eastern side of Dartmoor, and is in contact with the granite as far south as Skeriton, a little west of Dean Prior (see map, Pl. XLI.). Along its external edge it first rises, about Exeter, from beneath new red sandstone; near Chudleigh its relations to the calcareous masses of the base of Great Haldon are rather obscure, and such is also very generally the case in its course westward. There can be no question as to the geological position and equivalents of the arenaceous and conglomerate beds of Rydon and Ugbrooke, as over the whole of central Devon, and throughout the narrow band south of Dartmoor, the argillo-carbonaceous character of the culm series is remarkably uniform, but the mineralogical resemblance is not so great as to warrant their being considered portions of one formation. The central trough of Devon is believed by Prof. Sedgwick and Mr. Murchison* to be of the same age as the South Wales coal-field, on the evidence of mineral character. The inquiries of Mr. Lonsdale established the place which the South Devon limestones should hold in the scale of British formations; by means of these alone can be determined the age of the carbonaceous system. If along the line from Dean Prior to the Haldons the culm measures pass beneath the slates and limestones to the south, they must have a much greater antiquity than has been assigned to them; but if, like the beds of Ugbrooke and Rydon, they are superior to them, they may, as suggested by Professor Sedgwick, be the equivalents of the coal-measures. In the north of Devon, along a line extending from Fremington to Hockley Bridge, north of Bampton, the carbonaceous rocks pass downwards into the older system, which composes the range of Exmoor. At Boscastle, on the opposite side of the trough, the coast-section exhibits a similar passage. From this point inland, the line of separation is best marked by the distinct vegetation and barren tracts of the carbonaceous grit beds; but no good section is to be found of the relative positions of the two deposits till we reach Landue Mill, near which a road-cutting in 1837 exposed the following section, where the carbonaceous beds,

Fig. 11.



Carbonaceous beds (*a*) resting unconformably on older strata (*b*) near Landue Mill.

of inconsiderable thickness, rest unconformably upon slate and shales, very rich in fossils: from this point again the junction-line presents no section, though it can be easily traced upon the surface, until it abuts against the granite of Dartmoor, north-east of Tavistock.

Crossing the granitic tract of Dartmoor, and in the direction of the line of bearing of the carbonaceous rocks from the coast, we meet them again about Holne, perfectly identical in character and appearance with the beds about Tavistock; but on this side also there is the same difficulty as to sections. On the road from Buckfastleigh, south of Ashburton, to Holne, and in the ascent to Hembury Castle, the

* See vol. iv. p. 669 *et seq.*

fine fissile slates which compose the base of the hill appear in one place to arch over, and the carbonaceous beds set on, at the summit. They occupy a similar position from Skeriton to Holne Bridge, where the deep valley of the Dart cuts through both deposits nearly at right angles, and we might expect a good natural section; but the strata here are much disturbed by trap, which breaks out along the bed of the stream. At the point of junction both rocks are nearly vertical, or if there be any inclination, it is in favour of the infraposition of the carbonaceous beds: on the north bank, however, and at a very short distance, as near the entrance to the woods, they are to be seen dipping gently north, and for a considerable space. In the ascent from Ashburton to Buckland the fine-grained fissile slates dip south for some distance, till at length they arch over, as in the Hembury section, and the carbonaceous rocks set on with a south dip at the crown of the hill. The section at Rew Mill affords little information, but it should be visited by any one investigating the structure of the country. At Place, near Ashburton, the carbonaceous rocks, for the first time, come in contact with the great band of lower limestone, and on the north side of the great quarry they seem to rest on its surface. From this point they again retreat, and form the high barren tracts known as Ashburton, Ramshorn, and Goodstone Downs. At New Inn, the two rocks are not seen in juxtaposition, but at two points not very distant the carbonaceous beds are either horizontal, or have a gentle northern dip, and the fine slate rock has a steep southern pitch.

On the opposite side of the Bovey valley an interesting section was exposed, at the time the new house opposite the Chudleigh Rock was built: the excavations were altogether in perfectly horizontal carbonaceous shales and sandstones. A well was sunk at the same place (Pl. XLII. fig. 6.), and it was then seen, that these beds were only about fifteen feet in thickness, resting on the edges of highly inclined claret-coloured slates, dipping in the same direction as the Chudleigh lime-rock, and such slates as from Chudleigh to Barton may be seen at several places to underlie the limestone. In this section we are reminded of that at Landue Mill (p. 459, fig. 11.), and also of the Rydon sections (p. 458, figs. 9, 10.). The breadth of slate, which in position is inferior to the Ashburton limestone, and is interposed between it and the boundary-line of the carbonaceous rocks, is very unequal; yet if the latter dip beneath the rocks of South Devon, we must be prepared to admit, that whilst at one place they are in contact with that limestone, yet, at only a short distance, they dip beneath a great thickness of slate, which is undoubtedly inferior to that limestone; besides which, the outline of the carbonaceous rocks does not conform to the strike of the slates and limestones.

The evidence from sections leans towards the priority of the South Devon deposits, but it must be admitted that the structure of the country is obscure, from great disturbance; the present elevated position of the carbonaceous beds along the flanks of Dartmoor does not belong to the question, as it is due to the long subsequent protrusion of the granite.

On the other hand, the limestone of the Ashburton band is exceedingly carbonaceous, containing even seams of anthracite. The sections about Chudleigh are undoubtedly obscure, but I have endeavoured to represent the structure of the country from Oxencombe, beneath Great Haldon, to the disappearance of the limestone near Chudleigh Bridge, by figures 8 A. to E, Pl. XLII. Taking as a guide the apparent dip of the carbonaceous rocks at one place, they would seem to pass beneath the limestone; but against this is the well-section already noticed, and the fact, that where the base of the limestone is exposed, as at Waddon Barton (fig. 8 B.), it is seen to have a very different rock subjacent to it, namely, a fine-grained claret-coloured slate, like that which underlies the equivalent calcareous masses of Newton and Barton. The equivocal appearances along the south base of the Haldons (fig. 8 A.) are caused by a downcast fault of unequal amount, which has brought the different members of two distinct series of rocks into juxtaposition; and the small patches of limestone about Orchard-well, Luton, Colmansford, and Larcombe Bridge, are not included masses, but merely portions of a great unconformable band protruding here and there, owing to the inconsiderable thickness of the shales which cover it.

The mineral contents of the carbonaceous rocks of South Devon are numerous. Tin and copper have been found beneath Ashburton Down, where the Owlecombe mine has been long worked; tin also occurs at Ilsington, near which is an old stream-work, and at Christow, seven miles north of Bovey. Lead is found in the above-named parishes, and that of Hennock, between Bovey and Christow, contains silver. Some beds rich in iron have been worked at Ilsington, and they also contain numerous small garnets; in the same rock, but in an altered state, contiguous to the granite, are fine crystals of pseudomorphous amethystine, purple and red quartz. The limestone near Oakhampton contains copper in nodules, which are compactly imbedded in the rock, and present a radiating structure like the pyrites of the chalk, but without their metalliferous appearance; in the kiln the copper becomes a bright green carbonate.

Referable perhaps to this period, or more properly to the conglomerates of Rydon and Ugbrooke, is that thick mass of limestone breccia which at Petit Tor (Pl. XLII. fig. 1.), east of Babbacombe, is interposed between the solid limestone and the new red sandstone. It has been produced at the expense of the subjacent limestone, which is much diminished in thickness, and has partaken of a disturbance which has affected both it and the underlying slate. It was moreover consolidated and again fissured before the formation of the new red conglomerate, from which therefore it must be separated.

The evidence of the age of the carbonaceous rocks deducible from organic remains is as yet very meagre. *Pecopteris lonchitica*, *Neuropteris heterophylla*, *Sphenopteris latifolia* or *acutifolia*, with a *Cyclopteris*, are the only plants I have seen from the shales, except the Calamites of Ugbrooke and Orchard-well, which I cannot refer with confidence to any species described by Ad. Brongniart or Prof. Lindley. This

Flora, so far as it goes, is that of the carboniferous period. In the black limestones occur *Goniatites miscolobus* and *G. crenistria*, mountain limestone species.

Strata subjacent to the Carbonaceous Deposits.

(Map, Pl. XLI., Sect. Pl. XLII. figs. 1. to 4, 6. to 8.)

The general arrangement and direction of the older rocks of South Devon can be easily ascertained by means of long lines of roofing-slate, chains of lenticular masses of limestone, and subordinate beds of trappean matter; and by the same means the Devonshire deposits can be connected with those of Cornwall. It was on such considerations as these that I proposed the divisions suggested in 1839*, and which, though purely artificial, may still be conveniently adopted; they are as follows; but it is hoped that the map, Pl. XLI., and sections, Pl. XLII., will render the prolixity of a mineralogical description unnecessary.

1. Coral limestone of Newton, Barton, Torquay.
2. A red deposit, chiefly arenaceous, with a slaty structure, and occasional interchanges of fine fissile beds, extending from Paignton, Windmill Hill, near Berry Pomeroy, and across the Dart about Sharpham. It constitutes also the middle district of South Devon, where it is locally arenaceous, as at Blackdown and Morleigh, and it forms the east side of Plymouth Bay, south of the limestone of Mount Batten.
3. There is a considerable development of limestone north of the above, and which appears to dip beneath it: such is the position of all the limestone masses about Yalberton, Berry, and the lower limestone of the Ogwell country.
4. Separated from the above by a band of slate, with occasional lines of fine-grained fissile beds fit for roofing-slate, is a lower limestone mass and contemporaneous trappean beds, which ranges from Staple Hill, by Bickington, Ashburton, Buckfastleigh, and Dean Prior. At South Brent these beds are cut off by the granite of Dartmoor, but they resume their course on the opposite side about Newnham. They cross the river at Saltash, and are continued through South Cornwall, by Tredinick, Polpever, Looe, Fowey, Gorran, St. Michael, and Veryan to south of Falmouth, containing subordinate limestones and calcareous slates, with fossils throughout.
5. A lowest division may contain all the slate-range north of the foregoing.

Divisions 1, 3, 4, and 5, have a southern dip. The central portion of South Devon, which includes the red arenaceous series, presents many undulations. Proceeding south the dip of the beds is permanently reversed, and from Kingsbridge to the Prawle it is to the north, so that these strata must be considered as the equivalents of that part of the section on the north which rises from beneath the Plymouth limestone. In both localities are lines of roofing-slate, but limestone bands are wanting in the southern section; this however is in accordance with a general fact, that the calcareous masses have a southern dip throughout South Devon and Cornwall.

The rocks of the series above described are well calculated to correct the notions of those who would rely on mineralogical character and structure. The age of the beds between Stoke Fleming and the Prawle, as compared with the rest of the older strata of South Devon, is sufficiently clear; yet instead of a descending series

* Geol. Proceedings, vol. iii. p. 123.

of clay-slates, of an uniform character and composition, we see them pass from clay-slate, through talcose and micaceous slate, to true gneiss—the progressive metamorphic forms of strata, which are the geological equivalents of the lower part of the old red sandstone.

§ 1. *The coral limestones of Newton Bushell, Ogwell, Kingskerswell, Barton, and Torquay.*—These deposits form so striking a feature in the scenery of this portion of the county, and the map, Pl. XLI., so sufficiently indicates their positions, that a detailed account of their range and extent is not required.

The thin calcareous deposits constitute the uppermost portion of the older rocks of South Devon, and in most places they are distinctly stratified ; they also present two systems of divisional joints, one set of which runs a few degrees W. of N., and a cross set S. of E. ; locally, however, considerable deviations will be observed, some of which are given in the following table :—

Localities.	Range of joints.		Strike of the beds.	Dip of the beds.	
Chercombe Bridge	N. 45° W.	N. 25° E.	N. 25° E.	40° E.S.E.	In three places.
Do. Second Quarry.......	N. 45° W.	N. 45° E.	id.	id.	The same on the other side of the stream.
Ogwell Park................	id.	id.	id.		
	N. 70° W.	id.	id.		
	N. 45° W.				
	N. 25° W.	N. 65° E.			
	N. 45° W.	N. 45° E.			
Orchard-well	N. 25° W.	N.	N.		
	N. 45° W.				
Wolfsgrove	N.	E.	N. 25° E.	60° E.S.E.	
	N.	N. 70° W.	N. 45° E.	S.E.	
Ipplepen......................	N. 45° W.	N. 45° E.			

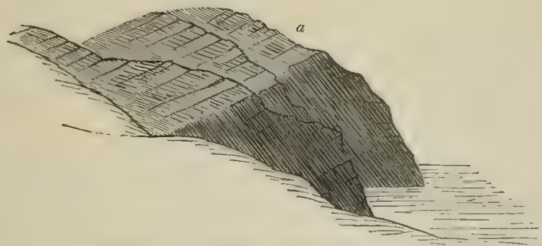
Another curious point connected with the structure of many of the great limestone masses of South Devon, particularly those of Brixham, will be noticed under the head of cleavage.

The relations of these large calcareous masses to the subjacent slate rocks is not very evident. At Pulser, the shales, at their junction with the base of the Torbrian limestone, through a thickness of about two feet, contain small lenticular portions of limestone, arranged in parallel lines, which correspond with the bedding. About Ogwell (fig. 3.) the limestone sets on, in compact beds, after a few trifling alternations with shales, and such is very generally the case.

Although these limestones dip in the same direction with the slate rocks of the district, and often at considerable angles, they do not appear to descend with them to any great depths, but either to thin away, as at Staverton (as does also the lower Ashburton band at Staple Hill), or else to end abruptly downwards, as near Newton (road-section) fig. 7. Pl. XLII. and the limestone of Denbury, as if they had been formed on a previously deposited mass of sediment, now converted into shales and slates. At Bunker's Hill, near Totness, the limestone, which on the south side of the hill dips with the slates composing the central portion, wraps round, and on the north side is inclined to the north, or conforms to the slopes of the hill. There is no ambiguity here respecting the stratification of the limestone, as it is made very apparent by alternating seams of good anthracite, though cleavage planes dipping south also traverse both limestones and slates; the Dartington limestone, at its west extremity, pitches down on the edges of the subjacent slate. The limestone of Yalberton, though it has all the appearance of being included in the grauwacke series, is found, when traced towards the Dart, not to dip with the slates and sandstones exposed in that section, but to have thinned away on the surface close to the village of Stoke Gabriel. In the same manner the great calcareous mass of the south and west of Torbay terminates in inconsiderable beds of shaly limestone, along an E. and W. line from Galmpton Creek towards Brixham, by Churston Ferrers, and of which there is a good section at Galmpton.

The termination of the great calcareous group of S.E. Devon, where it is exposed in the coast-section at Sharkham Point, is represented in the accompanying woodcut.

Fig. 12.



Termination of the limestone group (*a*) of South Devon, at Sharkham Point.

Along their N. and W. edges these limestones set on, either as a capping to the slate, when they often present a wall or low escarpment to the north, or they rest against the south slopes of the ridges and low hills of slate, as at Bradley; they then dip with the slope, but carry the edge of each constituent bed of limestone to the level of the crest of the ridge of slate. This is perhaps the most remarkable feature of these masses, and may be seen about Denbury and East Ogwell: whatever the angle of dip may be, or however far the succession of beds may be carried on, in a given linear direction, the upper surface forms a table-land. It is also the case with the lower limestone of Ashburton and that of Plymouth. An observer has only to ascend one of the higher slate hills in the vicinity of any of these limestone masses to be assured of the fact here mentioned, and which serves to connect all our limestone masses by one common feature.

Any inquiry whence so large a quantity of calcareous matter was originally derived, though a question of much geological interest, would be irrelevant in a mere local description; but it may be observed, that both in North and South Devon the existence of limestone appears in very many instances to have depended on subaqueous volcanic disturbance, as it is interstratified with beds of compact and ashy trap: thus the rock quarried at Leny near Launceston is a vesicular hornblendic mass, largely impregnated with calcareous matter; and beds of contemporaneous trappean ash run parallel with the limestones from Launceston to Oakhampton. In South Devon the coral limestones are in many places superincumbent on great sheets of volcanic materials, with which in some instances, as at North Whilborough, they alternate; and the compact greenstones of South Devon contain a variable, but in all cases, a considerable proportion of lime. This association may be accounted for by supposing, either that subsequently to such eruptions the waters may have held a greater quantity of lime in solution; or that the bed of the sea was altered and placed under conditions more favourable for the production of limestone masses.

Very little personal examination of the principal limestone mass of South Devon will satisfy any one, that it has resulted from the labours of *Polypi*; in other words, existed as a coral reef at the close of the transition period. In the parish of East Ogwell each bed is entirely composed of branching corals in the positions in which they grew; and in the parish of Denbury the partings between the beds of limestone are of volcanic sand, which is easily removed, and we then obtain an upper surface studded with projecting stars and branches, as perfect as when the sand was thrown upon them and suspended the labours of the Polyps. Among existing zoophytes the lamellated and cellulated orders seem to be the principal agents in constructing reefs, and their analogues mainly compose the Devonshire limestone.

The calcareous rocks of South Devon, in their structure, as well as in the position, preservation, and grouping of their corals, afford abundant evidence that their production was analogous to that of modern coral reefs; and in their general position they agree with the reefs of the southern hemisphere, where the Polyps raise their habitations on the summits or slopes of submarine hills to a level with the surface of the water, and hence the table form of land which the limestone masses still preserve.

A local association of certain generic, and even specific forms is often to be observed; thus the limestone of Newton abounds in *Cyathophyllæ* and *Coscinoporæ*; that near Chercombe Bridge seems to have been almost exclusively constructed by *Favosites polymorpha* and *F. spongites*: whilst about Denbury, *Favosites alveolaris* and other allied species are most abundant.

The organic remains contained in the rocks of South Devon are very numerous, and in beautiful preservation. A critical examination of a collection of these fossils by Mr. Lonsdale led to very interesting results connected with the older rocks of this country, and the rectification of an error as to their age and place. The generally adopted opinion at that time was, that the slates and limestones of South Devon were of the same age with the slates of the Berwyns and the limestone of Bala. Mr. Lonsdale's correction was arrived at by the only safe guide,—zoological evidence, by which he established, from the intermediate character of the forms, between those of the true mountain limestone on one hand, and those described by Mr. Murchison in the Silurian System on the other, that the older South Devon limestones were the equivalents of those deposits which in other parts of England underlie the mountain limestone.

The old red sandstone is in general mineralogically different, and sparingly fossiliferous; and until the publication of Mr. Murchison's work, we were but little acquainted with any forms from these thick deposits. This work contains descriptions and figures of seventeen fishes, twenty-seven shells, and one crustacean, in all forty-five species. It is proper only to state, that of these not one has as yet been found in South Devon, whilst, on the other hand, they strikingly resemble such as are contained in the arenaceous deposits in North Devon, which underlie the carbonaceous beds, and so far agree in position with the old red sandstone of the opposite coast of Pembrokeshire.

In no other part of England do we appear to have an association of fossil forms identical with those of South Devon. In 1839 I noticed the occurrence of certain similar forms in the rocks of the South of Ireland; and, guided by the identification of about forty species, I suggested, that in the Rhine and Eifel countries (Paffrath, Bensberg, Gladbach, Gerolstein, &c.) there were equivalent deposits*.

The not adopting, in this memoir, the name "Devonian" for these deposits, is not owing to ignorance of its value as a geological group, but because such a name is at variance with the nomenclature of well-

* Vide Report of British Association, 1839, p. 69.

established groups, and because the beds form only one portion of a great primary fossiliferous series for which we already possess materials for subdivisions founded on zoological views, which are preferable to geographical ones.

Though the limestone band of Chudleigh has not had that attention bestowed upon its fossils which it deserves, we know enough to place it with certainty with the slate and calcareous system of South Devon, rather than with the black limestone of Lew Trenchard, Trescott, Drewsteignton, &c. The *Favosites? fibrosa*, which alone forms strata many feet thick, connect it with the limestones of Ashburton and Plymouth, where that coral is equally abundant: it contains *Stromatopora concentrica*, in common with all the subordinate bands of Broadhempston, Staverton, &c.; *Stromatopora polymorpha* and large *Strygocephali*, as do the Ogwell beds; and the *Loxonema prœterita* and *Buccinum spinosum*, so numerous at Newton Bushell.

The suite of fossil shells and zoophytes contained in the limestones of Newton, Barton, and Babbacombe correspond in so remarkable a manner, that they may safely be considered as one group, formed at the same time, and under like conditions; but the Newton quarry, generally speaking, exhibits the specific characters of the fossils much more distinctly than that of any other locality, and it is therefore the best place to which the collector can be referred. This quarry has afforded me the following list of species, which is two-thirds more numerous than the list above alluded to*, by the addition of the zoophytes identified and described by Mr. Lonsdale†, and of the new species of Professor Phillips‡ and Mr. J. de Carle Sowerby§.

Brontes flabellifer, *Goldf. Nova Acta*‖.
Calymene Latreillii, *Stein. Mém. Soc. Géol.*¶
——— Sternbergii, *Munster, Beiträge.***
Orthoceras cinctum, *Sow. Min. Con.*
——— ellipsoideum, *Phil. Pal. Foss.*
——— pyriforme, *Sow. Silur. Syst.*††
——— tubicinella, *Sow. Geol. Trans.*§
——— ventricosum, *Stein. Mém. Soc. Géol.*
Cyrtoceras armatum, *Phil. Pal. Foss.*
——— fimbriatum, *Phil. id.*
——— marginale, *Phil. id.*
——— nautiloideum, *Phil. id.*
——— nodosum, *Phil. id.*
——— obliquatum, *Phil. id.*
——— ornatum, *Gold. MS.*
——— quindecimale, *Phil. Pal. Foss.*
——— reticulatum, *Phil. id.*
Cyrtoceras rusticum, *Phil. Pal. Foss.*
——— tridecimale, *Phil. id.*
Nautilus germanus, *Phil. id.*
Goniatites excavatus, *Phil. id.*
——— globosus, *Munster, Abhandl.*‡‡
——— serpentinus, *Phil. Pal. Foss. & Geol. Yorks.*§§
——— transitorius, *Phil. id.*
Bellerophon hiulcus, *Sow. Min. Con.*
——— striatus, *Bronn. Leth. Geog.*‖‖
——— Wenlockensis, *Sow. Silur. Syst.*
——— Woodwardii, *Sow. Min. Con. Index.*
Buccinum acutum, *Sow. Min. Con.*
——— arculatum, *Schloth. Petref.*¶¶
——— imbricatum, *Sow. Min. Con.*
——— spinosum, *Sow. id.*
Murex? harpula, *Sow. id.*

* Vide Report of British Association, 1839, p. 69.
† Geol. Trans., 2nd Series, vol. v.
‡ Phillips, 'Palæozoic Fossils.'
§ Geol. Trans. vol. v.
‖ Nova Acta Acad. Cæs. Leop. Cur. Nat. t. xix.
¶ Mém. Soc. Géol. de France, tome i.
** Beiträge zur Petrefactenkunde, Heft 1. 1839, Heft 3. 1840.
†† Mr. Murchison's Silurian System.
‡‡ Abhandl. über Planuliten und Goniatiten, 1832.
§§ Geol. Yorkshire, Part 2.
‖‖ Lethæa Geognostica.
¶¶ Schlotheim, Petrefactenkunde.

Pleurotomaria antitorquata, *Munster, Beiträge.*
——— aspera, *Sow. Geol. Trans.*
——— cancellata, *Phil. Pal. Foss.*
——— impendens, *Sow. Geol. Trans.*
——— monilifera, *Phil. Pal. Foss.*
Schizostoma tricincta, *Munster, Beiträge.*
Macrocheilus elongatus, *Phil. Pal. Foss.* (Phasianella?)
Terebra Hennahii, *Sow. Geol. Trans.*
——— nexilis, *Sow. id.*
Turritella abbreviata, *Sow. Min. Con.*
Loxonema reticulata, *Phil. Pal. Foss.*
——— lincta, *Phil. id.*
Turbo textatus, *Munster, Beiträge.*
Euomphalus annulatus, *Phil. Pal. Foss.*
——— circularis, *Phil. id.*
——— radiatus, *Gold. MS.*
——— serpens, *Phil. Pal. Foss.*
Nerita spirata, *Sow. Min. Con.*
Pileopsis vetusta, *Sow. Min. Con. & Geol. Trans.*
Cardium alæforme, *Sow. Min. Con.*
——— minax (Pleurorhynchus), *Phil. Geol. York. & Pal. Foss.*
Modiola scalaris, *Phil. Pal. Foss.*
Mytilus Damnoniensis, *Phil. id.*
Megalodon carinatum, *Gold. Pet. Germ.*
——— cucullatum, *Sow. Min. Con.*
Pterinea.
Avicula texturata, *Phil. Pal. Foss.*
———? reticulata, *Phil. id.*
Pecten plicatus, *Sow. Min. Con.*
Leptæna fragaria? *Sow. Geol. Trans.*
——— nodulosa, *Phil. Pal. Foss.*
——— rugosa, *Dalm., His. Leth. Suec.**
Orthis arachnoidea? *Phil. Geol. York. & Pal. Foss.*
——— arcuata, *Phil. Pal. Foss.*
——— crenistria, *Phil. Geol. York. & Pal. Foss.*
——— granulosa, *Phil. Pal. Foss.*
——— Hardrensis, *Phil. id.*
——— interstrialis, *Phil. id.*
——— resupinata, *Phil. id.*
——— lens, *Phil. id.*
Delthyris cuspidata, (Spirifer, *Sow. Min. Con.*).
——— distans (Spirifer, *Sow. id.*).
——— hirundo? (Spirifer, *Phil. Pal. Foss.*).
——— microgemma (Spirifer, *Phil. Pal. Foss.*).
Delthyris nuda (Spirifer, *Sow. Geol. Trans.*).
——— heteroclita, (Calceola, *Defrance.*).
——— oblata (Spirifer, *Sow. Min. Con.*).
——— plebeia (Atrypa, *Sow. Geol. Trans.*).
——— phalæna, *vid.* concent., *V. Buch, Mém. Soc. Géol. France.*
——— simplex (Spirifer, *Phil. Pal. Foss.*).
——— subconica (Spirifer, *Sow. Min. Con.*).
——— speciosa, *Bronn. Leth. Geog.*
——— unguicula (Atrypa, *Sow. Geol. Trans.*).
Strygocephalus? Burtini, *Defrance, Dict. Sc. Nat.*
Terebratula acuminata, *Sow. Min. Con.*
——— anisodonta, *Phil. Pal. Foss.*
——— aspera, *Schloth. Petref.*
——— bifera, *Phil. Pal. Foss.*
——— cassidea, *Dalm., His. Leth. Suec.*
——— comta, *Phil. Pal. Foss.*
——— crenulata (Atrypa, *Sow. Geol. Trans.*).
——— cuboides (Atrypa, *Sow. id.*).
——— desquamata (Atrypa, *Sow. id.*).
——— ferita, *V. Buch, Mém. Soc. Géol. France.*
——— flexistria, *Phil.*
——— galeata (Atrypa), *Dalm.*
——— hastata, *Sow. Min. Con.*
——— juvenis, *Sow. Geol. Trans.*
——— Mantiæ, *Sow. Min. Con.*
——— prisca, *Schloth. Petref.*
——— proboscidialis, *Phil. Pal. Foss.*
——— pleurodon, *Phil. Geol. York. & Pal. Foss.*
——— pugnus, *Sow. Min. Con.*
——— reniformis, *Sow. id.*
——— rhomboidea, *Phil. Geol. York. & Pal. Foss.*
——— sacculus, *Sow. Min. Con.*
——— Wilsoni, *Sow. id.*
Cyathocrinites geometricus, *Gold. Pet. Germ.*
———? nodulosus, *Phil. Pal. Foss.*
——— geometricus, *Gold. Pet. Germ.*
Actinocrinites triacondactylus, *Mill. Hist. Crin.*†
Platycrinites interscapularis, *Phil. Pal. Foss.*
——— pentangularis, *Mill. Hist. Crin.*
——— tuberculatus, *Mill. id.*
Sphæronites? *His. Leth. Suec.*
——— tessellatus, *Phil. Pal. Foss.*

* Lethæa Suecica.

† Miller, Natural History of Crinoidea.

Stromatopora concentrica, *Gold. Petref. Germ.*
——— polymorpha, *Gold. id.*
Fenestella, *Lons.* (Retepora, *Gold.*) *Silur. Syst.*
——— abnormis, *Lons. id.*
——— antiqua, *Lons. id.*
Retepora infundibulum, *Lons. id.*
——— prisca, *Gold. Petref. Germ.*
Lithodendron, *Gold. id.*
——— cæspitosum, *Gold. id.*
Amplexus, *Sow. Min. Con.*
——— tortuosus, *Phil. Pal. Foss.*
Cyathophyllum turbinatum, *Gold. Petref. Germ.*
Cystiphyllum (Cyathophyllum, *Gold.*), *Lons. Silur. Syst.*
——— Damnoniense, *Lons. Geol. Trans.*
——— vesiculosum.
Strombodes, *Schweigger Beobachtungen, &c.*
——— vermicularis, *Lons. Geol. Trans.*
Astræa, *Linn.*
——— ananas, *Gold. Petref. Germ.*
——— helianthoides, *De Blain.*
——— Hennahii, *Lons.*
——— pentagona, *Lons.*
Porites, *Lamarck.*
——— pyriformis, *Lons. Silur. Syst.*
Coscinopora, *Gold.*
——— placenta, *Gold. Petref. Germ.*
Favosites, *Lamarck.*
——— fibrosa (Calamopora), *Gold. Pet. Germ.*
——— Gothlandica, *Lam. Anim. sans Vert.*
——— polymorpha, } (Calamopora)
——— spongites, } *Gold. Pet. Germ.*

§ 2. *Red arenaceous slaty strata.*—The slate range, subjacent to the coral limestone, requires only a short notice, as any description would be purely mineralogical, and details of those local variations common to all deposits, have now little interest or value attached to them. These slates and shales are remarkably deficient in organic remains over wide areas, but productive localities occur in the parishes of East and West Ogwell, Denbury, Berry Pomeroy, the neighbourhood of Torquay, and in Mudstone Bay. They suggest the notion of slow and tranquil deposition, and an uniform condition as to depth; while the casts of molluscous and other animals, whose most delicate markings are admirably preserved, indicate that the sedimentary matter was in an exceedingly minute state. It is only with the red arenaceous portion, which often resembles the old red sandstone of Herefordshire, that different conditions are required,—such as would produce alternations of conglomerates, sandstones and shales. Near Broad Sands is an included calcareous bed, composed of rounded blocks of limestone imbedded in a hard matrix; the blocks show that at this early epoch, lime rocks had been formed in some quarter; but, in the absence of organic remains, it is impossible to say, whether they were conveyed from a distance, or were derived from some reefs existing in the vicinity.

Although the slates and coral limestones both belong to the same geological period, and were probably in many instances contemporaneous deposits, the suite of organic remains of the slate system differs widely from that of the coral limestones, a change, the natural result of the different habits of marine animals. Thus the *Terebratulæ,* which so swarmed about the reefs where they had the means of fixing themselves, that we find twenty-three species in the Newton quarry alone, are altogether wanting in the slate. The constancy of certain forms to rocks which indicate similar conditions is very remarkable; thus we find the same *Fenestellæ, Turbinoliæ, Pleurodyctium problematicum,* &c., ranging through the whole middle slate district of South Devon and continued into Cornwall; but it would be impossible in a local memoir to enlarge on the subject of the connexion constantly to be observed between the mineral character of rocks and the forms of the inclosed organic remains. The large *Strygocephali* of South Devon evidently covered extensive surfaces, as oyster-beds do now, thick strata being entirely composed of their uninjured shells at Chudleigh, Chercombe Bridge, Bradley, and Plymouth ; again, the habits of the *Calceolæ* are made very evident by the position in which they are found, being invariably in the thin partings of shale which separate the lower beds of sedimentary limestone. These calcareous flagstones probably soon became solid compact strata, to which fucoids attached themselves, and among which the *Calceolæ* lived.

The researches of fossil zoologists have hitherto been principally engaged with the forms which the calcareous groups of South Devon have afforded; the slate system not having as yet received much illustration; whenever this shall be done it will be found that the prevalence of certain generic forms, and even a total change in species, are unsafe guides as to relative age ; that though the shells which lived about the coral reefs of South Devon, resemble to a considerable extent such as occur in the mountain limestone tracts of other parts of England, yet that the slates of South Devon afford fossils which suggest comparisons with those from districts described by Mr. Murchison : such and very many other conditions must be taken into account before organic remains can be made the framework of an order of superposition for the older rocks.

The few following species, together with many not yet made known or described, will be readily found in the slates about Ogwell :—

Fucoids.
Turbinolopsis celtica, *Lamx. Expos. Méthod.**
Cyathophylla.
Fenestella antiqua, *Lons. Silur. Syst.*
Pleurodyctium problematicum, *Gold. Pet. Germ.*
Cyathocrinites nodulosus, *Phil. Pal. Foss.*
Crinoidal stems.
Spirifer speciosus, *var.* alatus, *V. Buch, Mém. Soc. Géol. France.*
——— aperturatus (Terebrat.), *Schloth. Petref.*
Strygocephalus —— ? (undescribed species).
Orthis compressa, *Sow. Silur. Syst.*
—— arachnoidea, *Phil. Geol. York. & Pal. Foss.*
Orthis sordida (Leptæna), *Sow. Geol. Trans.*
Leptæna depressa, *Dalm., His. Lethæa Suecica.*
Modiola scalaris, *Phil. Pal. Foss.*
Trochus Bouei, *Stein.* n. s.
Orthocerata.
Calymene accipitrina, *Munster, Beiträge.*
——— granulata, *Munster, id.*
——— lævis, *Munster, id.*
——— Sternbergii, *Munster, id.*
Asaphus granuliferus, *Phil. Geol. York. & Pal. Foss.*
Olenus punctatus, *Stein. Mém. Soc. Géol. France.*

§ 3. *Limestone of Yalberton, &c.*—The small subordinate masses of limestone indicated on the map are usually thin-bedded, but they occur in very distinct layers, are hard, sonorous, and very dark-coloured. They are also valuable, as they yield large slabs, and burn into a good lime, of which much is employed in agriculture throughout South Devon : organic remains but seldom occur ; I have seen only *Stromatopora concentrica* or *polymorpha.*

§ 4. *Lower Limestone of Ashburton.*—This great calcareous band of limestone closely resembles the foregoing in character and appearance ; it has also much carbonaceous matter in seams, in which respect it is very like the limestone of Bunker's Hill, near Totness ; and in both cases the vegetable matter seems due to marine rather than to terrestrial vegetation, as the only impressions I have found are those of fucoids. Fossil shells (Brachiopoda) and corals (Cyathophylla) are abundant, but the close compact structure of the rock renders it impossible to obtain detached

* Exposition Méthodique; for the other works referred to, see the titles in the notes to p. 466.

specimens ; the *Favosites** ? *ramosa*, however, appears as plentifully as at Plymouth and Chudleigh.

II. Igneous Rocks. (Map, Pl. XLI. Sect. Pl. XLII. figs. 1. to 4, and 6.)

Earliest Epoch.

§ 1. *Interstratified.*—The earliest proofs which we perceive in South Devon of igneous agency are the numerous bands of hornblendic matter and ashes interstratified with the older slate rocks.

In the coast-section at Babbacombe, trap rests on beds of shale ; and near the level of the sea (fig. 1.), the trap presents a rounded undulating surface, to the outline of which other beds of shale conform ; but the enclosing strata, neither above nor beneath, afford any indications of intrusion, or alteration by heat. Limestone shale, succeeded by compact limestone, followed the deposition of the trap ; the whole series dipping in one direction, and the disturbances which affect this part of the country being clearly of more recent date than the trap. Mr. De la Beche, it must be admitted, considers the trap at this place to be intrusive, and to be the cause of the dislocations ; but in the numerous instances which South Devon presents of undoubted eruptive masses, the mode of association is very different. All we have here is a gradual change from one rock into another, which cannot be better given than in the words of Mr. De la Beche's description : " The trap becomes so altered in its character as it ascends, that the highest portions scarcely deserve the name, presenting, where not in contact with the limestone, a base that effervesces, contains green specks and iron pyrites†."

To the west of Babbacombe the beds of trap again rise, and are followed by a much more considerable thickness of compact greenstone, which arching over forms the hill known as Black Head ; and the sea-cliff affords a section of the igneous rock with the underlying shales, &c. At Islam Farm this mass of trap, much reduced in thickness, is interposed between slates below and limestone above ; a similar position is to be observed at Chapel Hill, near Tor Moham, where in several places the trap can be traced passing from a bright green hornblendic rock into a harsh limestone with seams of ashes. From its very unequal thickness, this, and other similar masses, were probably erupted very near the spots at which we now find them.

In the neighbourhood of the little hamlet of North Whilborough, 3½ miles west of Babbacombe, igneous and aqueous rocks are similarly associated ; the trap putting on various forms and acquiring considerable thickness. In some places it is a compact

* *Caunopora* of Phillips, Pal. Foss. Cornwall, &c., 1841.

† Geol. Trans., 2nd Series, vol. iii. p. 168.

greenstone, in others a coarse hornblendic slate, and in both states it alternates with shaly limestone at the base of the great limestone mass of the above-named place.

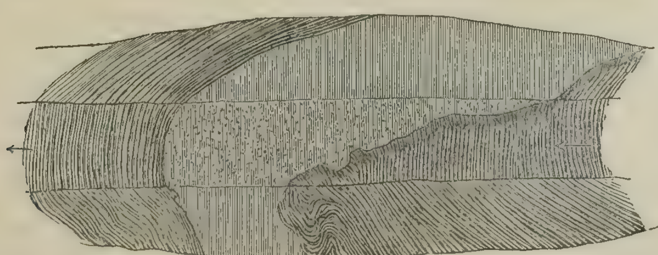
Another very instructive instance is to be found in the parish of East Ogwell. The lowest part of the trappean mass is there compact and crystalline, and rests everywhere on slate ; to this follow friable arenaceous beds, occasionally alternating with more solid ones, until they gradually give way to shaly limestone, which is quickly succeeded by the coral reef-limestone, so thickly developed in this and the adjoining parishes. These hornblendic beds swarm with organic remains, chiefly Fenestellæ, columnar joints of Crinoidea, and shells of Brachiopoda.

The contemporaneous trap rocks cannot be separated from the intrusive ones by inspection of mere hand specimens, particularly should they have been taken from the harder beds, for a crystalline arrangement is often as perfect in the one as in the other; even their included position, among sedimentary rocks, would be accounted for by some geologists (and equally erroneously) as instances analogous to phænomena which have been described from the coal strata of the North of England. But in addition to the evidence from included animal remains, which is not always available, the contemporaneous trappean beds, from having been exposed to precisely the same conditions with the associated deposits, present the same divisional lines both of jointed structure and slaty cleavage, as may be seen in the village of East Ogwell. (Pl. XLII. fig. 3.)

Similar contemporaneous trappean beds, the results of subaqueous volcanic action, occur at various intervals throughout the South Devon series : and such eruptions, occasionally accompanied with sheets of molten matter, and the subsequent dispersion by the action of the waves, as in the recent instance of Hotham Island, suggest that they originated by similar events at that distant period; submarine banks may thus have been formed where before was deep water, and thus the bed may have become suitable for animal life, and fit spots on which Polyps could fix and raise their structures.

§ 2. *Intrusive.*—The intrusive trappean rocks which the slate region of South

Fig. 13.



Ground-plan of a dyke intersecting slates near West Down, between Ogwell and Ashburton.

Devon presents are exceedingly numerous, and their eruption has produced very decided effects on the physical features of the country. They usually occur either at intervals along the ridges of hills, or at the points of conical elevations, in the form of protruding masses; and their injected nature is established by such natural sections as that presented at the break in the line of hill through which the Lemon stream flows past Holbeam Wood (Pl. XLII. fig. 2, Hobbin Wood, Ord. Map, two miles west of Newton Bushell), by the alteration which they have produced in the rocks which include them; or again by such horizontal sections as the one given in the woodcut, fig. 13, which represents the ground-plan of a dyke to be seen near West Down. In this instance it is very evident that the intrusion of the trap was subsequent to the time when the slates took their present structure. The whole line of the lower limestone band of Bickington affords numerous instances of intrusion of trappean rocks amidst slates and limestones; in the town of Ashburton, and in the street leading out to Buckland, is a large quarry in which broken beds are visible completely included in the greenstone.

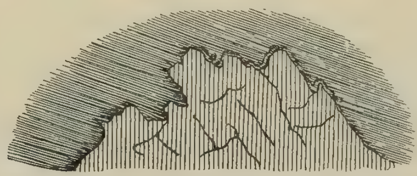
Wherever the trap produced a conical slate hill (a very common feature), radiating fractures necessarily resulted; and wherever these have been of sufficient width to allow the trappean matter to ascend to the surface, we have there a central mass with radiating branches, proving the fluid state of the injected rock: instances may be seen between Woodland and Bickington; road-cuttings, and other excavations, also expose the terminations of small veins which do not quite reach the surface.

The amount of alteration which the heated trap has effected, varies considerably. At Holbeam the dykes have quite obliterated the lines of deposition, and converted the slates into a compact flinty mass; at Bishopsteignton, where we may suppose the beds were originally in a slight degree calcareous, as they still retain traces of organic remains, the shales were reduced nearly to fluidity, and changed into a red jasper. Flexible asbestus often occurs at the junction of intrusive hornblende rocks with the slates, as at Highwick. In very many points also the eruptive trap rocks of South Devon resemble the Ophites of the South of France in the general outline of the country, producing lines of conical hills; they have been erupted in a fluid or semi-fluid state; they have possessed sufficient heat to have produced important changes on the rocks in contact with them; but they seldom have flowed over the neighbouring surface. Near Totness, in the quarry by the side of the Newton road (Pl. XLII. fig. 4.), is an exception; the trap is there seen resting on a dislocated surface of slate and limestone, and at one place the laminæ are much contorted, as if by the weight and lateral pressure of the trap: another instance occurs at Wear.

There are two mineral products which have resulted from these hornblendic rocks. Magnesia is abundant in those layers of limestone which immediately succeed the subordinate trappean beds; and from the large proportion of that earth in all hornblende rocks, we can easily account for its association with limestones which were deposited immediately after the eruptions that disseminated so much trappean matter in a state of subdivision at these particular places. Again, where great trap dykes have intruded among limestones, and long subsequent to their formation, as at Bickington, Ashburton, Bishopsteignton, Kitley, &c., the calcareous beds invariably contain magnesia. Manganese is also very abundant in South Devon, and great quantities are annually raised. In the majority of instances the metal is found in immediate association with masses of erupted trap, and filling the cracks and fissures which resulted from its intrusion, as at Denbury, Ideford, &c. The hornblendic are the only igneous rocks which contain manganese, and it is found in them from whatever part of the world they are brought. This circumstance would seem to indicate that the manganese has been given off by the trap; but the quantity of that earth contained in trap rocks has never been ascertained to exceed 0·25, whilst we constantly find bunches of metal of great extent and richness associated with dykes of inconsiderable bulk.

Fig. 14, which was taken from a road-section near Pulser, represents a mode of occurrence distinct from the cases already described; the mass of trap (*a*) is evidently intrusive, on account of the broken edges of the slate surrounding it, but it was, previously to its protrusion, compact and jointed. There is much trap in

Fig. 14.



Section near Pulser, junction of trap and slate.

the higher parts of the same ridge, which was evidently in a fluid state when it reached the surface. All masses in that condition at great depths, may have portions nearest to the solid crust in various stages of temperature, and some sufficiently cooled to be solid rock; so that whenever any disturbance should force the liquid mass amidst sedimentary deposits at the surface, portions of the mass which had already become solidified below, might also be brought up along with, or forced laterally among, such deposits. In this case, a greater amount of disturbance might be expected than when the entire body of trap was fluid; but at Petit Tor is an analogous case, where large angular blocks of limestone have been forced laterally into the slate, and have merely crushed the edges of the beds immediately about them.

Carbonaceous Epoch.

§ 1. *Interstratified.*—Volcanic products are interstratified with the beds of this series, in the same manner as in the older slates, presenting analogous mineralogical characters and modes of association. The phænomena indeed are identical, and prove, that in some quarters, volcanic agents continued in operation after that change (whatever it was), of which the character of the organic contents of the two deposits is the permanent evidence; being purely marine in the one, and partly terrestrial in the other. The broad and frequent bands which are associated with the lowest carbonaceous beds along their southern boundary, and which are more considerable than any trappean masses interstratified with the older slate rocks, seem to indicate that the change was accompanied by even increased volcanic activity. The contemporaneous trap of the carbonaceous period is however more local in its character, as it seems not only to be entirely wanting throughout the central portion of the deposit, but also along the northern boundary, among beds which in age we must consider to be the equivalents of the southern ones. These subordinate trappean beds may therefore be briefly described as ranging parallel with the southern outline of the carbonaceous series, and as partaking along the north side of Dartmoor of all the flexures and dislocations which the intrusion of the granite has produced. Good natural sections are exhibited along the course of the Teign, where that river cuts the beds at right angles to the strike; at Crocombe, near Chudleigh, fifteen trappean beds, varying from a few inches to several feet in thickness, alternate with black shales, and sections exhibiting similar phænomena may be obtained in many other places.

§ 2. *Intrusive.*—Though trap rocks have been erupted among beds of the carbonaceous series, the area occupied by the latter does not present, when compared with an equal portion of the older slate system, the same number of instances of intrusive masses. Beneath Ramshorn Down, $2\frac{1}{4}$ miles N.W. of Newton, are protrusions of greenstone, and the shales and flagstone are much altered; at Penwood, a little further east, the whole of a conical hill has been converted into flinty jasper; and at Hennock, $1\frac{1}{4}$ mile N.W. of Chudleigh, as well as Botter, great masses of erupted trap are in contact with, but do not enter the granite.

The igneous products hitherto mentioned seem to have been exclusively hornblendic, but the close of the carbonaceous period was marked by eruptions of a peculiar character, which produced the crystalline rocks of the neighbourhood of Exeter. This trap has been so often noticed, that no details respecting its mineralogical character are here requisite; it is simply a porphyry, generally red, only occasionally green, the base varying in texture from earthy to compact, and containing large crystals of that variety of felspar which has been made a distinct species, under the name of *Ryakolite*: near Silverton and some other places it contains a large proportion of mica, and some hand-specimens can hardly be distinguished from dark granite. This rock is seen at the eastern extremity of Great Haldon, at Dunchideock Bridge, &c., resting on the carbonaceous shales. It forms a considerable portion of Pocombe Hill, in which are several quarries; and on the western slope of the hill, the road exposes a good section showing the position of the porphyry resting on the smooth surface of the black shales; dipping as well as at the same angle with them: beneath the castle of Exeter, it rests on shales, from which place it plunges under the new red sandstone in the direction of Heavitree.

It has long been a favourite notion, that the lowest conglomerate beds of the new red series originated in a disturbed condition of things, and that in some instances, as in the case of the porphyritic rocks of Exeter, the true cause of the disturbance was apparent; it will be as well therefore to notice this rock with reference to such views. At all the above localities the porphyry rests on the undisturbed surface of the carbonaceous shales. A quarry yielding a very compact variety of the rock is worked on the summit of a hill at Western, in the parish of Ide: in this instance (one of those I believe adduced in proof of the association of the porphyry with the new red sand formation) the igneous rock would appear to rest upon the carbonaceous deposit, of which the lower part of the hill on every side is composed. The entire thickness of the porphyry has been cut through, and here, as elsewhere, it rests on carbonaceous shale; a section exhibited in a lane leading down to the stream near Dunchideock Bridge, might seem an exception to the above, and place a thick mass of porphyry within the new red sandstone; but I believe it to be the result of a small fault running parallel with the stream, and which has let down a portion of the porphyry to the west. As yet, I have seen no unexceptionable example of the Exeter porphyry resting on beds of new red conglomerate, but instances are abundant where the conglomerate rests on the abraded surface of the porphyry; and it must be remembered that the blocks of porphyry which enter so largely into the composition of the lower conglomerates, prove that the porphyry had cooled down into a crystalline mass before the production of the conglomerate commenced.

It will be seen, therefore, that this rock rests upon carbonaceous shales, and hitherto has not been observed to cut through them. It is found only in detached masses, placed at very different elevations, owing to the subsequent disturbances which have affected the district; and it has contributed largely to the sedimentary beds next in sequence to those on which it rests; and these reasons induce us to consider the few remaining portions of the rock as evidences of an extensive submarine eruption of felspathic lava which took place at the close of the carboniferous period, and long before the production of the lowest beds of the Exeter conglomerate.

The most recent trappean rock, so far as age can be established by association with beds of ascertained relative antiquity, is that of Wear. The experienced geologist is here quickly stimulated to look for those causes which produced the masses of crystalline limestone, jasper, and blocks of fused and altered rocks scattered over the surface of the soil, and built into all the walls, particularly in the vicinity of Bishopsteignton. A portion of the erupted trappean matter which has caused these appearances has been cut through longitudinally by the road from Teignmouth to Kingsteignton. In this section, the mass nearest Lower Wear is compact, and traversed by veins of quartz; about one hundred yards further on, is an included bed of hard and splintery slate, about fifteen feet thick; to the north of the road are several quarries, and in one of these the trap rests on the edges of limestone. Above Higher Wear included angular blocks of trap first appear, which in a short distance become so numerous as almost to form a conglomerate cemented by a trappean base; in a quarry at the east end of the section the trap assumes a columnar structure, and is very compact. By the map, Pl. XLI., the trap is seen to be the axis of a ridge, which has a direction from north-east to south-west; with slates and limestone resting against it on each side. The dyke can be traced by Colway Cross up to Rowdown Cross, a little beyond which it enters the new red sandstone: in the contrary direction it is just covered by a low rounded hill of shale, from beneath which it reappears at the level of the Teign at Clay-cellars: and on the opposite bank, owing to a fault in the direction of the valley, it forms a cliff of some elevation. The intrusive nature of the dyke is proved by the great changes it has produced along its course: the slates have lost their colour, and are either porous or baked and splintery; the limestone shales have been fused into jasper; the solid limestone has been crystallized to a very considerable distance from the dyke; the new red sandstone has been hardened into a compact mass, and the lines of stratification are in many places quite obliterated; but there are innumerable vertical fissures, which are coated with manganese. This altered rock is quarried above Bishopsteignton, as well as on the opposite side of the dyke, above Lindridge; and its course in the new red sandstone can be carried on by several abandoned excavations.

Certain appearances, such as that of the conglomerate above noticed, seem to require for their solution the supposition, that this was a subaqueous eruption; whilst the porous vesicular nature of some of the trap would indicate that the pressure of water was slight. With respect to the angular blocks contained in the compact greenstone, we must suppose that the liquid mass brought up with it from below, in the same manner as modern lavas, portions which had become solidified.

If the highly inclined position of the beds at Staple Hill, of which the upper portion is certainly post-cretaceous, has resulted from the local elevation of the slate on which they rest, and this elevation is owing to the great mass of trap which the hill contains, we ascertain the age of another band of erupted trap; and there are appearances exposed in a road-section on the opposite side of the same hill, on the way up to Ingsdon, which confirm this inference.

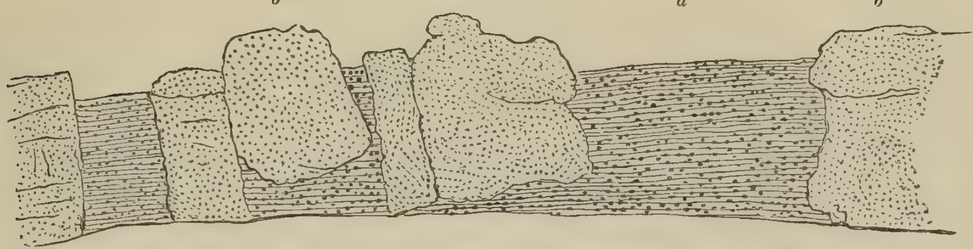
The granite of Dartmoor presents a similar composition and texture over the greater part of its area. The principal portion is porphyritic, containing large crystals of felspar, but its constituents vary locally in their relative proportions. At one place, near Oakhampton, is a very beautiful white felspathic rock, resembling pure trachyte: another form is that in which schorl takes the place of mica, as is the case along the edges of the moor, but I know of no spot where the mica is developed in such large plates as it usually is in most other extensive granitic masses. Wherever bare surfaces of this granite are exposed, as along the upper courses of the Teign and Dart, linear veins will be observed, filled with compact schorl. They are never very wide, and have the same direction (about east and west), which is that of one set of joints, but I have never seen a cross set so filled. There is another set of veins, usually much wider than the preceding, filled with matted crystals of quartz and schorl, which evidently occupy cracks opened in the rock after it had become hard and compact; and the growth of the contents of the fissure has been by successive additions from the walls on each side, until the two portions met, in the middle. Geodes also occur in the granite, lined with schorl, and crystals of quartz. Similar cavities have afforded large and beautiful specimens of tourmaline. These minerals give a very distinct character to a portion of the Dartmoor granite, which occurs universally along the edges of the mass and at various places within the interior, often forming tors, surrounded by a rock of a very different composition and appearance.

The granite of Dartmoor is altogether an intrusive mass; and it was stated by Prof. Sedgwick and

Mr. Murchison, at the meeting of the British Association at Bristol in 1836*, that it must have been erupted subsequently to the completion of the carbonaceous deposits, as along the northern slope of Dartmoor, about Oakhampton, beds of that part of the North Devon series had been greatly altered and disturbed by it. The same phænomena occur on the south. At Higher Alway, near Bovey, a branching vein of granite of considerable thickness extends a quarter of a mile from the main mass; and another vein may be seen at Lower Alway. At Ilsington, south-west of Bovey, a small mass protrudes through the carbonaceous shales, and the whole line of contact, along the southern flank of the moor, is an altered rock. In the upper part of the valley of the Dart, in the Holne Chase, numerous instances of granitic veins may be observed in the sides of the roads which have been cut through the woods, and the range of several smaller ones may be traced across the road at Ash, above Spitchwick.

The observation of Prof. Sedgwick and Mr. Murchison above quoted, as to the age of the Dartmoor granite, applies necessarily to that schorly portion alone which comes in contact with sedimentary deposits, for the entire mass is not of the same age. Fig. 15. represents a section exposed near Murcheton

Fig. 15.



Section near Murcheton. Porphyritic granite (*a*) intruded among consolidated granite (*b*).

and shows the manner in which the usual porphyritic granite has intruded itself among such as had already become compact and jointed, and containing schorl; and other instances occur in the same neighbourhood. Again, this porphyritic and micaceous granite is traversed by elvans of a compact, fine-grained stone, presenting no distinct crystallization of any of its constituents, and they have evidently been protruded posterior to the consolidation of the rocks in which they occur: good examples may be seen in the neighbourhood of Lustleigh, about six miles to the westward of Chudleigh. The Dartmoor region, like every other composed of plutonic rocks erupted on a great scale, presents fewer facilities for geological observations than inhabited and more intersected districts, but the facts, here noticed, warrant the conclusion that it contains granite of three distinct ages.

In Lower Normandy, on the opposite coast of France, where the geological features present so many points of resemblance with those of the west of England, the granite is an intrusive rock, and is generally supposed to be of no great antiquity; it is also intersected by trap dykes; in Devonshire, on the contrary, every dyke is cut off by the granite.

Dartmoor, as a physical region, presents two very distinct features: 1st, the great dome-shaped masses, of which Cawsand is the best illustration; and 2ndly, the long vertical walls, with lines of ruin and confusion, constituting the wild scenery about Lustleigh, and along the road from Bovey to Moreton. Viewed in connection with the Cornish masses of erupted granite, Dartmoor is the eastern

* See Athenæum 1836, p. 612, explanation of Section.

extremity of an axis of crystalline rocks, which, gradually decreasing in elevation and superficial importance, extends westward as far as the Scilly Islands. The general direction of the axis is about south-west to north-east, and we should naturally expect to find, in the undulations of the surface of these erupted masses, a general parallelism in conformity with this direction; such, however, is not the case, the whole surface showing north and south lines of hills, valleys and water-courses; a circumstance which suggests that the present outline and configuration of Dartmoor are the result of disturbing causes which have acted subsequently to its projection.

The Dartmoor mass of granite may be estimated as occupying about 200 square miles of surface: at Cawsand it attains an elevation of 2000 feet, but near Bovey it is exposed in the vicinity of secondary, and even much more recent formations little above the level of the sea; yet over the whole of this area, there is not the slightest appearance that any stratified formations were deposited; its deep valleys would certainly have presented some few traces of them, even allowing for extraordinary denudation, had the present outline of surface existed prior to only the cretaceous series.

In the study of detritic formations, the identification of mineral fragments becomes of almost equal importance with that of organic remains; in the present instance they afford only negative testimony; but as, from the absence of volcanic fragments in the conglomerate eocene beds of central France, we infer the relative age of the volcanic outbursts of that region, so, as no granitic pebbles have been found among the various materials of which the new red conglomerate is composed, we may conclude, that at the period of its accumulation the granite of Dartmoor could not have been exposed, particularly when we bear in mind that the two formations are at present separated only by the valley of the Teign.

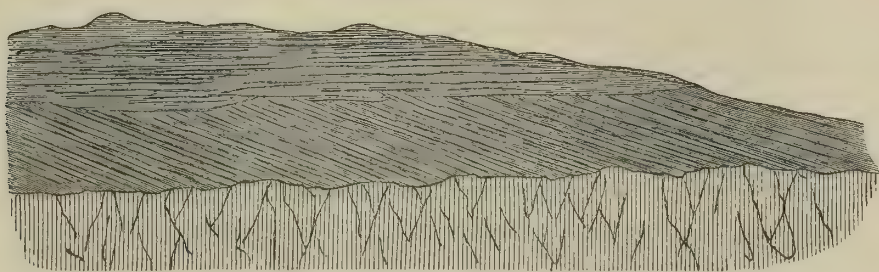
The beds of the greensand of the Haldons and the Bovey valley, in the thin mica, sharp quartzose crystals and seams of felspar clay, suggest that they may have resulted from a decomposed granitic district; but here again, although fragments of all the older rocks occur in the conglomerate beds at the base of the greensand, granitic pebbles are altogether wanting; nor do we meet with them until we arrive, in ascending order, at those superficial accumulations (p. 447) which cap the Haldons, when they appear in great abundance, associated with rolled flints, and worn like marine shingle. Possibly, then, the rise of the granite of Dartmoor in its present form may belong to a period comparatively recent, nor would such an inference be at variance with much that is already known: the granite of Arran, according to Professor Sedgwick and Mr. Murchison*, is more

* Geol. Trans., 2nd Series, vol. ii. pl. 3. p. 353, 1828; vol. iii. part 1. p. 34, 1829.

recent than the new red sandstone, and that of Brora, than the oolites. On the Continent, the observations of Elie de Beaumont*, Hugi†, Studer‡, and Dufrénoy§, show that in the Oisans, Bernese Alps, and Pyrenees, the central axes of granite must have been in a fluid state since the cretaceous period. In no part of the world can any granitic mass be proved to be of great antiquity,—an ancient fundamental rock; the masses which are now in contact with any of the palæozoic strata are all intrusive; and the granitic eruptions of the S.W. of England may be perhaps added to the proofs, already numerous, that this particular crystalline form was most extensively projected at the close of the secondary period, and caused or accompanied that contrasting condition of surface which the subsequent tertiary period must have presented.

Important changes have resulted in Devonshire from the intrusion of so many heated masses among sedimentary rocks, and some of these have been already noticed. The greenstone trap of Holbeam, Denbury, &c., very constantly obliterates the lines of deposition or cleavage of the slates. Fig. 16. represents a case to be seen in a quarry near Ogwell, where a great mass of trap would appear to have imparted diagonal lines to the slate. With the assistance of map, Pl. XLII., all the

Fig. 16.



Slate with oblique structure resting on trap near Ogwell.

various intrusive masses of trap will be so easily found by the field geologist, and the effects they have produced are so obvious at each locality, that any description in addition to what has already been incidentally given in other places, is not required.

Nor are less important changes exhibited in the neighbourhood of the granite: carbonaceous shales are converted into black slate; arenaceous beds become mica-

* Faits pour servir à l'Histoire des Montagnes de l'Oisans, Mém. Soc. Hist. Nat. de Paris, tome v. Mémoire pour servir Désc. Géol. de France, tom. ii.; also Dausse sur la forme, &c., de la chaine des Rousses, Mém. Soc. Géol. de France, tome ii. p. 125, 1837.

† Alpen Reise.

‡ Bulletin Soc. Géol. de France, tome ii. p. 51 *et seq.*, 1831; also Carte Géologique des Chaines entre les lacs de Thun et de Lucerne, Mém. Soc. Géol. de France, tome iii. p. 379, 1839.

§ Mém. pour servir Désc. Géolog. de la France, tome ii.

ceous sandstones, earthy hornblendic beds are rendered highly crystalline, as near Ilsington, and the associated strata abound with garnets; the development also of mica in beds which previously did not contain any (none occurring at a short distance) is very common. Some of the projected granite veins, which are usually composed of a homogeneous rock, hardly crystalline, terminate towards their points in a curious assemblage of plates of mica.

The old slates have been much altered along the line of the trap dyke near Bickington, N.E. of Ashburton, as may be seen where it crosses the summit of the high hill between that place and Ingsdon; the slate is also much changed, often passing into jasper. Large blocks of a similar altered rock are to be seen between Bickington and the bridge along the old road; also about Higher Wear on the Teign. These blocks, derived from beds of old slate affected by heat, are in one instance collected in great numbers, and of large size, along the summit of a ridge of carbonaceous sandstone and conglomerate, particularly at Hestow Farm, near Lindridge.

Cleavage and Jointed Structure.

Incidental mention has been made of those great divisional joints which traverse whole formations in given directions, and which are more particularly observable in the slate, limestone, and new red sandstone strata; besides these, the whole of the older series of South Devon rocks present what have been termed lines of cleavage.

Our knowledge of this branch of geological inquiry is exceedingly imperfect; it seems however to be generally supposed that the phænomena are due to the agency of heat, and an instance has been mentioned (p. 479) in which an intruded mass of heated trap may, on a small scale, have superinduced such a structure; and in further confirmation of this view, it will be found, that wherever the general appearance of the rocks in any particular spot indicates a greater degree of alteration than elsewhere, that there the subordinate lines of roofing-slate show an increased number of cleavage planes; and when we note the very great variation which the rocks of the same age may present in this respect, from one place to another at no great distance, we see enough to feel satisfied that such a structure can be no criterion of relative geological age.

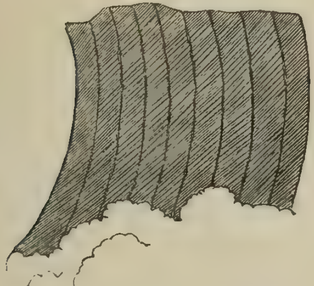
The superinduced cleavage structure of South Devon is as follows. In the south-east portions of the county the lines are in the same direction with the planes of deposition, and occasionally coincident, as at the Ingsdon Down and other quarries (Pl. XLI.); but very often, when at first sight such appears to be the case, a more careful examination shows that one set of lines crosses the other at small angles; and it is this structure which so frequently renders it difficult to procure perfect specimens of the fossils contained in those slates: thus the cleavage and bedding of the fossiliferous slates of Ogwell would be supposed to conform; but the cleavage planes are constant, whilst the bedding is waved, so that the agreement is only occasional. Throughout South Devon the planes which have a southern dip, and consequently a direction about east and west, are always the smoothest and best; on the Newton and Totness road, at Little Hempston, Staverton, north-west of Totness, &c., two planes or more may be observed, whilst in the slates N.E. of Plymouth there are as many as four systems of planes, all distinct from that of deposition.

This structure is not confined to the slate rocks, the cleavage planes passing equally through the subordinate bands of the contemporaneous hornblendic beds, as at East Ogwell (Pl. XLII. fig. 3) and Datton Mill; and affecting also masses of limestone of vast thickness, as about Gatcombe, two miles N.E. of Totness, and Bunker's Hill, where it is often difficult to ascertain the bedding in consequence of the more strongly marked lines of cleavage.

Many facts illustrative of the jointed and cleavage structures may be collected in that part of Torbay where the slate rocks come down to the coast between the limestone and new red sandstone.

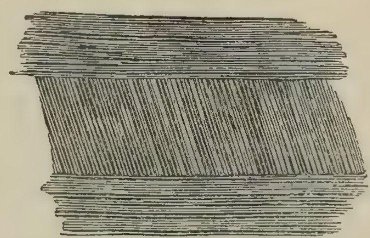
The great limestone masses about Brixham have similar cleavage planes, cutting through their entire thickness with striking regularity (fig. 17.); the bedding here being also very distinct. This structure is not confined to the old rocks of South Devon, nor is it any proof of their priority, as they do not alone afford roofing-slates. Throughout the carbonaceous series, slate-quarries are very numerous, but in no instance that I know of, are they worked parallel with the bedding. In a large quarry near Lew Trenchard, roofing-slates alternate with coarse flagstones (fig. 18.); the latter subdividing parallel with the

Fig. 17.



Cleavage in limestone near Brixham.

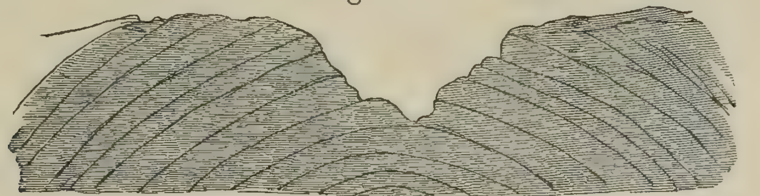
Fig. 18.



Oblique cleavage planes in roofing-slate (*a*), and horizontal in coarse flagstone (*b*) near Lew Trenchard.

planes of deposition, but the intermediate slates cleaving at a high angle. The contortions of this series of deposits are so constant and extraordinary, that illustrations of every possible position of the

Fig. 19.



Cleavage planes in arched strata near Yealm Bridge.

plane of cleavage, with relation to strike and dip, may be found often in a single quarry. The woodcut (fig. 19.) represents a section across the large slate-quarry near Yealm Bridge, at the back of Werrington Park, worked in arched beds of the carbonaceous series, and where the cleavage planes obviously conform to the lines of deposition at one place, and at another, within a very short distance, cut them at right angles. The older series of deposits which rise from beneath the carbonaceous beds on the north, if followed along the coast-section, exhibits the very striking fact of cleavage planes, with one constant angle and direction, cutting through strata of various mineralogical characters and most curiously contorted. The greatest amount of disturbance is to be seen in Morte Bay, where the bedding also is apparent, as well as the order of deposition of each stratum by means of lines of organic remains. Fig. 20. exhibits the manner in which these planes pass through some arched strata near Ilfracombe.

Most generally, the strike of the cleavage agrees with that of the beds, as in the older series just alluded to; but it will be found, that as soon as the carbonaceous deposits set on, as at Fremington, this strike alters and makes a small angle with that of the bedding: so also with the fossiliferous strata of South Devon; where, though the two lines of strike often coincide, they will yet be also found at various

Fig. 20.

Section of cleavage planes passing through bent strata near Ilfracombe.

angles to one another, and instead of dipping with the beds, to have an opposite inclination; in fact, the superinduced structure is everywhere much more strongly pronounced than the original one of deposition; and it pervades districts over which all order of accumulation is wanting, or more probably was never marked at all; so that the greatest caution is constantly required. There can be no question, that throughout large districts the cleavage lines have been given as those of stratification; such indeed was the case, only a very short time ago, with the whole of the Exmoor group: and calculations were made from these observations, which gave a thickness to some of the deposits entirely at variance with the conditions under which those strata were formed.

The few foregoing observations tend to show, that this remarkable change in the arrangement of the particles has not extended, in this part of England, to any beds higher than those of the carbonaceous series; and that it was superinduced subsequently to the disturbances which produced the contortions in all the older strata of Devon; and again, with reference to a given geological epoch, we know, from the materials in the lower conglomerate beds, that the process, as just stated, had been completed before the commencement of the new red sandstone formation; but there are also fragments in the Ugbrook strata which were derived from rocks possessed of a slaty structure; and the limestone blocks in the lowest beds of carbonaceous deposits at Rydon show that the limestone generally at that early time had its present crystalline, jointed structure.

Faults, Fractures and Dislocations of the Strata.

These phænomena are so familiar, that they require neither representation nor description beyond the statement whether any district under consideration presents such appearances, and if so, their degree of prevalence and general directions.

The whole of the county of Devon may be described as an assemblage of fragments of deposits, probably once continuous : it does not, that I am aware, present many of those vast dislocations which geologists have observed in other parts of the world, or even in this country, but the general amount of disturbance is extraordinary,—every quarry, every range of cliff, every artificial cutting for a road, or excavation for a dwelling-house, offering instances in endless succession. The vicinity of Dawlish may serve as an example (Pl. XLII. fig. 5.); but as to describe in detail the faults of such a district would be an endless task, the following observations relate more particularly to the connexion of faults, where such is possible, with the phænomena of those disturbing operations which successively placed the various rocks in the conditions and situations in which we now find them.

The surface of the new red sandstone district is remarkable for its undulations and deep combes. Many of these, it will be found, as exposed in the deep cuttings on each side of Dawlish, are not the result of mere excavation, but of elevation or depression; the angular inequalities, which must, in the first instance, have been produced, having been subsequently modified, as well as the hollows filled in part with the coarser debris, whereby an undulating outline resulted; and the upper surface never indicated the disturbance which can be traced beneath. (Pl. XLII. fig. 5.) At Watcombe, however, there is a fault which has evidently been produced since the rounding process was completed over the rest of the neighbouring district. The scenery at this place may be briefly described as the result of the subsidence of a tract half a mile in length, and less than a quarter in breadth, to much below its former level; leaving an open space bounded by vertical cliffs, one of which is of great height. The direction of the fault, from the coast inland, is due east and west, the amount of dislocation regularly diminishing; but soundings prove that it is continued with a like course beneath the sea. Should this spot ever be submerged, the angular summits of the cliffs would be soon removed; the larger materials would be collected below, in the same way as we now find them in the Dawlish valley, and on its next exposure as dry land, it would be in appearance a true valley of denudation, corresponding in every particular with those of the Sid, Otter, &c. The phænomena at Watcombe are just such as have recently been produced at Seton, except that, at the former, the amount of dislocation has been greater. The cause assigned for the Seton subsidence does not seem to be supported by concurrent evidence, even should it be deemed adequate; and, with respect to Watcombe, it is altogether inapplicable; whilst the east and west direction common to both, and other considerations, seem to point to some deeper-seated cause.

It may also be suggested, whether the arched strata at Petit Tor (Pl. XLII. fig. 1.), and the east and west vertical cliffs, may not have been produced by the same disturbance which caused the Watcombe fault. At the junction of the shales and limestone at Petit Tor, and at the level of the beach, good instances may be seen of the great pressure the beds experienced when the disturbance took place.

If the speculation as to the conditions under which the Bovey carbonaceous beds were formed be correct, and we couple with this belief the fact of several marine and estuary deposits having been raised, we must admit that, within a comparatively recent period, the surface of this part of England was placed at nearly its existing level, then at one much lower, and that it has again been raised to its present position. That the amount of oscillation has been unequal on different parts of the coast is most probable; but the greatest vertical movement did not much exceed seventy feet, and we may perhaps infer that such tracts as the ancient forest beneath Torbay, now permanently submerged, are portions which have not regained their former levels.

The whole of the west of England has experienced similar unequal movements, the amount of elevation increasing from east to west. Thus, the raised beds of the Dart (Staverton) are much above the level of those of the Exe; and still further west, as in Cornwall, they attain a much greater altitude; and indeed along the whole western side of Great Britain, the recent marine beds have their highest range.

The periods of these three distinct relative positions of the land with respect to the sea-level (which we must assume to have been constant) may be very distant from any historical times, but the forms of animal life were such as apparently have occupied this country only a few centuries back; and though the marine species contained in the raised marine beds seem to be few, which is but a negative fact, yet they afford no indication of a higher temperature than the present, and possibly the inference which I ventured to deduce in the account of these deposits may be ultimately established.

Intimately connected with this particular period, and intermediate between two distant faunas, are the marked effects of water moving in a definite direction, carrying along with it the loose surface materials, and filling the open fissures and cavities with debris. The traces of this action occur only at inconsiderable heights.

Antecedent to this, was a period when the country had a configuration exactly similar to the existing one, but was inhabited by races of animals which indicate a more elevated temperature than the present. Of the vegetation of this period, which we must suppose to have been different from that of the submerged forest of Torbay, not the slightest vestige has yet been found, though the requirements of the large Pachyderms would imply that it must have been abundant.

We know that during the period of those large Mammalia the fissures in the limestone rocks were open chasms: had they existed in that state whilst the denuding process was in action, and which laid bare the very beds traversed by the fissures, the latter must have certainly been filled with red sandstone debris; but, from the animal remains contained in the breccias, we learn that the chasms are of later origin, and were filled after the whole country had been in the condition of dry land for a long period. If we take the fissures of the Chudleigh country as a guide, we find that in every instance they have been opened along the lines of joints in the lime rocks: thus, the great mass of debris cemented by calcareous matter, which crosses the quarry at Chudleigh rock, like a huge wall of coarse masonry, is the contents of a north and south joint, from which the solid rock has been removed on each side: the same quarries afford many analogous instances. All the joints in a mass of arched limestone near Barton have been similarly opened and filled; and these, as well as all the fissures which are to be found along the base and west slopes of the Haldons, as at Orchard-well, Lindridge Hill Wood, &c., suggest that the strata must have been subjected to great tension, which caused them to yield along the joints as lines of least cohesion.

The whole period of denudation was probably one of slow emergence and gradual abrasion at successive levels; and that of the formation of open chasms towards the close of the same period, when the country reached its greatest elevation as dry land.

Along the entire line of the Haldons just described, there is abundant evidence of a great rise of the beds to the east; and the amount of this elevation is best ascertained by the relative position of the greensand deposits of Haldon and Bovey, which must have been at the same level, and under precisely similar conditions, when formed. The height of Little Haldon above the sea at Teignmouth is 890 feet; but at least half the thickness of the greensand of the Bovey valley must be below the level of the sea, so that there is a difference of 800 feet in the present positions of beds once continuous. This elevation took place perhaps slowly, but at the same time with that general rise of all the south of England, which happened towards the close of the tertiary period; and it is possible that previous to this event the whole was submerged as far as the high lands of the west of England; and I believe it was then that the pebbles of granite, schorl and quartz were distributed over what are now the summits of the Haldon and Blackdown hills.

Subsequent to this period of denudation, and under the same conditions with the fissures of the limestones, were formed those great fractures along one of which the Teign flows as far as Chudleigh, also the parallel valley from Bovey to Moreton, and the origin of which was evidently connected with the numerous abrupt movements that produced the deep valleys in the granitic region of Dartmoor, and which, being but little above the level of the sea, can have no great antiquity, as they are unoccupied by any sedimentary accumulations.

The lower part of the course of the Teign, like that of the Exe and many other streams, is through a valley of excavation along a line of fault; its course is due east and west, and it will be seen that the mouth of the Teign is the only point along the coast-section of the new red sandstone formation, where the strata have an anticlinal dip to the north and south (Map, Pl. XLI.). Higher up the valley, and on the north bank, opposite Combe-cellars, is a fault which for more than half a mile, in an east and west direction, brings up the slate in vertical juxtaposition with beds of new red sand; the downcast, as usual, being to the west, but the amount uncertain. Nearer Teignmouth the same fault may be traced through some conglomerate beds; and westward it ranges along the foot of the cliff of greenstone opposite Hackney claycellars, by Newton; and from Bradley to Holbeam Mill it traverses a great mass of limestone, in a zigzag course, owing to the rock having yielded alternately along its two sets of joints; beyond this it cuts a line of hill, consisting of slate with trap dykes: the direction of the hill is diagonal to the direction of the fault, which passes through at a right angle, but immediately resumes its course along the valley of the Lemon; still further it breaks the band of limestone below Bickington, then enters the carbonaceous deposits, and may perhaps be connected with some of the east and west faults, which, as at Owlecombe, become metalliferous as they approach the granite beneath Rippon Tor.

At Bickington and along its whole course (see map), the displacement of strata, both vertically and horizontally, is very remarkable, the beds on the north side of the fault being apparently shifted to the east.

The faults exhibited in the cliffs of Dawlish (Pl. XLII. fig. 5.) range westward in their inland course, and the lower beds of greensand on the Haldons are put at different levels, by faults having a like direction, and which traverse the superficial beds.

It appears therefore, that the more recent disturbances had a general east and west direction. In the description of the granitic region of Dartmoor it has been stated that very many of the lines of hill and valley, instead of conforming to the range of the several masses of Cornwall and Devon, have courses from north to south; and many of these lines of elevation extend from the granite into the area of the carbonaceous deposits on the north. The Haldon hills are on a line due north and south, and the proofs of elevation observable along the western slope have already been noticed; it was this disturbance which also opened the north and south joints of the limestone; and, parallel with the Haldons, is the greensand escarpment of the Blackdowns.

The course of the Exe, as low down as the head of the estuary, where it falls into another line of disturbance, is along a most extraordinary north and south dislocation, which, like the east and west fault already described, has severed beds once continuous, and to a much greater extent: numerous faults with the same direction range through the Blackdown hills*.

The character which principally distinguishes this system of faults, apart from direction, is the very great amount of vertical movement which the beds to the east experienced; thus we have seen that the greensand of Haldon acquired an elevation of 800 feet above that of the Bovey valley; and the displacement along the course

* This system of faults, which affects in a remarkable manner the Blackdown range and adjacent districts, was traced out and first described by Mr. De la Beche, in his 'Researches in Theoretical Geology,' and subsequently in his valuable 'Report on the Geology of Cornwall and Devon.'

of the Exe must also in places be very great. This system of faults, producing an upcast to the east, is proved to be referable to the tertiary period, by the beds which it traverses; and the movement was probably attended or produced by those causes which converted into dry land what before was covered by water, and imparted an uniform elevation to a great portion of the south of England, without reference to geological age.

The condition of things which had so long favoured the production of calcareous beds, and had allowed time for the segregation of the layers of flint, as well as the slow conversion of the calcareous shells and corals into siliceous casts, was succeeded by the partial destruction and removal of the chalk, whilst the uninjured state of the flints, which remain in place, shows that the process could not have been a violent one. That period of destruction immediately preceded the true commencement of the tertiary epoch, during which siliceous sands of considerable thickness were accumulated, and those internal changes took place whereby the siliceous breccias and grey-wethers were produced. To this again succeeded another extensive period of destruction and removal; the whole constituting a succession of events which indicate very variable conditions over the same place, and imply a long lapse of time.

The interval between the completion of the older series of rocks and the commencement of the new red sandstone period must have been very great. The early deposits, originally consisting of mud, ooze, or sand, had been placed in conditions by which great internal changes of structure and arrangement were superinduced; for in the materials which compose the lower new red conglomerate beds, we have abundant evidence that when the abrasion commenced from which the conglomerates resulted, the older deposits had passed into the same condition of compact siliceous rocks, fissile slates, and crystalline limestone which they now present.

We can never hope to know enough of the rate of increase of deposits at present in progress to serve as a guide in the important question of the lapse of time during geological periods; but as accumulations can only proceed *pari passu* with destruction and removal, it is perhaps in the action of breakers and the waste along our coasts that we have the most available means of approximating to the vast series of years during which our several formations were in progress; but of the intervals which elapsed from one to the other we can form no conjecture.

In certain instances destruction has been local, and evidently exerted over the same spot for a long continuance; thus the limestones of Babbacombe still preserve their massive tabular character; but close by, as at Petit Tor, the calcareous strata have been reduced to a few feet in thickness, of which the breccia is all that remains.

A very remarkable line of elevated strata, with a direction west 30° north to east 30° south, crosses the west of Devon, from Hope's Nose on the east of Torbay to

Stoke on the north coast of the county; and all the streams are thrown off on each side of the line. The high inclination of the limestone of Torquay and Chapel Hill is owing to this disturbance. The same direction is repeated in many places, including the boundary-line of the granite, from near Oakhampton to Botter, which runs parallel with it. The most striking line of depression apparently belonging to this system of disturbances, crosses the county from Barnstaple on the north to the broad estuary of the Exe on the south. The coast section, near the Tor Abbey Sands, shows that by this disturbance beds of new red sandstone were thrown into a vertical position.

Again, before the commencement of the new red sandstone period, these older strata experienced disturbances which produced an irregular outline of surface, and which, even in this limited district, have a very striking parallelism. The line of limestone cliff against which the new red conglomerate terminates, from Whiddon to Kingskerswell, ranges due east and west, as does the ridge of highly inclined limestone which protrudes through the new red conglomerate between Kingskerswell and Barton, and which was evidently thrown into its present position before the conglomerate strata were formed around it. The other protruding masses, as at Compton, Gallowsgate, and above Stanton, indicate the very unconformable condition of the two formations. Masses of limestone in places skirt the north and south edges of the red sandstone areas, as from Bulley Barton to Bowhill, and from Marldon to Wickaborough; and the whole of this portion of the new red sandstone area from Tor Moham to Bow Bridge*, as also that from Paignton to Blagdon, extend from the coast inland from east to west. The horizontal or slightly inclined position of these beds on the edges of the older red slates and sandstones may be observed in coast-sections in Torbay.

Further, the metamorphic rocks from the Start Point to the Bolt Head have been elevated along a line due east and west, and this disturbance apparently extends westward to the Eddystone rock, which is mineralogically the same with that at the Prawle Point. A valley corresponds to this line of crystalline rocks on the north, running from Start Bay to Bigbury Bay on the west, and at both openings of this valley with the sea, beds of new red conglomerate occur.

In the north of Devon and the adjoining parts of Somerset the older strata were also raised along an east and west line about the close of that period. In Morte Bay, where so many curious facts are to be observed, large blocks of igneous rocks are scattered over the beach, precisely at the place where the cliffs show that the strata have been greatly disturbed and altered. Lundy Island is placed on a line prolonged due west from this point, and as granite here throws up similar beds, it is

* The relative positions of the slate rocks and new red sandstone beds at this place, as seen in the road-section, require an east and west fault of considerable amount.

possible that to some extent, both in Devon and Cornwall, granite approached the surface during this comparatively early east and west disturbance. Some of the blocks on the beach in Morte Bay resemble the red porphyry of Exeter, which certainly belongs to the close of the carbonaceous period.

Parallel to the range of the older strata in North Devon and the west of Somerset there occurs in South Devon a line of elevated fossiliferous beds extending from Tintagel to Tavistock, and forming the southern boundary of the carbonaceous deposits.

The conditions suggested by the consideration of the great slate system of the west of England are those of slow and tranquil deposition, and an uniform condition as to depth; and the delicate markings which the casts of the various shells preserve, indicate the minute state of the sedimentary matter. We can never expect to ascertain the amount of dislocation and disturbance which such a system has experienced, owing to its uniform mineral character; but as we know, that in this very district, all the newer formations present such phænomena on a large scale, and that such disturbances have been propagated from below, the lowest deposits should exhibit the sum-total of the disturbances of every geological period.

The included limestone bands, as at Knowle, Broadhempston, and Little Hempston, of which a representation is given at fig. 9, Pl. XLII., will show that with the apparent uniformity, the result of cleavage, there may be much disturbance. The faults and contortions of the coral limestones may be observed in every quarry, and some instances in the neighbourhood of Torquay have been represented in the third volume of the Geological Transactions* by Mr. De la Beche. Near Broadsands in Torbay the red slates include a vein or bed, apparently composed of limestone pebbles; and though both the ground-plan and vertical section show it to be broken and heaved in several places, yet at a short distance on either side, it would be impossible to detect the disturbance.

It has been suggested (see *antè*, p. 477) that portions of the granite of Dartmoor may be of different ages: it certainly has partaken of all the disturbances of the district subsequent to those of an early period, with an east and west direction; and the highest portion, such as that of the Cawsand group, seems to occur at the intersection of two lines of elevation. The trappean bands of the slate system of South Devon and Cornwall; their abundance along the north skirts of Dartmoor, interstratified with beds which certainly were deposited before the intrusion of any granite; the remarkable lines of erupted trap on the south, running parallel with the present granitic axis of the county, and becoming less frequent as we recede from it, till in the southern slate district they are nearly wanting; and the great porphyritic mass of Exeter, at the eastern extremity of the same line, seem to indicate the continuance of igneous action along the same line, and through a vast period of time.

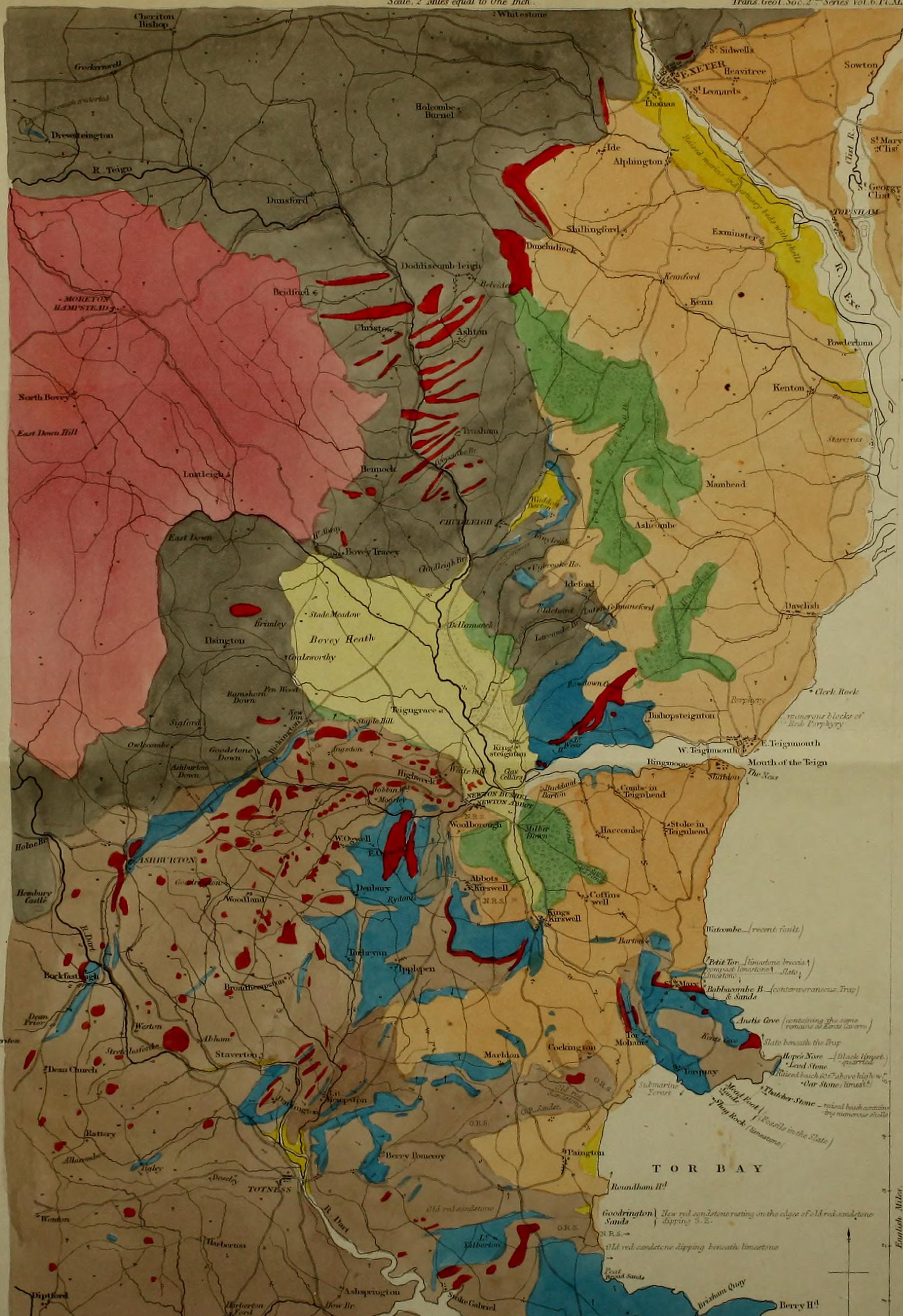
* Pl. XVIII. figs. 3, 4, and Pl. XIX. figs. 1, 2.

SOUTH EAST OF DEVONSHIRE.

TO ILLUSTRATE M[r] AUSTEN'S MEMOIR.

Scale, 2 Miles equal to One Inch.

Trans. Geol. Soc. 2[nd] Series Vol. 6. Pl. XLI.



SECTIONS TO ILLUSTRATE Mr. AUSTEN'S MEMOIR ON PART OF THE SOUTH EAST OF DEVONSHIRE.

John Arrowsmith.