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XXIII. *On the Form and Distribution of the Land-tracts during the Secondary and Tertiary periods respectively; and on the effects upon Animal Life which great changes in Geographical Configuration have probably produced.* By SEARLES V. WOOD, *Jun.**

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SECTION 1.—*Introductory.*

THE attempt to restore in description the outline of the lands and seas of a past geological period, although but in their broadest features, and from that restoration to draw conclusions as to results emanating from changes in the distribution of the continental tracts in succeeding periods, will probably in the present state of our knowledge be, by many at least, deprecated as illusory. The consideration, however, of a few leading principles to be observed in making such an attempt will, I trust, tend to remove from the minds of some such an impression, at least sufficiently so to induce a fair consideration of the views here put forward.

It is obvious that if any tract, large or small, be submerged or elevated by subterranean action, the relative levels of all parts of the tract would, if that tract were raised or depressed by a force exerted equally on every portion, remain the same, however frequently the elevation or depression occurred. Such an elevation or depression is, it is true, dynamically impossible, as all these

* Communicated by the Author.

elevations appear to have emanated from foci of force, where the volcanic action was the most exerted, or at least where it found the least resistance, and produced the greatest dislocations; in a word, the upheaval (however prolonged) of mountain chains, has converted large tracts falling within their influence into dry land. Now if we can in imagination remove the inequalities produced by any volcanic upheaval, and by so doing restore the surface as it existed before such upheaval took place, it is clear that we should remove the chief difficulty in arriving at a correct view of the relative configurations of the land and water during the antecedent period.

Again, consider how during every successive geological epoch since the close of the palæozoic period, but more particularly during the Jurassic and cretaceous epochs, the sea over the south-east of England and north of France has returned to the basin occupied by it during the immediately preceding geological period, where no anticlinal has interfered to change the relative levels of the surface: thus we see the outcrop of the jurassic and cretaceous formations, and even of the older tertiaries over this district, forming a series of concentric rings, the newer formation lying within the older*. If we can so plainly perceive this where powerful dislocations have taken place subsequent to the older tertiaries, which have not only interfered with the old and gradually narrowing sea-basin of the secondary and older tertiary seas, but reversed the very inclination of the surface, so that the land, from which came the sediment that supplied the clays and limestones of those ancient formations, now falls away to the west under the deepening water of the British Channel towards the Atlantic, how much more plainly ought we to perceive it in those parts of the world where the strata have remained over great areas undisturbed by anticlinals since they were deposited, as in Russia, North America, &c., places in which, if the tracts were now sufficiently depressed, the ocean would again wash almost the same coast-line which it did in the secondary periods. Even in England, which is a geological microcosm, and where a more regular succession of strata exists than in any other known tract of equal size, there is by no means that overlay of successive deposits to the extent that apparently exists, since not only does the whole jurassic series thin out as it recedes from those ancient lands the drainage of which formed the sources whence was derived the sediment of its deposits†, but the basins which the

* It is intended only to be said that this is the result of the geological changes since the commencement of the secondary period, broadly considered, as it is well understood that numerous local interruptions occurred in this order of events, causing local absence of some of the subordinate divisions of the several secondary groups.

† See Hull, Quart. Journ. Geol. Soc. vol. xvi. p. 63.

Jurassic and lower cretaceous deposits apparently fill are found to be traversed by anticlinals of anterior origin*, which formed either peninsulas or islands in the Jurassic and Neocomian seas that occupied the South-east of England, and parts of France and Belgium, during the formation of those deposits.

Further, we find, in the case of deposits since the palæozoic period, that almost all of them have been formed in the neighbourhood of land which has supplied the material for their composition. There are exceptions, such as the cretaceous and the nummulitic series of Europe and Asia; but even these fall far short of what we should conceive to be the bed of a great ocean, such as the Pacific, were it the case that deposits took place in it of a thickness sufficient to ensure their preservation on upheaval. It has been remarked by Mr. Darwin (Origin of Species, pp. 300 and 343) that seas have been seas, and continents have been continents, for periods far greater, geologically speaking, than we have been apt to assign for their existence.

In applying these principles to elucidate the broader features of the geographical configuration at any geological period, we have to bear in mind another and even more important fact, viz. the permanence through vast periods of the general direction of the lines of volcanic eruption over a whole hemisphere: I shall at a later stage of this paper enter into some detail upon this subject, and therefore only refer here to the fact of this permanence. Consider the chain of the Andes forming a line of volcanic eruption more or less active through near 60 degrees of the earth's circumference, and prolonged for an equal distance by the chain of the Rocky Mountains, and the almost continuous volcanic band extending from the Azores in a south-easterly direction to the centre of the Pacific, and we see that the development of volcanic eruptions has been exhibited with a permanence and persistency of direction over immense areas, and may therefore well assume that the influence of this persistence upon the geographical configuration of the period during which it prevailed must have been, perhaps beyond all other things, important and enduring. Into the causes of this persistency of direction during long periods I do not pretend here to enter, further than to remark upon the insufficiency of the adventitious action of percolated water upon the metallic bases to account for it. The fact so often mooted, of the contiguity of all active volcanoes to the sea or to great inland waters, is not only explicable on othe grounds, but is, I venture to suggest, the necessary concomitant of any elevatory action acting spasmodically like that of volcanoes.

* See Prestwich, Quart. Journ. Geol. Soc. vol. xii. p. 10; also vol. xiv p. 250; and Degousée and Laurent, Quart. Journ. Geol. Soc. vol. xii. p. 252.

If we admit that every elevation takes place at the expense of material removed from subterraneous places to the surface, the void thus caused must, even if we conceive a cavernous structure, be supplied sooner or later by other material subsiding into the cavity, so that in such case we may assume that every volcanic elevation is accompanied by a depression coequal in amount (although perhaps not in area), and also contiguous. Did mountain chains come into existence by one great catastrophe, instead of their being formed (as the evidence shows) by a multitude of minor and spasmodic volcanic outbursts, this contiguity would not so necessarily accompany the volcanic elevations; but the smallness of the effect produced by each volcanic elevation when compared with the sum of their action, as seen in mountain chains, shows that, upon the principle stated above, the depressions are contiguous. Thus, as it seems to me, every volcanic outburst has a tendency, by the contiguous depressions that it causes, to bring the drainage into its neighbourhood. This drainage is generally the ocean; but, as in the Caspian, it may be only waters having their origin from the surrounding land collected into the depressed area. And hence is it that great waters are not only contiguous to volcanoes at the present day, but that in all geological periods volcanic outbursts are associated with marine formations.

Section 2.—*The General Geographical Configuration of the Secondary Period.*

The volcanic forces which prevailed during the later part of the palæozoic period, at least during the carboniferous age, appear to have had a general direction from east to west. The convulsions which broke up the palæozoic deposits, and formed the mountain systems which governed the geographical configuration of the secondary period, have obliterated these features to a greater extent than have the tertiary upheavals obliterated those of secondary age; enough, however, remains to show this east and west direction in several well-marked and extensive anticlinals over the northern hemisphere which originated during the carboniferous period: witness the anticlinals of Nova Scotia, of South Scotland, of North Devon, of the Ardennes, of some of the Sierras of Spain, of Corbières in the Pyrenees*. The close of this period, however, appears to have been accompanied (or

* As to Nova Scotia, see Dawson, Proc. Geol. Soc. vol. iv. pp. 184, 269; Quart. Journ. Geol. Soc. vol. i. pp. 26, 322; vol. iv. p. 50; vol. vi. p. 349; vol. viii. p. 398; vol. x. p. 42. As to the Ardennes, see Austen, Quart. Journ. Geol. Soc. vol. xi. p. 533. As to North Devon, Scotland, and Spain, see Murchison's 'Siluria,' London, 1854. As to Corbières, see D'Archiac, *Bull. Soc. Géol. d. France*, vol. xiv. p. 507. In addition to which

probably was caused) by an entire change in this alignement: the volcanic bands which brought into existence the extensive mountain systems which are formed out of the palæozoic strata, broken up and thrown into parallel ridges of immense extent, obliterating almost entirely the alignement which the palæozoic strata had previously possessed, appear to have burst forth, not merely in one hemisphere, but over the whole world as far as hitherto examined, in a direction more or less from north to south, and to have maintained this direction during the whole secondary period. These old volcanic bands have left their evidences in several great systems which have been examined by competent geologists, and, there is reason to believe, in other mountain chains of similar direction not yet examined. The well-marked and examined systems consist, in the northern hemisphere, of the Alleghanies*, the Oural†, and of the system of Portugal‡ prolonged into the North of England; and in the southern hemisphere, of the great system of Eastern Australia §; of like origin with which appears to be the palæozoic and schistose system of New Zealand; and lastly, the grand systems of the Rocky Mountains || and of the Andes¶.

There seems reason also for inferring that the north and south ridges of Central and Southern Africa, crossed by the late travellers in that region (Burton, Speke, and Livingstone), of whose

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it may be added that, according to M. Abich, *Bull.* vol. xii. p. 116, a great east and west axis, presumably of carboniferous date (being formed of Devonian rock), traverses European Russia from the meridian of Smolensk to that of the Oural. M. Tchihatchef also describes similar axes running through Galatia and Paphlagonia (*Bull.* vol. viii. p. 312), and through the Antitaurus (*Bull.* vol. xi. p. 402).

* See Rogers, "Physical Structure of the Appalachian Chain," in 'Reports of Survey of Massachussetts,' p. 522 (Boston, 1838). See also Report on Geol. Explor. Pennsylvania, 1836, 1838, 1839, 1840, 1841. Report on Geol. Survey of Virginia, 1840, 1841.

† Murchison, Proc. Geol. Soc. vol. iii. pp. 398, 717. Also 'Siluria,' pp. 294 to 300, and p. 333.

‡ Sharpe, Quart. Journ. Geol. Soc. vol. vi. p. 135.

§ See Strzelecki's 'Australia,' Lond. 1845. See also Odernheimer, in Quart. Journ. Geol. Soc. vol. xi. p. 399. Clarke in same, p. 408. Selwyn, in vol. x. p. 299; vol. xiv. p. 533 (wherein the north and south strike of the palæozoic rocks and their unconformability to the secondary coal-bearing strata reposing on them is shown); vol. xvi. p. 147. Rosales, in vol. xv. p. 497 (showing the palæozoic strike below the drift).

|| See Hector, Journ. of Geograph. Soc. 1860; Edinb. New. Phil. Journ. vol. xi. p. 169; Quart. Journ. Geol. Soc. vol. xvii. p. 388. Shumard, Trans. Acad. St. Louis, vol. i. No. 3. p. 341.

¶ See Forbes, Quart. Journ. Geol. Soc. vol. xvii. pp. 38, 48. See also Darwin's 'South America' (1846), pp. 237–248, who at page 247 proceeds thus:—"Hence it would appear that the Cordillera has been probably, with some quiescent periods, a source of volcanic matter from an epoch anterior to our cretaceo-oolitic formation to the present day."

structure, however, we know nothing beyond the direction of their strike, will, when examined, present similar evidences of an origin at the close of the palæozoic period.

The way in which the secondary formations occur upon the flanks of these known systems, stretching from them in successive outcrops, indicate that throughout the secondary period the tracts falling within the influence of these volcanic bands were, with some interruption, undergoing a steady continuous elevation. Thus, to commence on the east with the Oural Mountains, we see that the elevatory action of that chain commenced after the close of the carboniferous period, but was in full action during the last age of the palæozoic period, the Permian, the deposits of which spread over large tracts, and that this action, prolonged into the secondary period, elevated the Permian deposits into ridges subordinate to the original ridge of the Oural but parallel with it, while the Jurassic deposits were formed in the same but diminished basin as that occupied by the Permian Sea, these now lying within the Permian deposits in a concentric form, precisely as we see the secondary deposits of England and France forming successive concentric rings of outcrop diminishing in the direct ratio of their age. The system of England and Portugal, although not so marked as the uninterrupted chain of the Oural, is yet distinctly apparent from a consideration of the manner in which the secondary deposits in those countries are assembled. The chief part of the Portuguese system appears now to have disappeared under the Atlantic; but the Jurassic and subcretaceous deposits which, fenced on the east by the schistose region of Eastern Portugal and Western Spain, occupy the littoral region of Central Portugal, have been shown by the late Mr. Sharpe* to have a regular outcrop along a line of strike from N. by W. to S. by E., in which the earliest-deposited Jurassic formations were elevated at intervals into ridges having this direction until the cretaceous age; while in England we find this line of the Portuguese strike traversing the island, and becoming conspicuous in the midland and northern counties of England, the volcanic outbursts appearing in the trappean beds of Skye, which there alternate with oolitic deposits. The elevatory effect of this band upon the formations of the great secondary gulf of England and Northern France I have before alluded to, in the concentric outcrop of the formations deposited in that gulf, which, like the Oural region and the secondary tract of Portugal, exhibit a gradual and successive elevation and desiccation of the sea-bottom during the whole period, at least until the cretaceous epoch.

Passing westward, we find under the Atlantic, within the

* Quart. Journ. Geol. Soc. vol. vi. p. 135.

distance of 400 miles from the Irish shore, ridges of considerable elevation apparently parallel with the line of Portugal and England, terminating with an abrupt declivity of upwards of 7000 feet, which would appear to be the western escarpment of the Anglo-Portuguese system. Crossing the immense valley which is occupied by the Atlantic between this point and the American shore, we find a magnificent development of parallel secondary movements in the Appalachian chain and the deposits flanking it. The elaborate surveys, by the State surveyors, of the Atlantic border of the Appalachian chain, and of that chain itself, enable us to speak with precision of the phenomena attending the development of the secondary formations of that region. The parallelism of the ridges into which the palæozoic deposits have been thrown in the Alleghanies is perhaps even more marked and persistent than in the Oural chain; and the persistence of outline of the shore of the secondary oceans, exhibited by the successive outcrop of the secondary formations along the littoral border of the Alleghanies, is almost uninterrupted, and so nearly coincides with the present Atlantic shore, that if the whole region were now to be depressed to the level it occupied during any age of the secondary period, the sea would again wash a coast-line agreeing in its main features with the outcrop of the formation of that age. We see represented here the same features that occur in England and France, viz. the return of sea after sea, from the Jurassic down to and including the older tertiaries, to the same, though in most cases shrunken, bed as that occupied by its immediate predecessor. This is most conspicuous in Virginia and the States to the south of it, the outcrop of the tertiary and secondary strata successively disappearing under the Atlantic as it advances northward. Here also we see that successive desiccation to which I have adverted in the case of Russia and England and Portugal; but the succession is less regular in the Alleghany region, the newer secondaries more generally overlaying the older, and exhibiting a greater alternation of level than is the case in Europe; indeed so considerable has this alternation been, that the equivalents of the middle secondaries of Europe have not been well made out, being mostly either absent or else hidden by the overlay of the newer secondary (cretaceous) deposits.

The investigations and explorations of Marcou, Shumard, Swallow, Heyden, Meek, and many other American geologists and explorers of the formations on the western flank of the Appalachian chain warrant an inference that the secondary sea, particularly during the cretaceous periods, swept round the southern termination of the chain and filled the area now occupied by Texas, Kansas, and the Indian territory, extending thence

northwards along the eastern side of the Rocky Mountains to the Polar Sea; the Alleghany region forming a great peninsula pointing southwards, and joined to a continental tract occupied by what is now the palæozoic region of the northern and north-western states of America and of Canada, and the crystalline region of the Hudson Bay territories, but separated from the Rocky-Mountain region by this secondary sea. Here, again, the same changes of level during the secondary period which the Atlantic flank of the Appalachian region presents seem repeated, the newer secondary (cretaceous) formations so overlapping the middle and older secondary that they are mostly found reposing here on the palæozoic,—the middle and older secondary formations being either absent or so far obscured that, in the present state of their knowledge of this region, the American geologists are at issue whether any formations really referable to the middle and older secondary periods have yet been found west of the Alleghanies*.

The extensive region of the Rocky Mountains, which includes within it the whole elevated tract between the Mississippi and Saskatchewan valleys on the east, and the Pacific on the west, was until recently almost an unknown region; but the report of Dr. Hector†, who, under Palliser's expedition, made a rapid survey of part of this chain, shows that, like the Alleghanies, the core of the chain consists of mural precipices of highly inclined palæozoic formations, flanked with secondary deposits lying quite unconformably on them, and stretching away from the chain with a very easy dip, the development of the cretaceous formation being such as apparently to have filled the whole valley lying between the Rocky Mountains on the west, and the palæozoic system of the United States and Canada, and the hypersthene system of the Lake and Hudson's Bay region on the east, from the coast of Texas on the south, to the Polar Sea on the north. Here again, therefore, is exhibited a yet more marked continental alignement from north to south during the secondary periods.

There remain to be noticed the great systems of the southern hemisphere, and first that of Australia. Considerable progress has been made by the surveyor of one of the eastern colonies of

* See Marcou, 'Geology of North America' (Zurich, 1858); his views are, however, repudiated by the American geologists. See Dana, in Silliman's Journal, vol. xxvi. p. 323. Heyden and Meek in same, vol. xxvii. pp. 35, 219. This overlay of the cretaceous deposits in many parts of the northern hemisphere, together with their great extent there, appears to indicate that extensive subsidences in this hemisphere preceded that general change in the geographical alignement which in the third section I propose considering.

† See Note ‖, *ante*, p. 165.

Australia in the examination of their geological features. The similarity of these features over a large tract, coupled with the exhibition of similar features wherever exploring vessels have examined the eastern sea border, favours the inference that the whole of Eastern Australia is one geological system composed of disrupted palæozoic formations, and having a strike throughout from north to south. The resemblance of this structure to that of the Appalachian and Rocky-Mountain chains is striking. Here, as there, the Devonian and carboniferous deposits have been broken up into numerous parallel ridges from north to south, showing the origin of the system to be subsequent to the carboniferous period, but prior to the deposit of the coal-bearing strata of this continent, which, like those of India, appear to be of secondary age, these coal-bearing strata resting in Australia unconformably on the true carboniferous and older palæozoic strata*.

The schistose system of New Zealand seems evidently due to the same elevatory action as that which formed the Australian system, since the coast-line of that island is almost identical with the opposite shore of Australia in a somewhat lower latitude.

Lastly, we have the grandest mountain system of the world—the Andes—exhibiting similar features to the other systems above discussed. This chain exhibits the greatest constancy of direction of any, and in its extent it is unrivalled. The reports and sections published of this chain, the latest of which is the elaborate memoir of Dr. Forbes, show that this system, although still in the height of its activity, had its origin as far back as the oolitic period†, if indeed it do not eventually prove, as there is reason to believe, to have been brought into existence, like the Oural and the other systems to which I have adverted, at the close of the carboniferous epoch. The activity of this volcanic chain during the secondary period is shown by the formations of that period being interstratified with porphyries and other volcanic rocks; and the direction of the volcanic band is shown to have been, during the period, coincident with that of the present chain, by the circumstance that these secondary deposits, so interstratified with volcanic rocks of contemporaneous date, lie in a band from north to south between the palæozoic formations of the central or higher region of the Cordillera and the Pacific, forming a subordinate division of the chain of lower elevation, and comprising within it the greater part of the existing volcanoes of the Cordillera. It is worthy of remark also, as showing the identity of this system with that of the Rocky Mountains, that Dr. Forbes in the one, and Dr. Hector in the

* See Selwyn, Quart. Journ. Geol. Soc. vol. xiv. p. 533.

† See Darwin's 'South America,' p. 247.

other, have observed a remarkable absence, or at least rarity, of volcanic rocks penetrating the palæozoic portion or core of the chains, these rocks being developed in the lateral region where the secondary formations were deposited,—illustrating, I venture to think, the hypothesis mentioned in Section 1, that the contiguity of the sea (as shown here by the deposits) to the volcanic foci is due to the depressions caused by the volcanic action, its absence from those parts of the chains deficient in volcanic rocks being due to the steadiness of level there permitted by the absence, during the period, of volcanic disturbances. These two great systems of the Andes and the Rocky Mountains, although originating early in the secondary period, have preserved their alignement and activity until the present time; for although the Andes be the only one of them in which the volcanic force is still entirely active, yet the Rocky Mountains themselves, as well as the Cascade Mountains and the other Pacific-coast ranges (which are but the lateral and subordinate chains of the great Rocky-Mountain system), exhibit evidences of very recent volcanic activity*.

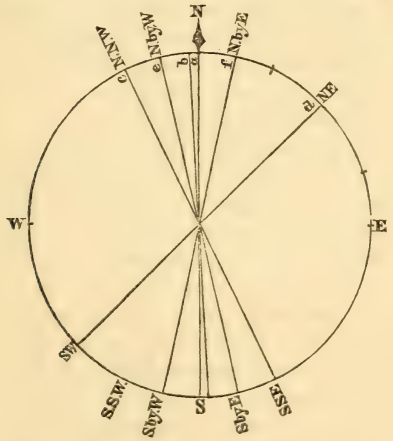
We thus see over half the northern hemisphere, and again in important parts of the southern, well-marked evidences of the continental development which prevailed during the secondary period, sufficient, I think, to justify an inference that during that period, when the chief part of the present Europeo-Asiatic continent and of Northern Africa was sea, the continents had an alignement from north to south as well marked as is the Europeo-Asiatic continent of the present day in the opposite direction (the great development of which from east to west being due, as I shall presently attempt to show, to the east and west development of tertiary volcanic bands), all the examples of great systems of secondary origin yet studied, with the exception of the Jura and of part of the Pyrenees (both of which originated very late in the secondary period), having this north and south direction. This inference will be greatly strengthened if further explorations should show that the north and south ridges of Central and Southern Africa, to which the configuration of that continent south of the Niger is due, and the north and south ridges of Madagascar are of contemporaneous origin with those of Australia, the Alleghanies, and the Oural, and contributed to the geographical configuration of the secondary period. In short, it may be asserted that the present configuration of our continents is due to the engrafting, as it were, upon secondary continents or their remains, of post-cretaceous land, elevated by mountain chains running from west to east which have come into existence since the close of the secondary period,—in some

* See Geology of California and Oregon, by J. S. Newberry (Washington, 1857). Bauerman, Quart. Journ. Geol. Soc. vol. xvi. p. 198.

cases, as in that of the Oural, incorporating them into the body of the new continent, but in others leaving them in the form of peninsulas extending north and south, as in the case of South America, or of insulated tracts, as in the case of Australia.

The following are the (known) important axes which governed the geographical configuration of the secondary period; the letters refer to the diagram below. Axes such as the Jura, which came into existence very late in the secondary period, and whose influence upon this configuration was but subordinate, or as the principal axis of the Pyrenees, which, although of secondary origin, preceded only the newer cretaceous epoch, and whose influence is rather to be considered among those to be discussed in the 3rd section as governing the post-cretaceous configuration, are omitted in this list and diagram.

	Direction.
a. Chain of Oural	N. to S.
b. Chain of Andes	N. to S.
c. Chain of Rocky Mountains . .	N.N.W. to S.S.E.
d. Chain of Alleghanies	N.E. to S.W.
e. System of England and Portugal.	N. by W. to S. by E.
f. System of Eastern Australia . .	N. by E. to S. by W.



[To be continued.]

XXIV. *On the Influence of Traces of Foreign Metals on the Electric Conducting Power of Mercury.* *By* A. Matthiessen, *F.R.S.; and* C. Vogt, *Ph.D.**

THE fact that mercury, when alloyed with traces of foreign metals, shows an increment, and not, as most pure metals,

* Communicated by the Authors.

sented by 25; or in other words, that *eight perimeters of the regular inscribed polygon of twenty sides* (and by still stronger reason, *eight circumferences of the circle* itself) *exceed twenty-five diameters.*

Observatory, March 7, 1862.

XXXVIII. *On the Form and Distribution of the Land-tracts during the Secondary and Tertiary periods respectively; and on the effects upon Animal Life which great changes in Geographical Configuration have probably produced.* By Searles V. Wood, *Jun.*

[Continued from p. 171.]

Section 3.—*The Changes in the Geographical Configuration which resulted from Post-cretaceous Volcanic Action.*

We have numerous evidences that, since the close of the secondary period, the volcanic energy has, with the exception of the chain of the Cordillera, its continuation in the Rocky Mountains, and the coast ranges of the latter, been exerted in a diametrically opposite direction to that which I have attempted to show prevailed throughout the secondary period, the tertiary bands having been, with these exceptions, from east to west. I have collected below the various tertiary geological systems and anticlinals of which I am cognizant, and also the existing volcanic bands, omitting the Andes, with the average direction they possess: the strictest accuracy in direction is not pretended, the point of the compass being given which coincides nearest with the general strike or direction of the chain or band.

The following are the systems or anticlinals whose direction is due to post-cretaceous action. (The figures on the left hand refer to the diagram.)

1.	The Antilles	E. to W.
2.	Venezuela and Trinidad	E. to W.
3.	The Isles of Portland, Purbeck, and Wight, and Weald of Kent	E. to W.
4.	The Pyrenees	E. to W.
5.	The Balearic Isles	W.S.W. to E.N.E.
6.	The Atlas	W.S.W. to E.N.E.
7.	Malta and Gozo	N.W. to S.E.
8.	The principal Alps, and the Noric Alps	E.N.E. to W.S.W.
9.	The Apennines, and the Julian and Dinaric Alps.	N.W. to S.E.
10.	Bosnia and Albania	N.W. to S.E.
11.	The Carpathians (Northern)	W.N.W. to E.S.E.
12.	The Carpathians (Southern)	W.S.W. to E.N.E.
13.	The Balkan	E. to W.
14.	The Caucasus and Crimea	W.N.W. to E.S.E.
15.	Armenia and Ararat	W.N.W. to E.S.E.
16.	Galicia and Cappadocia	W. by S. to E. by N.
17.	The Turco-Persian frontier	N.W. to S.E.
18.	Crete	E. to W.

19. Cyprus	E. by N. to W. by S.
20. Himalayah	W.N.W. to E.S.E.
21. The Salt-range, Punjab	W. by N. to E. by S.
22. The Trappean range of Nerbudda	E. by N. to W. by S.
23. The Lebanon and Anti-Lebanon	N. by E. to S. by W.
24. Corsica	N. to S.

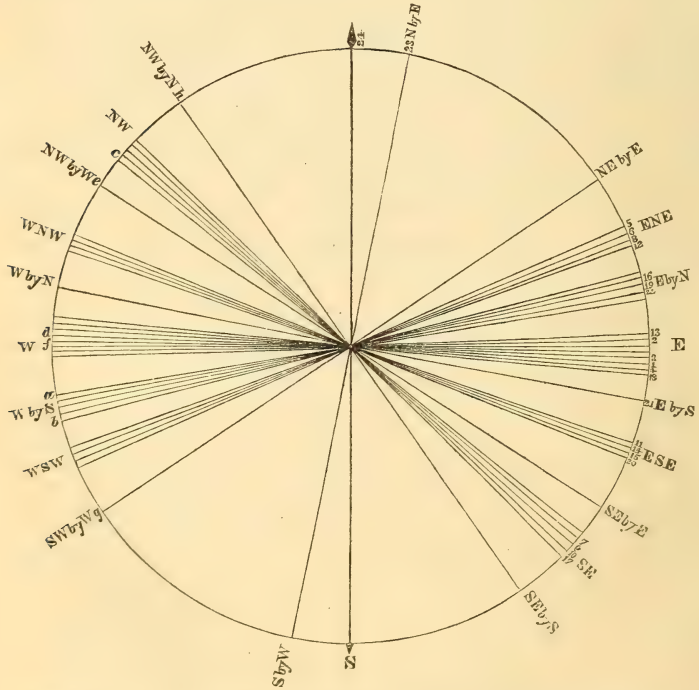
The following are volcanic bands. (The letters on the left hand refer to the diagram.)

a. The Aleutian Isles	W. by S. to E. by N.
b. The Canaries	W. by S. to E. by N.

The band from Andaman to the Society Isles, divided as follows :—

c. Andaman to Java	N.W. to S.E.
d. Java to New Guinea	W. to E.
e. New Britain to New Hebrides	N.W. by W. to S.E. by E.
f. The extinct band of South Australia and Victoria (Australia), extending probably to New Zealand	E. to W.
g. The band from the Aleutian Isles to Formosa, including Japan	N.E. by E. to S.W. by W.
h. The band from Formosa to the Moluccas	N.W. by N. to S.E. by S.*

The Andes, the Rocky Mountains, and the Pacific-coast ranges of North America are omitted.



* The following authorities may be consulted in reference to the ages of

It is remarkable how the general direction of all the tertiary anticlinals, with two exceptions, coincides with the direction of the existing volcanic bands (other than the Andes), the most im-

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the above systems, anticlinals, and bands, the numbers following referring to the corresponding numbers above :—

1. Heneken, "On St. Domingo," Quart. Journ. Geol. Soc. vol. ix. p. 115. Cuba, Yucutan, and the chain of active volcanoes crossing Central Mexico from E. to W. belong probably to this system.
2. Wall, Quart. Journ. Geol. Soc. vol. xvi. p. 460.
3. Weald : Hopkins, Trans. Geol. Soc. vol. vii. p. 1 et auctorum.
4. Durocher, *Comptes Rendus*, 1851, p. 163. Noulet, in same, 1857 ; also in *Bull.* vol. xv. p. 284. D'Archiac, *Bull.* vol. xiv. p. 507.
5. La Marmora, " On Majorca and Minorca." Turin, 1834.
6. Coquand, *Comptes Rendus*, 1847, vol. xxiv. p. 857. Nicaise, *Bull.* vol. viii. p. 263. As to the coast-ranges forming the sub-Atlan region, see the sections of Laurent's paper " On the Sahara," *Bull.* vol. xiv. p. 616. Consult also Pomel, *Bull.* vol. xii. p. 489 ; Ville, *Bull.* vol. ix. p. 362.
7. Spratt, Proc. Geol. Soc. vol. iv. p. 225.
8. Auctorum. See, however, Murchison, Quart. Journ. Geol. Soc. vol. v. p. 157.
9. Cocchi, *Bull. Soc. Géol. d. France*, vol. xiii. p. 226. Murchison, Quart. Journ. Geol. Soc. vol. v. p. 281. Ponzi, *Bull.* vol. x. p. 196.
10. Viquesnel, *Mém. Géol. Soc. France*, 1842, p. 35.
11 & 12. Boué, *Mém. Géol. Soc. France*, 1834, p. 224. Lilienbach, *Mém. Géol. Soc. France*, 1833, p. 224. Murchison, Quart. Journ. Geol. Soc. vol. v. p. 259.
13. The Balkan region is coloured cretaceous in Murchison and Nicol's Geological Map of Europe, but I have not met with the authority. See, however, Leonhard, *Bull.* vol. xii. (Old Series). Also Spratt, Quart. Journ. Geol. Soc. p. 79.
14. For Caucasus, see Abich, *Vergleichende geologische Grundzüge der Kaukasischen Armenischen und Nord-Persischen Gebirge*, St. Petersburg, 1858. Also in *Comptes Rendus*, 1856, p. 227. For Crimea, see De Verneuil, *Mém. Géol. Soc. France*, vol. iii. (1838).
15. See Abich, as above.
16. Hamilton, Quart. Journ. Geol. Soc. vol. v. p. 369. Tchihatcheff, *Bull. Soc. Géol. d. France*, vol. xi. p. 366.
17. Loftus, Quart. Journ. Geol. Soc. vol. xi. p. 247.
18. Raulin, *Bull.* vol. xiii. p. 439.
19. Gaudry, *Bull.* vol. xi. p. 120.
20. Strachey, Quart. Journ. Geol. Soc. vol. vii. p. 292, vol. x. p. 249. Vicary, Quart. Journ. Geol. Soc. vol. ix. p. 70.
21. Fleming, Quart. Journ. Geol. Soc. vol. ix. p. 192.
22. Hislop, Quart. Journ. Geol. Soc. vol. xi. p. 350. Sankey, Quart. Journ. Geol. Soc. vol. x. p. 55. Calder and Coulthard, 'Asiatic Researches,' Calcutta, 1833, pp. 13 and 47.
23. Botta, *Mém. Géol. Soc. France*, 1833, p. 135.
24. Collomb, *Bull.* vol. xi. p. 63.

f Smyth, Quart. Journ. Geol. Soc. vol. xiv. p. 227. Woods, Quart. Journ. Geol. Soc. vol. xvi. p. 253. Trans. Phil. Inst. Victoria, vol. iii. p. 85. Heaphy, Quart. Journ. Geol. Soc. vol. xvi. p. 242.

For the other volcanic bands, *a*, *b*, *c*, *d*, *e*, *g*, and *h*, see Mallet, Reports of British Association, 1852 to 1858.

portant and marked of which may be considered as parts of one large band, which extends from the Western Isles, with a varying breadth of from 10 to 20 degrees of latitude, through the Mediterranean, Black, and Caspian Seas, and is continued through Southern Asia, under the form of intense earthquake action, down to the head of the Bay of Bengal, and thence in its most active form through the Indian Archipelago to the centre of the South Pacific*. The general conformity in direction of the great tertiary mountain systems of Europe and Asia with that of this great volcanic band forms a striking coincidence. The reports of geologists upon most of the mountain systems of Europe and Asia show, with considerable precision, the part which these systems have played in the formation of the present Europeo-Asiatic continent.

I have in the introductory section alluded to the way in which the elevatory forces have been exerted in foci, forming volcanic bands and afterwards mountain chains, contorting violently the strata within a limited area only, but desiccating over great areas the pre-existing sea-bottom; thus it seems to have been with the bed of the cretaceous ocean, at least in Europe and Asia. Over the whole of Southern Europe and South-Western Asia the sections published show, with the exception of the Carpathians (where Sir R. Murchison has described the nummulitic deposits as resting unconformably upon the secondary beds), that the older tertiary and secondary formations, although thrown into the greatest disorder in the mountain chains, in some by older, but in most by middle and newer tertiary volcanic action, have a general conformability to each other. This, coupled with the well-known hiatus which exists between the fauna of the cretaceous and that of the older tertiary periods, justifies, I think, the conclusion that over the whole of this area the bed of the cretaceous sea must have been desiccated by the effect of elevatory forces having their foci separated by a wide interval, and the whole sea-bed (in order to have preserved its horizontality up to the time when it was again submerged to form the basin of the tertiary sea) have been formed into a continent unmarked by any considerable irregularity of surface. If the view advanced in the introductory section, as to the cause of the contiguity of the sea to volcanic foci, be well founded, this undisturbed condition of the desiccated bed of the cretaceous sea, coexisting with a gap in the geological succession of very great duration, is what we should *à priori* expect to find, by reason that, the volcanic bands of the period being remote from the area in question, an undisturbed permanence of level was permitted; and this level being that of dry land, we should find no formations until the area was again subjected to the direct action of the volcanic bands, and with that

* See Mallet, 'Reports of British Association,' 1852 to 1858.

to a return of the sea. We may to some extent trace the line of volcanic band to which this elevation was due (or rather in which it had its focus), along the northern border of the tract. Thus the great chain of the Northern Carpathians, although in convulsion during later tertiary periods, appears, from the sections of Sir Roderick Murchison, to have been upheaved, and the cretaceous strata to have acquired a considerable inclination, prior to the formation of the nummulitic deposits*. The Pyrenees also appear† to have undergone their principal elevation prior to the newer cretaceous period. Mr. Prestwich, again, has found reason to infer that the Weald anticlinal had begun prior to the close of the upper cretaceous formation‡. From these, and also from the system of the Jura or Côte d'Or, which, coming into existence in the early part of the cretaceous age§, possessed a direction from N.E. to S.W., or intermediate between those characteristic of the secondary and tertiary periods respectively, it appears that the movements which elevated the old secondary sea-bed, and brought into existence a continent which endured for a period long enough to change the complexion of the higher orders of the animal kingdom, had begun towards the close of the secondary period. To what other volcanic bands the elevation of this continent was due we have not at present the evidence to show; but the general conformity, between the tertiary and cretaceous beds in Southern Europe, to which I have adverted would point to these bands being further to the south than any of the places hitherto examined.

We see that the Maestricht, and also some other deposits of limited extent‖ which some geologists have referred to the newest cretaceous age, were formed in the contiguity of what appears to me to have been the volcanic band from which the elevation of the secondary sea-bed was proceeding; and their limited character thus becomes intelligible, as they would only endure during the comparatively brief period before the secondary sea-bed became converted into a continental tract, when, the volcanic forces to which that elevation was due becoming quiescent, no further deposits took place until these forces again burst forth and prevailed during the tertiary period over the areas occupied by the

* See the sections in Murchison, Quart. Journ. Geol. Soc. vol. v. p. 259.

† D'Archiac, *Bull.* vol. xiv. p. 507.

‡ Quart. Journ. Geol. Soc. vol. viii. p. 257.

§ See Lory, *Bull.* vol. xi. p. 780; Benoit, in vol. xv. p. 315.

‖ The equivalent of the Maestricht is said by M. Coquand to occur in the Charentes (*Bull.* vol. xiv. p. 571). The late Mr. Sharpe also referred some sands at Farringdon to the same epoch (Quart. Journ. Geol. Soc. vol. x. p. 176); but his views are disputed by others. See Davidson, *Bull.* vol. xi. p. 180.

mountain systems of Southern and Central Europe and South-Western Asia. The absence of deposits of a thickness sufficient to withstand subsequent degradation during a period of elevation has been urged by Mr. Darwin*; and if true (as it may well be in the sense of a general continental elevation, although not in that of the gradual shoaling of such gulfs as those which received the secondary deposits of France and England), we see in it an explanation of the limited extent of the newest secondary (supra-cretaceous) deposits, since it would only be on the skirts of the continent formed out of the cretaceous sea-bed where these would occur; and this skirt, except on its northern border, has not yet been explored. The intra-cretaceous and tertiary deposits would, I conceive, be taking place in the contiguity of any of the volcanic bands then in activity; and we may still therefore look for their discovery, unless they should now be beneath the ocean. The Cordillera of the Andes, Mexico, California and Oregon, places where, according to the views before discussed, the direction of the coast-line of America has remained since the secondary period unaltered in its main features, and perhaps even Southern India, offer probable sites for the occurrence of intra-cretaceous and tertiary deposits †.

We have seen that the conformability between the newer secondary and the tertiary formations, from the British Isles as far east as India, shows that the tertiary sea over that area returned mainly to the same bed as that occupied by the secondary sea; it differed, however, essentially in one particular, viz. in being shut in to the north by a barrier of land, no inconsiderable portion of which was composed of elevated cretaceous deposits: we find in the nummulitic deposits of Southern Europe, Northern Africa, Southern and South-Western Asia, the evidence of a vast gulf (interspersed with numerous islands) stretching from the Bay of Bengal north-west through Hindostan and Persia, across Asia Minor into Europe and North Africa, including within it the present Mediterranean, Black, and Caspian Seas; while, fringing the barrier of land which bounded it on the north, we find the richly stocked marine deposits of the English, Belgian, and French eocene basins generally associated with estuarine and fluviatile beds of contemporaneous age‡. Fringing land composed of elevated Jurassic deposits,

* Origin of Species, pp. 300 and 327.

† I entertain considerable confidence that some of the beds associated with the great lignite formation of North-Western America, California, and Vancouver will eventually prove to be of intra-cretaceous and tertiary date.

‡ The same association of fluviatile and estuarine beds with the nummulitic deposit seems to exist wherever an insular tract of land occurred in this gulf—as in the Pyrenees, where remains of eocene mammalia have been

and which in India bounded this gulf on the south, we have the nummulitic eocene beds of Cutch similarly connected with the fluviatile deposits intercalated with trap which occupy a considerable area in Western India. There seems to me every reason to infer that the suggestion of M. d'Archiac, quoted by Sir Roderick Murchison*, affords the true explanation of the phenomena presented, viz. that the eocene formations of Western Europe were but the littoral deposits of the great nummulitic gulf†, and were formed by the sand and mud of rivers debouching into the gulf at the spots where these formations occur, the deltas of which rivers have furnished the estuarine and fluviatile beds which are associated with these deposits. The mollusca of the eocene formations of England, France, and Belgium appear‡ to have all their affinities with the existing mollusca of the present Eastern seas (being those to which we trace the junction of the nummulitic gulf), but exhibit a dissimilarity to the mollusca of the eocene formations of America. M. Abich, in his 'Palæontology of Asiatic Russia' (*Mém. de l'Académie des Sciences de St. Pétersbourg*, 6me série, vol. vii.), figures thirty-two eocene species of mollusca, *of which twenty-six are*, he considers, *identical with English, French, and Belgian eocene forms*, two are given by him as indeterminate, and four only as new species, being respectively 81·25, 6·25, and 12·5 per cent. on the whole number of species described by him. These fossils, obtained from beds reposing on nummulitic rock and overlain by middle tertiary in the neighbourhood of the Sea of Aral, a district contiguous to the southern extremity of the Oural region (which formed the land fringing the sea these forms inhabited), lived at a distance from the English, Belgian, and French basins of upwards of 2500 miles, and strongly confirm the inference (arising from the outcrop across Russia of older strata uncovered by eocene) of a continuous coast-line joining these distant places, lying as

found. Similar fluviatile and estuarine deposits will doubtless hereafter be discovered associated with the eocene beds of the Aral Sea and Araxes. The return of the sea after the long intra-cretaceous interval to parts of its old secondary bed appears to have been very gradual, and the formation of the great nummulitic deposit to have been preceded by local tertiary formations, mostly fluviatile and estuarine. This, at least, was the case according to M. d'Archiac (*An. Foss. de l'Inde*, p. 77); his remark, however, admits of many exceptions, as the nummulitic deposits frequently repose immediately on the secondaries or other older rocks.

* Quart. Journ. Geol. Soc. vol. v. p. 301.

† MM. Hébert and Renesier also (*Bull.* vol. xi. p. 604) regard their upper division of the nummulitic deposit of the Alps as the marine equivalent of the upper eocene of the Paris basin, and probably also of the oldest miocene (Mayence, Limbourg, Sables de Fontainebleau, &c.).

‡ See Introduction to Eocene Bivalves, p. 10; Palæontographical Society's Volume for 1859.

they do under nearly the same latitude, this coast-line being what I have termed the northern shore of the great nummulitic gulf. It is worth observing, also, that such an identity of forms at so great a distance is, so far as I know, unexampled during other tertiary epochs (although it is conspicuous during the palæozoic period), and can hardly have existed, except by virtue of a similarity of conditions over the whole area and of easy communication by coast-line. M. Abich also describes the older tertiaries of the valley of the Araxes as containing a large proportion of the species of the mollusca common to corresponding horizons of the Paris basin, and, intermingled with them, many species agreeing with mollusca from India described by M. d'Archiac*, and containing also well-known forms of nummulites characteristic of the Pyrenean and other South-European nummulitic deposits. The proportion of the mollusca in the beds of the Araxes valley common to the older tertiaries of England, France, and Belgium is not so large as in the case of the beds of the Aral-Sea region; but the intermixture of Indian species much assists the proof of the continuous extension of the nummulitic gulf in the form I have described. The contiguity of the Aral-Sea region to the northern coast-line of the gulf (which, beginning perhaps to the north of the Indian beds described by M. d'Archiac†, extended to the Aral region at the extremity of the Oural chain, and thence to England) would account for the somewhat larger per-centage there of the shells of the basins of North-Western Europe. The beds of the Araxes valley, on the other hand, appear to have occupied a position more towards the centre of the gulf, in the vicinity of insular land (formed by the palæozoic plateau of that region which is uncovered by eocene deposits), but remote from the great coast-lines. The extraordinary range of the mollusca of the older tertiary period over the region filled by this sea tends, moreover, to show that the sea-bed formed by the submergence of the post-cretaceous continent—a continent which I have suggested was a vast tract uninterrupted by great mountains—was shallow over its whole area, the tertiary mountain chains of Southern Europe and South-Western Asia, which have since elevated portions of its bed into land, and deepened other portions into the Caspian, Black, and Mediterranean Seas, not having come into existence until a later date.

While we have thus evidence of a great gulf or land-girt sea stretching, at the dawn of the tertiary period, from the Bay of Bengal in a north-westerly direction to the British Isles, fringed

* *Animaux fossiles du terrain Nummulitique de l'Inde.* Paris, 1853.

† These beds are, Hala in Scinde, the Cashmere valley, and the range of Subathoo (part of Himalayan chain).

to the northward by a continuous shore, formed of deposits which had been land since the close of the secondary period, and closed from any connexion with the North American seas, we have in the Vertebrata of the period most satisfactory evidence of a continuous land-connexion between the American and the Europeo-Asiatic continents. Associated in the same bed at Kyson in Suffolk, there have been found remains of the *Macacus* (*Eopithecus*), an exclusively eastern genus of monkey, and the *Didelphis*, an exclusively American form of marsupial. In the fluviatile deposit of Hordle in Hampshire, the remains of a type of crocodile resembling the American form (the cayman) occur; at the not far distant locality of Bracklesham, in the marine though slightly older portion of the same delta, the true Asiatic gavial has been found; and in the London clay the true Eastern form of crocodile. In the same fluviatile of Hordle there occurs in the greatest abundance the remains of the peculiar freshwater fish the *Lepidosteus*, now an exclusively American form; and associated with these Vertebrata, a land-shell (*Helix labyrinthica*) now existing only in North America; and the river in whose deposits these forms occur, discharged into a sea containing mollusca whose affinities, as I have shown, are entirely with the East. Continuing eastward into Asia from the European termination of this Atlantic bridge, by following the line of secondary formations, which extend through Northern Europe and Western Asia uncovered by any eocene deposits (they having been already traced as far east as the Aral Sea), we perceive the wide stretch of land which at the dawn of the tertiary period connected the Asiatic region with America. The dissimilarity between the mollusca of the European and American eocene formations, to which I have already adverted, militates against any hypothesis of a coast-line joining the seas in which such formations were respectively deposited; and this agrees with what might be inferred from the indications afforded by the configuration of the secondary strata which skirt the eocene basins of England, Belgium, and France, which is, that the latter countries formed the head of the nummulitic gulf, the coast-line connecting England with the shore of the American eocene sea being on the other side of the land thus closing in that gulf.

The extension of the European continent westward at the dawn of the tertiary period, in the manner I have attempted to describe, that is, in the form of a tract cutting off the nummulitic gulf from the Atlantic, is further shown by the circumstance of the European and American fauna becoming more assimilated when they occur in formations which were due to the sediment of one common ocean, the Atlantic. Thus Sir Charles Lyell

long ago showed* the connexion of the American and European *miocene* formations by the presence of several marine molluscous forms in common. Now, the absence of any similar connexion between the eocene marine mollusca of the two continents, while so close a connexion exists between the terrestrial fauna of the eocene of Europe with that now existing in America, seems only intelligible upon the hypothesis of a land tract at once joining the continents, but severing the seas. That this land-connexion has been gradually disappearing since the eocene period, is shown by the agreement among naturalists that the molluscous fauna of the shores of the Western Isles, the Madeiras, and of Portugal, affords evidence of the extension of Western Europe in this direction between the miocene and the pleistocene epochs, forming a province to which they have given the name of Lusitanian†.

The probability of the configuration, at the dawn of the tertiary period, which I have described, receives support also from a consideration of the climatal conditions which the fossils of that period indicate.

It has not unfrequently been remarked, as inconsistent with any theory of a gradual refrigeration of climate during geological periods down to the pliocene, that the eocene fauna of Europe, both vertebrate and invertebrate, should at so late a stage in the geological succession, present at least as tropical a character as that presented by the fauna of any preceding stage in our latitudes. The explanation of this fact, standing out as it does at variance with any law of gradual refrigeration, should, I think, be sought in a consideration of the geographical configuration of the period. It is, with reference to this subject, also worthy of remark that we do not find this tropical eocene fauna extending up into high latitudes, as has been the case with the fauna of more ancient deposits, as the carboniferous of Spitzbergen and Melville Island, and even some of the secondary formations, whose fauna in our latitudes presents perhaps a less tropical appearance than does that of the eocene. In seeking the explanation of this tropical character of the eocene fauna of Northern Europe, we may refer to the existing conditions of such gulfs as the Arabian Sea and Gulf of Persia, the latter of which represents on a very small scale what I conceive the nummulitic gulf

* Proc. Geol. Soc. vol. iv. p. 554.

† See Forbes in 'Memoirs of Geological Survey of United Kingdom,' vol. i. 1846, p. 406 & pl. 7, who indicates the land as far west as the meridian of 30° W. See also Woodward, 'Rudimentary Treatise on Recent and Fossil Shells,' Weale, London, 1856, pp. 361, 385. See also this view, of the extension of the miocene land into the Atlantic, adopted, from other considerations, by De Verneuil and Collomb, *Bull.* vol. x. p. 77.

to have been. Now, the shores of these two seas or gulfs are the hottest of those of any seas on the globe, although the half of the former and the whole of the latter are extra-tropical. Let us conceive the nummulitic gulf thus extending from its mouth open to the tropical ocean at some point, how far east we have not yet materials to decide, but beyond the region of the Aral Sea, to its head in England and Belgium, and we may realize the effect which would result from that configuration. Not only would the tropical waters have free access and be closed by land from the contact of cold currents from the north, but the shores of this sea would be heated by the accumulation of land surrounding the greater part of it*, while at places on its shore the rivers which formed the deposits of the English and French and other eocene formations had their deltas, the more open portions of the sea furnishing the nummulitic deposits.

The view taken, that this formation of continent in the opposite direction to that theretofore prevailing commenced in the closing epoch of the secondary period contemporaneously with the first outbursts of the east and west bands which have governed the alignement during the post-cretaceous period (that is to say, with the band of the Pyrenees), seems supported by the greater approximation between the faunas of the eastern and western extremities of the Europeo-Asiatic continent which the newer cretaceous beds afford over those of the older and of the Jurassic deposits. The late Edward Forbes first remarked this in the comparison of the fossils from the cretaceous deposits of Verdachellam and Trinconopoly†, since which M. d'Archiac ‡ has found in the fossils of the uppermost cretaceous beds of Bains de Rennes, in the Pyrenees, a few species closely resembling forms described by Mr. Forbes from these Indian beds; and M. Abich also gives several upper-cretaceous forms from the Caucasus identical with, or closely resembling, species described from the cretaceous beds of England and France.

The remarks of Mr. Forbes on the fossils from Southern India are so germane to the views discussed in this section, and indeed lend so much support to them, that I am tempted by the weight always attached to the opinions of that deceased naturalist, to subjoin the following extract:—"Considered in regard to the

* The northern shore I have attempted to describe; the southern shore would be the peninsula of Southern India, where nummulitic or other marine eocene deposits do not occur, and probably Central Africa (which I have, in Section 2, referred to as land probably formed at the commencement of the secondary period), and that region, now sea, referred to in Section 4, containing the islands of Mauritius, &c., in which birds of the secondary continent have been preserved.

† Proc. Geol. Soc. vol. iv. p. 326.

‡ *Bull.* vol. xi. p. 202; see also his remarks, p. 204.

distribution of animal life during the cretaceous era, this collection is of the highest interest. It shows that during two successive stages of that era the climatal influence, as affecting marine animals, did not vary in intensity in the Indian, European, and American regions, whilst the later of the two [Verdachellam and Trinconopoly stage] had specific relations with the seas of Europe which are absent from the earlier [Pondicherry stage]. The cause of this remarkable fact is not to be sought for in a more general distribution of animal life at one time than at another, but rather in some great change in the distribution of land and sea, *and in a greater connexion of the Indian and European seas* during the epoch of the deposition of the upper greensand than during that of the lower. To this cause must also be attributed the peculiar tertiary aspect of the Indian collections, depending upon the presence of a number of forms usually regarded as characteristic of tertiary formations, such as *Cypræa, Oliva, Triton, Pyrula, Nerita,* and numerous species of *Voluta,* the inference from which, since not one of the species is identical with any known tertiary form, should not be that the deposits containing them are either tertiary or necessarily connected with the tertiary, but that the genera in question commenced their existence earliest in the eastern seas." By the expression I have copied in italics, the author, I apprehend, meant a greater connexion of the seas by a more continuous shore line, affording facility for migration of mollusca; and this, in order to join these regions, would necessarily be in an easterly and westerly direction. The origin of the characteristic eocene molluscous forms in the east, and their subsequent development westerly, thus suggested by Mr. Forbes, seems to me to lend support to the view that I have taken, of the connexion of the seas of Western Europe with those of Eastern Asia, in the form of a gulf stretching from Eastern Asia as far at least as the most westerly limits of Europe, at the epoch when the sea again occupied a part of the area which had been continent during the intra-cretaceous and tertiary interval.

If at the commencement of the tertiary period we find the evidences of a tropical climate extending northwards to the 52nd parallel, due to the peculiar geographical configuration of the period, how excessive may we conceive the climate of the intra-cretaceous and tertiary period to have been, when a vast level tract of desiccated sea-bottom, uninterrupted by mountain chains of any importance, extended through the whole region between the tropic of Cancer and the parallel of 50° N., from England on the west to the Bay of Bengal on the east, and (from the evidence of the eocene land-fossils) appears to have been continued westward in a lower latitude to America. Whether this

hypertropical belt of continent was continued eastward beyond the Aralian region, we have not any evidence to affirm; the opening-up of Central Asia will alone disclose this, and until then the limit of this extension cannot be realized; but it should not be overlooked that the great region of Oceanica, which Mr. Darwin has shown to consist of submerged mountain chains of immense extent, and to be now in a state of elevation and depression in alternate bands, is traversed by that great volcanic band to the operation of which has been due the formation of the major part of the Europeo-Asiatic continent, that is, the part which is composed of cretaceous and tertiary formations. It is to the extreme climate and widely different conditions to which this configuration must have given rise, that I venture to think may be attributed those complete changes in animal life which took place in the intra-cretaceous and tertiary interval. The effect of a continent stretching east and west, and lying in low latitudes, would operate not merely to exaggerate the terrestrial heat, and produce those interferences with the trade-winds which cause the monsoons and bring the alternations of extreme aridity and extreme moisture, but to affect the marine conditions by arresting the interchange of the tropical with the polar waters,—an example of the effects produced by such causes being now perceptible in the condition of the southern border of the Asiatic continent, and, to a less degree, in that of Africa, where the Bight of Benin washes its southern shore.

We have seen that, as in the palæozoic period, so in the secondary; the complete changes in the direction of the volcanic bands, which took place towards the termination of those periods respectively, did not occur absolutely at their close, but rather heralded it by occurring prior to the last of their epochs (assuming the Permian to be an epoch of the palæozoic period). In the former case, the changes occurred between the carboniferous and the Permian, and in the latter we have seen that the volcanic bands from east to west had come into existence, in the case of the Pyrenees, prior to the formation of the upper cretaceous deposits, while the system of the Jura (which seems to have originated during the cretaceous epoch, from the occurrence in it of detached portions of older cretaceous beds conformable to the Jurassic) possessed a direction midway between those opposite ones characteristic of the secondary and tertiary periods, being from N.E. to S.W. Both in the palæozoic and secondary periods, therefore, the complete changes in the fauna which marked their termination do not appear to have been immediate upon the changes of the geographical alignement, but to have required the lapse of an epoch for their fulfilment; and the completeness of that change is perhaps not less the indirect result

of the altered alignement, by the formation of continents where seas had been, and the opening out of new seas for the habitation of marine animals, thereby causing a gap in the geological records so far as they have hitherto been discovered, than the direct result of the changed conditions to which the inhabitants of the seas, and even those of the lands, came to be subject on account of the entire change in the alignement of the land over the globe.

[To be continued.]

XXXIX. *Theorems in the Calculus of Symbols.*

By W. H. L. Russell, *Esq.*, *A.B.**

THE following theorems in differentiation and integration may be proved by means of the Calculus of Symbols. They are a development of results which I gave in a Memoir published in the Philosophical Transactions for the year 1861, and will, I hope, be found interesting to mathematical readers. The proof of these theorems will be suggested by the original memoir.

$$x^{2n+1}\left\{\frac{d}{dx}+\frac{n}{x}\right\}^{2n+1}u=$$

$$\frac{d}{dx}x^3\frac{d}{dx}\cdot\frac{1}{x^2}\cdot\frac{d}{dx}x^5\frac{d}{dx}\cdot\frac{1}{x^4}\cdots\frac{d}{dx}x^{2n+1}\frac{d}{dx}\cdot\frac{1}{x^{n-1}}\frac{du}{dx}$$

$$\frac{d^{nr}u}{dx^{nr}}=\left\{\left(\frac{d}{x^{r-1}\,dx}\right)^n x^{nr+1}\right\}^r\frac{u}{x^{(n+1)r}}$$

$$\frac{d^{2n}u}{dx^{2n}}=\frac{1}{x^{2n+2}}\left(x^2\frac{d^2}{dx^2}\right)^n\frac{u}{x^{2n-2}},$$

$$(-1)^n\int\frac{dx}{x^2}\int\frac{dx}{x^2}\int\frac{dx}{x^2}\cdots\int dx\,x^{2n}\frac{d^nu}{dx^n}=\int dx\,.\,u$$

$$-n(n+1)\frac{1}{x}\int dx\,.\,xu+n\,.\,\frac{n-1}{2}\,.\,(n+1)\,.\,\frac{n+2}{2}\frac{1}{x^2}\int dx\,.\,x^2u$$

$$-n\,.\,\frac{n-1}{2}\cdot\frac{n-2}{3}(n+1)\,.\,\frac{n+2}{2}\cdot\frac{n+3}{3}\cdot\frac{1}{x^3}\int dx\,x^3u+\ldots,$$

the integral sign in the first member of the equation being repeated $(n+1)$ times.

* Communicated by the Author.

your notice, I thought you would perhaps excuse the liberty I take in addressing this communication to you. Of course it would be quite out of place and equally unnecessary for me to explain the philosophy of the matter here, or the difficulties connected with first attempts to break the eye of the habit of focusing itself according to the amount of convergence; but for the delight with which I, as a young student of astronomy, made the above observation, as also for my future independence of all stereoscopes, I feel greatly and entirely indebted to the course of lectures upon light. In performing the second of the two experiments named, so perfect a perspective inversion is seen in the case of landscapes, that one feels for the moment endowed with the fabled optical powers of the lynx, men being seen most distinctly through brick walls, houses, or even hills.

Hoping, Sir, that you will excuse the liberty I have taken in thus addressing so long a communication to you,

Believe me to be, Sir,

Yours very respectfully,

Richard T. Lewis.

LV. *On the Form and Distribution of the Land-tracts during the Secondary and Tertiary periods respectively; and on the effects upon Animal Life which great changes in Geographical Configuration have probably produced. By* Searles V. Wood, *Jun.*

[Concluded from p. 282.]

Section 4.—*The effect produced by the Post-cretaceous Geographical Changes upon the Secondary Fauna.*

If the foregoing inferences as to the respective geographical configurations of the secondary and post-cretaceous periods are well founded, the effect of the post-cretaceous changes upon the secondary fauna becomes more readily apparent.

An alignement of continent such as prevailed during the secondary periods from north to south, would, I conceive, necessarily have had the effect of assimilating the fauna of high and low latitudes in a great degree; a free and uninterrupted passage for currents of equatorial water along the coasts up into high latitudes, and the return currents from the poles, would have tended to the modification of the climate of the period, in the same way in which the western coasts of Europe and America are modified at the present day, and have produced that more equable rather than tropical character of climate which, it is now generally considered, characterized the prevalent climate of the secondary periods. The condition of the extreme lands of South America at the present time exemplifies the effect of the humi-

dity produced by this north and south alignement of continent upon the capacity of what are considered the inhabitants of warm countries to support a very inclement climate. Here is found the fuchsia having perennial foliage, but which when transported to the dry but less inclement climate of England becomes deciduous. Here also the humming-bird finds food, enabling it to continue through rain and snow, while within 10 degrees of latitude to the southward the snow is perpetual at the waters' edge.

The climatal effects of the contrary configuration are shown in the Asiatic continent, where the extremes of heat and cold alternately prevail in much lower latitudes than the southern point of America, and where in the tropical and hypertropical countries there are substituted for these extremes the equally trying alternations of extreme aridity and excessive moisture. It is true that at the present day the effect of a trend of continent from north to south, where it still occurs, does not, much as it modifies the climate, present us with conditions analogous to those afforded by the secondary period, as we cannot suppose that at the extreme southern point of America reptiles such as existed during the oolitic age could still exist. Nor is this to be expected, as allowance has to be made for the effect on terrestrial climate produced by the numerous mountain chains of great elevation which have come into existence since the secondary period, to which in point of altitude we find no approximation among the mountain chains of that period; for even the Andes (which during that period would seem to have been a chain of volcanic islands) could not have had an altitude at all approaching that which it has at present, since the secondary deposits now occur in it at a considerable elevation. Allowance also should be made for the effect on the temperature of the ocean, by the increase in the depths corresponding to this increased altitude of the mountains*. Besides this, we are not to lose sight of the principle of the gradual refrigeration of climates in order of time, however much it may have been interfered with by the distribution of land at different periods.

The extension, however, of a great equatorial continent, such as prevailed (as I have attempted to show) during the intra-cretaceous and tertiary periods, must, I conceive, have brought into existence a state of things the most opposite from that which prevailed during the secondary period which it is conceivable for geographical changes to produce. Continents upon which occurred those extremes of heat and aridity, alternating with excessive moisture, that are caused by the conversion of the

* See the views of M. Boué upon the heights and depths during geological periods, with his Table of them, in *Bull.* vol. xi. p. 62.

trade-winds into monsoons, which at the present day invariably occur in those continents that are washed on their southern border by tropical seas, would be no fit abode for terrestrial animals brought into existence under the opposite class of conditions, as were those which came into being during the long secondary period; and, as I shall attempt presently to show, the effect of the post-cretaceous changes was to raise into greater importance, during the tertiary period, those forms of terrestrial or fluviatile animals that are by their habits suited to sustain these altered conditions, and to destroy those which could support life only under the conditions of humidity and equable temperature prevailing when they came into existence.

Passing, however, for the present to the changes presented in marine animal life, we find one remarkable feature at the dawn of the tertiary period which appears to me to afford a clue to the entire change in marine vertebrate life that took place during the intra-cretaceous and tertiary interval; I allude to the disappearance of the tetrabranchiate family of Cephalopoda, with the sole exception of the Nautilus and Aturia, and to the preservation, and perhaps increase, of the dibranchiate Cephalopoda. We know that the Nautilus is a bottom feeder, and therefore *ex necessitate* a shore-follower; and there is reason to infer that the Ammonitidæ and other chambered Cephalopods of the newer secondary formations had similar habits: the abundance of these forms in those secondary formations which, like the lias, oolite, and cretaceous formations of England and Northern France, were deposited under littoral conditions, and in a partially land-locked gulf, supports this inference. We cannot suppose these chambered Cephalopods to have had habits in any way resembling the Dibranchiata, which at the present day are surpassed by no animal in their distribution over the ocean. This disappearance of the Ammonitidæ and preservation of the Nautilidæ, we may infer was due to the entire change which took place in the condition of the shores at the close of the cretaceous period; and this change was so complete, that such of the shore-followers as were unable to adapt themselves to it succumbed, while the others that adapted themselves to the change altered their specific characters altogether. The Nautilidæ having come into existence long prior to the introduction of the Ammonitidæ, and having also survived the destruction of the latter family, must have possessed in a remarkable degree a power of adapting themselves to altered conditions. It is evident also that ocean-rangers, such as the Dibranchiata, would be independent of those geographical changes; and these, again, are the forms which have been the most completely preserved, and which still exist as an important family*.

* The effect of geographical configuration upon marine life is shown

The disappearance of this great tetrabranchiate family affords, I think, the clue to the disappearance of the secondary marine saurians; while the development of the dibranchiate family has been commensurate with that of the Cetacean order, of some of which they form the food. The numerous family of Cestraciont fishes must have been mainly dependent upon a copious supply of mollusca for their food; and this most probably consisted mainly of the tetrabranchiate Cephalopoda, the means for the crushing of whose dense shells were afforded by the palate or tubercle teeth of these fishes. We may not unreasonably infer that the habits of fish feeding upon nearly stationary food, such as mollusca, would, unlike those of the Squalidæ, which now feed upon fish, have been sluggish. The marine Saurians, again, we may infer, procured their food from fish, and from those forms among them whose sluggish habits admitted of the easiest capture. Now the disappearance of the Tetrabranchiata, of the Cestracionts, and of the marine Saurians, was contemporaneous; and we can hardly refuse to admit that such a triple destruction must have arisen either from some common cause, or from these forms being successively dependent for existence upon each other. The habits of existing Squalidæ show that that order is not unsuited to a wide range remote from the shores, and thus independent of causes operating upon coast followers. The Squalidæ survived the post-cretaceous changes; but of the shore-followers existing at the cretaceous epoch, all the marine Sauria, all the Tetrabranchiata except the Nautilus and Aturia, and all the Cestracionts except the one-surviving Australian genus, perished between the cretaceous and the eocene epochs.

The changes of condition resulting from such an alteration in the geographical distribution as I have endeavoured to trace would, I conceive, by no means be confined to the marine fauna; its effects upon the Dinosaurian family by means of the extremes of aridity alternating with wet seasons, produced by monsoons parching up vegetation periodically, may be imagined if we reflect upon the prodigious amount of food required by the herbivorous forms of this order, and that the extinction of the herbivorous Dinosauria would involve that of the carnivorous. It is just those forms of Sauria which are suited to sustain these alternations of moisture and aridity which *did survive* the post-cretaceous changes, and still endure. The procœlian vertebrate form of Crocodile, which makes its appearance in the cretaceous deposits, has been throughout all the tertiary periods, and still is,

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notably in the case of the coral reefs, which occur almost exclusively on the eastern shores of the existing continents, although why this should be so we as yet know not.

the most important saurian; but the teleosaurian, or amphicœlian form of Crocodile, perished with the other marine Sauria with which it was by its structure of vertebra allied, whose habits it probably shared, and probably drew its sustenance from the same sources. The procœlian form, however, is and has been, through all tertiary periods at least, fluviatile or estuarine in its habits, and adapted by its vertebral column to sustain itself on land, and, inhabiting rivers, to draw its food from more than one source; this form also, by burying itself in mud, sustains periods of great drought by a species of hybernation, a habit partially shared by the peculiar reptilian form of fish (the Lepidosteus) which we find first appearing and in great abundance in the eocene formations.

These changes in animal life have been such as, reasoning *à priori*, one might predicate as likely to result from a change in geographical configuration from an alignement running north and south, producing a humid climate and an interchange of temperature between high and low latitudes, to an alignement from east to west with the land-tracts accumulated chiefly in low latitudes, producing a climate, not merely hot, but influenced by monsoons, which brought alternate seasons of moisture and aridity. Further, there is reason to infer that all the forms of terrestrial mammalia which are peculiarly adapted by migratory habits to obtain food in one region when, by the regular change of seasons, it has failed in another, of which the Ruminantia are the most striking example, have originated in that continent of which the Europeo-Asiatic one is a part, and which I have designated as the post-cretaceous continent.

The effect of the post-cretaceous changes upon reptile life, in extinguishing entirely several important orders and suborders, and nearly extinguishing others, was far greater than upon other forms of life. It is true that our knowledge of secondary warm-blooded life is as yet very limited; but none of the remains of that life hitherto obtained from secondary formations have been referred to any *order* not existing at the present day. It thus appears that the effect of the post-cretaceous changes upon animal life is commensurate with the degree in which that life is dependent upon climatal conditions. Reptilia at the present day are the most dependent upon climate, while Mollusca, Fish, and Mammalia are almost entirely independent of it; and the result of this dependence is, if the view put forward in the next section, of Australia being an isolated remnant of the secondary continents, be well founded, the state of change presented by the land and sea respectively of that country*.

* Of the orders of Reptilia at present known from the cretaceous deposits, viz. Enaliosauria, Pterosauria, Dinosauria, Crocodilia, Lacertilia, and

SECTION 5.—*The preservation, at the present day, of isolated remnants of the Secondary Continents, and of the Secondary Fauna inhabiting them.*

I have endeavoured to show that a remnant of the continental tracts of the secondary period appears in the present Australian continent. Now it is an important fact that, with the possible exception of the Stereognathus, the nearest living affinities of the Mammalia yet discovered in secondary formations exist in Australia and its adjacent islands*, and in Madagascar. Many of the trifid footprints from the red sandstone of the Connecticut valley are admitted to be those of birds; and Sir Charles Lyell states† that in the impressions of the skin in some of them, Prof. Owen has recognized a resemblance to the skin of existing Struthionidæ. We cannot any longer, I think, hesitate to admit, notwithstanding the absence of osseous remains, that birds having affinities with the modern Struthionidæ and Dinornidæ existed in the triassic period. It is therefore significant to find that these modern Struthionidæ exist only (with the exception of Sumatra) in lands which, I have attempted to show, are remnants of the secondary continents; and that as regards all the other modern wingless birds except the Struthionidæ, *i. e.* the birds of Madagascar, the Mauritius and adjoining islands, and of New Zealand, they exist only in *isolated* remnants of those continents: and not less significant is it, that these forms of Mammalia and of modern wingless birds are associated with vegetable forms having the nearest affinities to the vegetation of the secondary and carboniferous periods—as witness the tree ferns and Cycadæ of Madagascar, Australia, and New Zealand, and the Araucariæ of various parts of the southern hemisphere; while in the Cestracion and Trigonia of the Australian shores are preserved the only living examples of those secondary genera.

Chelonia, only the last three appear to have survived the post-cretaceous changes; the other existing orders, Amphibia, Batrachia, and Ophidia, may, however, be expected to occur in the cretaceous formations. Of the cretaceous fish, not only did all the orders survive these changes, but the suborders and families also, and even about a fourth of the genera; while of the Mollusca, about a third of the genera (including the Cephalopoda) only perished.

* Not merely Tasmania, but New Guinea and Arroo, which have been shown by Mr. Wallace to possess a fauna entirely agreeing with Australia, and differing as entirely from the islands of the Indian Archipelago near to them. These two last-named islands appear to have been very recently severed from the ancient continent of Australia by the oscillations produced by the intensely active volcanic band of the Indian Archipelago.

† Man. Elem. Geol. 1851, p. 298.

These coincidences have, it is true, been explained by some on the ground that Australia, like the secondary lands, was adapted only for such forms of life, and that the animals most fit to inhabit it have been specially created there; but this explanation fails completely before our daily experience; and the explanation of their occurrence must be sought on other grounds. The only explanation which appears to me to be consistent with all the phenomena of the case is, that in these lands we possess remnants more or less isolated of the secondary continents. I by no means pretend that any such coincidences warrant a conclusion that this isolation has been in each case from the same period. On the contrary, while the Mammalia of Australia (among which occur the only known forms of the true Monotremata, the Ornithorhynchus and Echidna) and the birds of New Zealand, coupled with the predominance in the latter country of the fern tribe, conspire to show an isolation of those lands from a remote part of the secondary period, the fauna of the island of Madagascar, comprising as it does (and almost exclusively) the family of the Lemuridæ, points to an isolation of that country at a later part of the secondary period*. It will be seen whether or not these conjectures are well founded when future discoveries shall have made us better acquainted with the secondary Mammalia, and particularly the triassic forms, the latter of which, I anticipate, will be found to have their affinities rather with those of Australia than with those of Madagascar. I should advert also to the occurrence of the Dodo and its kindred in islands forming but the peaks of a submerged mountain chain connecting Madagascar with India. The organization of these birds was most unfavourable to migration; and the submergence of a country inhabited by them must necessarily have reduced the birds, first to insulated tracts surrounding the elevated ridges, and lastly to the mountain peaks themselves, which became small islands, as are Mauritius, Bourbon, and Rodriguez, in the midst of the Indian Ocean†.

* See Lyell's 'Principles of Geology,' 1850, p. 610.

† These islands exhibit the very recent extinction of that volcanic action which has, as I conceive, reduced them from part of the mountain system of that ancient land which once united South Africa and Madagascar to India, into the condition of oceanic islands. See Maillard, *Bull.* vol. x. p. 499. These islands form, with the Cargados bank and the Chagos, Maldive, and Laccadive Archipelagos, a chain of submerged peaks parallel (as is Madagascar) with the eastern coast of Africa, and probably therefore part of the same geological systems which have imparted to the southern half of Africa and to Madagascar their geographical configuration—systems which, in Section 2, I have conjectured to be synchronous with the great known systems therein discussed—that governed the distribution of land during the secondary period, or at least then existing as part of the continents.

We find, further, that the only forms of wingless bird occurring in countries where the true Carnivora occur are those of the Struthionidæ; while, on the other hand, the lately exterminated forms of the Dodo and Pezophaps, the Dinornidæ and Notornis of New Zealand, and the wingless birds of Madagascar, have only been found to occur in lands where they have been secluded from these enemies, until, with the exception of the Apteryx, they perished at the hands of the most formidable of predaceous animals, Man. We are at no loss for the explanation why the Struthionidæ have sustained themselves in the face of these predaceous contemporaries; for the habits of wariness and swiftness of foot pertaining to this order of birds enable them successfully to escape the craft of man and the swiftness of his horse, and even the attacks of the lion. The gigantic birds of Madagascar and New Zealand have not yet been found to occur in Australia; but the presence of such gigantic forms of Carnivora in Australia as the Nototherium, may have been the cause of the extinction of these birds in that country, if indeed it were not man himself*. We see, further, that up to a certain period these gigantic birds survived upon the post-cretaceous continent, but hitherto they have not been found there in a deposit so recent as the period of the incoming of the true Carnivora. The Gastornis of the Paris Basin had, according to Prof. Owen, affinities with both the Notornis of New Zealand and with the Solitaire of the Indian Ocean, and it was perhaps almost as defenceless an animal; but we know of no more formidable Carnivora contemporaneous with that bird than the Hyænodon, and its allied Lophiodont carnivors.

Summary and Conclusion.

In the preceding sections I have endeavoured to deduce that the secondary continents, governed by the direction of the volcanic bands of the period, had an alignement trending nearly from north to south, and that this alignement had probably an important influence in the maintenance of the equable climates of the period; that while portions of these secondary continents have, we see, been incorporated into the post-cretaceous continents, other portions remain at the present day in a state of complete isolation, originating, however, at different dates; that an entire change in this alignement took place at the close of the cretaceous period, the east and west direction, in which the vol-

* That they will be found, however, to have at one time existed there I feel little doubt; indeed their remains are stated to have occurred in caverns near Melbourne. See Blandowski, Trans. Phil. Soc. of Victoria, p. 55.

canic bands prevailed during the carboniferous epoch, being resumed, and that this direction has prevailed to the present time, being that generally of the mountain systems and other anticlinals which have an origin more recent than the cretaceous period, as well as of the chief volcanic bands now in activity other than the Andean and Rocky-Mountain band, which, as I have shown, is of ante-cretaceous origin; that this resumption of the volcanic direction of the carboniferous epoch by no means reproduced the geographical features of that palæozoic age (which were those of low-lying lands having an insular rather than a continental character), but brought into existence those stupendous upheavals of the earth's crust that have culminated at a very recent date in the formation of mountain chains incomparably exceeding in elevation, and consequently in their climatal effect, any of the upheavals of the secondary periods*; that this change produced, during the intra-cretaceous and tertiary interval, a vast continental extent of land uninterrupted by great mountain chains, extending from America on the west, to the Bay of Bengal on the east, if not perhaps to the centre of the South Pacific, and accumulated mainly in low latitudes; that the formation of such a continent introduced climates the most unlike those of the secondary period, and had its effect both on the condition of the seas near the land, and on that of the land itself; in the latter case by the introduction of alternations of aridity and moisture such as now occur on the southern shores of Asia; that the disappearance of the marine Saurians was consequent upon that of the Cestraciont fishes, the destruction of the latter having proceeded from the failure of the tetrabran-

* The loftiest chain in the world (the Himalayah) has been formed *since* the *eocene* epoch, its area at that epoch having been comprised within the great nummulitic gulf, nummulites of a well-known European form (*N. Ramondi*) having been found in Cashmere 15,000 feet above the sea. See D'Archiac, *Bull.* vol. x. p. 380. *Animaux foss. de l'Inde*, p. 130.) The theory so long upheld, that the convulsions which the surface of the earth underwent in remote periods were on a far grander scale than those which have taken place during recent ages, is scarcely reconcileable with the fact that all the evidences which we have of mountain systems older than the tertiary (other than the Andes, whose elevation is due at least as much to tertiary as to older volcanic action) indicate not only a less entire disruption and inversion of strata than do many of the systems of tertiary origin, but they are altogether puny in point of elevation when compared with mountain chains whose grandest pinnacles are but the productions of a very late period (Himalayah, Ararat, Caucasus, Turco-Persian Mountains, Alps, &c.), and sink in comparison with such stupendous volcanoes as those of the Andes, of Teneriffe, of Timor, Hawaii, and the Antarctic Sea, and even with that of Etna. See the views of Ami Boué on the increasing heights of the mountains and depths of the seas in each successive geological epoch, and his Table of Heights and Depths, in *Bull.* vol. xi. p. 62.

chiate Cephalopoda which supplied their food; that the forms of Reptilia preserved or developed during this period were those (as the procœlian Crocodilia) which at the present day we find subsisting under these new and different conditions; that in several parts of the Southern Hemisphere there are still preserved to us remnants of the warm-blooded fauna of the secondary period in a state of isolation from different stages in that period; and that the disappearance of the wingless birds of the Trias, except the Struthionidæ, has taken place at the times when, and in the places where, they were exposed to the attacks of the Felinæ, or other carnivora of power and activity equal to the mastery of such powerful birds, or of man, and that the Struthionidæ alone, by their superior means of escape, have withstood these enemies.

The topics discussed in this paper are in harmony with Mr. Darwin's law of natural selection. The unequal rate at which some forms of mammalia have, when compared with others, changed their generic and specific characters, and even those of the suborders to which they belonged, as shown in the comparison of the change in the Opossum and Macacus with the true Ungulata, appears to be due to the greater influence which changing external conditions have upon some than upon other forms of life. The competition for existence, and the consequent elimination of new types of being, has had its maximum upon the Europeo-Asiatic continent; but the process has had its more limited parallel in the circumscribed regions formed by the isolated remnants of the secondary continents; for while the Lophiodontia, Solipedia, Ruminantia, Carnivora, and Pachydermata were eliminated in the former, a corresponding development of being in Australia, limited to the one order Marsupialia, took place in the introduction of the Macropi, Nototheria, Wombats, and other forms of Australian life, existing and extinct, analogous in their habits and powers with the characteristic mammalia of the Europeo-Asiatic continent, accompanied by a formidable carnivorous type, and in South America by the order Bruta and its allies.

The occurrence in Australia and its contiguous islands, and in Madagascar, of existing forms having the nearest affinities to the secondary Mammalia, and of the sole survivors of the once abundant Cestraciont fishes and mollusk Trigonia, appears to me susceptible of more rational explanation on the ground that in these regions we have preserved to us isolated tracts which once formed parts of the continents of the secondary period, in which a portion of the secondary inhabitants have, as it were, been imprisoned, than on the ground that the fauna of the secondary periods, and that of Australia, was and is respectively that most

adapted to the conditions of habitat, and especially created with reference to the conditions under which it was to exist. We see the latter hypothesis fail when tested by the effect which the introduction of domestic animals, and of some of the wild ones which follow man in his migrations, has had in these regions—an effect so unmistakeable, that we cannot doubt but that the later introductions will eventually exterminate the indigenous population, and would have done so ages ago had the geographical conditions permitted the migration of the animals of the Europeo-Asiatic continent into these sequestered portions of an earlier land.

The preservation of the fauna of past geological periods in a state of isolation more or less complete has not, so far as I am aware, yet received much notice from geologists, doubtless from the reluctance hitherto exhibited by them to argue from any premises which involved the admission that all animated beings originated from common parents; but we now appear to be on the eve of a change in this sentiment, and of an admission that every organism has originated by parturition from one pre-existing, and not by creation out of an inorganic matrix, and that the organic world resembles an ever-branching tree, in which the orders, classes, subkingdoms, and even the animal and vegetable kingdoms themselves, are respectively connected by the lower or simpler types of each, rather than a chain or succession of types in which the lower grades of one group have originated out of the highest grades of that usually placed next below it. We may therefore look for less reluctance among geologists to approach a subject which is by no means confined to the more conspicuous examples which I have here sought to bring into notice. The preponderance of the orders Bruta and Edentata on the American continent, and the existence of the latter order in Africa and India, will, I think, one day be attributed to the isolation of portions of very ancient land in those places, from an epoch when those simpler forms of mammalia constituted the highest stage to which the animal kingdom had attained, and to the subsequent incorporation of those parts with newer land containing more advanced forms, permitting the reciprocal migration of their inhabitants. The preservation on various parts of the earth remote from each other of animals of kindred structure, limited now to almost a single species, and unfavourable to migration, such as the Proteus and Lepidosiren, or the few surviving forms of the Salamander, points also, in my mind, to a somewhat similar process commencing at a much more remote date, when the characteristics of these solitary survivors were those of the highest grades to which life had then attained,—a process, however, which has been modified by many subsequent occurrences, that

have reduced the once great families to which these animals belonged to a few and scattered members*.

It has been demonstrated by Professor Owen, that in the earlier types of Vertebrata there were blended in one animal characters which have now become the peculiarities of suborders; and all the observations of naturalists conspire to show that as we recede in order of time, the confluence of types tends to a junction of branches with stems, and these again at remoter points with trunks conducting towards a root common to the animal and vegetable kingdoms. If, therefore, it can be shown with any degree of probability that there exist remnants of an earlier state of being, preserved in a state of complete isolation, which belong exclusively to one or more of the simpler forms, as is the case with the implacental mammalia of Australia, another link is added to the chain of evidence that all forms of life have originated, by a natural course of reproduction and slow variation, from one common root.

I would also lastly add that the unequal rate of change in some families of mammalia compared with others, and particularly the remarkable constancy of character exhibited by the Macacus since the eocene period, while entire suborders of Ungulata, which were coexistent with that genus, have disappeared, may serve to elucidate the antiquity of man, and seems to me to lead us to the presumption of a far greater antiquity for our race than has hitherto been accorded to it, reaching perhaps far back into the tertiary period.

Whether the inferences I have ventured to draw as to the alignement of the lands during the three periods into which geological formations are divided, and the preservation of portions of that land and of its inhabitants in an isolated condition, be or be not well founded, it will be my endeavour to collect all new facts bearing on the subject which the labours of geologists are constantly accumulating, and to collate them with impartiality, whether they support or militate against these inferences, and I hope at some future day to embody them in another paper.

* This process of the isolation and subsequent incorporation of detached lands taking place at very remote dates may perhaps afford an explanation of the much debated and apparently anomalous case of the anthraxiferous beds of the Alps, where, alternating with beds containing remains of plants all belonging to palæozoic genera, and in many cases to well-known carboniferous species, occur beds with true liassic forms of mollusca. See S. Gras, *Bull.* vol. xii. p. 273.