CHAPTER VIII.

Geological proofs that the geographical features of the northern hemisphere, at the period of the deposition of the carboniferous strata, were such as would, according to the theory before explained, give rise to an extremely hot climate—Origin of the transition and mountain limestones, coal-sandstones, and coal—Change in the physical geography of northern latitudes, between the era of the formation of the carboniferous series and the lias—Character of organic remains, from the lias to the chalk inclusive—State of the surface when these deposits originated—Great accession of land, and elevation of mountain-chains, between the consolidation of the newer secondary and older tertiary rocks—Consequent refrigeration of climate—Abrupt transition from the organic remains of the secondary to those of the tertiary strata—Maestricht beds—Remarks on the theory of the diminution of central heat.

WE stated, in the sixth chapter, our reasons for concluding that the mean annual temperature of the northern hemisphere was considerably more elevated when the old carboniferous strata were deposited; as also that the climate had been modified more than once since that epoch, and that it approximated by successive changes more and more nearly to that now prevailing in the same latitudes. Further, we endeavoured, in the last chapter, to prove that vicissitudes in climate of no less importance may be expected to recur in future, if it be admitted that causes now active in nature have power, in the lapse of ages, to vary to an unlimited extent the relative position of land and sea. It next remains for us to inquire whether the alterations, which the geologist can prove to have actually taken place at former periods, in the geographical features of the northern hemisphere, coincide in their nature, and in the time of their occurrence, with such revolutions in climate as would naturally have followed, according to the meteorological principles already explained.

We may select the great carboniferous series, including the transition and mountain limestones, and the coal, as the oldest system of rocks of which the organic remains furnish any decisive evidence as to climate. We have already insisted on the indications which they afford of great heat and uniformity of temperature, extending over a vast area, from about 45° to 60°, or perhaps, if we include Melville Island, to near 75° north latitude *.

When we attempt to restore in imagination the distribution of land and sea, as they existed at that remote epoch, we discover that our information is at present limited to latitudes north of the tropic of cancer, and we can only hope, therefore, to point out that the condition of the earth, so far as relates to our temperate and arctic zones, was such as the theory before offered would have led us to anticipate. Now there is scarcely any land hitherto examined in Europe, Northern Asia, or North America, which has not been raised from the bosom of the deep, since the origin of the carboniferous rocks, or which, if previously raised, has not subsequently acquired additional altitude. If we were to submerge again all the marine strata, from the transition limestone to the most recent shelly beds, the summits of some primary mountains alone would remain above the waters. These facts, it is true, considered singly, are not conclusive as to the universality of the ancient ocean in the northern hemisphere, because the movements of earthquakes occasion the subsidence as well as the upraising of the surface, and by the alternate rising and sinking of particular spaces, at successive periods, a great area may become entirely covered with marine deposits, although the whole has never been beneath the waters at one time, nay, even though the relative proportion of land and sea may have continued unaltered throughout the whole period. There is, however, the highest presumption against such an hypothesis, because the land in the northern hemisphere is now in great excess, and this circumstance alone should induce us to suppose that, amidst the repeated changes which the surface has undergone, the sea has usually predominated in a much greater degree. But when we study the mineral composition and fossil contents

* Our ancient coal-formation has not been found in Italy, Spain, Sicily, or any of the more southern countries of Europe. Whether any of the ammonitiferous limestones of the Southern Apennines and Sicily (Taormina for example) can be considered as of contemporaneous origin with our carboniferous series, is not yet determined; but it is conjectured, from the general character of the organic remains of the Apennine limestones, that they belong to some part of our secondary series, from the lias to the chalk inclusive.

of the older strata, we find evidence of a more positive and unequivocal kind in confirmation of the same opinion.

Calcareous rocks, containing the same class of organic remains as our transition and mountain limestones, extend over a great part of the central and northern parts of Europe, are found in the lake district of North America, and even appear to occur in great abundance as far as the border of the Arctic sea *. The organic remains of these rocks consist principally of marine shells, corals, and the teeth and bones of fish ; and their nature, as well as the continuity of the calcareous beds of homogeneous mineral composition, concur to prove that the whole series was formed in a deep and expansive ocean, in the midst of which, however, there were many isles. These isles were composed partly of primary and partly of volcanic rocks, which being exposed to the erosive action of torrents, to the undermining power of the waves beating against the cliffs, and to atmospheric decomposition, supplied materials for pebbles, sand, and shale, which, together with substances introduced by mineral springs and volcanos in frequent eruption, contributed the inorganic parts of the carboniferous strata. The disposition of the beds in that portion of this group which is of mechanical origin, and which incloses the coal, has been truly described to be such as would result from the waste of small islands placed in rows and forming the highest points of ridges of submarine mountains. The disintegration of such clusters of isles would produce around and between them detached deposits of various dimensions, which, when subsequently raised above the waters, would resemble the strata formed in a chain of lakes. The insular masses of primary rock would preserve their original relative superiority of height,

* It appears from the observations of Dr. Richardson, made during the expedition under the command of Captain Franklin to the north-west coast of America, and from the specimens presented by him to the Geological Society of London, that, between the parallels of 60° and 70° north latitude, there is a great calcareous formation, stretching towards the mouth of the Mackenzie river, in which are included corallines, productæ, terebratulites, &c., having a close affinity in generic characters to those of our mountain limestone, of which the group has been considered the equivalent. There is also in the same region a newer series of strata, in which are shales with impressions of ferns, lepidodendrons, and other vegetables, and also ammonites. These, it is supposed, may belong to the age of our oolitic series.—*Proceedings of Geological Society, March* 1828.

and would often surround the newer strata on several sides, like the boundary heights of lake basins*.

As might have been expected, the zoophytic, and shelly limestones of the same era, (as the mountain limestone,) sometimes alternate with the rocks of mechanical origin, but appear to have been, in ordinary cases, diffused far and wide over the bottom of the sea, remote from any islands, and where no grains of sand were transported by currents. The associated volcanic rocks, resemble the products of submarine eruptions, the tuffs being sometimes interstratified with calcareous shelly beds, or with sandstones, just as might be expected if the sand and ejected matter of which they are probably composed had been intermixed with the waters of the sea, and had then subsided like other sediment. The lavas also often extend in spreading sheets, and must have been poured out on a surface rendered horizontal by sedimentary depositions. There is, moreover, a compactness and general absence of porosity in these igneous rocks which distinguishes them from most of those which are produced on the sides of Etna or Vesuvius, and other land-volcanos. The modern submarine lavas of Sicily, which alternate with beds of shells specifically identical with those now living in the Mediterranean, have almost all their cavities filled with calcareous and other ingredients, and have been converted into amygdaloids, and this same change we must suppose such parts of the Etnean lava currents as enter the sea to be undergoing at present, because we know the water on the adjoining coast to be copiously charged with carbonate of lime in solution. It is, therefore, one among many reasons for inferring the submarine origin of our ancient trap rocks, that there are scarcely any instances, in which the cellular hollows, left by bubbles of elastic fluid, have not subsequently been filled by calcareous, siliceous, or other mineral ingredients, such as now abound in the hot springs of volcanic countries.

If, on the other hand, we examine the fossil remains in these strata, we find the vegetation of the coal strata declared by botanists to possess the characters of an insular, not a continental flora, and we may suppose the carbonaceous matter to

* See some ingenious remarks to this effect, in the work of M. Ad. Brongniart, Consid. Générales sur la Nat. de la Végét. &c. Ann. des Sci. Nat., Nov. 1828.

have been derived partly from trees swept from the rock by torrents into the sea, and partly from such peaty matter as often discolours and blackens the rills flowing through marshy grounds in our temperate climate, where the vegetation is probably less rank, and its decomposition less rapid than in the moist and hot climate of the era under consideration. There is only one instance yet on record of the remains of a saurian animal having been found in a member of the carboniferous series *. The larger oviparous reptiles usually inhabit rivers of considerable size in warm latitudes, and had crocodiles and other animals of that class been as abundant as in some secondary formations, we must have inferred the existence of many rivers, which could only have drained large tracts of land. Nor have the bones of any terrestrial mammalia rewarded our investigations. Had any of these, belonging to quadrupeds of large size, occurred, they would have supplied an argument against the resemblance of the ancient northern archipelagos to those of the modern Pacific, since in the latter no great indigenous quadrupeds have been met with. It is, indeed, a general character of small islands situated at a remote distance from continents, to be altogether destitute of land quadrupeds, except such as appear to have been conveyed to them by man. Kerguelen's land, which is of no inconsiderable size, placed in a latitude corresponding to that of the Scilly islands, may be cited as an example, as may all the groups of fertile islands in the Pacific ocean between the tropics, where no quadrupeds have been found, except the dog, the hog, and the rat, which have probably been brought to them by the natives, and also bats, which may have made their way along the chain of islands which extend from the shores of New Guinea far into the southern Pacific †. Even the isles of New Zealand, which may be compared to Ireland and Scotland

* Amongst other fossils collected from the mountain-limestone of Northumberland, the Rev. Charles V. Vernon has been fortunate enough

Unius sese dominum fecisse lacertæ,

having found a saurian vertebra together with patellæ and echinal spines, and an impression of a fern analogous to those of the coal-measures in the mountain limestone. In the same district, coal of a good quality and in great abundance occurs in the lower part of the limestone series. Annual Report of the Yorkshire Phil. Soc. for 1826, p. 14.

† Prichard's Physical History of Man, vol. i., p. 75.

in dimensions, appear to possess no indigenous quadrupeds, except the bat; and this is rendered the more striking, when we recollect that the northern extremity of New Zealand stretches to latitude 34°, where the warmth of the climate must greatly favour the prolific development of organic life. Lastly, no instance has yet been discovered of a pure lacustrine formation of the carboniferous era; although there are some instances of shells, apparently fresh-water, which may have been washed in by small streams, and do not by any means imply a considerable extent of dry land. All circumstances, therefore, point to one conclusion;—the subaqueous character of the igneous products—the continuity of the calcareous strata over vast spaces—the marine nature of their organic remains—the basin-shaped disposition of the mechanical rocks—the absence of large fluviatile and of land quadrupeds—the non-existence of pure lacustrine strata—the insular character of the flora, —all concur with wonderful harmony to establish the prevalence throughout the northern hemisphere of a great ocean, interspersed with small isles. If we seek for points of analogy to this state of things, we must either turn to the north Pacific, and its numerous submarine or insular volcanos between Kamtschatka and New Guinea, or, in order to obtain a more perfect counterpart to the coralline and shelly limestones, we may explore the archipelagos of the south Pacific, between Australia and South America, where volcanos are not wanting, and where coral reefs, consisting in great part of compact limestone, are spread over an area not inferior, perhaps, to that of our ancient calcareous rocks, though we suppose these to be prolonged from the lakes of North America to central Europe *.

No geologists have ever denied, that when our oldest conchiferous rocks were produced, great continents were wanting

* Captain King found a continued line of coral reef seven hundred miles in length, stretching from the N.E. coast of Australia towards New Guinea. It was interrupted only by a few intervals, not exceeding in all thirty miles. If we pass from these calcareous formations to the Friendly Isles and Society Isles, we find a succession of coral islands and submarine reefs; and Captain Beechey informs me, that in Ducie's Isle, W. long. 120°, he found the same formation in progress, and there he ascertained that the corals were growing at the depth *of one hundred and eighty feet*. He also observed that compact limestone constitutes a large portion of recent reefs.

in the temperate and arctic zones north of the equator; but they have even gone farther, and have been disposed to speculate on the universality of what they termed the primeval ocean. As well might a new Zealander, who had surveyed and measured the quantity of land between the south pole and the tropic of Capricorn, assume that the same proportion would be found to exist between the tropic of Cancer and the north pole. By this generalization, he would imagine twelve out of thirteen parts of the land of our temperate and arctic zones to be submerged. Such theorists should be reminded, that if the ocean was ever universal, its mean depth must have been inferior, and if so, the probability of deep water within the arctic circle is much lessened, and the likelihood of a preponderance of ice increased, and the heat of the ancient climate rendered more marvellous. To this objection, however, they will answer, that they do not profess to restrict themselves to existing analogies, and they may suppose the volume of water in the primeval ocean to have been greater. Besides, the high temperature, say they, was caused by heat which emanated from the interior of the new-born planet. In vain should we suggest to such reasoners, that when the ocean was in excess in high latitudes, the land in all probability predominated within the tropics, where, being exposed to the direct rays of the sun, it may have heated the winds and currents which flowed from lower to higher latitudes. In vain should we contend that a greater expanse of ocean, if general throughout the globe, would imply a comparative evenness of the superficial crust of the earth, and such an hypothesis would oblige us to conclude that the disturbances caused by subterranean movements in ancient times were inferior to those of later date. Will these arguments be met by the assumption, that earthquakes were feebler in the earlier ages, or wholly unknown,—as, according to Werner, there were no volcanos? Such a doctrine would be inconsistent with other popular prejudices respecting the extraordinary violence of the operations of nature in the olden time; and it is probable, therefore, that refuge will be taken in the old dogma of Lazzoro Moro, who imagined that the bed of the first ocean was as regular as its surface, and if so, it may be contended that sufficient time did not elapse between the creation of the world and the origin of the carboniferous strata, to allow the derangement necessary to produce great continents and Alpine chains.

But it would be idle to controvert, by reference to modern analogies, the conjectures of those who think they can ascend in their retrospect to the origin of our system. Let us, therefore, consider what changes the crust of the globe suffered after the consolidation of that ancient series of rocks to which we have adverted. Now, there is evidence that, before our secondary strata were formed, those of older date (from the old red sandstone to the coal inclusive) were fractured and contorted, and often thrown into vertical positions. We cannot enter here into the geological details by which it is demonstrable, that at an epoch extremely remote, some parts of the carboniferous series were lifted above the level of the sea, others sunk to greater depths beneath it, and the former, being no longer protected by a covering of water, were partially destroyed by torrents and the waves of the sea, and supplied matter for newer horizontal beds. These were arranged on the truncated edges of the submarine portions of the more ancient series, and the fragments included in the more modern conglomerates still retain their fossil shells and corals, so as to enable us to determine the parent rocks from whence they were derived*. By such remodelling of the surface the small islands of the first period increased in size, and new land was introduced into northern regions, consisting partly of primary and volcanic rocks and partly of the newly raised carboniferous strata. Among other proofs that earthquakes were then governed by the same laws which now regulate the subterranean forces, we find that they were restrained within limited areas, so that the site of Germany was not agitated, while that of some parts of England was convulsed. The older rocks, therefore, remained in some cases undisturbed at the bottom of the ancient ocean, and in this case the strata of

* Thus, for example, on the banks of the Avon, in the Bristol coal-field, the dolomitic conglomerate, a rock of an age intermediate between the carboniferous series and the lias, rests on the truncated edges of the coal and mountain limestone, and contains rolled and angular fragments of the latter, in which are seen the characteristic mountain-limestone fossils. For accurate sections illustrating the disturbances which rocks of the carboniferous series underwent before the newer red sandstone was formed, the reader should consult the admirable memoir on the south-western coal district of England, by Dr. Buckland and Mr. Conybeare, Geol. Trans., vol. i., second series.

the succeeding epoch were deposited upon them in conformable position. By reference to groups largely developed on the continent, but which are some of them entirely wanting, and others feebly represented in our own country, we find that the apparent interruption in the chain of events between the formation of our coal and the lias arises merely from local deficiency in the suite of geological monuments*. During the great interval which separated the formation of these groups, new species of animals and plants made their appearance, and in their turn became extinct; volcanos broke out, and were at length exhausted; rocks were destroyed in one region, and others accumulated elsewhere, while, in the mean time, the geographical condition of the northern hemisphere suffered material modifications. Yet the sea still extended over the greater part of the area now occupied by the lands which we inhabit, and was even of considerable depth in many localities where our highest mountain-chains now rise. The vegetation, during a part at least of this new period (from the lias to the chalk inclusive), appears to have approached to that of the larger islands of the equatorial zone†. These islands appear to have been drained by rivers of considerable size, which were inhabited by crocodiles and gigantic oviparous reptiles, both herbivorous and carnivorous, belonging for the most part to extinct genera. Of the contemporary inhabitants of the land we have as yet acquired but scanty information, but we know that there were flying reptiles, insects, and small insectivorous mammifera, allied to the opossum. In farther confirmation of the opinion that countries of considerable extent now rose above the sea in the temperate zone, we may mention the discovery of a large estuary formation in the south-west of England of higher antiquity than the chalk, containing terrestrial plants and fresh-

* In many parts of Germany, the newer red sandstone, and other rocks of about the same age, lie in conformable strata on the coal. In some districts, as in the Thuringerwald, among others, there is an immense series of formations intervening between the coal and the lias; one of these groups, called the *muschelkalkstein*, which seems to have no existence in England, is of great thickness and full of organic remains. See Professor Sedgwick's Memoir on the Geological relations and internal structure of the Magnesian Limestone, &c. Geol. Trans., second series, vol. iii., part 1, p. 121.

† Ad. Brongniart, Consid. Générales sur la Nat. de la Végét. &c. Ann. des Sci. Nat., Nov. 1828.

water testacea, tortoises, and large reptiles,—in a word, such an assemblage as the delta of the Ganges, or a large river in a hot climate might be expected to produce*.

In the present state of our knowledge, we cannot pretend to institute a close comparison between the climate which prevailed during the gradual deposition of our secondary formations and that of the older carboniferous rocks, for the general temperature of the surface must at both epochs have been so dissimilar to that now experienced in the same, or perhaps in any latitudes, that proofs from analogy lose much of their value, and a larger body of facts is required to support theoretical conclusions. If the signs of intense heat diminish, as some suppose, in the newer groups of this great series, there are nevertheless indications in the animal forms of the continued prevalence of a climate which we might consider as tropical in its character.

We may now turn our attention to the phenomena of the tertiary strata, which afford evidence of an abrupt transition from one description of climate to another. If this remarkable break in the regular sequence of physical events is merely apparent, arising from the present imperfect state of our knowledge, it nevertheless serves to set in a clearer point of view the intimate connexion between great changes in the physical geography of the earth, and revolutions in the mean temperature of the air and water. We have already shewn that when the climate was hottest, the northern hemisphere was for the most part occupied by the ocean, and it remains for us to point out, that the refrigeration did not become considerable, until a very large portion of that ocean was converted into land, nor even until it was in some parts replaced by high mountain chains. Nor did the cold reach its maximum until these chains attained their full height, and the lands their full extension. A glance at the best geological maps now constructed of

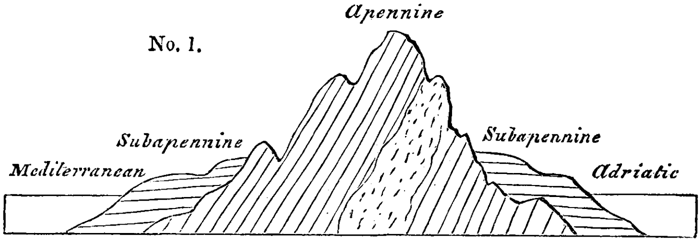
* We do not mean to compare the extent of the Wealden formation (from the Weald clay to the Purbeck limestone inclusive) to that of the Gangetic delta, for we shall afterwards see that the most modern addition made to the latter is equal in superficial area to North and South Wales. But, judging from the great continuity of some minor subdivisions of the Wealden group in our island, characterized as they are throughout their whole range by certain fresh-water remains, we may safely conclude that a considerable body of fresh water must have been permanently supplied by a large river.

various countries in the northern hemisphere, whether in North America or Europe, will satisfy the inquirer that the greater part of the present land has been raised from the deep, either between the period of the deposition of the chalk and that of the strata termed tertiary, or at subsequent periods, during which, various tertiary groups were formed in succession. For, as the secondary rocks from the lias to the chalk inclusive, are, with a few unimportant exceptions, marine, it follows that every district now occupied by them has been converted into land since they originated. We may prove, by reference to the relative altitudes of the secondary and tertiary groups, and several other circumstances, that a considerable part of the elevation of the older series was accomplished before the newer was formed. The Apennines, for example, as the Italian geologists hinted long before the time of Brocchi, and as that naturalist more clearly demonstrated, rose* several thousand feet above the level of the Mediterranean, before the deposition of the recent Subapennine beds which flank them on either side. What now constitutes the central calcareous chain of the Apennines, must for a long time have been a narrow ridgy peninsula, branching off at its northern extremity from the Alps near Savonna. A line of volcanos afterwards burst out in the sea, parallel to the axis of the older ridge. These igneous vents were extremely numerous, and the ruins of some of their cones and craters (as those in Tuscany, for example) indicate such a continued series of eruptions, almost all subsequent to the deposition of the Subapennine strata, that we cannot wonder at the vast changes in the relative level of land and sea which were produced. However minute the effect of each earthquake which preceded or intervened between such countless eruptions, the aggregate result of their elevating or depressing operation may well be expected to display itself in seas of great depth, and hills of considerable altitude. Accordingly, the more recent shelly beds, which often contain rounded pebbles derived from the waste of contiguous parts of the older Apennine rocks, have been raised from one to two thousand feet; but they never attain the loftier

* The greater number of Italian naturalists, and Brocchi among the rest, attributed the change of level to the lowering of the Mediterranean; rejecting the more correct theory of Moro and his followers, that the land had been upheaved.

eminences of the Apennines, nor penetrate far into the higher and more ancient valleys; for the whole peninsula was evidently subjected to the action of the same subterranean movements, and the older and newer groups of strata changed their level, in relation to the sea, but not to each other.

No. 1.



In the above diagram, exhibiting a transverse section of the Italian peninsula, the superior elevation of the more ancient group, and its unconformable stratification in relation to the more recent beds is expressed. The latter, however, are often much more disturbed at the point of contact than is here represented, and in some cases they have suffered such derangement as to dip towards, instead of from, the more ancient chain. There is usually, moreover, a valley at the junction of the Apennine and Subapennine strata, owing to the greater degradation which the newer and softer beds have undergone; but this intervening depression is not universal.

These phenomena are exhibited in the Alps on a much grander scale; those mountains being encircled by a great zone of tertiary rocks of different ages, both on their southern flank towards the plains of the Po, and on the side of Switzerland and Austria *, and at their eastern termination towards Styria and Hungary. This tertiary zone marks the position of former seas or gulfs, like the Adriatic, which were many thousand feet deep, and wherein strata accumulated, some single groups of which are not inferior in thickness to the whole of our secondary formations in England. These marine tertiary strata rise to the height of from two to four thousand feet and upwards, and consist of formations of different ages, characterized by dif-

* See a Memoir by Professor Sedgwick and Mr. Murchison, On the Tertiary Deposits of the Vale of Gosau, in the Salzburg Alps, Proceedings of Geol. Soc. No. 13, Nov. 1829.

ferent assemblages of organized fossils. The older tertiary groups generally rise to greater heights, and form interior zones nearest to the Alps. We may imagine some future convulsion once more to upraise this stupendous chain, together with the adjoining bed of the sea, so that the greatest mountains of Europe might rival the Andes in elevation, in which case the deltas of the Po, Adige, and Brenta now encroaching upon the Adriatic, might be uplifted so as to form another exterior belt, of considerable height, around the south-eastern flank of the Alps. Although we have not yet ascertained the number of different periods at which the Alps gained accessions to their height and width, yet we can affirm, that the last series of movements occurred when the seas were inhabited by *many existing species of animals* *.

There appears to be no sedimentary formations in the Alps so ancient as the rocks of our carboniferous series; while, on the other hand, secondary strata as modern as the green sand of English geologists, and perhaps the chalk, enter into some of the higher and central ridges. Down to the period, therefore, when the rocks, from our lias to the chalk inclusive, were deposited, there was sea where now the principal chain of Europe extends, and that chain attained more than half its present elevation and breadth between the eras when our newer secondary and oldest tertiary rocks originated. The remainder of its growth, if we may so speak, is of much more recent date, some of the latest changes, as we have stated, having been coeval with the existence of many animals belonging to species now contemporary with man. The Pyrenees, also, have acquired the whole of their present altitude, which in Mont Perdu exceeds eleven thousand feet, since the origin of some of

* Brocchi supposed the Subapennine beds to occur *abundantly* on both sides of the plains of the Po; but in this he was mistaken. The subalpine tertiary deposits are for the most part distinct and older formations. Professors Bonelli and Guidotti informed me, that they have recognized the Subapennine shells in one or two districts only north of the Po. They form in these cases, as might have been anticipated, the outermost belt, as at Azolo, at the foot of the Alps near the plains of Venice, and at Bassano, on the Brenta. In the section given by Mr. Murchison of the strata laid open by the Brenta, between Bassano and the Alps above Campese, it will be seen that the older chain must have partaken of the movement which raised the newest tertiary strata of the age of the Subapennines. Phil. Mag. and Annals, June, 1829.

the newer members of our secondary series. The granitic axis of that chain does not rise so high as a ridge formed by marine calcareous beds, the organic remains of which shew them to be the equivalents of our lower chalk, or a formation of about that age *. The tertiary strata at the base of this great chain are only slightly raised above the sea, and retain a horizontal position, without partaking of any of the disturbances to which the older series has been subjected, so that the great barrier between France and Spain was almost entirely upheaved in the interval between the deposition of the secondary and tertiary strata †. The Jura, also, owe the greatest part of their present elevation to subterranean convulsions which happened after the deposition of certain tertiary groups; at which time that portion which had been previously raised above the level of the sea underwent an entire alteration of form ‡. In other parts of the continent, as in France and England, where the newer rocks lie in basins surrounded by gently-rising hills, we find evidence that considerable spaces were redeemed from the original ocean and converted into dry land after the chalk was formed, and before the origin of the tertiary deposits. In these cases, the secondary strata were not raised into lofty mountain chains, like the Alps, Apennines, and Pyrenees, but the proofs are not less clear of their partial conversion into land anterior to the tertiary era. The chalk, for example, must have originated in the sea in the form of sediment from tranquil water; but before the tertiary rocks of the Paris and London basins were deposited, large portions of it had been so raised as to be exposed to the destroying power of the elements. The layers of flint had been washed out by torrents and rivers from their cretaceous matrix, rounded by attrition, and transported to the sea, where oysters attached themselves, and in some localities grew to a full size, until covered by other beds of flint-pebbles or sand. These newer derivative deposits are found abundantly along the borders, and in the inferior strata of our tertiary basins, and they are often interstratified with lignite. We may fairly infer, that the various trees

* This observation, first made by M. Boué, has been since confirmed by M. Dufrénoy.

† See a Memoir by M. Elie de Beaumont, Ann. des Sci. Nat., Nov. 1829, p. 286.

‡ M. Elie de Beaumont, ibid., Dec. 1829, p. 346.

and plants which enter into the composition of this lignite, grew on the surface of the same chalk which was then wasting away and affording to the torrents a constant supply of flint gravel.

We cannot dwell longer on the distinct periods when the secondary and various tertiary groups were upraised, without anticipating details which belong to other parts of this treatise; but we may observe, that although geologists have neglected to point out the relation of changes in the configuration of the earth's surface with fluctuations in general temperature, they do not dispute the fact, that the sea covered the regions where a great part of the land in Europe is now placed, until after the period when the newer groups of secondary rocks were formed. There is, therefore, confessedly a marked coincidence in point of time between the greatest alteration in climate and the principal revolution in the physical geography of the northern hemisphere. It is very probable that the abruptness of the transition from the organic remains of the secondary to those of the tertiary epoch, may not be wholly ascribable to the present deficiency of our information. We shall doubtless hereafter discover many intermediate gradations, (and one of these may be recognized in the calcareous beds of Maestricht,) by which a passage was effected from one state of things to another; but it is not impossible that the interval between the chalk and tertiary formations constituted an era in the earth's history, when the passage from one class of organic beings to another was, comparatively speaking, rapid. For if the doctrines explained by us in regard to vicissitudes of temperature are sound, it will follow that changes of equal magnitude in the geographical features of the globe, may at different periods produce very unequal effects on climate, and, so far as the existence of certain animals and plants depends on climate, the duration of species may often be shortened or protracted, according to the rate at which the change in temperature proceeded.

Let us suppose that the laws which regulate the subterranean forces are constant and uniform, (which we are entitled to assume, until some convincing proofs can be adduced to the contrary;) we may then infer, that a given amount of alteration in the superficial inequalities of the surface of the planet always requires for its consummation nearly equal periods of time. Let us then imagine the quantity of land between the equator and the tropic in one hemisphere to be to that in the other as thirteen to one, which, as we before stated, represents the unequal proportion of the extra-tropical lands in the two hemispheres at present. Then let the first geographical change consist in the shifting of this preponderance of land from one side of the line to the other, from the southern hemisphere, for example, to the northern. Now this would not affect the *general* temperature of the earth. But if, at another epoch, we suppose a continuance of the same agency to transfer an equal volume of land from the torrid zone to the temperate and arctic regions of the northern hemisphere, there might be so great a refrigeration of the mean temperature *in all latitudes*, that scarcely any of the pre-existing races of animals would survive, and, unless it pleased the Author of Nature that the planet should be uninhabited, new species would be substituted in the room of the extinct. We ought not, therefore, to infer, that equal periods of time are always attended by an equal amount of change in organic life, since a great fluctuation in the mean temperature of the earth, the most influential cause which can be conceived in exterminating whole races of animals and plants, must, in different epochs, require unequal portions of time for its completion.

The only geological monument yet discovered, which throws light on the period immediately succeeding the deposition of the chalk, is the series of calcareous beds in St. Peter's Mount at Maestricht. The turtles and gigantic reptiles there found, seem to indicate that the hot climate of the secondary era had not then been greatly modified; but as it seems that but a small proportion of the fossil species hitherto discovered are identical with known chalk fossils, there may perhaps have been a considerable lapse of ages between the consolidation of our upper chalk, and the completion of the Maestricht group *. During these ages, part of the gradual rise of the Alps and Pyrenees may have been accomplished; for we know that earth-

* It appears from a Memoir by Dr. Fitton, read before the Geological Society of London, Dec. 1829, that the Maestricht beds extend over a considerable area, preserving the same mineral characters and organic remains. Out of fifty species of shells and zoophytes collected by him, ten only could be identified with the copious list of chalk fossils published by Mr. Mantell, in the Geol. Trans., vol. iii. part 1., second series, p. 201.

quakes may work mighty changes during what we may call a small portion of one zoological era, since there are hills in Sicily which have gained more than three thousand feet in height, while the assemblage of testacea and zoophytes inhabiting the Mediterranean has only suffered slight alterations, and a large part of the countries bordering the Mediterranean have been remodelled since about one-third of the existing species were in being.

Before we conclude this chapter, we may be expected to offer some remarks on the gradual diminution of the supposed central heat of the globe, a doctrine which appears of late years to have increased in popularity. Baron Fourier, after making a curious series of experiments on the cooling of incandescent bodies, has endeavoured by profound mathematical calculations to prove that the actual distribution of heat in the earth's envelope is precisely that which would have taken place if the globe had been formed in a medium of a very high temperature, and had afterwards been constantly cooled *. He supposes that the matter of our planet, as Leibnitz formerly conjectured, was in an intensely heated state at the era of its creation, and that the incandescent fluid nucleus has been parting ever since with portions of its original heat, thereby contracting its dimensions,—a process which has not yet entirely ceased. But it is admitted, that there are no positive facts in support of this contraction; on the contrary, La Place has shewn, by reference to astronomical observations made in the time of Hipparchus, that in the last two thousand years there has been no sensible contraction of the globe by cooling down, for had this been the case, even to an extremely small amount, the day would have been shortened in an appreciable degree. The reader will bear in mind, that the question as to the existence of a central heat is very different from that of the gradual refrigeration of the interior of the earth. Many observations and experiments appear to countenance the idea, that in descending from the surface to those slight depths to which man can penetrate, there is a progressive increase of heat; but if this be established, and if, as some are not afraid to infer,

* See a Memoir on the Temperature of the Terrestrial Globe, and the Planetary Spaces, Ann. de Chimie et Phys., tom. xxvii. p. 136. Oct. 1824.

we dwell on a thin crust which covers a central ocean of liquid incandescent lava, we ought still to be very reluctant to concede on slight evidence that the internal heat is *variable in quantity*.

In our ignorance of the sources and nature of volcanic fire, it seems more consistent with philosophical caution, to assume that there is no instability in this part of the terrestrial system. We know that different regions have been subject in succession to a series of violent subterranean convulsions, and that fissures have opened from which hot vapours, thermal springs, and at some points red hot liquid lavas have issued to the surface. This evolution of heat often continues for ages after the extinction of volcanos and after the cessation of earthquakes, as in Central France, for example, and it seems perfectly natural, that each part of the earth's crust should, as M. Fourier states to be the fact, present the appearance of a heated body slowly cooling down. This may be owing chiefly to the shifting of the volcanic foci; but some effect may perhaps be due to that unequal absorption of the solar rays to which we have alluded, when speaking of the different temperature of the earth, according to the varying distribution of its superficial inequalities. M. Cordier announces as the result of his experiments and observations on the temperature of the interior of the earth, that the heat increases rapidly with the depth, but the increase does not follow the same law over the whole earth, being twice or three times as much in one country as in another, and these differences not being in constant relation either with the latitudes or longitudes of places. All this is precisely what we should have expected to arise from variations in the intensity of volcanic heat, and from that change of position, which the principal theatres of volcanic action have undergone at different periods, as the geologist can distinctly prove. But M. Cordier conjectures that there is a connexion between such phenomena and the secular refrigeration and contraction of the internal fluid mass, and that the changes of climate, of which there are geological proofs, favour this hypothesis *.

We cannot help suspecting that if it had appeared that *the same species of animals and plants* had continued to inhabit the

* See M. Cordier's Memoir on the Temperature of the Interior of the Earth, read to the Academy of Sciences, 4th June, 1827. Edin. New Phil. Journ., No. viii., p. 273.

seas, lakes, and continents, before and after the great physical mutations which the northern hemisphere has undergone since the secondary strata were formed, the difficulty of explaining the ancient climate of the globe would have appeared far more insurmountable than at present. It would have been so contrary to the elementary truths of meteorology to suppose no refrigeration to have followed from the rising of so many new mountain-chains in northern latitudes, that recourse would probably have been had in that case also to cosmological speculations. It might have been argued with much plausibility, that as the accession of high ridges covered with perpetual snow and glaciers had not occasioned any perceptible increase of cold, so as to affect the state of organic life, there must have been some new source of heat which counterbalanced that refrigerating cause. This, it might have been said, was the increased development of *central fire* issuing from innumerable fissures opened in the crust of the earth, when it was shaken by convulsions which raised the Alps and other colossal chains.

But, without entering into farther discussion on the merits of the hypothesis of gradual refrigeration, let us hope that experiments will continue to be made, to ascertain whether there be internal heat in the globe, and what laws may govern its distribution. When its existence has been incontrovertibly established, it will be time to enquire whether it be subject to secular variations. Should these also be confirmed, we may begin to indulge speculations respecting the cause, but let us not hastily assume that it has reference to the original formation of the planet, with which it might be as unconnected as with its final dissolution. In the mean time we know that great changes in the external configuration of the earth's crust have at various times taken place, and we may affirm that they *must* have produced *some effect* on climate. The extent of their influence ought, therefore, to form a primary object of enquiry, more especially as there seems an obvious coincidence between the eras at which the principal accessions of land in high latitudes were made, and the successive periods when the diminution of temperature was most decided.