CHAPTER VI.

Proofs that the climate of the Northern hemisphere was formerly hotter—Direct proofs from the organic remains of the Sicilian and Italian strata—Proofs from analogy derived from extinct Quadrupeds—Imbedding of Animals in Icebergs—Siberian Mammoths—Evidence in regard to temperature, from the fossil remains of tertiary and secondary rocks—From the Plants of the Coal formation.

THAT the climate of the northern hemisphere has undergone an important change, and that its mean annual temperature must once have resembled that now experienced within the tropics, was the opinion of some of the first naturalists who investigated the contents of ancient strata. Their conjecture became more probable when the shells and corals of the secondary rocks were more carefully examined, for these organic remains were found to be intimately connected by generic affinity with species now living in warmer latitudes. At a later period, many reptiles, such as turtles, tortoises, and large saurian animals, were discovered in the European strata in great abundance; and they supplied new and powerful arguments, from analogy, in support of the doctrine, that the heat of the climate had been great when our secondary formations were deposited. Lastly, when the botanist turned his attention to the specific determination of fossil plants, the evidence acquired the fullest confirmation, for the flora of a country is peculiarly influenced by temperature; and the ancient vegetation of the earth might, more readily than the forms of animals, have afforded conflicting proofs, had the popular theory been without foundation. When the examination of animal and vegetable remains was extended to rocks in the most northern parts of Europe and North America, and even to the Arctic regions, indications of the same revolution in climate were discovered.

It cannot be said, that in this, as in many other departments of geology, we have investigated the phenomena of former

eras, and neglected those of the present state of things. On the contrary, since the first agitation of this interesting question, the accessions to our knowledge of living animals and plants have been immense, and have far surpassed all the data previously obtained for generalizing, concerning the relation of certain types of organization to particular climates. The tropical and temperate zones of South America and of Australia have been explored; and, on close comparison, it has been found, that scarcely any of the species of the animate creation in these extensive continents are identical with those inhabiting the old world. Yet the zoologist and botanist, well acquainted with the geographical distribution of organic beings in other parts of the globe, would have been able, if distinct groups of species had been presented to them from these regions, to recognise those which had been collected from latitudes within, and those which were brought from without the tropics.

Before we attempt to explain the probable causes of great vicissitudes of temperature on the earth's surface, we shall take a rapid view of some of the principal data which appear to warrant, to the utmost extent, the popular opinions now entertained on the subject. To insist on the soundness of the inference, is the more necessary, because some zoologists have of late undertaken to vindicate the uniformity of the laws of nature, not by accounting for former fluctuations in climate, but by denying the value of the evidence on this subject *.

It is not merely by reasoning from analogy that we are led to infer a diminution of temperature in the climate of Europe; there are direct proofs in confirmation of the same doctrine, in the only countries hitherto investigated by expert geologists where we could expect to meet with direct proofs. It is not in England or Northern France, but around the borders of the Mediterranean, from the South of Spain to Calabria, and in the islands of the Mediterranean, that we must look for conclusive evidence on this question; for it is not in strata, where the

* See two articles by the Rev. Dr. Fleming, in the Edinburgh New Phil. Journ. No. 12, p. 277, April, 1829; and No. 15, p. 65, Jan. 1830.

organic remains belong to extinct species, but where living species abound in a fossil state, that a theory of climate can be subjected to the experimentum crucis. In Sicily, Ischia, and Calabria, where the fossil testacea of the more recent strata belong almost entirely to species now known to inhabit the Mediterranean, the conchologist remarks, that individuals in the inland deposits exceed in their average size their living analogues *. Yet no doubt can be entertained, on the ground of such difference in their dimensions, of their specific identity, because the living individuals attain sometimes, though rarely, the average size of the fossils; and so perfect is the preservation of the latter, that they retain, in some instances, their colour, which affords an additional element of comparison.

As we proceed northwards in the Italian peninsula, and pass from the region of active, to that of extinct volcanos—from districts now violently convulsed from time to time, to those which are comparatively undisturbed by earthquakes, we find the assemblage of fossil shells, in the modern (Subapennine) strata, to depart somewhat more widely from the type of the neighbouring seas. The proportion of species, identifiable with those now living in the Mediterranean, is still considerable; but it no longer predominates, as in the South of Italy, over the unknown species. Although occurring in localities which are removed several degrees farther from the equator (as at Sienna, Parma, Asti, &c.), the shells yield clear indications of a hotter climate. Many of them are common to the Subapennine hills, to the Mediterranean, and to the Indian Ocean. Those in the fossil state, and their living analogues from the tropics, correspond in size; whereas the individuals of the same species from the Mediterranean are dwarfish and

* I collected several hundred species of shells in Sicily, some from an elevation of several thousand feet, and forty species or more in Ischia, partly from an elevation of above one thousand feet, and these were carefully compared with recent shells procured by Professor O. G. Costa, from the Neapolitan seas. Not only were the fossil species for the most part identical with those now living, but the relative abundance in which different species occur in the strata and in the sea corresponds in a remarkable manner. Yet the larger average size of the fossil individuals of many species was very striking. A comparison of the fossil shells of the more modern strata of Calabria and Otranto, in the collection of Professor Costa, afforded similar results.

degenerate, and stunted in their growth, for want of conditions which the Indian Ocean still supplies *.

This evidence amounts to demonstration, and is not neutralized by any facts of a conflicting character; such, for instance, as the association, in the same group, of individuals referrible to species now confined to arctic regions. On the contrary, whenever any of the fossils shells are identified with living species foreign to the Mediterranean, it is not in the Northern Ocean, but between the tropics, that they must be sought †. On the other hand, the associated unknown species belong, for the most part, to genera which are either exclusively limited to equinoctial regions, or are now most largely developed there. Of the former, the genus Pleurotoma ‡ is a remarkable example; of the latter, the genus Cypræa §.

When we proceed to the central and northern parts of Europe, far from the modern theatres of volcanic action, and where there is no evidence of considerable inequalities of the earth's surface having been produced since the present species

* Professor Guidotti, of Parma, whose collection of Subapennine shells is unrivalled, and who has obtained from the North of Italy above twelve hundred species, showed me numerous suites of specimens in a fossil state, as well as from the Mediterranean and Indian seas, illustrating these views. Among other examples, the Bulla lignaria, a very common shell, is invariably found fossil of the same magnitude as it now reaches in the Indian sea, and much smaller in a living state in the Mediterranean. The common Orthoceras of the Mediterranean, O. raphanista, attains larger average dimensions in a fossil, than in a recent state. Professor Bonelli, of Turin, who has above eight hundred species of shells from the Subapennines in the public museum, pointed out to me many examples, in confirmation of the same point.

† Thus, for example, Rostellaria curvirostris, found fossil by Signor Bonelli near Turin, is only known at present as an Indian shell. Murex cornutus, fossil at Asti, is now only known recent in warmer latitudes, the only localities given by Linnæus and Lamarck being the African and Great Indian Oceans. Conus antediluvianus cannot be distinguished from a shell now brought from Owhyhee. Among other familiar instances mentioned to me by Italian naturalists, in confirmation of the same point, Buccinum clathratum, Lam. was cited; but Professor Costa assured me that this shell, although extremely rare, still occurs in the Mediterranean.

‡ Of the genus Pleurotoma, no living representative has yet been found in the Mediterranean; yet no less than twenty-five species are now to be seen in the museum at Turin, all procured by Professor Bonelli from the Subapennine strata of northern Italy. In a fossil state, they are associated with many shells, specifically identical with testacea, now living in the Mediterranean.

§ The genus Cypræa is represented by many large fossil species in the Subapennine hills, with which are associated one small, and two minute species of the same genus, which alone are now found in the Mediterranean.

were in existence, our opportunities are necessarily more limited of procuring evidence from the contents of marine strata. It is only in lacustrine deposits, or in ancient river-beds, or in the sand and gravel of land-floods, or the stalagmite of ancient caverns once inhabited by wild beasts, that we can obtain access to proofs of the changes which animal life underwent during those periods when the marine strata already adverted to were deposited farther to the south. As far, however, as proofs from analogy can be depended upon, nothing can be more striking than the harmony of the testimony derived from the last-mentioned sources. We often find, in such situations, the remains of extinct species of quadrupeds, such as the elephant, rhinoceros, hippopotamus, hyæna, and tiger, which belong to genera now confined to warmer regions. Some of the accompanying fossil species, which are identifiable with those now living, belong to animals which inhabit the same latitudes at present.* It seems, therefore, fair to infer, that the same change of climate which has caused certain Indian species of testacea to become rare, or to degenerate in size, or to disappear from the Mediterranean, and certain genera of the Subapennine hills, now exclusively tropical, to retain no longer any representatives in the adjoining seas, has also contributed to the annihilation of certain genera of land-mammifera, which inhabited the continents at about the same epoch. The mammoth (Elephas primigenius), and other extinct animals of the same era, may not have required the same temperature as their living congeners within the tropics; but we may infer, that the climate was milder

* Bones of the mammoth have been recently found at North Cliff, in the county of York, in a lacustrine formation, in which all the land and fresh-water shells, thirteen in number, have been accurately identified with species and varieties now existing in that country. Bones of the Bison, an animal now inhabiting a cold or temperate climate, have also been found in the same place. That these quadrupeds, and the indigenous species of testacea associated with them, were all contemporary inhabitants of Yorkshire (a fact of the greatest importance in geology), has been established by unequivocal proofs, by the Rev. W. V. Vernon, who caused a pit to be sunk to the depth of more than two hundred feet, through undisturbed strata, in which the remains of the mammoth were found imbedded together with the shells, in a deposit which had evidently resulted from tranquil waters.—Phil. Mag. Sept. 1829, and Jan. 1830. These facts, as Mr. Vernon observes, indicate that there has been little alteration in the temperature of these latitudes since the mammoth lived there.

than that now experienced in some of the regions once inhabited by them, because, in Northern Russia, where their bones are found in immense numbers, it would be difficult, if not impossible, for such animals to obtain subsistence at present, during an arctic winter *. It has been said, that as the modern northern animals migrate, the Siberian elephant may also have shifted his place during the inclemency of the season†, but this conjecture seems forced, even in regard to the elephant, and still more so, when applied to the Siberian rhinoceros, found in the frozen gravel of that country; as animals of this genus are heavy and slow in their motions, and can hardly be supposed to have accomplished great periodical migrations to southern latitudes. That the mammoth, however, continued for a long time to exist in Siberia after the winters had become extremely cold, is demonstrable, since their bones are found in icebergs, and in the frozen gravel, in such abundance as could only have been supplied by many successive generations. So many skeletons could not have belonged to herds which lived at one time in the district, even if those northern countries had once been clothed with vegetation as luxuriant as that of an Indian jungle. But, if we suppose the change to have been extremely slow, and to have consisted, not so much in a diminution of the mean annual temperature, as in an alteration from what has been termed an "insular" to an "excessive" climate, from one in which the temperature of winter and summer were nearly equalized to one wherein the seasons were violently contrasted, we may, perhaps, explain the phenomenon. Siberia and other arctic regions, after having possessed for ages a more uniform temperature, may, after certain changes in the form of the arctic land, have become occasionally exposed

* I fully agree with Dr. Fleming, that the kind of food which the existing species of elephant prefers will not enable us to determine, or even to offer a feasible conjecture, concerning that of the extinct species. No one, as he observes, acquainted with the gramineous character of the food of our fallow-deer, stag, or roe, would have assigned a lichen to the rein-deer. But, admitting that the trees and herbage on which the fossil elephants and rhinoceroses may have fed were not of a tropical character, but such perhaps as now grow in the temperate zone, it is still highly improbable that the vegetation which nourished these great quadrupeds was as scanty as that of our arctic regions, or that it was covered during the greater part of every year by snow.

† Dr. Fleming, Edin. New Phil. Journ. No. xii. p. 285. April, 1829.

to extremely severe winters. When these first occurred at distant intervals, the drift snow would fill the valleys, and herds of herbivorous quadrupeds would be surprised and buried in a frozen mass, as often happens to cattle and human beings, overwhelmed, in the Alpine valleys of Switzerland, by avalanches. When valleys have become filled with ice, as those of Spitzbergen, the contraction of the mass causes innumerable deep rents, such as are seen in the mer de glace on Mont Blanc. These deep crevices usually become filled with loose snow, but sometimes a thin covering is drifted across the mouth of the chasm, capable of sustaining a certain weight. Such treacherous bridges are liable to give way when heavy animals are crossing, which are then precipitated at once into the body of a glacier, which slowly descends to the sea, and becomes a floating iceberg *. As bears, foxes, and deer now abound in Spitzbergen, we may confidently assume that the imbedding of animal remains in the glaciers of that island must be an event of almost annual occurrence †. The conversion of drift snow into permanent glaciers and icebergs, when it happens to become covered over with alluvial matter, transported by torrents and floods, is by no means a rare phenomenon in the arctic regions ‡. During a series of milder seasons inter-

* See Dr. Latta's account of his escape, when the covering of a crevice in a glacier of Spitzbergen gave way with him as he passed. Ed. New Phil. Journ. No. v. p. 95. June, 1827.

† Dr. Richardson tells me, that in North America, about lat. 65°, he found the carcase of a deer, which had fallen into a fissure in a rock. It had become buried in snow, and the flesh, after the animal had been buried three months, had only become slightly putrescent. In the innumerable fissures, traversing a slippery glacier, these accidents must be far more frequent, so often as herbivorous animals pass over them in their migrations, or when they hastily cross them when pursued by beasts of prey.

‡ Along the coast, in particular, E. and W. of the Mackenzie river, when the sea is frozen over, the drift snow from the land forms a talus abutting against a perpendicular cliff. On the melting of the snow, torrents rush down from the land, charged with gravel and soil, and, falling over the edge of the cliff, cover the snow, which is often of considerable depth, with alluvium. Water, if any infiltration takes place, is frozen before it penetrates to the bottom of the mass, which is at last consolidated into a compact iceberg, protected from the heat of the sun, by a covering of alluvium, on which vegetation often flourishes. I am indebted to Dr. Richardson for this information, who has seen permanent glaciers, forming in this manner, in districts of North America now inhabited by many large herbivorous animals. The same process must evidently take place under river cliffs, as well as along the sea-shore.

vening between the severe winters, the mammoths may have recovered their numbers, and the rhinoceroses may have multiplied again, so that the repetition of such catastrophes may have been indefinite. The increasing cold, and greater frequency of inclement winters, would at last thin their numbers, and their final extirpation would be consummated by the rapid augmentation of other herbivorous quadrupeds, more fitted for the new climate.

That the greater part of the elephants lived in Siberia after it had become subject to intense cold, is confirmed, among other reasons, by the state of the ivory, which has been so largely exported in commerce. Its perfect preservation indicates, that from the period when the individuals died, their remains were either buried in a frozen soil, or at least were not exposed to decay in a warm atmosphere. The same conclusion may be deduced from the clothing of the mammoth, of which the entire carcase was discovered by Mr. Adams on the shores of the frozen ocean, near the mouth of the river Lena, inclosed in a mass of ice. The skin of that individual was covered with long hair and with thick wool, about an inch in length. Bishop Heber informs us, that along the lower range of the Himalaya mountains, in the north-eastern borders of the Delhi territory, between lat. 29° and 30°, he saw an Indian elephant covered with shaggy hair. In that region, where, within a short space, a nearly tropical, and a cold climate meet, dogs and horses become covered, in the course of a winter or two, with shaggy hair, and many other species become, in as short a time, clothed with the same fine short shawl-wool, which distinguishes the indigenous species of the country. Lions, tigers, hyænas, are there found with elks, chamois, and other species of genera usually abundant in colder latitudes*.

If we pass from the consideration of these more modern deposits, whether of marine or continental origin, in which existing species are intermixed with the extinct, to strata of somewhat higher antiquity, (older tertiary strata, Calcaire Grossier, London clay, fresh-water formations of Paris and Isle of Wight, &c.,) we can only reason from analogy, since the species,

* Narrative of a Journey through the Upper Provinces of India, vol. ii. pp. 166—219.

whether of mammalia, reptiles, or testacea, are scarcely in any instance identifiable with any now in being *. In these strata, whether they were formed in seas or lakes, we find the remains of many animals, analogous to those of hot climates, such as the crocodile, turtle, and tortoise, and many large shells of the genus nautilus, and plants indicating such a temperature as is now found along the borders of the Mediterranean. A great interval of time appears to have elapsed between the deposition of the last mentioned (tertiary) strata, and the *secondary* formations, which constitute the principal portion of the more elevated land in Europe. In these secondary rocks a very distinct assemblage of organized fossils are entombed, all of unknown species, and many of them referrible to genera, and families now most abundant between the tropics. Among the most remarkable, are many gigantic reptiles, some of them herbivorous, others carnivorous, and far exceeding in size any now known even in the torrid zone. The genera are for the most part extinct, but some of them, as the crocodile and monitor, have still representatives in the warmest parts of the earth. Coral reefs also were evidently numerous in the seas of the same period, and composed of species belonging to genera now characteristic of a tropical climate. The number of immense chambered shells also leads us to infer an elevated temperature; and the associated fossil plants, although imperfectly known, tend to the same conclusion, the Cycadeæ constituting the most numerous family. But the study of the fossil flora of the coal deposits of still higher antiquity, has yielded the most extraordinary evidence of an extremely hot climate, for it consisted almost exclusively of large vascular cryptogamic plants. We learn, from the labours of M. Ad. Brongniart, that there existed, at that epoch, Equiseta upwards of ten feet high, and from five to six inches in diameter; tree

* In the London clay, I believe, no recent species are yet discovered. But of twelve hundred species of shells, collected from the different fresh-water and marine formations of the Paris basin, M. Deshayes informs me, that there are some, but not perhaps exceeding one in a hundred, which he regards as perfectly identical with living species. Among these are Melanopsis buccinoides, from Epernais, now living in the Grecian archipelago, and Melania inquinata, now found between the tropics in the Phillippine islands. Venus divaricata is not uncommon in the calcaire grossier at Grignon.

ferns of from forty to fifty feet in height, and arborescent Lycopodiaceæ, of from sixty to seventy feet high*. Of the above classes of vegetables, the species are all small at present in cold climates; while in tropical regions, there occur, together with small species, many of a much greater size, but their development at present, even in the hottest parts of the globe, is inferior to that indicated by the petrified forms of the coal formation. An elevated and uniform temperature, and great humidity in the air, are the causes most favourable for the numerical predominance, and the great size of these plants within the torrid zone at present.† If the gigantic size and form of these fossil plants are remarkable, still more so is the extent of their geographical distribution; for impressions of arborescent ferns, such as characterize our English carboniferous strata, have been brought from Melville island, in latitude 75°‡. The corals and chambered shells, which occur in beds interstratified with the coal (as in mountain limestone), afford also indications of a warm climate,—the gigantic orthocerata of this era being, to recent multilocular shells, what the fossil ferns, equiseta, and other plants of the coal strata, are in comparison with plants now growing within the tropics. These shells also, like the vegetable impressions, have been brought from rocks in very high latitudes in North America.

* Consid. Générales sur la Nature de la Végétation, &c. Ann. des Sci. Nat. Nov. 1828.

† Humboldt, in speaking of the vegetation of the present era, considers the laws which govern the distribution of vegetable forms to be sufficiently constant to enable a botanist, who is informed of the number of one class of plants, to conjecture, with tolerable accuracy, the relative number of all others. It is premature, perhaps, to apply this law of proportion to the fossil botany of strata, between the coal formation and the chalk, as M. Adolphe Brongniart has attempted, as the number of species hitherto procured is so inconsiderable, that the quotient would be materially altered by the addition of one or two species. It may also be objected, that the fossil flora consists of such plants as may accidentally have been floated into seas, lakes, or estuaries, and may often, perhaps always, give a false representation of the numerical relations of families, then living on the land. Yet, after allowing for all liability to error on these grounds, the argument founded on the comparative numbers of the fossil plants of the carboniferous strata is very strong.

Martius informs us, that on seeing the tesselated surface of the stems of arborescent ferns in Brazil, he was reminded of their prototypes, in the impressions which he had seen in the coal-mines of Germany.

‡ Mr. Konig's description of the rocks brought home by Captain Parry, Journ of Science, vol. xv. p. 20.

In vain should we attempt to explain away the phenomena of the carboniferous and other secondary formations, by supposing that the plants were drifted from equatorial seas. During the accumulation, and consolidation of so many sedimentary deposits, and the various movements and dislocations to which they were subjected at different periods, rivers and currents must often have changed their direction, and wood might as often be floated from the arctic towards tropical seas, as in an opposite direction. It is undeniable, that the materials for future beds of lignite and coal are now amassed in high latitudes far from the districts where the forests grew, and on shores where scarcely a stunted shrub can now exist. The Mackenzie, and other rivers of North America, carry pines with their roots attached for many hundred miles towards the north, into the arctic sea, where they are imbedded in deltas, and some of them drifted still farther, by currents towards the pole. But such agency, although it might account for some partial anomalies in the admixture of vegetable remains of different climes, can by no means weaken the arguments deduced from the general character of fossil vegetable remains. We cannot suppose the leaves of tree ferns to be transported by water for thousands of miles, without being injured; nor, if this were possible, would the same hypothesis explain the presence of uninjured corals and multilocular shells of contemporary origin, for these must have lived in the same latitudes where they are now inclosed in rocks. The plants, moreover, whose remains have given rise to the coal beds, must be supposed to have grown upon the same land, the destruction of which provided materials for the sandstones and conglomerates of that group of strata. The coarseness of the particles of many of these rocks attests that they were not borne from very remote localities, but were most probably derived from islands in a vast sea, which was continuous, at that time, over a great part of the northern hemisphere, as is demonstrated by the great extent of the mountain and transition limestone formations. The same observation is applicable to many secondary strata of a later epoch. There must have been dry land in these latitudes, to provide materials by its disintegration for sandstones,—to afford a beach whereon the oviparous reptiles deposited their eggs,—to furnish an habitation for the opossum of

Stonesfield, and the insects of Solenhofen. The vegetation of the same lands, therefore, must in general have imparted to fossil floras their prevailing character.

From the considerations above enumerated, we must infer, that the remains both of the animal and vegetable kingdom preserved in strata of different ages, indicate that there has been a great diminution of temperature throughout the northern hemisphere, in the latitudes now occupied by Europe, Asia, and America. The change has extended to the arctic circle, as well as to the temperate zone. The heat and humidity of the air, and the uniformity of climate, appear to have been most remarkable when the oldest strata hitherto discovered were formed. The approximation to a climate similar to that now enjoyed in these latitudes, does not commence till the era of the formations termed tertiary, and while the different tertiary rocks were deposited in succession, the temperature seems to have been still farther lowered, and to have continued to diminish gradually, even after the appearance of a great portion of existing species upon the earth.