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Continental and Island Life.

A REVIEW OF WALLACE,

WITH REFERENCE TO THE BEARING OF GEOLOGICAL FACTS AND THEORIES OF EVOLUTION ON THE DISTRIBUTION OF LIFE.

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CONTINENTAL AND ISLAND LIFE: THEIR PRESENT STATE AND PAST HISTORY.

THE geographical distribution of living beings in connection with biological and geological science, has been perhaps more fully worked out by Mr. Alfred Russel Wallace than by any other English writer, and his recent work entitled "Island Life" is intended as a summing up of his labors in this direction. It thus affords a good occasion to inquire as to the present state of knowledge on this subject, and the extent to which naturalists of Mr. Wallace's school have succeeded in solving its problems. All are now agreed that to explain the extraordinary and often apparently anomalous distribution of animals and plants over the surface of the earth, and the occurrence of like forms in very distant localities, and even on islands separated by vast stretches of ocean from one another and from the continents, we must invoke the aid of geology. We must have reference to those changes of climate and of elevation which have occurred in the more recent periods of the earth's history, and must carry with us the idea, at first not apparently very reasonable, that living beings have existed much longer than many of the lands which they inhabit, or at least than the present state of those lands in reference to isolation or continental connection. To what extent we may further require to call in the aid of varietal or specific modification to explain the facts, may be more doubtful; and I think we shall find that a larger acquaintance with geological facts would enable us to dispense with the aid of hypotheses of evolution, at least in so far as the establishment of new generic and specific types is concerned.

One of the most remarkable and startling results of geological investigation, and one which must be accepted as an established fact, independently of all theoretical explanations, is that the earth has experienced enormous revolutions of climate within comparatively late periods, and since the date of the introduction of many existing species of animals and plants. To this great truth in some of its bearings I have endeavored to direct attention in two previous articles in this REVIEW, in connection more particularly with the origin and succession of plants, and with the antiquity of man. In the present case it will be necessary to consider these vicissitudes in their more general aspects and with some reference to their causes.

The modern or human period of geology, that in which man and his contemporaries are certainly known to have inhabited the earth, was immediately preceded by an age of climatal refrigeration, known as the glacial or ice age. This was further characterized not only by a prevalence of cold, unexampled so far as known either before or since, but by immense changes of the relative levels of sea and land, amounting, in some cases at least, to several thousands of feet. The occurrence of these changes is clearly proved by the undoubted traces of the action of ice, whether land ice or floating ice, on all parts of our continents more than half way to the equator, and by the occurrence of sea terraces and modern marine shells at high levels on mountains and table-lands. Perhaps we scarcely realize as we should the stupendous character of the changes involved in the driftage of heavy ice over our continents as far south as the latitude of 40°, in the deposit of boulders on hills several thousands of feet in height, and in the occurrence of shells of species still living in the sea, in beds raised to more than twelve hundred feet above its present level. Yet such changes must have occurred in the latest geological period immediately preceding that in which we live.

Proceeding farther back in geological time, we find the still more extraordinary fact that in the middle and earlier Tertiary the northern hemisphere enjoyed a climate so much more mild than that which now prevails, that plants at present confined to temperate latitudes could flourish in Greenland and Spitzbergen. Thus the age in which we live is one of mediocrity, attaining neither to the arctic rigor of the later Pleistocene nor to the universal mildness of the preceding Miocene. The cold of the glacial period is no doubt somewhat exaggerated by those geologists who imagine our continents to have been covered with a continuous ice-sheet of amazing thickness. Some portion of the marvellousness of the preceding warmth is also removed by the consideration of the local inequalities at present observed in the northern regions, as, for instance, between the comparatively temperate climate of Norway and Sweden and the perpetual ice of Greenland in the same latitude. Making all possible allowance for these mitigations, the magnitude of the revolution actually proved to have occurred remains but little extenuated while it seems certain that many of the plants and animals still living have continued through all these changes, and have been driven from place to place for safety as climatal revolutions proceeded.

So far we may be satisfied that we have certain knowledge; but when we inquire further as to the actual antiquity of the glacial period, as to its duration and rates of advance and recession, as to its causes, and the relation of these to the remarkable submergences and emergences of the land, we find ourselves adrift on a tempestuous sea of rival theories. To some extent these may be matters of indifference to the physical geographer or evolutionary biologist, but he is deeply interested in the questions of time and place, and these can scarcely be settled without reference to the causes and conditions of change.

Mr. Searles V. Wood, in an able summary of the possible causes of the succession of cold and warm climates in the northern hemisphere, enumerates no fewer than seven theories which have met with more or less acceptance, and he might have added an eighth. These are:

(1) The gradual cooling of the earth from a condition of original incandescence.

(2) Changes in the obliquity of the ecliptic.

(3) Changes in the position of the earth's axis of rotation.

(4) The effect of the precession of the equinoxes along with changes of the eccentricity of the earth's orbit.

(5) Variations in the amount of heat given off by the sun.

(6) Differences in the temperature of portions of space passed through by the earth.

(7) Differences in the distribution of land and water in connection with the flow of oceanic currents.

(8) Variations in the properties of the atmosphere with reference to its capacity for allowing the radiation of heat.

Something may be said in favor of all these alleged causes; but as efficient in any important degree in producing the cold and warm climates of the Tertiary period, the greater number of them may be dismissed as incapable of effecting such results, or as altogether uncertain with reference to their having occurred. The earth has been gradually cooling in the course of geological time; but this is a continuous process, and its effects within the later periods can be shown to have been inappreciable. The obliquity of the ecliptic is not believed to have changed to any great degree, and its effect would be merely a somewhat different distribution of heat in different periods of the year. The relations of the lines of upheaval of our continents to great circles of the earth tangent to the polar circle, and the distribution of sediments by the arctic currents along these lines, show that throughout geological time the axis of the earth's rotation has occupied its present position. That the absolute amount of heat given off by the sun varies from time to time there seems to be evidence in the periodicity of sun-spots, and the effects on climate attributed to this cause; but we know of no long and regular cycles of this kind. We can imagine that the sun's heat may have been increased at uncertain intervals by the fall of cometary matter or similar causes; but we have no knowledge of the actual occurrence of such accidents, and we know no similar cause of refrigeration. Of difference in temperature in portions of space traversed by the earth we have no evidence whatever. It is extremely probable that in early geological periods the presence of a larger quantity of carbonic dioxide in the earth's atmosphere may have diminished the radiation from its surface, and so have caused its heat to be retained; but this cannot have produced any material effect so late as the glacial period.

There remain two theories, the fourth and seventh of the above list, which may be said to divide between them the suffrages of geologists at present, tho some have endeavored to unite them in one comprehensive explanation. This last was the position of Sir Charles Lyell as it is that of Wallace; and Croll, who is the most able advocate of the fourth, also admits to some extent the influence of the other. The theory of precession and eccentricity depends on two well-known astronomical facts. First, owing to the elliptical form of the earth's orbit, our planet is about three millions of miles nearer to the sun in the winter of the northern hemisphere than in the summer, while the opposite is of course the case with the southern hemisphere; but 10,500 years ago this condition of things was reversed, and it will be reversed 10,500 years hence. If this has any effect on the seasons, it should be to make the climate of the northern hemisphere less extreme—that is, less warm in summer and less cold in winter; but the reverse of this is now actually the case, since the climate of the southern hemisphere is now the less extreme of the two, tho slightly the higher in temperature.[1] This we know to arise from the distribution of land and water, which must thus be a far more potent cause of difference. But there is a second cause affecting the result, and whose periods are much longer. This is the lengthening and shortening of the earth's orbit, placing the sun nearer to one end of it at one time than at another. The "eccentricity" of the earth's orbit is at present nearly at a minimum, or the sun is about as near the centre of our orbit as he can be; but about a hundred thousand years ago it was much greater, so that one pole of the earth would in winter be nearly eight millions of miles nearer to the sun than in summer. In these circumstances the effect of the north pole, for example, being nearer to the sun in winter would be much greater than at present in producing a difference of temperature; but it would be a difference not so much in the total amount of heat as in its distribution throughout the year. In the hemisphere which had the coldest winter there would be a correspondingly warm summer.

In order, therefore, to establish a probability that these changes could have any effect in producing cold and warm periods, it is necessary to call in other considerations, in themselves so important that they quite outweigh the astronomical causes, and to make some assumptions more or less conjectural. Let us consider the latter first.

It is assumed that the tendency of an exceptionally cold win-

[1] Fenel, "Meteorological Researches" (Washington), 1877.

ter would be to accumulate so great a quantity of snow and ice that these could not be removed in the short tho warm summer, and so would go on accumulating from year to year. Actual experience and observation do not confirm this supposition. In those parts of North America which have a long and severe winter, the amount of snow deposited is not in proportion to the lowness of the temperature, but, on the contrary, the greatest precipitation of snow takes place near the southern margin of a cold area, and the snow disappears with great rapidity when the spring warmth sets in. Nor is there, as has been imagined, any tendency to the production of fogs and mists which have been invoked as agencies to shield the snow from the sun. In North America the melting snow is ordinarily carried off as liquid water or as invisible vapor, and the sky is usually clear when the snow is melting in spring. It is only when warm and moist winds are exceptionally thrown upon the snow-covered land that clouds are produced; and when this is the case the warm rain that ensues promotes the melting of the snow. Thus there is no possibility of continued accumulations of snow on the lower parts of our continents, under any imaginable conditions of climate. It is only on elevated lands in high latitudes and near the ocean, like Greenland and the antarctic continent, that such permanent snow-clad conditions can occur, except on mountain-tops. Wallace very properly maintains, in connection with these facts, that permanent ice and snow cannot under any ordinary circumstances exist in low lands, and that high land and great precipitation are necessary conditions of glaciers. He attaches, however, rather too much importance to snow and ice as cooling agents; for tho it is true that they absorb a large amount of heat in passing from the solid to the liquid state, yet the quantity of snow or ice to be melted in spring is so small in comparison with the vast and continuous pouring of solar heat on the surface, that a very short time suffices for the liquefaction of a deep covering of snow. He quotes the remarks of Siberian travellers on this, and the same fact is a matter of ordinary observation in North America.

Setting aside, then, these assumptions, which proceed from incorrect or insufficient information, we may now refer to a consideration of the utmost importance, and which Mr. Croll, tho he adduces it in aid of the astronomical theory of glacial periods, has treated in so masterly a manner as really to give it the first place as an efficient cause. This is the varying distribution of ocean currents, in connection with the differences in the elevation and distribution of land. The great equatorial current, produced by the action of the solar heat on the atmosphere and the water, along with the earth's rotation, is thrown, by opposing continental shores, northward into the Atlantic and Pacific in the Gulf Stream and Japan current, giving us a hot-water apparatus which effectually raises the temperature of the whole northern hemisphere, and especially of the western sides of the continents. Mr. Croll imagines that if his astronomical causes could, to ever so small an extent, intensify the action of these currents or their determination to the north, we should have a period of warmth, while a similar advantage given to the southern hemisphere would produce a glacial age in the north. But this requires us to assume what ought to be proved; namely, that the position of aphelion and the increase or decrease of eccentricity would actually so swing the equatorial current to the north or south. It further requires us to assume—and this is the most important defect of the theory—that no change occurs in the distribution of land and water; because any important change of this kind might obviously exert a dominant influence on the currents. Let us take two examples in illustration of this.

At the present time the warm water thrown into the north Atlantic not only increases the temperature of its whole waters, but gives an exceptionally mild climate to western Europe. Still the countervailing influence of the arctic currents and the Greenland ice is sufficient to permit numerous icebergs to remain unmelted on the coast of Labrador and Newfoundland throughout the summer. Some of the bergs which creep down to the mouth of the Strait of Belle Isle, in the latitude of the south of England, actually remain unmelted till the snows of a succeeding winter fall upon them. Now let us suppose that a subsidence of land in tropical America were to allow the equatorial current to pass through into the Pacific. The effect would at once be to reduce the temperature of Norway and Britain to that of Greenland and Labrador at present, while the latter countries would themselves become colder. The northern ice, drifting down into the Atlantic, would not as now be melted rapidly by the warm water which it meets in the Gulf Stream. Much larger quantities of it would remain undissolved in summer, and thus an accumulation of permanent ice would take place, along the American coast at first, but probably at length even on the European side. This would still further chill the atmosphere, glaciers would be established on all the mountains of temperate Europe and America, the summer would be kept cold by melting ice and snow, and at length all eastern America and Europe might become uninhabitable, except by arctic animals and plants, as far south as perhaps 40° of north latitude. This would be simply a return of the glacial age. I have assumed only one geographical change; but other and more complex changes of subsidence and elevation might take place, with effects on climate still more decisive.

We may suppose an opposite case. The high plateau of Greenland might subside or be reduced in height, and the opening of Baffin's Bay might be closed. At the same time the interior plain of America might be depressed, so that, as we know to have been the case in the Cretaceous period, the warm waters of the Mexican gulf might circulate as far north as the basins of the present great American lakes. In these circumstances there would be an immense diminution of the sources of floating ice, and a correspondingly vast increase in the surface of warm water. The effects would be to enable a temperate flora to subsist in Greenland, and to bring all the present temperate regions of Europe and America into a condition of subtropical verdure.

It is only necessary to add that we actually know that changes not dissimilar from those above sketched have actually occurred in comparatively recent geological times, to enable us to perceive that we can dispense with all other causes of change of climate, tho admitting that some of them may have occupied a secondary place. This will give us in dealing with the distribution of life the great advantage of not being tied up to definite astronomical cycles of glaciation which do not well agree with the geological facts, and of correlating elevation and subsidence of the land with changes of climate affecting living beings. It will, however, be necessary, as Wallace well insists, that we shall hold to a certain fixity of the continents in their position, notwithstanding the submergences and emergences which they have experienced.

Sir Charles Lyell, more than forty years ago, published in his "Principles of Geology" two imaginary maps which illustrate the extreme effects of various distribution of land and water. In one all the continental masses are grouped around the equator. In the other they are all placed around the poles, leaving an open equatorial ocean. In the one case the whole of the land and its inhabitants would enjoy a perpetual summer, and scarcely any ice could exist in the sea. In the other the whole of the land would be subjected to an arctic climate, and it would give off immense quantities of ice to cool the ocean. Sir Charles remarks on the present apparently capricious distribution of land and water, the greater part being in the northern hemisphere, and, in this, placed in a very unequal manner. But Lyell did not suppose that any such distribution as that represented in his maps had actually occurred, tho this supposition has been sometimes attributed to him. He merely put what he regarded as an extreme case to illustrate what might occur under conditions less exaggerated. Sir Charles, like all other thoughtful geologists, was well aware of the general fixity of the areas of the continents, tho with great modifications in the matter of submergence and of land conditions. The union, indeed, of these two great principles of fixity and diversity of the continents lies at the foundation of theoretical geology.

We can now more precisely indicate this than was possible when Lyell produced his "Principles," and can reproduce the conditions of our continents in even the more ancient periods of their history. An example of this may be given from the American continent, which is more simple in its arrangements than the double continent of Eurasia. Take, for instance, the early Devonian or Erian period, in which the magnificent flora of that age, the earliest certainly known to us, made its appearance. Imagine the whole interior plain of North America submerged, so that the continent is reduced to two strips on the east and west, connected by a belt of Laurentian land on the north. In the great mediterranean sea thus produced the tepid water of the equatorial current was circulated, and it swarmed with corals, of which we know no less than 150 species, and with other forms of life appropriate to warm seas. On the islands and coasts of this sea was introduced the Erian flora, appearing first in the north, and with that vitality and colonizing power of which, as Hooker has well shown, the Scandinavian flora is the best modern type, spreading itself to the south.[1] A very similar distribution of land and water in the Cretaceous age gave a warm and equable climate in those portions of North America not submerged, and coincided with the appearance of the multitude of broad-leaved trees of modern types which appeared in the early and middle Cretaceous, and prepared the way for the mammalian life of the Eocene.

We have in America ancient periods of cold as well as of warmth. I have elsewhere referred to the boulder conglomerates of the Huronian, of the early Lower Silurian, and of the Millstone-grit period of the Carboniferous; but I have not ventured to affirm that either of these periods was comparable in its cold with the later glacial age, still less with that imaginary age of continental glaciation assumed by the more extreme theorists. We know that these ancient conglomerates were produced by floating ice, and this at periods when in areas not very remote temperate floras and faunas could flourish. The glacial periods of our old continent occurred in times when the surface of the submerged land was opened up to the northern currents drifting over it mud and sand and stones, and rendering nugatory, in so far at least as the bottom of the sea was concerned, the effects of the superficial warm streams. Some of these beds are also peculiar to the eastern margin of the continent, and indicate ice-drift along the Atlantic coast much as at present, while conditions of greater warmth existed in the interior. Even in the more recent glacial age, while the mountains were covered with snow and the lowlands submerged under a sea laden with ice, there were interior tracts in somewhat high latitudes of America in which hardy forest-trees and herbaceous plants flourished abundantly, and these were by no means exceptional "interglacial" periods.[2] Thus we can prove that

[1] As I have elsewhere shown, a warm climate in an arctic region seems to have afforded the necessary conditions for the great colonizing floras of all geological periods.

[2] "Notes on the Post-Pliocene of Canada."

from the remote Huronian period to the Tertiary the American land occupied the same position as at present, and that its changes were merely changes of relative level as compared with the sea, but which so influenced the ocean currents as to cause great vicissitudes of climate.

Having thus endeavored, however roughly and imperfectly, to define the nature, extent, and causes of the vicissitudes of climate and other physical conditions on our continents, we shall be in a position to consider their present state and the causes of the distribution of their living inhabitants.

In speaking of continents and islands it may be as well to remark that all the land existing, or which probably has at any time existed, consists of islands great or small. It is all surrounded by the ocean. Two of the greater masses of land are, however, sufficiently extensive to be regarded as continents, and from their very extent and consequent permanence may be considered as the more special homes of the living beings of the land. Two other portions of land, Australia and the antarctic polar continent, may be regarded either as smaller continents or large islands, but partake of insular rather than continental characters in their animals and plants. All the other portions of land are properly islands; but while these islands, and more especially those in mid-ocean, cannot be regarded as the original homes of many forms of life, we shall find that they have a special interest as the shelters and refuges of numerous very ancient and now decaying species.

The two great continents of America and Eurasia have been the most permanent portions of the land throughout geological time, some parts of them having always been above water, probably from the Laurentian age downward, tho at various times they have been reduced to little more than groups of islands. On them, and more especially in their more northern parts, in which the long continuance of daylight in summer seems in warm periods to have been peculiarly favorable to the introduction of new vegetable forms, and to the giving to them that vigor necessary for active colonization, have originated the greater number of the inhabitants of the land.

Regarded as portions of the earth's crust, the continents are areas in which the lateral thrust, caused by the secular contraction of the interior of the earth, has ridged up and folded the rocks, producing mountain-chains. This process began in the earliest geological periods, and has been repeated at long intervals, the original lines of folding guiding those formed in each new thrust proceeding from the flat oceanic areas. Along the ridges thus produced, and in the narrower spaces between them, the greater part of the sediment carried by water was laid down, thus producing plateaus in connection with the mountain-chains. The tendency of the ocean to be thrown toward the poles by the retardation of the earth's rotation, alternating with great collapses of the crust at the equator, proceeding from the same cause along with the secular cooling, have produced alternate submergence and emergence of these plateaus. This has been further complicated by the constant tendency of the arctic and antarctic currents, aided by ice, to drift solid materials, set free by the vast denuding action of frost, from the polar to the temperate regions, and by the further tendency of animal life to heap up calcareous accumulations under the warm waters of the tropical regions. All these changes, as already stated, have conspired to modify the directions of the great oceanic currents, and to produce vicissitudes of climate under which animals and plants have been subjected in geological time to those migrations, extinctions, and renovations of which their fossil remains and present distribution afford evidence.

Still it is true that throughout the whole of these great mutations, since the beginning of geological history, there seems never to have been any time when the ocean so regained its dominion as to produce a total extinction of land life, still less was there any time when the necessary conditions for all the various forms of marine life failed to be found; nor was there any climatal change so extreme as to banish any of the leading forms of life from the earth. To geologists it is not necessary to say that the conclusions sketched above are those that have been reached as the results of long and laborious investigation, and which have been illustrated and established by Lyell, Dana, and many other writers. They are on the whole fairly stated by Wallace in his work on "Island Life."[1] Let us now place beside

[1] The writer has endeavored to popularize these great results of geology in his work the "Story of the Earth." They are often overlooked by specialists and by compilers of geological manuals.

them some facts as to the present distribution of life and of the agencies which influence it.

If we examine Petermann's map of the ice of the north and south polar regions, reproduced by Wallace, we shall find a remarkable contrast. In the southern polar region a space extending in all directions twenty degrees, and in some directions twenty-five degrees, is occupied with permanent snow. Thus we have a snow-clad continent, at the outer edge of which the stratum of solid water is at least a mile in thickness, attaining a diameter of over 2000 miles. Around this we have floating ice dispersed in all directions, on the Atlantic side beyond the parallel of 40°, and on the Pacific side only a little short of this. In other words, we have a distribution of floating ice, bearing with it stones and other land material, over a radius of about 3000 nautical miles from the south pole. This is an extension of polar ice nearly equal to that which occurred in the northern hemisphere in the great glacial age, and as it evidently results from the existence of a compact mass of high land serving as a condensing-ground for the aqueous vapor of the surrounding ocean, we have only to imagine a few spurs of high ground like Greenland projecting from the antarctic continent to render the present glacial age of the southern hemisphere even more severe than that of the Pleistocene probably was in the north. As it now is, Heard's Island, in south latitude 53°, is glaciated down to the sea, and New Zealand, in south latitude 43° 35′, has a glacier descending to within 705 feet of the sea.[1]

If we turn now to the north polar region, the case is very different. Here the area of permanent ice is scarcely more than half that of the south pole, and if we were to remove the exceptionally high and ice-covered tract of Greenland it would be scarcely more than one third. The distribution of floating ice is in like manner limited to a narrow belt along the west side of the north Atlantic and to the coasts of the most northern part of the Pacific. Geological facts indicate that within a comparatively recent period the state of matters in the north was much less favorable as to temperature, but that previously to this for

[1] It is a significant fact that while in latitudes lower than 40° the southern hemisphere is the colder, in higher latitudes it is the warmer. Thus a glacial age may affect temperate latitudes more than those which are polar.

a very long time, extending apparently through nearly the whole Cretaceous and Tertiary periods, the geographical conditions were such that the arctic climate was very much milder than at present. In testimony of this we have not only the temperate flora of Greenland and other northern lands in the Cretaceous and Tertiary, and the evidence that then Greenland was not a snow-clad table-land as at present, but the fact vouched for by Nordenskjöld that no boulders or ice-drifted materials are to be found in any of the arctic deposits older than the glacial age. We shall find that these facts throw much light on the distribution of those animals and plants which have come down to us from the preglacial times, as well as on that of more modern species.

Just as political geography sometimes presents boundaries not in accordance with the physical structure of countries, so the distribution of animals and plants shows many peculiar and unexpected features. Hence naturalists have divided the continents into what Sclater has called zoological regions, which are, so to speak, the great empires of animal life, divisible often by less prominent boundaries into provinces. In vegetable life similar boundaries may be drawn, more or less coincident with the zoological divisions. Zoologically, North America and Greenland may be regarded as one great region, the Nearctic, or new arctic, the prefix not indicating that the animals are newer than those of the old world, which is by no means the case. South America constitutes another region, the Neotropical. If now we turn to the greater Eurasian continent, with its two prolongations to the south in Africa and Australia, we shall find the whole northern portion, from the Atlantic to the Pacific, constituting one vast region of animal life, the Palearctic, which also includes Iceland and a strip across north Africa. Africa itself, with Madagascar, whose allegiance is, however, only partial, constitutes the Ethiopian region. India, Burmah, the south of China, and certain Asiatic islands form the Oriental region. Australia, New Guinea, and the Polynesian islands constitute the Australian region. All of these regions may in a geological point of view be considered as portions of old and permanent continental masses, which, tho with movements of elevation and depression, have continued to exist for vast periods. Some of them, however, seem to have enjoyed greater immunity from causes of change than others, and present accordingly animals and plants having an antique aspect, geologically speaking, in comparison with the others. In this sense the Australian province may be regarded as the oldest of all in the facies of its animal forms, since creatures exist there of genera and families which have very long ago become extinct everywhere else. Next in age to this should rank the Neotropical or South American region, which like Australia presents many low and archaic forms of animal life. The Ethiopian region stands next to it in this, the Oriental and Nearctic next, and last and most modern in its aspect is the great Palearctic region, to which man himself belongs, and the animals and plants of which vindicate their claims to youth by that aggressive and colonizing character already referred to, and which has enabled them to spread themselves widely over the other regions, even independently of the influence of man. On the other hand, the animals and plants of the Australian and South American regions show no such colonizing tendency, and can scarcely maintain themselves against those of other regions when introduced among them. Thus we have at once in these continental regions a great and suggestive example of the connection of geographical and geological distribution, the details of which are of the deepest interest and have not yet been fully worked out. One great principle is, however, sufficiently established; namely, that the northern regions have been the birthplace of new forms of land life, whence they have extended themselves to the south, while the comparative isolation and equable climate of the South American and Australian regions have enabled them to shelter and retain the old and moribund tribes.

Those smaller portions of land separated from the continental masses, the islands properly so called, present, as might be expected, many peculiar features. Wallace divides them into two classes, tho he admits that these pass into each other. Continental islands are those in the vicinity of continents. They consist of ancient as well as modern rock-formations, and contain animals which indicate a former continental connection. Some of these are separated from the nearest mainland only by shallow seas or straits, and may be assumed to have become islands only in recent geological times. Others are divided from the nearest continent by very deep water, so that they have probably been longer severed from the mainland. These contain more peculiar assemblages of animals and plants than the islands of the former class. Oceanic islands are more remote from the continents. They consist of rocks belonging to the more modern geological periods, and contain no animals of those classes which can migrate only by land. Such islands may be assumed never to have been connected with any continent. The study of the indigenous population of these various classes of islands affords many curious and interesting results, which Wallace has collected with vast industry and care, and which on the whole he explains in a judicious manner and in accordance with the facts of geology. When, however, he maintains that evolution of the Darwinian type is "the key to distribution," he departs widely from any basis of scientific fact. This becomes apparent when we consider the following results, which appear everywhere in the discussion of the various insular faunas and floras: (1) None of these islands, however remote, can be affirmed to have been peopled by the spontaneous evolution of the higher animals or plants from lower forms. Their population is in every case not autochthonous, but derived. (2) Even in those which are most distant from the continents, and may be supposed to have been colonized in very ancient times, there is no evidence of any very important modification of their inhabitants. (3) While the facts point to the origin of most forms of terrestrial life in the Palearctic and Nearctic regions, they afford no information as to the manner or cause of their origination. In short, so far is evolution from being a key to distribution that the whole question would become much more simple if this element were omitted altogether. A few examples may be useful to illustrate this, as well as the actual explanation of the phenomena afforded by legitimate science.

The Azores are situated in a warm temperate latitude about 900 miles west of Portugal, and separated from it by a sea 2000 fathoms in depth. The islands themselves are almost wholly volcanic, and the oldest rocks known in them are of late Miocene age. There is no probability that these islands have ever been connected with Europe or Africa, nor is there at present any certainty that they have been joined to one another or have formed part of any larger insular tract. In these islands there is only one indigenous mammal, a bat, which is identical with a European species, and no doubt reached the islands by flight. There is no indigenous reptile, amphibian, or fresh-water fish. Of birds there are, exclusive of water-fowl, which may be regarded as visitors, twenty-two land birds; but of these four are regarded as merely accidental stragglers, so that only eighteen are permanent residents. Of these birds fifteen are common European or African species, which must have flown to the islands or have been drifted thither in storms. Of the remaining three, two are found also in Madeira and the Canaries, and therefore may reasonably be supposed to have been derived from Africa. One only is regarded as peculiar to the Azores, and this is a bullfinch, so nearly related to the European bullfinch that it may be regarded as merely a local variety. Wallace accounts for these facts by supposing that the Azores were depopulated by the cold of the glacial age, and that all these birds have arrived since that time. There is, however, little probability in such a supposition. He further supposes that fresh supplies of stray birds from the mainland, arriving from time to time, have kept up the identity of the species. Instead of evolution assisting him, he has thus somewhat to strain the facts to agree with that hypothesis. Similar explanations are given for the still more remarkable fact that the land plants of the Azores are almost wholly identical with European and African forms. The insects and the land snails are, however, held to indicate the evolution of a certain number of new specific forms on the islands. The beetles number no less than 212 species, tho nearly half of them are supposed to have been introduced by man. Of the whole number 175 are European, 19 are found in Madeira and the Canaries, 3 are American. Fourteen remain to be accounted for, tho most of these are closely allied to European and other species; but a few are quite distinct from any elsewhere known. Wallace, however, very truly remarks that our knowledge of the continental beetles is not complete, that the species in question are small and obscure, that they may be survivors of the glacial period, and may thus represent species now extinct on the mainland; and that for these reasons it may not be irrational to suppose that these peculiar insects either still inhabit or did once inhabit some part of the continents, and may be portions of "ancient and wide-spread groups" once widely diffused, but now restricted to a few insular spots. Among the land snails, if anywhere, we should find evidence either of autochthonous evolution or of specific change. These animals have existed on the earth since the Carboniferous period, and, notwithstanding their proverbial slowness and sedentary habits, they have contrived to colonize every habitable spot of land on the globe—that is, unless in some of these places they have originated *de novo*. In the Azores there are sixty-nine species of land snails, of which no less than thirty-two, or nearly one half, are peculiar, tho nearly all are closely allied to European types. What, then, is the origin of these thirty-two species, admitting for the sake of argument that they are really distinct and not merely varietal forms, tho it is well known that in this group species are often unduly multiplied. Three suppositions are possible. (1) These snails may have originated in the islands themselves, either by creation or evolution from lower forms, say from sea snails. (2) They may have been modified from modern continental species. (3) They may be unmodified descendants of species of Miocene or Pliocene age now existing on the continents only as fossils. As the islands appear to have existed since Miocene times, it is no more improbable that species of that or the Pliocene age should have found their way to them than that modern species should; and as we know only a fraction of the Tertiary species of Europe or Africa, it is not likely that we shall be able to identify all of these early visitors. Unfortunately no Miocene or Pliocene deposits holding remains of land snails are known in the Azores themselves, so that this kind of evidence fails us. In Madeira and Porto Santo, however, where there are numerous modern snails, there are Pliocene beds holding remains of these animals. In Madeira there are, according to Lyell, 36 Pliocene species, and in Porto Santo 35, and of these only eight are extinct. Thus we can prove that many of the peculiar species of these islands have remained unchanged since Pliocene times. While differing from modern European shells, several of these species are very near to European Miocene species. Thus we seem to have evidence in the Madeira group, not of modification, but of unchanged survival of Tertiary species long since extinct in Europe. May we not infer that the same was the case in the Azores? These results are certainly very striking when we consider how long the Azores must have existed as islands, how very rarely animals, and especially pairs of animals, must have reached them, and how complete has been the isolation of these animals and how peculiar the conditions to which they have been subjected in their island retreat.

Other oceanic islands present great varieties of conditions, but leading to similar conclusions. Some, as the Bermudas, seem to have been settled in very modern times with animals and plants nearly all identical with those of neighboring countries. Others, like St. Helena, are occupied apparently with old settlers, which may have come to them in early Tertiary or even in Secondary periods, which have long since become extinct on the continents, and whose nearest analogues are now widely scattered over the world. Islands are therefore places of survival of old species—special preserves for forms of life lost to the continents. One of the most curious of these, according to Wallace, is Celebes, which seems to be a surviving fragment of Miocene Asia, which, tho so near to that continent, has been sufficiently isolated to preserve its old population during all the vast lapse of time between the middle Tertiary and the present period. This is a fact which gives to the oceanic islands the greatest geological interest, and induces us to look in their actual faunæ and floræ for the representatives of species known on the mainland only as fossils. It is thus that we look to the marsupials of Australia as the nearest analogues of those of the Jurassic of Europe, and that we find in the strange barramunda of its rivers the only survivor of a group of fishes once widely distributed, but which has long since perished elsewhere.

Perhaps one of the most interesting examples of this is furnished by the Galapagos Islands, an example the more remarkable that no one who has read in Darwin's fascinating "Journal" the description of these islands, can have failed to perceive that the peculiarities of this strange archipelago must have been prominent among the facts which first planted in his mind the germ of that theory of the origin of species which has since grown to such gigantic dimensions. It is cirious also to reflect that had the bearing of geological history onthe facts of distribution been as well known forty years ago as il is now, the reasoning of the great naturalist on this and similar cases might have taken an entirely different direction.

The Galapagos are placed exacty on the equator, and therefore out of reach of the glacial colc, tho from their isolation in the ocean, and the effects of the currents flowing along the American coast, their climate is nt extremely hot. They are 600 miles west of South America, ınd the separating ocean is in some parts 3000 fathoms deep. The largest of the islands is 75 miles in length, and some of th(hills attain an elevation of about 4000 feet, so that there are cosiderable varieties of station and climate. So far as known tley are wholly volcanic, and they may be regarded as the summits of submerged mountains not unlike in structure to the An(es of the mainland. Their exact geological age is unknown, bıt there is no improbability in supposing that they may have exsted with more or less of extension since the Secondary period. In any case their fauna is in some respects a survival of that age. Lyell has truly remarked, "In the fauna of the Galapagos Islnds we have a state of things very analogous to that of the Secoıdary period."

Like other oceanic islands, the Galapagos have no indigenous mammals, with the doubtful exce)tion of a South American mouse; but, unlike most others, tley are rich in reptiles. At the head of these stand several secies of gigantic tortoises. This group of animals, so far as lnown, commenced its existence in the Eocene Tertiary; and iı this and the Miocene period still more gigantic species existed oı the continents. It has been supposed that at some such early dte they reached the Galapagos from South America. Anothergroup of Galapagan reptiles, perhaps still more remarkable, is tıat of iguana-like lizards of the genus *Amblyrhyncus*, which ar(vegetable feeders,—one of them browsing on marine weeds. They recall the great iguana-like reptiles of the European Wealdn, and stand remote from all modern types. There are also snakes of two species, but these are South American forms, and may have drifted to the islands in comparatively modern times on loating trees. The birds are a curious assemblage. A few are common American species like the rice-bird. Others are quaint and peculiar creatures allied to South American birds, but probably representing forms long since extinct on the continent. The bird fauna, as Wallace remarks, indicates that some of these animals are old residents, others more recent arrivals; and it is probable that they have arrived at various times since the early Tertiary. He assumes that the earlier arrivals have been modified in the islands "into a variety of distinct types," but the only evidence of this is that some of the species are closely related to each other. It is more likely that they represent to our modern eyes the unmodified descendants of continental birds of the early Tertiary. Darwin remarks that they are remarkably sombre in coloring for equatorial birds; but perhaps their ancestors came from a cooler climate and have not been able to don a tropical garb; or perhaps they belong to a far-back age when the vegetable kingdom also was less rich in coloring than it is at present, and the birds were in harmony with it. This, indeed, seems still to be the character of the Galapagos plants, which Darwin says have "a wretched, weedy appearance," without gay flowers.

These plants are in themselves very remarkable, for they are largely peculiar species, and are in many cases confined to particular islands, having apparently been unable to cross from one island to another, tho in some way able to reach the group. The explanation is that they resemble North American plants, and came to the Galapagos at a time when a wide strait separated North and South America, allowing the equatorial current to pass through and drift plants to the Galapagos, where they have been imprisoned ever since. This was probably in Pliocene times, and when we know more of the Pliocene flora of the southern part of North America we may hope to recover some of the ancestors of the Galapagos plants. In the mean time their probable origin and antiquity, as stated by Wallace, render unnecessary any hypothesis of modification.

Before leaving this subject, it is proper to observe that on the continents themselves there are many remarkable cases of isolation of species, which help us better to understand the conditions of insular areas. The "variable hare" of the Scottish highlands and of the extreme north of Europe appears again in the Alps, the Pyrenees, and the Caucasus, being in these mountains separated by a thousand miles of apparently impassable country from its northern haunts. It no doubt extended itself over the intervening plains at a time when Europe was colder than at present. Another curious case, which has evidently much interested Mr. Wallace, since he gives a special map to its illustration, is that of the marsh-tit of Europe. This little bird is found throughout south-western Europe. It reappears in China, but is not known anywhere between. In Siberia and northern Europe there is, however, a species or distinct race which connects these isolated patches. In this case, if the Siberian species is truly distinct, we have a remarkable case of isolation and of the permanence of identical characters for a long time, for in that case this bird must be a survivor of the Pliocene or Miocene time. On the other hand, if, as is perhaps more likely, the marsh-tit is only a local variety of the Siberian species, we have an illustration of the local recurrence of this form when the conditions are favorable, even tho separated by a great space and long time.

The study of fossils gives us the true meaning of such facts, and causes us to cease to wonder at any case of local repetition of species, however widely separated. The "big trees" of California constitute a remarkable example. There are at present two very distinct species of these trees, both found only in limited areas of the western part of North America. Fossil trees of the same genus (*Sequoia*) occur as far back as the Cretaceous age; but in this age no less than ten species are known, and there were probably more. Nor are they confined to America, but occur in various parts of the Eurasian continent as well. Two of the Lower Cretaceous species are so near to the two modern ones that even an unbeliever in evolution may suppose them to be possible ancestors; the remaining eight are distinct, but some of them intermediate in their characters. In the Tertiary period, intervening between the Cretaceous and the modern, fourteen species of *Sequoia* are believed to have been recognized, and they appear to have existed abundantly all over the northern hemisphere. Thus we know that these remarkable Californian giants are the last remnant of a once widely distributed genus, originating, so far as known, in the Cretaceous age. Now had a grove of *Sequoias*, however small, survived anywhere in Europe or Asia, and had we no knowledge of the fossil forms, we might have been quite at a loss to account for their peculiar distribution. The fossil remains of the Tertiary rocks, both animal and vegetable, present us with many instances of this kind.

In his recent work Wallace has done a great service to science, and indeed to humanity, by showing the entire untenableness of the idea that a land connection existed in recent times between Australia and Africa—that hypothetical "continent of Lemuria" of which Haeckel has made so much use as the supposed home of his "alali," or speechless men, the missing link between man and the apes. The theory of the former existence of such a continent was based on certain resemblances of the animal population of Africa and Madagascar to that of Australia and the Indian Islands. The great depth, however, of the intervening sea, as well as the faunæ of its islands, preclude the supposition of any continental connection; and the history of the animals in question, so far as known to us, favors the belief that they entered independently into Africa and Australia from the great Palearctic region, in which they existed in early Tertiary times. A similar explanation applies to a few forms of plants common to South Africa and Australia. Lemuria thus becomes a mere "survival of a provisional hypothesis which affords what seems an easy solution of a difficult problem, and has received an appropriate and easily remembered name." It is to be feared that it does not stand alone in this respect among modern scientific hypotheses. Failing Lemuria, however, the doctrine of the "descent of man" becomes more difficult than before. This hypothetical continent was connected with the habitats of our supposed earliest simian ancestors, the lemurs, and also with the countries in which we find the lowest types of man, as well as with those regions in southern Asia to which historical affiliation traces the origin of the earliest nations. Thus it formed a very convenient region to which to refer anxious inquirers after the "missing link," and Haeckel did not hesitate to affirm that from this perished continent "the distribution of the various species and races of men probably took place over the surface of the earth." What new discovery or "provisional hypothesis" will take the place of Lemuria remains to be seen. In the mean time we have no reason to believe that the Tasmanians or the Bushmen are the originals of humanity; but may rather conclude that they are degraded races produced by banishment to less congenial abodes than the original home of the species in the Palearctic region.

The discussion of the distribution of animals and plants, when carried on in the light of geology, raises many interesting questions as to time which we have already glanced at, but which deserve a little more attention. As to the vast duration of geological time all geologists are agreed, and recently the advocates of evolution have even exceeded the geologists in such demands. It is, however, now well understood that science sets certain limits to the time at our disposal. Edward Forbes humorously defined a geologist to be "an amiable enthusiast who is content if allowed to appropriate as much as he pleases of that which other men value least, namely, past time;" but now even the geologist is obliged to be content with a limited quantity of this commodity, and Wallace has the credit of being the first biological evolutionist who has boldly faced this difficulty.

The well-known estimate of Sir William Thomson gives one hundred millions of years as the probable time necessary for the change of the earth from the condition of a molten mass to that which we now see. On this estimate we might fairly assume fifty millions of years as covering the time from the Laurentian age to the modern period. Other physicists, however, reasoning on the constitution of the sun, would greatly reduce this time, and even confidently affirm that "twenty millions of years ago the earth was enveloped in the fiery atmosphere of the sun."[1] Geology itself has attempted an independent calculation based on the wearing down of our continents, which appears to proceed at the rate of about a foot in four or five thousand years, and on the time required to deposit the sediments of the several geological formations, estimated at about 70,000 feet in thickness. These calculations would give us, say, eighty-six millions of years since the earth began to have a solid crust, which would, like Sir William Thomson's estimate, give us nearly fifty millions of years for the geological time since the introduction of life. In revising these calculations a few years ago I was

[1] Newcomb, Helmholtz, Tait, etc.

inclined to fix on forty-eight millions of years as the probable limit of available time; but new facts and suggestions recently obtained induce me to think that the modern rates of denudation and deposit must be taken as far below the average, and that perhaps the estimate stated by Wallace as resulting from one mode of calculation, namely, twenty-eight millions, may be not far from the truth, tho perhaps admitting of considerable abatement.

This reduced estimate of geological time would still give scope enough for the distribution of animals and plants, but it will scarcely give that required by certain prevalent theories of evolution. When Darwin says, "If the theory (of natural selection) be true, it is indisputable that before the lowest Cambrian stratum was deposited long periods elapsed, as long as or probably far longer than the whole interval from the Cambrian to the present day," he makes a demand which geology cannot supply; for independently of our ignorance of any formations or fossils, except the Laurentian and its *Eozoön*, to represent this vast succession of life, the time required would push us back into a molten state of the planet. This difficulty is akin to that which meets us with reference to the introduction of many and highly specialized mammals in the Eocene, or of the forests of modern type in the Cretaceous. To account for the origin of these by slow and gradual evolution requires us to push these forms of life so far back into formations which afford no trace of them, but, on the contrary, contain other creatures that appear to be exclusive of them, that our faith in the theory fails. The only theory of evolution which seems to meet this difficulty is that, advanced by Mivart, Leconte, and Saporta, of "critical periods," or periods of rapid introduction of new species alternating with others of comparative inaction. This would much better accord with the apparently rapid introduction of many new forms of life over wide regions at the same period. It would also approach somewhat near, in its manner of stating the problem to be solved, to the theory of "creation by law" as held by the Duke of Argyll, or to what may be regarded as "mediate creation," proceeding in a regular and definite manner, but under laws and forces as yet very imperfectly known, throughout geological time.

It seems singular, in view of the facts of paleontology, that evolutionists of the Darwinian school are so wedded to the idea of one introduction only of each form of life, and its subsequent division by variation into different species, as it progressively spreads itself over the globe or is subjected to different external conditions. It is evident that a little further and very natural extension of their hypothesis would enable them to get rid of many difficulties of time and space. For example, certain millipedes and batrachians are first known in the coal-formation, and this not in one locality only, but in different and widely separated regions. If they took beginning in one place and spread themselves gradually over the world, this must have required a vast lapse of time, more than we can suppose probable. But if, in the coal-formation age, a worm could anywhere change into a millipede, or a fish into a batrachian, why might not this have occurred in many places at once? Again, if the oldest known land snails occur in the coal-formation and we find no more specimens till a much later period, why is it necessary to suppose that these creatures existed in the intervening time, and that the later species are the descendants of the earlier? Might not the process have been repeated again and again, so as to give animals of this kind to widely separated areas and successive periods without the slow and precarious methods of continuous evolution and migration? This apparent inconsistency strikes one constantly in the study of "Island Life," when we find the author laboriously devising expedients for the introduction of animals into the most unlikely places, when it would seem that they might just as well have originated in those places by direct evolution from lower forms. Those who believe in a separate centre of creation for each species must of course invoke all geological and geographical possibilities for the dispersion of animals and plants; but surely the evolutionist, if he has faith in his theory, might take a more easy and obvious method, especially when in any case he is under the necessity of demanding a great lapse of time. That he does not adopt this method perhaps implies a latent suspicion that he must not repeat his miracle too often. He also perceives that if repeated and unlimited evolution of similar forms had actually occurred, there could have remained little specific distinctness, and the present rarity of connecting links would not have occurred. Further, a new difficulty would have sprung up in the geographical and geological relations of species and genera, which would then have assumed too much of the aspect of a preconceived plan. It is only fair to a well-known and somewhat extreme European evolutionist, Karl Vogt, to state that he launches boldly into the ocean of multiple evolution, not fearing to hold that identical species of mollusks have been separately evolved in separate Swiss lakes, and that the horse has been separately evolved in America and in Europe, in the former along a line beginning with *Eohippus*, and in the latter along an entirely separate line commencing with *Paleotherium*. The serious complications resulting from such admissions are evident, but Vogt deserves credit for faith and consistency beyond those of his teachers.

With reference to the actual distribution of species, the question of time becomes most important when applied to the glacial period, since it is obvious that much of the present distribution must have been caused or greatly modified by that event. The astronomical theory would place the close of the glacial age as far back as 70,000 or 80,000 years ago. But if we reject this theory, we are not under this limitation as to time, and the geological evidence would lead to the conclusion that the glacial period was much nearer to our own epoch. Croll himself has shown that in Scotland the removal of material from the surface since that period might be taken to indicate a much shorter time. In Canada, the character of the river-courses cut through the glacial beds, and their very unformed and imperfect excavations, would lead to the belief that only a few thousands of years have elapsed since the glacial beds were laid down. The same conclusion can be drawn from the good preservation of the glaciated surfaces and of the shells and bones found on the terraces. Similar evidence is afforded by the rate of recession of coasts and waterfalls, and by the condition of eskers and lake ridges. If we adopt the shorter estimates afforded by these facts, it will follow that the submergences and emergences of land in the glacial age were more rapid than has hitherto been supposed, and that this would react on our estimate of time by giving facilities for more rapid denudation and deposition. Such results, would greatly shorten the duration assignable to the human period. They would render it less remarkable that no new species of animals seem to have been introduced since the glacial age, that many insular faunas belong to far earlier times, and that no changes even leading to the production of well-marked varieties have occurred in the post-glacial or modern age.

In conclusion, does all this array of fact and reasoning bring us any nearer to the comprehension of that "mystery of mysteries," the origin and succession of life? It certainly does not enable us to point to any species and to say precisely here, at this time and thus it originated. If we adopt the theory of evolution, the facts seem to restrict us to that form of it which admits paroxysmal or intermittent introduction of species, depending on the concurrence of conditions favorable to the action of the power, whatever it may be, which produces new organisms. Nor is there anything in the facts of distribution to invalidate the belief in creation according to definite laws, if that really differs in its nature from certain forms of the hypothesis of evolution. We have also learned that, time being given, animals and plants manifest wonderful powers of migration, that they can vary within considerable limits without ceasing to be practically the same species, and that under certain conditions they can endure far longer in some places than in others. We also see evidence that it is not on limited islands but on the continents that land animals and plants have originated, and that swarms of new and vigorous species have issued from the more northern regions in successive periods of favorable arctic climate. The last of these new swarms or "centres of creation," that with which man himself is more closely connected, belongs to the Palearctic region. We can scarcely be wrong in supposing that the six months' sunlight of arctic regions, along with abundant heat and moisture, were important factors in the creation of many new plants, or at least conditions of their production. In the case of new marine animals we have a double source in the equatorial and polar waters, and for the lower forms of life principally in the former. In every geological period, when the submerged continental plateaus were pervaded by the warm equatorial waters, multitudes of new species appear. In times when, on the contrary, the colder arctic currents poured over these submerged surfaces, carrying mud and stones.

great extinction took place, but certain northern forms of life swarmed abundantly. Everywhere and at all times multiplication of species was promoted by facilities for expansion. The great limestones of our continents, full of corals and shells of new species, belong to times when the ocean spread itself over the continental plateaus, affording wide, untenanted areas of warm and shallow water. The introduction of new faunas and floras on the land belongs to times when vast supplies of food for plants and animals and favorable conditions of existence were afforded by the emergence of new lands possessing fertile soils and abundantly supplied with light, heat, and moisture. Thus geological and geographical facts concur with ordinary observation and experience in reference to varietal forms, in testifying that it is not mere struggle for existence, but facilities for easy existence and rapid extension, that afford the conditions necessary for new and advanced forms of life. These considerations do not of course reach to the first cause of the introduction of species, nor even to the precise mode in which this may have acted in any particular case; but perhaps we cannot fully attain to this by any process of inductive inquiry. The study of geographical distribution, therefore, does not enable us to solve the question of the origin of specific types, but, on the contrary, points to marvellous capacities for migration and a wonderful tenacity of life in species. In these respects, however, it is a study full of interest, and in nothing more so than in the evidence which it affords of the practically infinite provisions made for the peopling of every spot of land or sea with creatures fitted to flourish and enjoy life therein, and to carry on the great and progressive plan of the Creator.

J. W. DAWSON.