# 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 estab-

lished 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 revolutions 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 o- 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