

are not faults, in the ordinary sense of the word, but heaves due to the contraction of an individual bed or of a series of beds. An oblique riban in certain argillaceous beds, has already been discussed in a paper read before the Geological Society of Dublin (Nov. 11, 1863).

VII.—ON CHANGES OF CLIMATE DURING LONG PERIODS OF TIME, AND THE CONJOINT ACTION OF PRECESSIONAL MOVEMENTS AND OF THE ELEVATION AND DEPRESSION OF MOUNTAIN RANGES IN PRODUCING THEM.

By JOHN GUNN, M.A., F.G.S.

IN my former Paper (see *GEOLOGICAL MAGAZINE*, 1884, Decade III. Vol. I. pp. 73–78) I endeavoured to show that as the elevation of mountain-ranges caused cold, so their subsidence in long periods of time was the cause of a warm temperature.

Astronomical agencies were expressly excepted from consideration, because they are independent of, and are the same under all changes of the level of the land and the consequent changes of the Fauna and Flora.

My object in this paper is to point out what those astronomical agencies are, such as the Precessional and Perihelionic Cycles, which are constantly in operation.

They are well described in the late Mr. Mitchel's popular work, "*The Orbs of Heaven*," p. 116, as follows:—

"The line of equinoxes divides the earth's elliptic orbit into two unequal portions. The smaller part is passed over in the fall and winter, causing the earth to be nearer the sun in this season than in summer, and making a difference in the length of the two principal seasons, summer and winter, of some seventeen and a half days. This inequality, which is now in favour of summer, will eventually be destroyed, and the time will come when the earth will be furthest from the sun during the summer, and nearest in the winter. But at the end of a great cycle of more than 20,000 years, all the changes will have been gone through, and in this respect a complete compensation and restoration will have been effected."

Thus he describes the Precessional Cycle, and then proceeds to give the following account of the Perihelionic. "The Precessional epoch of subordinate restoration will find the perihelion of the earth's orbit located in space far distant from the point primitively occupied. Five of these grand revolutions of upwards of 20,000 years must roll round before the slow movement of the perihelion shall bring it back to its starting-point. 110,000 will then restore the axis of the earth's orbit and the equinoctial line nearly to their relative positions to each other, and to the same region of absolute space occupied at the beginning of this grand cycle."

Next Mr. Mitchel describes the still more extended cycle of all the Planetary orbits, when all their perihelia meet together in their original position. "If now," he says, "we direct our attention to other planets, we find their perihelion-points all slowly advancing

in the same direction. That of the orbit of Jupiter performs its revolution round the sun in 186,207 years, while the perihelion of Mercury's orbit occupies more than 200,000 years in completing its circuit round the sun. To effect a complete restoration of the planetary orbits to their original position with reference to their perihelion-points will require a grand compound cycle amounting to millions of years. Yet the time will come when all the orbits will come again to their primitive positions, to start once more on their ceaseless journeys."

Of these three great astronomical cycles, we have to deal, geologically, chiefly with the first, the Precessional; the second, the Perihelionic, affects us mainly by shortening the Precessional orbit; the third is supposed to act in extremely long periods of time, millions of years, which are invoked by a very high authority, to account for the Great Ice Age.

I propose first to consider the effects produced upon the Fauna and Flora by Precession, which are independent of the elevation of mountain-ranges.

Herbert Spencer (Essays, 1863, Second Series, p. 87) gives an admirable and precise detail of the phenomena attendant upon the Precessional cycle.

"It seems," he observes, "beyond all question that there must have been a consequent rhythmical change in the distribution of organisms, a rhythmical change to which we here wish to draw attention, as one cause of minor breaks in the succession of fossil remains. Each species of plant and animal has certain limits of heat and cold within which only it can exist, and these limits in a great degree determine its geographical position. It will not spread north of a certain latitude, because it cannot bear a more northern winter, nor south of a certain latitude, because the summer heat is too great; or else it is indirectly restrained from spreading further by the effect of temperature, on the humidity of the air, or on the distribution of the organisms it lives upon. But now, what will result from a slow alteration of climate produced as above described? Supposing the period we set out from is that in which the contrast of seasons is least marked, it is manifest that during the progress towards the period of the most violent contrast, each species of plant and animal will gradually change its limits of distribution, will be driven back, here by the winter's increasing cold, and there by the summer's increasing heat—will retire into those localities which are still fit for it. Thus during 10,000 years each species will ebb away from certain regions it was inhabiting, and during the succeeding 10,000 will flow back into those regions. From the strata there forming, its remains will disappear; they will be absent from some of the superimposed strata, and will be found in strata higher up. But in what shapes will they reappear? Exposed during the 20,000 years of their slow recession and their slow return, to changing conditions of life, they are likely to have undergone modifications; and will probably reappear with slight differences of constitution, and perhaps of form—will be new varieties, and perhaps new species."

As these are observations well known to geologists, it is unnecessary to do more than refer to them.

It may be safely affirmed that there is no part of the world in which, from the continuity and duration of the deposits, the effects of the Precessional movements are more clearly and fully developed than in the County of Norfolk. The consequence of this is that, if the definite extent and number of these deposits could be ascertained, their precise age and duration would also be arrived at, by multiplying them by the length of each Precessional cycle; and if five such can be counted, then the Perihelionic will be completed, amounting to 110,000 years.

In the circumpolar regions the Precessional agency is very powerful, from the accumulating effects of the greater length of $17\frac{1}{2}$ days of the summer portion of the earth's orbit at either Pole alternately. This is unceasingly going on, adding to and diminishing the store of ice and snow in the Arctic and Antarctic regions by turns. And wherever the more powerful and violent phenomena of the elevatory process of mountain-ranges may be traced, in concurrence with Precession, the result is very great.

This is shown in Sir C. Lyell's account of the glaciated condition of Greenland, *Student's Manual*, p. 147.

This is so well known that a reference to it also will suffice.

"Greenland is a vast unexplored continent buried under one continuous and colossal mass of ice that is always moving seaward, a very small part of it in an easterly direction, and all the rest westward, or towards Baffin's Bay. All the minor ridges and valleys are levelled and concealed under a general covering of snow, but here and there some steep mountains protrude abruptly from the icy slope, and a few superficial lines of stones or moraines are visible at certain seasons, when no snow has fallen for many months, and when evaporation promoted by the wind and sun has caused much of the upper snow to disappear. The height of this continent is unknown, but it must be very great, as the most elevated lands of the outskirts, which are described as comparatively low, attain altitudes of 4000 to 6000 feet. The icy slope gradually lowers itself towards the outskirts, and then terminates abruptly in a mass about 2000 feet in thickness, the great discharge of ice taking place through certain large friths, which at their upper ends are usually about four miles across. Down these friths the ice is protruded, in huge masses, several miles wide, which continue their course grating along the rocky bottom like ordinary glaciers long after they have reached the salt water. When at last they arrive at parts of Baffin's Bay deep enough to buoy up ice-bergs from 1000 to 1500 feet in vertical thickness, broken masses of them float off, carrying with them on their surface not only fine mud and sand but large stones. These fragments of rock are often polished and scored on one or more sides, and as the snow melts they drop down to the bottom of the sea, where large quantities of mud are deposited, and this muddy bottom is inhabited by many molluscs."

The extent to which the glaciers and icebergs from Greenland

and other districts are carried sea-ward bears most importantly on the geology of the county of Norfolk. Precisely as Lyell describes them, the Boulder-clays with striated rocks, and containing arctic shells, appear to have been stranded and impinged upon the shores of the eastern coast. A striking instance of this, north of Cromer, was pointed out on an excursion of the British Association in 1868, where an iceberg seems to have driven up the Laminated beds, and as a proof that they had been imported from the north-east, it may be stated, on the authority of Mr. Lartet, that no Boulder-clays are discovered on the French coast or in France.

The effects produced by these glaciers and icebergs appear to belong to the concurrent agency of the elevation of mountain heights, and Precessional movements, and it is difficult to separate the one from the other. In this country we may observe the peaks of mountains, which have never been submerged, projecting above the lowlands, as it were islands above the sea, just as islands may be observed rising above the Pacific Ocean.

In order to understand what the Northern Hemisphere has undergone, we may with advantage turn our attention to what is now passing in the Southern Hemisphere. So far as its condition can be made out through the observations of voyagers and charts, there appears to be a reproduction of the so-called Glacial epoch, just as it prevailed in the Northern Hemisphere. There is the like over-spread of ice and snow, and numerous islands exist in the adjacent ocean, which, if upraised, would form the mountains of a continent or vast tract of land, so that it is difficult not to recognize a correspondence between the present condition of the Antarctic and that of the Arctic during the Glacial epoch.

This correspondence is well described by the Rev. W. S. Symonds, F.G.S., in his admirable treatise on the "Severn Straits," page 51.

"The Antarctic Continent," he observes, "may be said to be passing through a Glacial epoch. Ships cannot pass the 70° of latitude for ice, and the Antarctic lands are not known to possess a single land animal. The Ice King reigns everywhere.

"What the Antarctic regions are now, the Arctic regions of the distant north must have been during the Glacial periods, and the musk-ox, the polar bear, the walrus, and the rein-deer, must have migrated southwards, for they could not have existed there."

With respect to the causation of these Glacial phenomena at either Pole, we have a remarkable and beautiful coincidence of cause and effect, the greater length of the earth's orbit traversed in the summer portion, compared with that traversed in the winter portion, causes an alternate increase and diminution of heat and cold in the two hemispheres, as we have seen, and a corresponding change in the Fauna and Flora.

Still it must be allowed that there is an excessive irregularity to be accounted for, arising from the conjoint action of the uniform and unvarying Precessional movements, and the changes of climate induced by the elevation of mountain-ranges.

The correctness of this theory is attested by the concurrent elevation of the principal mountains, as the Alps, the Andes, and the Himalayas, at the close of the Miocene, and of its continuance, with some variations probably, through the Pliocene into the Pleistocene periods, when the climax was reached.

A no less strong proof is afforded by the return of a warmer climate and coincident change of animal and vegetable life on the subsidence and partial wearing down of the mountain-ranges.

Besides the above, no other cause has been assigned, which, in respect of power, or time, seems to be admissible.

The Precessional orbit has revolved for ages without any signs of striated and glaciated rocks being left, which was pointed out in my former paper as its relics, and the necessary accompaniments of the elevatory process of mountain ranges.

The Perihelionic orbit consists merely in the repetition of five Precessionals, and mainly acts upon the earth by reducing the length of the Precessional.

With respect to the larger compound orbit, which requires millions of years for its completion, it is obviously too lengthened and extensive to fall in with, or to act upon, the shorter and more limited changes that have been brought under our notice.

In regard to the views of those who would confine the agency of all the causes of glaciation to the annual revolutions of our Globe, they appear to be scarcely less extravagant, than the having recourse to the *most extended orbit of the Heavenly bodies that astronomy can supply*, in order to account for the Great Ice Age or Glacial Epoch.

On these grounds I humbly submit that the elevation of mountain-ranges, from whatever source they may arise, and their alternate subsidence or depression, offer, in conjunction with the Precessional movements, the most probable solution for the changes of Climate and of the Fauna and Flora.

VIII.—NOTES AS TO POSITION OF MOA BONES IN NEW ZEALAND.

By CHARLES SMITH, Esq.

[THE following list of localities in New Zealand where the remains of the *Dinornis* have been discovered has been most obligingly drawn up for me by Mr. Charles Smith, an old resident in New Zealand, and I gladly publish it as a useful list for reference. —EDIT. G. M.]

NORTH ISLAND, WEST COAST.

A few bones have been found on the coast at Awitu, about six miles south of Manukau Harbour. They were six feet from the surface, and belonged to *Dinornis giganteus*.

Moa bones are continually found in many places on or near the shore from about the Waingongoro River southwards, especially in the sand flat Te Rangatapu near the mouth of the Waingongoro. At the Awamoa Creek and about the Wanganui Heads. They are in the sand hills, often in little heaps which are noticed when partly uncovered by the wind.