PROCEEDINGS
OF THE
GEOLOGISTS' ASSOCIATION.

ADDRESS

AT THE OPENING OF THE SESSION 1874-75.

NOVEMBER 6th, 1874.

BY THE PRESIDENT,

HENRY WOODWARD, ESQ., F.R.S., F.G.S., &c.

It is with no small degree of pleasure that, at the commencement of a new session, I am again permitted the honour to address you from this chair. For, though months and years are periods of which, as geologists, we can take but little heed, we are forcibly reminded by passing events that we are but ephemera; and even when regarded, not as individuals, but as a race, belonging merely to the very latest epoch of time.

Nevertheless, the more civilised of mankind, especially geologists, are by no means satisfied with the Epicurean doctrine, "Let us eat and drink, for to-morrow we die." Man's intellect, once aroused and awakened from the torpid state of mere animal existence, seeks to rise above the barriers by which he is hemmed in, and with straining gaze, looks backwards into the misty regions of the far-off past, or, though dazzled by the glare, would even strive to penetrate the veil and gaze along the vista of futurity.

Be it ours to achieve the possible, and labouring diligently, and with patience, as heretofore, to unravel the past by the light of the present, go forwards hopefully into the future with firm and unwavering steps.

Standing as "look-out" in the "fore top" of our bark, it is my duty to inform you, from time to time, what points of interest come in view, as we voyage in association onwards. Nay, I may even venture, perhaps, to warn you against pursuing certain courses which seem inviting, but are really too shallow for us to adopt; or, I may cry out, and not without reason, "Icebergs ahead!"—for if ever there was a period in the geological sea when ice was more rampant than at any other, it is certainly at the present time. One might verily believe that "the Great Ice Age" (about which Mr. James Geikie has written so eloquently) had commenced again in good earnest.

I would not have you suppose, from these remarks, that I am unwilling to admit the Ice King to be a most powerful geological agent. No one can doubt his might, or that he has left his mark on mountain, hill, and valley. But after all he is only a demi-god, to whom, with other meteoric agents, has been relegated the task of rounding and wearing down the features of our earth; but the main lines of those features were there before the Ice-King came.

To borrow from heathen mythology:—

When Vulcan, by the labours of the Cyclops, had lifted Earth above the reach of Neptune's chariot, Phœbus beheld the newly-risen lands, and scorched them with his burning gaze. Then, pitying her fate, Jupiter Pluvius descended in mist and showers, furrowing Earth's surface and hiding her form beneath an ever-green mantle, which, though rudely torn by Boreas, still encircles her.

Many of the views originally put forward by Ramsay, Jukes, Geikie, and others, on Denudation as well as Glaciation, have been strenuously opposed for years, but after passing through the fire of criticism, they have, in a more or less modified form, been admitted as Articles of Geological Faith.

But the days of our geological warfare are not yet ended!

Even so recently as the present year, the sounds of broadsword and claymore have been plainly audible, and Highlander and Lowlander have measured weapons and laid on with a will in the geological cause; the Highlander in this case being the more polished swordsman, whilst the Lowlander's strokes have much more resembled those of the redoubted Roderick Dhu;—not that we would predict such a reversal of the issue of the fight in this

case, but would only deprecate such a rough style of hacking at a noble foe, and especially one whom Professor Geikie says he is anxious to secure as an ally for the "Younger School of Geologists."*

Mr. Kinahan's recent papers in the "Geological Magazine" and elsewhere, together with his larger Book on "Faults and Fissures and their relation to the origin of our Valleys and Lakes" [now in the press], will doubtless have a wholesome tendency on geological thought, and prevent the student from rushing wildly into *extreme views* as to the causes in operation affecting the physical features of our earth. He will be led to reflect that the same subterranean forces by whose aid the land was originally lifted above the sea have also influenced the direction of those lines of weak resistance along which the denuding forces have subsequently operated, although by attrition and denudation some of the original lines may have been rubbed out.

In reviewing the theories recently put forward to explain the Glacial Epoch, I would desire to pay a tribute of well-deserved respect to Mr. James Croll, who has devoted so many years to the task of solving these problems by the aid of rigorous and exact mathematical calculations.

It would be beyond the scope of this Address to give a full account of Mr. Croll's labours, but his most recent paper "On the Submergence and Emergence of Land during the Glacial Epoch"* deserves some notice here.

Starting with the proposition that a sheet of ice upon a level surface will be to all intents and purposes in a state of rest, and

* See Professor Geikie's Address to the Edinburgh Geological Society, 6th November, 1873, published 1874; being a reply to the Duke of Argyll's papers and Address, Quart. Journ. Geol. Soc. Lond. 1868, and subsequently.

S. POLE.

FIG. 1.—Section across Antarctic Ice-cap, drawn to a natural scale.
Length represented by section = 2,800 miles. Thickness at centre (South Pole) = 12 miles.
Slope of upper surface = half-degree.

(Copied from Mr. James Croll's paper in the *Geological Magazine*, 1874. Decade II., Vol. I., July No., p. 307.)

that therefore, for a mass of continental ice to be set in motion, there must be a piling up of ice in the interior; or, in other words, the ice-sheet must thicken from the edge inwards: and following Hopkins, Mr. Croll proceeds to point out that ice barely moves on a slope of one degree.

Assuming, therefore, for the South Polar Continent a diameter of 2,800 miles—that is to say, from the Pole to 70° S. latitude—or 1,400 miles from the centre to the circumference; a slope of one degree would give 24 miles as the thickness of the ice at the South Pole. (*See woodcut, Fig. 1.*) But, for the sake of argument, Mr. Croll reduces his estimate of the Ice-cap to a slope of a quarter of a degree, or six miles in thickness at the South Pole, with a mean thickness of two miles.

“Is there,” Mr. Croll asks, “any well-grounded reason for concluding the above to be an over-estimate of the thickness of the Antarctic ice?”

[In order to put this still more clearly before my readers, I subjoin a diagram of the earth upon which a dark line at the South Pole represents, to *true scale*, an ice cap 80 miles in thickness! (See Fig. 2.)]

FIG. 2.

ICE-CAP.
80 Miles in Thickness.

FIG 2.—Diagram to illustrate the relative proportion of the South Polar Ice-cap to the mass of the entire globe. The Ice-cap is here represented as nearly $13\frac{1}{2}$ times as thick as Mr. Croll has estimated it to be. It would require an enormously large diagram to show, in an appreciable manner, an Ice-cap only six miles in thickness.

From the explorations of Dr. Rink, Dr. Hayes, and Professor Nordenskiöld in Greenland, we know that the ice is actually from 2,000 to 3,000 feet in thickness, and that "the inland ice continued constantly to rise towards the interior." Dr. Hayes informs us, that he and his party attained to an altitude of 5,000 feet at 70 miles from the coast, and found themselves "in the midst of a vast frozen Sahara immeasurable to the eye." Assuming for the interior a gradual continuity of the same slope as that recorded by these separate observers, this would give a height of 15,000 feet above the sea-level at the centre of dispersion of the ice in Greenland. Taking the land at 5,000 (a height which Croll, however, thinks improbable), this would still give us 10,000 feet for the thickness of the central ice.

If, then, the Continental ice in Greenland attains this thickness—and its thickness depends on the relative diameter of its area—*à fortiori*, the ice on the Antarctic land must be thicker, for the South Polar Continent is at least a dozen times greater in extent than Greenland, and its *area for evaporation* far larger.

We have evidence of this in the superior magnitude of the Antarctic icebergs. To a number of bergs, recorded by ships as having been seen and measured, Mr. Croll applies the well-known principle as to the density of ice compared with sea-water, and that every foot of ice above water represents 8·7 feet below water. These bergs were therefore from 3,880 to 9,312 feet thick, or *upwards of a mile and three-quarters!* In an extreme period this ice-sheet would, Mr. Croll assumes, be much thicker.

Applying the ice-sheet theory to North America, Professor Dana estimates the ice in the Glacial Epoch to have covered New England to a depth of 6,500 feet, or considerably over a mile; whilst for the Canadian watershed he assumes a thickness of not less than 12,000 feet, or upwards of two miles and a quarter.

Mr. Croll thinks it is not necessary to assume a largely increased quantity of ice on the globe for the Glacial Epoch above that which exists at the present time. But as Mr. Croll's theory of glacial Epochs is based on the assumption of an extreme of temperature at one or other Pole, it is, he concludes, only necessary to transfer two miles of ice off the Antarctic regions and place it on the northern hemisphere, in addition to that which now exists there, when we should in all probability be as effectually annihilated as if we had been actually in the Glacial Epoch; "at

least, before it reached its maximum of severity." The bare idea of such a state of things is quite "enough to make one's blood run cold," and we instinctively stir up the fire and put some more coals on, regardless of the present price of 'Wallsend.'

The main feature in Mr. Croll's latest theory is, that by the melting of the Antarctic ice and the increment of that at the North Pole, we should have a displacement of the earth's centre of gravity, and a corresponding rise in the sea-level in our northern hemisphere. (See the subjoined Diagrams, Figs. 3 and 4, copied from Mr. Croll's paper.)

FIG. 3.

FIG. 4.

(Copied from Mr. James Croll's paper in *Geological Magazine*, 1874, *Decade II*, Vol. I, August No., p. 352.)

- O. The Ocean. S. Solid Crust or Shell.
 F, F¹, F², F³. The various concentric layers of the fluid interior. The layers increase in density towards the centre.
 I. The Ice-cap. C. The centre of gravity.
 C¹. The displaced centre of gravity.

["In Figure 3, where there is no Ice-cap, the centre of gravity of the earth coincides with the centre of the concentric layers of the fluid interior." "In Figure 4, where there is an Ice-cap placed on one pole, the concentric layer F¹, being denser than layer F, is attracted towards the cap more forcibly than F, and consequently sinks to a certain depth into F." "Again F², being denser than F¹, it also sinks to a certain extent into F¹. And again F³, the mass at the centre, being denser than F², it also sinks into F². All this being combined with the effects of the Ice-cap, and the displaced ocean outside the shell, the centre of gravity of the entire globe will no longer be at C, but at C¹, a considerable distance nearer to the side of the shell on which the cap rests than C, and also a considerable distance nearer than it would have been had the interior of the globe been solid."—James Croll, *op. cit.*, p. 352.]

Mr. Croll thus places his argument before us:—"The Antarctic ice-cap is equal in area to 1-23·46 of that covered by the ocean. The density of ice to that of water being taken at ·92 to 1, it follows that 25 feet 6 inches of ice melted off the cap would raise the general level of the ocean one foot, and that one mile melted off would raise the level 200 feet. To this 200 feet rise resulting from the melted ice we must add the rise resulting from the displacement of the earth's centre of gravity. The removal of the two miles of ice from the Antarctic Continent would displace the centre of gravity 190 feet, and the formation of a mass of ice, equal to one-half of this, on the Arctic regions, would carry the centre of gravity 95 feet further; giving in all a total displacement of 285 feet, thus producing a rise of sea-level at the North Pole of 285 feet, and in the latitude of Edinburgh of 234 feet. Add to this the rise of 200 feet resulting from the melted ice, and we have then 485 feet of submergence at the Pole, and 434 feet in the latitude of Edinburgh.

"A rise to a similar extent might probably take place after the period of maximum glaciation, when the ice would be melting on the northern hemisphere more rapidly than it would be forming on the southern.

"Assuming the Ice-cap to be six miles in thickness, the extent of submergence would be proportionably increased, and we might have a rise of the sea in the latitude of Edinburgh of 800 or 1,000 feet. It is clear, then, that the quantity of ice on the Antarctic Pole is perfectly sufficient to account for the submergence of the Glacial Epoch, for the general submergence did not much exceed 400 or 500 feet.

"In certain places there is evidence of from 1,000 to 2,000 feet submergence, but these may be quite local, resulting from subsidence of the land in those particular areas, elevations and depressions of land having taken place in all ages, and no doubt during the Glacial Epoch also.

"If, then," says Mr. Croll, "we admit that an increase in the eccentricity of the earth's orbit was the cause of the Glacial Epoch, then we must admit that all those results followed as necessary consequences. For if the Glacial Epoch lasted for upwards of one hundred thousand years or so, there would be a succession of cold and warm periods, and consequently a succession of elevation and depressions of sea-level. And the elevations of the sea-level

would take place during the cold periods, and the depressions during the warm periods."

Mr. Croll further points out that assuming the nucleus of the earth to be fluid, surrounded by a thick and rigid crust, a further displacement of the centre of gravity would take place by the re-arrangement of the heavier and denser materials in the earth's fluid interior; the heavier materials being attracted by the Ice-cap more forcibly than the lighter, consequently they will approach towards the cap to a certain extent, thus further tending to shift the earth's centre of gravity in the direction of the Ice-cap. (See *supra*, Fig. 4.)

Mr. Croll concludes that "if we knew the extent of the general submergence during the Glacial Period, and the present amount of ice on the southern hemisphere, we could determine whether or not the earth is fluid in the interior." [*Geol. Mag.* 1874, Decade II., Vol. I., p. 353.]

In a recent paper communicated to the "Philosophical Magazine" for September, 1874, p. 218, Mr. Tylor writes—"Some geological difficulties might be explained by periodic changes of position of part of the interior of the earth."

"Also the quantity of water in the ocean can only be the difference between that of the vapour held in the atmosphere or condensed into snow or ice on the land, and the quantity of water, or vapour of water, mechanically or chemically combined with the strata of the earth. These are quantities capable of *enormous* variation in geological periods under different conditions."

Mr. Tylor believes that the theory he advanced in 1853, as to the inconstancy of rainfall and the fluctuations of the level of the sea in past geological periods, is gaining ground.

But perhaps the most elaborate essay on this subject is that by Mr. Thomas Belt, F.G.S., entitled "An examination of the Theories that have been proposed to account for the climate of the Glacial Period," which appeared in the "Quarterly Journal of Science" for October last. The outline of these views was given by him in a most interesting book, entitled "The Naturalist in Nicaragua," published in the early part of the present year.

After reading Mr. Belt's views, as propounded by him in his "Naturalist in Nicaragua," in March last, I wrote as follows:*

* See *Geol. Mag.* April, 1874, Decade II., Vol. I., p. 183.

“The present day is one of surprises and startling propositions, and it cannot be denied that in the progress of scientific research and discovery, many of our pre-conceived and long-cherished notions have been swept clean overboard. It may be that the ideas propounded by the author shall hereafter become a part of the geological principles of a future day; but will the astronomer and mathematician allow as feasible, under any circumstances, the notion of an ice-cap 8,000 feet or more in thickness simultaneously at *each Pole*, and extending thence *nearly* to the Equator over either hemisphere?”

We have now Mr. Belt's more complete statement before us in the article already quoted, and on the fuller evidence which he has adduced, I admit that his theory deserves our careful study; and with that conviction I propose to submit it this evening, in as condensed a form as practicable, for your favourable consideration.

In order to present his own speculations in a clearer light, the author first discusses those of Sir Charles Lyell and Mr. Croll.

He refers to Lyell's theory that changes of climate in past epochs were due to a change in the relative distribution of the continents and oceans, and points out that Sir Charles himself no longer relies on this cause alone, but upon a combination of astronomical causes, with certain geographical changes.

In considering Mr. Croll's theory of an increase in the ellipticity of the earth's orbit, we must not omit to remember the vastness of time it occupies. The last period was about 200,000 years ago, and when at its greatest eccentricity, in aphelion, the earth was 98,500,000 miles distant from the sun, or 8,500,000 miles further off than at the present time.

The eccentricity of the earth's orbit, combined with the obliquity of its ecliptic, would give us the sun $7\frac{1}{2}$ days longer in the northern hemisphere than in the southern; the latter would therefore have $7\frac{1}{2}$ days less summer, and a corresponding extension of its winter period. In consequence of this (according to Mr. Croll), that hemisphere, in winter solstice, when the earth was in aphelion, would lose more heat by radiation into space during the long Polar night than it would gain in the short hot summer from the sun when in perihelion, and it would therefore be growing colder.

But, Mr. Belt replies, radiation goes on by day as well as by night, the warmth of the day depending on the excess of heat received over and above that which is radiated, not that there is no

radiation. Taking this into account, we shall find that no more heat is lost in one hemisphere than in the other. Nor does ellipticity affect the absolute amount of heat received from the sun. Therefore, if the absolute amount of heat received, and the absolute loss by radiation, be equal in the two hemispheres, then their mean temperatures, due to these causes alone, must be the same, whatever the amount of the ellipticity of the earth's orbit may be.

Mr. Croll affirms that the lengthened-winter in aphelion would enable more ice and snow to accumulate than the short but hot summer in perihelion could melt.

But, Mr. Belt replies, winter does not begin on the day on which the sun passes the autumnal equinox, though what is called the "winter solstice" does. The nights are longer than the days, but snow does not fall, nor water freeze, nor winter actually set in, until many weeks after the 22nd September. Moreover, some excess of heat is stored up in the shorter but hotter summer in the earth, the sea, and the atmosphere, which is not entirely given up till long after the winter solstice has begun. Nor would all the heat so gained be expended in melting the ice accumulated in winter; for a pound of water, in passing from a liquid to a solid state, evolves just as much heat as is required to melt it again. So that the heat given off in winter by water in freezing is equivalent to that absorbed in spring when it melts again. Thus the *mean temperature* remains unaffected.

Clouds are not inimical to climate, for they arrest radiation by night, as well as intercept the sun's rays by day.

Mr. Belt points out a cause (not touched upon by Mr. Croll) why the summer's heat cannot overcome the cold of winter in high latitudes, where snow covers the ground. It is because so much of the sun's heat is reflected back again from the white surface. But for this circumstance, snow would nowhere be perennial, but everywhere the heat of summer would dissolve the snows of winter.

Only at the Poles is there really six months' winter and six months' summer; beyond this, the ice-accumulating period gradually decreases and reaches zero long before we arrive at the Tropics.

Mr. Croll imagines that when the obliquity of the ecliptic was at its *maximum* ($24^{\circ} 50' 34''$), the temperature at the Poles would

increase some 15° , and that when the obliquity was at its *minimum* there would be a decrease of temperature. But the reverse of this seems really to be the fact; for if the obliquity be increased the Arctic Circle will be enlarged, and a greater area of the earth's surface brought within the influence of the long Arctic night. A diminished obliquity, on the contrary, would lessen the difference in the Temperate Zone between day and night, and so tend to moderate the extremes of heat and cold in summer and winter.

Thus, by way of illustration, if the obliquity of the earth were diminished to zero, and the axis of rotation perpendicular to the plane of its orbit, the seasons would disappear, and perpetual spring would reign in the Arctic regions. All over the globe there would be 12 hours day and 12 hours night, and no amount of ellipticity of the earth's orbit could have any effect in lengthening the nights or days. (*See woodcut Fig. 12, p. 30.*)

An essential part of Mr. Croll's theory is, that during the greatest eccentricity of the earth's orbit, periods of great warmth would alternate with periods of extreme cold. That whilst one hemisphere was undergoing the extreme rigour of a glacial period, the other would rejoice in perpetual summer.

These extremes of climate would oscillate slowly from pole to pole at intervals of 10,500 years; the ice that had been piled up at one pole would melt and be piled up at the other.

According to Mr. Croll's calculations, during the last great period of ellipticity (which occupied 160,000 years), each hemisphere must have alternately passed through *several glacial periods and several warm periods*. If this were so, we ought to find confirmation of these alternations in the successive Faunas and Floras of the Tertiary rocks. Instead of this, however, we find a gradual and continual decrease of temperature in Europe from the earliest Tertiary times. As we ascend in the series, the shells of successive groups of strata consist less and less of southern forms, whilst the northern species are always augmenting, until in the uppermost beds the fauna is very Arctic in character, even in the 52nd and 54th degrees of N. latitude.

The floras, from the Eocene upwards, attest the same gradation, from the palms and tropical fruits of the London Clay to the subtropical *Proteacææ*, fig-trees, cinnamon, etc., of the Bournemouth beds and of Switzerland; followed by poplar, hornbeam, oak, elm, and other trees now characteristic of temperate latitudes.

The Miocene of Oeningen contains many exotic genera, but the facies of the flora indicates a climate which was gradually becoming unsuitable for sub-tropical plants.

In the Lower Pliocene of Italy, most of the sub-tropical genera have disappeared; and in the Newer Pliocene deposits the trees and shrubs are such as characterise European forests, and suggest that the climate was such as is at present enjoyed in Europe. Whilst the Newer Pliocene beds in England, and the Cromer Forest Bed, represent a somewhat lower temperature than the south of Europe, and agreeing with the existing climate of Britain—the lignite beds of Bure and Westleton contain *Salix polaris*, now only known within the Arctic Circle, and *Hypnum turgescens*, an Arctic moss. These last-mentioned beds are succeeded by the Till and Boulder Clay of the Glacial period.

The evidence afforded by the remains of the higher land or marine animals, from the Eocene upwards, yields a precisely similar succession of types, from tropical forms in the Eocene to sub-tropical in the Miocene, more temperate forms in the Pliocene to Arctic Mammalia which usher in the Glacial Epoch.

All the evidence points to a gradual cooling of the climate, and none can be adduced in favour of a succession of warm and cold periods.

The local interglaciation of ice-transported materials in Miocene deposits in Piedmont, and of seams of lignite resting on Boulder-clay at Dürnten, in the Canton Zurich, capped by beds of gravel with erratic blocks, only proves—says Mr. Belt—that in the former case, *as now*, local glaciers existed; and in the latter that peat-mosses accumulated in low swampy places. None of the plant-remains indicate a warmer climate. Cones of Scotch and spruce fir, leaves of oak, ash, and yew, all evidence trees which range far north of Switzerland.

The advance and retreat of the ice of local glacier-systems is a matter of fact within the compass of historic records, as those of the Swiss Alps abundantly testify.

No evidence in favour of a mild interglacial period can be adduced from the shells found in the so-called interglacial beds in Wales, Macclesfield, or South Lancashire; on the contrary, Mr. Geikie admits that “upon the whole, the fossils indicate colder conditions than now obtain in the Irish Sea.” Nor do the deposits along our eastern coasts, or those of Ireland or Scandinavia, afford evidence of milder conditions.

The Sicilian Tertiaries have been more favourably preserved than elsewhere, and they attest the fact that the northern forms of Mollusca appear *only in the latest deposits*, and are in no instance accompanied, followed, or immediately preceded by Tropical forms. To obtain these, we must go back to the Miocene and Eocene periods.

Having endeavoured to show that neither by a change in the relative position of land and sea, nor yet by the eccentricity of the earth's orbit, can one in a satisfactory manner account for the Glacial Epoch, Mr. Belt proceeds to propound his theory of a change in the Obliquity of the Ecliptic.

So long ago as 1688, Dr. Robert Hooke endeavoured to explain the evidences of Tropical climates having formerly prevailed in Europe, and indulged in speculations as to a change in the axis of the earth's rotation, or a shifting of the earth's centre of gravity, or a change in the obliquity of the ecliptic.

The last theory was a favourite one among the early English geologists, but received little favour from astronomers. Newton opposed it, and declared that Astronomy could not countenance the theory that there had been any change in the direction of the earth's axis.

Laplace investigated the problem of the effect of the attraction of the sun, moon, and planets on the earth's equatorial protuberance, and came to the conclusion that this could only cause a variation in the obliquity of the ecliptic of $1^{\circ} 21'.$ *

More recently, Leverrier examined the same question, and arrived at the result that it might vary $4^{\circ} 52'$, but not more.

The difference between the conclusions of Laplace and Leverrier is a wide one, but assuming these great geometricians could not have erred, there may yet have been other elements of disturbance to be taken into account besides those which they knew and investigated.

Thus, for instance, they assumed the thickening of matter around the Equator to be a constant quantity; whereas there is abundant evidences of great upheaval and depression in remote ages which may have altered the question most materially.

The gradual piling up of ice at the Poles in the Glacial period must have in some measure diminished the difference between the Polar and Equatorial diameters. Even now, many

* Herschel's Astronomy, art. 640.

physicists believe that a gradual elevation of land at the Poles, and a depression of land at the Tropics is taking place.

The Equatorial bulge is not a regular one, but is in the form of an ellipse, of which the greater diameter is two miles longer than the lesser. This has not been taken into account at present, therefore the problem cannot be said to be definitely decided.

The great preponderance of land in one hemisphere, not arranged around the earth, but in a mass whose centre is situated near the English Channel, must also be a disturbing element of no mean importance.

Mr. Belt points out that our knowledge of other planets teaches us that there is *no limit* to the obliquity of their axes.

In JUPITER the axis is nearly perpendicular to its orbit, so that there is no change in the length of the day there on any part of its surface,

In SATURN the obliquity is 29°

In MARS ,, ,, $30\frac{1}{4}^\circ$ *

FIG. 5.—Diagram to illustrate the variation in the obliquity of the axes of rotation of certain planets to the plane of their orbits.

And in VENUS it reaches the extreme of 75° , so that its tropics overlap its arctic circle, and there are no temperate zones.

* Mr. Dunkin, in Lardner's "Handbook of Astronomy" (1867), gives it as $28^\circ 27'$. "The exact direction of the axis is, however, still subject to some uncertainty." (p. 210).

The inclination of the polar axis to the plane of our earth's orbit—that is, to the Ecliptic—is $23\frac{1}{2}^{\circ}$, but it is known that this is diminishing at the rate of $48''$ in a century.

As no original cause for the inclination of the axes of the planets has been assigned, it may be allowable to suppose that changes in the obliquity of our earth's ecliptic may occur through the same series of causes as have originated it in our own and other planetary bodies.

The Rev. Professor Haughton, F.R.S., of Dublin, a most able mathematician and geologist, writing in McClintock's "*Voyage of the Fox*," in 1859 (p. 395), observes: "The only speculation I am acquainted with, which is capable of solving this *opprobrium geologicorum* is the hypothesis of a change in the axis of rotation of the earth, the admission of which as a geological possibility is mathematically demonstrable, and which has recently had some singular evidence in its favour advanced by geologists."

It is an established fact that the obliquity of our earth is less than it was some centuries ago. But this, it is argued, is due to those small variations that Laplace and Leverrier showed to be possible; that the outline of the polar circle is a waved one, and that during the time these observations were made the direction of the pole has been down towards one of these waves; but that it will again rise as much above as it has dipped below.

The movement of the pole is, in all probability, that of an ellipse, or of a spiral, as none of the heavenly bodies describe a circle, all the orbits being ellipses of varying degree.

This question needs to be re-investigated by the astronomer; meantime geologists are at liberty to speculate on the possibility of great changes in the obliquity of the Ecliptic having caused former great variations of temperature.

According to Lient.-Col. Drayson, the obliquity has been as much as 35° . The effect of this was, he supposed, the production of the Glacial Period. The Arctic Circle would then reach nearly to Lat. $54\frac{1}{2}^{\circ}$; there would be an accumulation of snow during the winter, which in summer would all be melted *nearly* to the Poles, causing enormous floods. But if this would really be the effect of the greater obliquity of the ecliptic, we might at once dismiss it as a possible cause of the accumulation of ice during the Glacial period.

Such results might very well accord with Mr. Alford Tylor's theory of a great Pluvial period.

When we consider the enormous masses of ice (thousands of feet in thickness) which we know, from their "spoor," must have moved down southwards over the northern parts of Europe, Asia, and America, we are sure that they could not have been produced from the snowfall of a single winter.

Let us consider for a moment the question of the effects of the present inclination of the earth's axis.

FIG. 6.—The Earth at the present period, having an obliquity of $23\frac{1}{2}^{\circ}$ to the plane of its orbit, producing all the variations, in climate, from temperate to arctic conditions, and in length of day and night 12 hours daylight and 12 hours night at the Equator, to 6 months day and 6 months night at the Poles.

To it is due the varying length of days throughout the year in the Temperate and Arctic zones, and the consequent production of the Seasons. If the axis were perpendicular (see Fig. 12) as in Jupiter there would be one uniform day and night, and one uniform climate, throughout the world. The piling up of ice and snow at the sea-level would be impossible, except, perhaps, in the immediate neighbourhood of the Poles, where, from the small altitude of the sun, its rays would have but little heating power.

Our seasons are, then, due to the present obliquity of the Ecliptic; as also the glaciation of circumpolar lands; indeed, but for that obliquity, snow and ice could not accumulate save upon mountain chains.

The obliquity of the Ecliptic does not affect the mean amount of heat received from the sun at any given point, which remains the same, but it causes the heat and the cold to predominate at different seasons of the year.

Thus, near the Poles, there are six months night and six months day; but the absolute amount of heat that arrives from the sun is the same as if there were twelve hours' light and twelve hours' darkness every day.

Mr. Belt affirms that neither the cooling of the air by the melting of the snow in summer, nor the formation of clouds, tend to prevent the accumulation of snows from year to year, but that their conservation is due really to the reflection of the sun's rays by the white, snow-covered surface of the earth. Therefore a country which endures a long hot summer and a long cold winter is more likely to favour the accumulation of perennial snow than another under similar conditions of sunlight and warmth, but where the sun rose and set every twelve hours, so that the heat by day and the cold by night were never so excessive.

FIG. 7.—Ideal figure of the Earth in the Glacial period. The axis (like that of Mars at the present day) is assumed to have then been more inclined towards the plane of its orbit than now, and, like Mars, both poles were greatly glaciated.

If the obliquity of our earth were increased, a greater and yet greater area would be brought under Arctic conditions. When the obliquity reached $35\frac{1}{2}^{\circ}$, the Arctic Circle would extend to Lat. $54\frac{1}{2}^{\circ}$,

and the Tropics to $35\frac{1}{2}^{\circ}$, reducing the Temperate Zones from their present width of 43° each, to 19° , one-half the decrease being added to the Tropics, and the other half to the Arctic Zone. (See Fig. 7.) The half near the Equator would have its temperature greatly raised, and become an additional area of evaporation; whilst that nearest the Poles would be an additional area of condensation.

As the ice extended and consolidated, it would gradually shut off the warm currents of the ocean, now extending nearly to the Pole, and the heat so diverted would tend to assist and increase evaporation, and thus precipitation would also be proportionably increased.

It is a fundamental part of Mr. Croll's theory (already discussed) that the glaciation of the two hemispheres should take place separately and alternately.

It is an equally fundamental principle of Mr. Belt's theory that they should be glaciated simultaneously.

In support of his views, Mr. Belt reminds us—

(a) That glacial conditions due to the obliquity of the Ecliptic exist at the present time around *both Poles*.

FIG. 8.

FIG. 8.—Diagram of North Polar Sea, to contrast with South Pole. The South Pole having a land-surface surrounded on all sides by water; whereas the North Pole appears to be a marine area almost entirely surrounded by land.

That more ice is heaped on the Antarctic regions than upon the Arctic is explicable by the fact that a larger area for evaporation is afforded in the southern hemisphere by its more extended ocean basins; whereas, in the north, not only are the Arctic regions almost encircled by lands, and so offer a far less area for evaporation, but much of the snow which would doubtless reach the Polar regions is intercepted by mountain chains and added to local glacier systems, such as the Alps, the Himalayas, and other high northern ranges. (Compare Diagrams, Figs. 8 and 9.)

FIG. 9.

FIG. 9.—Diagram of the South Polar Continent, to illustrate the vast land area forming the gathering ground for the great Antarctic Icebergs, referred to by Mr. James Croll. (See p. 5.)

The darker parts along the margins of the South Polar Land indicate those portions which have been, more or less, accurately surveyed, such as South Victoria Land (with Mount Erebus), Enderby Land, Trinity Land, &c.

That the difference is due to lessened precipitation, and not to differences of temperature, will be seen by following the isotherm of 30° around each hemisphere.

In the southern hemisphere it deviates but little from the line of 60° S. Lat. In the north it is much more irregular, but the mean is again about 60° N. Lat., proving that if the precipi-

tation were the same, there would be as much snow and ice north of Lat. 60° N. as there is south of Lat. 60° S.

(b) Accumulations of snow have only been observed on one planet, viz., Mars, which, with an obliquity of $31\frac{1}{2}^{\circ}$, is *glaciated at both Poles* at the same time.

Judging, then, from analogy, we might expect the Glacial period to have been *contemporaneous* in both hemispheres.

(c) Many plants and animals are found in both the northern and southern temperate zones, having close affinities, and even pointing to a common origin, yet separated by the whole width of the Tropics, which they cannot now pass.

Mr. Darwin has explained their presence by supposing that during the Glacial Period they were driven to the high lands of the Tropics by the advancing ice, and that on its retreat they followed it north and south.

A glacial period in one hemisphere only would not, Mr. Belt thinks, afford this means of migration. The plants and animals driven south by the northern ice would always have a hot zone to the south of them which they could not pass.

(d) Mr. Tylor has suggested that the piling up of ice in the northern hemispheres during the Glacial Period would lower the level of the general ocean 600 feet.

Mr. Croll, on the contrary, in his recent papers on this subject (Geol. Mag., July and August, 1874), shows that if each hemisphere were glaciated alternately, the level of the ocean would be raised and *not* lowered in the one in which the ice accumulated (as already explained) by the melting of the ice at the opposite pole, and the shifting of the centre of the earth's gravity towards that covered by an ice-cap. (See p. 6, Fig. 4.)

Mr. Belt concludes that one Polar ice-cap could not materially lower the general ocean if the opposite pole was freed from ice; but, on the contrary, if the Glacial Period in the two hemispheres was contemporaneous, then the water abstracted from the sea and frozen into ice at the Poles, together with that impounded in the great lakes of North America, North Europe, and North Asia, by the blockade of the northern drainage of the continents with ice, must have lowered the general level of the ocean to a great extent.

From data gathered in Central America, and in Siberia, Mr. Belt estimates the lowering of the sea-level by the accumulation

of ice at the Poles could not have been less than 2,000 feet, and may have been much more.

Applying this result to the solution of the problem of insular floras and faunas, the author points out that their derivation has usually been explained by supposing such islands to have been at one time joined to the continents nearest to them, and to each other in Post-Tertiary times. In every case, therefore, the last movement has been one of depression, the bridge by which they passed over has been submerged and destroyed.

The lands uniting Greenland with Europe, England with Ireland and with the Continent, Malta with Africa, the Malay Archipelago with Asia, on the one hand, and with Australia on the other, the West Indian Islands with Venezuela and Yucatan, and that uniting Tasmania with Australia, are all supposed to have been submerged by a sinking of land, unaccompanied, in most instances, by a corresponding elevation.

It is a significant fact, first noticed by Wallace, that whilst all islands having *shallow channels*, however broad, separating them from each other, and from not distant continents, give evidence of a former connection in Post-Tertiary times; on the other hand, islands surrounded by *deep water* are marked by peculiar faunas.

Thus Madagascar, though near the coast of Africa, is separated by a deep sea, and its fauna and flora are singularly distinct.

The Galapagos Islands have also a peculiar fauna, indicating the antiquity of their insulation.

A uniform lowering of the sea-level would afford a satisfactory solution to these difficulties, which cannot so readily be explained by local subsidences and elevations.

Again, the ancient Submerged Forests so frequently to be met with around our coasts almost everywhere pass under the bed of the ocean. Mr. Lucy, F.G.S., in a recent communication to the Cotteswold Club, "On the Submerged Forest at Sharpness," records the occurrence of 25 of these old littoral forest-tracts, now destroyed by the invasion of the sea around our coasts. Their present submerged condition can easily be explained if we assume that the sea has risen above them, not that the land has subsided.

The upward growth of Coral-islands from great depths affords another admirable case which the theory of Mr. Belt serves to explain. Darwin first proved that they were due to the gradual

deepening of the ocean bed from which the coral islands rise. Dana estimated the deepening to be at least 3,000 feet, and that the subsidence extended around one-fourth of the earth's circumference in the Pacific, marked by atolls for 6,000 miles in length and 2,000 in breadth. The Bahamas also cover a submerged area of land 600 miles in extent from N.W. to S.E., whilst the long line of the Florida Keys trending away from the land of Southern Florida, evidence the same downward movement.

A rise of the sea, owing to the increase of its volume—liberated after the Glacial Period from the ice of the Polar regions—would produce the same effect as the lowering of the land, which might not occur *generally* with the same precision of level as that of the waters of the ocean.

Again, the continent of South America—and indeed the mountain chains generally, all over the world—testify to the fact that they have been glaciated to lower levels upon their slopes than that to which ice and snow now descend, or where they occur perennially. A general lowering of the sea-level would produce precisely the same effect on climate as the raising of the continental surfaces; the atmosphere, following down, would bring the freezing point so much lower than it otherwise would be.

An increase in the present obliquity of the Ecliptic would not only permit a greatly-increased accumulation of ice on circum-Polar lands, but it would be the cause of lowering the mean temperature of the Tropics; so that the snow-line would even descend still further from increased precipitation, due to the greater evaporation.

An examination of the deltas of great rivers, such as the Ganges, the Mississippi, the Nile, and the Po,* has shown that there are numerous land-surfaces and fresh-water deposits *hundreds of feet below* the level of the sea. Indeed, the channels of most of our rivers are really much deeper cut than their present bed.

Mr. Belt thinks that evidence of the close of the Glacial Epoch, and of the gradual retreat and melting of the ice in lower latitudes, may be found in those universal traditions of mankind as to floods and inundations, the heritage alike of civilized and barbarous races. Whether this be so or not, it is at least satisfactory to be able, as geologists, to indicate a probable cause which may adequately explain these wide-spread legends of the Deluge.

* See Alfred Tylor's paper on the Delta of the Po; *Geol. Mag.*, 1872, Vol. IX., p. 392 and 485.

If man had already peopled the earth in the still older times when—

A solid wall of ice hemmed in the earth
Both north and south; from which, at times,
Huge fragments, sailing forth, by ocean borne,
Grounded on old Atlantis' fabled strand,
Cooling the breeze for many a league around

—then the difficulties of the anthropologist are also greatly reduced; for many an island, beside the fabled Atlantis, or St. Brandred's Isle, then lifted its head above the wave, and many a—to us—pre-historic Columbus accomplished with ease what our modern discoverer achieved with so much difficulty less than 400 years ago.*

If, as Mr. Belt concludes, the melting as well as the accumulation of the ice of the Glacial Period must have occupied thousands of years in accomplishment, this is quite in accordance with the gradual growth of coral-reefs, and the silting up of deltas filled with fresh water deposits. But probably some sudden rises did from time to time occur, causing local floods and the inundation of vast low-lying tracts of country.

Since the close of the great Ice Age, there is clear and indisputable *evidence of the rise of land* both towards the North and South Pole, which is probably even now in progress.

In the south, the extremity of South America, and a part of New Zealand, has been elevated.

In the north, the coasts of Scandinavia, commencing on the eastern side near Stockholm, and on the western coast near Gothenburg, and increasing northwards as far as the North Cape. The raised beaches, with Arctic shells, everywhere rest upon Boulder-clay with transported blocks.

The coasts of the Arctic Sea are also slowly rising (according to Adminal von Wrangel); marine beds containing shells of existing species, together with remains of the Mammoth, occur several feet above the present sea-level.

On the American side, the elevation commences near New York, where, at Brooklyn, raised sea-beaches, with marine shells, occur 100 feet above the present level of the sea. This elevation increases in a northerly direction. At Quebec and Montreal it reaches to 400 and 500 feet, whilst still further north, within

* A.D. 1492, Discovery of America by Christopher Columbus.

the Arctic Circle, on the shores of Barrow Straits, sea-shells of *existing species* have been carried up to a height of 1000 feet above the ocean. The movement clearly increases towards the Pole.

A part of the coast of Greenland is said to be in a state of subsidence, but Greenland *is now* undergoing *intense glaciation*, and is buried in snow and ice piled mountains high. All the geological evidence is in favour of these lands having been above the sea in pre-Glacial times. The lands around the Poles must then have sank down after they were covered with ice, and they have been slowly rising since it melted away.

Mr. Belt believes the *cause of the depression* was the piling up of so vast a weight of ice around the Poles, and that the *cause of the elevation* was the removal of that vast weight by the gradual melting of the ice.

FIG. 10.—Diagram to illustrate Mr. Belt's theory of the depression of land at the Poles during the Glacial Epoch, by the heaping up of ice (*a*), causing the crust (*b*) to be depressed to (*c*), which again rises to (*b*) upon the removal of the Ice-cap (*a*).

That the movement of elevation still continues in some places only shows that the earth is a (more or less) rigid body, and but slowly gives way to great strains.

In considering the theories which have been put forward in order to account for the cold of the Glacial Epoch, one important point to be borne in mind is, the *relative time* assumed to be occupied by the respective operations of eccentricity of the earth's orbit on the one hand, and by the greater obliquity of the Ecliptic on the other.

Thus, Mr. Croll's theory of the eccentricity of the earth's orbit requires a period of 200,000 years to elapse. On the other hand, Mr. Belt's theory of the greater obliquity of the Ecliptic would not require much more than 20,000 years, or one-tenth of the time demanded by Mr. Croll.

We have not the least desire needlessly to question the time

assumed to be required for the completion of any particular geological change on our earth; but if each deposit, as we recede in time, represents, as there is reason to believe, a longer and yet longer period of our earth's past history than that which preceded it, it becomes very like the old story of doubling the price of the nails in the horse's shoes—the sum becomes millions long before we reach the base of the Palæozoic rocks, and the earliest traces of life on the earth.

Diagram illustrating the comparative thicknesses of the several Deposits forming the stratified crust of the Earth.

			Feet.	Thickness.
Post Tertiary	{	Recent	...	50
		Glacial	...	200
				250 feet
Tertiary	{	Pliocene	...	100
		Miocene	...	125
		Eocene	...	2,600
				2,825 „
Secondary	{	Cretaceous	...	1,420
		Wealden	...	750
		Jurassic	...	2,750
		Triassic	...	1,800
				6,720 „
Newer	{	Permian	...	600
		Carboniferous	...	15,000
		Old Red Sandstone	...	6,000
Primary	...			21,600 „
Older	{	Silurian	...	24,000
		Cambrian	...	20,000
		Laurentian	...	30,000
				74,000 „
Total			...	105,395 feet = 20 miles.

RELATIVE THICKNESS (after Hæckel:—*corrected*).

Quaternary	...	...	...	2.
Tertiary	...	...	...	2·7.
Secondary	...	...	...	6·4.
Newer Palæozoic	...	...	...	20·3.
Older Palæozoic..	...	...	...	70·4.

But to resume :—

If our Glacial period merely necessitated, as Mr. Croll supposes, the heaping up of snow and ice around the North Pole, the only result would be a slight shifting of the centre of gravity of the earth northwards; but if it was contemporaneous in the two hemispheres (as Mr. Belt assumes), the figure of the earth would be changed, its Polar diameter would be lengthened, its mean Equatorial diameter shortened, and a series of strains would be

FIG. 11.

FIG. 11.—Diagram to illustrate the increase of the Equatorial diameter during the Glacial Epoch, and the diminution of the Equatorial bulge since; caused by the removal of the Polar Ice-caps. E. the equator. (See also fig. 10, p. 24.)

set up, tending to restore its figure to a state of equilibrium. (Figs. 10 and 11.)

And if, during the Glacial Epoch, that state had been arrived at by the sinking down of the circumpolar land, and the rising of land in the Tropics, then, when the ice melted away, the Polar diameter would be shortened, the mean Equatorial diameter lengthened, and forces would be set in operation tending to lower the land at the Tropics, and raise that around the Poles.

That the deepening of tropical seas, as evidenced by the growth of coral islands, is due to an actual sinking of the bed of the ocean is perfectly in accord with this theory. But whether by the deepening of the sea by addition to its volume, or by depression of its bed, the cause (according to Mr. Belt) has been the gradual melting of the ice piled up during the Glacial Epoch, which, by its liberation, has disturbed the equilibrium of the figure of the earth.

The movements of the earth's surface have hitherto been ascribed to the contraction of its crust by secular cooling. But Laplace, reasoning on the astronomical observations of Hipparchus, could find no appreciable difference from the contraction of the earth during the last 2,000 years. The length of the day has not been shortened by even the space of 1-30th of a second, so that the contraction, if any, must be in-appreciable.

Mr. Belt thinks that even the radiation of heat into space is probably not greater than that which our earth receives from the sun, and that he is justified in concluding that volcanos and earthquakes, and the increase of heat in mines, are all referable to the strains set in action by the melting of the ice-caps of the Glacial Period.

The insufficiency of the central heat theory is shown by the state of the ground in Northern Siberia. At Yakutsk the soil—

save a few feet which is thawed every summer—is *permanently frozen* to a depth of about 400 feet.

This soil extends to the shores of the Frozen Sea, the cliffs bordering the rivers being in many places composed of alternate layers of soil and ice. It is in these cliffs that the bodies of the Arctic Rhinoceros and Mammoth have been found, with their flesh still preserved. The soil cannot have been thawed for a single season since they were entombed, or their flesh would have putrefied. The ice, therefore, is as old as the close of the Glacial Period, at which time these great animals flourished.

It could not have remained frozen, however, at a depth of 400 feet from the surface if the earth were a cooling globe. If, however, the heat of the earth be due to movements within it, we can understand that in Siberia it may not have been developed to the same extent as elsewhere; for, according to Murchison, Siberia is a country of great geological stability; von Cotta even thinks it has never been submerged since the close of the Permian period.

From a personal examination, Mr. Belt finds that the steppes are composed of freshwater deposits, excepting those on the extreme northern border of the country.

If it be true that volcanos are due to movements of the crust of the earth—not to *secular cooling*—but to those forces tending to restore the equilibrium of the earth's figure—disturbed alternately by the accretion of ice at the Poles during the Glacial Period, and to its subsequent liquefaction, it will add yet another to the many marvellous effects due to the action of the sun upon our planet.

Whether the earlier and greater geological folds and upheavals may not be due to other causes, is not ventured to be denied.

But in accounting for the cold of the Glacial Period we have only answered half the problem we are called upon to solve. There is the heat of early Tertiary times to be likewise explained.

Over barren wastes, with here and there a stunted bush of *Salix polaris*, or a scanty covering of Arctic mosses and lichens; where the musk ox and Greenland lemming found their northern limit in summer, there stretched, at the commencement of the Tertiary period, rich and luxuriant tropical forests. Palm trees, of types now restricted to the Moluccas, the Philippines and Bengal, with custard apples, melons, and many other tropical plants, flourished in the neighbourhood of Paris and London.

Huge animals resembling tapirs, but larger, roamed in the forests; monkeys chattered amongst the trees; tortoises and other chelonianæ abounded along its shores, whilst sea-snakes, crocodiles, and enormous sharks tenanted the waters.

The climate of the Eocene period was even *much warmer* in proportion than that of the great ice age was colder than the present.

Mr. Carruthers lately remarked to me that even at the present time snow lies in the hollows of the Grampians all the year round.

Indeed, if we had a mountain near London, 6,000 feet high, we should have its top covered by perennial snow.

When the tropical fauna and flora occupied central Europe as far as 52° N. lat., still nearer the Pole, vegetation flourished similar to that which characterizes the milder portions of the Temperate Zone, and the representatives of our present fauna and flora in Northern Europe lived and thrived within 11° of the Pole.

Thus at Spitzbergen, far within the Arctic Circle, in latitude 78° 56' flourished species of hazel, plane, poplar, lime, and beech trees. Professor Heer is of opinion that firs and poplars must have reached to the pole itself, if there was land for them to grow on.

The Arctic plant-beds are described as of "Miocene Age," because out of 137 species of plants found in Greenland, 46, or one-third, are identical with those of Miocene age in Central Europe. This fact seems, however, to favour the opposite conclusion. It is improbable that so many species should have had such a wide range.

As in the Eocene period, central Europe was occupied by a sub-tropical fauna and flora. Mr. Belt asks—Is it not most probable when the greatest heat prevailed in Europe, that was also the time of the greatest heat within the Arctic Circle, and that on the advent of the cooler Miocene climate some of the species, living much further north, migrated southwards into central Europe, and took the place of the Eocene flora, for which the climate had then become too cool?

That many deposits, hitherto referred to different geological ages, have been actually accumulated contemporaneously in contiguous areas, is now becoming a recognised fact, yet few are aware that the doctrine was enunciated nearly fifty years ago by Mr. G. Poulett Scrope,* and subsequently was more carefully elaborated by the late Professor Edward Forbes.†

* Scrope, *Volcanos*, 1825, p. 239.

† See Wilson and Geikie's *Memoir of Forbes*, p. 395.

Heer records more than sixty different species of plants from N. Greenland in latitude 70° N.* Amongst them *Sequoia Langsdorfi*, cones of the Magnolia, vines, and broad-leaved ferns were abundant. The trunks of some of the trees were thicker than a man's body.† In Spitzbergen they were equally abundant in Lat. $78^{\circ} 56' \text{ N.}$, or within 11 degrees of the Pole.

No redistribution of land could make the climate of Spitzbergen more tolerable than it is, lying as it does in the line of the warm current, nor could it obviate the length of the Arctic night, which must prove fatal to all the higher types of vegetation.

The shortest night attainable in Arctic regions under present astronomical allowances is three months, during which the sun would not rise above the horizon.

"It is well worthy of remark" (writes the Rev. Professor Haughton),‡ "that the arguments from the occurrence of coal-plants and ammonites strengthen each other; the coal-plants rendering the question of *light*, and the ammonites that of *heat* insuperable objections to the admission of any received geological hypothesis to account for the finding of such remains *in situ*, in latitudes so high as those of Melville Island, Prince Patrick's Island, and Exmouth Island."

The presence then of trees in Tertiary deposits in Greenland and Spitzbergen may serve as a crucial test for this investigation.

The long Arctic nights are caused by the obliquity of the Ecliptic, and only by the lessening of that obliquity can they be shortened.

Having shown that an increase of cold at both Poles would result from a greater obliquity of the Ecliptic, let us consider the effect of a great decrease in that obliquity.

The present position of the axis of Jupiter proves that there is nothing impossible in the supposition that the axis of the earth may also, at one time, have been perpendicular to the plane of its orbit. The immediate effect of such a change would be the equalisation of day and night all over the globe. Every parallel of latitude would have but one season. At the equator alone would the sun rise vertical overhead at noon. In the temperate zones would reign perpetual summer, and within the Arctic Circle perpetual

* See Prof. Heer's "Lecture on the Miocene Flora of the Polar Regions," Geol. Mag., 1868, Vol. v., p. 273.

† See "Nordenskiöld's Expedition to Greenland," Geol. Mag., 1872, Vol. ix. p. 456.

‡ Appendix p. 395, to McClintock's "Voyage of the Fox" (1859).

spring. In central Europe subtropical vegetation might then flourish.

FIG. 12.—Ideal figure of the Earth in the European Eocene Period. The Axis (like that of Jupiter at the present time) is assumed to have then been perpendicular to the plane of its orbit.

In North Greenland the sun would rise every day to a height of 20° above the horizon and give twelve hours' sunshine. Spitzbergen would be colder, as the sun would rise to such a small altitude above the horizon, but even there, says Mr. Belt, the warmth of the Gulf-stream would cause frost to be unknown.

I fear I may have wearied your patience by this lengthened exposition of the new Glacial hypothesis, and, after all, may have failed in my attempt to place clearly before you the main points to which I desire to direct your thoughts. On the question of the internal heat or cold of the interior of our earth, I will not descant; but the theory of the variation of the obliquity of the Ecliptic should not be allowed to remain long unsettled after this date.

May we, as geologists, venture to question the past verdict of astronomers on this point? And may we ask them to re-examine their data? I think we may safely do so. For the internal evidence afforded by the Tertiary Floras of Greenland and Spitzbergen, and the conclusions of some of our ablest Botanists, as

Heer and Carruthers, thereon, are as incontrovertible as the effects of gravitation. Happily for the younger school of geologists, astronomers no longer *insist* on our conceding to them the dogma of infallibility. Popes in Science, who would bend facts to fit theories, are quickly dethroned now a-days, and only those theorists command our respect who build upon a coherent foundation of well-arranged facts. If in the Tertiary epoch the earth's axis has passed through a gradual movement from a position in which, like Jupiter, its axis was perpendicular to the plane of its orbit, to one in which, like Mars, its axis was inclined at an angle of 30° or even 35° , and if it be now as slowly returning to its former phase, it seems but probable, that in past geological ages the same slow variations have been taking place, producing, at long intervals, the same climatal changes we have just discussed.

Prof. Ramsay, Mr. Geikie, and others, believe they have detected physical evidences of several past glacial epochs—it is for the palæontologist to apply climatal tests to the older faunas, in order to confirm or refute these conclusions.

During the past year Mr. J. W. Judd, Profs. Geikie and Hull, have contributed to our knowledge of the existence in Ireland and the Western Highlands of successive series of volcanic rocks capable of identification with periods of eruptive activity in the Silurian, the Old Red and the Tertiary periods. Several of the volcanic vents have been discovered with their “necks” still surrounded by bombs and scorix, clearly indicating the sites of eruptions similar in character and in their attendant phenomena to those of to-day. There is no *ground*, then, for the assertion of Mr. Robert Mallet that the later volcanos alone have thrown out ashes and scorix, and the earlier only lavas.

That Lundy Island may probably be, as pointed out by Mr. Judd, relegated to the same volcanic series as that of the Western Highlands; and, as Mr. Allport has more recently suggested, that the “Wolf Rock” between Land's-end and the Scilly Islands may probably mark a more southern extension of this great line of Tertiary volcanic action—the thermal springs at Bath, so long isolated, now form an harmonious link in the chain of evidence (referred to in my last year's address), attesting an axis of volcanic disturbance running north and south equal in longitude to that of the two Americas, although now in great part sunk beneath the Atlantic.

This Association is essentially a practical one, as a retrospect of its published proceedings will clearly attest. Even in the past twelve months sufficient good solid work has been accomplished to lift it above the level of a mere dilettanti society. And if, in the earlier days of its existence, some among its promoters may have formed somewhat utopian notions as to its future career, the more practical working members have fully achieved for it a high character for usefulness and durability.

Since its foundation in 1858, a period of sixteen years has elapsed and although from 1863 to 1870 the Association appears to have somewhat languished, yet, on the whole, the amount of work done and of country traversed geologically has been very considerable. More than 100 excursions have been made, and nearly 200 papers read, of which a large proportion have already been published in our "Proceedings."

But whilst congratulating you on the progress of the Association hitherto, let us not, like the Lotophagi, rest lost in idle contemplation—

"Propt on beds of amaranth and moly,"

but rather seek new grounds to explore, new materials to classify, and new theories to be tested.

As a London society, we are especially interested in all connected with the Thames valley. Can we not complete the history of its past faunas, and map its old physical conditions?

Mr. William Davies, of the British Museum, has this year completed an admirable catalogue of its Pleistocene Mammalia, as illustrated by the grand collection from the Brick-earth at Ilford, formed by Sir Antonio Brady, Knt., F.G.S. (now in the British Museum). May we not add to this?

The valuable work by our late lamented friend and associate, Professor Phillips contains much; surely, we may still add more.

Mr. Frederick Edwards' celebrated collection of Eocene Tertiary fossils, and that of Mr. Nathaniel Wetherell, F.G.S., of Highgate, are now national property, and are easily accessible to the scientific student. Of the 2885 species of Eocene mollusca in Mr. Edwards' collection, 742 species are MS, and need to be described and figured. The Palæontographical Society will find the plates; who will volunteer to find the descriptions? I believe in this Association we have at least three or four members fully qualified, and probably quite willing to combine and carry out this object.

Our excellent Vice-President, Mr. Robert Etheridge, F.R.S., has kindly furnished me the latest column in the subjoined table, from which it appears that there are 13,275 species of described British fossils.

	Dr. H. G. Bronn's Index Palæontologicus, 1849. (Cosmopolitan)	TOTAL	Prof. Morris's Catalogue of British Fossils, 1854.	TOTAL	Mr. Robert Etheridge's List of British Fossils, 1874.
VERTEBRATA.					
MAMMALIA	708	.....	97	.....	198
AVES	148	.....	12	.....	18
REPTILIA	381	.....	184	.....	280
PISCES	1,461	.....	755	.....	883
Total VERTEBRATA		2,701		1,048	1,379
INVERTEBRATA.					
Insecta, etc.	1,699	.....	74	.....	97
Crustacea	894	.....	367	.....	996
Annelida	292	.....	137	.....	194
Mollusca	13,885	.....	5,057	.....	7,416
Polyzoa	810	.....	264	.....	534
Echinodermata	1,232	.....	494	.....	681
Zoophyta	825	.....	471	.....	573
Protozoa	2,028	.....	395	.....	582
Total INVERTEBRATA		21,665		7,262	11,073
PLANTÆ.		2,055		729	823
GRAND TOTAL		26,421		9,039	13,275
	Probably not less than fossils have been described in Europe and America, etc., since 1849, making as the Total for all the world	12,500	If to the above we add for the newly described species during the past 20 years, we shall have British Fossils...		
		38,921		6,000*	
				15,039	

I have estimated the cosmopolitan lists roughly at 39,000 species, so that we may still hope to find many more new forms in Britain.

One of our Members, Mr. Hopkinson, is already prepared to make a considerable addition to the Graptolites of the Arenig Group; Mr. F. G. H. Price and Mr. Gardner are both working up the Fauna of the Gault; the latter gentleman hopes (aided by Mr. Carruthers, F.R.S.), to monograph the Flora of the Bournemouth-and Alum Bay Plant-beds. Many British Fossil Crustacea still remain to be described, and I have also a new fossil Scorpion from the Coal-measures of Sandwell Park Colliery, near Birmingham, to place before you shortly.

Our able Honorary Secretary, Mr. Hudleston, will this Session present his second great paper on the Oolites for your acceptance, and our distinguished colleague, Professor Morris, has incidentally

* The admirable summary given by the Rev. Thos. Wiltshire, M.A., F.G.S., V.P.G.A., the Hon. Sec., in this year's volume of the Palæontographical Society, shows that during the 28 years of its operations upwards of 4,000 British species have been described and figured in the Society's Monographs.

mentioned that he has several discourses ready for delivery on a variety of topics, but especially upon the appearance of the great groups of animals in time, and their relation to the functions which they fulfil, as well as to each other.

Mr. G. Smith, another of our Members, has prepared with great skill and ability more than 100 sun-pictures of fossils illustrative of the chief types of ancient life on our planet, well suited for lecture-purposes, and admirably adapted to promote a taste for geological studies among the young.

I have already had the pleasure to exhibit some of these (by means of the oxy-hydrogen lantern) before the Members of this Association during the course of last Session, but many new ones have lately been added to the series. I have much pleasure in commending them for their accuracy and clearness. They deserve to be very widely known, and are sure to be appreciated.

According to established custom, I shall vacate this chair at the next Annual Meeting in February, 1875, but it is not my intention to cease to co-operate with you, or to feel a lively interest in the welfare of the Association, which has done me the honour to call me to its highest office, a position I feel I am but little worthy to occupy.

In his Anniversary Address to the Geological Society of London in February last, His Grace the Duke of Argyll has laboured to point out how much, as geologists, we have yet to learn concerning this great universe "in which we live and move and have our being," and he has reminded us of the words of that excellent and highly-gifted lady, Mrs. Somerville, who exclaimed, after a life given up to the earnest pursuit of science, "Ah! how little it is we know."

While fully concurring in that truth, as applied to geology, I would record here another equally terse and apt remark which fell from the lips of my esteemed friend, Professor Morris, a few days since. It is—"How much we owe to that Older School of Geologists, who, fifty years ago, first expounded the great and fundamental facts of geology for us, and yet whose writings we too often pass over unread, and whose very names will soon be forgotten by the Younger School of Geologists."