

37. *On some FOSSIL REEF-BUILDING CORALS from the TERTIARY DEPOSITS of TASMANIA.* By PROFESSOR P. MARTIN DUNCAN, M.B. Lond., F.R.S., &c., President. (Read May 10, 1876.)

[PLATE XXII.]

A DESCRIPTION of a very remarkable species of *Dendrophyllia* from the Tertiary deposits of Table Cape, in North Tasmania, was read before this Society on June 9, 1875\*; and shortly afterwards I received a parcel of other kinds of corals from the same locality, accompanied by a request from the Royal Society of Tasmania that I would undertake their examination. I was then made aware, from an abstract of a paper read before the Royal Society of Tasmania, that all these corals had been under the careful hands of the Rev. Julian Woods, to whom the palæontology of the Australian province is so much indebted.

The Rev. Mr. Woods gave his reasons for believing the Table-Cape deposits to be of the same Lower Cainozoic age as that which I had given them, and supported his opinions by references to the similarity and identity of the species of Echinodermata, Mollusca, and Corals found in them and in the Lower Cainozoic deposits of the mainland. As my inferences were derived second-hand from Mr. Woods, he clearly has the priority of having decided the geological position of the Table-Cape beds. He stated that, after a comparison of the Tasmanian and Australian specimens, he found in the deposits of both countries such well-known forms as *Hemipatagus Forbesi*, Woods & Dunc., *Cellepora gambierensis*, *Pectunculus laticostatus*, *Cucullæa concamerata*, *Dentalium Hicksii*, *Trigonia semiundulata*, *Corbula sulcata*, *Cypræa eximia*, *Voluta Hannafordii*, *Voluta antiscalearis*, *Conotrochus M'Coyi*, and a large *Placotrochus deltoideus*. This is a fauna which is characteristic of the Muddy-creek series in Hamilton, Victoria, and partly of the Mount-Gambier limestone, deposits which are low down in the Australian Cainozoic series (Miocene of some geologists).

In noticing one of the corals the description of which forms part of this communication, Mr. Woods considered it to belong to the genus *Isastræa*, explaining that it was new to science, and that its presence indicated that there was evidence of a deeper sea and warmer climate than now existed on the area.

The examination of the coral in question and of some other specimens from the same locality, whilst it necessitates the rejection of the generic nature of Mr. Woods's species and of its bathymetry, quite confirms his opinion regarding the former climate of Tasmania.

The specimens about to be described are included in the group of compound *Astræida*, called the *Astræacæ* by Milne-Edwards and Jules Haime, and belong to the genera *Heliastrea* and *Thamnastrea*.

*Heliastrea*, a large genus, culminated during the Miocene, and

\* Quart. Journ. Geol. Soc. vol. xxxi. p. 673.

was, and is at the present day, a reef-building and not a deep-sea group. *Thamnastræa*, so common in the Jurassic ages, was then a reef-builder and a littoral form, and after a great number of species had been evolved, it became rare in the Nummulitic period, and died out in the subsequent geological age in the Australian region, having been probably destroyed in the European areas by the changes which ensued upon the destruction of the Eocene reefs.

List of species from Table Cape, Tasmania :—

1. *Dendrophyllia epithecata*, *nobis* \*
2. *Heliastrea tasmaniensis*, sp. nov.
3. *Thamnastræa sera*, sp. nov.

#### Genus HELIASTRÆA.

HELIASTRÆA TASMANIENSIS, sp. nov. Plate XXII. figs. 1-3.

The corallum is incrusting, and the corallites are subcylindrical and distant. The calices project but slightly, and differ much in size; the fossa varies in depth, being in some instances slight and in others more than equal to the diameter of the calyx; and the margin is thin. The septa are alternately long and short, are straight and thin, and are marked with separate granules or with linear groups of them. They are not exsert, and are only slightly thicker at the wall than elsewhere: their arrangement is irregular; for in the largest corallites there are four cycles in six systems, and a few members of the fifth cycle in one or two also, whilst in the majority the fourth cycle is incomplete, there being three cycles in six systems, and in one or two members of the fourth. In some calices the quaternary arrangement of the septal numbers exists, there being only four primaries and four cycles in four systems. The distinction between the primary and secondary septa is slight; but the existence of a very small septum between two much larger ones is very decided. The large septa reach far inwards and are entire. The columella is very small, and is formed of trabeculæ between the septal ends. The wall is thin, and in some instances more so than are the larger septa. The endotheca is largely developed, and the dissepiments are thin, long, and curved downwards.

The costæ of the large septa are well developed; and they are either long and wavy over the cœenchyma, or are short and restricted to the corallite; those of the small septa are rudimentary, and exist either as faint projecting lines or as spines; and their presence between the more prominent ones is very marked; they are all thin and delicate. The exotheca is greatly developed and is largely cellular, the direction of the upper parts of the cells being nearly horizontal; but all parts of it, including the vertical partitions, are thin.

The diameter of the calices is under  $\frac{1}{8}$  inch, and their distance apart is rather more or slightly less.

The species is remarkable for the tenuity of the whole of the struc-

\* Quart. Journ. Geol. Soc. vol. xxxi. p. 677.

tures of the corallum, the great development of the exotheca, the long filiform continuations of the greater costæ which connect the corallites, and their occasional absence, and also for the small columella and indefinite septal number. The presence of corallites with the quaternary arrangement is very suggestive.

*Alliances.* The species is eminently *Solenastræan* in its aspect; and were it not for the costal development, it would be associated with that genus. In some parts of the corallum the distinction between the structures and peculiarities of the genera *Heliastrea* and *Solenastrea* are by no means decided; but in others the long wavy costæ mix in and amongst the exotheca, and unite with those of the neighbouring calices. The alliances of this *Heliastrea* must be sought amongst those with long costæ, much exotheca, a fair amount of endotheca, and a small columella. Species thus distinguished are not found amongst the recent reef-building coral faunas. The nearest allies of the new species have been found in the same strata as the congeners of the Australian *Placotrochi*, namely in the Miocene of the West Indies; but in estimating the value of this remote connexion, it must be remembered that there is hardly any palæontological evidence relating to the Tertiary reef-corals of the Pacific area.

The species differs much from the *Heliastrea* I described from the Tertiaries of Java\*.

*Heliastrea immersa*, Reuss.†, from the older Tertiaries of Monte Grumi, near Castelvetro, is of the same general type as the new form, as it has distant corallites, a peculiar septal number, long wavy costæ, and apparently a thin wall and a small columella.

The new species, when compared with the *Heliastrea*s of the Ootator group of the Cretaceous formation of Southern India, presents remarkable affinities with *Heliastrea cortica*, Stol.‡; for this interesting Indian reef-coral has all the characters of the Tasmanian form, but differs in possessing thick costæ, those of the small intermediate septa being large. Even the other species from these Indian rocks (*Heliastrea rotunda*, Stol.) is not without its resemblance to the Tasmanian species.

*THAMNASTRÆA SERA*, sp. nov. Plate XXII. figs. 4-6.

The corallum is solid and short, being about  $\frac{9}{10}$  inch in height; and the base is incrusting; the upper surface is subplane; and the corallites are distant and widely apart. The calices are slightly depressed below the level of the long and numerous costæ; their fossula is small and shallow; and the columella is papillary, being formed by oblique and rounded processes from the free ends of the septa. The septa are continuous with the costæ, and are at the margin of the fossula about twenty-six in number; they are subequal,

\* Quart. Journ. Geol. Soc. vol. xx. 1864, p. 72.

† Reuss. Pal. Stud. über die ält. Tertiär. der Alpen, 1868, 1. Abtheil. p. 30.

‡ Stoliczka, Palæontol. Indica, vol. 14, 4 ser. pl. viii. f. 4-8; The Corals or Anthozoa, Mem. Geol. Survey of India, 1873.

and their upper edge, finely dentate, dips down very slightly towards the columella. Some septa are continued on to long and wavy costæ, which become thickened halfway between the calices; and others soon unite to two or even more costæ, or simply bifurcate in their path towards the nearest corallites. Occasionally there are three costæ united to one septum. The costæ are long, slightly wavy, slightly exsert, narrow, except midway, and are dentate at their free edge. The small spiny dentations, when removed, leave open pits on the surface of the costæ, which give them a very characteristic appearance. The costæ are also finely and distinctly granular laterally; but the tips of the grains do not meet. There are eighty costæ in connexion with the calicular septa in the largest corallite.

The sides of the septa are marked with closely packed, large, but flat granules, as are those of the costæ (as seen in sections); and the endotheca is largely developed, being close, and curved both upwards and downwards. It reaches to the columellary space, across it, and high up in it.

The wall appears to be rudimentary; and the costæ are united by exotheca and by a growth from their sides. Synapticulæ barely exist; for it is very rare to find a few of the lateral granules of the costæ and septa attached by their ends.

Diameter of largest calice  $\frac{5}{10}$  inch.

*Alliances.* This is a well-marked species, and has large calices, long dentate costæ, and largely developed endotheca and exotheca, the synapticular element being very small. It is the only form of the genus which has hitherto been discovered in deposits later in age than the Nummulitic; and it does not closely resemble those from that series\*. Very Jurassic in its appearance, the coral would almost pass for *Thamnastræa Walcottii*, nobis†, from the Inferior Oolite of England; and it has no alliance, except that of a generic nature, with the species from the Indian Cretaceous rocks.

#### THAMNASTRÆA, species.

A much-worn specimen of a *Thamnastræan*, greatly resembling and probably identical with the last-described species, was cut, and microscopical sections were made. One section passed through several corallites at a slight distance from the surface; and another was taken in a longitudinal direction and parallel with the septa. A wall separating the corallites is not to be found, and the costæ are continuous with the septa of different calices, the laminæ being bound together by their sides. The septa and dissepiments, especially the former, are marked by opaque and either rounded or more or less elongate spots, which apparently coincide with the large granules which constitute the beauty of the ornamentation of the septa. These granules are very numerous and evidently are of more importance than simple ornaments; for the microscope shows them to be centres of sclerenchymatous spicular growth. They are probably ill-developed synapticulæ.

\* Consult D'Achiardi, *Coralli Eocenici del Friuli*, 1875.

† *Pal. Soc. Supplement to Brit. Foss. Corals, Oolitic part.*

The sclerenchyma, as a whole, may be said to consist of spicules radiating from centres in more or less linear series; and each spicule is joined laterally and before and behind to its fellows. The whole coral is infested with the tube-like penetrations and ramifications of a parasitic unicellular Alga; and this has been described in a former communication (see Quart. Journ. Geol. Soc. vol. xxxii. p. 205).

*Remarks on the Species.*

The Heliastreaen just described was evidently a rapid grower, and a true reef-building form, having its bathymetrical distribution restricted to 20 fathoms; and the Thamnastraean (so solid, yet so abundantly supplied with endothecal structures) appears to have had a corresponding habitat. They required the external conditions peculiar to coral-reefs.

In considering how these physical conditions could be found on the area from which their absence is now so conspicuous, the general physical geography of the Australian seas during the Cainozoic periods must be considered. This was attempted to be explained in 1870 (Quart. Journ. Geol. Soc. vol. xxvi. p. 284), by the author of this communication; and the relation of the past and existing coral-faunas of Southern Australia, and the former distribution of land and sea, were noticed in the concluding parts of his essay on the fossil corals of the Australian Tertiary deposits. As there is no reason for altering the opinions therein expressed, reference must be made to that communication; and the bearings of the suggestions therein contained will be found to be explanatory of the existence of reefs in Tasmania. The open sea of the vast area to the west of Cape Howe, running up into the tropics, would place the old hills of Tasmania and those of Eastern Australia in the midst of an ocean, even if the Australian land were prolonged away to the north-east, as it probably was in those days. But even admitting that probable insular distribution of land in the South Pacific during the Miocene epoch which has been so frequently suggested by zoologists, botanists, and geologists, the fact of the sea-temperature being sufficient for the development of reefs in Tasmania is insufficiently explained.

There is a faint relic of the old reef-fauna still lingering on the Tasmanian shores in the form of *Echinopora rosularia*, Linn. It forms thin incrusting layers, and not masses of limestone; but it is clearly a relic of that reef-building coral-fauna which has long since died off from the area. Even the hardiest of the Pacific corals, the stronger forms of *Porites*, are absent. In fact, the only surface-water coral lingers on in a temperature in which *Porites* could neither exist nor propagate.

Evidently the reefs around Tasmania, now long extinct, existed amidst all the physical conditions peculiar to coral-growth on a large scale. Pure sea-water in rapid movement and having a temperature of not less than 74° Fahrenheit, was as necessary to them as it is to those far away to the north and north-east at the present day.

The coral-isotherm would have to be  $15^{\circ}$  of latitude south of its present position in order that reefs should flourish south of Cape Howe; and this could only be produced by a different distribution of land and sea, and by a different position of the polar axis to that which now prevails.

A south-polar continent reaching, in the Miocene age, northwards to  $50^{\circ}$  S. lat., would meet the requirement of a land reflecting the equatorial currents and tides and adding in no way any great amount of cold water; and large islands off its coast extending to the American and African coast would satisfy most of the biological requirements of the period. To the north and north-east there existed then the land whose memorials are the atolls and fringing reefs of the great Pacific. On the other hand there was the open sea, already noticed, of Central Australia, and to the north the great volcanic islands were sea-floors on which Miocene detritus was accumulating. 'Lemuria' may be assumed to have existed.

Vast surfaces of South and Central America, and some of North America, were sea-floors; and the ocean and coral-tracts prevailed over a great space in Europe and Western Asia. Much of North Africa was still submerged. On the other hand there was probably an Atlantis, and a huge continent existed in the north of Central Asia, N. America, and N. and Central Europe. In those days and before, even during the Nummulitic period, the coral-isotherm of  $74^{\circ}$  F. reached fully  $25^{\circ}$  N. of its present possible position in the portion of the globe antipodean to Tasmania; and the winter's cold could not have been sufficient to chill the surface-water in the latitude of Vienna and N. Italy. The question arises,—Could the temperature of this broad belt of warm water be maintained by geographical causes alone? and a second question requires a satisfactory solution, bearing as it does on the question of alternations of season and of light and darkness,—Could such geographical causes as the distribution of the land in polar masses and in central islands overcome, in high latitudes, the effects of the position of the globe in relation to the sun in perihelion and aphelion? It appears to me that they might to a certain extent modify the severity of climate, but not sufficiently to permit of important reefs existing in Western, Central, and Southern Europe, and in Tasmania synchronously. That the reefs were contemporaneous, there is every reason to believe.

An examination of the flora which underlies the marine Cainozoic deposits of the mainland of Victoria has shown that the plants found there resemble those of Tropical rather than of Extra-tropical Australia; and as will be noticed in a communication about to be presented to the Society, the Echinodermata of the succeeding strata afford the same kind of evidence.

The proofs of the existence of higher temperatures, and of the absence of the long and dark months in the Arctic regions, are abundant from the age of the Carboniferous formation to the Miocene. During all the ages of the globe down to that period when such vast alterations in the relative level of land and sea occurred, there is found evidence in favour of the theory that perpetual frost

and snow and months of darkness did not exist in the Arctic regions. Contemporaneously a corresponding genial climate existed in the southern hemisphere. It is perfectly certain that, under the existing astronomical arrangements, there must be prolonged day and prolonged night at the poles and for a certain number of degrees in the equatorial direction; and the inclination of the polar axis to the plane of the ecliptic necessitates the perpetuation of the present arctic and antarctic climates. The astronomical conditions under which a sufficient amount of light could be given to the plants within twenty degrees of the pole are not those which now prevail; but were the polar axis at right angles to the plane of the ecliptic, and were there no greater node than at present, there would be equal day and equal night. The biologist claims this as the earliest position of the globe. The arguments against such an inference relate, of course, to the nature of the forces which could bring down the north pole, or rather which would incline the polar axis, and to the amount of solar heat which would reach the polar regions. Probably no force acting on the globe as a mass, such as gravitational energy, could alter the position of the poles as they are now, with reference to the ecliptic; for after a very slight inclination had been produced, the force would produce no more obliquity, but only a more or less rapid precessional movement.

Nor is it possible to understand how any external force could cause the approach of one pole to the sun and the recession of the other, the globe being comparatively homogeneous, for the sake of argument, and the polar axis being supposed to be at right angles to the plane of the ecliptic.

But it would be possible if a vast alteration in the relative distribution of land and sea occurred, in one hemisphere especially. It is perfectly reasonable to infer that the great subsidences of the Miocene lands, and the formation of the Southern Ocean, whose area is greater than that of all the land to the north, and the vast upheaval of the Central-Asian, Caucasian, and Alpine and other areas, producing great alterations in the homogeneous condition, brought the land-surfaces of the north with their higher specific gravity and great mass within the influence of the gravitational energy of the sun. From that time dated the long winter's night and the presence of perpetual ice and frost in the highest latitudes; and those changes in the climatal conditions of the northern and southern areas, where reef-corals had built and the light-requiring floras had flourished. The objection regarding the small amount of heat which would be granted to the high latitudes under the conditions of a vertical polar axis are of the nature of those which sadly troubled our science with respect to the impossibility of animals living at very great depths in the sea in consequence of the pressure to which they would have to submit, and to the warm temperatures which must prevail in the oceanic abyss.

The presence of land in the extreme north or south on which no perpetual ice rested except on the high hills, would introduce an element into the argument which would suffice to demonstrate a tem-



perate zone. Oblique as would be the path of many solar rays, still the corresponding loss of temperature would be compensated for by the warming of the atmosphere by the radiation from the masses of the land-surfaces to the north and south. It is, moreover, reasonable, according to the principles of thermodynamics, to assert that the sun was then producing more heat, and that the internal temperature of the globe was greater than now; and this may have had some slight influence.

In bringing these theories before you, which have been in the minds of so many geologists, and which have been brought forward by succeeding generations of us, Belt and Woodward being their last supporters, my excuse must be that possibly they may be improved upon by those physicists who will admit the necessity of comprehending biology in their dynamical and kinetic arguments, —or that in the true interests of science they may be disproved, so that we may seek explanations of the facts brought forward in this and other cognate essays in other directions.

*Note.*—This communication was forwarded to the Society before my predecessor in the Presidential office read his admirable Address. I now refer the reader to his remarks on those questions of astronomical interest which I have introduced in this paper. (See Anniversary Address of the President, John Evans, Esq., F.R.S., Quart. Journ. Geol. Soc. vol. xxxii. Proc. p. 101 *et seq.*)

#### EXPLANATION OF PLATE XXII.

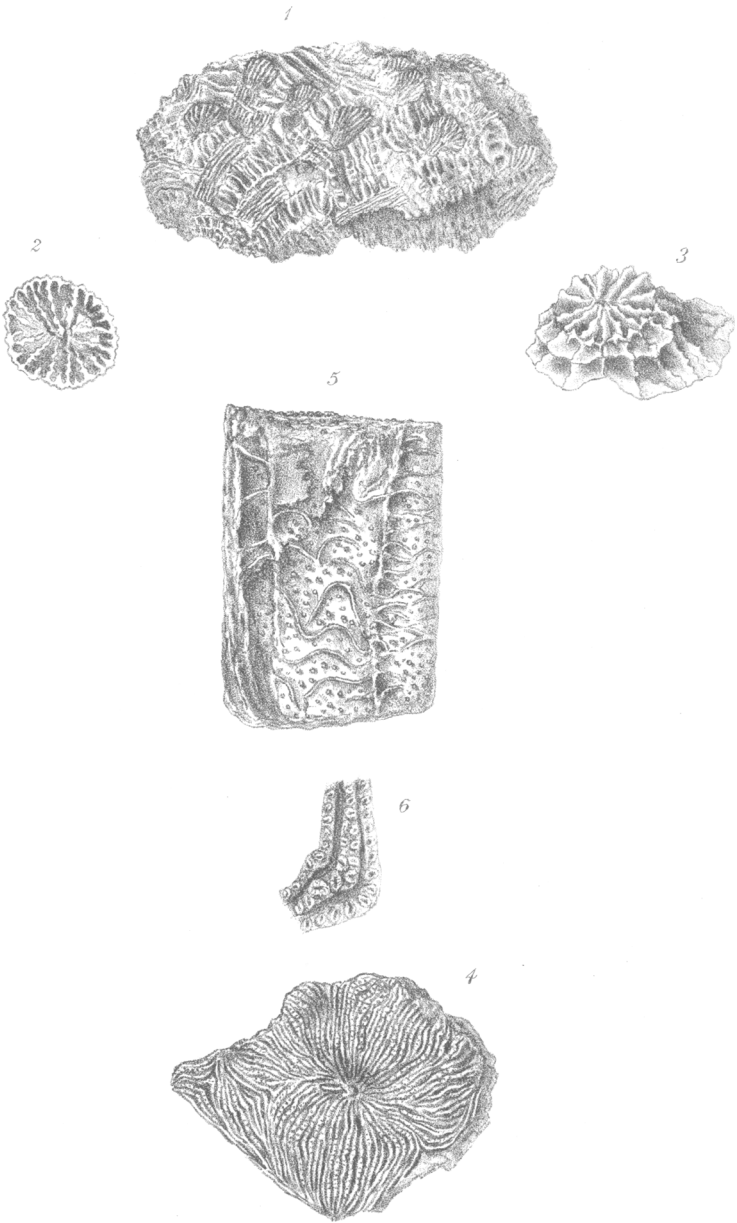
- Fig. 1. Corallum of *Heliastrea tasmaniensis*, sp. nov.
2. Calice, magnified 3 diameters.
3. Costæ and exotheca,  $\times 3$ .
4. Calices of *Thamnastraea sera*, sp. nov.
5. Longitudinal section of corallum.
6. Details of septa,  $\times 3$ .

#### DISCUSSION \*.

MR. EVANS was glad to find that this subject, concerning which he had lately expressed his own views, had been taken up by the author; but he thought it possible that Dr. Duncan would, on further consideration, be inclined to modify somewhat the theory promulgated in this paper in favour of some other view. In order to account for the occurrence of reef-building corals of Miocene age in latitudes now too cold for them, the author had reverted to the old idea of the vertical position of the poles. If the interior of the earth is fluid, a sliding crust such as the speaker had formerly suggested is possible, though it would be difficult to prove the existence of a fluid interior, and still more difficult, did that exist, to prove that the crust would slide on it. But even supposing the earth to be a nearly solid body, elevations and depressions enough

\* This discussion relates also to Prof. Duncan's paper "On the Echinodermita of the Australian Cainozoic Deposits."





Foord lith

M&N Hanhart imp

TASMANIAN CORALS.

must take place on the surface to alter the relative positions of the poles with regard to the surface of the earth. Because there were proofs of warmer climate having existed in Miocene times in Greenland, near the one pole, and in New Zealand near the other, there was no need to suppose that belts of warmer temperature had extended nearer the poles than at present, for the same sliding of the crust that brought Greenland nearer the equator would also bring New Zealand nearer the tropics, both being on nearly the same meridian, but on opposite sides of the globe. The subject was one that deserved the attention of geologists, as it lay at the root of many important questions affecting the past history of the earth.

Professor HUGHES believed implicitly what the astronomers told him *must be*; and if observations on the distribution of life necessitated any thing more than such alterations of climate as could be accounted for by geographical changes and modification and adaptability in the forms of life, he would prefer to leave it as one of the many things he could not explain, than accept an explanation inconsistent with accepted astronomical theories. If, as explained by Sir John Herschel, the transference of large masses from one part of the earth's surface to another would disturb the equilibrium, we must remember that this action would be mostly compensative; and if the cumulative effect of many such disturbances might be a partial readjustment of the mass, we must regard such movements only as a tendency to keep the whole mass and its axis of rotation as it was in spite of the transference of portions from one place to another by denudation. Moreover he disputed the data on which the views advocated by both the present and the late President were founded. He asked whether we should say that the climate of the period of our older river-gravels was that of Egypt or of Northern Siberia, seeing that the *Corbicula fluminalis* and *Unio littoralis* were now found only much further south; while the hairy elephant and reindeer, which had once lived with them, were now held to prove an arctic climate. When we know that flowering plants and evergreens now live in Alpine regions, where they are buried in total darkness under snow for four months, shall we say that the absence of light would render it impossible for evergreens and flowers to have flourished where the arctic winter-night is four months long, even though we could account for a milder climate by geographical changes.

Mr. WOODWARD remarked that as it was not merely a question of one fauna and flora, Mr. Hughes's statements must be received with caution. There were evidences in northern latitudes, not only of a Miocene, but also of a Carboniferous, a Jurassic, and a Cretaceous flora. Nor was it a question merely of lowly organized plants which would be more likely to withstand the climate; for Prof. Nordenskiöld had found tree-trunks standing erect in the soil in which they grew, and it was impossible for them to have grown in a climate so rigorous as now exists at that latitude. If the geologists are wrong in the conclusions they have drawn from these facts, let the astronomers show

them how to account for the occurrence of fossils indicative of such a warm climate in such high northern latitudes; for the absence of cold must be accounted for to explain the growth of these trees in that spot.

Prof. ANSTED maintained that the geologists had certain natural-history facts on their side with regard to the occurrence of fossils near the poles; it remained, therefore, for the astronomers and physicists to find a new theory to account for these facts.

Prof. GREEN thought that the astronomers should be asked if the change of axis was a possible explanation, and to calculate what would be the result of a change in the distribution of land and sea, and how would such a change affect the position of the poles. The question was one of mechanics.

Mr. SORBY considered that the amount of heat and light received from the sun should also be taken into account, and the fact that this may have varied at different periods.

Sir ANTONIO BRADY stated that there were many facts which tended to prove that the sun had varied in heat &c.; but the sun had probably little to do with the warmer climate of the poles in past ages. The heat of the earth in its various stages of cooling would be sufficient to account for these changes of climate on the surface of the globe.

Prof. RAMSAY could not agree with the last speaker in thinking that radiation in cooling would produce any palpable effect on the surface of the globe. So far from there being any proof that the climate had been gradually growing colder from the earliest times down to the present date, there was every evidence to show that glacial periods had recurred at different periods in past time. Dr. Duncan and Mr. Evans had merely given suggestions, but had not attempted to solve the problem. The poles probably occupied the same position in Miocene times that they do to-day. Darwin and Dana were both agreed in thinking the present continents to be of extreme antiquity. Great elevations of land had taken place prior to the Miocene epoch. The Alps and the Himalayas were both pre-Miocene, and were probably higher in pre-Miocene times than at present, having been subjected to great denudation.

Mr. GWYN JEFFREYS pointed out that certain species of shallow-water mollusca now found in the Arctic Ocean had formerly lived in post-Tertiary times lived as far south as Sicily.

Dr. WRIGHT remarked that there was a wonderful similarity between the Miocene echinoderms from Australia and those found at Malta.

Prof. MORRIS considered the abundance of echinoderms belonging to the Spatangoid group in these Australian beds to be very interesting. The feature presents itself in the New-Zealand Tertiaries, where forms allied to *Arachnoides* occur. The distribution of these echinoderms in New Zealand was excessively complex and difficult to understand. There was a remarkable similarity between the Miocene floras of Greenland and Central Europe; and the question to be asked was, Did they spread over a continent formerly existing

between these points, or had they emigrated from some one central spot ?

Dr. DUNCAN, in reply, stated that it was only by the united investigations of all students of geology that the question could be in any way settled. The belief in the recurrence of glacial epochs was founded on some erroneous conclusions drawn from beds in England, South Africa, and in India, which were related to local glacier action or to volcanic agglomerates. The Miocene plants could not have existed without sufficient light; and severe frost would have destroyed them; and therefore they could not have extended so far north under conditions similar to the present. The Echinoderms did certainly present a striking resemblance to those found in the Miocene beds of Malta; but there were still sufficient specific and generic differences to justify him in describing them as distinct.