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Climatic Changes in Japan since the Pliocene Epoch.

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With 1 Plate.

As is well known, one of the striking features of the climate of the primæval world was the occasional interruption of a comparatively warm and uniform climate by one of intense cold. The time during which such a cold climate prevailed is called an *ice-age*, because of the enormous quantities of ice which in the form of glaciers covered the land, smoothing, polishing and scratching the rocks over which they moved, and carrying with them erratics and moraines, just as they do to-day in the Alps and in Arctic countries. Geologists have ascertained that such ice-ages have visited the earth at least three times during the past. The first visit was during the Eozoic or Precambrian, the period in which the first dawn of life appeared in the world. Evidences of this age have been discovered in China, Canada and Northern Norway. The second was toward the close of the Palæozoic era, in a period called Permian. This time the ice chiefly invaded the countries around the Indian Ocean—India, Australia and Southern Africa. The so-called *Glossopteris flora*, which resembles that of the succeeding Mesozoic more than that of the Palæozoic and which flourished during the Permian period in the above named countries, is often brought into connection with this second glaciation, on the assumption that it was the result of the transforming power of the cold acting on plants of the Palæozoic which remained unchanged until its close in places where there was no glaciation.

The third and the last ice-age was of a comparatively late date. It was in the Diluvial. During the Tertiary, a period which immediately preceded this age, the climate of Europe and America was very warm, so warm in the beginning that tropical plants grew in Southern England and chelonians and crocodiles inhabited its waters. This great heat, however, gradually diminished as time went on, becoming subtropical in the Miocene and temperate in the Pliocene, the last subdivision of the Tertiary. Within this Pliocene, too, the lowering of temperature still went on from the beginning to the end, a sure indication of the approach of an ice-age. And this is nowhere more clearly mirrored than on the molluscous animals of the so-called *Crag Formation* of England which belongs to the above-said Pliocene Epoch. The Mollusca in the lowest division of this Crag, called the *Coralline Crag*, in spite of an admixture of a few northern or boreal forms, still bears in general the stamp of a very genial climate. But in the *Red Crag*, the Crag next above it, the number of boreal forms increases to 10% and in the still higher *Norwich Crag* to still more, until at last in the uppermost Crags,—the *Chillesford* and *Wegbourne Crags*—their number is so great that the fauna may be called really Arctic, and there is even a doubt whether these Crags might not be better classed among the deposits of the ice-age itself.

With the dawn of the Diluvial Epoch, the whole aspect of Europe and America was changed. Enormous glaciers were moving everywhere. They formed a continuous sheet of ice several thousands of feet in thickness and covering the greater part of the two continents. They looked very much like those now found in the interior of Greenland or on the Antarctic continent. This ice-age, however, was not one continuous age of ice. There were also times in which the ice partly melted and shrunk and the climate became comparatively mild. Such times are called *Interglacials*, their number varying in different regions but amounting to as many as six, as has been ascertained in America. Thus the ice-age after several fluctuations in the extent of the ice at last disappeared, and in the Alluvial or Modern Epoch we see the

once ice-covered Europe and America again covered with meadows and woods, and quite as inviting as in by-gone ages.

Hereupon a thinking mind is naturally led to ask whether this state of things was limited to the above two continents, or was more world-wide in nature, in which case the old remains of erratics and moraines and of polished and scratched rocks should also be found in other parts of the world. And so when Japan was opened to international traffic and geologists, both foreign and native, began to scour the country, they naturally looked for evidences of glaciers. But strange to say, they were nowhere to be found. They were not found in Honshu, nor in the Hokkaido, nor even in the cold island of Sakhalin where even in the southernmost part the mean January temperature falls far below the freezing point, to —13°C, a temperature which we find in Labrador and Southern Greenland. From this negative evidence they were obliged to infer that glaciers had never existed in Japan, probably because the climate had never been cold enough to generate them. But why had it not been cold? There was no one who could answer this question.

Since about a year ago, I have been studying our Pliocene fossils found at a place called Koshiba, some eleven kilometres south of Yokohama and beautifully situated on the shore of the Tokyo Bay. The rock in which the fossils are entombed is a coarse tufaceous sandstone, sometimes so coarse as to look like a conglomerate, thus betraying the shallowness of the sea in which it was deposited. The fossils are chiefly *Molluscs* and *Molluscoids* with some *Echinoderms*, *Tubicolous Annelids*, *Balanids*, *Fish-teeth*, etc. The *Molluscs* seem to be very rich in species, while the case seems to be quite the contrary with the *Molluscoids*, though they are rich in individuals. The number of the species of these two groups of animals which I have been able to distinguish up to this time, amounts to seventy-one,[1] of which the following thirty-nine are living ones:—

1. *Cylichna cylindracea* Pennant.

1) Detailed descriptions of these fossils will appear in a future number of this journal.

2. *Conus sieboldi* Reeve.
3. *Pleurotoma kamakurana* Pilsbry.
4. *Mangilia robusticostata* Smith.
5. *Admete viridula* Fabricius.
6. *Voluta megaspira* Sowerby.
7. *Mitra ebenus* Lamarck.
8. *Chrysodomus phœniceus* Dall.
9. *Chrysodomus pericochlion* Schrenck.
10. *Trophon clathratus* Linné.
11. *Priene oregonensis* Redfield.
12. *Natica clausa* Broderip et Sowerby.
13. *Leptothyra amussitata* Gould.
14. *Puncturella conica* Orbigny.
15. *Acmœa heroldi* Dunker var. *pygmœa* Dunker.
16. *Patella pallida* Gould.
17. *Dentalium weinkauffi* Dunker.
18. *Corbula venusta* Gould.
19. *Lucina borealis* Linné.
20. *Cardium modestum* Adams et Reeve.
21. *Anomia cytœum* Gray.
22. *Lima goliath* Smith.
23. *Lima smithi* Sowerby.
24. *Lima japonica* A. Adams.
25. *Pecten swiftii* Bernardi.
26. *Pecten yessoensis* Jay.
27. *Pecten vesiculosus* Dunker.
28. *Pecten similis* Lasky.
29. *Pecten irregularis* Sowerby.
30. *Pecten tigerrinus* Müller.
31. *Ostrea gigas* Thunberg.
32. *Arca kobeltiana* Pilsbry.
33. *Arca decussata* Sowerby.
34. *Arca stearnsii* Pilsbry.
35. *Limopsis crenata* A. Adams
36. *Leda ramsayi* Smith.
37. *Nucula insignis* Gould.

38. *Terebratulina crossei* Davidson.
39. *Terebratulina cailleti* Crosse.

I also found three forms which, if not quite identical with, are at least close to, living species. They are

40. *Sipho* cf. *gracilis* Da Costa.
41. *Natica* cf. *pallida* Broderip et Sowerby.
42. *Fissuridea* cf. *tanneri* Verrill.

The remaining twenty-nine species are those which are not yet known to be living, and belong to the genera *Conus*, *Pleurotoma*, *Drillia*, *Mangilia*, *Mitra*, *Trophon*, *Bittium*, *Trichotropis*, *Turritella*, *Solarium*, *Acrilla*, *Scala*, *Dentalium*, *Diplodonta*, *Lucina*, *Astarte*, *Cardita*, *Crassatella*, *Myodora*, *Pecten*, *Ostrea*, *Nemodon*, *Terebratulina*, etc. They amount to about 40% of the whole, and even when reduced by future discoveries, can hardly be imagined as falling below 20%. From this we may safely infer that the fauna can not be younger than the *Middle Pliocene*.

But it is not this high percentage of extinct forms which has struck me most. It is the decidedly boreal character of the entire fauna. The following species are those which point to it:—

1. *Admete viridula*.
2. *Chrysodomus phœniceus*.
3. *Chrysodomus pericochlion*.
4. *Sipho gracilis*.
5. *Trophon clathratus*.
6. *Priene oregonensis*.
7. *Natica clausa*.
8. *Natica pallida*.
9. *Leptothyra amussitata*.
10. *Puncturella conica*.
11. *Corbula venusta*.
12. *Pecten yessoensis*.
13. *Pecten swiftii*.
14. *Leda ramsayi*.
15. *Nucula insignis*.

Trophon clathratus and *Admete viridula* are well known circumboreal species. *Chrysodomus phœniceus* is now found on the coast

of British Columbia near 51° N. Lat. and at a depth of 240 fathoms where the temperature of the water is 7°C. *Puncturella conica* is now living only near the Falkland Islands. *Leda ramsayi* is found in New South Wales, but at a depth of 950 fathoms. Also all the others are now living north of Tokyo Bay, and the three species of *Lima* before mentioned, though existing near Central Japan, have never yet been met with in the shallow waters of the coast. Although the boreal forms together with these deep-water ones make up about one-half of the living species, there is not a single one which is limited to the warmer seas. Moreover, the occurrence of such genera as *Trichotropis* and *Astarte* among the new species clearly indicates that the temperature of the waters in which the Koshiba shells had lived must have been a pretty low one.

Now what makes this boreal character of the Koshiba fauna the more important is the less boreal nature of the *Mollusca*[1] of the upper Pliocene found in the immediate neighbourhood of Tokyo, at Oji, Shinagawa, Tabata, etc., which, when compared with the recent, are still boreal enough. From these facts, I am forced to conclude that the climate of Central Japan during the Pliocene Epoch was on the whole *colder than now*, and indeed, *colder in the earlier than in the later part of it*. This is quite in accordance with the conclusion already arrived at by Prof. Nathorst[2] from studying our Pliocene plants. This eminent palæobotanist recognized plants of the said epoch occurring in a rock exposed at the sea-coast near Yokohama and also at Mogi[3] as corresponding to those now growing on our higher mountains and not on the lowlands, as the situation of the fossils would naturally suggest; and although he does not touch the question of the rise of temperature in the course of the Pliocene, he advances the view that the Yokohama plants are probably upper Pliocene and are younger

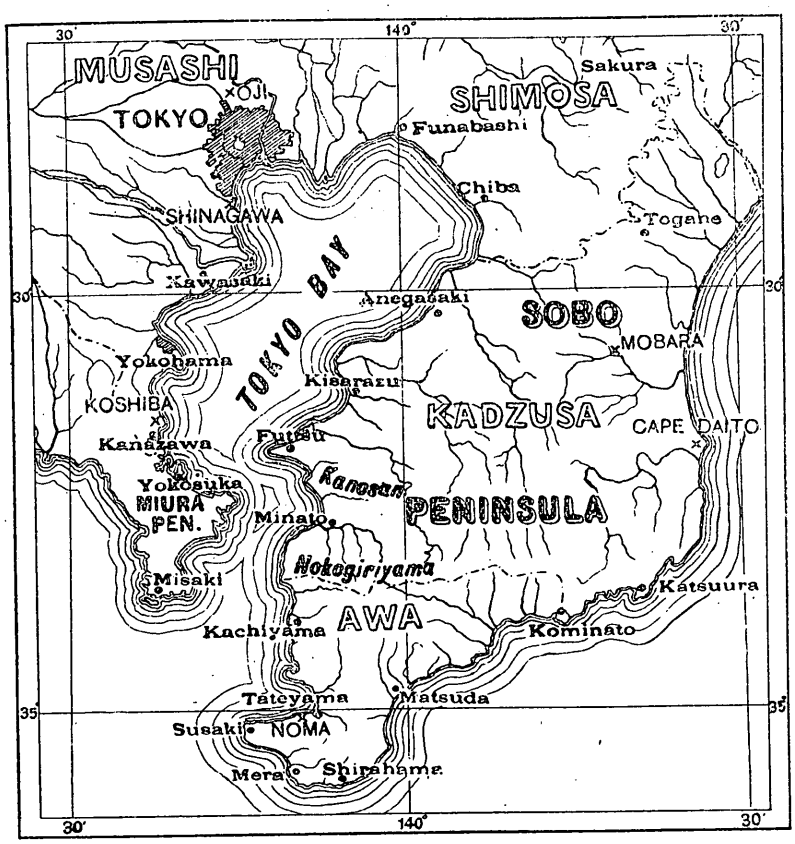
1) These fossils have been studied by Dr. Tokunaga and the results given in his "Fossils from the Environs of Tokyo," article 2, vol. XXI of this journal. Unfortunately he took them for Diluvial, probably led by the boreal nature of the fossils of the same age in Europe, which can not be, for they contain at least about 10% of extinct forms. Tokunaga himself describes more than 20% of extinct species.

2) Contribution à la flore fossile du Japon, 1883. Zur fossilen Flora Japans. 1888.

3) Near Nagasaki.

than those of Mogi, a view which can partly be proved both geologically and palæozoologically.

As soon as I became aware of the above stated increase of temperature, it occurred to me that the so-called *coral-bed* of Noma[1] in the southern part of the Sōbō Peninsula might belong to the succeeding Diluvial age. The bed is a muddy sand filling the valley-bottoms between the hills of the Pliocene rocks and not far from the sea. The fossils consist of large masses of corals mixed with shells and possess a very young looking aspect, on which account they were hitherto supposed—quite vaguely of course—to



be Prehistoric. But, as we do not find now such large corals in the neighbouring seas, no one could tell how they happened to be

1) Near the town of Tateyama in Awa; latitude 35° N. and Longitude 139° 50' E.

found there. Therefore I immediately took up the examination of the shells of the bed and was agreeably surprised to find them to be such as can only be interpreted as *Diluvial*, not younger, not older; for, although the thirty-five species[1] which I have been able to distinguish are all living, yet fourteen of them are now living only south of Kyushu—in the China Sea, in the Philippines and the tropical portions of the Pacific and Indian Oceans, etc. Such are

1. *Purpura alveolata* Reeve.
2. *Cuma rugosa* Born.
3. *Triton obscurus* Reeve.
4. *Cyprœa carneola* Linné.
5. *Trochus atropurpureus* Gould.
6. *Fissuridea rupellini* Sowerby.
7. *Cytherea tigrina* Lamarck.
8. *Venus lacerata* Hanley.
9. *Venus* cf. *jukesi* Deshayes.
10. *Chama multisquamosa* Gmelin.
11. *Cardita* cf. *gubernaculum* Reeve.
12. *Arca kraussi* Philippi.
13. *Arca fusca* Brugière.
14. *Perna marsupium* Lamarck.

Of the remaining twenty-one species, fourteen are those living in tropical as well as in Japanese seas, while only six are purely Japanese.

As to the corals which are found together with these shells, I have not yet been able to determine their species; but this much is certain that they are true reef-building corals belonging to such genera as *Heliastraea*, *Cyphastraea*, *Prionastraea*, *Mussa*, *Goniophora*, *Stylophora*, *Alveopora*, *Domoseris*, *Madrepora*, several genera of *Fungidæ*, etc., all which we do not find now living north of the Ryukyus (the northernmost is 28° 20′ N. Lat.) or of the Bonins (about 27° N. Lat.).

From this we see that we have here a layer which corresponds to the Diluvium of Europe. Just as the latter contains many forms which have since retreated to the north, the Noma

1) These will be described in a future number of this journal.

bed contains those which now inhabit tropical seas only. This is an unmistakable sign of the very warm climate which then prevailed in that part of Japan, much warmer than that of to day, for the sea near Noma now cools down to about 10°C, while the minimum temperature of the water in which the reef-corals live is 19°C. Indeed I am quite sure that while the Occident was buried under the heavy burden of ice millions of tons in weight, Central Japan was exposed to the heat of the tropical sun. Beyond in the West, one speaks of the *ice-age;* here in the Far East we can talk only of the *coralline.* Such being the case it is quite natural that geologists should have been unable to find any glacial remains in this part of the world.

It may perhaps be asked whether in Japan there are no beds which are the equivalents of the Interglacials and Postglacials of the West. I think there are. Several years ago I was passing by the town of Mobara in Kazusa situated on the Pacific side of the Sōbō Peninsula and much to the north-east of Noma, when I discovered a sand-layer exposed along the two sides of a stream flowing through a coastal plain at the foot of the Tertiary hills. In this layer I found about sixty species of marine Mollusca all living. Some of these are either tropical or are at least not yet known to exist in the neighbouring seas. Such are *Arca symmetrica* Reeve, *Tapes* cf. *quadriradiata* Deshayes, *Venus* cf. *listeri* Gray, *Eulima solida* Sowerby and *Subemarginula carinata* Reeve. I also examined shells brought from a sand-layer at Cape Daito, somewhat to the south-east of the above mentioned place, and found them to contain, besides one or two tropical forms, a species of *Turritella* which hitherto has been known to occur only in the Koshiba Pliocene. And as these layers contain no such large corals as those found at Noma, they must be considered to be deposits of a time or times in which the climate was much more temperate. This leads us to ask, if they are not *Intercoralline* or *Postcoralline.*[1]

From all that I have stated above, it follows quite naturally that the temperature in Central Japan has gradually increased

1) Similar shell-layers seem to occur also on the coast between Noma and Kachiyama.

since the earlier Pliocene, attaining its maximum in the Diluvial and then again decreasing down to the present time. This is, as every one can see, a state of things just the *reverse* of what we find in Europe and America, a singular contrast for which there must surely be a cause.

But before entering into the discussion of this cause, let us go back a little to the Miocene Epoch when Switzerland is said to have enjoyed a climate such as we find now in the southernmost cape of Kyushu (Sata-no-misaki in Osumi with a mean annual temperature of 18°C) and Amami-Oshima (the northenmost of the Ryukyu Islands with 20,8°C). The Japanese fauna of this epoch has not yet been fully studied, but we know something of its plants from the investigations of Nathorst.[1] This palaeobotanist found them to consist of a mixture of the European Miocene and of the so-called Arctic-Tertiary flora, indicating that the climate of Japan, at least between 35° and 40° N. Lat. in which the plants were collected, was not in the least warmer than now. This would naturally lead us to assume that a difference in climate had already at that time existed between Europe and Japan, but that this difference was not so marked as in later epochs. And I think this is quite in accordance with the already known fact that the further back we go into the past, the more uniform the climate becomes throughout the world.

About the Pre-Miocene Tertiary fossils of Japan we do not yet know much. And the few that I myself have lately described[2] are not enough to enable us to draw any conclusion as to the climate of those times.

The phenomena of Nature which have been already set forth as the probable causes of the climatic changes of the past, and especially of the ice-age, are partly astronomical and partly physical. Among the former we may mention the change in the eccentricity of the earth's orbit or in the obliquity of the ecliptic, the precession of the equinoxes, the displacement of the poles and the formation of the smaller planets. Among the latter we may count

1) Zur fossilen Flora Japans, 1888.
2) Some Tertiary Fossils from the Miike Coal-field; 1911.

the variation of the quantity of carbonic acid gas in the air due to the greater or less frequency of volcanic eruptions and the different distribution of land and water in past times.

Among these supposed causes, those which can be brought into connection with our Coralline Age are only three, viz., the displacement of the poles, the quantity of carbonic acid gas and the distribution of land and water; as for the others, if they were ever real causes, they must have been of a more general character, either affecting the whole earth at once, or at least one-half of it, the Northern or the Southern Hemisphere, and not one-half of the same hemisphere as in our case.

That carbonic acid gas is very effective in keeping the air warm by preventing the too rapid radiation of heat from the ground, is quite true. Therefore, if it is used in explaining the occurrence of our Coralline Age only, it seems to work very well; for we may assume that the volcanic eruptions were quite violent at that time, so many active volcanoes still exist in our country. But then, how can we explain the temperate climate of our Miocene and the cool climate of our Pliocene, when volcanic eruptions were at least equally as violent as in the later times? That such was the case, we know by the profuse occurrence of liparites and andesites and of their respective tuffs containing either Miocene or Pliocene fossils. Have we any evidence that the European Miocene and Pliocene were richer in volcanic eruptions than ours? Can any one prove that the quantity of carbonic acid gas has been increasing in Europe and decreasing in Japan since the Diluvial Epoch? I think this gas, if it ever be used to explain the change of climate in the past, can be more advantageously applied in the case of the Pre-Tertiary or at least the Pre-Miocene period, when the climate of the world was more uniform throughout.

The distribution of land and water also can hardly be said to give a more satisfactory explanation; for the Diluvial was a time in which the configuration of the land was not much different from the present. Looking at our Pacific side, the ocean itself must then have been long in existence, since it is a great

geosynclinal, as the geologists call it, whose formation is said to go back at least as far as the Mesozoic. Then the American and the Asiatic coast-regions, Japan, Formosa, the Philippines and even the greater part of the Ryukyu Islands were already in a form very nearly as we see them to-day. And if any one expects to find out any great change in the form of the land, it would be just at the head of the Tokyo Bay. This place is coloured in our geological maps as Diluvial which, if marine, would transform the Sōbō Peninsula at that time into an island. But what is here called Diluvial is a thick layer of subaerial loam evidently derived from a volcanic ash which had fallen on the preexisting land made up of Pliocene strata. From this we know that, in the Diluvial Epoch, the topography of the region surrounding the Tokyo Bay was not much different from what we see at present.

It is a well known fact that ocean-currents exercise a great modifying influence on the climate of a country near which they flow. And as the Kuroshio[1] flows just south of the Sōbō Peninsula, one might think that by a little change of its course, it might come to wash the shores of the Peninsula, thus raising the temperature of the water to a degree sufficient to fit it for the growth of the reef-corals. But such a change in the course of the current can never have been brought about without a marked change in the configuration of the surrounding countries. Those who look only on maps and are not well acquainted with actual meteorological conditions are easily misled by the proximity of the Kuroshio and over-estimate its warming power on our country. One must always bear in mind that in winter in Japan a cold wind sets in from the Asiatic continent either as a north wind or a north-west wind, which not only cools down the land to a temperature quite low in comparison with its latitude, but also prevents the warm air floating over the Kuroshio from ever approaching it and even causes the current itself to deviate a little to the south. Therefore the warming power of this current at this season is reduced to a

1) Kuroshio means black current or black salt-water, and not black salt as often translated in European books. This mistake is undoubtedly due to our shio 鹽 salt and shio 潮 salt-water being phonetically the same, though different in written characters. Another name for Kuroshio is Kurosegawa which signifies *dark rapid river*.

minimum, and if there is any influence from it, as Prof. Schott rightly remarks,[1] it would be on the Japan Sea side, where flows a branch stream along the coast whose influence, however, is of course much weaker and only limited to that side. As the result of this cooling power of the wind on the land, the waters of the immediate neighbourhood of the coast are also cooled down, often to about 10°C as has been already mentioned. Also we must not forget to mention that, except in midsummer, there is always a counter-current intervening between the coast and the Kuroshio which is taken by Schott for its backset, but which from its comparatively low temperature was formerly even thought to be a southern continuation of the cold *Kurile Current* which comes down at least to the north-eastern shores of Honshū. Under such circumstances it would be impossible to attribute a *specially warming* power to the current just for the Diluvial age. But supposing that we can do it for some reason or other, can we then attribute a great *cooling* power to the Gulf Stream which now exercises such a great influence on the climate of Western Europe, simply because there was an ice-age on that side of our Northern Hemisphere? It goes without saying that such an arbitrary way of explaining things is of no value at all in science.

Accordingly only one cause remains, viz., the displacement of the poles or, as it may perhaps better be expressed, a change in the position of the earth's axis. This is, I believe, the most plausible explanation in a case like ours.

Neumayr[2] in 1887 and Nathorst[3] in 1888 already attempted to explain the curious geographical distribution of the Arctic-Tertiary flora of the Miocene period by this change of the earth's axis. The plants of this flora which betray a rather temperate climate of 8°—10°C in the yearly average, a climate roughly corresponding to that of our Southern Hokkaido, were found in Grinell Land (81° 45′ N.L.), Greenland (70° N.L.), Spitzbergen ($77\frac{1}{2}$ and $77\frac{2}{3}$ N.L.), the Lower Lena (65° N.L.), the Lower Amoor

1) Oberflächen-Temperaturen und Strömungen der ostasiatischen Gewässer, p. 45.
2) Erdgeschichte II. p. 511.
3) Zur Fossilen Flora Japans, p. 53.

(Bureja), Sakhalin (51° N.L.), Kamtchatka, Alaska, etc., forming so to say a wreath around the present North Pole, but far nearer to it on the Atlantic side than on the Pacific. Neumayr wished to bring the pole ten degrees nearer to the Asiatic side on the meridian of Ferro, while Nathorst increased the displacement to twenty degrees on the meridian of 120° E. long., which would bring the position of the supposed North Pole in the lower region of the Olenek just west of the Lower Lena. Nathorst also sought to account for the smallness of the leaves of the fossil plants found at Lena by the proximity of the pole and the temperate character of our Miocene plants, which according to him contain not a single element which points to a climate warmer than the present. But Neumayr in the second edition of his Erdgeschichte[1] seems to be inclined to renounce his former assumption, because of the discovery of ordinary Arctic-Tertiary plants in one of the New Siberian Islands which are not far off from the supposed North Pole of Nathorst.

Now, if I may be allowed to express my own opinion on the above subject, I would say that it is not at all necessary to fix the position of the pole so as to make it as equidistant as possible from the various fossil localities. It may as well be taken as lying more to the east, nearer to a meridian passing through the Bering Strait. In saying this, however, I am by no means trying to establish the position of the Miocene pole. On the contrary, I think it is very difficult to locate this, because the distribution of land and water was then very different from what it is to-day. Furthermore, other factors which determined the geographical distribution of plants at that time are utterly unknown to us. Therefore I simply say that the North Pole may have been then in a different position from now, but that the data, now at our disposal, are too scanty to justfy us even in guessing at it.

The case becomes different in the succeeding ages. Here the climatic contrasts in the East and the West are very strong, and always in such a way that when it is cold on one side it is warm

1) Vol. II, p. 385. 1895.

on the other, and vice versa. This, I think, can only be explained by the movement of the poles to and fro. We may assume that during the earlier Pliocene, the North Pole was more to the Asiatic side. Then it began to move to the Atlantic side until the Diluvial, when that side fell into ice-age and the Asiatic side into coralline age; after that it may be taken as having made a backward movement, that is to say, back again to the Asiatic side. So far as I know, this mode of explanation meets with no serious objection. Therefore, if theories are made to explain a phenomenon whose cause is unknown, and if, among these theories, the one which explains it in the easiest and most unconstrained way is the most plausible, then *the movement of the poles to and fro* must be regarded as the most plausible explanation of the climatic changes of the Northern Hemisphere since the Pliocene Epoch.

It is a singular coincidence that Prof. Simroth of Leipsic, led by a peculiar geographical distribution of the organisms in the present creation, had already tried to explain it also by the so-called "Theory of the Oscillation of the Poles," first propounded by Reibisch to account for the displacement of the beach-line. In this theory,[1] the North and South Poles are made to swing to and fro on the meridian of 10° E.L. which corresponds to 170° W.L. on the Pacific side, a line just passing through the Bering Strait. This meridian has been called by Reibisch the *circle of oscillation*. Now Simroth had recognized a more or less symmetrical distribution of similar or vicarious forms either east or west of this circle or, if under the same circle, north and south of the equator. The first is called by Simroth the *transversal symmetry*, and is said to be caused by the organisms diverting to the east or the west as the quickest means of evasion of the approach of a pole or of the equator. The second is called by him *meridial symmetry*, and is thought to be caused by organisms on the approach of the equator, climbing up high mountains on which they can wander south and even cross the equator beyond which they can again come down to the low-land, where the climate is suited for their existence. As

1) Simroth. Die Pendulationstheorie, 1907.

examples of the transversal symmetry he mentions, among others, the occurrence of the *giant salamander* in Japan and of *Menopoma* in the United States, of the genus *Alligator* in China and America, of *Ceratodus* in Queensland and of *Lepidosiren* in South America, etc. Of course it is not my object here to reproduce all the details given by Simroth in his book. I only mention them to show how this eminent naturalist was led to assume the movement of the poles from the distribution of recent organisms, just as I have been led by that of the fossils.

Lastly, it may perhaps be asked: If the poles ever moved, in what position were they during the Japanese Coralline Age? To such a question, I can only say that I have found only enough evidence to suggest the movement of the poles and no more. I even doubt if palaeontologists will ever be able to establish the position of the poles in the past by simply studying the fossils. Therefore, let it suffice for me to say that during our Coralline Age, the poles were in such a position as to cause the sun to shine on the Sōbō Peninsula with about the same intensity as it now shines at least on the Ryukyus or the Bonin Islands.

CLIMATIC CHANGES IN JAPAN SINCE THE PLIOCENE EPOCH.

PLATE I.

Explanation of the Plate (I).

Some of the Noma Fossils.

Fig. 1. Heliastræa sp. $^1/_5$ nat. size.

Fig. 2. Do. A fragment in natural size.

Fig. 3. Madrepora sp. A fragment.

Fig. 4. Perna marsupium Lam. (Tropical species).

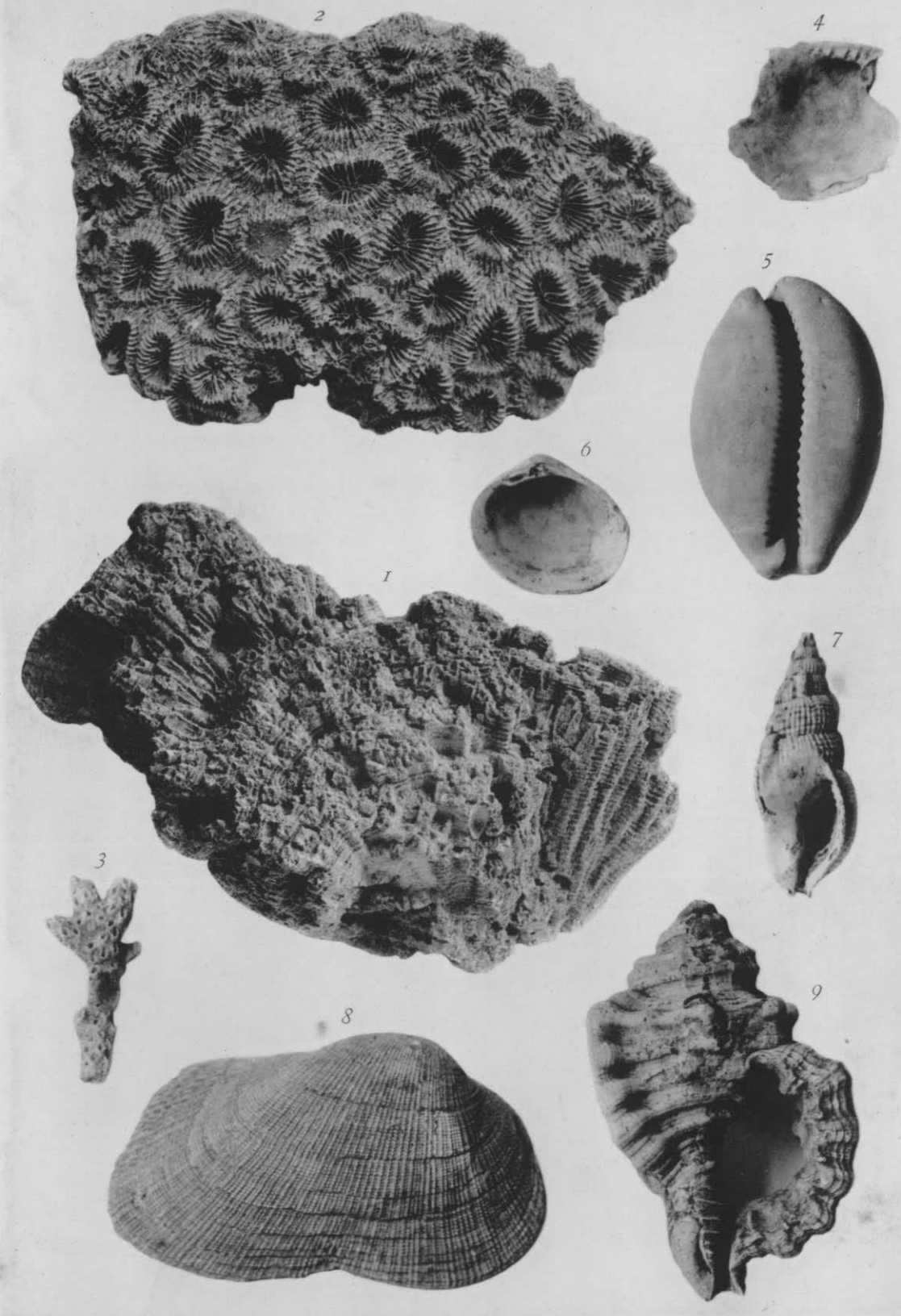
Fig. 5. Cypræa carneola Linné. (Tropical species).

Fig. 6. Cytherea tigrina Lam. (Tropical species).

Fig. 7. Triton obscurus Rve. (Tropical species).

Fig. 8. Arca fusca Brug. (Tropical species).

Fig. 9. Triton costatus Born. (Tropical and Japanese species).



M. Yokoyama: Noma Fossils.