SOME PROBLEMS OF ARCTIC GEOLOGY.[1]

II. FORMER ARCTIC CLIMATES.

IN a summary of the geological history of the Arctic Ocean (*ante*, p. 301) it was remarked that in Silurian times the water was warmer than it is at the present day; and there is no doubt that the climate of the Arctic regions has varied greatly. According to the belief generally accepted there have been periods when the climate of the northern hemisphere was so severe that an ice sheet extended from Ireland to Siberia, from the Thames Valley to the North Pole; and then at other times, as the whole earth enjoyed the doubtful benefits of a tropical climate, Greenland's now icy mountains were bordered by a coral strand. This view of the great variation of Arctic temperature has been so widely held that it has exercised a very great influence on theories of faunal migrations and on the former climates of the world. The volumes which summarise the results of the *Challenger* expedition show to what an extent some of the latest speculations as to climatic change have been influenced by this theory; for in that work Dr. Murray strongly advocates Blandet's suggestion that in late Palæozoic times there was "over the whole globe an almost complete equality in the distribution of light and heat" due to the "very much greater size of the sun in the early stages of the earth's history." And this bigger Palæozoic sun was assumed in order to explain the fact that "the Arctic Ocean was a coral sea in Carboniferous times."

Let us, therefore, briefly consider how far the evidence of Arctic geology supports the statements that have been based upon it in this respect. The theory that the Arctic regions once enjoyed a tropical climate was first advanced on the evidence of some fossil plant beds, of which the most famous occur in Disco Island and neighbouring parts of the coast of Greenland. The fossil plants from these beds were described by Heer, whose conclusions have been summarised by Lyell as follows:—"In this rich flora considerably more than half are trees, which is the more remarkable since trees do not exist in any part of Greenland even 10° further south. More than fifty species of Coniferæ have been found with species of Thujopsis and Salisburia now peculiar to Japan. There are also beeches, oaks, planes, poplars, maples, walnuts, limes, and even a magnolia. Among the shrubs were many evergreens, as *Andromeda* and two extinct genera, *Daphnogene* and *M'Clintockia*, with fine leathery leaves; together with hazel, blackthorn, holly, logwood and hawthorn. *Potamogeton*, *Sparganium* and *Menyanthes* grew in the swamps; while ivy and vines twined around the forest trees, and broad-leaved ferns grew beneath their shade. Such a vigorous growth of trees within 12° of the pole, where now a dwarf willow and a few herbaceous plants form the only vegetation, and where the ground is covered with almost perpetual snow and ice, is truly remarkable."

These statements were so positively made and so fascinatingly sensational, that they have been repeated in every text-book, while the protests against them have been generally ignored. Protests, however, have been often made. The first botanist to visit the Disco plant beds was the late Dr. Robert Brown; and as the result of his investigations he wrote—"I must protest against the way in which Prof. Heer has been making species and genera out of these fossils with a recklessness regardless of consequences." Mr. Starkie Gardner checked a long series of Heer's determinations, and declared them valueless; he remarked that Heer's conclusions were "based upon specimens too fragmentary to be of any value, and belong to types of leaves which are so universal that they would, even if perfect, fall into the undeterminable residuum of a fossil flora." He concluded that at least half of these genera and species of Heer's must be suppressed.

Prof. Nathorst, in whose care Heer's type specimens are now resting, is fortunately undertaking a careful revision of the evidence, and he is as emphatic as Brown and Gardner regarding the unsatisfactory nature of Heer's identifications.

The most important point in this reduction of Heer's species, is that it is the plants which are most indicative of the tropical conditions, such as the palms, which have to be abandoned. That many big-leaved plants grew in areas which now support only an insignificant growth of saxifrages and crucifers, is undeniable; and the leaves in question often present resemblances to those of trees, such as the plane, maple and lime. But palæobotanists now distrust the evidence of leaves alone, which are, moreover, especially untrustworthy in the Arctic regions. If a specimen of a Norwegian shrub that has grown at Tromsö be compared with a specimen of the same species that has grown at Christiania, the former will be seen to have less wood but larger leaves. The continual daylight in the summer has a very stimulating effect on leaf production, and the leaves are larger and fleshier than they would be if once a day their growth were stopped by night.

Concluded from page 303.

But it may be said, this will not explain the occurrence of the great tree stems which are found in association with the Arctic coal seams and leaf beds. It was mainly to explain the growth of these tree trunks that Sir John Evans introduced his well-known theory of the shifting of the pole; for at one time it was held that an annual exposure for three months to continuous darkness would have been quite inhibitory to the growth of trees. Botanists, however, now tell us that in a cold climate the winter's darkness would be an advantage to vegetation instead of a fatal objection; and the darkness is actually secured artificially in the gardens of St. Petersburg as a protection to trees. Trees even now do grow beyond the Arctic Circle, and the darkness is no absolute bar to their having ranged many degrees further north. That pines and other conifers did so in the past is proved both by the mode of occurrence of the fossils and by the histological structure of the wood. But that all the trees found buried in the rocks of Spitsbergen and Greenland grew where they now occur is by no means so certain. It is probable that most of them have been carried to their present latitude as drift wood. The famous Forest Bed at Cromer was so named in the belief that it was the site of an old forest; but it is now regarded as an estuarine deposit, formed at some distance from the place where the trees that occur in it grew. Similarly, the description given by Brainerd of the petrified forest found in the north of Greenland by the Greeley expedition is as consistent with the view that the tree trunks were drifted as that they grew *in situ*. In the case of the Disco leaf beds we fortunately have the opinion of a trained botanist, the late Robert Brown. He examined the plant beds especially in reference to this point, and he tells us that not "in any instance did I find the leaves in conjunction with or attached to the stem, by which I could positively say that these were the leaves of the tree to which the stem belonged, or that the stem was brought there, or was in any way connected with the same natural or physical causes which influenced the leaves." Brown quotes, and apparently approves, Steenstrup's remarks, "perhaps they [the leaves] were blown by the wind to their present locality." So Brown saw no evidence that the West Greenland plant beds mark the site of ancient forests.

The quantity of drift wood cast upon the Arctic shores is enormous. Many raised beaches are strewn with pine and larch logs, to which the roots are often attached and are buried in the mud. Mosses and sedges, willows and saxifrages grow upon the beach; their remains, together with wind-borne material, may gradually fill up the spaces between the tree trunks, and the whole may be buried by rainwash from cliffs above the beach, or by tide-borne sand should the beach again sink below sea-level. Under such circumstances an impure coal seam would be formed; and a future geologist might easily be deceived by the numerous tree trunks, and the rich leaf remains, into the belief that at the era of its formation the locality had supported a forest growth, which could not now be paralleled less than 20° further south.

Most of the Arctic drift wood consists of logs of pine and larch from the Siberian forests; but blocks of mahogany from Central America sometimes occur, and West Indian beans are not uncommon. Hence the occasional presence of tree stems of tropical types may easily be explained without assuming any great change of climate. But the action of ocean currents is not the only factor that may have complicated the evidence of these northern plant beds. Many limitations are necessary in the application of fossils to the elucidation of former climates. Genera that once lived in cold regions may now be restricted to the tropics owing to a change in habit; and plants that were once world-wide in distribution may now survive only in a few especially favourable localities. Thus in the Carboniferous period the most abundant ferns belonged to the order Marattiaceæ, of which there are twenty-seven living species; twenty-two of these occur in the torrid zone, three in the south temperate zone, two in the north temperate zone, and there are none in the frigid zone. This does not prove that, wherever Marattiaceæ are found in carboniferous rocks, the climate was

torrid; it only illustrates the fact that the order was a primitive type once very widely spread throughout the world, and now restricted by the competition of more specialised types. Therefore the occurrence in the Cretaceous rocks of Greenland of the tree-fern *Dicksonia*, which, although it still lives in New Zealand, is said to be most characteristic of the tropical parts of Northern Queensland, is no proof that the Arctic regions had a tropical climate. And it would not be so, even if Sir J. D. Hooker had not warned us, that ferns are the least trustworthy witnesses as to climatic conditions.

Hence an examination of the evidence of the fossil plants of the Arctic regions leads to three conclusions: (1) that, as current opinion rests on Heer's determination of fossil palms and tropical leaves which cannot now be supported, the changes of climate have been greatly exaggerated; (2) that without a complete revision of Heer's work, such as is now being carried out by Prof. Nathorst, the exact extent of the climatic changes cannot be estimated; (3) that the conclusions based on the belief that three months' darkness would be fatal to the growth of trees, cannot be maintained, while most of the fossil tree trunks in question have probably been brought as drift wood from the south.

The fossil faunas of the Arctic regions have been held to demonstrate climatic changes no less enormous than do the fossil floras. The most striking proofs quoted were the asserted occurrence of fossil coral reefs in the Silurian and Carboniferous rocks of various parts of the Arctic area, notably Bank's Land, Grinnell Land, Spitsbergen, and the New Siberian Islands. It is, perhaps, the best-known fact in the science of geographical distribution that coral polypes cannot build coral reefs in water of a lower temperature than 68° F. If, therefore, coral reefs formed by madreporarian corals do occur in the Arctic regions, this would be conclusive evidence of a great change in the temperature of the northern ocean. Let us take the case of the corals of Grinnell Land, of which specimens were brought home by Colonel Feilden, and determined by Mr. Etheridge. The collection included eleven species; of these six were simple corals, one was a simply branching, another was a cluster of simple corals, and the remaining three species, although compound, occurred in small nodules. Of corals in the condition of reef builders, there are none in the collection. Simple corals live in the Arctic ocean at the present day, while compound corals as large as the specimens from Grinnell Land are found far outside the range of existing coral reefs, and at far greater depths. The collection from Grinnell Land gives no proof that coral reefs were ever formed there. We have only to compare the few insignificant species from that region, with the massive corals that lived at the same time in English seas, to realise that there was almost as great a difference between the temperature of the sea in the two areas in Silurian times as there is to-day. Baron von Tol's list of Anthozoa from the Silurian rocks of the New Siberian Islands also includes eleven species; but of these only three are true Madreporaria. Compound Hydrozoa and Alcyonaria have a greater range than the reef-building Madreporaria, both in latitude and depth. Hence, in arguing from the distribution of the fossil corals, we must eliminate all except Madreporaria; and the moment we apply this rule to the New Siberian coral reefs, we lose all but a few small Madreporaria, which certainly cannot be described as forming reefs.

If limestones as full of corals as the Silurian rocks of Wenlock Edge, or some of the beds in the Carboniferous series at Clifton, be ever found north of 80° N. lat., they will no doubt prove that at the time of their formation the Arctic Ocean was a coral sea. But the evidence so far seems insufficient. That the northern seas had a warmer temperature at some parts of the Palæozoic era than at present is not denied. It is proved by the occurrence of coral reefs in various parts of Europe and America; and in places massive corals grew as far north as the Arctic Circle, as in the Timan Mountains, and sometimes even a few degrees beyond, as in Bank's Land. But the northern coral faunas are poorer than those of temperate Europe, and as we go nearer the pole, they become so stunted that they ceased to form reefs.

The corals alone, therefore, are insufficient to prove the universality of a tropical climate in early geological times, and it is advisable to consider the evidence of the fossil faunas as a whole. Arctic marine faunas are known from six of the geological systems—the Silurian, Devonian, Carboniferous (including Permian), Triassic, Jurassic and Cretaceous. The six faunas are characterised by the following general features: –

(1) They are often rich in individuals, but poor in species.

(2) Crustacea, trilobites, zoophytes, and other animals with chitinous exo-skeletons are proportionately common and often large in size.

(3) Compound corals are scarce, and occur in nodules instead of in reef-forming masses.

(4) Sea-urchins and sea-lilies are extremely scarce—in fact, barely represented.

(5) There is a striking poverty in new or special types.

But these are, in the main, the characteristics of the existing Arctic fauna; and it is difficult to compare the Arctic fauna of any one period with that which then lived in southern Europe, without concluding that all through geological time the northern faunas have lived under the blight of Arctic barrenness.

This reminds us of the question of the shifting of the position of the pole, which was proposed as a help to palæontologists in explaining the former Arctic faunas and floras. But the facts seem explicable without the aid of this hypothesis. Neumayr has published a map of the probable climatic zones in the Jurassic period, which appear to have been as parallel to the equator then as they are now. In Tertiary times the evidence of the fossil plants seems to show the same; for, from whatever direction we approach the pole, the fossil floras become sparser and more boreal in aspect, as we may see by a comparison of the plants of Disco Island and Grinnell Land, of the Great Slave Lake and Prince Patrick Land, of Iceland and Spitsbergen, and of Saghalien and New Siberia.

Hence the palæontological evidence, instead of demanding the shifting of the pole, seems to be opposed to this theory, and to show that, in all the periods for which palæontological evidence is available, the pole stood near its present position. Palæontological evidence, moreover, when freed from sensational exaggeration, shows that the variations in the climate of the Arctic region have not been so extreme as have been assumed, and thus it greatly simplifies the discussion of the causes of the changes that have occurred. The size of the Palæozoic sun was increased to warm the Arctic Ocean up to the temperature of a coral sea; the pole was shifted to remove the fatal spell of Arctic night, and clothe parts of the polar lands in subtropical forests. When Lyell proposed to explain the climatic variations by alterations in the position of land and water, he called upon his theory to account for the alternation of a vast polar ice-cap with tropical conditions. Such results could not be explained by the geographical theory, which accordingly fell into disrepute.

But if we call upon that theory to explain changes for which there is valid evidence, it is not improbable that it may not suffice. A different distribution of land and sea, a greater or less elevation of the mountain ranges, a deflection of the ocean currents, the reduction of the ice-covered sea, and the meteorological changes that would be thus produced may, as Lyell thought, be quite sufficient to account for all the climatic variations which the facts of Arctic geology require.

J. W. GREGORY.

THE IRON AND STEEL INSTITUTE.

THE annual summer meeting of the Iron and Steel Institute was held last week at Cardiff. The President this year is Mr. E. P. Martin, who is at the head of the executive of the great Dowlais Iron Works; and it was appropriate, therefore, that the meeting should be held in the commercial metropolis of Wales. The meeting was in every respect most successful, though certainly it fell off somewhat from a technical point of view; but that, after all, was largely due to the weather, it being too hot to sit in a lecture theatre and discuss details of iron and steel manufacture. An unusually large number of members attended, and many of them were accompanied by ladies.

On the members assembling on Tuesday morning, the 3rd inst., they were welcomed by the Mayor of Cardiff, after which Mr. Martin took the chair, and other formal business having been transacted, Mr. Thomas Wrightson's paper, "On the Application of Travelling Belts to the Shipment of Coal," was read. In this he described a new method of placing coal into a ship, expeditiously and without breaking it. The latter is a very important point, as small coal or dust is worth very little; and the old-fashioned method of shooting coal from a staith direct into the hold of a vessel, leads to the formation of a great deal of small coal. The apparatus Mr. Wrightson has designed,