3. KNOWN FACTS AND UNKNOWN PROBLEMS OF ARCTIC GEOLOGY.

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Before entering into the more immediate subject which I have the pleasure of bringing before you to-night, it may be well to take a rapid glance over the means by which our knowledge of the Arctic Regions was obtained, and the causes which led to another expedition being considered necessary for the advancement of science. The British Government have despatched no less than six scientific expeditions to explore the North Polar area within the last century, 1773-1845, which on the sad and untimely fate of the last under Sir John Franklin, were followed by fourteen Government and private expeditions devoted to search alone, but which, nevertheless, brought back large additions to our knowledge of the geography and geology of the Arctic area. On the solution of the fate of Sir John Franklin and his brave companions, in 1859, Great Britain withdrew from the task of Arctic research, and the efforts that were made to reach the pole, from time to time, were carried out by other nations. The American expeditions were all made by way of Smith Sound, or the head of Baffin's Bay. The *Polaris*, commanded by Captain Hall—a small river steamer, with a crew of only twenty-five men—passed up the strait to the north, a distance of two hundred and fifty miles, in one season, and her boats' crews succeeded in reaching latitude $82^{\circ}16'$ N. In the winter quarters of the Expedition, in $81^{\circ}38'$, the climate was milder than further south, and animal life abounded, including musk oxen.

The German expedition, following the directions of the Continental geographers, attacked the Pole from the eastern side of Greenland, reaching the latitude of $77^{\circ}0'$ —or but little beyond that attained by the present Sir Edward Sabine in 1823. Formidable ice-barriers on the 80th parallel repelled the Swedish expeditions, made on the northern side of Spitzbergen and Nova Zembla; while the Austrian expedition, which left Norway in 1872, managed to travel on the ice in sledges as far as longitude 82° , and observed continuous land as far north as 83° , but were obliged to abandon their vessel in the ice-barrier of the 80th parallel; but none of the expeditions from Spitzbergen, though carried out with so much determination, skill, and labour, managed

to reach so high a latitude as Parry, in his sledge and boat journey from Spitzbergen, in 1827.

It is worthy of note that the first expedition to the Arctic Regions, dispatched rather more than a century since, was organized at the request of the Royal Society, who urged upon the First Lord of the Admiralty, Lord Sandwich, the service the discovery of the North Polar Area would be to the promotion of natural knowledge. At this time the entire Arctic Zone was a blank on the maps, with the exception of a few outlines of Baffin's Bay and a part of Spitzbergen, to which Captain Phipps, afterwards Lord Mulgrave, was dispatched, and in which expedition Lord Nelson served as a midshipman.

In 1818 the Royal Society, prompted by Sir Joseph Banks and Sir John Barrow, impressed on the Government the necessity of further investigation, and the expeditions led by Franklin, Parry, Back, John and James Ross, Sabine, Buchan, Beechey, and Lyons, were the result. Notwithstanding the large number of persons employed in these numerous expeditions, no loss of life occurred over the whole fifteen years. After the discovery of the precise position of the Magnetic Pole by Sir James Ross, in 1831-33, Arctic exploration paused.

In 1845 the Royal Society again urged the necessity of further knowledge of the Polar area, and Sir John Franklin was dispatched in charge of the last scientific expedition sent by Britain to the Arctic Regions, until that which left our shores last year in May.

GLACIAL PHENOMENA.

The western coast of Greenland is guarded by a circle of bare bleak islets two thousand feet in height, separated from each other by fjords, through which passes the drainage of the enormous *mer de glace*, which covers the country to an unknown depth, and conceals the rocks beneath—the *inlands iis* of the Danes, which abruptly terminates in steep cliffs—*sermik soak* (ice-wall) of the Esquimaux—three thousand feet in height, where deep glens and fjords penetrate the country.

The surface of the ice field is described by all observers as exhibiting a marked "escaladed structure," as it was termed by Dr. Kant, the ice rising towards the snow shed in a series of steps; but the general effect of the scene appears to closely resemble that of sailing out to sea, for though Professor Nordenskjöld found the

ice thirty miles inland to rise to a height of three thousand feet, yet the slope is so imperceptible that in travelling inland the land appears to be left behind, and an interminable ocean of ice encountered. In summer the surface of ice melts to a certain extent, and rivers of ice-cold waters flow over the inland-ice, and fall into crevasses of unknown depth, which are exceedingly numerous, and increase in size and number the further inland the observer has advanced.

Dr. Rink believes that only two inches of the Greenland precipitation of snow and rain reaches the sea in the form of glacier ice, while he estimates the total precipitation at twelve inches; or that evaporation being exceedingly small, nearly ten inches must be carried off by sub-glacial rivers. It is needless to point out the important influence these sub-glacial streams must have on the underlying clay deposits, the *moraine profonde* or *couche de boue* of Agassiz, the result of the trituration of the rocks over which the ice passes. The crevasses descend to a depth of probably not less than two thousand feet; and into one of these chasms, with vertical walls of blue ice, Professor Nordenskjöld and Dr. Berggren found magnificent rivers precipitating themselves and disappearing, at a height of two thousand two hundred feet above the sea, and in a locality thirty miles inland from the coast, in lat. $68^{\circ}22'$ N. It was on the surface of the ice of this area that the observers noticed the grey sandy trachytic mineral *Kryokonite*, associated with a brown polycellular algæ, the dark masses of which absorbing the sun's rays cause the ice to melt and form the deep holes which traverse the surface.

The height of the rock surface of Greenland beneath the ice is exceedingly problematical, but that it is much lower than the circles of islands which fringe the coasts and form a barrier to the inland ice is certain. The Danish settlements are situated on these islands, and on the narrow strip of land between them and the ice-wall, where fjords or valleys intersect the country, the ice pours over and makes its way to the sea as distinct glaciers; the seaward channel generally becomes choked up with the immense quantity of fine material brought down by the sub-glacial streams, flowing out beneath the ice. In most cases the glacier extends far out into the water channel, terminating in the "iis-blink" (ice-glance) of the Danes, from the face of which bergs break off, and plough their way seaward through the drift deposits choking up

the channel. Further north, in Melville Bay, Sutherland describes the ice as forming a continuous wall seventy to eighty miles in length and 1200 to 1500 feet high, of which about an eighth is above the water level, the Esquimaux halibut fishers requiring three hundred fathoms of line to reach the bottom of the face of the ice. In lat. 68°, near Claushavn, where valleys come down to the coast, the ice is not less than 2,000 feet in thickness, and the bergs of great size. Still further north, however, beyond Cape York, the glaciers are smaller, the air not being so charged with watery vapour from the Atlantic.

The specific gravity of the sea-water of Davis Straits, according to Scoresby, is 1.0263, freezing at $28\frac{1}{2}^{\circ}\text{F}$., when the salt, 5 $\frac{1}{2}$ oz. to the gallon, is precipitated, and the "bay-ice" of the whalers formed: this eventually becomes a floe, which, uniting with others, forms "pack-ice." In summer the ice near the sides of a channel melts first, and the strip left intervening constitutes the "middle ice" of the whaler; the left, between the open water and the land, which hangs and clings to the cliffs, forms the "iis-fod" (ice-foot) of the Greenland Danes, which receives large quantities of landslips and other *débris*, which, when the ice breaks up, are carried seaward, on the bottom of which they deposit their stoney freight.

Terraces of Glacial Drift were found by Karr and Hayes at various heights from 32 to 110 feet above the high tide, along the whole coast of Greenland and Smith's Sound. Hollows, also, extending as high as 500 feet above the sea were filled with this clay, which, in some cases, formed banks overlooking the glaciers. The clay contains, in some places, Echinodermata, Crustacea, and Mollusca, of living local Arctic species, with the exception of two—*Glycimeris siliqua* and *Panopæa Norvegica*. In nodules of this clay occur the well-known impressions of the angmaksætt (*Mallotus Arcticus*, O. Fabr.), a fish still living in Davis Straits. Examples of these nodules may be seen in the British Museum split longitudinally; their great density is noticeable from their great analogy to the fossil-bearing ironstone nodules of the Coal Measures.

The icebergs of Davis Straits are described as covered with rocks and boulders, often weighing one hundred tons each, frozen into their mass. Where the bottom of the sea is hard, and the depth shallow, the berg is brought to a stand; and even when the

sea bottom consists of soft glacial clay the result is often the same, and a talus is pushed up. These submarine banks constantly increase in size, from the clustering of small bergs upon them, and form the haunt of shoals of cod and halibut and myriads of sharks. In Melville Bay Dr. Brown describes the bergs as reaping immense crops of *Laminaria*, torn from a depth of one hundred fathoms with their seaweed and broken shells of *Mya* and *Saxicava*, which may be thus transported by currents long distances, and these littoral shells deposited in deep water.

No more remarkable fact was, I think, brought back by the officers of the *Polaris*, than the occurrence of erratic fragments, derived from Fiskernaes, in South Greenland, in the Glacial Drift overlying the Upper Silurian limestone as far north as $81^{\circ}30'$ N. and forming the coast north of the Humboldt Glacier, indicating a distinct drift from south to north. It is also worthy of note, that a large number of freshwater lakes were noticed, inhabited by *marine* Crustacea, indicating a comparatively modern upheaval of this tract thirty feet above the sea level.

A great number of observers have recorded the decided evidence of a subsidence now going on on the west coast of Greenland. Arctander, in 1777, noticed that land in a firth, called Igalliko ($60^{\circ}49'$), was submerged at spring tides, though walls five feet in thickness still remained; half a century later the tract was entirely submerged. Houses built in 1721, at the time of Egede, the Apostle of Greenland, have now the sea flowing into them at high tide.

From an early date the peculiar discolouration of portions of the Arctic sea has been commented on by the navigators and whalers who traversed the frozen ocean. Henry Hudson, in 1607, believed that the sea was blue or green, according to whether ice was present or absent. Scoresby considered that the discoloured water formed one-fourth of the surface of the Greenland Sea, between the parallels 74° and 80° north latitude. He describes the appearance as occurring in long bands lying north and south, and varying in dimension. "Sometimes the transition between the *grass-green* water (with a shade of black) and the *blue* is progressive, passing through the intermediate in the space of three or four leagues; in others, it is so sudden that the line of separation is seen like the rippling of a current." Dr. Robert Brown, to whom it was reserved to discover the cause of this discolouration,

noticed that a vessel in the space of a few hours, sails through alternate patches of deep black, green, and cerulean blue; while in the upper reaches of Davis Straits and Baffin's Bay one hundred miles may be traversed with one uninterrupted space of the latter colour. Scoresby believed immense numbers of *Medusæ* caused the discolouration of the water, and afforded the food of the countless "right whales" which frequented the "black water." Dr. Brown, however, found that on several cold days, the *Medusæ*, both large and small, sunk, and yet the water retained its usual colour, and being microscopically examined, was invariably swarming with *Diatomaceous* life, the large proportion of which belonged to a beautiful siliceous moniliform diatom, which is described by Dr. Oberg as having the appearance of a minute beaded necklace, about $\frac{1}{400}$ th part of an inch in diameter, with articulations containing a brownish-green granular matter, which gives the colour to the plant, and again to the sea, in which it grows so abundantly. The swarms of diatoms found at the surface of the Greenland seas, in Davis Straits, Baffin's Bay, and in Spitzbergen, do not appear to live in water of any great depth, for even in samples brought up from two hundred fathoms no traces of them were found.

In June, 1861, Dr. Brown noticed that the long brown streaks on the ice, of the breaking up floes, were due to the presence of the same siliceous moniliform diatom, which he found to mainly contribute to the food of the whale; for on examining the alimentary canal of these animals, microscopically, he found the contents to consist of these *Diatomaceæ*, which give the sable hue to the Arctic seas, and also afford food for the smaller Mollusca and Echinodermata. The long slimey bands, resembling the fronds of *Laminariæ*, found by the early whalers, immediately under the ice, were found by Dr. Sutherland to be masses of diatoms, which Dr. Brown describes as filling the cavities which honeycomb the surface of the gigantic floes, and, by generating a certain amount of heat, convert them into cavernous sheets, the "rotten ice" of northern navigators.

Dr. Brown records some interesting observations on the effect of the lowering of the surface-temperature of the sea on the presence of animal and *Diatomaceous* life. On the evening of the 4th of June a pint measure of Entomostraca, Pteropoda, and *Medusæ*, was collected in the towing net in a few minutes, with a tempera-

ture of 32.5° ; the next morning, in the same position, no ice to be seen, the same air temperature, but that of the sea sunk to 27.5° , no trace of organic life was left.*

The food of the northern whale is *Olio borealis* and *Cetochilus septentrionalis*, which feed on the diatom which stains the northern seas black, and which is found most plentifully during the calm Arctic nights, during which the greater number of whales are taken whilst seeking the "whales' food."

PALÆOZOIC ROCKS.

Dr. Karl Vrba examined microscopically more than 200 rocks, from South Greenland, brought home by Prof. G. C. Laube, the Geologist attached to the second German North Polar Expedition; they consisted of hornblende and zircon granites, gneiss, eurite, syenite, orthoclase porphyry, diorite, diabase, gabbro, weichstein, and serpentine.

Professor Laube in his Map of the Geology of South Greenland, represents the granite and gneiss as also extending along the East Coast as far as 61° N. These crystalline rocks continue along the whole coast of Western Greenland, from these the Greenlanders derive the steatite, from which they make their lamps, and other utensils. The only exception in the continuity of the gneiss and crystalline rocks, in the coast section of West Greenland and its islands, is the projecting peninsula of Noursoak and the Island of Disco, where sedimentary coal-bearing beds of Cretaceous and Miocene age occur in the hollows and old valleys of the gneiss, from which tinstone, magnetic pyrites, and other minerals have been obtained in Disco. Graphite is also reported in a fine-grained granite, with grey quartz, and felspar of a watery lustre, with garnets.

Should it be proved, that the Gneissic and Granitic Rocks of Greenland are of Laurentian age, it would appear that this tract had been more extensively denuded before the Cretaceous epoch than the Arctic Archipelago,—where the Laurentians are overlaid by the Upper Silurian, Devonian, and Carboniferous rocks and the Lias.

The remarkable fluoride of sodium and aluminium—*Cryolite*—is peculiar to the west coast of Greenland, with the exception of Miask in Siberia. The veins of it occurring at Evigtok, 12 miles

* "Journal of a Voyager," &c., 1852, Vol. i.

from Arksut, were discovered, through weights of this material used in the fishery for capelins, cod, and Arctic salmon (the lodde of the Norwegians), being sent to Copenhagen by Danish missionaries at the beginning of the century. The white cryolite vein is 80 feet in width, and has been worked by Mr. Taylor, F.G.S., fifteen feet from the surface the cryolite was of a dark colour, so that it is probable that the other vein of black cryolite is merely less decomposed. The Greenlanders value the white variety most, which they pound with tobacco leaves, and use the product as snuff. Cryolite is used in Denmark for the manufacture of soda, by mixing it with lime and applying heat; the fluoride is sent to Paris to be used in glass etching. Its use as a source of aluminium, discovered by Mr. Dick in 1856, has since been abandoned in favour of bauxite. The white cryolite vein dips south, with the planes of the gneiss in which it occurs; near the higher portion of the vein, a large quantity of galena occurred, which was worked in 1854, giving 45 ozs. of silver to the ton of ore.

Crystalline rocks form the entire west coast of Baffin's Bay and Davis Straits, from Cumberland Sound to Lancaster Sound, with the exception of Cape Durban, where coal-beds occur, which may possibly be a continuation of those of Disco.

Granite, gneiss with garnets, greenstone and mica schist, were brought home by Ross, from Waigatt Island, the Three Islands of Baffin ($74^{\circ} 1' N.$ lat., $57^{\circ} 28' W.$ long.); Cape Melville, Bushman Isle ($36^{\circ} 4' N.$ lat., $65^{\circ} 66' W.$ long.); between Cape York and Cape Dudley Digges, including the Crimson Cliffs; and from Agnes Monument ($70^{\circ} 37' N.$ lat., and $67^{\circ} 30' W.$ long.). A large number of specimens were brought home by Capt. John Ross* in 1819, from Davis Straits and Baffin's Bay, and determined by Dr. J. Mac Culloch, who describes the gneiss with green compact felspar, pyrites and garnet occurring at Possession Bay and Cape Byam Martin ($73^{\circ} 33' N.$ lat., $77^{\circ} 28' W.$ long.), as being exactly "similar to that which occurs abundantly in the Western Isles, and more particularly on the western coast of Ross-shire, prevailing particularly about Loch Ewe and Loch Greinord," rocks which have since been determined to be Laurentian.

The Granitic and Crystalline Rocks of the Hudson's Bay Territory, described by Sir John Richardson, were believed by Sir Roderick Murchison to be referable to the Laurentian System, and

*"Ross's Voyage of Discovery," &c., 2nd, 1819. 8vo. Vol. ii.

he points out that the rocks which overlie these in the northern parts of this territory, are characterized by the prevalence of Upper Silurian corals of the Niagara and Onondaga Limestone group, the equivalents of our Wenlock and Dudley. From the occurrence of *Encrinurus punctatus*, and the shell *Pentamerus oblongus*, and the absence of any Lower Silurian rocks or fossils in the whole of the known Polar regions, Sir Roderick inferred that the whole district north of the Laurentian mountains was dry land during the Lower Silurian period. In the area to the south, and in the European Lower Silurians, the sea was evidently not deep, and even in Upper Silurian times the depth was not very great, as evidenced by the presence of *Pentamerus*, which in North America is borne out by Sir William Logan's discovery that the Silurian limestones of Lake Temiscamang include enormous blocks of sandstone, on which they rest.

Dr. Conybeare appears to have been the first, in his Report on Geology to the British Association, 1832, to have noticed the similarity of the fossils from the Arctic Regions to those of the English Upper Silurian series. Mr. Salter, after a minute examination of the specimens brought back by the various expeditions, found that though many species found at Wenlock, Dudley, and in Gothland, occur in the Arctic Regions, the facies of the forms is rather American than European.

From the rocks and fossils brought from the Arctic Archipelago by Sir Leopold M'Clintock, and placed in the Museum of the Royal Dublin Society, Dr. Haughton was enabled to draw up a geological map of the group of islands, which I have taken as the basis of that exhibited this evening.

Silurian limestones occupy the south of North Devon, and nearly all the islands south of Melville and Lancaster Sounds, including the south of Banks' Land, Prince Albert's Land, Prince of Wales' Land, King William's Island, North Somerset, Boothia Felix, &c. The limestones of Boothia are chalky, and without fossils; those of Prince of Wales' Land are fossiliferous, and overlaid by bright red ferruginous limestone, interbedded with bright red sandstone, resembling those of Transition Valley in North Somerset. The base of the Silurian in the latter district consists of red sandstone and coarse grit (resembling those of Cape Warrender and Wolstenholme Sound), overlaid by ferruginous limestones with quartz grains, pale-cream-coloured limestones

dipping 5° to the N.N.W., forming the terraced arrangement so characteristic of all limestone districts, the effect of weathering on soft shales and hard limestone being well shown in Parry's "First Voyage," where a sketch is given of Port Leopold, by Beechey.

Dr. Hayes obtained 13 species of fossils from the cliffs of Lady Franklin Bay, and Cape Frazer in Grinnel Land, in lat. $81^{\circ} 35' N.$, long. $70^{\circ} W.$, which were identified by Prof. Meek as Upper Silurian species belonging to the fauna found in the New York Catskill Shaley Limestone, of the Lower Helderberg group. Some of the species, however, were new to science, as *Zaphrentis Haysii*, Meek, and *Loxonema Kanei*, Meek.

One of the most northern promontories of Grinnel Land is named after the late Sir Roderick Murchison, who, commenting on the collections brought from the Arctic Archipelago by Parry, Franklin, Ross, Back, Austin, Ommaney, the expeditions sent by Lady Franklin, particularly those of Penny and Inglefield, and by the expedition under Sir E. Belcher, endorses the results arrived at by Mr. Salter, that the species exhibited have an American rather than an European facies. These Upper Silurians of Grinnel Land appear to continue across Hall Basin to Hall Land, from which Dr. Emil Bessels, the Naturalist of the American Polaris Expedition under the late Captain Hall, and who had previously served in the Prussian Polar Expedition, collected a number of fossils.*

At Dundas Island, in lat $76^{\circ} 15'$ one of Capt. Penny's crew found a Silurian trilobite and preserved it, tied in his shirt, when the boat had to be abandoned, and a retreat effected. The presence of Silurian rocks at a point so far north, and of sandstones at Wolstenholme Sound, appears to render it probable that the E.N.E. strike of the Carboniferous strata, with the overlying Liassic patches, is cut off eastward, and the Silurian rocks surround them in a basin-like form, an E.N.E. synclinal running through Prince Patrick Island towards Hayes Sound. Detailed examination of the West Coast of Smith Sound and Kennedy Channel will have great geological interest, as it will prove whether such a synclinal exists, and if so, whether the Carboniferous rocks are brought in by it, and whether the Lower Coal-bearing measures are present on both sides of it, and in what manner they rest on the Silurians of Grinnel Land.

* For calling my attention to these observations, I have to thank Captain Feilden, R.A., Naturalist of the senior ship of the British Arctic Expedition.

The Upper Silurian rocks of Banks' Land are overlain by close-grained sandstone, striking N.E. and E.N.E., with their coal seams. These were first discovered by Parry in the group of islands named after him; the fossils from this series are similar to those of the Irish Calp series and the Eifel, and forms the "Ursa Stage" of Heer. The sandstones are close-grained and white, and with their associated coals strike across Melville Island, and Bathurst Island, where they were noticed by Austin and Belcher. On the south-east corner of Melville Island several seams occur, the coal burns with a bright flame and much smoke, resembling some of the gas coals of Scotland.

On the beach of North Cornwall, Belcher found granite pebbles of a kind, Dr. Haughton states, not occurring in any other part of the Arctic Regions; and inland he observed ravines consisting of sandstone with large masses of clay-ironstone, septaria, and lumps of coal. Considering that this land is on the strike of the limestones of the Carboniferous age of Prince Patrick Island, the northern portions of Melville Island, Bathurst Island, and Grinnel Land, and North Devon, and that Exmouth Island, in Belcher Channel, consists of limestone dipping, capped with Lias, it appears probable that the sandstones of the Ursa Stage of the southern portions of the islands just mentioned, are of similar age to those of North Cornwall, but separated from them by a synclinal depression filled with Carboniferous Limestone, with an axis ranging E.S.E. and W.N.W., of older date than the deposition of the Lias.

Dark ferruginous shales, clay-ironstone and coal were also brought from Buckingham Island (Victoria Archipelago), by Sir Edward Belcher, and Dr. Haughton states they closely resemble those from Liddon Gulf, on the west side of Melville Island, which would appear to place the position of the axis between this island and Exmouth Island, or about 10° north of west.

In Ohio a transition between the Devonian and Carboniferous floras takes place, but in Eastern America the Lower Carboniferous Coal Measures (Calcareous Sandstone of Scotland), lie unconformably on the Devonian.

From an examination of the fossils from the rock exposures of the Mackenzie River, between Clearwater River and the Arctic Ocean, Prof. Meek has determined these rocks to be of Devonian age, and to correspond to the Hamilton formation and Genesee slate of the United States. From the Mackenzie slates many

new corals and brachiopods were obtained, also a cephalopod, *Gyoceras Logani*, collected by the late Mr. R. Kennicott. The slates contain brine springs and petroleum, and it is believed that they extend from Rock Island, Illinois, to the Arctic Sea, a distance of 2500 geographical miles, with identical fossils throughout the whole of the tract, proving a uniformity of conditions in these old Palæozoic times prevailing over a very large area.

It appears exceedingly probable that the coal-bearing beds of the Arctic Archipelago are a continuation of these rocks, and are referable to the "Ursa Stage" of Heer, who believes that this stage is referable to the Lower Carboniferous age, from the fact that not a single species of the Upper Devonian *Cypris*-shales of Saalfeld in Thuringia, exists in the Bear Island flora, which is characterized by *Calamites radiatus*, *Lepidodendron Veltheimianum*, *Knorria acicularis*, and *Stigmaria ficoides*, all of which are found in the Yellow Sandstone of Kiltorkan, and should the latter prove to be of Lower Carboniferous age, considering the persistence of freshwater genera, the occurrence of the Old Red Sandstone of Scotland genera of fish in the Kiltorkan beds is not remarkable. Should, however, fish and plant remains be found in the strata overlying the Upper Silurians of the Arctic unknown regions, their specific determination or that of the associated forms, may be expected to throw much light on the vexed question of the exact position of the line of demarcation between Devonian and Carboniferous. The presence of *Knorria acicularis* in the Melville Island flora, is a link between the flora of the South of Ireland and that of Bear Island, and the latter is undoubtedly an outlier of the Lower Carboniferous coal tract of Russia. Looking to the fact that the rocks yield the first rich flora of the earth's history, and to the number of species which can be traced both in the old world and in the new, from 47° to 74° and 76° north lat., there is evidence of wide-spread continental conditions, occupying much of the temperate, as well as the Arctic zone, over which continent ran large rivers, tenanted by freshwater mussels (*Anodonta*), and neuroporous insects.

From the plants and specimens collected by Professors Nordenskjöld and Malmgren, in Bear Island, the following classification of the rocks of the island has been established:—

MILLSTONE GRIT.—Siliceous schists.

MOUNTAIN LIMESTONE.—*Productus*-limestone, *Spirifer*-limestone with gypsum, resting on *Cyathophyllum*-bearing limestone, with dolerite, possibly the equivalent of the Carboniferous Shale of South Ireland.

URSA STAGE of O. Heer.—Sandstones with shale and coal-seams. All the beds contain coal-seams.

DEVONIAN.—Russian Island Limestone, red shale.

The "Ursa Stage" Prof. Heer correlates with the Kiltorkan beds in Ireland, the Greywacke of the Vosges and Southern Black Forest, and the *Spirifera Verneulei* shales of Aix, and the sandstones of the Arctic Archipelago. This stage he regards as Lower Carboniferous, the base of which he considers to be beneath the Yellow Sandstone; but Sir Charles Lyell, from the fact that these sandstones at Durn Den, in Fife, and in the County Cork, contain the exclusively Devonian fish *Asterolepis* or *Glyptolepis*, believe these deposits to be Devonian, which opinion Mr. Carruthers also expressed in regard to the plants of the Irish and Bear Island deposits.

The subsidence which brought in the deposition of the Mountain Limestone, and the existence of extensive coral reefs equally affected the Arctic Zone, and these formations are well represented in the islands of the archipelago, Spitzbergen, and Bear Island. In the latter, the continental conditions expressed by the European Millstone Grit, are represented by the schists, during this period many Ursa-stage plants still lived on in Europe, proving that islands existed covered with the old flora throughout the whole of the time occupied by the deposition of the Mountain Limestone.

It is clear that the climate of these Arctic regions must have been far warmer than at present, even if the darkness of the long winter nights was the same as now, for Prof. Heer has pointed out that the leaves of the evergreen tree *Lepidodendron*, and the large fronds of *Cardiopteris frondosa*, are as fully developed as those from the South of Ireland and the Vosges.

The hard red sandstone of Igalliko and of the fjord of Tun-nudleorbik, discovered by Dr. Pingel, the geologist attached to the Danish Expedition of 1828, in lat. 61° N. in South-west Greenland, is believed to be of Devonian age, the rock consists of fused quartz particles. This is probably the same bed as that observed in the last-mentioned locality, by Prof. G. C. Laube, the geologist attached to the second German North Polar Expedition, who describes the red sandstone as associated with *Amphibolite*, and a

large area of hornblendic granite, with a narrow belt of zircon granite intervening between it and the sea.

The first discovery of Lias fossils in these high latitudes, was that by Lieut. Anjou, of the Russian Navy, in New Siberia, on the north coast of Asia, in 74° N. lat., described by Wrangel. The fact appears to have remained unnoticed until Belcher's discovery of a patch of Lias on Exmouth Island (77° N. lat., and 95° W. long.). The base of this island is soft sandstone, overlaid by Carboniferous Limestone, dipping west at 7° , containing *Zaphrentis*, *Spirifer Keilhavii*. Resting on this, at a height of 570 feet above the sea, occurs the Lias, in which Belcher discovered the ribs and vertebrae of an *Ichtyosaurus*, stated by Prof. Owen to be near to *Ichtyosaurus acutus* of the Whitby Lias. From this island, and from Table and Princess Islands, between North Cornwall and North Devon, and from Dépôt Point, on the north coast of the latter a large number of other Lias fossils were obtained by Sir Edward Belcher in 1855, which were described by Mr. Salter.

Another remarkably fossiliferous patch, resting on Carboniferous Limestone, has since been discovered at Point Wilkie, in Prince Patrick's Island. Lias resting on Carboniferous Limestone with ferruginous and siliceous grits also occurs at Eglinton Island, between Prince Patrick's and Melville Island. A large number of Lias fossils have been brought to England by Sir Leopold M'Clintock and the late Admiral Sherard Osborne, including *Ammonite Maclintockii*, of Haughton. Point Wilkie (Prince Patrick's Land, $76^{\circ} 20'$ N. lat., $117^{\circ} 20'$ W. long.), consists of Carboniferous limestones and sandstones, with bands of chert, believed by M'Clintock to be of the same age as those of Melville Island, for at Point Wilkie these are overlaid by reddish limestone with casts of shells, amongst which Dr. Haughton determined *Ammonites Maclintockii*, *Monotis septentrionalis*, and other Liassic forms.

In East Greenland occur Jurassic marls and sandstones on the east and south side of Kuhn Island. Calcareous sandstones, with organic remains, are found on the south coast of False Bay; the sandstones are coarse and alternate with shell-breccias with coal-seams,—the whole series rest on the Crystalline rocks, which form a high ridge with glaciers. The finer-grained Jurassic sandstones contain casts of *Goniomya v-scripta* (Sow.), *Ostrea*, *Myacites* sp., and are possibly the equivalents of the carbonaceous Jurassics of

Brown, Mull, and Sky—"Middle Dogger" (?). In the sandstones of the southern coast of False Bay occurred a *Rhynchonella* perfectly agreeing with *Rhynchonella fissicostata*, Suess, a characteristic Rhætian form; the brown-coal occurred associated with these rocks.*

It is remarkable that the Jurassics on the east coast of Kuhn Islands contain a fauna very nearly allied to the Russian Jurassics, containing the characteristic genus *Aucella*, which is frequent in all the Russian Jurassics, from the Lower Volga to the mouth of Petschora, and is represented in Spitzbergen by the species *A. Mosquensis*. The western limit of this genus is the east coast of Kuhn Island, where five varieties of *A. concentrica* are connected by intermediate forms. Other fossils occurring here are *Ammonites perisphinctes*, Payeri (a very highly involute form), *Belemnites Panderianus*, D'Orb., *B. absolutus*, Fisch., and a *Cyprina*.

In Spitzbergen, Professor Nordenskiöld has described a series of rocks 1500 feet in thickness as being of Triassic age: they consist of black bituminous shale, stratified hyperite limestone, bone beds, and sandstones. The analogy of these deposits to the European Rhætic and Lias is at once apparent, and is borne out by the occurrence in these rocks of *Ichthyosaurus polaris*, Hulke, *Ichth. Nordenskiöldii*, Hulke, and *Hybodus Spitzbergensis*, named and described by Mr. J. W. Hulke, F.R.S., and still further supported by the association of these reptiles and fishes with ammonites. Over these rocks occur another 1200 feet of Jurassic deposits, consisting of shales, limestones, and sandstones, giving at Mount Agardh the thickness named.

The *Atane*, or Upper Greenland Cretaceous beds of Nordenskiöld, occur on the southern side of the Noursoak peninsula, between Atanekerdluk and Atane. Dicotyledonous leaves occur, one being very near to the species *Magnolia alternans*, Heer, from the Upper Cretaceous of Nebraska: these do not occur in the lower or Kome strata, and appear to point to a "limit fauna" occurring in the Arctic Cretaceous beds, corresponding to that found in the European Gault, in which dicotyledonous plants make their first appearance in Europe. To the *Atane* beds belong the thick coal of Atane, 750 feet above the sea, the Ritenberg coal of Kudliset, and the retinite beds of Hare Island.

* Zweiter Band, Wissenschaftliche Eryebnisse. Zweite Abtheilung. Leipzig, 1874.

Three analyses of the coals from Disco are recorded, but whether of Cretaceous or Miocene age I do not know. No. 1 is by Professor Fyfe, of Aberdeen; No. 2, by Mr. Keates, of London; and No. 3, by Professor H. Wurtz, from a specimen brought by the U.S. steamer Juniata, in 1873:—

	I.	II.	III.
Gaseous or volatile matter ...	44.45	50.60	35.38
Moisture	.75	...	14.00
Sulphur.....	.55	...	trace.
Coke { Fixed Carbon	47.75	37.86	41.79
{ Ash	5.50	9.54	8.33
	<hr/> 100.00	<hr/> 100.00	<hr/> 100.00
Specific Gravity	1.369	1.384	

The coke is non-caking and useless.

The basalts, ferruginous clays, sandstones, and brown-coal of Disco Island were first described by Sir Charles Giesecke, F.R.S., in the "Transactions of the Royal Society of Edinburgh" for 1874. The later researches of Professor Nordenskjöld and Dr. Brown have conclusively proved these basalts to be all of Miocene age, and deposited, according to Nordenskjöld, in the form of volcanic ash and sand, since consolidated by pressure, which has caused the rock to assume a crystalline structure. Associated with the basalts are thick beds of clay, which at Atanekrdluk, at a height of 1000 to 1200 feet above the sea, yield a vast number of plant impressions. The strike of the strata corresponds to the direction of Waigat, across which it extends to Disco Island, where it forms the east coast as far as Godhavn, consisting of sand-hills 2000 to 3000 feet in height, with their horizontal bands of coal, and erect bitumenized trees. No coals of economic value appear to occur in these Lower Miocenes, which rest directly on coal-bearing Atane strata; above these plant-bearing Lower Miocene clays and soft sandstones occur several thousand feet of basalt, on which rest the higher coal-bearing strata of Ifsorisok and Assakak of Middle Miocene age, the coals cropping over on the tops of the high fells.

Professor Nordenskjöld found the Greenland meteorites, spread over an area of two hundred square miles in the south-west corner of Disco, to occur both in areas occupied by granite and gneiss, and that consisting of basalt, which latter he found to often contain fragments of the meteorites, which must have fallen, or

been forced into cracks, before the basalt tuff was consolidated, and must, therefore, have taken place during Miocene times. The large meteorite in the British Museum from this locality weighs about 87 kilogrammes, while the largest observed by Nordenskjöld probably weighed no less than 21,000 kilogrammes.

Nauckhoff analysed ten rocks from Ovifak, and found the basalt to be of a compact greyish-green colour, composed of felspar (anorthite) penetrating magnetite, augite, and iron, the mass containing 49·18 per cent. of silicic acid. Tschermak describes the augite as of a light green tint, and as filling in spaces between other materials, the felspar crystals being transparent, and filled with some transparent substance; and he compares the Ovifak rocks, with the meteorites of Juvinas, St. Petersburg, and Stannera. Dr. Flight, who quotes these authors, further compares them with the old augite and anorthite lavas of Java, Iceland, and the Eifel.

Amongst the specimens brought from Baffin's Bay by Captain Ross were several implements, or flat stones, composed of porphyritic greenstone, used by the natives of the Arctic Highlands in cutting off masses of iron from a mountain called "Sowallick," twenty-five miles inland from Cape York, lat. $76^{\circ}12'N.$, long. $53^{\circ}W.$ This iron Dr. Wollaston estimated to contain between 3 and 4 per cent. of nickel, and Mr. Fyfe found in it 2·56 per cent., from which they believed it to be of meteoric origin. It occurred to Captain, now Sir Edward Sabine, that these masses of iron were of meteoric origin, and knives made of it, given to Sir Joseph Banks, were examined by Mr. Brande, and found to be free from rust, and to have the peculiar silvery appearance of meteoric iron and to contain more than 3 per cent. of nickel.

Prof. Nordenskjöld comments on the complete agreement between the character of the basalt from West Greenland and the British Isles, and the certainty of the identity of the geological age of the two, and suggests that a continuous tract of this formation, extends across Greenland to the cliffs on the east coast, from which Scoresby obtained his plant impression, and from which the last German Expedition brought back basalts and Miocene plants coeval with those of Disco, thence by way of Jan Mayen to Spitzbergen, and from Jan Mayen by the Faroe Islands to the Hebrides and Ireland; and also suggests that this line marks a volcanic mountain chain, which limited the Miocene Polar Continent, in

the way that similar chains now fringe the western coast of America, and the eastern coasts of Asia.

The observations of Lieut. Julius Payer and Dr. Copeland in East Greenland, and the report on the specimens brought by them from that coast between lat. 73° and 76° N., and reported on by Dr. Fr. Toula, is of great interest as bearing on this question. Crystalline rocks, sometimes associated with fine-grained gneiss, constitutes the greater part of the coast and the inland mountains observed. The coast is cut back into deep fjords extending far inland, at the mouth of which are a group of islands, some of which, as Shannon Island, are of volcanic origin, while in others various Mesozoic and Tertiary formations are associated with the crystalline rocks, or rather rest upon them.

The Basalts extend along a line ranging N.E. to S.W., beginning on Shannon, and continuing through Sabine and Pendulum Islands—the protruding peninsula between False Bay and the Tyrol Fjord, the eastern side of Clavering Island and Jackson Island, as far as the coast between this island and Capes Broer Ruys and Franklin. The basalts are both of the dolerite and anamesite (genuine peridotite) groups of these rocks, and occasionally basalt tuffs occur, with zeolites and double refractive calcite. The basalt is described by Payer, as forming immense plateaux capping the hills; it will be noted that a prolongation of the direction of these basalts across Greenland, emerges on the west coast, precisely where the basalts of Disco are found.

The Miocene Beds exist at the base of the crystalline ridge from the south end of Hochstetter's Foreland to the south of Cape Seebach, rising to a height of 300 to 500 feet. Overlying the rocks of the Ursa Stage of Spitzbergen, are the Miocene Beds, which have yielded so rich a fauna and flora to the various expeditions which have visited them. At King's Bay a lime (*Tilia walmnemi*), a juniper, and an arborvita (*Thuites Ehrenswaerdi*) occur—many of the species occur in West Greenland—and two of them were found by Lieut. Payer, in the fossiliferous marls of the Germania Mountains in Sabine Island, East Greenland, viz., *Saxodium distichum*, and *Populus Arctica*. It is worthy of note, that at the present time, firs and poplars grow in an area 15° further north than plane trees; so that assuming the former to have reached their northern limit in Spitzbergen, in lat. 79° , the latter may have grown provided there was land, as far north as the Pole.

Lieut. Payer states that the newly discovered Frantz-Joseph Land equals Spitzbergen in extent, consisting of several great masses of land, separated by Austria Sound. Broad horizontal sheets of dolerite, identical with that of North-East Greenland, form steep table mountains. The rocks in the north are coarse-grained, and contain nepheline; those in the south are appanitic in their structure, and pass into true basalt, the mountains here being about 5000 feet high, while those in the north only attain 2000 to 3000 feet. Tertiary sandstone, with brown-coal, occurs, so probably the basalts may be of Miocene age. The depressions between the mountains are filled with gigantic glaciers, which form mural precipices on the coast 100 to 200 feet in height; the glaciers were found to be characterized by their greenish-blue colour, the paucity of crevasses, the coarse grain of the ice, slow motion, thickness of annual layers, and the small development of moraines. Geographers of Petermann's school, believe the abrupt mountainous coast of East Greenland trends away to the north-east, north of Parry's furthest point of Spitzbergen, and a writer in the "Academy" (Sept., 1874), has suggested that in Franz-Joseph Land may be the eastern termination of this coast-line.

The Miocene of Spitzbergen and Franz-Joseph Land extended probably across the Polar tract itself, for on the banks of the Mackenzie, we find Miocene plants and coals, described by Sir John Richardson as associated with potter's clay and sandstones, while on the north coast of Siberia, the so-called Wood Hills, discovered by Sirowatskoi, in 1806, are stated by Wrangel to consist of horizontal beds of sandstone, alternating with vertical trunks of bituminized trees, forming a hill 180 feet in height. Amongst the proofs of the former continuity of Miocene land, is the fact of the occurrence in Greenland of the Japanese genera *Glyptostrobus* and *Thujaopsis*, while east *T. Europæus* occurs in Europe, both in the Baltic amber, and at Armissan (Narbonne); associated with it are American forms, which Prof. Göppert has pointed out, are species which are found associated with the amber pines of the tract now under the south-east corner of the Baltic.

In the Upper Miocene beds of Œningen, North American types still live, amongst them is a vine, four palms of the American type, and conifers *Sequoia* and *Taxodium*. The palms, both of the European and American type, and other exotic forms, are found to be absent in the Miocenes of the northern area, proving that the climate

became cooler in advancing northwards, as at the present time; for through the enormous expanse of continental land, the climate was much more equable than at present. There is, therefore, no reason to believe, from the absence of these plants, and of bones of long-armed apes present in the Miocene of Central Europe, that the Lower Miocene is absent in the Arctic zone; and from the determination by Prof. Heer, of Cretaceous forms in the Greenland deposits, it is probable that the continental conditions expressed by the Miocene of Europe and India, had commenced in these Polar regions as early as Cretaceous times. Should further discoveries of freshwater Cretaceous and Miocene deposits, lying in the hollows of the older rocks, be found in the northern lands visited by the British Arctic Expedition, it will be of great interest to see how far southern species die out in advancing to the present Pole, and what minimum of cold the surviving species appear to indicate.

The Esquimaux inhabitants of the coasts of Arctic America, from Behring's Straits to Greenland, speak the same language and use similar implements. There is no more interesting passage in Prof. Dawkins' work "Cave Hunting" than that in which he compares the identity of type of those implements with those from Dordogne and other parts of France and Belgium, both as regards fowling and fishing spears, darts and arrows. Their likeness extends to the actual shape of the base of insertion into the haft, the haft being formed of mammoth-ivory, derived from the frozen cliffs, of the very species that was hunted by paleolithic man in the south of France. These two peoples, separated so widely in time and space, were alike in their artistic feelings and methods of incising on tusks, antlers and bones, representations of familiar objects; alike also in their habits of splitting bones for marrow, and accumulating them around their dwellings, in their disregard for the sepulchre of their dead, in their preparation of skins for clothing, and in the pattern of the needles used in sewing them together; alike also in their feeding on the musk sheep and the reindeer, and in countless other characteristics. It is well-nigh impossible to resist Prof. Dawkins' conclusion that the Esquimaux is the descendant of palæolithic man, who retreated northwards with the Arctic fauna, with which he lived in Europe; though before the close of the Glacial Epoch it is probable that a continuous land connection existed between France and North America, by way of

Siberia ; remains of the true horse having been discovered associated with *Bison priscus*, and the mammoth in Arctic America, and representations of the horse, by a palæolithic artist, occurring on an antler from La Madelaine, and the entire skeleton of a horse from a palæolithic station being preserved in the Lyons Museum.

VISIT TO THE MINERALOGICAL DEPARTMENT OF THE BRITISH MUSEUM.

MARCH 18TH, 1876.

Director—PROFESSOR N. S. MASKELYNE, F.R.S.

DEMONSTRATION ON THE FELDSPARS AND MICAS.

(*Report by* W. H. HUDLESTON, Esq., M.A., F.G.S.)

The Feldspars are prominent in granitic districts, such as those of the Land's End, where prisms and square masses of orthoclase, or potash feldspar, are especially to be noted. In their crystallography, which the learned Professor declared to be the bane of chemists, although there are many points of contrast between orthoclase and the anorthic feldspars, they possess one feature in common, viz., an easy cleavage in one direction—the basal cleavage. The second system of cleavage is less perfect and presents fewer features in common, but taken altogether there is a certain correspondence with respect to cleavage and general form, though one individual feldspar belongs to the oblique, the rest to the anorthic system. Usually these two different systems are not comparable, but in extraordinary cases we may compare them, as practically some of the angles of the oblique are near to those of the anorthic feldspars. Thus in the oblique (orthoclase or potash) feldspar the angle between the easy and the second cleavage is a right angle, or 90° ; whereas in the anorthic feldspars it is only $86\frac{1}{2}^\circ$: the prism angle, on the other hand, was shown in orthoclase, belonging to the oblique system, to be about 118° , and that of albite, belonging to the anorthic system to be about 122° . Still the two belong to essentially different orders of symmetry, and what was here shown of albite will apply to all the other anorthic feldspars.

As regards twinning, or multiplication of the crystal, the feldspars are acted upon in accordance with a certain law. In orthoclase a crystal may be divided symmetrically, and repeated, being turned round a certain line, as it were, completely through