centre of the earth, the first external contact occurred on December 6, at 15h. 47·8m. Greenwich mean time, at 35° from the north point of the sun's disc towards E. for direct image, and the last external contact at 18h. 26·8m. about 4° towards W. At Paris the final contact took place at 18h. 50·3m. local mean time, but the sun did not rise till 19h. 39m.; the planet therefore had left his disc less than fifty minutes before he was on the horizon of Paris.

ARCTIC GEOLOGY*

IV.

Vardö Island,† at the end of a long promontory in the polar basin, is described by Mr. Campbell, of Islay,‡ as consisting of metamorphic slates, dipping at 45°, and striking with the hollows and ridges north and south, ground into shape by ice, but since submerged and wave-worn; drifts packed and rolled by the sea are left in a grass-grown raised beach at 60 feet, a peat-covered beach at 100 feet, and rolled stones occur on the summit level of the island, 220 feet above the sea, resting on red sandstones, with fossil markings in concentric rings. At 30 feet above the sea occurred a "storm beach," with large and sub-angular stones, sweeping in a crescent round the bay, the fortress of Vardö, and the church of Vadsö. He describes it as built on coral sand, and refers to the warm equatorial current affecting the climate in the polar basin to lat. 80° in Spitzbergen, and to long. 66° E. in Novaya Zemlya, which enables a luxuriant vegetation to live on the shore at Yeredik, about 70° N., in spite of the winter's darkness.

The most northern island of Novaya Zemlya has been called Castanjenö by Capt. Mack, from the "Mimosa beans" or chestnuts found there, which tropical brown nuts in Spitzbergen reach 20° E.;§ but Mr. Lamont considers the large quantities of drift wood found on that coast to be derived from pines (*Abies excelsa*) that have grown on the banks of the large Siberian rivers;‖ and states that when wood occurs inland it is associated with bones of whales. He therefore does not agree with Lord Dufferin that it is brought to Spitzbergen by the Gulf Stream,¶ which Mr. Lamont states has no influence north and east of Black Point and the Thousand Isles, even during June, July, and August, while during the winter months ice-laden currents sweep round Spitzbergen on both sides from the north, and bear back the equatorial current, and envelop the entire island with a wall of ice.

These rapid changes of direction of currents, with accompanying marked alteration of climate, appear to bear a close analogy to those which must have obtained in South Britain when the alternating beds of boulder-clay and sands and gravels were being deposited, clay with scratched stones during the colder intervals, and sands during the warmer episodes, when the waves were fretting coasts unprotected by ice.

Icebergs appear to have ground the surface of the rudely columnar trap-rocks of the Thousand Islands, which are covered with countless smoothed and rounded boulders of the local trap, and of red granite derived from the centre of Spitzbergen, forty miles distant.

In one of the cluster of islands off the coast at Black Point is a channel 100 yards long, three or four feet wide, and four deep, running N.E. and S.W., excavated in the boulders, which Mr. Lamont believes to have been produced by the passage of an iceberg, when the land stood lower than at present. The power of bergs to groove and scoop out hollows has been denied, and it is to be hoped that the officers of the Arctic Expedition will have opportunities of ascertaining what the usual character of the bottom portion of a berg is, how far it is capable of grooving rocks and excavating hollows in soft sea beds, with or without coming to rest.

Separated from the great glacier of Deeva Bay by two miles of sea covered with fast ice, is a terminal moraine of mud, 3½ miles long, 200 to 400 yards broad, and 20 to 30 feet high, on the top of which grow Arctic plants. Observations as to what extent glaciers can extend into the sea, and push moraines before them without breaking off into bergs, would have great interest, for in this instance the sea must have been deeper during the maximum size of the glacier than now, as bones of whales occur at heights of more than forty feet above the present sea-level.

One of the three large glaciers that protrude into the sea between Black Point and Ryk-Yse Islands has a sea front of thirty miles, sweeping in three great arcs, five miles beyond the coast line, terminating in a precipitous wall from 20 to 100 feet in height, from which bergs are constantly tumbling into the sea, carrying stone and large quantities of clay and stones seawards. The position of the melting area of such bergs as these, and consequent deposition of erratic material, is a point of great interest in attempting to unravel the British glacial phenomena.

Prof. Wyville Thomson, dredging on the edge of the southern ice pack, brought up fine sand and greyish mud, with small pebbles of quartz, felspar, and small fragments of mica-slate, gneiss, and granite, derived from the melting of icebergs found in lat. 65° or 64° S., which represents their melting area, while further south in 200 to 250 fathoms of water, in which they first commence to float, land débris is much rarer; at the surface of the water in the melting area, *Globigerina* and diatoms are numerous, but do not form a deposit at the bottom, owing to the deposition of silt obliterating them.

Recent Elevation of Spitzbergen.—From the observations of Mr. Lamont it may be inferred that during the past 400 years Spitzbergen has been rising at the rate of thirteen feet per century.

Bear Island (lat. 74° 30′ N.)—From the plants and specimens collected by Professors Nordenskjöld and Malmgren, the following classification of the rocks of the island has been established*:—

MILLSTONE GRIT.—Siliceous schists.

MOUNTAIN LIMESTONE STAGE.—*Productus* limestone, *spirifer* limestone with gypsum, resting on *Cyathophyllum*-bearing limestone and dolerite, possibly the equivalent of the Carboniferous shale with *Cyathophyllum* of the south of Ireland.

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

DEVONIAN.—Russian Island limestone, red shale.

The Russian Island limestone, which spreads over so large an area in Spitzbergen, contains no determinable fossils, and, like the shales beneath it, is of doubtful geological age, probably, as suggested by Nordenskjöld, belonging to the Devonian. No true coal measures are present either in Spitzbergen or Bear Island.

The "Ursa Stage" Prof. Heer correlates with the Kiltorkan beds in Ireland, the Greywacke of the Vosges and southern Black Forest, and the *Spirifera Verneuilii* shales of Aix, and the sandstones of Parry and Melville Islands in the Arctic Archipelago; and from the marked absence of Devonian and coal-measures species, regards the stage as of Lower Carboniferous age, the base of which he considered to be beneath the yellow sandstones; but Sir Charles Lyell, from the fact that these sandstones at Dura Den, in Fife, and in the co. Cork, contain the exclusively Devonian fish *Asterolepis* and *Glyptolepis*, believed these deposits to be Devonian, which

* Continued from p. 494.

† In the following notes on Spitzbergen and other neighbouring islands, only those points have been touched on as have a direct bearing on the geology of the area already described.

‡ Quar. Jour. Geol Soc., vol. xxx. p. 455; 1874.

§ "Frost and Fire," by J. F. Campbell, vol. i. p. 483.

‖ "Seasons with the Sea Horses." London, 1861.

¶ "Letters from High Latitudes." (London.)

* Quar. Journ. Geol. Soc., vol. xxviii. p. 161. (Read Nov. 9, 1868.)

opinion Mr. Carruthers also expressed in reference to the plant both of the Irish and Bear Island deposits.*

In Eastern America the Lower Carboniferous Coal-measures (Calciferous Sandstone of Scotland) lie unconformably on the Devonian, which contains different fossils; but in Ohio a transition between the Devonian and Carboniferous flora takes place, according to Principal Dawson, at the base of the latter,† and he suggests a similar blending in Bear Island.

Prof. Meek has shown that the rock exposures of the Mackenzie River between Clearwater River and the Arctic Ocean are of Devonian age, and correspond to the Hamilton formation and Genesee slate of the United States. The slates contain brine springs and petroleum, and it is through that they extend in a north westerly direction from Rock Island, Illinois, to the Arctic Sea, a distance of 2,500 geographical miles, the fossils being identical on each end of the tract, proving how little the palæozoic marine life was influenced by climate. From the Mackenzie slates many new corals and brachiopods were obtained, also a cephalopod, *Gyoceras Logæni*, collected by the late Mr. R. Kennicott.‡ It is therefore in the highest degree probable that the coal-bearing beds of Parry and Melville Islands belong to a continuation of these beds, and are referable to the "Ursa Stage" of Heer, whether that slate is the top of the Devonian or the bottom of the Carboniferous; and from the fact that not a single species of the Bear Island flora exists in the Upper Devonian Cypris shales of Saalfeld in Thuringia, Prof. Heer believes that the Ursa Stage is Lower Carboniferous. In Bear Island it is characterised by *Calamites radiatus*, *Lepidodendron Veltheimianum*, *Knorria acicularis*, *Stigmaria ficoides*, all of which are found in the Yellow Sandstone of Kiltorkan; and considering the persistence of freshwater genera, it is not remarkable that some genera of fish that occur in Old Red of Scotland still lived on in these Kiltorkan sandstones. Should, however, fish remains be found in the strata lying in synclinal hollows of the Silurian rocks of the Arctic regions, their specific determination and that of the associated forms, may be expected to throw much light on the vexed question 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; the latter is undoubtedly an outlier of the Russian Lower Carboniferous coal tract. Looking to the number of species in this flora, which can be traced in the northern hemisphere, both in the Old and New World, from 47° to 74° and 76° north lat., and to the fact that it is the first rich land flora in the earth's history, there is evidence that a widespread continent occupied much of the Arctic as well as of the temperate zone, over which ran large rivers tenanted by the freshwater mussel (*Anodonta*) and Neuropterous insects.

The subsidence which brought in the deposition of the Mountain Limestone and the existence of extensive coral reefs equally affected the Arctic zones, and these formations occur both in Spitzbergen and Bear Island, as in the islands of the Arctic Archipelago. Equally also is the return of continental conditions expressed by the European Millstone Grit, represented in the Arctic zone by the siliceous schists of Bear Island. During this period many plants of the Ursa Stage still lived in Europe, proving that islands covered with the old flora existed throughout the whole era occupied by the deposition of the Mountain Limestone. And it is worthy of note, as Prof. Heer has pointed out, that the leaves of the evergreen tree *Lepidodendra*, and the large fronds of *Cardiopteris frondosa*, are as fully developed as those from the South of Ireland and the Vosges; and 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 were the same as now.*

Spitzbergen.—In the Klaas Billen Bay of the Eis Fjord, Wilander and Nathorst discovered the Ursa Stage in 1870; overlying it are the Miocene beds which have yielded so rich a flora and fauna to various expeditions which have visited the island. In the black shales of Cape Staratschin, *Sequoia Nordenskjöldi* and *Taxodium distichum* are the most characteristic trees. At King's Bay, a Lime (*Tilia Malmgreni*), a Juniper, an Arborvitæ (*Thuites Ehrenswaerdi*)—many of the species occur in West Greenland—and two, *Taxodium distichum* and *Populus arctica*, were found by Lieut. Payer, of the German Exhibition, in the fossiliferous marls of the Germania Mountains, in Sabine Island, East Greenland, also. 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 oaks must have grown, provided there was land, as far north as the pole.†

The so-called *wooa-hills* discovered in 1806 by Sirowatskoi on the south coast of the island of New Siberia, stated by Wrangel ‡ to consist, according to Henenström, of horizontal beds of sandstone, alternating with vertical bituminous trunks of trees, forming a hill 180 feet in height, are no doubt part of the great Miocene deposit which stretches from Vancouver's Island through Northern Asia into Europe. The evidence of the former continuity of land is borne out by the presence in Greenland of species of the Japanese genera *Glyptostrobus* and *Thujopsis*, which last, *T. Europæus*, occurs in Europe, in Amber and at Armissan (Narbone); associated with it are American forms, which, as pointed out by Prof. Göppert (Geol. Trans. 1845), chiefly characterise the flora associated with the Amber pines of the south-eastern part of what is now the Baltic.

An examination of the fauna and flora of the Miocene rocks of Europe and Asia indicates a continental period of long duration, which experienced at its commencement a tropical climate, gradually becoming more temperate as time elapsed.

In the Upper Miocene beds of Œningen, North American types still live, and are more numerous than in the later Italian Pliocene flora: amongst them is a vine, four palms of the American type, *Sabal*, planes of American type, and conifers *Sequoia* and *Taxodium*. The palms, whether of the European or American type (*Chamærops* and *Sabal*), 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.

C. E. DE RANCE

* Geol. Mag., vol. vii p. 580.
† Quar. Jour. Geol. Soc., vol. xxix. p. 245.
‡ Trans. Chicago Acad. of Science, vol. i. (Chicago, 1868.)

* Prof. Ramsay has directed my attention to Mr. Croll's recent work, "Climate and Time," in which the occurrence of Carboniferous and Miocene species in the Arctic zone is adduced as evidence of "warm interglacial periods" in these regions.

† Heer: "Miocene baltische Flora;" "Fossil Flora von Alaska," 1869; "Flora Fossilis Arctica," vols. i.–iii.; "Ueber die Fossile Flora der Polar lände." Zurich; Fr. Schulthess, 1867.

‡ "Reise längs der Nordküste von Siberien in den Jahren," 1820-24, th. i. s. 102.