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ART. XV.—*Preliminary Report upon the Geology of Peary Land, Arctic Greenland;* by LAUGE KOCH.

INTRODUCTION (by Doctor Clark and Professor Schuchert).

Mr. Lauge Koch was a member of the second Thule expedition (1916-1918) to north Greenland, led by Mr. Knud Rasmussen, which explored the ice-free areas as far as De Long Fjord, in 83° N. Lat., 40° W. Long. On this expedition he carried out the geological and cartographical work. A preliminary report, on the geological results, with a map, was published in the *Meddelelser fra Dansk geologisk Forening,* vol. 5, No. 17, 1920, under the title "Stratigraphy of Northwest Greenland."[1] In 1920 Mr. Koch again left for Greenland to continue his investigations under the auspices of a committee consisting of Rear-Admiral C. S. Wandel, Mr. J. Daugaard-Jensen, director of the administration of Greenland, Professor (emeritus) Eug. Warming, and Mr. V. Glückstadt, consul-general for Italy; and established his headquarters at Robertson Bay in Inglefield Gulf. Early in 1921 he left for Peary Land, accompanied only by an Eskimo of the Cape York tribe. Mr. J. N. Nygaard, formerly an assistant at the Danish Arctic Station at Disco, also joined the expedition, but traveled independently, collecting fossils and plants on Washington and Inglefield lands. Mr. Koch is still continuing his work in north Greenland.—AUSTIN H. CLARK.

We congratulate Doctor Koch and the Danish Government upon the great progress that is here made in discerning the stratigraphy and geology of northernmost Greenland. For a series of years, Koch has been working in the most inhospitable of regions for geologic study,

[1] See notice by W. M. Davis in this Journal (5), 4, 251, 1922.

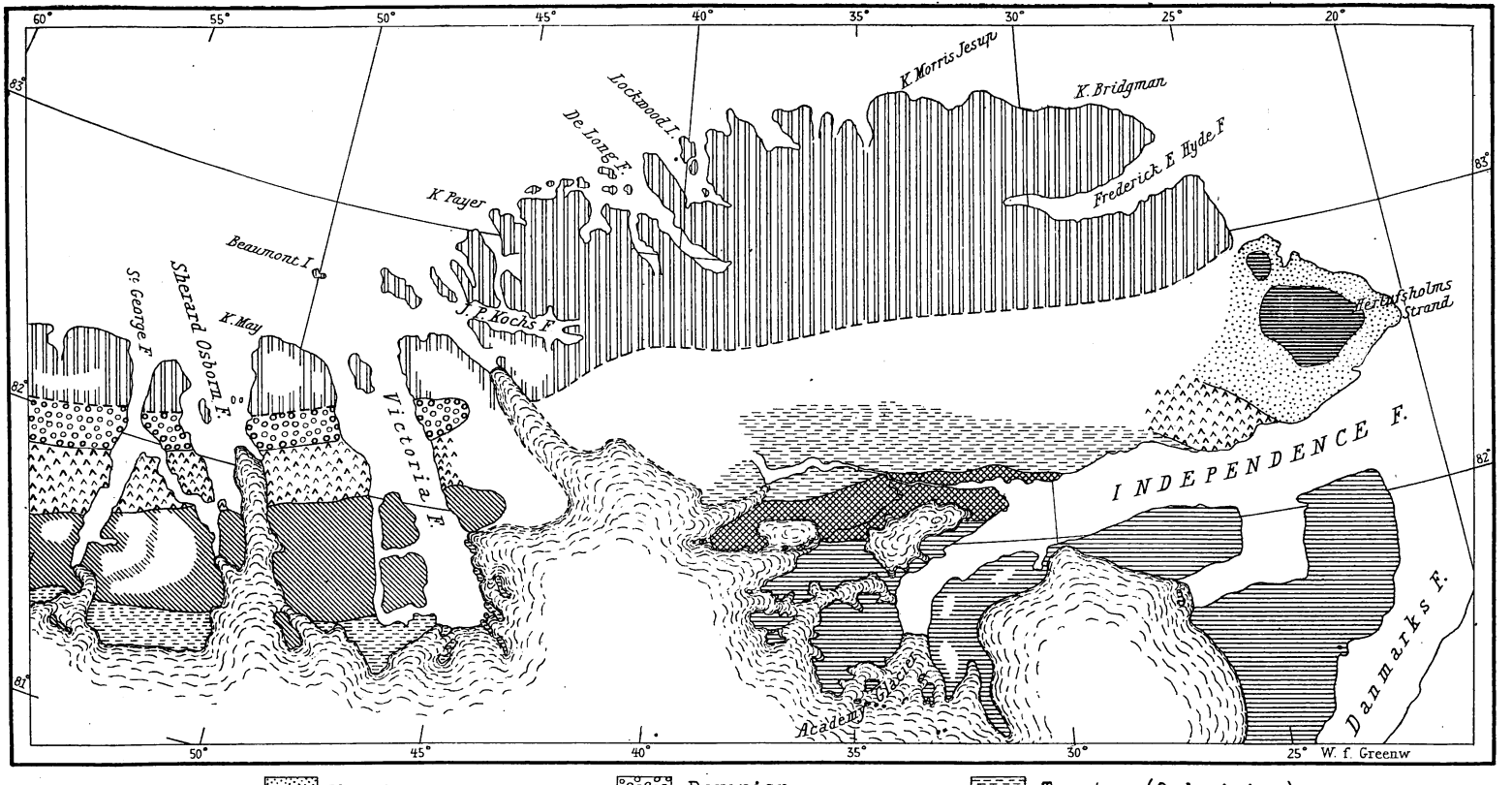


FIG. 1.

Stratigraphy of northernmost Greenland

and his fossil collections and his geographic and geologic results are large. We hope he will bring the fossils all out of Greenland and will be enabled in Denmark to describe them in detail. American stratigraphy needs these results, since many of our earlier Paleozoic faunas have come from the Arctic realm.—CHARLES SCHUCHERT.

STRATIGRAPHY OF PEARY LAND.

(See Fig. 1.)

In 1917 I worked out the stratigraphy of northwest Greenland.[2] As we might expect, Peary Land and the tracts south of it directly continue the geology of the regions farther to the west, but the sequence is still more evident here as the sections of strata are far more complete. A sandstone with diabase dykes, like that known far to the southwest in the Cape York region (see map of 1920), forms the whole northern part of Mylius Erichsens Land, the southern part of Heilprin Land, the whole of Adam Biering Land and Vildtland (fig. 2). The strata are red or gray, forming a series over 900 m. (2925 feet) in thickness, and it was impossible to find any differences in the nature of the sediments of the entire series.

Ripple marks and cross-bedding are extremely common. Very numerous diabase dykes and effusives occur throughout the region. The environs of the outlet of Hagens Fjord consist of an extensive diabase effusive the surface of which is about 100 m. above sea-level. Diabase also forms the great majority of the nunataks of Academy Glacier and plays an important rôle on Vildtland and Adam Biering Land. Around the head of Independence Fjord I found, besides diabase, other effusives of more acid character. They occur especially from Glacier Cape towards Astrup Fjord. In addition, there are four exceptionally well developed laccoliths.

After the deposition of these shallow-water sandstones, and after the eruptions had ceased, the sea seems to have become somewhat deeper. This is indicated in that the upper coarse and purple-red sandstones are inter-

[2] Medd. Dansk geol. Forening, 5, No. 17, 1920.

bedded with layers of finer grain. Gradually the latter become numerous, and finally the sandstone disappears entirely and a series of limestones and dolomites with thin layers of siliceous slates follows. The thickness of this series is about 400 m. (1300 ft.). Fossils are not found in any part of the sandstone series, but in the succeeding limestones well developed *Cryptozoon* structures are very common. The limestone series is especially well developed on both shores of Jorgen-Brönlunds Fjord, and undoubtedly Wandels Dal originated as a river in this rock, since it is softer than the sandstone and the younger Silurian limestone.

The geologic age of the entire sandstone and limestone series appears to be uppermost Cambrian or lowermost Ordovician, since I have not been able to find a discordance between the red sandstone and the Cryptozoon limestone.

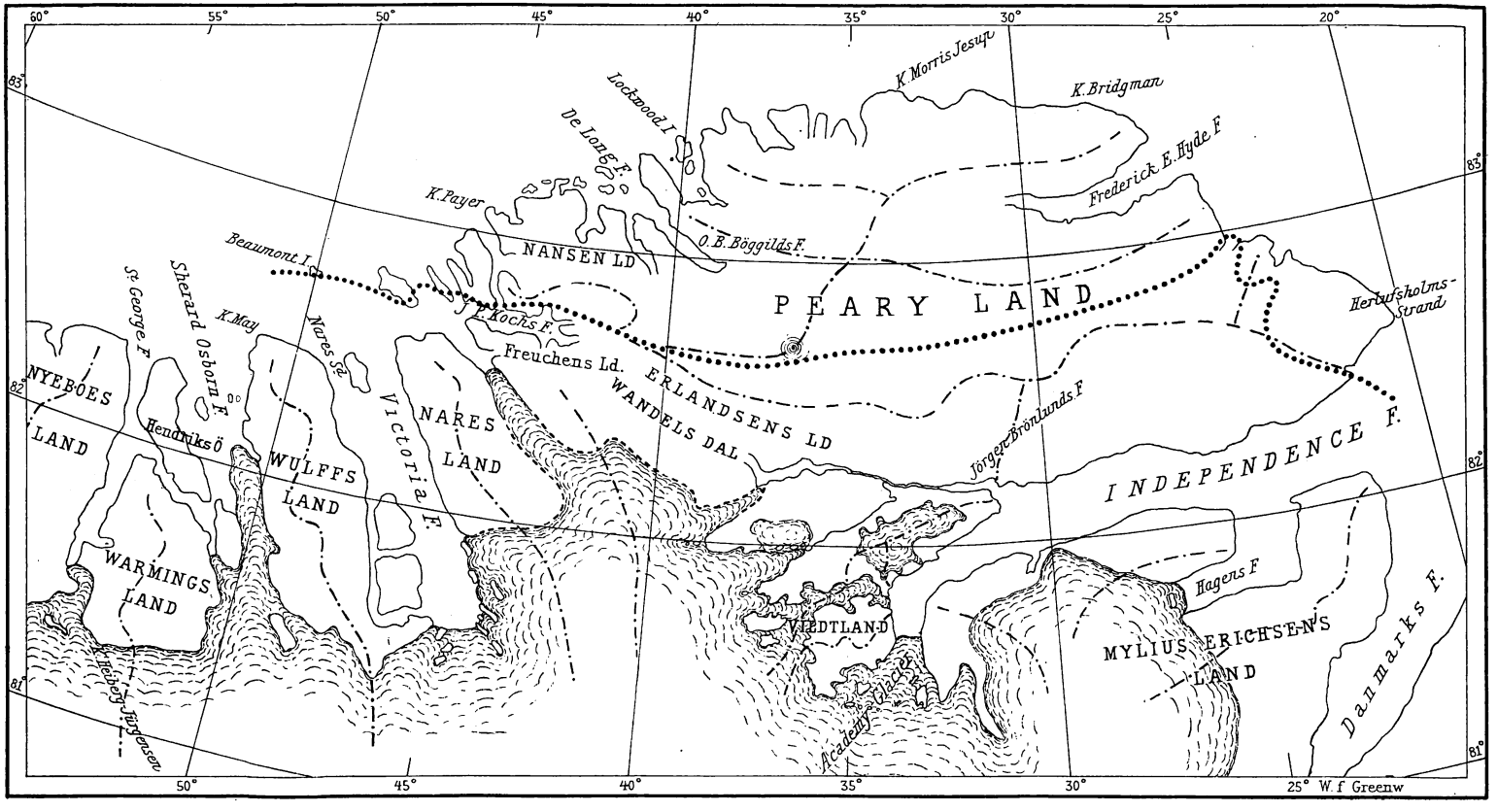
North of Wandels Dal the strata consist of a very thick sequence of Ordovician limestone, attaining to a thickness of at least 1000 m. (3250 ft.). On the Cryptozoon limestone follows a series of white limestone 100 m. thick, devoid of fossils, then 400-500 m. of grayish blue limestones with badly preserved fossils, followed by about 100 m. of gray limestone in which *Maclurea* is common. Over this come 300 m. of coral-bearing limestones with *Halysites, Calapœcia, Receptaculites,* and numerous other fossils, without doubt a Trenton fauna like that known elsewhere in northwestern Greenland and Arctic America. This series is especially well developed from Wandels Dal along the south coast of Peary Land to Cape Caroline Marie. The strata show a slight dip toward the northeast, hence, as one proceeds in this direction, continually younger strata are met with. At Cape Caroline Marie all are covered with moraines, hence a further examination of the series was impossible. East of Cape Caroline Marie, however, I found in river gravels pieces of sandy shales with *Monograptus priodon?*. Therefore on the southern part of Peary Land at about the 25th meridian, Silurian (Gotlandian) formations undoubtedly also occur. Strange to say, on Peary Land I did not find a trace of the Pentamerus limestone so characteristic of northwest Greenland.

Farther to the east, the country is very low and covered

by such huge morainic deposits that every trace of the underlying strata has become invisible, and they do not again appear until Herlufholms Strand. At this place is found basally a dark shale, very rich in fossils, and over it a limestone, poorer in fossils, which merges upward into sandstone and finally into coarse conglomerates. The fossils are very well preserved, mostly brachiopods (*Productus, Spirifer*) and *Fenestella,* indicating clearly a Carboniferous age. They appear to be most nearly allied to the Carboniferous fauna found 200 km. farther to the south by the Denmark Expedition.

The whole northern half of Peary Land consists of metamorphosed rocks altered at the time of their folding, and I regret that circumstances did not permit me to investigate the central parts of its mountain chain as I had hoped. The range is here over 100 km. broad, and I think the central parts contain granitic batholiths; at any rate, intrusives indicating such occur on the northernmost point of Greenland (in one place I found solid mica slate with garnets). Overthrusts I did not see, but they probably do occur. The coastal region from here to west of De Long Fjord is especially characterized by great series of eruptives of more recent date than the folding. We find here numerous dykes and extensive areas of effusives as well, which, being extraordinarily resistant to erosion, cause the landscape to become decidedly alpine in appearance. The mountains are high, steep, and rugged, and between them occur unusually numerous local glaciers.

As becomes evident from the preceding, the whole of Peary and Mylius Erichsens lands belong geologically to the great area of Paleozoic transgression comprising northwest Greenland and closely connected with the similar sediments that extend over most of the Arctic American archipelago. The thickness of the sedimentary series is very considerable, in the aggregate at least 3000 m. (9750 ft.). Their age extends from Cambrian (ca. 1000 m.), through Ordovician (ca. 1000 m.) to Silurian; there may be Devonian; and finally, there is at least 700 m. of Carboniferous.



Limit of ice cap

Limit of ice cap during maximum of Ice Age

Main Water Divides

FIG. 2.

Limit of glaciers and topographic divides in northernmost Greenland

Glaciology of Peary Land.

(See Fig. 2.)

Peary long ago distinguished between ice-bound Greenland proper and the ice-free country north of "Peary Channel." All later expeditions have verified this observation and hence Peary Land must be regarded as the largest ice-free area of Greenland, being somewhat larger than similar tracts on the west coast in the region of the polar circle. The large plateau in the southern part of Peary Land is absolutely ice-free, having no glaciers and only isolated and small snow-fields. The mountain range in the northern section abounds in local glaciers, which, however, are all small. Only in a few places, as, for example, to the west of the northern point of Greenland, is the ice-covered area larger than the ice-free. The landscape is here distinctly alpine, and only rarely do the individual snowfields cross the passes and become confluent. Such an exception is found south of De Long Fjord, but even here it is easy to trace every valley glacier to its individual snowfield.

On both journeys, in 1917 and in 1921 as well, I examined the erratic boulders of Cambrian and Silurian ages that during the maximum glaciation were carried northward. The late Cambrian red sandstone with its diabase and the Silurian limestone rich in fossils are easily distinguished in the drift. These boulders are extremely common. They are found all along the northwest coast as far as Beaumont Island, and even farther east on Nansens Land, but they are totally lacking to the northward. I searched for them in vain everywhere on the north coast of Peary Land, and only at the mouth of Schley Fjord did I find the red sandstone common again on two islets, the remains of a big moraine across the fjord. On Herlufholms Strand the red sandstones are rare, but not totally wanting; on the other hand, on the extensive plateau of the southern section of Peary Land they are common everywhere.

I also found a large morainic area, several kilometers broad and made up of three or four marginal moraines, that marks the extent of the ice-cap during the Glacial Epoch. It contains numerous boulders of the red sandstone, whereas such are totally absent or only represented

in small fragments outside the morainic zone. From Cape Köbenhavn the morainic zone makes an arched curve outside the plateau of Carboniferous strata north to the mouth of Schley Fjord and thence westward along the foot of the range. Without doubt this morainic zone marks the maximum of glaciation during the Glacial Epoch. Another marked stage in the retreat seems to be the north slope of Wandels Dal, where enormous moraines are also found. At the outlet of Brönlund Fjord, I saw a big moraine, and where the large valley from the southwest joins Wandels Dal, extensive moraines occur, having dammed up a lake and influenced the river courses.

The plateau of Carboniferous strata and the northern section of Peary Land certainly never were covered with glaciers. On the other hand, these areas probably were not quite ice-free during the Glacial Epoch, since remains of glacial drift are found on Herlufholms Strand. This material was undoubtedly derived from the Piedmont Glacier, and similar glacial drift is found on the flat country from Cape Bridgman towards Sands Fjord. In front of the Moore Glacier such material is especially conspicuous.

Drainage System of Peary Land.

(See Fig. 2.)

On the accompanying map I have also sketched the main drainage divides of northern Greenland. On Peary Land they are especially interesting. Here in the northernmost part a high divide trends along the north coast, and parallel to it there is another one that extends from Dannebrogstinden to Hagens Land. From the latter divide, yet another leads from a little east of Böggild Fjord to the regions east of Koch Fjord. The major part of the great mountain range, i. e., the northern slope of Roosevelt Range, drains partially towards the north, partially to Hyde Fjord, and beyond there are two drainage systems, that of Weyprecht and De Long fjords.

A great central drainage system, comprising nearly the whole northern part of the plateau of Silurian strata, discharges into Schley Fjord by means of a river which is undoubtedly very large, but which was not actually seen. I only saw its sources and some of its tributaries.

The great drainage area called Wandels Dal is also especially interesting. The trend of the divide between Brönlund Fjord and the interior parts of Independence Fjord proves that the valley of Marie Louises Glacier has relatively recently cut a passage here through the numerous large diabase dykes.

I do not yet know where the water divide across Wandels Dal is to be placed. Certainly it is much nearer to Koch Fjord than to Brönlund Fjord.

The remaining divides present nothing unusual, and are shown on the map.

Geologic Investigations about the 80th Parallel.

From the middle of August to the middle of September, 1921, I had the opportunity to make a detailed investigation of the region lying immediately to the north of Humboldt Glacier. During this time I was supported by two large caches of food and by the Eskimo placed here to support me, and for the first half of my exploration I had favorable weather without snow on the hills.

In this area the stratification is uniform without any disturbances, dipping slightly towards the northwest, and from Humboldt Glacier outwards towards the coast constantly younger formations are met with. The composite section shows:

N. Limestone with Silurian trilobites.	
M. Coral conglomerate.	
Discordance. Cambro-Ordovician.	
L. Brown limestone, devoid of fossils	40 m.
K. Shales with brachiopods	20
J. Limestone with *Halysites*	130
I. Dark colored limestone with *Receptaculites*	120
H. Yellow foliated limestone with orthoceratites	210
G. Limestone with ostracods	30
F. Limestone with brachiopods and sandstone with gastropods	10
E. Limestone with trilobites	40
D. Blue limestone	70
C. Intraformational limestone conglomerates	60
B. Limestone with *Cryptozoon*	100
A. Sandstone with *Eophyton*	40
Total	870 m. (2827 ft.)

The Eophyton sandstone outcrops close to the Humboldt Glacier about Cape Forbes. Undoubtedly it rests upon red sandstone, as the drift along the glacier margin is replete with boulders of red sandstone, resembling fully the outcropping sandstones to the south on Inglefield Land.

In Inglefield Land, Cryptozoon limestone rests upon the Eophyton sandstone. This limestone forms the coastal bluffs to Cape Clay, where it becomes more and more interstratified with intraformational conglomerates. These are very easily eroded, and on both sides of Cass Fjord, which extends far into the country, there are outcroppings. In one place only I found a fragment of a trilobite (*Ptychoparia?*); otherwise no fossils are known other than the *Cryptozoon* in the older strata.

Upwards, the conglomerates contain numerous thin bands of blue limestone (D of section), which gradually become quite dominant. Higher in the series fossils are rather common. The most abundant of these are large trilobites and brachiopods and gastropods. Thin layers of shaly limestones (G of section) have, besides an enormous number of ostracods, many small trilobites. Cephalopods and corals do not occur in these strata, but a little to the north of Cape Webster, in Wright Bay, they are especially well developed.

Then follows a very long series of yellow, foliated limestones that are nearly devoid of fossils. Only in a few places did I find crinoid columns, and very rarely, badly preserved orthoceratites.

In the inner parts of Wright Bay the yellow limestone is overlain by dark limestones (I of section) very rich in fossils, especially in the lower layers, which are characterized by a wealth of cephalopods and *Receptaculites*. Over these (from Cape Calhoun and northwards) come lighter limestones (J) with *Halysites*, while the numerous shaly layers higher in the section (K) have a great wealth of trilobites, brachiopods, gastropods, and corals.

Still higher in the section (L) occurs a brown limestone devoid of fossils. Then follows a considerable discordance, and the brown limestone at several places is totally eroded away.

Over all of the previous formations are deposited thick conglomerates with boulders of rolled corals from the

layers beneath. In the limestone over the conglomerates, trilobites are found that are clearly of Silurian age.

The series beneath the discordance contains two well marked fossil horizons. The uppermost of these I have distinguished as Receptaculites limestone (I), Halysites limestone (J), and Brachiopod shale (K). Common to these strata are *Gonioceras occidentale* and *Receptaculites oweni*, both characteristic of the North American Trenton series. The lower fossiliferous strata are divided into Trilobite limestone (E), Brachiopod limestone and Gastropod sandstone (F), and Ostracod limestone (G). Their faunas are totally different from the higher ones and I judge them to be Cambrian or perhaps transitional into Ordovician. From these lower strata over one ton of fossils have been collected and cached, a single locality having yielded more than 400 pieces with trilobites.

We may therefore conclude that there is in the region of the Humboldt Glacier an Ordovician series, 870 m. (2827 ft.) thick, and very rich in fossils, and I do not doubt that the whole of the eastern part of Washington Land, discovered and surveyed by me in 1921, is made up of Ordovician formations. The Ordovician of north Greenland as a whole hence proves to be of far greater extent and thickness than I supposed in 1917.

Copenhagen, Denmark.