

DET NORSKE VIDENSKAPS-AKADEMI I OSLO

**RESULTATER**  
AV DE NORSKE STATSUNDERSTØTTEDE  
SPITSBERGENEKSPEDITIONER

**BIND I**

---

**Nr. 8**

**OLAF HOLTEDAHL:**  
**NOTES ON THE GEOLOGY OF**  
**NORTHWESTERN SPITSBERGEN**

---

UTGITT PÅ  
DEN NORSKE STATS BEKOSTNING  
VED SPITSBERGENKOMITEEN

**REDAKTØR: ADOLF HOEL**

**OSLO**  
**I KOMMISJON HOS JACOB DYBWAD**  
**1926**

**Nr. 8**

**NOTES ON THE GEOLOGY OF  
NORTHWESTERN SPITSBERGEN**

BY

**OLAF HOLTEDAHL**

11 FIGURES IN THE TEXT AND 7 PLATES



## Introduction.

**D**uring the summers of 1909, 1910, and 1911 the writer worked as a geologist in Spitsbergen, the first two years as a member of the Isachsen expedition, in 1911 as a member of the Hoel-Staxrud expedition. The results of my investigations in the coastal and inland districts between Kings Bay and the western part of the Ice Fjord as well as in the lava district on the east side of Wood Bay have been published long ago<sup>1</sup>. Further, two small preliminary reports on the results of the investigations of A. HOEL and the writer, especially in the pre-Devonian and Old Red districts of northwestern Spitsbergen, have been published<sup>2</sup>.

I shall here give a few, mostly very short additional notes concerning my personal, as yet unpublished, observations during the said expeditions together with some general remarks on the geology of the areas visited. For most of the areas mentioned in this paper my investigations had the character of a first reconnaissance, with no very detailed study of each locality. A number of photographs illustrating the geology of the areas mentioned are reproduced in plates I—V.

Concerning the older literature on the regions, I may refer to NATHORST's well-known paper of 1910<sup>3</sup>. The geological results of the Monaco—Isachsen expeditions 1906—1907 have been published in papers by A. HOEL<sup>4</sup> and J. SCHETELIG<sup>5</sup> etc. In 1914 appeared another

---

<sup>1</sup> O. HOLTEDAHL, Zur Kenntnis der Karbonablagerungen des westlichen Spitzbergens, I & II. — Vidensk.selsk. skrifter, Mat.-Nat. Kl. 1911 and 1912.

A. HOEL et O. HOLTEDAHL, Les nappes de lave, les volcans et les sources thermales dans les environs de la Baie Wood au Spitsberg. — Vid.selsk. skr. Mat.-Nat. Kl. 1911.

<sup>2</sup> O. HOLTEDAHL, On the Old Red Sandstone Series of Northwestern Spitzbergen. — *Compte Rendu, Congrès Géol. Int.*, XII. Sess., Toronto 1913, p. 707.

O. HOLTEDAHL, New features in the Geology of Northwestern Spitzbergen. — *American Journ. of Science*, 37, 1914, p. 415.

<sup>3</sup> A. G. NATHORST, Beiträge zur Geologie der Bären-Insel, Spitzbergens und des König-Karl-Landes. — *Bull. Geol. Inst. Upsala*, X, 1910.

<sup>4</sup> A. HOEL, Geologiske iagttagelser paa Spitsbergenekspeditionerne 1906 og 1907. — *Norsk Geologisk Tidsskrift* I, 1910.

A. HOEL, Géologie. — Résultats des campagnes scient. accomplies sur son yacht par Albert I<sup>er</sup> etc. Fasc. XLII, 1914.

<sup>5</sup> J. SCHETELIG, Les formations primitives. — Résultats des camp. scient. etc. Fasc. XLIII, 1912.

paper by HOEL<sup>1</sup>, dealing especially with his observations in the Wood Bay—Wijde Bay districts during 1912, a paper where to some extent the general geological structure of the Wood Bay region is discussed. In 1916 J. KLÆR<sup>2</sup> published a preliminary paper on the faunas of the Old Red divisions, based on the material collected by the Norwegian expeditions. Finally O. NORDENSKJÖLD's summary<sup>3</sup> of our knowledge of Spitsbergen up to 1920 should be mentioned.

### Observations.

(Cp. map pl. VI).

Mt. Sars in Kings Bay. On July 21st 1910 I made a brief visit to this mountain (cp. fig. 1). I found here (1) a thick series of

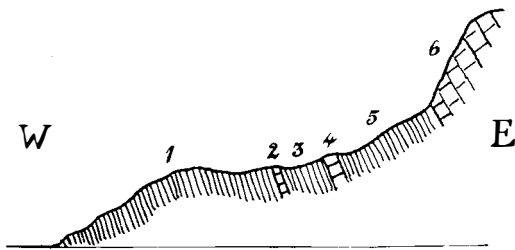


Fig. 1. Section from the western part of Mt. Sars.

Heclahook-quartzites, generally of a rather schistose character, with dip about 60° towards the east. Passing eastwards another rock is met with, viz. a light-coloured, finely crystalline (dolomitic) limestone with nodules and irregular layers of chert-like quartz (2). This rock makes up a zone about 8 m. thick (in the place visited). Further east comes more quartzite (3), then limestone (4), about 20 m. thick, then again quartzite with layers of mica schist (5), and finally a very considerable sequence of limestone with nodules of chert-like quartz (6).

Inland trip Kings Bay—Wood Bay—Ekman Bay. In August 1911 the writer with two assistants made an inland journey from the Blomstrand Harbour in Kings Bay to the head of Wood Bay and from that point to Ekman Bay in the Ice Fjord area<sup>4</sup>. Due to extremely bad weather conditions, with fog, snow storms, etc., (conditions which made the pulling of the sledge a rather hard job that claimed nearly all our energy) we were able to do only very little geologic work, especially in the first part of the journey. Besides at Blomstrand Harbour we found (Heclahook) limestone zones at various places farther

<sup>1</sup> A. HOEL, Nouvelles observations sur le district volcanique du Spitsberg du Nord. — Vid.-selsk. skr. Mat.-Nat. Kl. 1914.

<sup>2</sup> J. KLÆR, Spitsbergens devoniske faunaer. — Forhandl. ved 16. skand. naturforsker-møte, p. 490.

<sup>3</sup> O. NORDENSKJÖLD, Die nordatlantischen Polarinseln. — Handb. d. reg. Geologie. IV, 2 b, 1921.

<sup>4</sup> O. HOLTEDAHL, Gjennem ukjendte strøk av Spitsbergens indland. — Det Norske Geografiske Selskabs aarbok 1910—11, p. 121.

east in the mountain sides along the Blomstrand Glacier, and north of the glacier, about 13 km. from the sea, a schistose granite was seen. On the way down from the plateau north of the Snow Mountains (Montagnes neigeuses) to the Hoffnung Glacier alternating zones of crystalline limestone and of mica schists were passed. The dip is here towards the east. In the moraine material in the lower part of the Hoffnung Glacier boulders of schistose granites were very common, so undoubtedly there occur one or several zones of granite in the district to the SW.

One of the objects of this inland trip was to try to study the volcanic mass in Mt. Sigurd (first observed by G. WATNELIE in 1910) and the geological conditions around it. Unfortunately, the upper part of the mountain was heavily covered with snow at the time. I climbed the mountain from the southeast and collected specimens of the rocks at the summit. There were 6 different crags, made up of volcanic rock, visible above the snow; the rock was in places lava (with inclusions of olivine, also of older rocks: limestone, granite, sandstone), in places tuff. It was evident that below the snow existed great quantities of debris of the tuffaceous rock. As to the petrological character of the material as well as the general geological features of the district I may refer to WATNELIE's observations published in HOEL and HOLTEDAHL: "Les nappes de lave", p. 28, and p. 24 and the section pl. XIII, fig. 2 in HOEL's paper "Nouvelles observations sur le district volcanique du Spitsberg du Nord"<sup>1</sup>. A photograph of Mt. Sigurd taken by me on that occasion is reproduced in the latter paper, pl. X, fig. 1. From my diary notes I may cite: "The sandstone in the eastern slope of the mountain is, for the lower 300 m., green, fine-grained or with the round calcareous bodies" (as known from Red Bay). "In the upper part the ordinary red sandstone" (as known from the Wood Bay area) "occurs, containing fish remains and with nearly flat-lying beds. The boundary towards the lava-tuff rock is probably fairly vertical. The crags lie exactly on the fault-line" (between the Heclahook area to the west and the sandstone area to the east).

On the further trip to Ekman Bay we passed along the west side of the Snow Mountains where the rock was a limestone conglomerate, reminding strongly of the conglomerate seen north of Bruce's Cairn in Red Bay 1909 (see below). Separated from the Snow Mountains by a wide ice plateau (the western part of the Holtedahl Plateau) then comes to the south the beautiful, often pyramid-shaped mountains (cp. pl. V, fig. 2) made up of Devonian sandstone — Carboniferous limestone, some of which have been treated to some extent in my paper of 1912

---

<sup>1</sup> HOEL visited this locality during the summer of 1912. The ice conditions were then much better than in 1911 and Wood Bay could be reached by ship.

on the Carboniferous of Western Spitsbergen. On the east side of the ice-plateau, north-west of Mt. Elfdalen (See ISACHSEN's map<sup>1</sup>), lies a small mountain hill with rounded contours which I visited (it is called "Sne-kolle" in my sketch map in the paper "Gjennem ukjendte strøk etc.", p. 122). I found here a light coloured, crystalline limestone, lying fairly flat. This is the most southern occurrence of Heclahook rocks in this district. The southern boundary line of the Heclahook area which

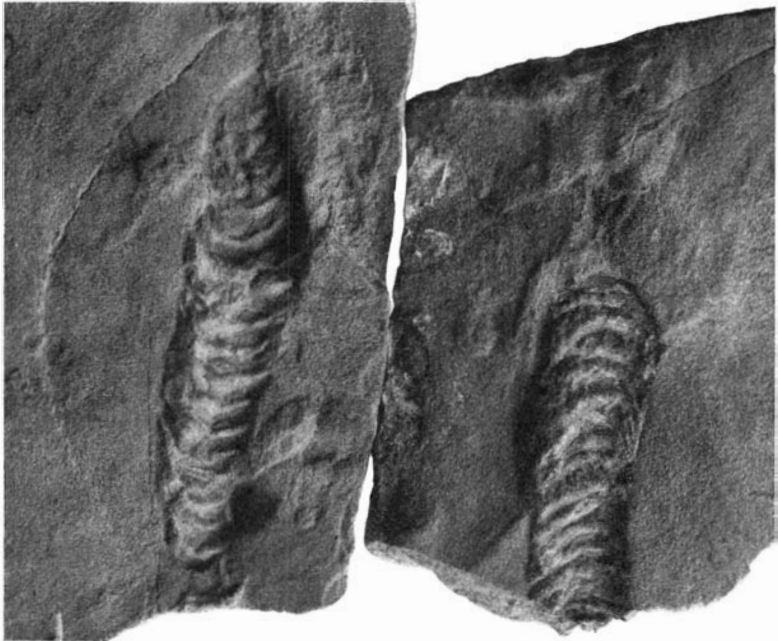


Fig. 2. Trails of unknown origin on bedding plane of sandstone of Wood Bay series, Mt. Dana.

reaches the north coast on the east side of Red Bay must cross the snow-covered area just south of the said hill.

In my paper "Karbonablagerungen, II", I have some notes on the Devonian sandstones making up the lower part of the mountains of the areas south of the Holtedahl Plateau and the Three Crowns Glacier. I shall only add that in the debris of red and greenish sandstone in the most southerly of the Three Crowns (Mt. Dana) I collected specimens showing peculiar trail-marks as shown in fig. 2. They remind one strongly of the marks found by the writer in the Artinsk sandstone of N. W. Novaya Zemlya<sup>2</sup>.

At the head of Möller Bay. High up in the western slope of the mountain just north of Möller Bay, Mt. Prince Olav, occur mica

<sup>1</sup> "Spitsberg (Partie Nord-Ouest)". Scale 1:200000. 1915.

<sup>2</sup> On the Rock Formations of Novaya Zemlya, (Rep. Scient. Res. Norw. Exp. to N. Z. 1921, No. 22, 1924, p. 18, pl. XIII, fig. 2).

schist or phyllite dipping eastwards, farther down schistose quartzite dipping west, and in the low country near the bay a limestone (or dolomite), lying fairly horizontally. Boulders of grey granite, sometimes huge angular pieces of rock, occur very commonly in the southern slope of the mountain; in fact they are so common that it is probable that granite occurs in solid rock in the immediate vicinity. Both schistose and undeformed granites were noticed.

Northwest of Cross Bay. On August 2nd 1909, starting from our camp near the head of Lilliehöök Bay in Cross Bay, I made (accompanied by R. MARSTRANDER) a skiing-trip towards the northwest to try to fix the boundary-line between what was at that time thought to be the Archean area to the northwest and the Heclahook area to the southeast (cp. e. g. the coloured map in NATHORST's "Beiträge"). Bad weather (much fog), however, made observations difficult. We passed along the Hess Glacier without seeing any mountains at all, continued across the ice-plateau farther to the northwest, and finally reached the northeastern part of Mt. Seiersted (cp. ISACHSEN's above mentioned map). The rock here was a dark mica schist of a type similar to that in the Cross Bay area. The strike was N or somewhat W of N. The fog dispersed somewhat at periods, and we continued northwards across the upper part of "Glacier No. II" till we reached the mountains on the north side, viz. the most eastern of the Ræder Mts. We passed along the eastern flank of this mountain and observed only mica schists, no granite or gneiss. As the fog had grown very thick again — we could not see objects 100 m. away — we did not proceed farther but returned, the result of the trip being that the Heclahook continued farther to the north than previously thought.

Inland trip Cross Bay—Red Bay. The days August 4th—14th were spent on a sledging-trip from Cross Bay to Red Bay. We were two sledge parties, one commanded by HOEL<sup>1</sup>, the other by the writer. After much hard work we reached the Penck Glacier on the 6th. In the mountain side to the south of the glacier (cp. pl. I, fig. 1) we observed a schistose granite in contact with a mica schist (containing quartz lenses) of the ordinary Cross Bay type. The schistosity of both rocks showed a NNW strike with a rather steep dip towards the WSW, the boundary planes having the same dip. This observation of a granite and a typical Heclahook rock occurring as parallel belts, with the ordinary Heclahook strike, and with an intrusive and no erosional contact, was one of great interest, as it indicated that the huge masses of granites occurring in the NW corner of Spitsbergen were not older than the

---

<sup>1</sup> A popular account of this trip has been given by HOEL: "En slædetur paa Spitsbergen under ritmester Isachsens ekspedition i 1909". — Den Norske Turistforenings aarbok 1912.



Heclahook, but younger, they were not of Archean age but more or less contemporary with the Caledonian deformations in Spitsbergen.

Similar conditions were found in other localities in the same area. In the mountain side north of Penck Glacier a section like that shown in fig. 3 was seen.

We passed eastwards along the Penck Glacier to the ice-shed towards the Løuet Glacier. The weather, which most of the time had been bad, now grew still worse. A very thick fog and then a heavy snow-storm checked our movements for three days. Of geological observations, therefore, we have very little. The mountain side to the east of the valley in question is made up of a light-coloured, rather coarsely crystalline dolomite (or dolomitic limestone) containing nodules and irregular layers of chert-like quartz of various colours. In places also quite

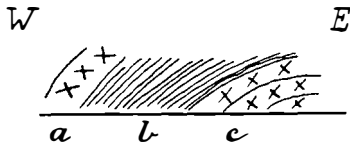


Fig. 3. Section in mountain side north of Penck Glacier. *a* granite, without marked schistosity. *b* mica schist with quartz lenses. *c* granite with well-marked schistosity.

small irregular silicified bodies were observed. The dolomite was distinctly folded and with strike N or more NNW. The writer made a trip towards the east, down the Løuet Glacier till the southern slope of the eastern part of the Strengenhagen Mts. was reached. Alternating zones of granite and mica schist were seen here. The fog made a more complete survey of the section

here difficult. On the 11th we started again northwards from our camp, turned westwards south of "Le Mur" and "La Tente" and camped again on the divide between Lillehöök and Grand Glacier, the latter stretching down to Red Bay. A trip to a mountain side to the east showed granite to occur there. One of the assistants, R. JOHANSEN, went as far west as the nunatak 931 in the Staxrud Plateau, from which locality he brought back a specimen made up of pegmatite feldspar and quartz.

The next day we went on skis down the upper part of Grand Glacier to Ida Glacier. HOEL climbed Mt. Pteraspis and collected fossils there, while the writer went southwards to the mountain (633) projecting into Liefde Bay at the very head of the fjord. The most eastern part of this mountain evidently consisted of another rock than seen further west, where zones of granite (with distinct schistosity, strike N—S) alternating with limestone-dolomite zones were observed. The most eastern part of the mountain is chiefly made up of somewhat folded sandstones, with a fault separating them from the older rocks to the west. Besides sandstones arenaceous shale occur, the colour of the sedimentary rocks being mostly grey and greenish. Of fossils some poor plant remains were seen in the shales. The strike and dip of the sedimentary rocks were rather irregular. Besides a strike NNW, parallel to the fault line to the west, more W—E directions were

noticed. For any more detailed survey of this sandstone area the stay was too short. On August 14th we reached Red Bay at the head of the Klinckowström branch.

Area east of Red Bay. I have been ashore at various places in the most northern part of the peninsula east of Red Bay and noticed Heclahook-rocks of various types, chiefly mica-schists, sometimes with garnet, and quartzites of different types. The strike is NNW, while the dip varies considerably.

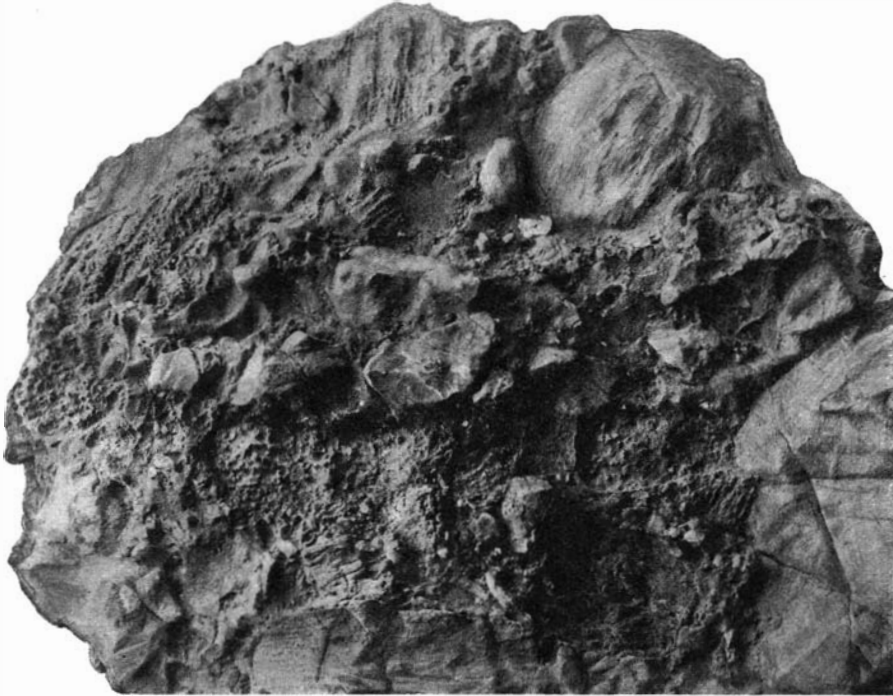


Fig. 4. Specimen of conglomerate from locality shown in pl. I, fig. 2.  $\frac{4}{5}$  nat. size.

The most northern occurrence of younger sediments is in a small mountain (a western outlier of the Mt. Solander group) southeast of the lagoon that occurs somewhat north of Pt. Bruce. G. NORDENSKIÖLD made observations in this area in 1890<sup>1</sup>.

In the small mountain shown in the photograph pl. I, fig. 2 occur, in the lower part, Heclahook rocks, mica schist and hornblende schist, to the right with a rather regular dip towards SW; farther to the left (east), in the basal part of the hill, distinct folds are seen. Still farther east quartzites and mica schist were observed, having a very steep dip towards ENE. Resting on this basement-complex lies then the congl-

---

<sup>1</sup> G. NORDENSKIÖLD, Redogörelse för den svenska expeditionen til Spetsbergen 1890. — Bihang K. Sv. Vet. Ak. Hdl., 17, no. 3, 1892, p. 52 etc.

merate rock mentioned by G. NORDENSKIÖLD<sup>1</sup>, a coarse conglomerate of a brick-red colour. The conglomerate-mass shows a dip towards the SW, very much like the dip of the underlying schists; this does not of course mean that there is no unconformity between the two series, the unconformity being, in other places, well enough marked.

Now as to the character of the conglomerate (cp. fig. 4) we are dealing with a rather characteristic rock, the fragments mainly consisting of dolomites and limestones, the former rather commonly with a more or less yellowish weathering, the latter more grey. The rocks are finely crystalline, generally very fine-grained so that no crystalline structure can be seen with the naked eye. The crystalline character of the thin, silicate layers which are common in certain types of the carbonate rocks, indicates, however, that we are dealing with rather strongly metamorphic sediments. Generally the fragments are fairly well rounded, but angular pieces also occur. Smaller fragments are rather commonly made up of other types of rocks, viz. various types of quartzites or massive quartz.

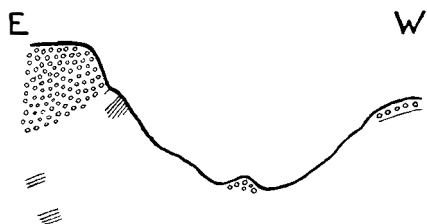


Fig. 5. Section south of the southern end of Lake Richard.

The most ordinary size of the dolomite-limestone pieces is probably that of an egg to an apple, much larger boulders being, however, not at all scarce. The thickness of the conglomerate mass at the locality has not been measured; I should think it is not far short of 100 m.

Now continuing southwards, this strip of conglomerate on the east coast of Red Bay soon widens as the boundary towards the Heclahook rocks has a SE direction, while the coast line soon gets a southern one.

A conglomerate series younger than that just mentioned appears in the Pt. Bruce Peninsula. Here we meet a quartz (or quartzite) conglomerate of a deeper red colour, with well rounded, nicely water-worn pebbles of mostly nut to walnut size. The dip is WSW, less steep than in the locality mentioned before; there it was about 25°—30°, here about 10°.

The quartz-conglomerate mentioned stretches southeastwards and is seen e. g. south of Lake Richard. Eastward in the valley here the conglomerate apparently comes to an end in the bottom of a little

<sup>1</sup> G. NORDENSKIÖLD found an occurrence of Old Red conglomerate on the west side of Red Bay (l. c. p. 54, map p. 53). This locality was revisited by HOEL and the writer in 1910. The conglomerate here is, as mentioned by N., a very coarse rock, boulders as large as a man's head being common. I noticed in one place a dip of 50° towards ESE. The boulders seem to be principally made up of granite, quartzite, crystalline limestone (or dolomite), various schists etc.

side-valley stretching towards the SE (fig. 5). On the other side of the valley appear Heclahook-schists (mica-schists, also a massive green igneous rock<sup>1</sup>) with dip towards the east. In the top of the mountain here, the Pudding Mt. in ISACHSEN'S map, again occurs an isolated mass of the red quartz conglomerate. The conglomerate mainly consists of quartzite-pebbles; of other rocks may be mentioned mica-schist and a red or violet porphyry-rock, with phenocrysts of feldspar and blue quartz. In a specimen at hand the feldspar individuals are rather big, attaining a length of about 15 mm. These porphyries do not show any schistosity. The bedding of the conglomerate is not very distinct; my impression was that it is fairly horizontal, while the lower boundary plane seemed to dip quite steeply towards the NE. The thickness of the conglomerate here must be at least 100 m.

Farther southwards we reach the valley in which, somewhat more to the NE, Lake Rabot is situated. The conditions here are very interesting, though very complicated. They would deserve a detailed investigation. The older — Heclahook — rocks show here a good deal of variation. Besides mica-schist and mica garnet-schist we meet here with zones of amphibolite, of gneiss (pressed granite), and some very

coarse granitic or gneissic garnet-bearing rocks of types that I have not seen represented elsewhere in the NW-corner of Spitsbergen. Mr. OFTEDAL has kindly made a microscopical investigation of some of my specimens. A type with no distinct schistosity was found to be made up of large individuals of microcline, also of quartz, muscovite, garnet. In many cases the mineral grains show a well-marked breaking up through pressure. Another related rock has structurally the character of an augengneiss. It contains microcline in individuals not seldom of a size

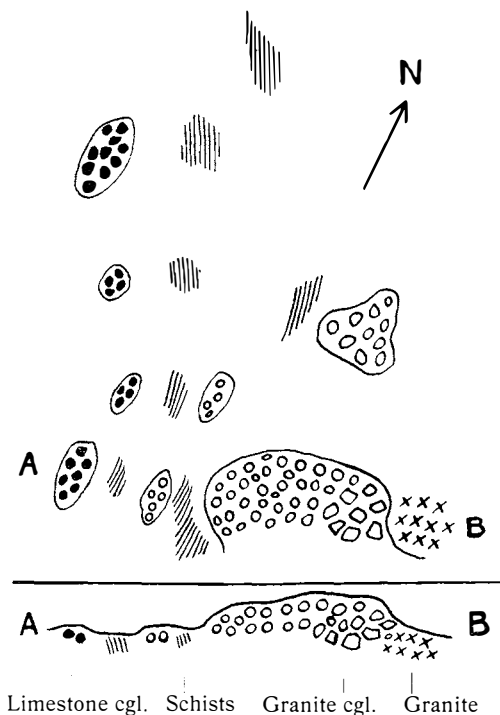


Fig. 6. Distribution of pre-Downtonian rocks and basal conglomerates in an area 2,5 km. SW of Lake Rabot. Section below line.

<sup>1</sup> Mr. I. W. OFTEDAL has kindly studied this rock in the microscope and found it to consist mainly of a mineral belonging to the clinozoisite-epidote series, further of pyroxene, hornblende, a little quartz and calcite, and finally garnet.

3 × 5 or 3 × 7 cm., with a lenticular section, the ground mass with microcline, plagioclase, quartz, muscovite, and garnets, of a size up to 1 cm.

The strike of these rocks is NW or NNW. On the southeastern side of the valley there rise some crags and here appear several types of conglomerates (fig. 6). In places, small isolated patches of these rocks occur also in the lower area to the north. To the SW occurs a limestone-conglomerate, like that described from the coastal area north of Pt. Bruce. Further NE the conglomerate is to a large extent made up of granitic rocks, among others of the garnet-bearing varieties occurring in the basement complex of the same area. In one place one sees a real transitional layer between the basement rock and the conglomerate, a zone made up of huge, often angular pieces of the older rocks. Higher in the section the boulders are somewhat more rounded and of smaller size, indicating a transport by running water. A photograph of the breccia-like lower part of the conglomerate is reproduced in pl. II, fig. 1.

Of some general interest is the occurrence of small zones of Hecla-hook schists alternating with conglomerate. This feature can here probably only be explained by assuming a considerable amount of crust movement, after the deposition of the conglomerates. Also the conditions shown in fig. 5 indicate such movements.

The long ridge-like mountain mass of Mt. Lillieborg, and its southern continuation Mt. Fränkel, is principally made up of conglomerates, with quartzite, quartz, mica-schist as the most common rocks in the fragments. In the photograph pl. II, fig. 2 one sees in the distance the exceedingly rough and wild summit of Mt. Lillieborg, and in the foreground blocks transported by ice and made up of conglomerate, the rounded boulders being very commonly the size of a man's head or even larger. Through weathering of the rocks these boulders and pebbles again become isolated and are thus accumulated as seen in the immediate foreground of the picture.

While the ridge and eastern slope of Mt. Fränkel is made up of quartz-conglomerate, the thickness of which is very important indeed, probably about 200 m., we meet on the western slope of the mountain more fine-grained, younger beds. As farther north these younger, western beds lie less steeply inclined than the eastern ones. In the eastern precipice of Mt. Fränkel the dip of the beds is sometimes seen to be as much as 35°—40°, nearer the shore a dip of 15°—20° is the common one. In a part of the western slope, (stratigraphically) above the conglomerate, occurs an unfossiliferous, fairly light-coloured, mostly yellowish sandstone. This sandstone is of a rather compact type; often it shows cross-bedding. It is generally rather coarse-grained, with many grains as large as 1 mm., not seldom even with small pebbles. It is a typical sandstone and not a quartzite rock, the separate grains, mostly made up of quartz, being seen very distinctly with the lens. Small scales of light-coloured mica are fairly common.

Above this sandstone comes the fossiliferous part of the Red Bay series, with fish remains and lamelli-branches in great quantities in certain layers. This division has been especially studied by HOEL, who has devoted a very considerable amount of time and work to a systematic stratigraphical collecting in this series. Quite recently, during the summer of 1925, TH. VOGT carried out detailed investigations in the sandstone area at Red Bay and a detailed description of the Red Bay series will therefore probably appear before long. Suffice it to say that the sandstone in question, making up the high mountains which rise east of Grand Glacier, consists of alternating zones of rather dark greenish grey and red sandstone, the sandstones being of varying grain, scales of light-coloured mica mostly occurring in great quantities. The layers are often of a rather shaly character and small patches, originally thin flat pebbles, of clay are commonly seen in the sandstone beds. Very often the sandstone has, on the surface, a porous character with innumerable rounded holes, the size varying from quite small up to several centimetres in diameter. These holes are due to the occurrence in the rock of nodules, sometimes of a fairly round, ball-like form, sometimes very irregular, made up of impure limestone material. This is a type of rock known from the Old Red Series of Great Britain as well as from other continental deposits of various ages ("Kunkar" of India).

As to the fossils from the Red Bay series as well as from the younger Old Red deposits of Northern Spitsbergen, I may refer to KLÆR's paper of 1916 and to future papers by KLÆR and by Prof. STENSIÖ in Stockholm (fish-faunas) and by Dr. W. QUENSTEDT, Berlin (lamelli-branches).

From the horizon *K* of HOEL's section of Ben Nevis I have at hand a valve of a poorly preserved *Leperditia* or perhaps, more probably, an *Isochilina* (size 6 × 8 mm.), from horizon *U* a left valve of a small *Leperditia*, (cp. 1, fig. 9 p. 15). The valve is fairly strongly and evenly convex. A small eye tubercle is visible, although rather faintly developed. The valve reminds one of small specimens of *Leperditia alta* CONR. from the North American Manlius-Lower Helderbergian, any exact identification being out of question with such poor material.

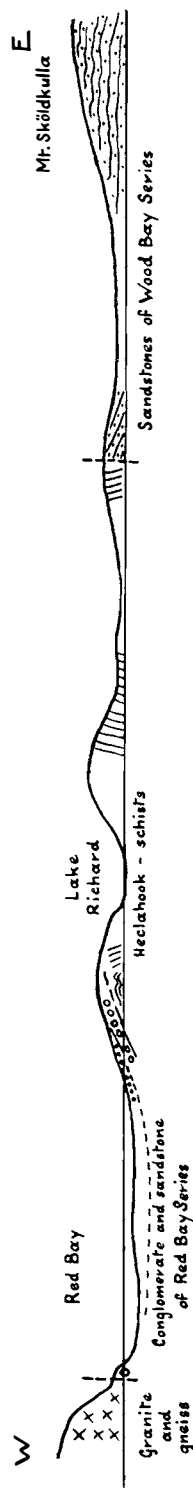


Fig. 7. Section (height exaggerated) from west side of Red Bay to Mt. Sköidkulla.

The whole of the eastern part of the peninsula between Red Bay and Broad Bay is made up of Heclahook-rocks (to a large extent of quartzites) but when passing along the southeastern side of Broad Bay other rocks are suddenly met with (fig. 7). (It was in the latter part of August 1909 that I noticed for the first time the big fault which later on was met with by both HOEL and the writer in more southern districts, cp. the papers on the volcanic districts in the Wood Bay region). In the northern part of the mountain ridge which separates the Arla Glacier from

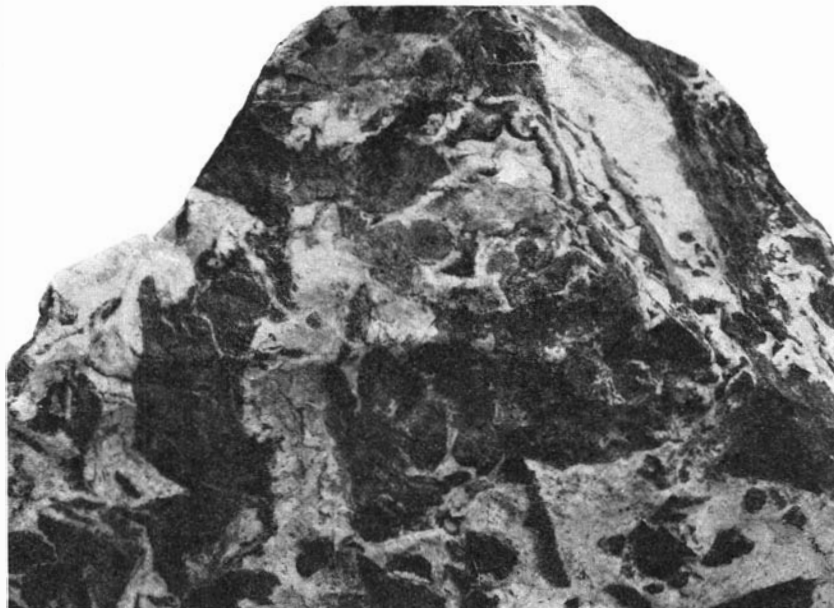


Fig. 8. Fault-breccia from the valley shown in pl. III, fig. 2 (west of Mt. Högkulla).  
1/2 nat. size.

the sea we pass suddenly from phyllitic schist, dipping  $60^\circ$  towards the ENE to red sandstone (of the lower Devonian Wood Bay Series) with only a slight inclination in the same direction or somewhat more straight E. A photograph of the mountain side here, as seen from the coast, is reproduced in fig. pl. III, fig. 1.

Also the ridge between Arla and Serla Glacier is cut by the fault and to the south of the latter glacier the fault passes in the valley, on the west side of Mt. Högkulla. In the said ridge the red sandstone to the east and the Heclahook rocks (quartzite and a red and yellow limestone) were separated by only a few metres of covered ground. The valley, with the nicely rounded, only slightly snow-covered mountain made up of Lower Devonian red sandstones to the left, the much more ragged, snow- and ice-covered Heclahook mountains to the right, is shown in pl. III, fig. 2. At this locality the Heclahook consists of mica-

schists with garnets, dipping steeply towards the WSW, while farther down in a slope was observed a breccia (fig. 8), made up of irregular fragments of a very fine-grained quartzitic rock, cemented by white quartz (sometimes with small druses with quite small quartz crystals).

In the red sandstone of this area, just east of the fault line, a considerable material of fish remains was collected.

Mt. Högkulla and the mountains farther east and northeast all consist of the red sandstones of the Wood-Bay series, the beds generally showing slight dips, mostly of an undulating character. To a great extent these mountains are covered by a heavy debris of broken-up sandstone.

The red sandstones of this area are rather fine-grained rocks, with more compact beds alternating with more shaly ones, the planes of bedding generally with a very great amount of scales of light-coloured mica. The most common size of the mineral grains in the typical



Fig. 9. *Leperditia* from NW-Spitsbergen. 1 from Red Bay series, Ben Nevis (cp. p. 13), 2-6 from Wood Bay series, Mt. Sköldkulla.

sandstones is about 0,1 mm., the form is commonly rather angular. Also greenish and grey zones occur. In grey arenaceous shale in Mt. Sköldkulla poor plant remains (fragments of stems) were observed. In the said mountain small faults were very commonly seen with the fissures filled by calcite or quartz.

There occur in places thin red-coloured limy layers, the rock might sometimes be called an impure limestone. In such a limy layer some ostracods, *Leperditia* were found.

Besides numerous indeterminable fragments I have worked out of the rock a few somewhat more complete single valves, mostly right valves, some of which are figured in fig. 9. The outline of the valves in question varies considerably, yet I do not think it probable that they represent more than one species. The best preserved specimen, the original of 5, shows a rather short, evenly rounded, oval outline, while the original of 2 has a much more elongate form. Another right valve (of about the same size as the latter) shows also such a relatively long outline. While the anterior and posterior part of the specimens mentioned show considerable symmetry as far as the general outline is concerned, the original of 6 has a distinctly more oblique form. This specimen is considerably broken and this is probably the reason why the eye-tubercle, which is very prominent in the other specimens, is less



distinctly marked in that particular valve. I have to add, however, that the eye-tubercle in all the specimens is seen only in internal casts of the valves, as the shell substance in that region in no case is preserved. A slight elevation is seen in the muscular-spot area, which is situated at or somewhat above the middle of the valve.

All the right valves at hand show a distinct peripheral rim in the anterior, ventral and posterior part of the valves, this rim varying considerable in width in the different specimens. It is broader on the interior than on the exterior side of the shell. In the ventral part a row of minute, circular depressions are seen in some of the valves, most strongly marked on the interior side (in the cast). Only in the original of 6 these pits are so distinct that they are well seen with the naked eye.

Also the left valve figured in 4, a specimen that represents an internal cast, has a (very narrow) marginal rim. According to this fact one should judge that we have here a species with equal valves, thus belonging to *Isochilina*, while in other features it is quite *Leperditia*-like. Now there exists, however, a fragment (the anterior part) of the cast of a complete specimen, which, in size, convexity, and the existence of a very pointed eye-tubercle agrees fairly well with the other specimens, yet being somewhat larger and rather elongate in outline. The height corresponds to that of fig. 5, while the length has evidently been greater. Now this cast does not show any full symmetry, the vertical transverse section being like that shown in fig. 3, the left valve here being that shown to the left, the right to the right.

T. R. JONES has, a long time ago, in 1883<sup>1</sup> described *Leperditia* collected by the Swedish expedition to Spitsbergen in 1882, the material occurring "in argillaceous schist of Devonian age from Klaas Billen Bay". Further is mentioned *Leperditia* from "a specimen of reddish limestone (waterworn), labelled "Liebde Bay, North-polar Expedition, 1868" — —". The specimens from both localities are described under the name *Leperditia isochilinoides* n. sp., the material being, however, as is evident from the illustrations, very poor, in fact too poor to give any detailed knowledge of the characters of the form. Now JONES' specimen from Liefde Bay, figured in JONES' fig. 9, and occurring in reddish limestone (which fact might indicate that we are dealing with an horizon near to that from which the Mt. Sköldkulla-specimens have come) has a section very much like that shown in 3 of fig. 9 of this paper, and in outline this Swedish specimen from Liefde Bay resembles the more elongate types found by me. The eye-tubercle of the former specimen seems, however, to be less distinct than in the Sköldkulla-

---

<sup>1</sup> T. R. JONES, Notes on the Palæozoic Bivalved Entomostraca. No. XVI, II. Some Palæozoic Bivalved Entomostraca from Spitzbergen. — The Annals and Magazine of Natural History, Vol. XII. — Fifth Series, 1883, p. 247, pl. IX.

specimens which also lacks a well-defined "nuchal furrow just behind it", as is mentioned by JONES for the specimen figured by him. The latter has a marginal rim, and a still much broader rim is shown in the specimens mentioned from Klaas Billen Bay. These are highly deformed, giving no very exact idea of the original shape of the valves. A specimen of much the same type as e. g. shown in JONES' fig. 2 and 3 is present also in my material, from a more shaly rock.

Because of the poor state of preservation of the Swedish material it is difficult to tell with certainty whether the specimens found by me belong to the same species or not. As to what genus the specimens should be referred to, JONES emphasizes that because of the existence of a comparatively broad marginal rim "the species seems at first sight to belong to *Isochilina*; but as there is a slight inflection of the ventral edge of one valve under that of the other, we must refer it to *Leperditia*" (p. 248). To judge from the Sköldkulla specimen figured in 3, fig. 9 the left valve seems to be the larger one and not the right one as in a true *Leperditia*. In JONES' fig. 9c also the larger valve shows a faint marginal rim, showing in that respect a transition between the character of my originals of 3 and 4. We get the impression that the species with which we are dealing is apt to vary considerably in different respects.

The most probable conclusion is that these Lower Devonian beds of Spitsbergen contain varieties of a well-sized ostracod which is more symmetrically built than a true *Leperditia*, without, however, having the full symmetry of an *Isochilina*. A marginal rim in one, most probably in both valves, is a typical feature.

JONES mentions that "In outline this species from Spitzbergen somewhat resembles *Leperditia Nordenskjældi*, FR. SCHMIDT", a form from (probably) the Lower Devonian of Vaygatch Island (Mém. Acad. Imp. Sc. St.-Pet., ser. 7, vol. XXXI, no. 5, p. 25). However, as JONES emphasizes, there are also important differences. There is, at any rate, no particular likeness between the specimens figured by SCHMIDT and the originals of the figures of the present paper.

Neither is the form from Vaygatch a true *Leperditia* if we restrict the genus to forms of the *L. Hisingeri* type, and the same may be said of various other Devonian forms referred to *Leperditia*, like e. g. another form from Vaygatch, described by SCHMIDT in the paper cited, viz. *L. Lindströmi*, which species has a marginal rim that in places is extremely wide.

These Devonian *Leperditia* need a general revision as to the generic classification. Already from the material found in Spitsbergen the establishment of a new generic name seems to be justified. In order to be able to work out a complete diagnosis of this type, however, one

needs more material than is at hand at the present time, and the above remarks must therefore suffice here.

East coast of Wood Bay. In August 1910 I made investigations along the eastern coast of Wood Bay, from Stjördalen Valley to Grey Hoek.

The red sandstones of the Wood Bay series are seen in the Stjördalen Valley and in Mt. Sörli, below the lava-sheets (pl. IV, fig. 1). A number of fish-fragments (among others referable to the genus *Arctolepis*, according to KLÆR) were collected in this mountain. The main dip of the beds is towards the E or ENE, yet rather varying.



Fig. 10. Mud-cracked sandstone from transitional zone Wood Bay—Red Bay series, east of Cape Aug. Viktoria.  $\frac{4}{7}$  nat. size.

When we go as far north as the Værdalen Valley we find mainly the sandstones and shales of the Grey Hoek series on the eastern side, while on the western one the Wood Bay sandstones are seen to great extent, to the north with a cover of Grey Hoek beds. The beds dip slightly, somewhat irregularly. The boundary line between the Wood Bay and the Grey Hoek series reaches the coast somewhat north of Cape Auguste Viktoria. The transitional beds occur just east of the Cape, with Grey Hoek beds in the upper part of Mt. Prismefjell, below the lavas. The transitional beds show, besides (mostly red) sandstones, highly argillaceous and limy layers, generally with a marked yellowish weathering. In beds of fine-grained sandstone very distinct mud-cracks were noticed (fig. 10).

Besides poor fragments of fishes, ostracods were seen here: some large specimens (quite flattened by pressure), belonging to a *Leperditia* or *Isochilina*, and lots of quite small ones, probably a species of *Bythocypris*. Farther inland the beds pass into the grey arenaceous shales alternating with argillaceous (often also calcareous) sandstones that make up the Grey Hoek series. The typical mollusc fauna of the Grey Hoek beds are not seen in the transitional division. The Grey Hoek beds have evidently been far less resistant to tangential pressure than the red sandstones, for very marked folds are seen immediately we pass into their area (pl. IV, fig. 2). The Grey Hoek sediments now make up the country along the eastern coast of Wood Bay to the northern point, Grey Hoek, where the beds have previously been studied by NATHORST, who has given (1910, p. 316—318) a general description of the characters of the beds, pointing out the marked folding which is seen.

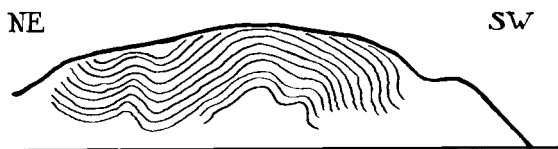


Fig. 11. Folds in Grey Hoek beds as seen in a mountain on the south side of the valley just SW of Grey Hoek.

The folding has often been very intense (fig. 11), dips of  $70^{\circ}$ — $80^{\circ}$  being commonly seen. The strike varies somewhat, in places it is NW, generally more N—S. At Jakobsen Bay a more W—E strike was noticed<sup>1</sup>. At Grey Hoek a strike somewhat east of N has been observed. A secondary cleavage is generally well developed in the shale.

In the shaly rocks the shell of the molluscs has often been dissolved, and only casts are to be seen, while in certain more massive, limy layers the shell substance is still present, as distinctly crystalline calcite. The material of fossils collected is now being studied by Dr. W. QUENSTEDT in Berlin.

### Some general remarks on the geology of NW-Spitsbergen.

The Heclahook-system with intrusive masses. We have not as yet even any approximate idea of the true stratigraphy of the NW Spitsbergen-Heclahook, of the relative age of the different sedimentary zones of which it is made up. It will certainly require very

<sup>1</sup> To judge from the colour of parts of some mountains in the inland area here (seen at distance only) the uppermost part of the Wood Bay sandstone may here be exposed in places. — Mr. CONRADI and Mr. LEWIN, mining engineers, have mentioned to the writer that they have observed, during a visit to Wood Bay a few years ago, the occurrence of thin coal seams with plant remains in the Grey Hoek beds at Jakobsen Bay. Further south they had noticed cupriferous quartz-barite veins in red sandstone.

detailed investigations, also a geological mapping in fairly wide areas before any definite results are gained.

The Heclahook-system of Prince Charles Foreland has fairly recently been studied by G.W. TYRRELL<sup>1</sup>, who has divided the rocks into three separate groups: Ferrier Peak series, Mt. Scotia series, Northern Grampian series, the relative age of these series being still uncertain, due to the highly complicated tectonic structure of this area like other Heclahook-areas of Western Spitsbergen. "The junction relations of the three series among themselves throw very little light on the question of their relative ages, because in practically all cases the junctions are lines of movement, either faults or thrust-planes" (l. c. p. 469). TYRRELL has tentatively suggested that the Mt. Scotia Series may be an equivalent of the "slate-quartzite series" of Bear Island<sup>2</sup>.

The Heclahook of Bear Island compared with the Heclahook of Spitsbergen, taken as a whole, is rather different in so far as it is to a much larger degree made up of carbonate rocks. The most natural explanation of this fact is that we have in Spitsbergen a stratigraphically more complete pre-Downtonian sequence than in the southern island. Taking into consideration the difference in size of the two areas the said conclusion is *a priori* an extremely probable one. The part of Spitsbergen where correlations with the Bear Island Heclahook most favourably can be made, is naturally the most southern area, the Horn Sound—South Cape area.

In the Bear Island paper of 1919 the writer emphasized that dark grey, often rather schistose limestones occurring in the Foreland Sound region of Spitsbergen, must be considered an equivalent of the Tetradium limestone. A locality in the said area of Spitsbergen where this limestone can be well studied, is Mt. Heidenstam, on the east side of the sound, rather far south. The beds lie here almost horizontally, with a thickness of at least 60 m. (Karbonablagerungen, II, p. 53). The same series has been observed also farther north in the same area, between St. Johns Bay and the Heclahook-Carboniferous boundary in Brøgger Peninsula.

It is very probable that dark grey limestones occurring still further north in NW-Spitsbergen belong to the same stratigraphical zone. I might mention e. g. limestone occurring in the Blomstrand Harbour region, and, to judge from specimens collected by HOEL, now in the Paleontological Museum of the University, limestone occurring in Wulff Mts. north of Liefde Bay. In the most northwestern corner of Spitsbergen this type of rock must not be expected to occur, the carbonate rocks here, near

<sup>1</sup> G. W. TYRRELL, The Geology of Prince Charles Foreland, Spitsbergen. — Transact. R. Soc. Edinburgh, LIII, Part II, 1924.

<sup>2</sup> O. HOLTEDAHL, On the Paleozoic Series of Bear Island etc.— Norsk Geol. Tidsskrift, V, 1919, p. 141.

the great intrusive masses, being altered into crystalline, more or less light coloured, often nearly white rocks.

Another type of carbonate rock commonly occurring in NW-Spitsbergen is a light coloured dolomite, weathering yellowish or grey, and often with layers or chert-like nodules of quartz (in fact a rock that, in not too metamorphic varieties, resembles types of the *Cyathophyllum* limestone of the Carboniferous). This rock variety is also met with in localities east of Foreland Sound and probably the carbonate rock of Mt. Sars (cp. p. 4 of the present paper) belongs to this group. Further the (highly metamorphic) rock east of the Loüet Glacier (p. 8). HOEL has brought light coloured dolomite from Wulff Mts., the carbonate mass here (as seems to be frequently the case in NW-Spitsbergen) being made up in part of darker grey limestone, in part of light coloured, often yellowish weathering and rather impure dolomite or dolomitic limestone. Fragments belonging to these two types of rock make up the greater part of the coarse conglomerate north of the Pt. Bruce Peninsula in Red Bay (p. 9), a fact also indicating that the two types are more or less related. The dolomite mentioned above is the type which in my Bear Island paper I have considered a probable equivalent of "the younger dolomite series", this series in Bear Island lying directly below, and apparently passing into the dark Tetradium limestone. A more detailed study of some of the imposing zones of carbonate rocks occurring in NW-Spitsbergen, e. g. east of Kings Bay—Cross Bay, will no doubt give stratigraphical results of interest.

Quite recently N. E. ODELL<sup>1</sup> has published a stratigraphical table of the Heclahook formations studied by him in districts of the northeastern part of West Spitsbergen. According to this table the lowest member 1. is a thick quartzite series, then comes 2. dark shales etc., 3. marbles and dark dolomitic limestones, 4. red shales etc., 5. pale and dark dolomites and limestones of great thickness, 6. black and white chert-horizon, 7. cherty conglomerate. Here number 5 may correspond with the younger dolomite series and the Tetradium-limestone of Bear Island (and with the dolomite-limestone succession just mentioned from parts of NW-Spitsbergen).

I do not know of any occurrence of conglomerate horizons in the NW-Spitsbergen Heclahook, north of Kings Bay, but it is rather improbable that one or more should not occur, as conglomerates are known from different areas further south, in the west coast zone.

In my Spitsbergen paper of 1912 (*Karbonablagerungen II*) I drew attention to the fact that in the area east of the Foreland Sound the Heclahook-rocks seem to be more metamorphic to the north than to the south, this fact making it probable that "man im Norden die

<sup>1</sup> In Abstract of the proceedings of the Geological Society of London, No. 1139. November 11th 1925, p. 4.

Faltungszone in einem tieferen Niveau entblösst findet als im Süden" (p. 60). Specimens collected by later Norwegian expeditions in the Horn Sound district show the rocks to be, at least in part, very little altered in that southern region (there occur clay-slates and practically undeformed oolitic and conglomerate rocks), while in the Cross Bay region, even in regions very far from any visible mass of granite, the Heclahook are always, as far as I have seen, rather highly metamorphic. This, then, might indicate that in general the west coast zone, due to a greater upheaval to the north after the time of the Caledonian deformation, has been eroded to a greater depth to the north than to the south.

According to TYRRELL the conditions seem to be different in Prince Charles Foreland, the Ferrier Peak series, which shows "a more advanced recrystallisation-metamorphism than the rocks of the other two series", occurring in the southern part of the island. TYRRELL states: "In other words the Ferrier Peak series may represent the rocks of the central and deeper parts of the orogenic belt to which Prince Charles Foreland belongs; the Mt. Scotia and Northern Grampian Series representing the more marginal and superficial parts" (l. c. p. 467). The writer's investigations on the east side of the Foreland Sound were far too short to cover the whole ground, yet my impression is that the Heclahook rocks met with by me along the northern part of the sound, are rather different from the compact dark mudstones and the finely banded, arenaceous, argillaceous or calcareous rocks, making up the Mt. Scotia and Northern Grampian Series respectively, occurring on the western side, in the northern part of the Foreland. The Ferrier Peak Series, of the more southern part of the island, seems to be well represented also on the east side of the Foreland Sound. The facts as yet known may indicate that the Foreland-Heclahook-zone tectonically has behaved as an independant area compared with the adjacent Heclahook-zone of the mainland of West-Spitsbergen.

The occurrence of a large area, mainly made up of intrusive masses, in the most northern part of NW-Spitsbergen seems to go well with the idea of a greater original upheaval and greater denudation of the Heclahook-mass to the north. Here the erosion has reached the zone of the great intrusions, the igneous masses farther south occurring (at the present surface) either as relatively narrow zones or as fairly small isolated masses.

The granites of the NW-corner have been microscopically studied by SCHEDELIG (cp. introduction), on the basis of material collected chiefly by HORNEMAN. A number of various types have been identified, belonging to two generations, the first represented mainly by grey granites, often of a gneissose character, the other by undeformed red rocks.

Now passing eastwards, the pre-Downtonian area east of Red Bay is petrologically evidently very different from the area to the west of that

bay. The igneous rocks are quantitatively of secondary importance, and there does not occur here, as far as I have seen, granites of the type found to the west. Instead I have noticed here the rather peculiar garnet-bearing rocks of granitic or gneissic structure, mentioned on p. 11. Now this fact may have two explanations: either the great intrusions of the NW corner have had, in the Red Bay area, a rather well-marked eastern boundary originally (which is rather probable, to judge from conditions elsewhere in NW-Spitsbergen) or a different depth of denudation may be the explanation also in this case.

Farther south in the horst west of the Bock Bay-fault, granite occurs in very great quantities (cp. e. g. HOEL's sections in "Les nappes de lave — —", p. 20). To judge from specimens at hand these eastern granites seem to belong to a rather distinct type; they are rather dark rocks, rich in biotite, with very commonly a certain porphyritic character. They may be more or less schistose.

The Old Red Series. Rather interesting rocks are the basal conglomerates at Red Bay. As stated in my paper of 1913 (p. 708) these conglomerates, of continental origin, "were laid down in troughs in the still not base-levelled land surface". That the surface was far from even is shown by the coarseness of the transported rock fragments of various of the conglomerate varieties and also by the fact that the material of the boulders or pebbles is highly different in various localities, the rock sometimes being made up almost exclusively of limestone-dolomite rocks, sometimes with no such rocks at all. This must mean that there existed ridges separating between various basins of deposition. That these basins from the beginning had the form of long and narrow depressions is probable, both from the conditions found and from general considerations, the basement complex containing both very resistant and more easily denuded rocks, arranged in zones striking about N—S.

Now, as to the mother-rock of these conglomerates, the basement breccia SW of Lake Rabot, figured pl. II, fig. 1, is derived from the pre-Old Red rock lying directly below it. Concerning the limestone-dolomite conglomerate occurring immediately to the west of this breccia and, in the direction of the strike, farther north, the material cannot well have come from the northeast or east, as in these directions no such rocks occur (at any rate in greater quantity) in the immediate vicinity. From observations made by HOEL important masses of limestone-dolomite rocks occur just to the south, in Wulff Mts., this carbonate zone being probably the continuation of limestone-dolomite masses which I have observed (from the ship) on the south side of Liefde Bay in 1910. If we continue this zone northwards we reach the eastern side of the Red Bay basin. With the existence of ridges stretching NNW as a probable supposition, the most natural conclusion seems



to be that the limestone-dolomite conglomerates on the east side of Red Bay have got their material from a ridge of carbonate rocks now buried beneath the sea and beneath the rocks of the Red Bay series in the eastern part of Red Bay.

On the eastern side of the Isachsen Plateau one can still see limestone conglomerate, in a zone of very great length, resting on the limestone basement rock. Here in the south, as at Red Bay, the conglomerate shows a marked dip, towards the west, caused by a dislocation after the Red Bay series were laid down. The result of this orogenic movement was not only that this particular zone of the crust got a westward dip; also other deformations have taken place, as is evident from the conditions shown in fig. 6. The close occurrence of two conglomerate rocks of so different a character as seen here, strongly indicates tangential movement, and when studying the isolated conglomerate mass south of Lake Richard (fig. 5) I got the impression that this rock does not rest on its original basement but has been thrust in some way or other.

Rather interesting rocks, occurring in the conglomerate last mentioned, are the quartz-porphyrines, as these rocks, showing no deformation, probably belong to the younger, red granite-series known from the inland southwest of Red Bay (— east of Magdalena Bay, Smerenburg, etc. — cp. HOEL's map in the Monaco publication, pl. XXII). Now the region to the north of this granite-area, especially the central part of the Albert I Peninsula, has not yet been investigated, so there is a possibility that red granites (with porphyritic facies) may occur also there, thus to the west of the occurrence of the conglomerate in question.

Previously has been mentioned the occurrence of granite, highly crystalline limestone etc. in the conglomerate on the west side of Red Bay, this occurrence indicating a transport from the west — or no important transport at all — the feature also telling of a very important denudation of this part of the Caledonian zone of folding before the time of the deposition of this conglomerate. Where the detrital material of the preceding part of the period of erosion has gone, we do not know.

While the basal part of the conglomerate division of the Red Bay series shows a great variety of rocks, indicating to a large extent a local origin, we find higher typical quartz-conglomerates (made up of quartzite and vein-quartz), with well-rounded, water-worn pebbles of moderate or small size, these characters indicating the sorting and wear caused by a longer transport, by rivers.

As to the general mode of deposition of the sandstones of the Red Bay Series — and the sediments of the Old Red Series of NW-Spitsbergen in general — a few remarks were published in my paper of 1913, to

which paper I may refer. The occurrence of *Leperditia*<sup>1</sup> can only mean that at times the extremely shallow water bodies which more or less covered the flat delta-land<sup>2</sup> were a part of a (probably brackish) inland sea, communicating with the ocean.

The round calcareous bodies found in such enormous masses in certain beds of the Red Bay sandstone do not — though in some cases a sort of stratification can be seen on the weathered surface — represent a true conglomerate rock with fragments of older (pre-Down-tonian) limestones, the limy material having been deposited in the same main period as the sand of which the greater part of the rocks now consist. We might perhaps speak of some of the layers as intraformational conglomerates, the stratification that seems to exist in some of the round limy bodies indicating a broken-up layer, rather than a true concretion. (However, we know, e. g. from the Cambrian alum-shales, that concretions of lime may have a sort of bedding.) A well known occurrence of similar limy bodies in sandstones of continental type is that of the Lower and Middle Siwalik (Tertiary) formation of India. I might in this connection refer to a statement concerning the formation of concretionary limestone deposits in terrestrial sediments of tropical countries at the present time, given by H. B. MAUFE, while discussing the Triassic “cornstones” of the Morven Island, in Western Scotland<sup>3</sup>.

Quite typical concretions formed around fish-fragments are found in the Red Bay Series in Mt. Pteraspis near Liefde Bay (cp. HOEL 1910, p. 7).

That the Old Red sandstones of Spitsbergen have been mainly deposited below water and do not represent subaerial sediments, is indicated both by their regular bedding with generally no marks of erosion and by the common occurrence of remains of organism living in water (fishes and bivalves).

I shall not here go into the question as to the source of the enormous quantities of clastic material which make up the Old Red system of Northern Spitsbergen. I may refer to remarks in my paper of 1913, p. 710 and to my paper “Paleogeography and Diastrophism etc.” of 1920<sup>4</sup>, where I have maintained, from considerations of a

---

<sup>1</sup> From the Lower Old Red Sandstone of the Oban district of western Scotland a number of ostracods have likewise been reported, thus from one locality (the rock is a grey, bituminous shale): *Aparchites* sp., *Isochilina* sp., *Beyrichia* (?) sp. or *Drepanella* sp. Cp. Mem. Geol. Surv. Scotl.: The pre-Tertiary Geology of Mull, Loch Aline, and Oban, 1925, p. 31.

<sup>2</sup> While using the term delta-deposits for sandstone formations of the kind here discussed, one does not of course indicate that the area of deposition had a well pronounced delta-form, geographically speaking, but that we are dealing with thick and widespread river-laid deposits in the boundary area between land and sea.

<sup>3</sup> Cited p. 64 in the Mull, Loch Aline, and Oban Memoir cited above.

<sup>4</sup> Am. Journ. of Science, XLIX, p. 1. There are here some misprints: Titles of

more general nature, that the material has mainly come from a land area, at that time existing to the west of the Spitsbergen region of to-day, in the present area of the Norwegian Sea. Of course, at times, as during the initial deposition of the Red Bay Series, the material has been derived also, or only, from the present landarea of Spitsbergen.

There is at the present time a tendency in geologic thought to trace the individuality of various geological units, even very small ones, back to very old times, a tendency, for instance, to assume a depressed or sunken area with sedimentary rocks to represent, in the main features, an original trough of deposition. One might e. g. apply this principle to the Red Bay area and its continuation to the south and maintain that we had, just in this area, an original trough into which material was carried from both sides by rivers. This would further point towards the conclusion that we need not assume any continent west of the present land area as the source of the huge accumulations of conglomerates and sandstones. However, I do not think that such a supposition answers to the original conditions. The basal conglomeratic part is, of course, of a more or less local origin, but not the enormously thick, mostly rather fine-grained sandstones. The occurrence of a coarse conglomerate at the western border of the sedimentary area, at Red Bay, might be taken to indicate that the border of the original area of deposition of the corresponding time was not situated very far away; at the head of Liefde Bay, however, sandstone and shale occur close to the boundary towards the granites and limestone and the boundary is of fault-origin. We must further bear in mind that sandstones which must be regarded as contemporaneous and originally connected with the Red Bay sandstones occur rather far east, viz. below the Wood Bay Series just SW of the head of Wood Bay. Thus the W—E range of the zone of Red Bay sandstones is not at all so very small, and the only natural conclusion is that it has once been very much wider.

The Wood Bay sandstones show similar fine-grained types at the western boundary of the area, in which they now occur, as they do farther east, this fact indicating that they have once stretched much farther westwards. This conclusion is strengthened by the conditions farther south where the Wood Bay sandstones exist at least as far west as the western end of Mt. Pretender SE of Kings Bay with, as far as I have seen, about the same coarseness of grain here as more than 50 km. to the east, on the east side of Dickson Bay.

---

maps 9 and 11 should be changed and the remarks (p. 12) on the unrest of the North-Atlantic continent in Devonian time read thus: This unrest is seen in the Devonian sediments in the districts bordering the Norwegian Sea, the Skandik of De Geer, which sediments tell of enormous deposition of terrigenous material.

The present distribution of the Old Red sandstones now found in northwestern Spitsbergen has been principally determined by a very prominent faulting. That this faulting took place under a very considerable lateral pressure is indicated both by the conditions in the area east of Red Bay and east of Wood Bay as will be evident from what has been stated in p. 12 and p. 19.

The remarkable similarity in geological structure which exists between the faulted area of northern Spitsbergen and of Scotland has recently been pointed out by the writer<sup>1</sup>. The Red Bay fault has its parallel in the Great Glen fault, the Bock Bay fault in the Highland Boundary fault. In places the conditions along the latter faults correspond even in detail. One might e. g. compare the section at the fault-line just SW of the upper end of Wood Bay (where we have Heclahook to the west, then east of the fault Red Bay (Downtonian) sandstones, rather steeply inclined, overlaid by Wood Bay (Lower Devonian) sandstones which gradually get a more gentle dip<sup>2</sup>, with the section from southeastern Kincardineshire, shown by R. CAMPBELL in his paper of 1913 in *Transact. Royal Society of Edinburgh*, XLVIII, 4, pl. III, fig. 2.

As to the age of the marked N-S-running faults here mentioned, the Red Bay and Bock Bay faults respectively, we must decide on that point from a more general view-point only, as no rocks younger than the Old Red sediments themselves occur at or near the fault lines. From the conditions known to exist in the Klaas Billen Bay region (cp. e. g. NATHORST'S simplified diagrams in "Beiträge" p. 321), it must be concluded that the Wijde Bay dislocation (or dislocations), at any rate to a considerable extent, must be older than the Upper Carboniferous, and it seems then to be a natural conclusion that the dislocation bordering the main Devonian Graben also to the west, viz. the Bock Bay fault, is (primarily) of the same age. Now this Bock Bay fault does not cut the Devonian-Carboniferous area southeast of Kings Bay and northwest of Ekman Bay—Dickson Bay, but must have its continuation in a line of dislocation running WSW, crossing the Holtedahll Plateau and the Three Crowns Glacier. The question then is if this dislocation here is older or younger than the Carboniferous limestone series. What can be said definitely is that the occurrence of the *Cyathophyllum* limestone etc. (cp. pl. V, fig. 2) on the southern side of the said plateau and of the eastern part of the said glacier does not contradict

---

<sup>1</sup> O. HOLTEDAHL, Some Points of structural Resemblance between Spitsbergen and Great Britain etc. — *Avh. utgit av Det Norske Videnskaps-Akademi i Oslo*, 1925. — A detail not pointed out in that paper is that in the southern continuation of the structural belt of the NW-Highlands (with old rocks) we meet in the Mull district with Mesozoic and Tertiary (to a great extent volcanic) downfaulted rocks, while in Spitsbergen the Tertiary area near Kings Bay has a similar situation.

<sup>2</sup> Cp. HOEL'S section pl. XIII, fig. 2, of his paper (*Nouvelles observations etc.*) of 1914.

the conclusion that the fault is older than this limestone. I have in "Karbonablagerungen, II", p. 80 marked with figures the height (above sea level) of the base of the Carboniferous limestone at a number of places in this area, this map showing a southward inclination of that basal plane amounting to about 50 m. per kilometre. If we continue this basal plane towards the north it will be situated far above the Heclahook mountains north of the said line of dislocation, while if we continue the Devonian beds of the mountains east of The Diadem towards the north, we get straight into the Heclahook rocks, e. g. at the locality mentioned by me p. 6 (the "Snekolle" of the map in "Gjennem ukjendte strøk", p. 122). As far as can be seen, a fault must divide between this Heclahook mass to the north and the Old Red sandstones to the south, while we have no direct proof that also the Carboniferous limestone has been cut by this fault.

In the lower part of the Three Crowns Glacier there exist quite other conditions; here we find faults that are directly seen to cut also the Carboniferous beds (cp. map II and section p. 79 in "Karbonablagerungen" II), but this area is of another structural type, being influenced by the post-Eocene west-coast dislocations.

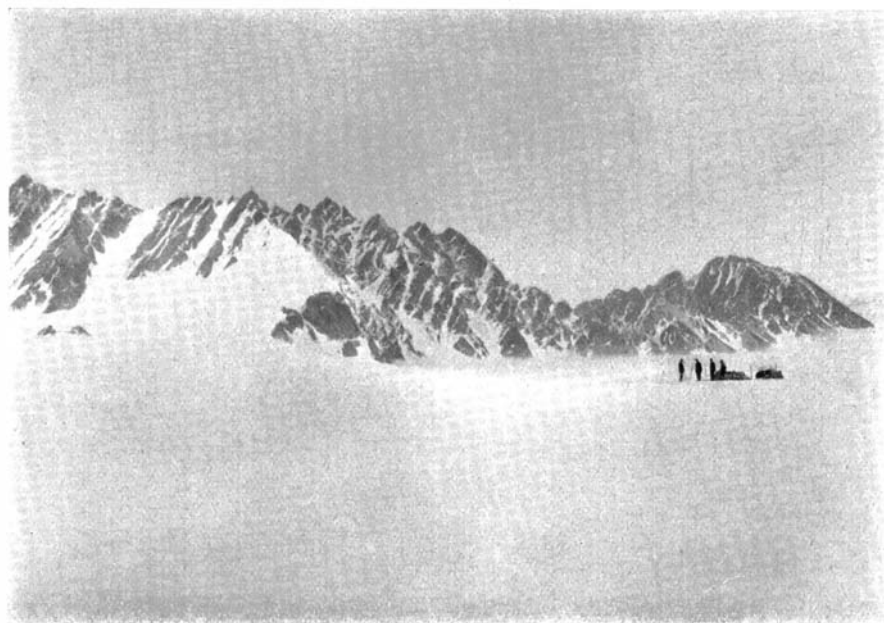


Fig. 1. Mountain on the south side of Penck Glacier. In the western part (to the right) alternating zones of granite and mica-schist occur (p. 8).

O. Holtedahl phot. Aug. 7. 1909.



Fig. 2. Mountain on the east side of Red Bay, north of Point Bruce (just SE of the lagoon). Below: Hecla-hook-schists; above: basal (limestone-dolomite) conglomerate of Red Bay series. (The boundary line is specially marked) (p. 9).

O. Holtedahl phot. Aug. 17. 1909.

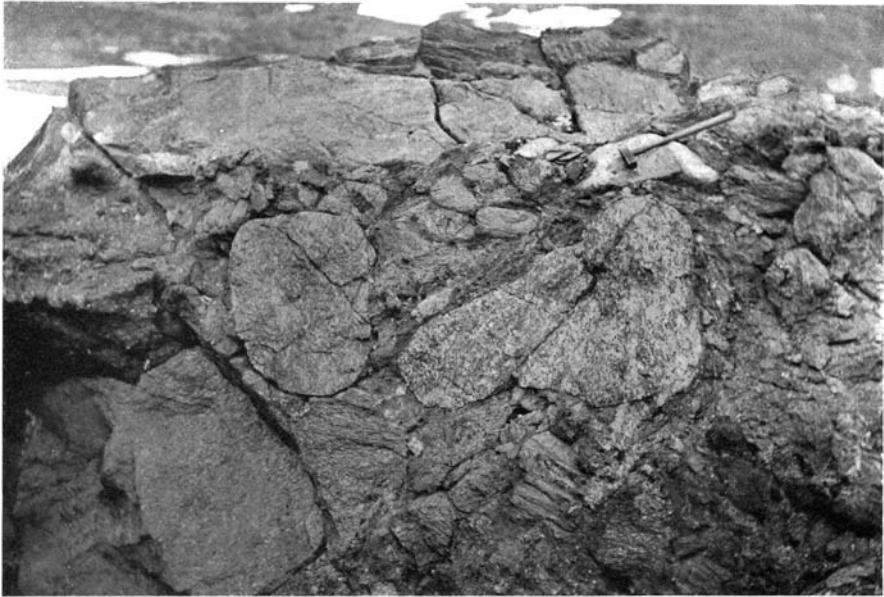


Fig. 1. Very coarse, basal conglomerate (or breccia) just above the pre-Downtonian basement complex. SE-side of valley, SW of Lake Rabot (p. 11).

O. Holtedahl phot. Aug. 1. 1910.



Fig. 2. Conglomerate (boulders commonly the size of a man's head) NW of Mt. Lillieborg, which is seen in the distance (p. 12).

O. Holtedahl phot. Aug. 17. 1909.



Fig. 1. At the fault-line at Broad Bay. To the left (NE) sandstones of the Wood Bay series, to the right Hecla hook-schists (p. 14).

O. Holtedahl phot. Aug. 24. 1909.



Fig. 2. The rounded mountain to the left (E) is Mt. Högkulla, made up of the red sandstones of the Wood Bay series; the mountains to the right consist of Hecla hook rocks, the fault-line running SE-wards in the valley (p. 14).

O. Holtedahl phot. Aug. 22. 1909.





Fig. 1. View from Mt. Sørli towards W and SW. In the foreground red sandstones of the Wood Bay series. In the distance: Heclahook and granite mountains west of Bock Bay, and, nearer to the right, the peninsula (of Wood Bay sandstones) between Bock Bay and Wood Bay. The igneous mass of Mt. Halvdan occurs in a mountain slope to the left.  
O. Holtedahl phot. Aug. 13. 1910.



Fig. 2. Folds in the shales and sandstones of the Grey Hoek series, seen towards the north. Valley north of Mt. Prismefjell (p. 19).  
O. Holtedahl phot. Aug. 9. 1910.

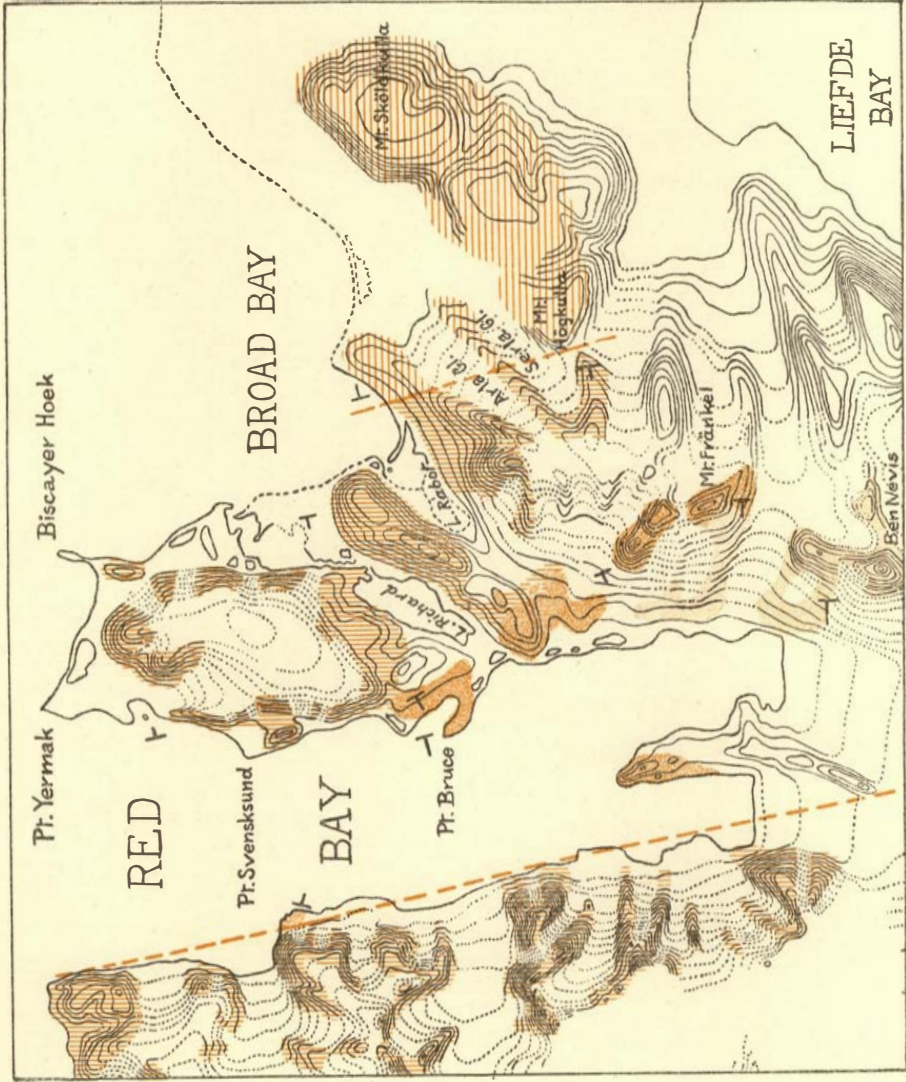
# THE RED BAY AREA

## Topography

from Isachsen's map  
"Spitsberg (Partie Nord-Ouest)"

Contour intervals 50 m

1:200000



Sandstones of  
Wood Bay Series.



Sandstones of  
Red Bay Series.  
Basal conglom. of  
Red Bay Series.



Hecla hook with  
intrusive masses.  
West of Red Bay  
mainly gneiss and  
granite, east of the  
bay mainly metam.  
rocks of sed. origin.

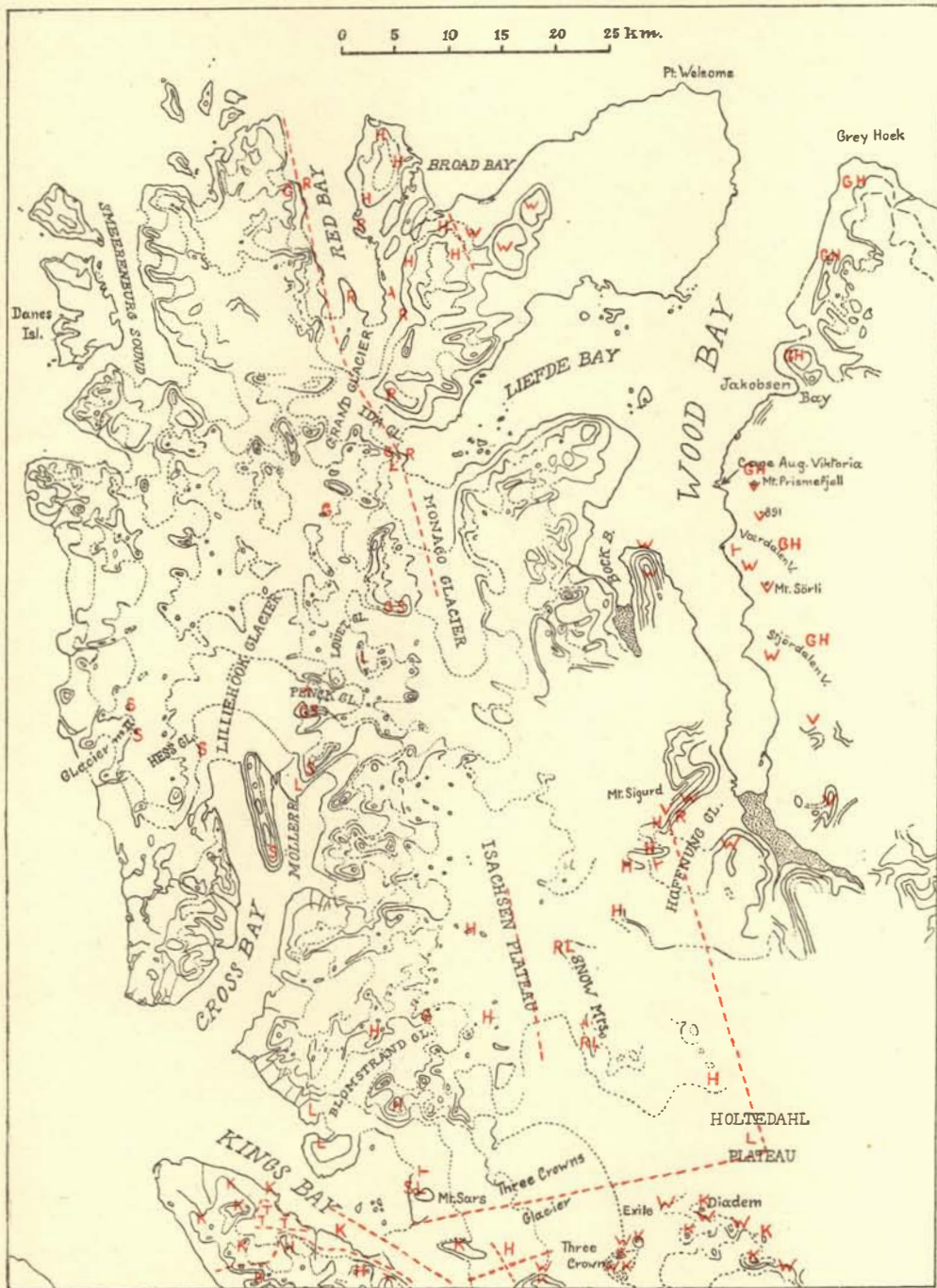


Principal faults.



### NORTH-WEST SPITSBERGEN

Topography from Isachsen's map "Spitsberg (Partie Nord-Ouest)"  
 Contour intervals 200 m. In glaciated areas the contour lines are dotted  
 Geological observations by the writer 1909—1911



- |                                    |                             |                                 |                         |
|------------------------------------|-----------------------------|---------------------------------|-------------------------|
| <b>F</b> Faults and thrusts.       | <b>GH</b> Grey Hoek Series. | <b>G</b> Granite.               | } Pre-Down-tonian rocks |
| <b>T</b> Tertiary.                 | <b>W</b> Wood Bay Series.   | <b>L</b> Limestone and dolom.   |                         |
| <b>V</b> Post-Paleoz. volc. rocks. | <b>R</b> Red Bay Series.    | <b>S</b> Schists and quartzite. |                         |
| <b>K</b> Carbonif.-Permian.        |                             | <b>H</b> Pre-Downt. in general. |                         |
|                                    |                             |                                 |                         |

A. W. BRØGGERS BOKTRYKKERI A/S