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NOTES ON THE DEVONIAN STRATIGRAPHY OF EAST GREENLAND

BY

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WITH 16 FIGURES IN THE TEXT

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I. Introduction.

The Devonian stratigraphy of East Greenland has previously been treated by several authors viz. NATHORST (1901), KOCH (1929 and 1931), WORDIE (1927), ORVIN (1930), BACKLUND (1930), KULLING (1930 and 1931), and PARKINSON and WHITTARD (1931). All these publications, however, have the character of pioneer work or preliminary notes and so has the present brief note, which is only intended to give a closer description of the rather limited areas investigated by the author during the Danish expedition in 1931. In connection herewith the author proposes to discuss some points regarding the principles to be followed during a future, more extensive, investigation of the East Greenland Devonian, and finally to make some comparisons with other Devonian areas.

During the whole investigation the author was assisted by Mr. E. NIELSEN and during the greater part of it further by Mr. H. LETH-PEDERSEN and Mr. D. LAURSEN. To them all he wishes to express his sincere thanks for much help and for pleasant collaboration. The author's thanks are also due to the distinguished leader of the Expedition, Dr. LAUGE KOCH, whose great experience and interest in our work rendered it possible to make effective use of the short time at disposal during an Arctic summer expedition. The author is especially indebted to Professor E. STENSIÖ for much help and a stimulating interest in this work. All determinations of fossil vertebrates are due to, or have at least been checked by, him.

II. Description of the localities visited in 1931.

Since the main task of the author this summer was to collect Devonian vertebrates, and the localities discovered in 1929 were by no means exhausted, most of the work was done within a few restricted areas, all more or less thoroughly investigated by previous authors (KULLING 1930 and 1931, and, to a less extent, KOCH 1931 and ORVIN 1930). The areas visited this summer are as follows in their chronological order:—

1. The northern slope of *Mt. Celsius* on Ymer Island, investigated during nearly 12 days;

2. *Cape Graah* on Gunnar Andersson Peninsula, visited during a two days' excursion from the main camp at Mt. Celsius and rapidly revisited on two later occasions;

3. *Margrethe Valley*, W. of Cape Franklin, rapidly and insufficiently surveyed on a motor-boat excursion leaving some hours only for the work on land, which was also much impeded by thick fog; and finally,

4. the southern part of *Kungaborgen* on Traill Island, where the last two and a half days on land were spent.

1. Mount Celsius.

The geology of the northern slope of Mt. Celsius has in the main been accurately described by KULLING (1931) on the basis of observations made during the Danish expedition in 1929, when great collections were secured from the talus at the "Coulisses" ("Kulisserna", KULLING's locality 3).

Last summer still greater collections were made, mostly somewhat more to the E., in the localities described below as the "East Plateau". The geology of Mt. Celsius was studied in somewhat greater detail and a profile through the fossiliferous red and varicoloured strata above the richest locality was investigated.

For purposes of description the northern slope of Mt. Celsius may be considered to consist of three larger units, the Western, Central, and Eastern part (see fig. 1). Its boundary to the W. is formed by a deep and rather narrow valley, the Fault Valley, so called by us because it marks a great fault, separating the "upper red" strata of Mt. Celsius from the "lower grey" series W. thereof, as was already pointed out by KULLING in 1931. The fault does not, however, as shown in KULLING's fig. 1, extend down through the whole valley but only follows its uppermost part, crossing it at the point where the valley bends from a NE. to a more northerly direction and is joined by a great glacier from Mt. Celsius (see KULLING, 1931, fig. 1). The lower part of the Fault Valley cuts through "lower grey" strata only. The uppermost part of the valley narrows very rapidly upward until it is only a deep cleft wholly filled up by a river. In this narrow part the fault-line can be very beautifully seen, as the lowered red beds, generally dipping some 10° to the SW., have here been tilted so as to dip 45° at the boundary towards the grey beds (see fig. 2). The latter are much disturbed and here dip 80—90° in various directions.

The high degree of disturbance of the grey beds can also be observed

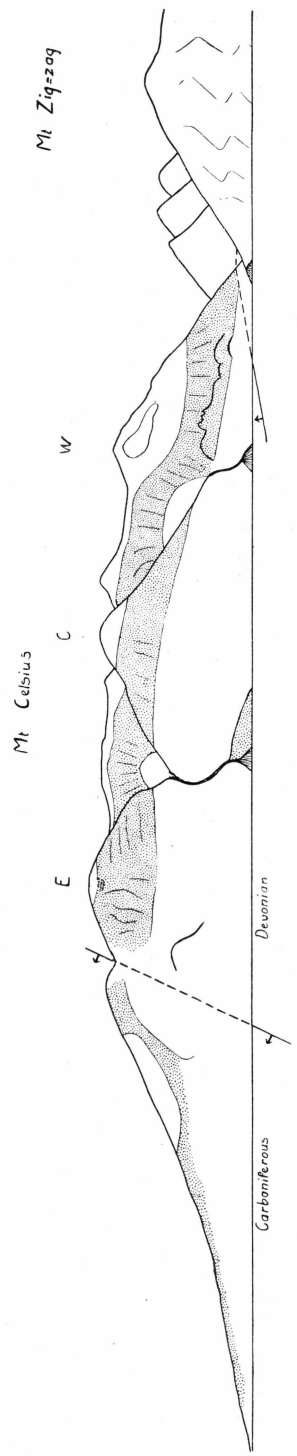


Fig. 1.
Mt. Celsius and Mt. Zig-zag seen from the N.
(After a sketch by the writer).

in the lower portion of the Fault Valley, where they are almost vertical (figs. 3 and 4). Here the sandstones are penetrated by some dykes of basalt. — In the northern side of the mountain rising W. of the Fault Valley, as seen from Cape Graah (fig. 1), the strata seem to have been folded in zig-zag, with the main dip about vertical. This mountain I propose to call Mt. Zig-zag.

The grey strata in Mt. Zig-zag and in the lower part of the Fault



Fig. 2.
The upper part of the Fault Valley seen from the E.
The writer's photo.

Valley were referred by KULLING to his "lower grey" series, though only in the figure (fig. 1, 1931). His motives for doing so are not mentioned in the text. No fossils have as yet been found in these strata; we only encountered some indeterminable plant remains, preserved as a coaly substance. Petrographically the strata under consideration consist of a light grey, faintly greenish, loose sandstone with more pronouncedly green parts. They often contain clay-balls and rounded pebbles of quartz.

From the lower end of the uppermost narrow part of the Fault Valley, where it has a direction E. 30° N.—W. 30° S., the fault-line bends in a direction E. 10° S.—W. 10° N., and crosses the valley. It

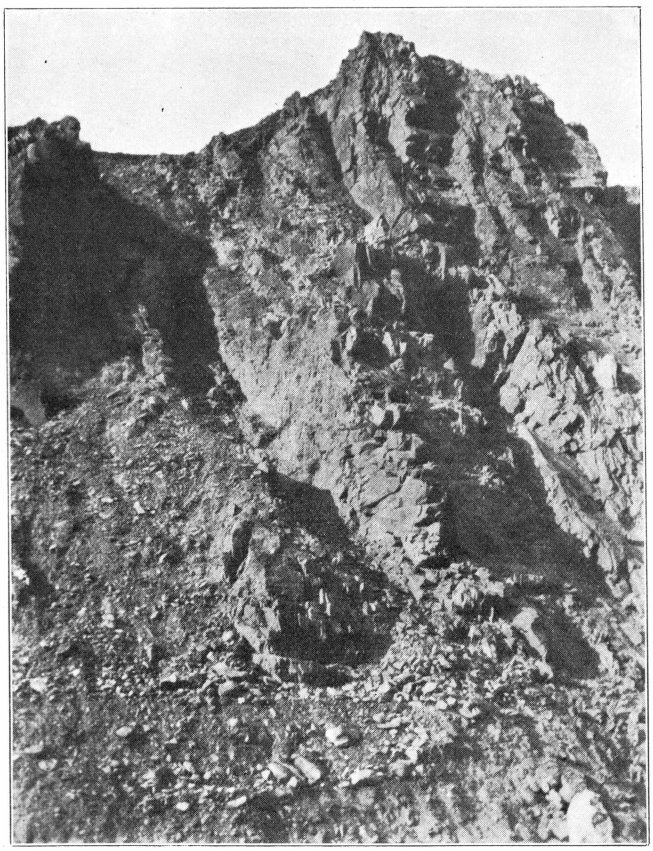


Fig. 3.
Vertical grey layers in the Fault Valley.
The writer's photo.

can again be beautifully seen in the eastern valley side (fig. 4). Here the thrust-plane dips 60—70° to the NNE. Then the fault probably passes

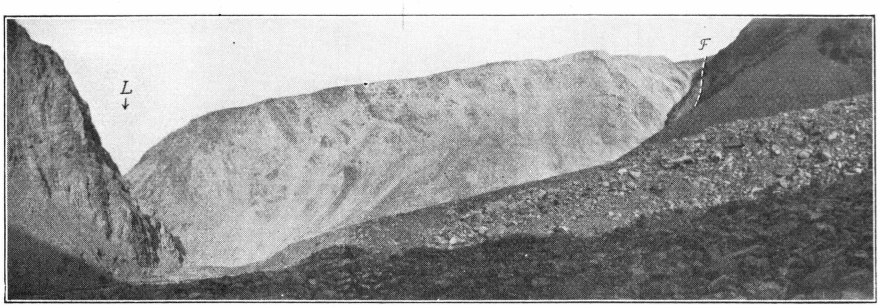


Fig. 4.
Part of the Fault Valley seen from the W.
The writer's photo.

not far north of the "Coulisses", where the ground, however, is covered with débris, so as to render direct observations impossible. No continuation of the disturbed grey strata can be seen E. of the Fault Valley. The rest of the Western and Central parts of the northern slope of Mt. Celsius belongs to the same large tectonical unit, lowered in relation to Mt. Zig-zag. However, this does not mean that there are no disturbances within the former unit. As we shall see later on, there are several minor faults and slips and possibly there are some greater ones too.

As is well known, the Coulisses were supposed by KULLING (1931 p. 8) to be "down-slid portions of the upper red sandstone series".

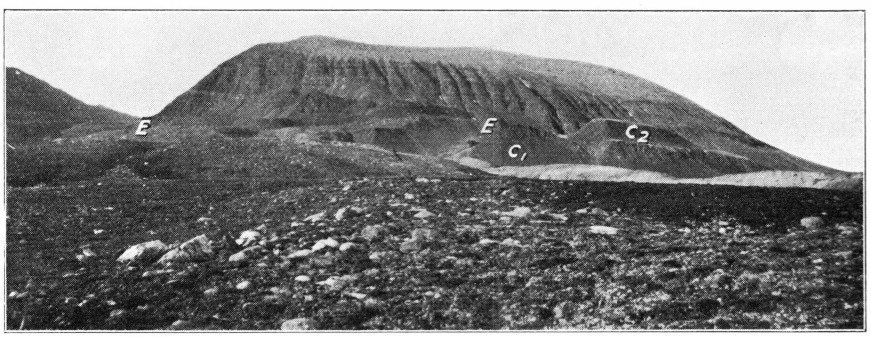


Fig. 5.
The western part of the northern slope of Mt. Celsius.
E—E, The East Plateau, C_1 the eastern, C_2 the western Coulisse.
Leth-Pedersen photo.

From our observations we are inclined to think that this is true, not only of the Coulisses but also of all the lower, terrace-like, parts of the red beds in the western part of the northern slope of Mt. Celsius. These terrace-like parts form a more or less continuous stretch from behind the Coulisses to the circus valley, cutting in between the central and the western part of Mt. Celsius. They form the locality called by us the "East Plateau" (fig. 5, E—E), a somewhat inaccurate appellation, as it is rather a terrace than a plateau. The conditions found in the eastern part of the East Plateau would seem to support the theory of the terraces being lowered in relation to the main mass of Mt. Celsius. Here the main dip was about 4° N. both in the main rock-wall and in the outer part of the terrace, whilst in an intermediate part the beds were inclined at an angle of 10°, and even 20°, towards the N., i. e. towards the lowered outer part of the terrace. — By far the greater part of the large collections of fossil vertebrates secured this summer were collected on the slope of the Western Mt. Celsius, partly at the Coulisses (especially on the northern slope of the western Coulisse: i. a. a well preserved

material of *Remigolepis emarginata* n. sp.), but mainly in the eastern part of the East Plateau. A great number of isolated plates of *Remigolepis Kochi* STENSIÖ were found on the western side of the sharp ridge (covered by the right E. in fig. 5), separating the locality of 1929 from the East Plateau. The East Plateau itself yielded abundant plates of *Remigolepis acuta* STENSIÖ and several fairly perfect specimens of other *Remigolepis*. Some crossopterygian and other non-antiarch remains were also found, especially in the higher parts of the slope, a little above the East Plateau proper.

All the fossils enumerated above were found in the more or less

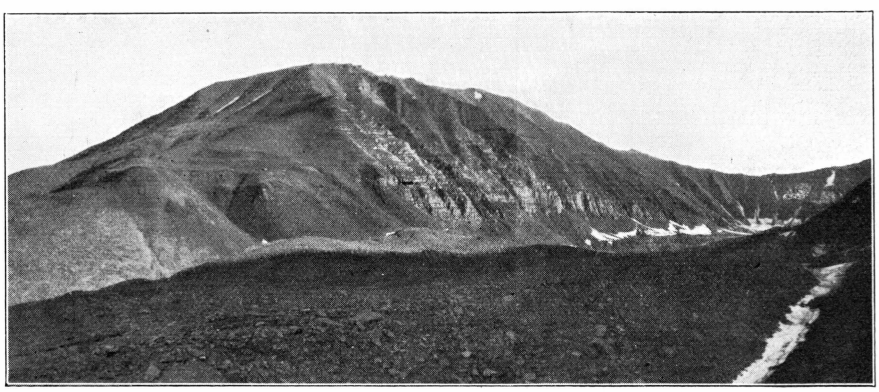


Fig. 6.
The Western Circus Valley.
The writer's photo.

local débris-masses and give no sure indication of the stratigraphy. But also an investigation of the solid rock was made at the East Plateau, though little time could be spared for this purpose. Below the plateau we found the "midmost grey" series of KULLING represented by banks of light yellowish grey sandstone with small (about 0.5 mm diam.) patches of a brown, and greater (3—5 mm diam.) patches of a greyish-green, colour. This sandstone occurred in situ here at a height of 165 to about 200 m and from 137 to 172 m farther to the W., in the bed of the rivulet issuing from behind the Coulisses. Its dip was 10—15° towards N. 10—30° W. Most of the lower part of the slope was found to be covered with débris of grey sandstone up to a height of 465 m at the easternmost corner of the East Plateau. Then followed upward the highly fossiliferous red and blackish talus of the East Plateau, and above it the first observable solid rock at a height of 529 m: dark reddish-brown, irregularly splitting, fine-grained sandy shale (1 m). This was overlain by 1.5 m of grey, richly carbonaceous shales, overlain by 1 m of red, irregularly splitting, sandy shales. At a height of 534 m the first fossiliferous

horizon occurred, a black-grey bank of very micaceous sandstone with three bands of irregularly splitting rock yielding *Remigolepis* sp.

Above this fossiliferous horizon lie 11 m of red irregularly splitting sandy shale with a harder bank at 540 m, and, at a height of 545 m, overlain by the second fossiliferous bank. This consists of a rock quite similar to that of the first one, the only difference being that it contains one fossiliferous bed only, situated at the base of the 1 m thick bank. The fossils found at this horizon were principally *Remigolepis emarginata* n. sp., of which species one specimen with head and arms and several isolated plates were found. The horizon may suitably be termed the *emarginata*-niveau. Apart from the species mentioned it has yielded isolated plates of *Remigolepis Kochi* STENSIÖ and possibly of *R. Kullingi* STENSIÖ as well.

The upper part of the profile contained no fossiliferous horizon equally rich or well defined. Scales of the type generally described as *Holoptychius nobilissimus* AG. and undeterminable crossopterygian scales were found in several types of rock and at different heights; as we shall see later on, such scales are, however, of little importance for the special stratigraphy of the East Greenland Devonian, since they occur throughout all the parts of it that have as yet yielded any determinable fossils. *Remigolepis*-plates of the *acuta*-type were found in the local débris at different altitudes, but the bank or banks from which this species originated could not be found.

The continuation of the profile, which thus gives no stratigraphical information of real importance, will not be enumerated in detail here, all the more so since unfortunately our altimeter, by an accident, did not function on the occasion when the profile was first studied. (The lower part with the stratigraphically important fossiliferous beds was revised on a later occasion when the altimeter was in order and repeatedly checked). So we shall only mention the main rock-types in the rapidly alternating[1]) strata found in the profile and point out some of the more striking features in their distribution. The rock-types include:

dark reddish-brown, irregularly splitting, fine-grained sandy shales with $CaCO_3$, very common throughout the "upper red sandstone series". These shales constitute about half of the whole thickness of this series. They often contain harder red banks and were also noticed to alternate with thin banks of black sandstone rich in small flakes of mica,

dark greyish-green, grey, and black, irregularly splitting, sandy clay-stone, without $CaCO_3$, also common throughout the "upper red" series,

[1]) In our notes the whole profile is stated to consist of not less than 58 distinct strata, one of which represents about 45, another about 30 m of the "alternating red and blackish sandy shales".

bright greenish-grey, sandy, calcareous, irregularly splitting, clay-stone with sun-cracks; occurred as a bank from a height of about 600 to about 620 m, with 1 m of red beds in the middle and 0.5 m of red strata in the upper part of the bank. This characteristic bank can be followed as a leading horizon even at some distance and will allow of a fairly sure correlation in the neighbourhood;

a dark grey, hard, thin-bedded, micaceous sandstone frequently occurs in the profile. Several somewhat different types can be recognised: with coarse or small mica-flakes, with flat or wavy bedding-planes, with or without cross-bedding, etc.;

a dark grey clayey conglomeratic rock, with small, bright, carbonaceous balls and often with small fragments of bone is another very prominent rock-type here, being most frequent in the middle part of the profile and often occurring as thin banks or lenses in the dark grey sandstone. It is in this conglomerate that most of the plates of *Remigolepis acuta* STENSIÖ, occurring in the talus on the East Plateau, are imbedded.

Reddish-brown, partly micaceous, thin-bedded hard sandstone and other rock-types also occur, forming more subordinate beds.

The transition to the overlying grey division, which latter must once have been of a very great thickness (see fig. 1, where it constitutes the whole upper third of the western part of Mt. Celsius though it is eroded at the top), contains a very typical rock, a thin-bedded, brown (faintly reddish) micaceous sandstone. The transition was built up as shown in the following profile:

top: débris of yellowish grey sandstone (KULLING's and ORVIN's "upper grey" series)
2 m brown, thin-bedded sandstone, rich in coarse mica-scales,
2.5 m débris of bright yellow sandstone, with small grains of red felspar,
6 m brown, thin-bedded sandstone,
8 m bright greyish-green, partly sandy clay,
10 m débris of grey sandstone,
0.5 m grey sandstone,
1 m reddish-brown, irregularly splitting, sandy shale,
2 m débris of grey, irregularly splitting, sandy shale,
1 m dark grey shaly sandstone, rich in small mica-scales,
9 m débris of grey and brownish-red sandy shale,
1 m brown, cross-bedded sandstone, rich in mica,
8 m red-brown, irregularly splitting, sandy shale, with thin harder banks,
5 m dark grey, irregularly splitting, sandy shale, with thin harder, brown banks,
1 m dark grey, hard sandstone with wavy bedding-planes (ripple-marks),
2 m brown thin-bedded sandstone and sandy shale,

11 m débris of thin-bedded brown sandstone,
0.5 m light-grey sandstone,
1 m thin-bedded brown sandstone, rich in small mica-scales,
base: 30 m alternating black and red sandy shale.

Owing to the circumstances mentioned above, the thicknesses are only approximate, but this part of the profile furnishes a good example of the rapidly alternating character of the rock.

In the upper grey division very few fossils were found, only a plate, possibly of *Bothriolepis*, and certain indeterminable plant-remains (*Knorria*-like stem-fragments, examined by Prof. HALLE, Stockholm).

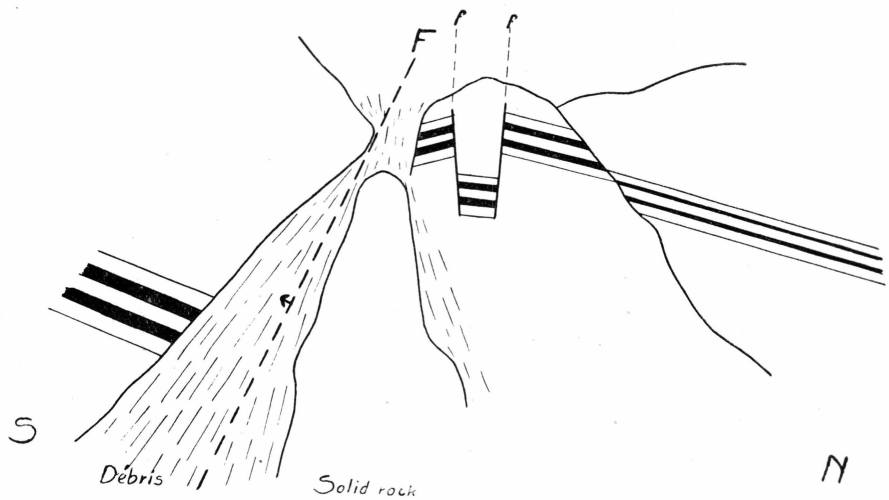


Fig. 7.
Diagrammatic sketch of the conditions in part of the western valley side of the Western Circus Valley. F, greater, f, minor faults.

As far as could be ascertained during an ascent to the western top, the whole upper, grey-coloured part of the northern slope of Mt. Celsius is concealed by the great masses of débris in which the fossils mentioned were found.

E. of the western part of Mt. Celsius now described lies a great circus valley, the Western Circus Valley (fig. 6), filled up by a glacier, now covered by such great masses of débris, that the ice can only be seen in the larger crevices. The western side of the valley was more closely examined in its northern and lowermost parts. The strata described from the profile above the East Plateau can be seen to continue round the corner along the whole western side of the valley and round to the E. The green bank with the two red beds mentioned above can be followed as a guide horizon, and by means of this it was possible to recognise smaller faults in the northern part of the western valley side.

Near the corner at the boundary towards the East Plateau such a fault of a throw of about 50 m was noticed, the southern side being lowered in relation to the northern, with a minor fault in the southernmost part of the raised mass (see diagram fig. 7). The dip was here 10—15° N. 30° W. Further a very prominent joint-system, striking E. 40° S. and dipping 60° towards the NE., and a subordinate one, dipping 45° towards S. 40° E., were noticed.

Below the Circus Valley the continuation of the "midmost grey" sandstone was observed, still higher than before, in the bed of the river issuing from the great glacier. — The inner parts of the valley will be more closely investigated next summer. Probably it will be possible to obtain a new profile here and to verify the horizontal distribution of the fossiliferous niveaus observed above the East Plateau.

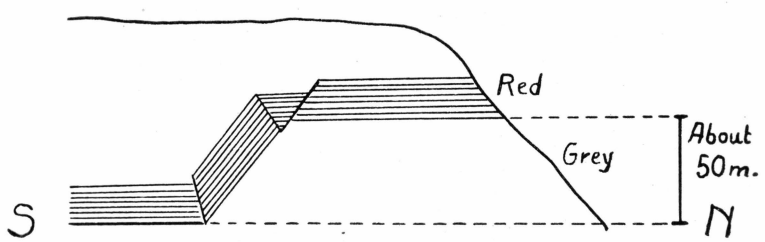


Fig. 8.
Diagrammatic sketch of a part of the western valley side of the Eastern Circus Valley.

The slope of the Central part of Mt. Celsius was crossed at a height of about 500—700 m and collections were made in the débris-masses, including i. a. *Remigolepis acuta* Stensiö, *R. Kullingi* Stensiö, *Holoptychius nobilissimus*? Ag.[1]) and *H. giganteus*? Ag.[1]). This part of the mountain is not very well suited for stratigraphical studies, owing to the broken and débris-covered character in the W. and the steep walls in the E. The boundary between the "midmost grey" and the "upper red" series is seen to lie at constantly higher altitudes the more one moves towards the E., as the central and western parts of Mt. Celsius form the western side of an anticline observed already by Kulling (1931 p. 6). The "midmost grey" sandstone, here with brown patches, forms terraces in the lower part of the slope, and lowest down, near the river descending from the Eastern Circus Valley (separating the

[1]) The scales here and in the following called *H. nobilissimus*? Ag. and *H. giganteus*? Ag. cannot be seen to differ from what is usually ascribed to the species mentioned. The ? points to the uncertainty as to which systematical unit or units correspond to a type of scale, and has no relation to the stratigraphical value of the fossils.

eastern part of Mt. Celsius from its central part) a red division was observed (KULLING's "midmost red" series). Fig. 9 illustrates the conditions here, showing in the foreground bright red, hard quartz-sandstone (I) with dark brown dots, overlain by bright coarse sandstone and conglomerate (II) with bright red grains of felspar and well rounded quartz boulders, and in the background the grey layers (III), consisting of brownish grey medium-grained sandstone with brown spots and

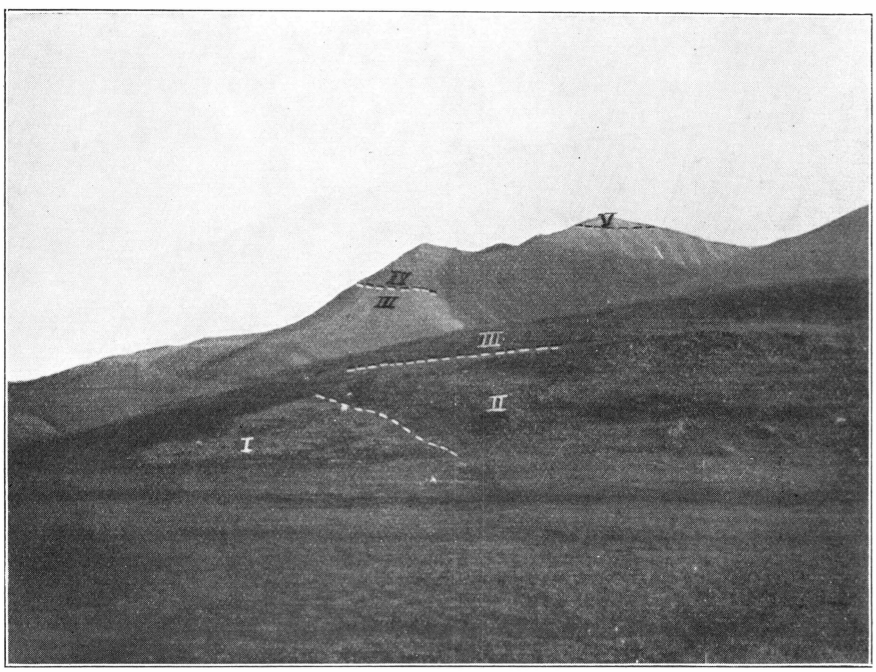


Fig. 9.
In the foreground red sandstone (I) and red (II) and grey (III) conglomerate and sandstone below the Eastern Circus Valley. In the background the Eastern part of the northern slope of Mt. Celsius with grey (III, V) and red (IV) layers.
The writer's photo.

conglomeratic parts containing well rounded quartz boulders. A dip of 32° N. 30° W. was noticed in the red sandstone. — In the easternmost corner of the central part of Mt. Celsius a minor disturbance was observed, as shown in fig. 8.

On the other side of the great Eastern Circus Valley, the northwestern corner of the Eastern part of Mt. Celsius (fig. 9) is seen to consist in the lower part of grey strata (III), overlain by red and variegated beds (IV). On the top grey strata (V) are seen, corresponding to the "upper grey" series of KULLING. The transition zone between the grey (III) and the red (IV) beds is observable in the solid rock and consists of bright

reddish-grey and yellowish sandstone, partly with brown patches, and alternating with dark brown thin-bedded sandstone rich in mica. Downwards the yellowish sandstone predominates and at the same time becomes brighter and finally yellowish-white with current-bedded brown grains and partly also with green patches.

The easternmost part of Mt. Celsius, separated from the other parts by a large fault, consists of basalt and continental Carboniferous rocks, studied this summer by Mr. D. MALMQVIST, to whose future publications the reader is referred.

2. Cape Graah.

On Cape Graah the previously known fossil localities of ORVIN (1930 p. 16) and of KULLING (1931 p. 9 and 12) were revisited and the

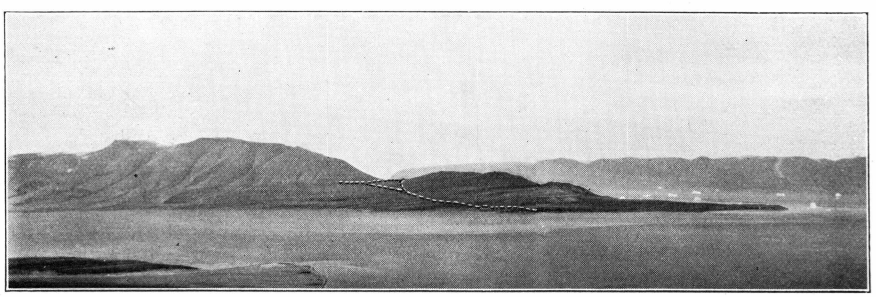


Fig. 10.
Cape Graah, seen from Mt. Celsius.
The writer's photo.

stratigraphy, especially of the southern slope, was studied. The stratigraphical relation of KULLING's locality 6 to ORVIN's locality with *Phyllolepis* was determined. KULLING's localities 4 and 5 on the northern slope of Cape Graah yielded nothing, or almost nothing, new and their stratigraphy was already described in some detail by KOCH in 1929 and subsequently by KULLING in 1931. Here we shall therefore only examine the conditions on the southern slope of the cape.

As is well known, Cape Graah consists of a broad syncline, whose axis dips to the N. Following the route indicated on fig. 10 from the Dusén Fjord to the localities of ORVIN (farthest W) and KULLING, we first encounter beds of grey to white sandstone with scattered conglomeratic boulders of small size. At the coast the sandstone is penetrated by a small basalt dyke, in the neighbourhood of which the sandstone assumes a greenish colour. Not far inland an indeterminable bone fragment occurred in the grey sandstone, but this was the only fossil we could find in the grey series. This grey series corresponds to KULLING's, and most probably also to ORVIN's, "lower grey series" as far as the descriptions by

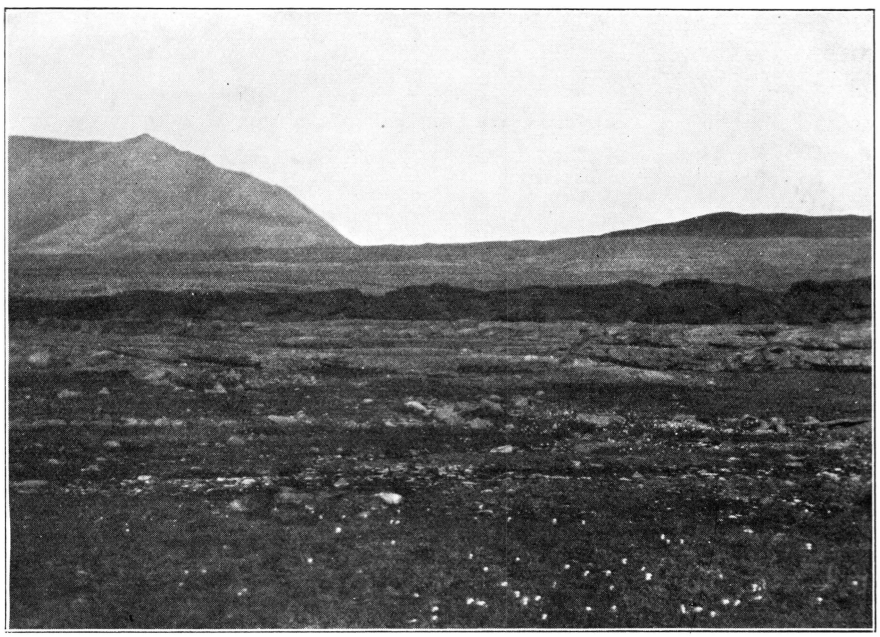


Fig. 11.
Basalt dyke in grey sandstone, Cape Graah.
The writer's photo.



Fig. 12.
Red conglomerate bank, Cape Graah.
E. Nielsen photo.

the said authors of the geology of Cape Graah go. It continues westward to and a little beyond a long basalt dyke shown in fig. 11. A sample from this basalt dyke has been handed over to Mr. MALMQVIST for petrographical examination.

The grey series is overlain by a red, coarse, strongly cross-bedded sandstone with scattered conglomerate balls. From a height of 210 m there occur banks of conglomerate (fig. 12), growing coarser upwards

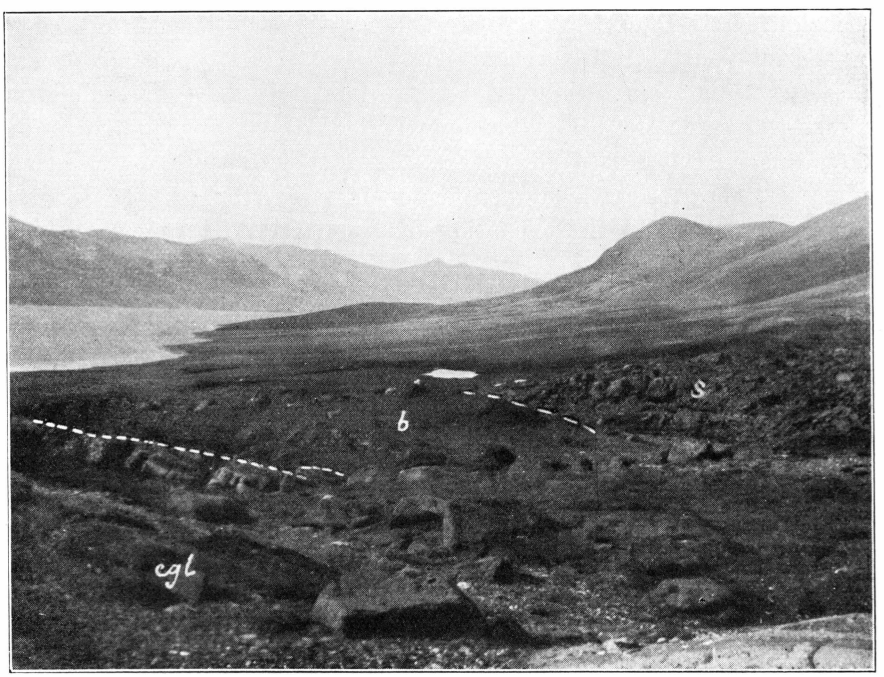


Fig. 13.
Basalt dyke (b) between red conglomerate (cgl) and red sandstone (s), Cape Graah.
The writer's photo.

and also containing examples of double conglomerate. At a height of 243 m a scale of *Holoptychius nobilissimus*? AG.[1]) was found in the neighbourhood of a small basalt dyke (fig. 13). — Above the conglomerates follows a series of bright red sandstone without conglomerate balls. Bright greyish-white patches occur throughout the series from the conglomerates up to the fossil horizon of ORVIN. The green-dotted type of rock in which ORVIN's fossil locality is also situated, occurs in isolated banks without fossils already some 15 m from the conglomerates and then appears over and over again, often in banks only one or a few centimetres thick. The sequence of strata in the upper part of the

[1]) See foot-note p. 15.

sandstones below ORVIN's locality and upward towards KULLING's locality 6 in the pass is illustrated in the photograph fig. 14. Below bed I in fig. 14 there is a bed of alternating green-dotted, light-red, and red-grey-mottled sandstone, underlain by a bed of light-red sandstone with dark-red lines of current-bedding and decimeter-thick bands of green-dotted light-red sandstone. The description of the rock-types I—V is given in the explanation of the figure. Above bed V (fig. 14), which shows the transition from the red zone with fossils to the overlying grey and varicoloured strata, on a level with a small lake below the pass, lies a grey coarse sandstone with brown clay-balls (1—2 cm diam.) and green dots (0.5—1 mm diam.). This is overlain by a light rose-coloured, somewhat reddish-white mottled sandstone, partly with faint green patches, and above this, in the pass itself, occurs a grey only faintly red-weathering sandstone. The rocks of the upper part of the series from type II in fig. 14 to the top, all, with the exception of the uppermost grey sandstone, contain $CaCO_3$.

KULLING's locality 6 is situated on a small ridge extending eastward from the pass. Thus topographically it lies higher than the pass, but owing to its more easterly position it is in about the same stratigraphical horizon as the pass. The petrographical character of the rock in KULLING's locality agrees well with the above-mentioned red-white mottled type, which near the above-mentioned lake below the pass yielded abundant scales of *Holoptychius*. Such scales were also found some 20 m above ORVIN's locality in the great masses of débris. *Holoptychius nobilissimus*? AG.[1]) and *H. giganteus*? AG.[1]) were recognised in this material.

In ORVIN's locality, at a height of 280 m, a rather large collection of *Phyllolepis*-plates and *Bothriolepis grönlandica* HEINTZ was secured. Scales of *Holoptychius nobilissimus*? AG.[1]) and *H. giganteus*? AG.[1]) also occurred and further a fragmentary posterior dorso-lateral plate of a large *Remigolepis*, not definitely determinable as to species. A less rich fossiliferous horizon was found some 8 m above the locality of ORVIN in a rock-type identical with the one at 280 m.

An average dip of 20—30° NW. was noticed in the eastern part of the great syncline.

The synclinal structure of Cape Graah was already pointed out by NATHORST (1901, p. 294), and later by KOCH (1929, p. 78), ORVIN (1930, p. 16), and KULLING (1931, p. 13). But as to the detailed sequence and the correlation with the beds on the opposite side of the Dusén Fjord there is still no certainty. ORVIN first expresses himself very cautiously, saying that "wenn längs dem Dusén Fjord keinerlei Verwerfung stattgefunden hat, müssen es die oberen Schichtenserien sein, die im Gebirge

[1]) See foot-note p. 15.

von Kap Graah wieder zum Vorschein kommen" (1930, p. 16). But later on (p. 17) he seems more certain about the correlation (the grey sandstone, underlying the fossiliferous red one "muss zur mittleren grauen Sandsteinabteilung gehören"), and the conclusion seems justified that he considered the red sandstone with green dots, in which *Phyllolepis* and *Bothriolepis grönlandica* HEINTZ were found, to be a somewhat aberrant type of the lower part of his "obere rote Sandsteinabteilung". In Mt. Celsius, where ORVIN's type profile is situated, this division is identical with KULLING's "upper red" series. — KULLING, however, evidently arrives at quite a different opinion concerning the stratigraphy of Cape Graah, the grey strata, in which his locality 6

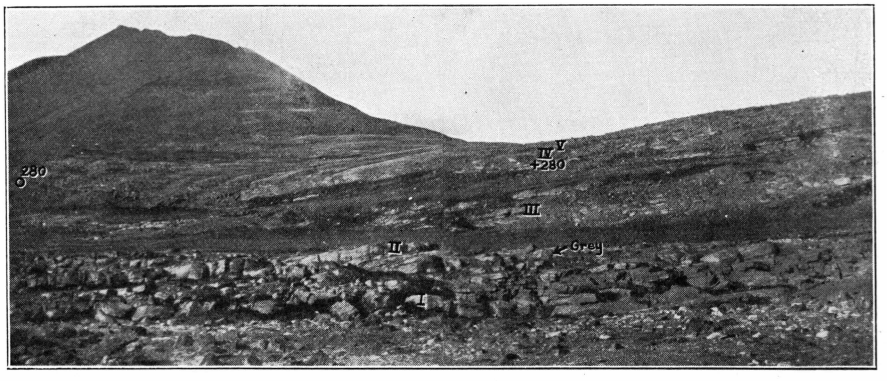


Fig. 14.
East of ORVIN's fossil locality, Cape Graah.
I, mixed grey and light-red, fine-grained sandstone, "Grey", grey, faintly greenish sandstone, II, III, IV, green-dotted (dots 1—4 mm in diameter), light-red, medium-grained sandstone, V, light reddish-grey sandstone, rather fine-grained, o 280 ORVIN's fossil locality, + 280 point in the same bank and in the same height as ORVIN's locality.
The writer's photo.

is situated and which overlie the fossiliferous red sandstone found by ORVIN, being by him correlated with his "midmost grey" division. The difference of opinion depends partly upon KULLING's supposition that the fault separating Mt. Celsius from Mt. Zig-zag continues through Dusén Fjord between Cape Graah and the Vinter Islands. — As will be emphasized later on, the only certain method of settling the question will be an investigation of the fossil content of the layers overlying (and underlying) those so far investigated in order to get a direct correlation of the faunas. A priori it does not seem very probable that the fauna of ORVIN's locality should belong to the same horizon as our localities on the northern slope of Mt. Celsius, as there seem to be no common species except *Holoptychius nobilissimus*? AG. and *Holoptychius giganteus*? AG., which are widely distributed throughout the Upper Devonian of East Greenland.

3. Margrethe Valley.

This is the same locality as the one called "W. of Cape Franklin" in earlier publications. It is especially interesting, as there occurs here a bright red (brick-coloured) series of rocks, part of which was supposed by KULLING (1931, p. 4) to be the uppermost division of the Devonian in East Greenland ("uppermost red" division). It consists of conglomerates[1]) and coarse sandstone. However, all investigations carried out here in regard to the Devonian are rather fragmentary and do not allow of any certain conclusions concerning the stratigraphy.

There are four areas of the "uppermost red" sandstone and conglomerate in the Margrethe Valley, two of which were visited by us last summer. The easternmost locality, close to the coast, showed some 20 m of a coarse red conglomerate, dipping 5—10° W. and overlain by the supposed upper Carboniferous *Posidonomya* shales. There are several small faults along the coast and the conglomerate is evidently bounded on the E. by a fault, *Posidonomya* shales occurring at the same height as the "uppermost red" conglomerate. — The second locality is situated in a deep ravine[2]) W. of the main river of the Margrethe Valley and here the strata are apparently much disturbed and according to KOCH tilted to the S. Our examination of this locality was much impeded by thick fog, which made it impossible to see even one or two metres in advance. For a description of the tectonic conditions the reader is therefore referred to the recent work by KOCH (1931). The "uppermost red" series is represented in this locality by a very micaceous, coarse, often intensively red-coloured sandstone, showing cross-bedding and, at least in part, containing sandy nodules. Grey patches and greater grey-coloured parts occur. The boundary towards the supposed "upper grey" series is marked by a conglomerate. The supposed "upper red" series has the striped appearance common to this division; this fact forms the only, and indeed a very slight, basis for a correlation of the beds of Margrethe Valley with those of Mt. Celsius.

The third locality is the high mountain[3]) W. of the ravine just mentioned and another ravine W. thereof. Here the brick-coloured strata, apparently more undisturbed, seem to overlie the grey and the striped strata, but according to information given by Dr. KOCH, this mountain has as yet only been examined from a distance and we did not get an opportunity of examining it owing to the fog and the limited time at our disposal.

If we now try to form an idea of the stratigraphical relations of the "uppermost red" strata, we come to the disappointing result that

[1]) Referred by KULLING to the base of the Carboniferous.

[2]) KOCH's "Coral Creek" (1931, Pl. VI).

[3]) Corresponding to the area W of F 2 and F 3 on KOCH's sketch-map (1931, Pl. VI).

these are as yet quite obscure. No fossils have been found in the conglomerates and sandstones under consideration, and their position in relation to the "upper red" series, which is the only division of the East Greenland Devonian somewhat characteristic petrographically, has not been proved in a convincing manner. In fact, at present we cannot even say whether the "uppermost red" strata are Devonian or Carboniferous (corresponding to the continental lower parts of the Carboniferous of other localities). And even if they are Devonian, it has not yet been proved that they really represent the uppermost part of the said formation, as owing to erosion the supposed Upper Carboni-

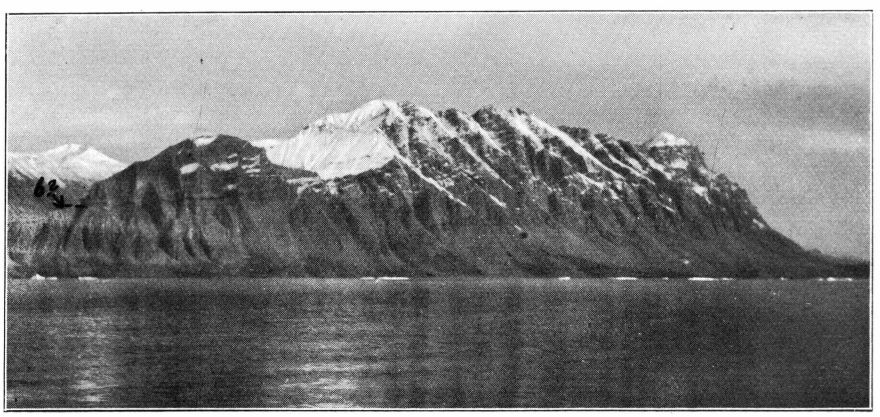


Fig. 15.
Kungaborgen, western side. — b? probably basalt.
D. Laursen photo.

ferous *Posidonomya* shales may, of course, just as well rest upon a lower as upon a higher part of the Devonian. And if the "uppermost red" beds actually lie on top of the Devonian, we do not know whether they differ stratigraphically from the grey layers elsewhere making up the uppermost observed part of the profiles or only represent a local facies of the upper part of the "upper grey sandstone series". In favour of the latter supposition speaks the strikingly small thickness of what would correspond here to the "upper grey" sandstone so well developed in Mt. Celsius.

4. Kungaborgen.

On the way from Ymer Island to the southern part of Kungaborgen I made several sketches of the Devonian in the fjord sides. My observations as to the apparent structure of the fjord sides agree in the main with Orvin's results of similar observations but, as also pointed out by Orvin, such investigations are but little exact. One may get an idea of the relativity of their value by comparing for instance Orvin's conception of the stratigraphy of the western part of Gauss Peninsula

(1930, fig. 4: III) with that of KULLING (fig. 4, 1931). For this reason I prefer not to publish any sketches based upon observations from the boat only, but to await an opportunity of making investigations on land.

The southern part of Kungaborgen (fig. 15) consists of sandstones, dipping mainly to the NE.[1]). On the western side is seen a dark band (fig. 15,b?), and as the masses of débris at the coast below contain several blocks of basalt, it is probable that the said band consists of this kind of rock. However, owing to lack of time the ascent of this part of Kungaborgen must be postponed till next summer. Judging from the débris and the striped appearance, the rocks constituting the uppermost part of Kungaborgen on this side seem to include more varying types of rock than the southern and lower part more closely investigated last summer (see below!). The types of rock occurring in the débris include greyish-green, striped grey, light grey, and red sandstones. As the uppermost beds, owing to the general dip mentioned above, continue downwards towards the sea in the N., it will probably be possible to investigate them by an ascent of the more accessible parts of Kungaborgen farthest to the left (N.) on fig. 15.

The southern corner of Kungaborgen, representing the lowermost part of the deposits exposed here, consists almost exclusively of a monotonous greyish-green sandstone at least up to a height of 900 m along our route, indicated in fig. 16. From the coast reddish areas can be seen, but upon arrival at the spot this colour was found to be due only to a superficial crust of light brownish-red calcite.

The first solid rock in the southern slope of the main mass of Kungaborgen was encountered at a height of 370 m: hard greyish-green sandstone. A little higher up micaceous brown banks up to 2 dm thick occurred. According to information given by Mr. MALMQVIST, the colour is probably due to weathering. Conglomerate lenses occur in the sandstones and a small basalt dyke and a sill were also noticed in the southern slope of the mountain. Minor disturbances were observed, small masses of rock having slid down and standing nearly vertical. The upper part of the greygreen sandstone was noticed to be more purely grey.

From 922 m upwards the sandstone becomes dotted with red, owing to the occurrence of pink grains of felspar. Fish remains were found at different heights in the local débris; the best pieces allowed of a generic determination. One articular plate from the arm of a *Bothriolepis* was found at an altitude of 797 m in the ordinary grey to greyish-green rock. A scale of *Holoptychius* was found at an altitude of 497 m.

[1]) For instance a dip of 30° to the N. 50° E. was measured at a height of 300 m in the western side, not far from the southern corner.

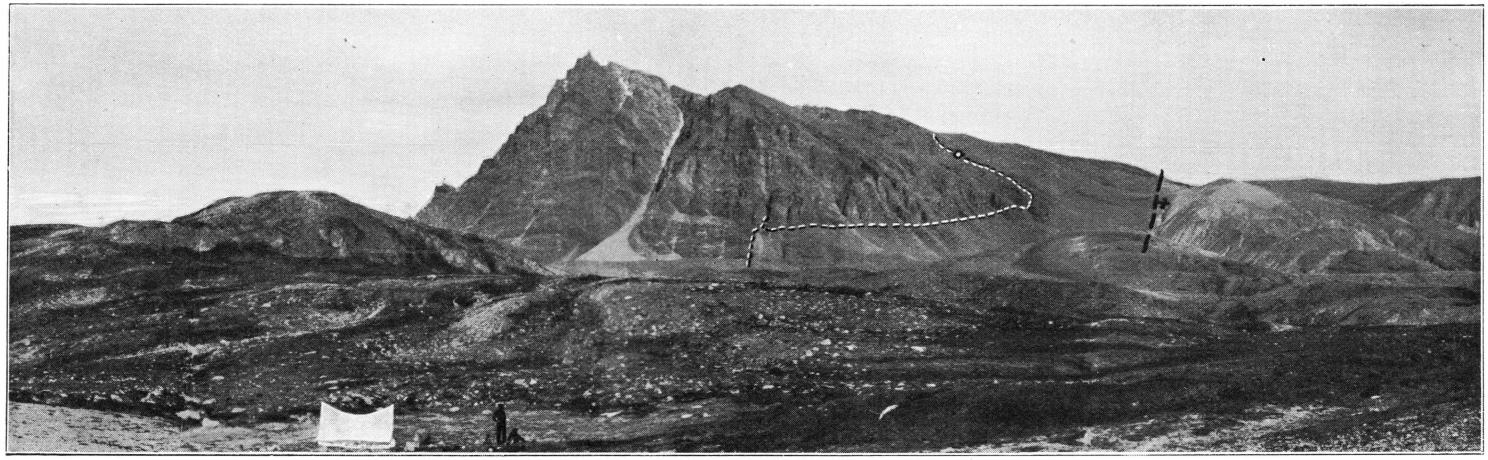


Fig. 16.
Southern side of Kungaborgen. -------- route of excursion: o 797 m.; — — — — fault line. The writer's photo.

Owing to lack of time the highest parts of the mountain were not investigated. Judging from the débris, red and red-green-mottled rocks with fish remains occur[1]). Basalt sills are also to be seen here.

The above description applies to the main wall of Kungaborgen. Minor rock-masses may be studied along the coast. The hill seen to the left in fig. 16 consists of banked greyish-green sandstone with shaly horizons, green clay-balls and lenses of fine and coarse conglomerate. The dip varies very much in the coastal rocks, which must all be interpreted as downslid masses. Intense folding was observed in some places along the western side of Kungaborgen. The joints in the coast rocks are often rich in calcite. — To the N. along the western side of Kungaborgen the sandstone becomes dotted with pink grains of felspar, and in one place it is conglomeratic and light red-white-mottled. Here some poorly preserved fossils were found. They are at present indeterminable.

To summarise; the southern part of Kungaborgen is made up of at least some 500 m of greygreen sandstone, overlain by greyish-green sandstone sprinkled with pink and at the top probably varicoloured strata. Fossils occur at least in the upper part of the greyish-green sandstone and in the overlying beds.

The basalt will be more closely discussed by Mr. D. MALMQVIST, who made excursions in this area in company with the author.

Finally it should be mentioned that when shortly before leaving Greenland we visited Mr. NOE-NYGAARD at the station of Cape Brown, he informed us that he had found Devonian sandstones, alternately red and grey, in the neighbourhood of the station. Poorly preserved fossils occurred. This is the southernmost Devonian area so far known in East Greenland. The fossils have as yet proved undeterminable.

III. General remarks on the sequence of strata within the East Greenland Devonian.

Turning now to the question of the general stratigraphical sequence within the East Greenland Devonian, we find that the previous attempts at classification, though they may, of course, turn out to be correct in the main features, are as yet founded on too slight a basis. If we examine the classification made by KULLING (1930 and 1931), we find that his different profiles are correlated by no common fossil horizon. Each profile contains one fossiliferous horizon only, and the

[1]) The fossils found in these débris-masses were very poorly preserved and are at present indeterminable.

fauna of the fossiliferous horizons differs in each profile. The classification is based on petrographical characters. These, however, do not seem to be very stable bases in the case of the East Greenland Devonian. One might for instance compare ORVIN's and KULLING's conceptions of the stratigraphy at Cape Graah, both founded on a detailed study of and comparison with the sequence of strata in Mt. Celsius. Of course we can accept the sequence in Mt. Celsius, which, according to ORVIN (1930), shows the strata from the "lower grey" to the "upper grey" series, as a petrographical norm. We know that the "upper red" series, as examined by KULLING, STENSIÖ (1931), and the present author, is characterised by the occurrence of the genus *Remigolepis* and especially of the species *R. emarginata* n. sp. and *R. Kochi* STENSIÖ. No other division in Mt. Celsius is as yet well characterised by fossils or even by its petrographical type. Therefore, as long as none of the said species of *Remigolepis* has been found on Cape Graah, and none of the typical forms from the well characterised fossil horizon of this area (*Bothriolepis grönlandica* HEINTZ and *Phyllolepis*) have been found in a determined horizon at Mt. Celsius[1]) we really cannot state what is their relative stratigraphical position, nor even which fossil horizon is the younger.

As to Gauss Peninsula it cannot be gathered from KULLING's statements on what grounds he parallelises the divisions of the beds there with those of Cape Graah and Mt. Celsius. But in the latter case it is probably on the basis of the striped appearance of the "upper red" division. In any case, a continued investigation of Gauss Peninsula, and especially a search for *Remigolepis*, are necessary for a well-founded judgment of the correlation with Mt. Celsius. As to the correlation of Gauss Peninsula with Cape Graah it would seem from the previous publications that the locality of ORVIN and KULLING's locality 7 (on Gauss Peninsula), both having yielded fossils mentioned as *Bothriolepis grönlandica* HEINTZ, must be contemporaneous. There exist, however, certain differences between the form from Gauss Peninsula and the true *B. grönlandica* from Cape Graah, i. a. a great difference in size, the latter being by far the larger of the two. According to Prof. STENSIÖ, who has examined our material from ORVIN's locality and KULLING's from his locality 7, we are probably here concerned with two different species.

The greyish-green sandstone of Kungaborgen was referred by KULLING (1930, p. 336) to his "lower grey" sandstone series, but was regarded as "probably somewhat younger than the grey sandstones farther north". KULLING was very likely influenced by Prof. HALLE's

[1]) HEINTZ (1930 p. 44) mentions one fragment of *Bothriolepis grönlandica* HEINTZ from the "Moräne des Tales westlich von Kap Humboldt".

determination of a plant from Kungaborgen as cfr. *Arthrostigma* (Lower to Middle Devonian). But in his latest publication HALLE (1931, p. 4, 5) has withdrawn his former determination, and the only fossil of any stratigraphical importance as yet found at Kungaborgen is the plate of *Bothriolepis* found last summer. This does not allow of a specific determination and cannot therefore be used for comparisons with other East Greenland fossil localities.

The "basal beds" (including the basal conglomerate and KULLING's "lower red sandstone series") also need further investigation. No determinable fossils have as yet been found in them and moreover they are not connected with any of the superior divisions in any of the fossiliferous profiles as yet published.

To summarise: we have now three well characterised fossil faunas in the East Greenland Devonian: 1. the *Remigolepis emarginata—R. Kochi*-fauna, 2. the *Bothriolepis grönlandica—Phyllolepis Orvini*-fauna, and 3. the less well known fauna with *Bothriolepis* from Gauss Peninsula. It remains for investigators to secure during the next few years a convincing correlation of these faunas. For this purpose especially Gauss Peninsula and the higher parts of Cape Graah must be investigated, and on the whole a diligent search for stratigraphically important fossils must be made throughout the Devonian series. So far the investigation of the East Greenland Devonian has only begun.

Before concluding this critical review of the present possibilities for determining the questions of the general sequence of strata in the East Greenland Devonian, I wish to point out the possibility that all the faunas discussed above may only be facially different and will turn out to be more or less contemporaneous. In that case it will afford an interesting study to investigate their distribution in relation to geographical and sediment-petrographical conditions. But a much more extensive search for fossils will be necessary before this question can be settled.

IV. Distribution of the East Greenland fossils in other areas.

Despite the scanty knowledge of the special stratigraphy of the East Greenland Devonian it is already possible to make interesting comparisons of its fauna with that of other areas and also to arrive at a definite opinion of its age. For the latter purpose we must first try to ascertain the general distribution of the Devonian vertebrates found in East Greenland. These comprise:

a) 1. *Remigolepis incisa* (A. S. Woodw.)
2. *R. acuta* Stensiö
3. *R. Kochi* Stensiö
4. *R Kullingi* Stensiö
5. *R. cristata* Stensiö
6. *R. emarginata* n. sp.
7. *Bothriolepis? ymeri* Stensiö
all from the "upper red" series of Mt. Celsius;
b) 8. *Remigolepis? tuberculata* Stensiö from Muskox Fjord;
c) 9. *Remigolepis* n. sp.? Stensiö (1931, p. 193) from Kulling's loc. 5 ("W. of Cape Graah"[1])
d) 10. *Bothriolepis grönlandica* Heintz
11. *Phyllolepis Orvini* Heintz
12. *Remigolepis* sp.
from Orvin's locality, Cape Graah;
e) 13. *Bothriolepis* n. sp. from Gauss Peninsula;
f) 14. *Bothriolepis* sp. from Kungaborgen;
and finally
15. *Holoptychius nobilissimus*? Ag.[2])
16. *Holoptychius giganteus*? Ag.[2])
both widely distributed, the former at least in association with the faunas a, c, d, the latter with the faunas a, d, and both moreover in various other localities;
17. other vertebrates not yet determined[3]).

Of the fossils enumerated above Nos. 7 and 8, being new and not generically determined, cannot be used for stratigraphical purposes. Of the rest only the two species of *Holoptychius* and the genera *Phyllolepis* and *Bothriolepis* are mentioned in the previous publications on Devonian fossils from other areas. But, as will be seen from the following, owing to most valuable information given by Prof. E. Stensiö, the author here is able to make use of observations as yet unpublished concerning the distribution of the species *Bothriolepis grönlandica* Heintz and the genus *Remigolepis*.

To avoid unnecessary repetition on discussing the distribution of the East Greenland forms in other areas, we shall proceed area by area instead of species by species.

Beginning with a most classical area, we shall examine the distribution of our fauna in England and Scotland. We find that (according

[1]) Cape Graah is used by Kulling in a more restricted sense than in the present paper.

[2]) See foot-note p. 15.

[3]) Cf. Addendum p. 37.

to SMITH WOODWARD's Catalogue, EVANS 1917, and information given by Prof. WATSON to Prof. STENSIÖ) *Holoptychius nobilissimus* AG. and *Phyllolepis* (*concentrica* AG.) are characteristic of the fauna of Clashbennie (Perthshire) and *Phyllolepis* also of the allied fauna of the Dura Den beds with *Bothriolepis* (*hydrophila*). According to TRAQUAIR (1895, p. 252, 253, 259, 271, 1906, p. 76) the last-named genus, in the Moray Basin, is typical of the Elgin beds in contrast to the Nairn beds characterised by *Asterolepis*. GOODCHILD (1904) mentions TRAQUAIR's observation and states the Elgin beds to be the upper, the Nairn beds the lower, horizon. Both are included in his "Upper Old Red", considered by EVANS (1917, p. 136) a. o. to be equivalent to the Upper Devonian (cf. below p. 35, 36!). The genus *Bothriolepis* together with *Holoptychius nobilissimus* AG. and (except in the Rosebrae beds) *Holoptychius giganteus* AG. are also said by SMITH WOODWARD, EVANS, and WATSON to be characteristic of the Scaat Craig and Alnes beds (*Bothr. major*) and the Rosebrae beds (*Bothr. cristata*), all near Elgin (SMITH WOODWARD, Catalogue p. 325, 327, EVANS 1917, p. 118). In the Rosebrae beds *Phyllolepis* is also found (EVANS 1917, p. 119).

Bothriolepis and *Holoptychius* (probably *H. nobilissimus* AG.) likewise occur in the beds found by the boring at Southall (PROCTOR and SMITH WOODWARD 1913) in a sort of bone breccia; in the Pickwell Down sandstone near Woolacombe (ROGERS and SMITH WOODWARD 1919) there occur i. a. *Bothriolepis* and scales of *Holoptychius*, and the former fossil is found in the Upper Old Red sandstone of the Ludlow District (Farlow, WOODWARD 1904) and, together with i. a. *Phyllolepis*, *Holoptychius nobilissimus* AG. and *H. giganteus* AG., in the same series of sandstone in the Bristol District (WALLIS 1928). The red sandstones and conglomerates of the Cheviot Hills (EVANS 1917 p. 112) have also yielded *Bothriolepis* together with scales of *Holoptychius nobilissimus* AG.

According to a very recent publication by LERICHE (1931), the sandstone of the Condroz (famennien) in the Belgian Devonian contains i. a. *Holoptychius flemingi* AG., *H. murchisoni* AG., two species of *Bothriolepis* (*lohesti* LERICHE and sp.), and one of *Phyllolepis* (*undulata* LOHEST). It is evident from LERICHE's description that his *Hol. murchisoni* AG. is the species generally called *H. giganteus* AG. and his figures of *Holoptychius flemingi* AG. cannot be distinguished from the East Greenland *H. nobilissimus*? AG. and what is generally called by this name (cf. his figures on Pl. VII with STENSIÖ's Pl. XXXV). Thus there is a fairly good agreement in the composition of the fauna of the Condroz and that of East Greenland, though there also occur some species in the former that have no equivalent in the latter. This, on the other hand, differs in yielding representatives of the genus *Remigolepis*. With regard to the distribution of the fossils in the different parts of

the sandstones of the Condroz it is interesting to note that *Holoptychius nobilissimus* Ag. (or "*H. flemingi* Ag." according to Leriche) is distributed throughout the series from the beds of Montfort to the "macignos d'Ouffet", in the latter occurring in association with *Spirifer verneuili* and 8 species of fishes not common with East Greenland (i. a. *Dinichthys*, *Dipterus*, *Onchus*). The middle part of the beds of Evieux (the uppermost of which is the "macigno d'Ouffet") contains the fauna most closely allied to that of East Greenland viz. *Phyllolepis*, *Bothriolepis*, both species of *Holoptychius*, and only three other forms, whilst the lowest fauna (fauna of Montfort) is very insufficiently known.

In the Baltic Provinces and western Russia we have another classical Old Red area. In the Baltic Provinces, according to Gross (1931, p. 6), there is a very marked faunal difference between the lower sandstone division (below the marine transgression, which according to Gross is upper Middle Devonian) with abundant *Asterolepis ornata* Eichw., Psammosteids etc. and the upper sandstone division (above the marine layers) characterised by *Bothriolepis* (*B. panderi* Lahusen), *Holoptychius giganteus* Ag. and "other Holoptychians with their thick and great scales". *Phyllolepis* seems not to occur E. of the Belgian localities. As pointed out by Gross the Upper Devonian fishes of western Russia and the Baltic Provinces need renewed investigation. However, the stratigraphical distribution of the fishes in the Devonian of NW. Russia has recently been treated by Dm. Obrutschew in a highly interesting article (Obrutschew 1930). This author points out the striking contrast that exists between the fish-fauna of the "lower sandstone" with *Asterolepis* and *Psammosteus* and that of the marine limestones and "upper sandstone" characterised by *Bothriolepis* (*B. ornata* Eichw. and *B. panderi* Lahusen) *Holoptychius giganteus* Ag., *Holoptychius nobilissimus* Ag. and *Holonema* (*H. rohoni* Obrutschew). In the next chapter, when discussing the age of the fish-faunas, I will return to Obrutschew's important paper.

The fishes of the Timan are unfortunately very little known (cf. Stensiö 1931, p. 10!). These fishes, when once well known, will become of special interest owing to the possible correlation with the marine layers. Tschernyschew (1890) mentions the abundant occurrence of *Bothriolepis* and *Holoptychius* in the porous dolomite, lying between the limestone etc. with *Spirifer anossofi* (below) and the beds with *Spirifer archiaci* and *Productus aculeatus* (above). The latter beds are again overlain by beds with *Rhynchonella cuboides*, *Spirifer elegans* etc. and by the Domanik (*intumescens*-zone). Rohon (1899) i. a. mentions *Bothriolepis*, *Holoptychius nobilissimus* Ag., *H. giganteus* Ag. and *Asterolepis*, but his determinations must be revised before a definite opinion of the fauna under consideration can be formed. In any case,

it seems to be of a type at least comparable to that of East Greenland, and a fresh investigation of the Timan is highly desirable from a stratigraphical as well as from a paleontological point of view. — In the Ural and farther E. the Devonian offers no point of comparison with that of East Greenland, the Upper and Middle Devonian, where developed, being of a marine type almost without fishes. (TSCHERNYSCHEW 1887, v. TOLL 1890 etc.). In the N., on the contrary, we meet with a comparable fish-fauna in the Upper Devonian of Novaya Zemlya. The Norwegian expedition of 1921 brought home from the base of the Mashigin series (HOLTEDAHL, Report no. 22, 1924) a small fauna, which was examined by KIÆR (Report no. 32, 1926). The material includes plates of a *Bothriolepis* and scales, teeth etc. of other fishes, i. a. *Glyptolepis*. The fauna is said to be distinctly older than those of East Greenland and Bear Island (KIÆR p. 11). In the same beds was found a *Lingula* and the layers were thought by HOLTEDAHL to have been deposited under brackish conditions. The Mashigin series is underlain by Lower and possibly Middle Devonian limestone and dolomite and above it follows a black limestone which seems to correspond well to the Domanik (see HOLTEDAHL, Report no. 22!).

Other Arctic areas also contain Old Red faunas comparable to that of East Greenland. Thus, according to previous publications (SMITH WOODWARD 1899, HOLTEDAHL and KIÆR in HOLTEDAHL 1919, HORN and ORVIN 1928), the basal conglomerate of the Ursa series on Bear Island has yielded *Holoptychius nobilissimus* AG., *H. giganteus*? AG., other species of *Holoptychius*, and plates of an Asterolepid. The very valuable information given me by Prof. STENSIÖ permits me to add to the knowledge of this fauna the determination of the Asterolepid as *Bothriolepis* cf. *grönlandica* HEINTZ. — The relation to the East Greenland fauna must be said to be very important, as there is only one of the definitely determined forms of Bear Island (*Holoptychius monilifer* A. S. WOODW.) that has not been found in East Greenland. There is another analogy between the two areas, in that in both of them a continental type of sediment prevails in all the formations observed, from above the Ordovician (top of the Franz Joseph beds or the Tetradium limestone) through the whole Devonian and Lower Carboniferous up to the Middle Carboniferous Ambigua limestone on Bear Island and the Upper Carboniferous in East Greenland.

On Spitzbergen the Upper Devonian, if really present[1]), should be represented by the Wijde Bay Series, yielding *Psammosteus*, *Asterolepis* (*A. scabra* (A. S. WOODW.)), *Onychodus*, *Dictyonosteus*, Ostracodes, and *Psygmophyllum* (STENSIÖ 1918, NATHORST 1920). This fauna seems more

[1]) Cf. KIÆR 1916 and STENSIÖ in NATHORST 1920.

comparable to the *Asterolepis*-fauna of the Baltic Provinces and NW. Russia than to any Upper Devonian fauna. *Bothriolepis* plates and scales of *Holoptychius* have not been found here and it also seems possible that the beds with *Rhadinichthys* (STENSIÖ 1918, p. 71) are of Middle Devonian age: another Paleoniscid has been found on Shetland together with Middle Devonian forms (FINLAY and SMITH WOODWARD 1926).

In the westward area nearest to ours we are also disappointed in regard to a possible correlation. The "unfolded post-Silurian sandstones" lying upon the Graptolite Shales in North Greenland (KOCH 1920) are as yet wholly unfossiliferous. KOCH in 1920 compared them to the series C of P. SCHEI's profile on Ellesmere Land but in his latest paper (1929b, p. 242) he has withdrawn this comparison and says, that "there is no evidence of a Devonian age" of the sandstones mentioned. — The age of the different Devonian series on Ellesmere Land has been a matter of controversy. Series B is generally regarded as Silurian or lowermost Devonian (see for instance HOLTEDAHL 1917, FOERSTE 1929), series C is as yet unfossiliferous and series D was first parallelised with the Lower Helderberg (middle part), upper Middle Devonian, up to the Chemung (MEYER and LOEWE, Reports nos. 29 and 30, 1913). The correlation with the Chemung was already claimed to be wrong by KIÆR (Report 33, 1915) on the basis of the fish-faunas found in the upper part of series D (Dh: *Macropetalichthys scheii* KIÆR, indicating Lower or Middle Devonian) and in series E (fishes indicating lower Upper Devonian, see below!), and also because of the scantiness of the facts brought forward to support the said correlation. More recently TOLMACHOFF (Report no. 38, 1926) has studied the invertebrate fauna of series D, arriving at the conclusion, that Dh represents the upper Middle Devonian or the transition from the Middle to the Upper Devonian, Di the lowermost Upper Devonian, and the lower part of the series not Helderberg, but Middle Devonian. The latter point of difference from the previous publications is partly due to new evidence from other areas, partly also to a revision of the determinations of the fossils.

To sum up, it now seems most probable that series B represents Silurian or lowermost Devonian, series C Lower Devonian, series D Middle Devonian, and series E at least lowermost Upper Devonian; the top of the series is not sufficiently known. The fish-fauna from series E, as described by KIÆR (Report 33, 1915) includes *Bothriolepis* (cf. *B. hydrophila* AG.), *Holoptychius scheii* KIÆR ("most closely related to *Holoptychius nobilissimus* AG."), *H.* cf. *tuberculatus* NEWB. ("might, however, be regarded as belonging to *H. giganteus* AG.") *Glyptolepis*- and *Osteolepis*?-scales, fish-teeth, a great coccosteomorph fish and two new species of *Psammosteus*. The fishes occur together with mussels

(*Phtonia* cf. *cylindrica* HALL). *Psammosteus* and *Glyptolepis* indicate a lower stratigraphical position than the fauna of East Greenland and Bear Island (cf. KIÆR 1915, p. 53, also KIÆR 1926, p. 11!). NATHORST (Report no. 1, 1904) has examined the material of fossil plants found in the series E, and describes them as Upper Devonian.

On the mainland of Canada we have one of the most cited occurrences of *Bothriolepis*. The Devonian of Scaumenac Bay, situated where the Restigouche River falls into the Baie des Chaleurs, has in fact yielded a material of *Antiarchi* that, according to our present knowledge of the forms, is only equalled by the Danish collections from East Greenland. The stratigraphical position of the interesting Canadian locality does not, however, seem to be wholly settled. The fish-bearing strata, described as "essentially grey sand-shales and sandstones" with fossiliferous nodules, concretions and blocky parts, are underlain by "loosely cemented boulder beds", the boulders containing "fossils which are for the most part of normal marine Lower Devonian age" and furnish no evidence of an age later than the Helderbergian (CLARKE 1911 and 1913). However, farther inland the fish-beds are underlain by "marine deposits with a lower Middle Devonian fauna" (CLARKE 1913). The fish-beds are overlain by conglomerate and sand of a red colour, the Bonaventure Formation. This formation (see CLARKE 1913, p. 91—92) is considered to represent the uppermost Devonian and early Carboniferous, though the only fossils found in it are "plant remains as yet undetermined". — The fauna of the fish-beds (see for instance CLARKE 1913) includes abundant *Bothriolepis* (*B. canadensis* WHITEAVES), further *Holoptychius quebecensis* WHITEAVES, *Scaumenacia*, *Eusthenopteron*, *Coccosteus*, Acanthodians, etc. and, curiously enough, also a species of *Cephalaspis* and possibly an Anaspid, *Euphanerops*.

In the fish-bearing Devonian of the United States there are two distinct faunal provinces, the eastern interior and the western interior (see for instance EASTMAN 1907). The former includes the well known New York Devonian. Here *Bothriolepis* is found in the Chemung and Catskill together with *Holoptychius giganteus* AG. and *H. americanus* LEIDY, which latter according to SMITH WOODWARD (1900, p. 6) is hardly different from *H. nobilissimus* AG.; a species of *Phyllolepis* (*P. delicatula* NEWBERRY) has been found in the Chemung of Pennsylvania[1]). — From the Elbert Formation in Colorado (CROSS 1904) EASTMAN (1904) has described a most interesting fauna, consisting i. a. of *Holoptychius giganteus* AG. and an Antiarch "*Bothriolepis coloradensis*" EASTM., which, as mentioned by STENSIÖ (1931, p. 11), judging from

[1]) The so called "*Phyllolepis elegans*" from the Rhinestreet shale (Portage) (HUSSAKOF and BRYANT, 1918, p. 21, Pl. 32, fig. 2) is quite indeterminable as far as can be judged from the description and the figure.

the illustrations seems to have a pectoral fin suggestive of the one in *Remigolepis*. It may be added that EASTMAN's description of the sculpture also differs from *Bothriolepis* and agrees with *Remigolepis*. The above-mentioned forms, all from Devon Point, seem to constitute a fauna somewhat different from the Aspen fauna of the same formation, the latter, according to Eastman, consisting of Arthrodires and Dipnoan scales. In any case, a revision of the Colorado fauna would be of special interest in regard to the possible great agreement with the fauna of the East Greenland Devonian.

Finally we shall consider some very remote faunas showing a most astonishing agreement with that of East Greenland. From the grey to black "Beacon sandstone" of Granite Harbour, Antarctica, SMITH WOODWARD described in 1910 a fragmentary fish-fauna, comprising i. a. a new species of *Bothriolepis* and small scales of *Holoptychius* (*Holoptychius antarcticus* WOODW.). It is said to be a clearly Upper Devonian fauna. A still more interesting fauna has been recently described by HILLS (1929, 1931) from Taggerty and Briagolong NE. and E. of Melbourne, Australia. Here i. a. a new species of *Bothriolepis* (*B. gippslandensis* HILLS), Phyllolepid plates, and, curiously enough, according to information by Prof. STENSIÖ, also representatives of the genus *Remigolepis* were found. The fossils originate from the yellow and red sandstones, and the red, blue, and green shales forming the middle part of the Upper Devonian, otherwise built up of rhyolites and basalts, and a basal conglomerate. Apart from the fishes and some not definitely determinable plant remains, no fossils are found here. The next fossiliferous beds below are Upper Silurian; above the Upper Devonian there follow, in the "upper paleozoic belt", beds that probably represent the Lower Carboniferous (HILLS 1931).

V. Age of the fauna.

As will be seen from the last pages, there are many, geographically widely separated, faunas which show a more or less close relation to that of East Greenland. In fact, the combination *Bothriolepis-Holoptychius* is a very cosmopolitan one, often, in western Europe and the eastern United States, combined with *Phyllolepis*. To form an idea of the age of this remarkable association we shall examine the stratigraphical position of some of the faunas compared above to that of East Greenland.

The greatest interest in this respect attaches to the three areas: NW. Russia, Belgium, and the United States. As mentioned above, the first of these areas has been recently treated by OBRUTSCHEW (1930). According to this author the fauna of the "lower sandstone" with *Asterolepis* etc. is Middle Devonian and contemporaneous

with the Nairn fauna of Scotland, which latter was formerly regarded as Upper Devonian (see for instance EVANS 1917)[1]). OBRUTSCHEW regards *Asterolepis* as an exclusively Middle Devonian genus. In the uppermost part of the "lower sandstone" (red and white sands with clay of Wjelik and Oredesch) the *Asterolepis*-fauna becomes mixed with *Bothriolepis* and *Holoptychius*, and here OBRUTSCHEW places the boundary between the Middle and the Upper Devonian. In accordance with NALIVKIN (for instance 1922) he regards the overlying limestones as Upper Devonian. Thus, according to the most recent investigations the combination *Bothriolepis-Holoptychius* occurs in NW. Russia throughout the Upper Devonian limestones and sandstones, though most frequently within the latter, i. e. within the upper part of the Upper Devonian. However, this greater freqency within the sandstones most probably has a facial, not a stratigraphical significance.

In Belgium and the United States, on the contrary, the forms under consideration occur — together with *Phyllolepis* — in the upper part of the Upper Devonian only, in the Famennien or the Chautauquan (Chemung and Catskill), whilst the lower Upper Devonian of the United States (Senecan) is characterised by other forms (*Ptyctodus*, *Dinichthys*, *Dipterus*; see EASTMAN 1907).

To sum up the results of the foregoing pages, the fauna of the East Greenland Devonian contains forms of very wide distribution in the Upper Devonian (*Bothriolepis-Holoptychius*), more especially in the upper part of the Upper Devonian (*Phyllolepis* only in the upper part). It is most closely related to the faunas of Bear Island, Elgin and Dura Den in Scotland, the Upper Old Red sandstone of the Bristol District, the beds of Evieux in Belgium, the Chautauquan, and possibly also the Elbert Formation in the United States. It is further related to the faunas of the "upper sandstone" in NW. Russia and the Baltic Provinces, of the Upper Devonian in Victoria, Australia, of the Beacon Sandstone, Antarctica, and of various localities in England and Scotland (Clashbennie, Farlow, Southall etc.).

The fauna of Ellesmere Land with *Psammosteus* and the related fauna of Novaya Zemlya with their mixed Middle and Upper Devonian character seem to correspond to the uppermost part of the "lower sandstone" in NW. Russia and the fauna of Whitemire in Scotland (with *Asterolepis* and *Bothriolepis*). To this group of faunas perhaps also belongs the fish-fauna of the Timan (cf. p. 31) and of Scaumenac

[1]) The question of the age of the divisions in the Old Red of England seems to have been often influenced by the occurrence, or non-occurrence, of disconformities (see for instance GOODCHILD 1904). These, however, — striking geological features, as they may be — are essentially local phenomena and for correlations at greater distances the faunas only can be used.

Bay in Canada. As to Spitzbergen there is as yet no evidence of the occurrence of any Upper Devonian, since the genus *Asterolepis* and its allied fauna here, at Nairn, in the Baltic Provinces and in NW. Russia, must now be regarded as most probably Middle Devonian.

Addendum.

When this paper had already been sent to the press, I received from Dr. A. HEINTZ an interesting paper on some new material of Devonian fishes from East Greenland (ANATOL HEINTZ, Beitrag zur Kenntnis der devonischen Fischfauna Ost-Grönlands, Norges Svalbard- og Ishavsundersøkelser, Skrifter om Svalbard og Ishavet, Nr. 42, Oslo 1932). He describes i. a. a new interesting Arthrodire, *Grönlandaspis mirabilis*, from the southern slope of Mt. Celsius. The plate of an antiarch, figured by HEINTZ in Pl. III, fig. 2 and described by him as *Asterolepis* sp. is indeterminable, but may possibly belong to a *Remigolepis*. It should be pointed out in this connection, that HEINTZ's paper ist dated June, 1931, i. e. before the publication of STENSIÖ's important paper on the far better preserved Danish material.

It may finally be added that Professor STENSIÖ has recently recognised also remains of a Dipnoan in our collection from the central part of the northern slope of Mt. Celsius.

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