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THE STRUCTURE OF THE KEJSER FRANZ JOSEPHS FJORD REGION, NORTH-EAST GREENLAND

BY

N. E. ODELL

WITH 22 FIGURES IN THE TEXT AND 6 PLATES

KØBENHAVN
C. A. REITZELS FORLAG
BIANCO LUNOS BOGTRYKKERI A/S, KBHVN.
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PREFACE

The field observations and data upon which this paper is based were obtained by the writer as geologist to the "Louise A. Boyd Expedition to North-east Greenland, 1933", of which Miss LOUISE BOYD of San Francisco, U. S. A., was leader and photographer, and which was planned and conducted by her with the cordial cooperation and assistance of the American Geographical Society of New York, U. S. A.

The itinerary of the Expedition, and other studies by several of its members, have already appeared in Miss BOYD's book "The Fiord Region of East Greenland", published in 1935 by the American Geographical Society. Elsewhere also the present author has described additional observations, especially those relating to the glaciology and geomorphology of the region[1]).

Herein it is proposed to give a somewhat summarised account of certain stratigraphic and tectonic findings, made particularly within the inner districts of the Kejser Franz Josephs Fjord region. It is intended later to follow up this study with petrographic descriptions of the rather comprehensive collection of material made.

The substance of the present paper was read at the Norwich Meeting of the British Association in 1935[2]). Delay in its publication has been occasioned by the subsequent absence of the author on expeditions in the Himalaya during 1936 and 1938.

Cambridge University, England
June, 1937.

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[1]) "The Glaciers and Morphology of the Franz Josef Fjord Region of N.E. Greenland", Geograph. Journ. 90, 1937.

"Franz Josef Fjord, and the Mystery Lakes District. Some Discoveries during the Boyd Expedition, 1933", Scottish Geograph. Mag. 53, 1937.

"Within and Without the Arctic Circle", Alpine Journ. 46, 1934.

[2]) British Association Report 1935, Sectional Transactions-C., 1935.

INTRODUCTION

To WILLIAM SCORESBY junior, the whaler, must be given the credit for making the first geological collection on the east coast of Greenland in 1822. His quite extensive finds were examined by Professor JAMESON, and the material was pronounced to be predominantly of gneiss and other "primitive" rocks. But it was the Second German North Polar Expedition of 1869—70, the discovers of the Kejser Franz Josephs Fjord, that made the first real contribution of merit, and showed the presence of a wide variety of formations. NATHORST's Swedish Expedition in 1899 and OTTO NORDENSKJÖLD in 1900, however, first laid the foundations of our later knowledge of the stratigraphy and structure. The two Cambridge Expeditions under J. M. WORDIE, in 1926 and 1929, carried on the good work, and the many Danish and Norwegian expeditions, especially, have all made valuable contributions and published important geological maps in recent years.

A rather remarkable feature of North-east Greenland, i.e. that part lying north of Scoresby Sound, is the number of representatives of the Geological Succession which lie exposed in the ice-free strip of country between the Inland Ice-cap and the Greenland Sea. These formations which range indeed from Pre-Cambrian through Palaeozoic, Mesozoic and Kainozoic to Quaternary, have a general trend north and south, with the older rocks situated mostly inland and the younger ones along the fringes of the coast-line. Consequently, as one sails westwards up the immense fjords which cut transversely across the formations, one moves downward in the succession towards the older rocks. But the older rocks underlie by far the greater part of the ice-free area, and of these, Devonian sandstones and conglomerates; Ordovician to Pre-Cambrian quartzites, slates and limestones; and metamorphic rocks and granites of the so-called Basement or Metamorphic Complex; are to be found in three great belts in order from east to west, between Lats. 72° and 74°. [See Plate 1, reproduced, with permission, from Geological Magazine 67, 1930.] North of 74° the continuity of these belts if they survive at all is interrupted by the encroachment of the

Ice-cap, and south of 72° extensive coverings of Mesozoic sediments and Tertiary basalts break across and obscure them. But between these limiting latitudes, approximately, the numerous inlets and deeply entrenched fjords, whose great bare walls display the formations and structures to a remarkable degree, have yielded an immense amount of information in recent years about the important older rock systems.

The Lower Palaeozoic, and older stratified group, outcrop on the main Kejser Franz Josephs Fjord between the head of Antarctics Sound and the entrance to Geolog Fjord, and it was in this area, at Cape Weber, that NATHORST first identified Ordovician fossils in the upper part of the succession. He called attention, moreover, as LENZ of the German Expedition of 1869 had done, to the striking resemblance between these rocks and the Hecla Hook Formation of Spitsbergen, a parallel in which the present writer, incidentally, from personal acquaintance with the latter, can fully concur. It has seemed indeed very probable that the much discussed Hecla Hook beds are coeval with this old succession of N.E. Greenland, and KULLING of the Swedish-Norwegian Arctic Expedition of 1931 has recently further demonstrated the fact practically to the point of certainty [10].

On account of the great thickness of quartzites and slates lying conformably below NATHORST's fossil bed, some of which extended down beneath rocks to which a Cambrian age might be ascribed, WORDIE provisionally gave the group-name of "Franz Josef Beds" [22]. L. KOCH later found Lower Cambrian and other fossils in these beds, and preferred to designate the whole series the "Eleonore Bay Formation", after the locality where the German Expedition had in 1870 first noted the formation [6]. It was left to POULSEN and KULLING of the Danish Expeditions to make the first detailed stratigraphical examination of this series, and in order to obviate confusion in the future in the writer's opinion they have very desirably restricted the term "Eleonore Bay" to that part of the formation which lies below the tillite horizon ('Cape Oswald' or 'Tillite Cañon') of demonstrable Lower Cambrian age [9] and [15]. In this restricted sense alone the term is used in this paper, as the lowest serial member of the pre-Devonian 'Franz Josef Beds'.

The Eleonore Bay Formation itself consists of a spectacular assemblage of multi-coloured quartzites, slates, and limestones, which, vividly displayed in the great cliffs bordering the fjords, provides a scene that must have few if any equals in any other part of the world. The formation is much faulted and at places abruptly folded, and since it is discordantly overlain on the east by Devonian rocks of Old Red Sandstone type, it has been inferred by most observers that the folding is "Caledonian" in age. The junction to the westward against the Meta-

morphic Complex is in practically every case found to be a faulted one, of either the thrust or the reversed type, the movement being from the east, i.e. of the Eleonore Bay Formation pressed against and over the metamorphic rocks of the Complex.

In view of the largely granitic character of much of the Basement or Metamorphic Complex, Professor HELGE BACKLUND of Sweden, who worked under the auspices of KOCH'S Danish expeditions, formed the opinion that widespread "granitisation" of the older stratified rocks had taken place, i.e. of the Eleonore Bay Formation [1]. On the analogy of what has been claimed as a fundamental process in Fenno-Scandia, intimate granite injection ("migmatisation") was said to have taken place at the time of the Caledonian folding, so that the metamorphic condition of the Complex could be considered as essentially brought about by thermal "activation" at that period of revolution. BACKLUND, in a letter to the writer, and elsewhere, has been anxious to emphasise, however, that the process is not to be considered one of heat digestion alone, that might come under the category of normal thermal metamorphism, but one appertaining to "syntexis", with all the somewhat obscure physico-chemical reactions that are thereby involved. He admits that within the Central Metamorphic Complex, in the neighbourhood of the impressive mountain Ättestupan, there may be represented an old Archean 'core', but that generally speaking "there is no normal 'junction-line' between the sediments and the crystalline rocks, the line being everywhere a special disjunctive one of a very considerable magma-intrusion with extraordinary magma-effects." Whatever the actual age of the magma that is credited with having brought about this wholesale granitisation of the lower part of the Eleonore Bay Formation, whether Caledonian, as claimed by BACKLUND, or earlier, as argued by others, it does not seem to have been appreciated by the former observer that at least two distinct kinds of granite, with quite different habit, are to be found within the western area of the Metamorphic or Basement Complex. Evidence for this was found by the writer in several localities in 1933 as will be instanced below.

As opposed to the thermal doctrine of syntexis and granitisation to produce the phenomena to be found within the Basement Complex, PARKINSON and WHITTARD [14] from field-evidence, and WISEMAN [21] from a petrological examination of the material collected on the two Cambridge Expeditions, have argued that the metamorphic effects in the Complex cannot be attributed to Caledonian granites. That on the one hand the distribution of the granites relative to the metamorphosed sediments is not such as to give the regional effects claimed; and on the other hand the microscopical evidence suggests, either that regional dynamic metamorphism has been operative, or that elsewhere a meta-

morphic condition was attained by members of the Complex clearly prior to the Caledonian folding.

Lastly there is the recently published view of Dr. CURT TEICHERT of Berlin, based upon field work in the neighbourhood of Wordie Glacier and of Geolog Fjord, that the 'Caledonides' were of such a minor character, involving only some block-faulting and but little folding, that no extensive metamorphic effects could be attributed to them. TEICHERT found that on Strindberg Peninsula and north thereof the pre-Devonian rocks are practically unfolded, and that Caledonian movements were confined to the country south of about Lat. 73°30′ [17].

With these and other rival hypotheses in mind, plans were formed for the summer of 1933, in conjunction with other expeditionary aims, to visit those districts where crucial evidence might be found, or where this might be combined with original exploration and survey work.

THE LOUISE A. BOYD EXPEDITION TO NORTH-EAST GREENLAND, 1933.

In the course of this Expedition six principal areas of the inner parts of Kejser Franz Josephs Fjord, or its attributaries, were geologically examined in greater or less detail, although landings for brief reconnaissances, as opportunity offered, were able to be made at other localities.

These principal areas were:—

1. The head of Kejser Franz Josephs Fjord: comprising, in Fraenkels Land, Knækdalen (Gregory Valley), Mysteries Øer district, and Upper Jättegletscher.
2. Is Fjord, and "Louise Boyds Land".
3. Geolog Fjord.
4. Blomsterbugten, Ymer Island; and the Teufelsschloss, Andrées Land.
5. The Giesecke Bjærge and Muskox Fjord.
6. Cursory examination was also made of the Tertiary basalts in the neighbourhood of Hold-with-Hope, and Mackenzie Bay; and of Bontekoe Island, and Arundel Island.

1. The head of Kejser Franz Josephs Fjord and "Mysteriesøer" district, Fraenkels Land.

The area at the head of the innermost reach of Kejser Franz Josephs Fjord was one of the most important objectives of the Expedition. WORDIE's explorations in 1929, at the time of his party's ascent of Petermanns Bjærg, and his discovery of a belt of sedimentary rocks, the "Petermann Series", extending north and south through the district, threw new light upon the stratigraphy and tectonics of the whole area [23].

Earlier investigations had shown that rocks of crystalline character and Archaean affinities extended westward approximately of Long. 26°. East of that line lay the multi-coloured quartzites and slates of the Eleonore Bay Formation (= WORDIE's "Franz Josef Beds" in part), and these could be seen at such localities as Junctiondal, opposite the

northern end of Antarctics Sund, to have been thrust over the so-called Archaean of the west [22]. It had been inferred that the latter crystalline formation was part of the main Basement Complex which, on account of its extensive outcrops along the west coast of Greenland, was presumed to underlie the whole of the country. It was therefore a matter of some interest to investigate further, if possible, the far western sedimentaries of the Petermann Series, and ascertain if any similarity, or even identity, could be established between them and members of the "Franz Josef Beds" lying to the east.

As an alternative to WORDIE's line of approach through the range of the Cambridge Toppe, and in order to find the extension along the strike of this series, two ways into the interior here-abouts offered themselves: one leading southward via the Kjerulfs Fjord and the Hisingers Gletscher into Goodenoughs Land; and the other northward and westward through Fraenkels Land[1]). In spite of some anticipation of difficulty, surprisingly easy access was found into the western parts of Fraenkels Land from a small cove (Gregory Cove) just east of Point 1870 m (DUSÉN's map) on the main fjord. From the cove Knækdalen, which ran north and then branched west, led one via a splendid cañon-section to the snout of WORDIE's Gregorys Gletscher, which he first espied from the top of Petermann Peak, in the vicinity of the "Mysteriesøer".

The trend of Knækdalen from the shores of Kejser Franz Josephs Fjord to the eastern border of the mountain range running north of Petermann Peak (the 'Petermanns Bjærge'), enabled one to make a continuous traverse across the strike of the formations, from the highly altered and granitic rocks of the Metamorphic Complex to the quartzite and slate Petermann Series.

Situated about 6 miles due north of Petermann Peak, and standing in the same range opposite the head of Knækdalen, was a fine peak of about 8700 feet in altitude, which is identifiable with Mount Gog, as first seen from the Cambridge Toppe by WORDIE's party in 1926. During an ascent of this peak by the writer and his wife, the Petermann Series itself was investigated and found to be the same thick series of variously coloured slates and quartzites as described by WORDIE and WITTARD [24]. The whole series conformed to the prevailing westerly dip of about 50° for this end of the range, which is rather more than that of 30° found in Petermann Peak. The lower part of the peak was a mass of scree and débris, with some intermixed moraine, no solid outcrop of the Petermann Series occurring for more than 2000 ft. above the valley: the prime reason for this shattered condition of the base of the range was

[1]) See DUSÉN's map of the Swedish Expedition, 1899, by whom this territory was named: Fraenkels Peninsula.

not seen until later. It was estimated that not less than 10,900 feet of the series was present in Mt. Gog, i. e. above this shattered zone.

From the Jätte Gletscher in the vicinity of the Mysteriesøer, there was discovered a quite unexpected and important new structural feature of the Petermann Series. Here in the truncated end of the Petermanns Bjærge, the quartzite series was seen to be abruptly overfolded in the base of the range on its eastern flank. The great recumbent fold was

Fig. 1. Mount Gog (left) and Mount Magog (right): Petermann Series overlying Mysteriesøer Overfold (Gregory Series).

seen to impinge on and lie beneath the Petermann quartzites and slates, and it appeared as if they had been forced along a thrust-plane, or "slide", over their folded and inverted lower members within the fold. A confusion of mashed rocks lay between this plane of movement (whether thrust or slide) and the fold itself, and a zone of drag folds was to be seen below the latter. The main fold was at first taken to be a portion of a recumbent syncline, whose disposition might indicate regionally directed pressure from west to east, the reverse of the observed Caledonian direction of folding elsewhere in N.E. Greenland. The arrangement of the drag folds, however, and due consideration of all the facts and features of the case, enabled this fold to be equally well and more reasonably interpreted as a recumbent anticline, nosing its way westward into the main Petermann Series. [See Pl. 5.] As such it would conform to the prevailing regional pressure from east to west, while the movement has resulted in the tilting back of the upper slates and

quartzites to the attitude they are seen to occupy all along the range. Moreover the prevailing dip of the series in Petermann Peak relative to that in Mount Gog suggests that this recumbent fold either pitches southward or dies out in that direction.

There seems to be no doubt that the pronounced valley feature, linking the great north-south bend of the Jätte Gletscher with the Mysteriesøers valley, together with the trough occupied by the Gregorys

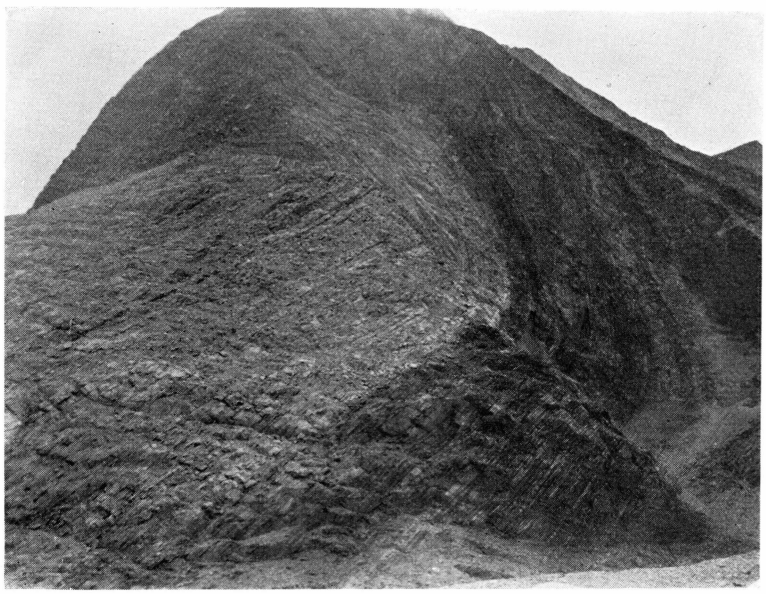

Fig. 2. Mysteriesøer Overfold from Upper Jättegletscher.

Gletscher, and the upper course of the Nordenskiölds Gletscher, is tectonically controlled by this major structure, having been carved out along the crest of the fold. [See Pl. 2 & Pl. 3.] It constitutes, accordingly, a beautiful example of how the major geomorphological features of the region may be directly due to structural control, and not the chance result entirely of past or present glacial or other erosion. It was of considerable interest, moreover, to find along the line of this feature, near the lower Mysteriesø and the Gregorys Gletscher, basic intrusive rocks that may represent geosynclinal greenstones, injected as in the Alps, as the result of deep folding.

Since this fold can only satisfactorily be attributed to the Caledonian movements, it is evident that these movements extended well to the westward into the region of the margin of the present Ice-cap, and perhaps beyond it as will be shown below, from evidence obtained in the neighbourhood of the upper Jätte Gletscher.

In the vicinity of Nathorsts Bjærg, which was ascended in the company of Mr. WALTER A. WOOD of the American Geographical Society, the assistant surveyor of the Expedition, important evidence was found of the relationship of the conspicuous light granite to the sedimentary series. It is a fresh two-mica granite, which in thin section is characterised by much microcline as well as considerable oligoclase, so that at times it approaches the composition of a quartz-monzonite,

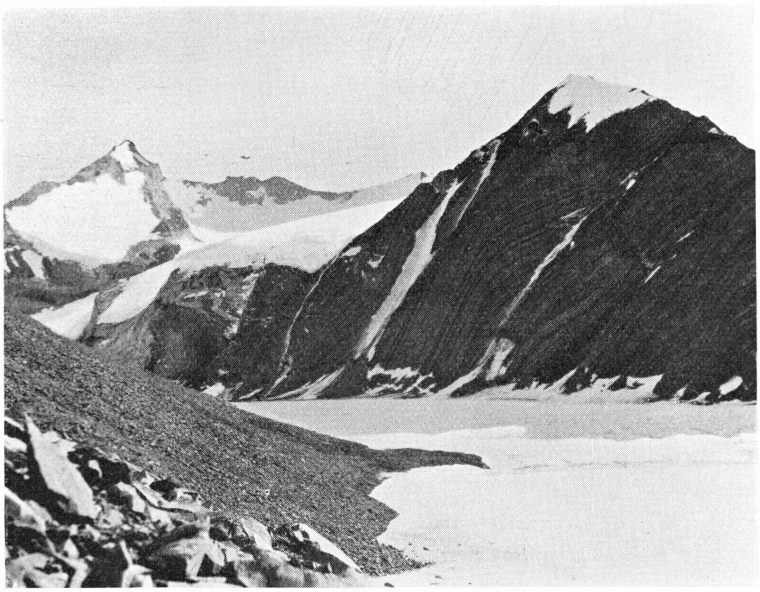

Fig. 3. Nathorst Bjærg (left) from junction of Nathorst and Lower Gregory Gletscher showing Gregory Series and granite injections.

or an adamellite. The granite has been intruded into the lower members of the quartzite-slate series (the so-called 'Gregory Series' — see later), which lie below and are stratigraphically continuous with the Petermann Series, in a complicated and irregular manner, and it has quite clearly taken part in the major folding movements. The structural relations both here and elsewhere in the neighbourhood suggested a system of complicated phacoliths, or a sheet-complex, for many of these ramifying injections. Sills and apophyses of granite or pegmatite ran off into the sediments, and the latter were observed to have been altered preferentially along the pelitic inter-beds to biotite schists; also, much alkaline material seems to have been introduced into some of the dominant quartzitic horizons. The granite sill, on which the top cone of Nathorsts Bjærg sits, is about 500 feet thick, and the dark cone itself is an impure quartzite with garnets sparingly distributed through it. In the gorge of the Nathorsts Gletscher, by which the upper Gregorys Gletscher

unexpectedly drains into the Nordenskiölds Gletscher, and particularly in the northern flanking wall, was a magnificent display of the complete engulfing of great xenoliths of the biotitic quartz-schists, or granulites, by the granite. A few miles to the south, in the neighbourhood of the junction of the Nordenskiölds Gletscher with its tributary the Disas Gletscher, Wordie and Whittard in 1930 [24] had recorded the phenomenon of "floating" masses of dark sedimentary rock within the granite,

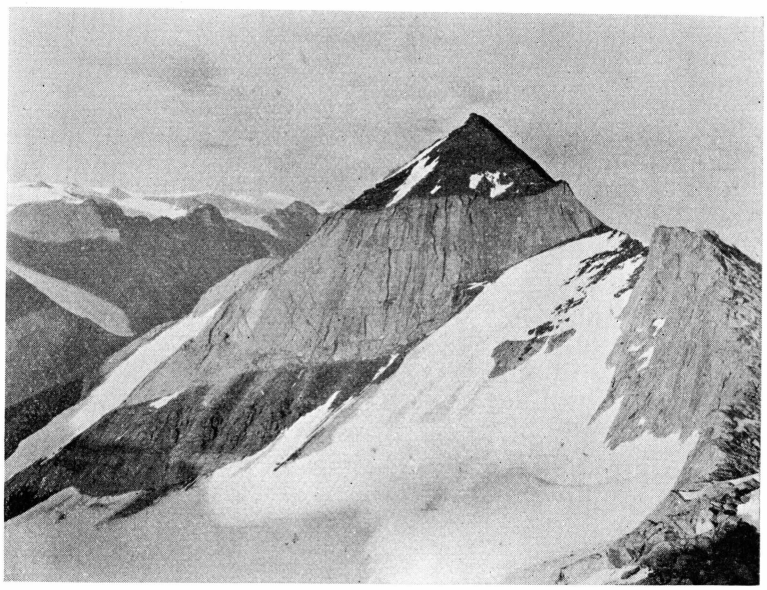

Fig. 4. Summit of Nathorst Bjærg from west, showing two-mica granite intruding pelitic Gregory Series.

but they supposed the occurrence here of a batholith or a large "subjacent" stock which obscured the junction between the Petermann Series and the Metamorphic Complex, and which might, or might not, have been intruded during the Caledonian movements.

In the course of several other ascents in the neighbourhood, and much rambling in the district round, it was ascertained that the two-mica granite, always fresh and white, has been irrupted along a N.E.—S.W. line just east of the Gregorys Gletscher, and its extent eastwards, about 12 miles, as sills and lenses forms a much wider belt than that indicated by Wordie and Whittard. But it is localised along that belt, and the same granite is not to be found farther east within the Central Metamorphic Complex. Nor does the field evidence allow of its being regarded as a batholith, as postulated by Wordie and Whittard [24]: see also Whittard's section in [20]. It is perhaps best described as a complex sheet-intrusion. [Plate 3.] Moreover the contact effects to be

definitely attributed to this belt of granite appear to have been moderate, and mostly confined to a low metamorphic grade. It has quite clearly been in no wise responsible for wide-spread regional metamorphism. If the deformation of this western area be Caledonian in age, then these granite injections must be considered also of that age, since their structural relationship is very largely 'concordant': they have taken part in the latest folding to which the sedimentary series has been subjected.

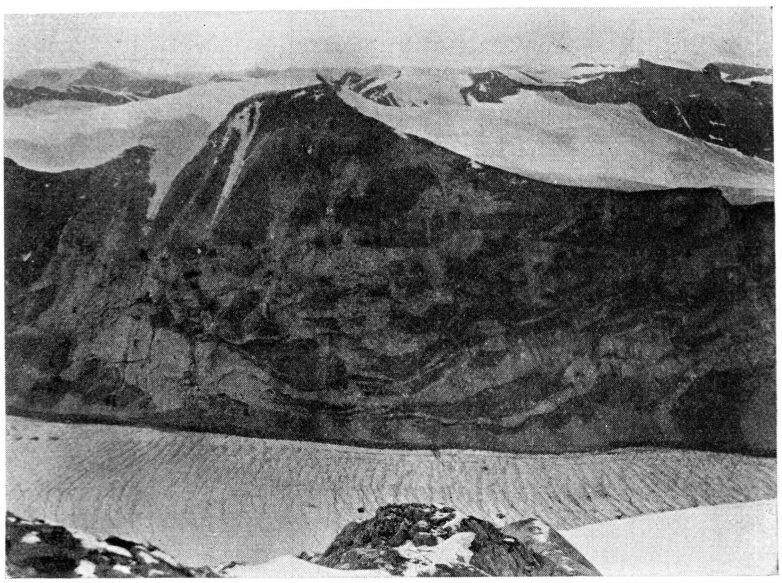

Fig. 5. Injection phenomena of Gregory Series by two-mica granite as seen from top of Nathorsts Bjærg looking north.

It may be added that such sections as were so well exposed in the neighbourhood of Nathorsts Bjærg and to the northward, seemed clearly to demonstrate many of the ideas of H. Cloos in regard to granite-tectonics, and the way in which sheets of injected magma progressively advance with the folding and engulf plates of host-rock.

The rocks forming the eastern flank of the Mysteriesøer trough, and the head of Knækdalen, consist of purer granulose quartzites interbedded with other schistose phases characterised by biotite and sericite and occasional garnet. Out of range of the influence of the granites, and situated stratigraphically below the Petermann Series, these rocks are of higher regional metamorphic grade than the latter. But that this is only part of the story is indicated by some evidence of retrogressive metamorphism in certain of these schists and granulites. Provisionally the writer has used the term 'Gregory Series' for this part of the succession which reaches garnet grade; although the field-evidence here,

and to the north, does not suggest any stratigraphical break between Gregory Series and Petermann Series. Descending Knækdalen eastwards the attitude of the beds departs little from the horizontal, but their metamorphic grade increases as one gets lower in the succession, until in the vicinity of Camp I and Arch Glacier the quartzitic series has assumed a dip of 30° N.W., the grain is coarser, and garnet is a conspicuous and sometimes dominant constituent. On disintegration some

Fig. 6. Albitic quartz granulites, Knækdalen.

of these garnet-rich rocks yield a heavy soil that by the natural processes of sorting consists of little else than red garnet. This was especially in evidence on the arid bench on which our Camp I was situated. At one place in the cliffs of the upper Knækdalen, a little below Camp III, was evidence of drag-folding and thrusting towards the west; while above Camp II was a conspicuous injected mass of the light granite on the south side, and high up in the cliffs on the northern side a great granite lens, with anastomosing veins and sills permeating the dark quartzitic series. It was noticeable that in the vicinity of each of these injections there was an increased concentration of biotite, matching the pneumatolytic introduction of alkalis, etc., to be seen in Nathorsts Bjærg and elsewhere. The result was to give a conspicuous dark banding within the lighter beds, which with the white and yellowish granitic lenses and sills provided a truly remarkable section in the cliffs of the cañon-like main valley.

From Camp I eastwards the situation is complicated and somewhat obscure, partly by reason of faulting, and partly on account of extensive

Fig. 7. Injection Gneisses, lower part of Gregory Series below Camp I.

débris-covering. The dominant dynamic factor evinced in the albitic quartz-granulites and schists is supplemented locally by pneumatolytic effects, such as the incoming of pyrite, and probably alkalis, etc. In the gorge where Knækdalen takes an abrupt turn southwards, at the convergence with the valley of the Trident Gletscher from the north, composite and injection-gneisses are well displayed. These consist of the typical broad-banded pegmatite and amphibole- and biotite-rich

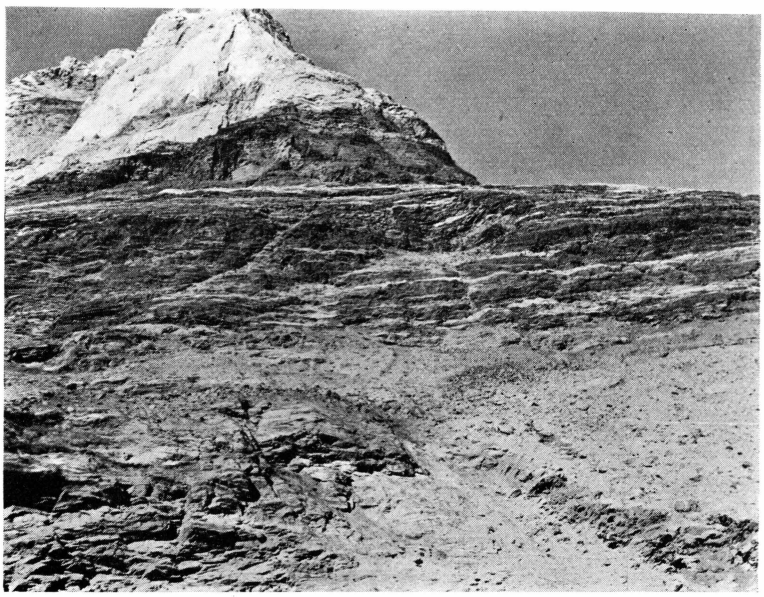

Fig. 8. Granite sills in sheared quartzites and slates. Knækdalen.

phases, with ptygmatic injection elements, such as are to be found elsewhere in the inner fjord region, and as figured by BACKLUND. But these composite gneisses were lying below and were apparently conformable with the sedimentary schists and granulites farther west: there appeared no break in the succession, only change in texture and composition, with decrease of metamorphic grade the farther west and higher in the sequence one proceeded.

The light granite was hereabouts mostly confined once again to great sills and lenses high in the upper crags of the mountains [see Fig. 8] although occasional intrusions of the same rock were to be seen lower in the succession. But this granite appeared to be an irruptive phase distinct from the igneous elements of the composite and other gneisses below and farther east. Much of the latter appeared to conform to what might be considered 'ultrametamorphic' processes. Such processes, however, need not be attributed to the Caledonian deformation: they are probably pre-Cambrian in age, as emphasised below. To regard all the

granites and gneisses as belonging to one intrusive period, the Caledonian, would be to repeat the error made in the Central Highlands of Scotland before GEORGE BARROW differentiated between 'older' and 'newer' granites.

An ascent was made of a peak in the vicinity, lying to the north of the "Trident Gletscher", which was conspicuous for a remarkably vivid band of scarlet rock running across its southern face. The scarlet

Fig. 9. Granite lenses and blocks in pelitic portion of Gregory Series, Knækdalen.

rock proved to be nothing more than a quartzite, whose joints were stained with the earthy iron oxide reddle. It was one of a series of altered quartzitic rocks, which with gneisses of igneous origin, formed a group akin to others of the Metamorphic Complex. The lower north-south trending portion of Knækdalen seems to follow a fault, or an abrupt anticlinal fold, that appears farther south across the Kejser Franz Josephs Fjord on the western side of Riddarborgen. WORDIE and WHITTARD [24] describe a remarkable recumbent fold and thrust-plane, a section of which can be seen for nearly 4,000 ft. in the S.E. face of Ridderborgen. This particular feature, though sought, was not seen, but most striking was the box-like summit of Ridderborgen formed out of a remnant of a sill of the younger light granite; and it may be that other ramifying granite-veins, or banded structures, were mistaken by WORDIE for parts of his supposed recumbent fold: in conversation he has admitted the possibility of this. So far as could be ascertained the younger light granite does not outcrop east of Knækdalen and

Kjerulfs Fjord. It is very probable that Kjerulfs Fjord, as Backlund remarks, may be the result of this same north-south system of faulting.

The so-called "Central Metamorphic Complex", of Parkinson & Whittard.

East of this line of faulting are to be found a variety of orthogneisses, paragneisses, schists, amphibolites, with pegmatite or aplite phases, and

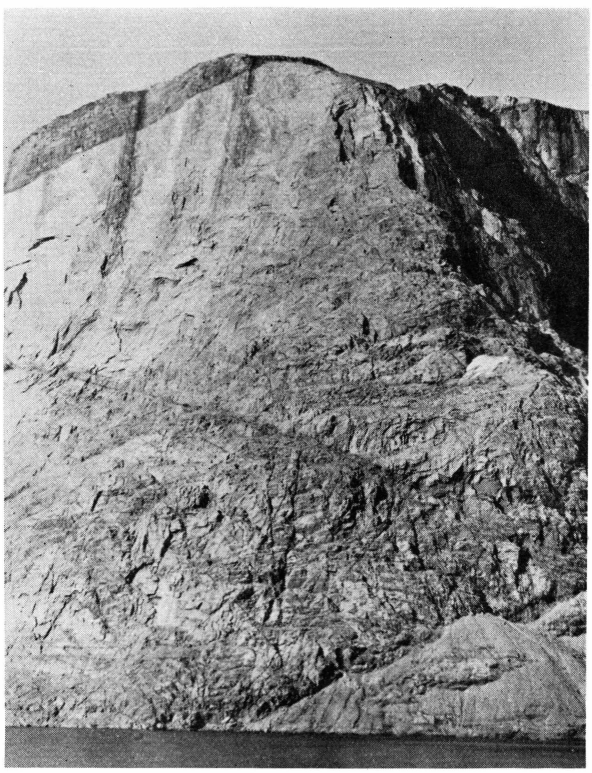

Fig. 10. Ättestupan (1800 m above fjord-level): Granitoid gneiss capped by pelites of Gregory Series (see Plate 1).

though time permitted of few landings the main features of structure were clearly discernible in the bold fjord walls. The darker pelitic elements, within the lighter psammitic ones, formed long sweeping undulations until in the great cliff of Ättestupan they rose to surmount its horst-like mass of granite gneiss. Flattening out again beyond it, and often enclosing great lenticular structures, suggestive of amphibolite bodies, the banded series continued eastward to the zone of thrust in the neighbourhood of Antarctics Sound. [See Plate 3.] Nowhere in this stretch of some 50 kms could it be seen that the grey granite gneisses occupied an intrusive relationship to the rest of the series, or that the meta-

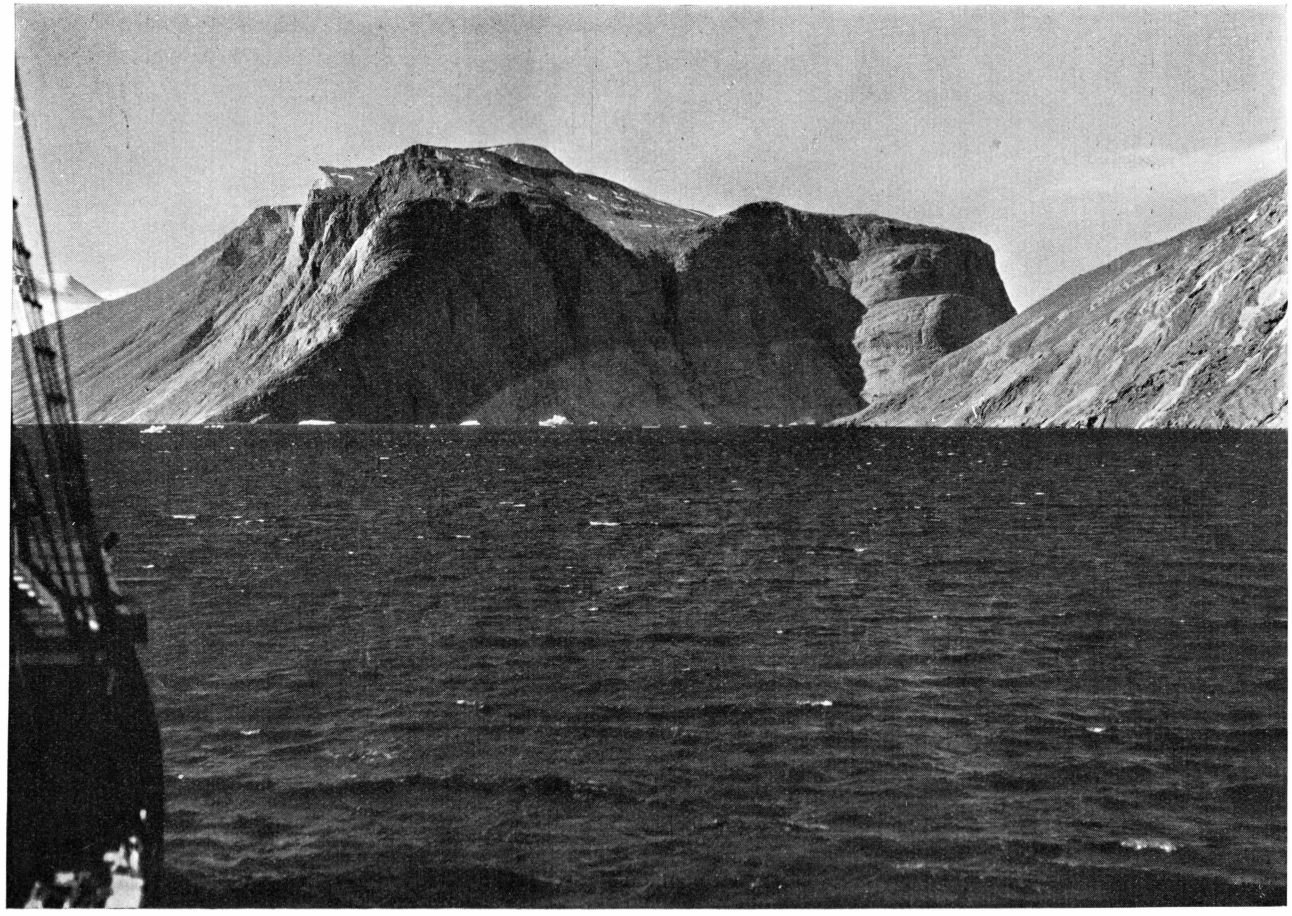

Fig. 11. Pelitic, psammitic, and (?) granitoid phases of Metamorphic Complex in Kejser Franz Josephs Fjord at entrance to Isfjord.

morphism was purely of the regional contact or syntectic type, as BACKLUND suggests. As exemplified in other Archaean terrains, it may be that the whole heterogeneous mass has been reduced at one period to a state of plasticity and fusion, but this was no doubt long anterior to the events of the Caledonian revolution. That episode, however, has contributed its dynamothermal effects to this Archaean mass, and the latter itself may have suffered movement to increase the compression farther westward; or alternatively it may have remained merely or partly an obstacle round which and over which the Caledonian thrust was largely transmitted. The actual zone of thrust at Antarctics Sund and Junctiondal, discovered by WORDIE'S party, the association with it of 'boudinage' structure in the overthrust Eleonore Bay Formation [see Fig. 132 in [4], with incorrect interpretation as "injection-gneiss"], as well as the display of giant "phacoids" and "incongruous folds", all bear witness to the magnitude of the Caledonian compression within this area. In the latter respect it would seem to be in marked contrast to the districts farther north, where, as will be shown later, radial block movements of like age appear to predominate.

As far as the west is concerned it will be seen, then, that a more or less continuous succession was found from the low-grade Petermann quartzite-slate series, downward through higher metamorphic grade of the meso-zone (Gregory Series), to composite gneisses of the injection type. Although considering the region as a whole, no marked hiatus in the metamorphic sequence was discovered, the structure is by no means an undisturbed one, while evidence was found of important overfolding and thrusting: unfortunately restricted time in the field disallowed the extent and full character of these movements being ascertained. In any case there seems to be a clear indication that the movements in the more eastern portion of the Caledonian geosyncline, namely that of the "Central Metamorphic Complex", have been transmitted to the west, and that they have been the direct cause of the disturbance of the Petermann Series as revealed in the Mysteriesøer district.

Mention must here be made of the preliminary conclusions of C. E. WEGMANN in regard to the Caledonian orogeny of the area. That author wishes these conclusions to be considered as merely preliminary and without proofs, and consequently they need be only briefly discussed in this place. WEGMANN envisages a disharmoniously folded geosyncline showing "an upper structure of wide folds in the non-metamorphic sediments, and a deeper-lying structure of migmatitic flowing-folds". He follows BACKLUND and KOCH in attributing the main metamorphic effects to wholesale granitisation or migmatitisation during Caledonian deformation. That some, however, of this plutonic igneons activity may be pre-Caledonian is considered a possibility by WEGMANN himself.

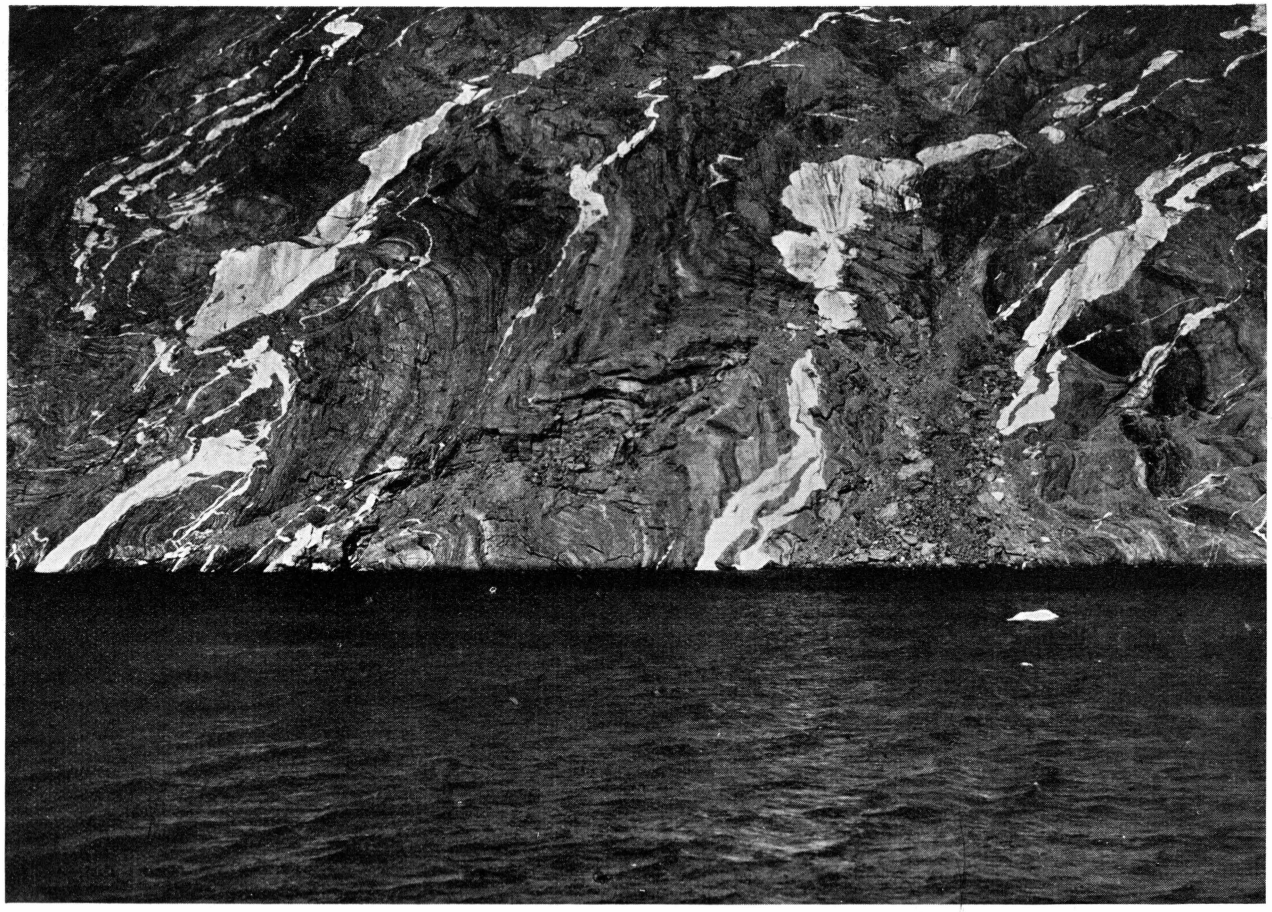

Fig. 12. Pegmatitic injection corresponding with fracture cleavage: Andrées Land, near entrance to Isfjord (= detail of fjord-level on right of Fig. 19).

And if some of it is so, the question at once arises as to how much. Details cannot here be discussed, but in regard to the "white granites" (= my two-mica granite), which are clearly of Caledonian age, WEGMANN is incorrect when he states that they form a separating sheet between elements of the Complex and the Petermann Series: on the contrary they form, as has already been noted herein, occasional intrusions only of minor metamorphic effect.

Moreover, in postulating the necessary genesis of flysch during the Caledonian movements, is not WEGMANN in danger of drawing too closely on Alpine analogy? Certainly the present author discovered no flysch in the western mountains of the nunatak zone, where WEGMANN considers it should be found; and in view of the evident dissimilarity between the East Greenland and Alpine Geosynclines it seems unlikely that it ever will be found there. Many geologists [cf. 25] are agreed that the Devonian of East Greenland corresponds to the Alpine molasse (Nagelfluh), but unless we are bound to the idea of a precisely similar sequence of folding phenomena for the Caledonian of the former region as the Tertiary of the latter, the necessity for the presence of a flysch formation is not so evident.

While realising the extent of WEGMANN's researches in Switzerland and Scandinavia, and recognising the admirable attempt at a comprehensive picture that he has put forth for this portion of East Greenland which he has studied, the present author cannot help thinking that that picture may eventually have to be considerably modified when more is known of the geological conditions in Andrée Land and the nunatak region to the northward and westward of it. At any rate the incidence of the dynamic factor in metamorphism may later be shown to be more real in the case of the East Greenland geosyncline than WEGMANN and his colleagues will at present allow. For it is not all of us who can follow the Fenno-Scandian school so far as to apply without considerable reserve the thermal tectonic hypothesis to another region of such different intrinsic character as East Greenland. While it would appear that the chief process operative in N.E. Greenland has been dynamic metamorphism, it cannot as yet be decided whether all the effects seen are to be attributed to the Caledonian deformation, or whether some may not be due to earlier compression in pre-Cambrian times. As in the case of the N.W. Highlands of Scotland, where opinion varies as to whether the metamorphic condition of some at least of the terrain (i.e. the Moine Schists) may not have been reached prior to the Caledonian orogeny, so in the East Greenland geosyncline there may well have been a superimposition of metamorphisms. Moreover, there is a possibility that the earlier metamorphism in the latter region may have been static, and the effect, at least in part, of depth of burial under

the great column of Palaezoic strata which had accumulated prior to the Caledonian deformation. The writer, having some years ago studied what was claimed by R. A. DALY to be the result of load-metamorphism in the Shuswap terrain of British Columbia, would hesitate to exclude the possibility of its incidence at an early stage from the rocks of the so-called Central Metamorphic Complex of N.E. Greenland: as hinted at above, the long flatlying structures in the neighbourhood of the entrance to Isfjord, and elsewhere, rather suggest it.

Upper Jätte Gletscher.

A reconnaissance was made up the Jätte Gletscher for about 6 miles west of the Mysteriesøers valley. The difficult character of the glacier prevented extensive movement over its vast surface, but interesting data were obtained from the abundant morainic materials. It was not surprising to find that a large proportion of this material, even out on the medial moraines, was derived from the Petermann Series, since tributary glaciers from the western flanks of the Petermanns Bjærg debouch into the Jätte Gletscher farther west. In addition, and not altogether unexpected, was a considerable quantity of augen gneiss as well as hornblende, biotite and garnet-bearing varieties, of medium metamorphic grade. From the top of a sérac of the upper icefall it could be seen that the westward dipping Petermann Series on either side of the glacier flatten out into a synclinal[1]), and farther west again dark banded rocks become much disturbed. In a prominent bluff, perhaps 9 or 10 miles off at the edge of the Inland Ice itself, it appeared as if there were an overfold beneath some nearly horizontal upper beds. It would seem that from these outcrops the higher grade erratic material might be derived.

That the Caledonian folding extended at least as far west as the borders of the Ice Cap, and probably farther, appears to be clearly indicated. Interesting evidence bearing on this question was obtained in 1931 by HØYGAARD and MEHREN, who in making their bold crossing of the Ice Cap from West Greenland emerged on the eastern side at the head of what they named Adolf Hoel Gletscher, which is a tributary of the Waltershausen Gletscher. The area in question lies to the N.W. of Andrées Land, and from nunataks were obtained not only specimens representative of the Petermann quartzites, but a dark-coloured limestone, suggestive of the calcareous facies of the Eleonore Bay Formation, as well as amphibolite, corresponding with morainic material obtained

[1]) This synclinal structure has been lately confirmed by aerial observation, see WEGMANN [27], p. 29.

by WORDIE in the Cambridge Toppe, and myself in Knækdalen (Gregory Valley) district [13]. The limestone is perhaps of especial interest, since neither WORDIE nor myself, in our respective areas, found this associated with the dominant quartzite slate series, but only morainic specimens of metamorphic limebearing rocks. The presence farther west of limestone is an indication that the late Pre-Cambrian, and possibly lower Palaeozoic, calcareous facies was laid down there in what must

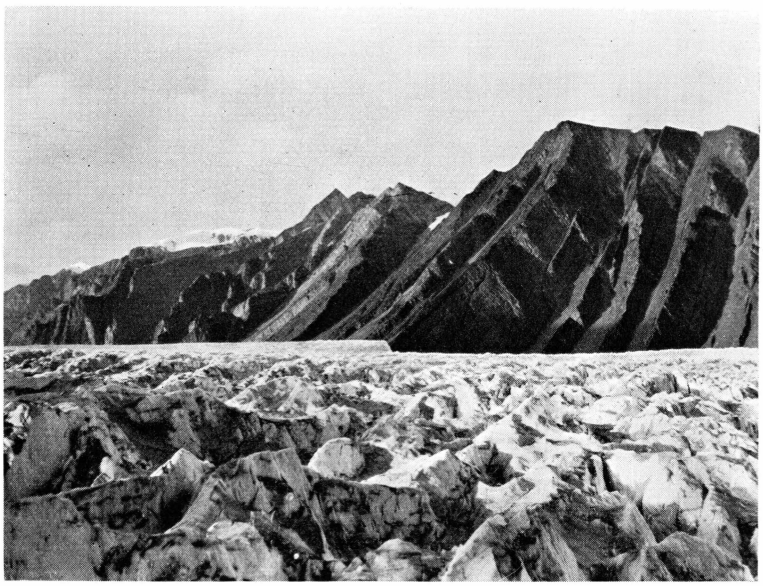

Fig. 13. Westward dipping quartzites and slates of Petermann Series. Upper Jättegletscher.

be considered part of the Caledonian geosyncline. Such an extension of the geosynclinal deposition, even as far west as Long. 29°, introduces a new view, and one quite different from that held by KOCH, FREBOLD and others of the disposition of the Caledonian orogeny in these parts [16]. Not only is it claimed that the western half alone of the old mountain range is now represented, the eastern half having subsided beneath the Greenland Sea, but that the Eleonore Bay-Petermann Series must be regarded as "laid down on the plateau (personal communication by KOCH), presumably purely as an "epeirogenic" sedimentation. It is premature perhaps on the basis of this western nunatak-material alone to detect evidence of "thalattogenic" sedimentation (i.e. within the deeper parts of the geosynclinal basin), but there is ample material in the moraines streaming from the border region of the Ice Cap to show that characteristic deeper metamorphic facies, both igneous and sedimentary, are represented farther west than has so far been thought to

be the case. When these features are taken into consideration, together with the fresh evidence of overfolding and westward thrusting just east of Petermanns Bjærge, it must be duly emphasised that at present we have nothing to indicate where the western limits of the Caledonian geosyncline lie. Indeed it would seem that those limits are buried beneath the Inland Ice, possibly far to the westward.

In connection with these views, it should be mentioned that to the writer there seems to be little doubt that the Petermann Series, with the altered quartzites beneath it, is the equivalent of that part of the Eleonore Bay Formation referred to by Oscar Kulling as the (lower) Quartzite Series [9], and by Curt Teichert as the "Bunte (i.e. variegated) Serie" (above) and "Quarzit Serie" (below) [17]. Wordie and Whittard showed that the series in Petermanns Bjærg itself was lithologically remarkably similar to the strongly coloured alternating beds of the Eleonore Bay Formation [24]. On Mount Gog, and elsewhere in the district north of Petermanns Bjærg, the writer found the same striking resemblance, and although the series has so far proved to be unfossiliferous in a light grey quartzite were discovered some scolithus-like bodies[1]) such as have been shown to occur in what are believed to be Eleonore Bay Formation boulders along the east coast. Moreover the regional metamorphic grade of both series is in general similar, and each bears a corresponding structural relationship to the higher grade products of the so-called Metamorphic Complex. Proximity to the western belt of granites has alone, and only locally, rendered the condition of the Petermann Series markedly different from the Eleonore Bay Formation.

During their east to west crossing of the continental Ice Cap in 1913, J. P. Koch and A. Wegener collected from Queen Louise Land specimens of quartzites and shales that are generally agreed to be a northern extension of the Petermann Series. They would appear to have been laid down under the same conditions of variable sedimentation as the latter, and within the Caledonian geosyncline of East Greenland.

Spread moreover over a wide expanse of northern Greenland is the Thule Formation, mapped by Lauge Koch as mainly an unvarying thick red sandstone although overlain in places by dolomite [7]. Koch is of the strong opinion, confirmed by his extensive flights over the north-east in 1933, that this formation is the equivalent of the Petermann and Eleonore Bay rocks. Its homogeneous character and general points of distinction from the latter stamp it, however,

[1]) In these specimens the bodies are parallel to the bedding and therefore correspond more with '*planolites*' (Nicholson), than with scolithus.

as one laid down outside the geosyncline on the foreland of the Caledonian deformation[1]).

It was WORDIE and WHITTARD's opinion that if the contemporaneity of the Eleonore Bay Formation and the Petermann Series could be demonstrated, then the presence of folding or thrusting on a grand scale in this region would ipso facto be implied [24, p. 152]. In other words, presumably, that the Petermann Series and its western equivalents would represent the frontal portions, remaining as klippen, of great overthrust decken (nappes), whose hinder or distal parts would be the Eleonore Bay Formation proper. But this would appear to be an elaborate as well as a premature generalisation until more is known of the tectonics throughout the region. The overfolding and thrusting found by the writer in the Petermann Range and Gregory Valley suggests nothing on the Alpine scale of overthrusting so far as has been observed; and insufficient is known at present of the faulted western junction of the Eleonore Bay Formation to safely postulate that it is a line of thrust of vast horizontal displacement. In the writer's opinion the contemporaneity of the two formations can be regarded as one consistent with the view of wrinkles and furrows within the sedimentary cover, with only minor thrusts and overfolds. Post-Caledonian isostatic rise or upwarping of the "Central Metamorphic" horst-like mass, or Hercynian block-movements, or both, together with later erosion, will then have brought about the observed detachment of the two portions of the Pre-Devonian sedimentary series.

2. Isfjord and Louise Boyds Land.

A short visit was made to Renbugten at the entrance of Isfjord, and in view of the extremely good ice-conditions to the head of the fjord, and thence into Louise Boyds Land, via "Hendil Valley" lying just north of Cape Hendil.

The prevailing rocks at Renbugten near the entrance to the fjord were strongly banded biotite gneisses, with aplitic sills, lenses and streaks. The steep walls of the inner parts of the fjord showed these injection- and composite-gneisses to lie nearly horizontally for a distance of more than a mile. But on closer inspection there were to be seen in some places contorted structures and even S-folds that appeared to be large-

[1]) News comes to hand from WORDIE's Expedition to Baffin Bay, 1937, that the Thule sediments of N.W. Greenland were traced into Ellesmere Land, and were found to pass conformably upwards into Lower Cambrian rocks with a trilobite and brachiopod fauna. This series was also found as far south as Jones Sound, proving a greater extension into Canada than was hitherto suspected: v. Nature, 140, 1937, p. 1083. The work of R. BENTHAM, now being pursued in Ellesmere Land, should go far towards settling these important stratigraphical considerations.

Fig. 14. Giant ptygmatic injection, Isfjord: height of cliff about 1800 m.

scale ptygmatic injections, indicating the rotational strain and buckling to which these rocks have been subjected.

At the inner basin into which pour the great ice-streams of the Gerard de Geer and the Jätte Gletschers, were to be found ortho-gneisses and para-gneisses and schists of higher metamorphic grade.

A two-day reconnaissance up the Hendil Valley and into the higher mountains of the interior revealed that this area is entirely underlain by metamorphic rocks of dioritic as well as granitic and psammitic type, and of dominant garnet grade. No rocks of lower grade, corresponding with the Petermann Series south of the Jätte Gletscher, were encountered in the ranges of the great cirque enclosing the Hendil Valley. It is probable, however, that these outcrop in the extreme west of Louise Boyds Land, since erratic material of purple quartzite, equivalent to that of the Petermann and the Eleonore Bay rocks, was found in the neighbourhood of Renbugten; and moreover from the upper reaches of the Jätte Gletscher, as instanced earlier, were to be seen rocks on the north side of it that had all the appearances of, and duplicated the structures observed in, the truncated end of the Petermanns Bjærge on the Fraenkels Land side of that glacier.

The rocks of Louise Boyds Land, then, are the northern extension of the higher grade facies of Suess Land, of Goodenoughs Land and of Fraenkels Land. Owing to the fact that the narrow Isfjord is during some seasons entirely blocked by icebergs and impossible of negotiation, Louise Boyds Land will often prove difficult of approach. But a splendid field for future geological investigation, and an area that is apparently untouched, is the western and south-western parts of Andrées Land, to which access is particularly easy from Renbugten at the entrance of Isfjord. From the high summits bordering the western side of the great Gerard de Geer Gletscher the writer had an excellent view into Andrées Land, and its vast ice-free areas could be seen to be a promising field for obtaining further data towards the solution of the above aspects of the 'Caledonian problem' of East Greenland. It is not improbable, moreover, that in the interior of Andrées Land, somewhere between Isfjord and Geolog Fjord, a definite and visible connection may be established between rocks to the eastward that are now designated Eleonore Bay Formation, and those of the Petermann Gregory Series lying to the westward. To the writer, however, it seems that at Geolog Fjord itself we have in effect the actual unification of the two portions of this Pre-Devonian formation, although definite proof of that unification is required from the interior.

That in the eastern and western groups of Pre-Devonian rocks we find, from an assessment of approximate average thicknesses, a comparable total assemblage of strata (as shewn in the accompanying table),

is a matter of considerable relevent interest. Caution, however, in such an estimate is called for, since, in view of its advanced metamorphic grade, the lower limit of the western group is somewhat arbitrary.

Approximate-Thicknesses of Pre-Devonian Succession of Northeast Greenland.

Eastern Group [= "Franz Josef Beds" (WORDIE)] from data by POULSEN, KULLING, TEICHERT, and WEGMANN.	
Various local formations within limits of Narwhal Sound Formation (Lower Ordovician) and Spiral Creek Formation (Lower Cambrian)	7,000 ft.
Tillite Series = Tillite Canyon and Cape Oswald Formation (late pre-Cambrian or Lower Cambrian)	3,000 -
Eleonore Bay Formation [= "Greenlandian Series" in part (KOCH)] (pre-Cambrian)	16,000 -
	26,000 ft.

NB. WEGMANN considers that 9,000 metres is probably a conservative figure for the total thickness of this group [27].

Western Group.	
Petermann Series [= "Greenlandian Series" in part (KOCH)] — in Mt. Gog above recumbent fold	10,900 ft.
(in Petermanns Bjærg, .. 3,500 ft. — WORDIE).	
Petermann Series — along upper Jättegletscher	.. 12,000 -
Gregory Series — involved in recumbent fold	1,600 -
Gregory Series — in Knækdalen etc.	5,000 -
	29,500 ft.

3. Geolog Fjord.

Geolog Fjord, or Geologist Fjord (not Geology Fjord, as incorrectly termed by some), was first discovered by NATHORST, who remarked that the characters of its folds, faults, and beautifully coloured beds are so conspicuous as to be capable of exciting the interest even of a layman.

It was unfortunate that the exigencies of time, and poor weather at the end of the season, prevented our paying more than a brief visit to this fjord. We were, however, able to reach its head, and I spent a day examining the area on the south-west side of the Nunatak Gletscher which descends directly from the Inland Ice to the fjord. Prominent in this area is a boss of light granite covering more than a square mile of outcrop. In the field, and in thin section, it shows itself to be precisely the same biotite-muscovite-granite, containing ample microcline and oligoclase, apart from orthoclase, as was seen to have been irrupted farther south-west at the head of Kejser Franz Josephs Fjord, where

it is clearly affected by Caledonian deformation. On the other hand its field relationship and composition, as well as its fresh and unfoliated condition, stamp it, like those occurrences at the head of that fjord, as quite distinct from any granitic types within the main Metamorphic Complex. The Geolog Fjord granite itself with its pegmatitic and aplitic apophyses had been responsible for a certain amount of local contact effect, with the introduction of alkaline and boric solutions, and the development of increased mica and tourmaline within the surrounding quartzite-slate series.

The deeper gneissose rocks were not exposed in the restricted area examined, but interesting morainic specimens of ortho- and para-gneisses were found indicating that the higher grade elements occur farther westward in the nunataks, or beneath the Inland Ice-sheet. These consisted of garnet-bearing gneisses and amphibolites similar to types collected farther south in the Mysteriesøer district.

The quartzite-slate series here represented is a replica of the sedimentaries of Knækdalen-Petermann region: the same predominant quartzite facies with pelitic zones, running upward into the conspicuous variegated beds that distinguish the remarkable walls of Geolog Fjord as far as its junction with the main Kejser Franz Josephs Fjord. And it is this series, of course, in the Cape Weber district that, with the overlying limestone-dolomite series, is the type Eleonore Bay Formation as designated by KOCH, and first examined by the earlier German and Swedish Expeditions [6].

During our progress up and down Geolog Fjord ample opportunity was afforded to gain a general idea as to the tectonics of this area. The marked stratification, the folds, and the faults, are all developed on the text-book scale, truly so that he who runs, or sails swiftly as we did, may read! But although folding and faulting is in evidence it is not on an intensive scale. As CURT TEICHERT, who has made a special study of this area has demonstrated, close-folding, overfolding, and thrusting are here conspicuous by their absence [17]. A certain amount of reversed faulting is in evidence in the outer part of the fjord as instanced below, but the ruling structures of the inner fjord are long rolling anticlines and synclines with block-faulting. Indeed it is step-faulting and block-structure, with interesting local developement of "boudinage"-structure, that clearly dominate this section of country.

In the outer half of the fjord the lower quartzite-slate series has been down-faulted, and it is only the upper limestone-dolomite series of the Eleonore Bay Formation that appears above sea-level. Here again the succession is much split up into blocks, and it is not until opposite Bjørne Ø, near the entrance to the fjord, that there is the first appearance of a thrust-fault. Well brought out by colour-contrast, a magnificent

section on the north side of the fjord shows the junction of the dark banded Eleonore limestone-dolomite series against the ruddy Old Red Sandstone conglomerate. This junction, which dips nearly due east at approximately 30°, TEICHERT had shown to be a reverse-faulted one [17]. The Devonian has in other words been thrust westward over the Eleonore Bay Formation. Farther east again the Devonian sandstone has similarly been over-thrust upon its own conglomerate.

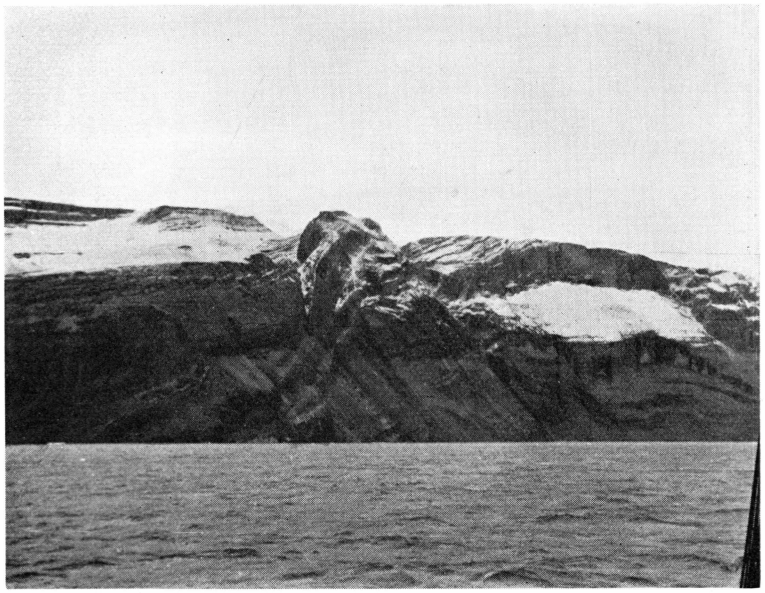

Fig. 15. Step-faulting, Geolog Fjord.

These post-Devonian movements have been shown elsewhere, and particularly in the adjoining region to the east and south-east, to be associated with Hercynian diastrophism, and KOCH believes that the effects of the latter are strictly confined to an area extending from Hudson Land on the north to the neighbourhood of Davy Sound on the south. Accordingly he considers that all deformation existing in Geolog Fjord, and therefore outside this area, is to be attributed to Caledonian movements. In this view KOCH is followed by most East Greenland geologists, not all of whom it must be said have actually sailed to the head of the Geolog Fjord, and most of whom have nevertheless formed an opinion that typical overfolding and thrusting, commensurate with that farther south, must surely exist in this area. It has been left, however, to TEICHERT to show, as above referred to, that such is not the case, and that mountain folding is only to be found south of Geolog Fjord [17]. Working indeed in the region to the north-east of the latter, TEICHERT discovered that the Eleonore Bay Formation is lying nearly

flat, or only slightly removed from horizontality, with the same prevalence of block-structure. It is his belief, and he has stated his case very convincingly, that these block-structures are mainly, if not entirely, due to Hercynian movements, and that Caledonian mountain deformation was confined to the country south of about latitude 73°30′. On the other hand it may be, although not in TEICHERT's view, that Geolog Fjord lies in a belt of country that has escaped the full effects of the Caledonian compression, the latter having folded areas east and west of it, and merely block-faulted the intervening belt. It is the present writer's opinion that, while the light granite intrusion, and certain other structures at the head of the fjord on the west side, bespeak Caledonian action, the fault tectonics and general configuration of the area suggest Hercynian agency in pronounced degree.

4. Blomsterbugten (Flower Bay), Ymers Ø, and the Teufelsschloss, Andrées Land.

In the course of four days a short study was made of the Eleonore Bay Formation, in the region of perhaps its most characteristic development and deformation, on the western coast of Ymers Ø, and also at that most remarkable of mountains, the Teuffelsschloss. The bulk of the work was done in the neighbourhood of Blomsterbugten, the little cove, lying opposite the Teufelsschloss across the fjord, which gives access through the central depression of Ymers Ø to Duséns Fjord.

The rocks represented here, at any rate in the higher parts of the mountains, are the conspicuous and variously coloured Bunte Series (TEICHERT), but lower down in the valley tracts are members of the Quartzite Series, dipping from 15 to 20° to the S.E. or S.S.E. To the south-west of Blomsterbugten along the coast upper members of this formation can be seen to be notably folded and faulted, and it is the more remarkable to find in the Dusén depression close at hand such an apparent absence of disturbance of lower members of the same formation. From an attitude of verticality in a faulted monocline to the south-west, where a block of the (upper Eleonore Bay) Limestone-Dolomite Series has been brought up against the Bunte Series, the latter, with the (lower) Quartzite Series, flattens out almost to horizontality. A closer study, however, revealed that there has been in these flatter-lying quartzites a considerable amount of differential movement. Slices of competent massive quartzite have been pushed forward and westward on incompetent thin quartzites or slates, there being an imbricate arrangement of slice upon slice. A beautiful example of mullion-structure was to be seen beneath one of the larger thrusts, and thin sections show much mylonitisation of the overridden rocks. Following the first hori-

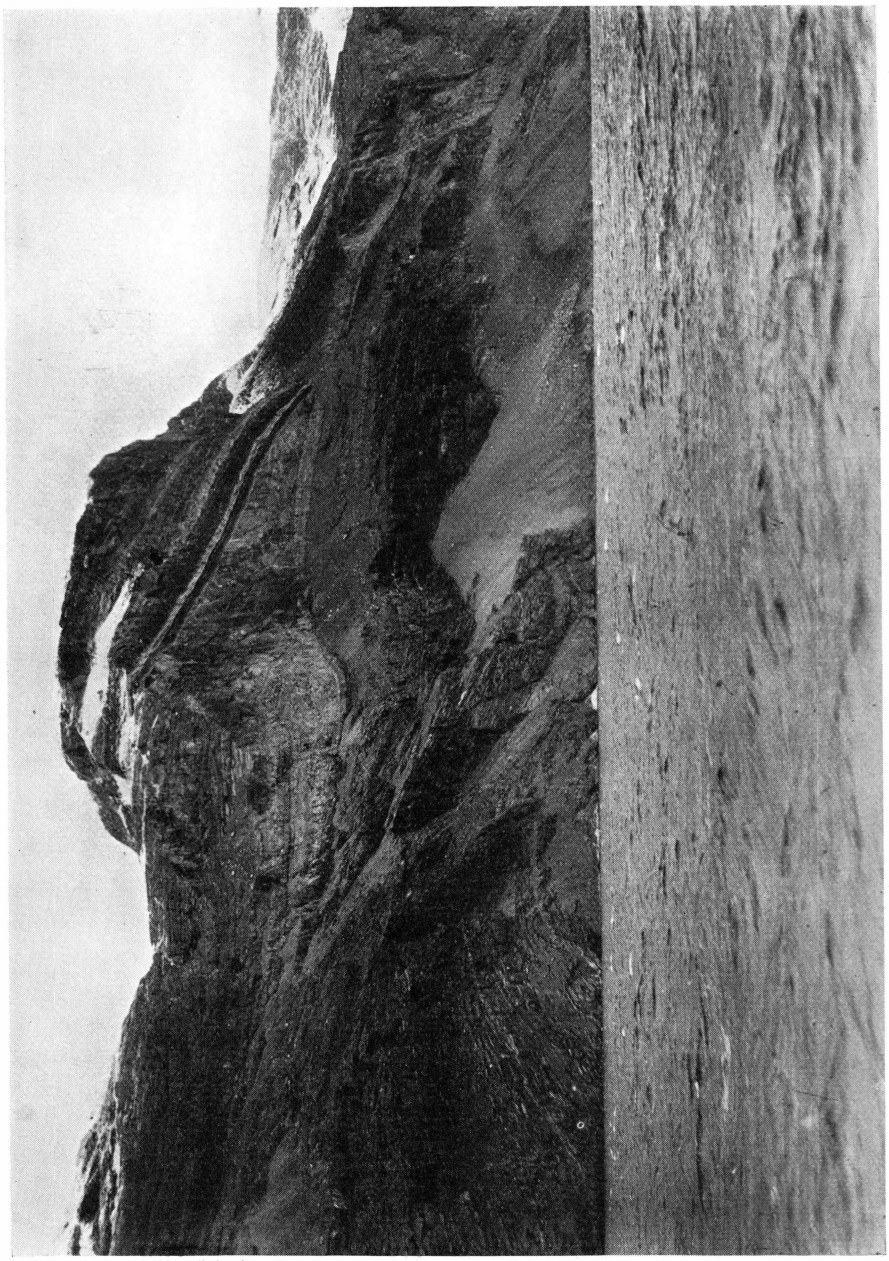

Fig. 16. "Boudinage" structure in Eleonore Bay Formation, Geolog Fjord.

zontal displacement, sections of the Dusén depression, as evidenced westward and north-westward of Noa Sø, have been moved forward as wedges, which have themselves moved differentially one from the other, the boundaries of these wedges being in some cases clean-cut vertical fault-planes with variable throw, and in other cases tear-faults. It is of interest, moreover, to note that these tear-faults, accompanied by friction-breccia, extended down into the 'passive' block below, and

Fig. 18. Main overthrust, Blomsterbugten.

were not confined, as usually occurs in such cases, to the thrust blocks themselves. Consequently it is inferred that there may have been repeated movement along these same lines of fracture, although this would appear to have been small in amount[1]). [See Plate 5.] What the total horizontal displacement of the slices has amounted to it is difficult to say but the wedges can be seen to have moved little. In only one case was any folding seen accompanying the thrusting, and this was in some quartzitic shales and silt-stones, lowermost members of the Bunte Series, at the base of "Chocolate Peak", S.E. of Cape Petersen: and these were merely small drag-folds at what appeared a minor thrust-plane. The case for major thrusting and displacement in this particular neighbourhood, with the development of nappe-tectonics, as has been supposed by some, remains in the writer's opinion unproven and undemonstrable.

[1]) See JAS. GEIKIE, "Structural Geology" (3rd edn.), p. 179; and E. L. PERRY, "Flaws and Tear-Faults", Amer. Journ. Sci. 29, 1935.

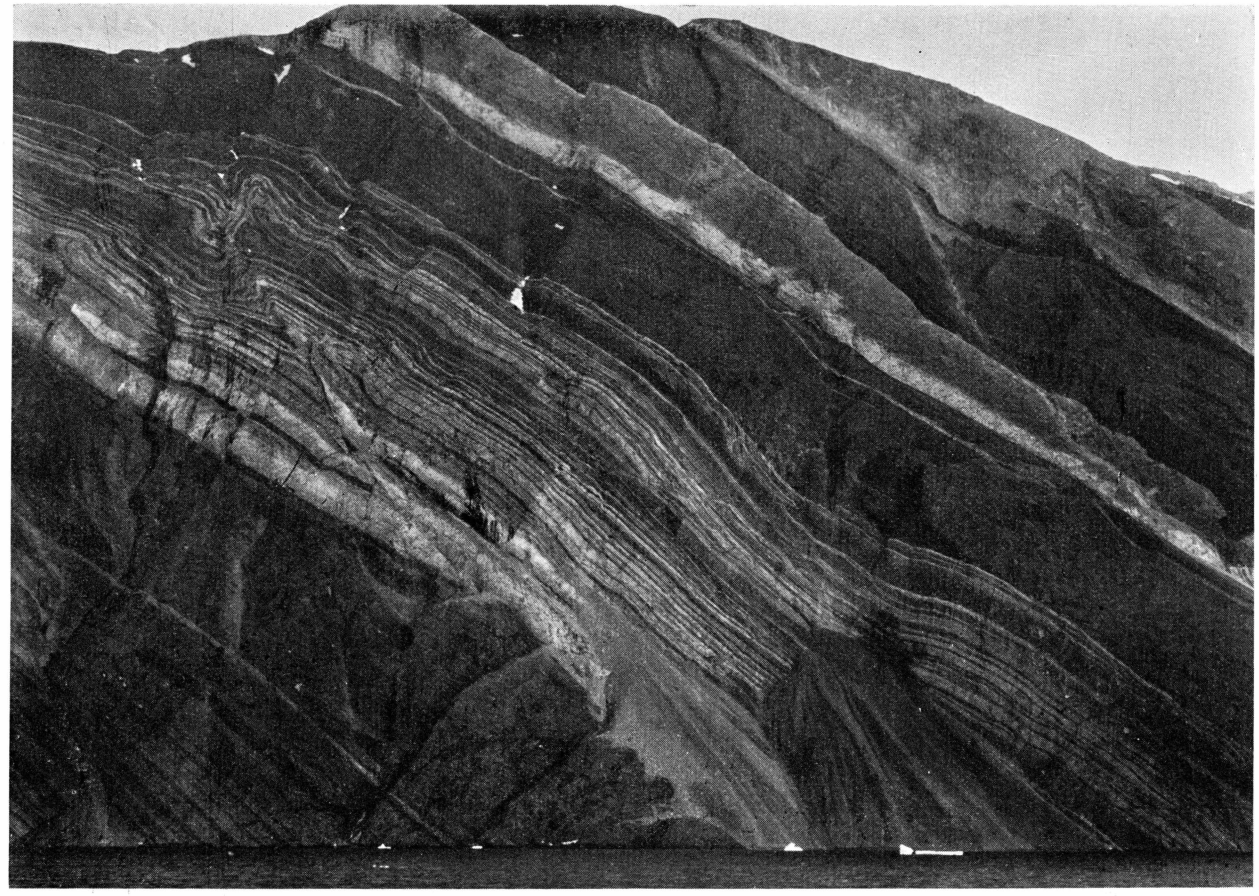

Fig. 17. Eleonore Bay Formation, Andrées Land, S.W. of Blomsterbugten: note the folded (incompetent) slaty beds and reversed faulted (competent) quartzitic beds.

Recently there has appeared a paper by A. B. CLEAVES and E. F. FOX on the succession of formations between Blomsterbugten and Dusens Fjord [26]. They support the view that no actual thrust-faults of major proportions were developed in this district, and that normal faulting is the most conspicuous structural feature of the western part

Fig. 19. Crushed quartzites in tear-fault zone. Blomsterbugten.

of Ymers Ø. They claim, however, on the evidence mainly of a single fossil arachnid (*'Sidneyia groenlandica'* n. sp.) of doubtful value, that these rocks are to be regarded as not older than(?) Middle Cambrian in age. From three small gastropods, found in limestone north of Dusens Fjord an upper age of (?)Middle Ordovician is also supposed for the succession. In view of the careful and comprehensive work of POULSEN, KULLING, and TEICHERT in this district and its vicinity, to which incidentally no reference at all is made (except a solitary one in regard to KULLING's views on the Old Red Sandstone), there is much that can be said against the conclusions of CLEAVES and FOX as to the age of the bulk of the succession, the greater part of it having been shown from the evidence on Andrées Land and at Ella Ø to be definitely pre-Cambrian

in age. TEICHERT and H. BÜTLER have demonstrated that only one restricted area in the hills east of Cape Petersen is underlain by Cambro-Ordovician strata, and this is faulted against the Eleonore Bay Formation to its westward.

KOCH, mis-quoting WORDIE, who spoke of "the limestones, 'of' (not 'at') the Devil's Castle, thrust over Archean", has maintained that the Teufelsschloss is a 'mountain without roots', i.e. that the main mass

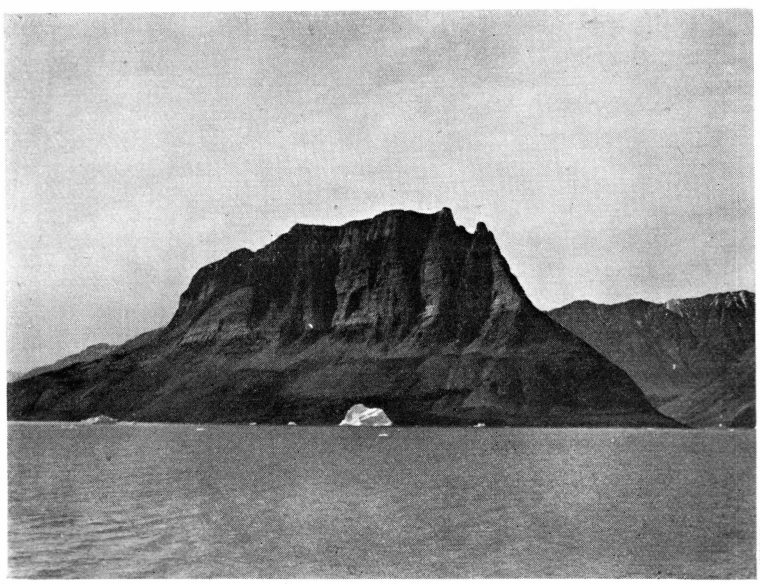

Fig. 20. Teufelsschloss (1310 m).

of it rests on a thrust plane [6]. In this hypothesis KOCH is assumed correct by PARKINSON and WHITTARD, who therefore speak of the mountain as a 'klippe', or tectonic outlier [14]. In the course of a brief examination of the Teufelsschloss, when at the same time an ascent was made of it by the western side, no major thrust-plane was found nor seen by the writer to suggest that the mountain block has moved as a whole on its base. In concert with the structure on Ymers Ø described above, there has been no doubt minor movement of stronger beds on weaker at the time of the Caledonian compression but evidence is wanting of the mountain being a travelled mass in the tectonic sense. The summit rises 4300 feet above the waters of the fjord, and the Eleonore Bay Formation (Bunte Series) of which the mountain is composed lies remarkably horizontal except for a slight westward dip (5°) of the series, best seen on the western side. The culminating point of the table-top crest was found to be composed of some 80 ft. in thickness of the calcite-veined black dolomitic limestone, which forms the uppermost series of

the Eleonore Bay Formation. The presence of this limestone, although but a veneer on the highest part of the crest, was a corroboration both of WORDIE and of KULLING in their references respectively to "the limestones of the Devil's Castle" [22], and "quite a small area of overlying dolomite which has resisted erosion" [9] although as a matter of fact neither of these geologists had visited the summit!

The coloured quartzites and siltstones, which make this mountain such a striking object, descend in succession to the fjord-level, and one

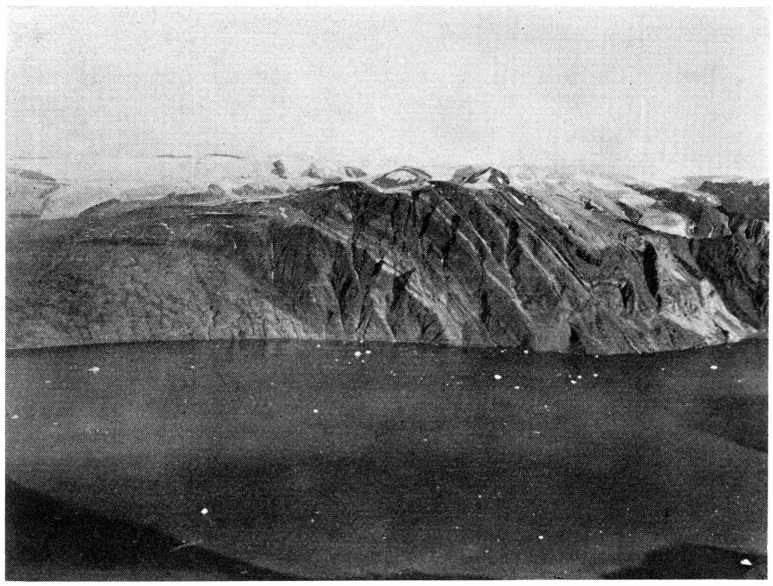

Fig. 21. Folded Eleonore Bay Formation, Ymer Island, from summit of Teufelsschloss.

could see no evidence of highly folded strata at the base of it, as described by KOCH: this he claims to be a factor indicative of thrust-movement of the upper horizontal part on its folded foundation. Extensive stretches of scree obscure much of the lowermost rocks on the eastern side of the mountain, but there are sufficient outcrops to trace the undisturbed bedding-planes of the (lower) Quartzite Series. Nor could evidence of any major thrust plane be found on the western side of Teufelsschloss.

Westward of the mountain is a range that is composed of the Quartzite Series, as shown by TEICHERT, and its position can only be explained by the presence of a fault separating it from the Bunte block of the Teufelsschloss. Indeed it would seem that the latter mountain, and also the adjoining trough of the Kejser Franz Josephs Fjord, are due to differential block movements of this portion of country, as is suggested by TEICHERT. To postulate that the Teufelsschloss is a klippe

only involves the district in tectonics of an unnecessarily complex and most unlikely order, which the field evidence itself cannot justify.

If we attribute the major folding of this district to the Caledonian orogeny, then it would seem that the later block-faulting, and some of the minor thrusting and 'wedging' on Ymers Ø, may be Hercynian in age. Only a few miles farther east on Ymer Island, KOCH and others have emphasised the presence of an "Asturian Thrust Line" running northward to Strindbergs Land and southward through Traill Island, supposing this to mark the extreme western limit of all Hercynian movements. But can this safely be postulated? TEICHERT, as earlier stated, from his work in Geolog Fjord and the interior of Strindbergs Land has shown that the wide-spread step-faulting there must chiefly if not entirely be attributed to post-Devonian (Hercynian) movements. Consequently there seems little doubt that following the Caledonian folding of parts of Andrées Land, of Ymers Ø, and of the region immediately to the southward and westward, block-faulting of an important character set in that may in the present state of our knowledge be ascribed to Hercynian age.

5. The Giesecke Bjærge, Moskusokse Fjord.

These mountains, which trend north to south from near the head of Muskox Fjord to Cape Franklin in Foster Bay, were visited in 1926 at their northern end by WORDIE's party and that same winter a surmise as to their structure was made by KOCH from distant observation. The latter considered them to be underlain in greater part by Caledonian granite with extensive Tertiary basalt injections, while WORDIE emphasised that the neighbourhood of Ladder Bjærg in the north of the range seemed to be one of several centres for the ejection of Tertiary basic volcanic rocks [22]. He makes no reference, however, to the associated sediments. In 1929 and 1930 during his mapping of the inner portions of Moskusokse Fjord, BACKLUND showed that with the basalts of the northern end of the Giesecke Bjærge are associated, not only what seem highly probably to be Tertiary sandstones and shales, but also older granites and gneisses, for which he postulated a Caledonian age [1]. On the east side of Ladder Bjærg, BACKLUND found evidence of the younger sediments resting upon an eroded platform of the older granites and gneisses, the whole cut by basalt dykes. But his important contribution to the geology of this district was secured from La Cours Bjærg and Ramsays Bjærg to the westward, where, instead of wide-spread granites (KOCH) within extensive outcrops of Eleonore Bay Formation, was found an interesting suite of acid and basic extrusive and intrusive rocks [2]. These consist of quartz-keratophyres and kerato-

phyres, as well as spilites and albite diabases, and he attributes them to the period of 'evolution' of the Caledonian geosyncline, while the granites of the neighbourhood belong to the phase of its 'revolution'. Moreover, Backlund proved that west of Cape Franklin, apart from basalts, there also occur acid phases of Tertiary age, namely quartz porphyry dykes, and beds of rhyolite (liparite) [1].

During a brief visit to the central part of the Giesecke Bjærge, on its eastern flank, in the face of Bonney Plateau (The 818 m Plateau,

Fig. 22. Basalt sills in (?) Upper Carboniferous eastern flank of Giesecke Bjærge.

15 km S. of Ladder Bjærg. See map of the geodetic institution in Copenhagen 73° Ø. 1 Hold with Hope), I found suggestive evidence of one at least of the granites of the district being younger than Caledonian. Into a predominant series of sandstones, shales, and dark limestones, unfossiliferous and cut by nearly horizontal basaltic dykes, was found intruded a pale pink granite of fine texture. A single sill, or dyke, of this rock was discovered fairly low down in the exposed succession, but it was one that quite clearly had nothing to do with the older granitic and gneissic series seen farther north by Backlund in the base of Ladder Bjærg. In the absence of fossils the age of the enclosing sediments remains in doubt, but lithologically they closely resemble Upper Carboniferous facies. Their condition of consolidation, apart from local induration in the proximity of basalt or other dykes, and their associated limestone, denies their being Tertiary, which is the age ascribed by Backlund for the unfossiliferous soft shales and sandstones of Ladder Bjærg.

Mesozoic age is not impossible for the rocks in question, and as seen from the Badland Dal in the vicinity of Myggebugten to the east, the whole succession between Ladder Bjærg and Bonneys Plateau, a distance of approximately 15 kilometres, seems to dip regularly to the north-east. This would permit of the known Mesozoic stratigraphic column of East Greenland occupying the space between these latter mountains, with the possibility of the series of Bonney Plateau coming within the Upper Carboniferous, as alternatively suggested. KOCH has described Upper Carboniferous, Triassic, and Cretaceous rocks as occurring just west of Cape Franklin at the southern end of the Giesecke Bjærge [8] and it may very well be that these extend into the central parts of the range.

As far as the evidently post-Caledonian granite is concerned, it would seem probable that further search might reveal the presence in this range of more of this igneous phase, and also that some of the granitic rocks ascribed by BACKLUND to the Caledonian period of activity, may later turn out to be Mesozoic (Hercynian), if not Tertiary, in age. The writer understands that the work of KOCH's field parties during the summer of 1933 has proved that early Kainozoic orogeny in certain areas of East Greenland was much more intense than had been previously assumed: not only considerable uplift, but granitic intrusion and local folding as well, have been shown to be of much more than minor importance [16]. As cited above, BACKLUND himself has recorded in the vicinity of Cape Franklin, at the southern end of the range, the presence of Tertiary quartz-porphyry and rhyolite, and it may well be that these acid eruptives are related to certain of the granitic occurrences to be found farther north in the range, such as that I found in Bonney Plateau.

The igneous phenomena of the Giesecke Bjærge are many and complicated, particularly along its western flanks, and admirable though the attempts by BACKLUND have been to unravel the difficulties, the last word has by no means yet been said. The work of H. BÜTLER in 1934, to be referred to below, confirms this. Early in September at the end of the season our party made a brief visit to Moskusokse Fjord, and I was enabled to collect a few specimens from the northern slopes of La Cours Bjærg. Two of these specimens were from a ledge of pink porphyry that turns out to be remarkably like the quartz-keratophyre shown by BACKLUND to occur in Ramsays Bjærg and Sederholms Bjærg next to the westward. There he has described its being associated with effusive spilites and albite diabases that are interstratified with what he incorrectly took (cf. H. BÜTLER) to be Eleonore Bay Formation sediments, and he claims that these eruptive types are restricted to this more western locality [2]. My find emerged from a "Felsen-meer" of loose talus, and no other solid outcrops with which to make any cor-

relation could under the circumstances be found. BACKLUND'S map of 1931 indicates somewhere in this vicinity a curious "infaulted zone of Upper Carboniferous basal conglomerate and dolomite" within what he claims to be "sediments appertaining to the Caledonian cycle". The descriptions given by BACKLUND are somewhat involved, and in the absence of fossils or other reliable comparative data, his conclusions as to the ages and relationships of these infaulted series are somewhat unconvincing. He speaks of a brick-red porphyry in La Cours Bjærg, which he claims can be identified without difficulty with the 'Caledonian' effusives of Ramsays Bjærg and Högboms Bjærg. But BÜTLER has recently shown the latter to be of Devonian sandstones and conglomerate [25]. The age, therefore, of the porphyry found by me remains at present in doubt.

BACKLUND has pointed to the good evidence of pre-Devonian age for the keratophyres, spilites, and albite-diabases of this district, since boulders and pebbles of these types are found in the tillites of Ella Ø and Cape Weber (Eleonore Bay Formation). And he has claimed that the products of eruption and irruption are distributed respectively between the evolutionary and the revolutionary phases of the Caledonian geosyncline. But apart from other later evidence to the contrary it is not clear why BACKLUND at this stage so readily lumped all the granites, granite-gneisses, granophyres, porphyries, keratophyries, etc. of this district into one general cycle — the Caledonian. Can it be that behind it lay his devotion to the one prime cause for the observed phenomena of widespread thermal metamorphism, or granitisation, of Caledonian age, in the grand example of which, in the process of anatexis, he has been so well trained in Fenno-Scandia? It is to the work of H. BÜTLER in this district that we owe quite a different picture both of the sedimentaries and their related igneous plases [25]. Instead of the widespread occurrence of the Eleonore Bay Formation as displayed on BACKLUND'S map [2]. BÜTLER'S detailed investigations have shown that almost the whole district west of La Cour Bjærg and Anker Bjærg is underlain by Devonian sandstone and conglomerate. But more important is his discovery that the keratophyres and other effusive rocks, considered to be Caledonian by BACKLUND, are in reality of Devonian age. This fact, together with the notable deformation of Devonian strata, throws new light on the nature of the later phases of Caledonian orogeny in these parts. As far as the considerable complications of La Cours Bjærg are concerned, BÜTLER opines that, in addition to Caledonian crystalline rocks, there probably occur Devonian eruptive in company with folded post-Caledonian sediments. In the opinion of the writer, however, there seems to be no good reason why some of the granitic types of the Giesecke Bjærge, and its immediate environs, may not belong to Her-

cynian or Tertiary epochs of diastrophism, and the present somewhat scrappy field evidence rather suggests it. The recent work of SÄVE-SÖDERBERGH in this same area, not yet published, should throw further light upon the problem.

The Giesecke Bjærge form part of what is sometimes referred to by East Greenland geologists as the "Koch Line". Strongly marked in the landscape almost throughout its length from Scoresby Sound (latitude 70°) as far north as Denmark Harbour (latitude 76°50′), LAUGE KOCH showed [6] that Mesozoic and Tertiary sediments are confined to the area east of this notable line. He claimed that the evidence, at any rate in its southern portion, pointed to its coinciding with a major fault-line of probably Permo-Carboniferous age, movement of which had likely recurred in later times and might be considered to have been responsible, in part at least, for the eruption of the widespread Tertiary basalts.

The significance of the Koch Line has been discussed by other workers, and FREBOLD in particular has emphasised [5] its importance as an oscillating dislocation progressively developed from Middle Carboniferous times onwards. Whether it is correct to ascribe such significance to this feature, or to regard it as an ancient and long continued shoreline, does not seem to be altogether clear. Recent work has rather tended to diminish the importance, if not the existence, of such a significant line. BACKLUND [1] in his references to the northern part of the Giesecke Bjærge, and Ladder Bjærg in particular, has agreed that the eastern flank of the Giesecke Bjærge seems to be virtually a fault-scarp, the result of late block-movement along the Koch Line, with down-throw to the east, or more probably considerable uplift to the west. If this is so, and the conditions farther south in and near the Giesecke Bjærge would certainly seem to comply with such a thesis, we may picture with BACKLUND a grand display of Tertiary volcanic activity that was preceded by local block-faulting to the east of the Koch Line, and succeeded by regional uprise along the western border of the Line to form the present Range. As far as this Range alone is concerned, however, the field-evidence would suggest that the southern end of it has been up-warped considerably more than the northern section in the vicinity of Ladder Bjærg. The real amount of warp is not, however, shown in the longitudinal section through the range (Plate 4) owing to the prevailing dip being oblique to it.

Extensive block-faulting has undoubtedly taken place in early Tertiary, and probably late Cretaceous, time from ample evidence up and down the coast. But as mentioned above, faulting and basic eruptions were not the only activities, and evidence seems to be accumulating that Tertiary orogeny in certain areas involved folding and granitic

intrusion in addition. When to this is added the impress of Caledonian and Hercynian orogenies as well, it is not surprising that we find East Greenland so complicated and so fascinating a diastrophic picture.

6. Tertiary Basalts of the Coastal Area.

Tertiary igneous rocks have been erupted on a grand scale in East Greenland, particularly to the south-west of Scoresby Sound. Farther north in the neighbourhood of the entrance of Kejser Franz Josephs Fjord, and confined to the coastal districts, are considerable out-pourings of these rocks, as well as intrusions, the vicinity of Hold-with-Hope being largely underlain by massive basaltic rocks.

Earlier observations in the surrounding neighbourhood by the Cambridge parties, and by LAUGE KOCH, had demonstrated that the Tertiary basic rocks consist of flows as well as dykes and sills, and later petrographical work by BACKLUND and MALMQUIST [3], and by TYRRELL [18], has shown there to be a good deal of variety within the dominant basalts and dolerites. As far as the Norwegian district (of meteorological and hunting interests) at Myggebugten is concerned, the writer understands that basic igneous material collected there during recent years is now being worked up in Norway.

Time only permitted of a few localities being cursorily visited in 1933, while our ship was awaiting the break-up of the ice in the fjords. These localities were at Myggebugten in Mackenzie Bay, and on Hold-with-Hope, Bontekoe Island and Arundel Island, apart from occurrences of these same rocks in the Giesecke Bjærge as already referred to.

In the majority of areas examined field-observation was much hindered by the enormous extent of the frost-riven mantle of débris that has accumulated since the Pleistocene ice-covering of the coastal districts. On slopes this tends to flow and envelope outcrops and even cliffs, making assessment of local structure a matter often of great difficulty.

By far the great part of the Tertiary basic rocks concerned appear to be intrusive dolerites and basalts of very usual composition, and the sections examined show them to be mostly devoid of olivine. Such surface flows as were found were confined to the district of Hold-with-Hope and Bontekoe Island. Apart from these flows great areas of sill, or dyke, approximate closely to horizontality, and departure therefrom in the coastal strip would seem to be due merely to local deformation, or tectonic adjustment of blocks. There is ample evidence that differential block-movements have taken place in late Tertiary times, apart from a regional tilt of the whole coastal belt east of the so-called 'Koch Line' earlier referred to. How much of the igneous activity may be considered

as due to fissure eruption along the supposed 'Koch Line', or how much may have taken place from distant volcanic centres such as those at Sabine Island, Clavering Island, etc., referred to by WORDIE [22] and BACKLUND [1], cannot at present be determined. It is at Sabine Island, incidentally, apart from Cape Dalton on the S.E. coast of Greenland, that the association of the basalts with sedimentary strata has determined the Lower Eocene age of the greater part of these basic eruptions. The occasional occurrence of hot springs, however, suggests that basic igneous activity in one form or another may have extended into the late Tertiary [6]. No plutonic phase of this Tertiary activity has been found, to correspond with the gabbro-granite occurrences described by WAGER in S.E. Greenland [19], unless certain of the acid phases in the Giesecke Bjærge (viz. granite and quartz-porphyry) mentioned above can be so ascribed. It should not be forgotten in this connection that the alkaline igneous rocks of Cape Parry, Traill Island, though considered by KOCH [6], and in part by NOE-NYGAARD [11], to be Hercynian in all probability, are by WORDIE [22] and TYRRELL [18] thought quite likely to be Tertiary in age: in view of the discovery of Tertiary alkaline syenites by WAGER on the south-east coast, a corresponding age for these northern occurrences seems not improbable. And as far as these Tertiary eruptives in general are concerned, and as emphasised by NOE-NYGAARD [11, p. 66], there is no real hiatus geographically or otherwise between the northern and the southern basalt areas. In contrast to the widespread tensional dyke phenomena of the south-east coast, cited by WAGER [19], such phase of eruption is not so apparent on the north-east, where sills and nearly horizontal sheets prevail. If the occurrence of the Tertiary plateau basalts be regarded as a function of tension in a W.N.W.—E.S.E. direction throughout this region [19], then the related and smaller eruptions on the north-east coast would seem to lie on a transverse fracture coinciding approximately with the present coast-line, and running athwart the regional dislocation that gave rise to such major outpourings as those at Scoresby Sound, and the Blosseville Coast, as well as Iceland, and the British Isles.

SUMMARY OF CONCLUSIONS

1. In the western parts of Fraenkels Land at the head of Kejser Franz Josephs Fjord, a continuous stratigraphical succession was found, extending downwards from the lower grade metamorphic Petermann Series of quartzites and slates, into the higher grade rocks of the so-called Central Metamorphic Complex. A corresponding case occurs at the head of Geology Fjord in the neighbourhood of Nunatak Gletscher.

2. The Petermann Series, within the mountain range extending northward from Petermann Peak, was found to be abruptly overfolded, and thrusting also was in evidence in the neighbourhood: which demonstrate the much farther extent westward of the Caledonian deformation than has generally been thought to be the case.

3. Granite, and some basic, sheet-intrusions accompanied the Caledonian folding, but these were not responsible for more than local metamorphism. BACKLUND's view of wholesale granitisation, and the hypothesis of widespread syntexis, cannot be applied in general to the region under review. Only in one restricted area at the head of Kejser Franz Josephs Fjord, and near Ättestupan, where granitoid gneisses occur, would such a thesis be possible, but even in this neighbourhood dynamic metamorphism seems to have been paramount.

4. There seems to be little doubt that the Petermann Series of the west is the equivalent of the Eleonore Bay Formation (= Franz Josef Beds of WORDIE) lying to the east. The equivalence is based upon general lithological and structural grounds, fossils being absent. Also, there is a good deal to suggest that the Hecla Hook Formation of Spitsbergen is a coeval series.

5. In Andrées Land, just north of Isfjord, Caledonian compression seems to disappear, and its place be taken at Geolog Fjord and to the northward by dominantly vertical movements of block-type. This may be due to a swing in the direction of Caledonian thrust from westward to south-westward, giving the effect of tensional and radial movements in Payers Land, Strindbergs Land, and part of Andrées Land, and the observed compression from Junctiondal southwards.

6. Block-movements, and limited local thrusting, in western Ymers Ø appear in part to be post-Caledonian probably to the latter age may also be attributed some of the similar movements that have taken place in those areas mentioned above lying north-west of Ymers Ø. The Teufelsschloss has not moved on its foundation and cannot be regarded as a klippe.

7. The view held by KOCH, FREBOLD, etc., that the western half only of the Caledonian geosyncline is exposed in this mountain belt of N.E. Greenland, and that the eastern half has sunk in the Greenland Sea cannot be subscribed to, and evidence is cited to show that the western limits of the geosyncline are still unknown. As to the northward continuation of the geosyncline, and how it may link up with the postulated Caledonian folding of extreme northern Greenland on the one hand (KOCH) and the somewhat better known folded belt of Spitsbergen on the other, there is insufficient data forthcoming at present. Further work in extreme north-east Greenland, as well as gravity determinations and ocean-bottom sampling (possibly by such a submarine expedition as that planned by Sir H. WILKINS) should contribute to this important problem.

8. The Giesecke Bjærge seem to be a block composed mainly of Upper Palaeozoic and Mesozoic strata, while their northern end may be of Kainozoic rocks. The succession is shot through with basaltic dykes of the latter age predominantly, but acid igneous phases of doubtful (and some possibly Hercynian) age are present in the central and southern parts of the range.

9. Tertiary igneous phenomena in the coastal portion of the region under review, although considerable, are not of the order of magnitude of the tectonically related area of Scoresby Sound and S.E. Greenland.

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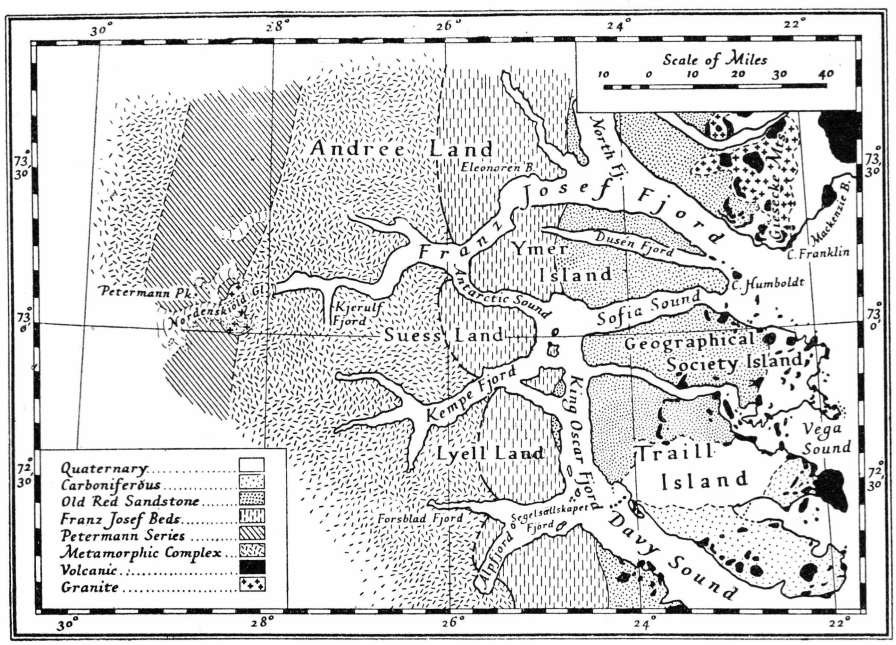
LIST OF PLATES

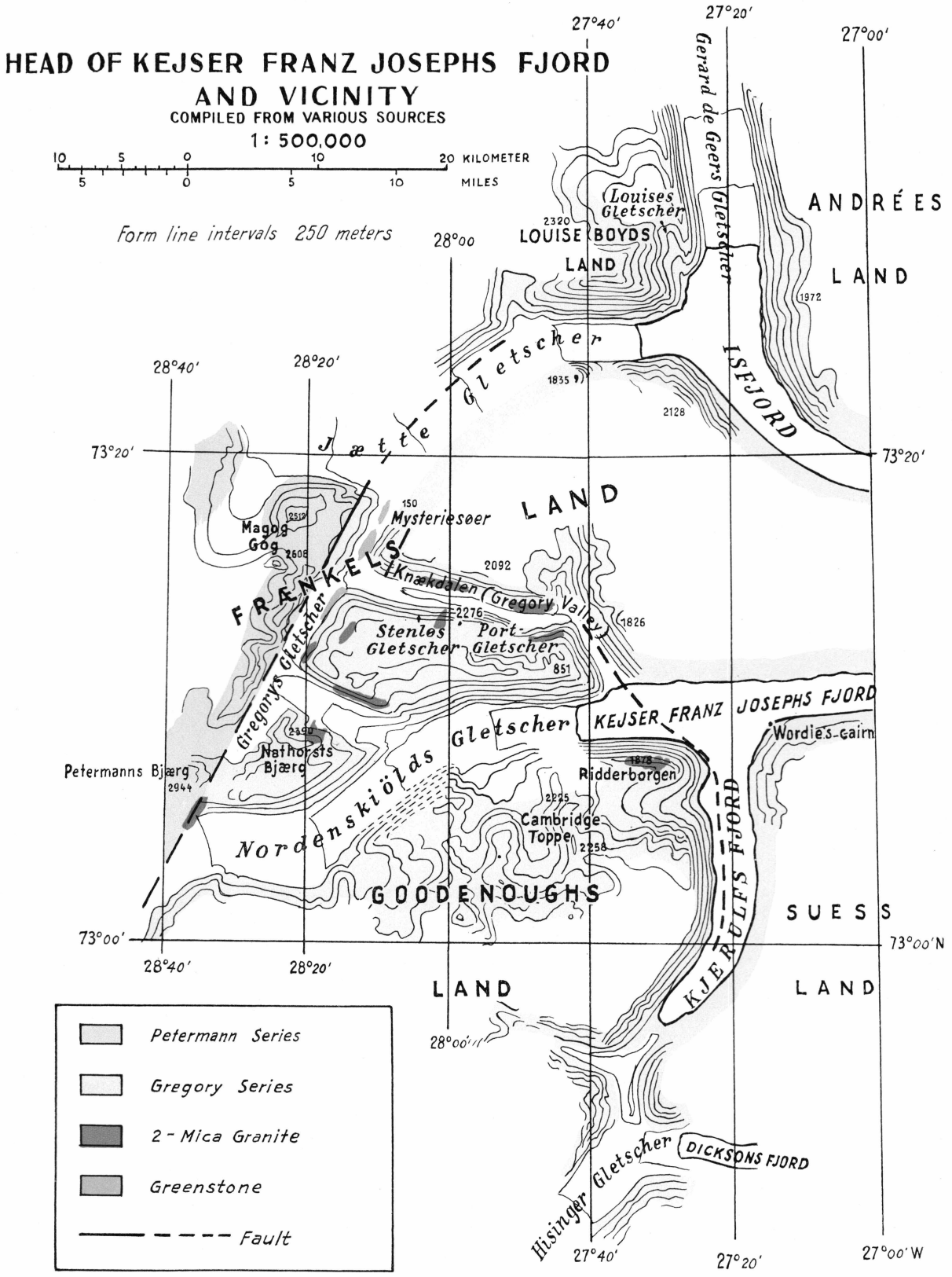
Færdig fra Trykkeriet den 3. Januar 1939.

GENERALISED GEOLOGICAL MAP

after Wordie and Whittard, 1930.



N.B. Geological boundaries [esp.? in West] are not consistent with later knowledge.


HEAD OF KEJSER FRANZ JOSEPHS FJORD
AND VICINITY
COMPILED FROM VARIOUS SOURCES
1: 500,000
10 5 0 10 20 KILOMETER
5 0 5 10 MILES
Form line intervals 250 meters
27°40'
27°20'
27°00'
28°00
28°40'
28°20'
73°20'
73°00'
73°00'N
27°00'W
Gerard de Geers Gletscher
Louises Gletscher
2320
LOUISE BOYDS LAND
ANDRÉES LAND
1972
ISFJORD
1835 ?
2128
Jætte Gletscher
Mysteriesøer
150
LAND
Magog
2519
Gog
2608
FRÆNKELS
Knækdalen (Gregory Valley)
2092
2276
1826
Stenløs Gletscher
Port-Gletscher
851
Gregorys Gletscher
KEJSER FRANZ JOSEPHS FJORD
Wordie's-cairn
2350
Nathorsts Bjærg
Petermanns Bjærg
2944
Nordenskiölds Gletscher
1878
Ridderborgen
2225
Cambridge Toppe
2258
GOODENOUGHS
SUESS
LAND
KJERULFS FJORD
Hisinger Gletscher
DICKSONS FJORD
Petermann Series
Gregory Series
2-Mica Granite
Greenstone
Fault

GENERALISED STRUCTURAL SECTION

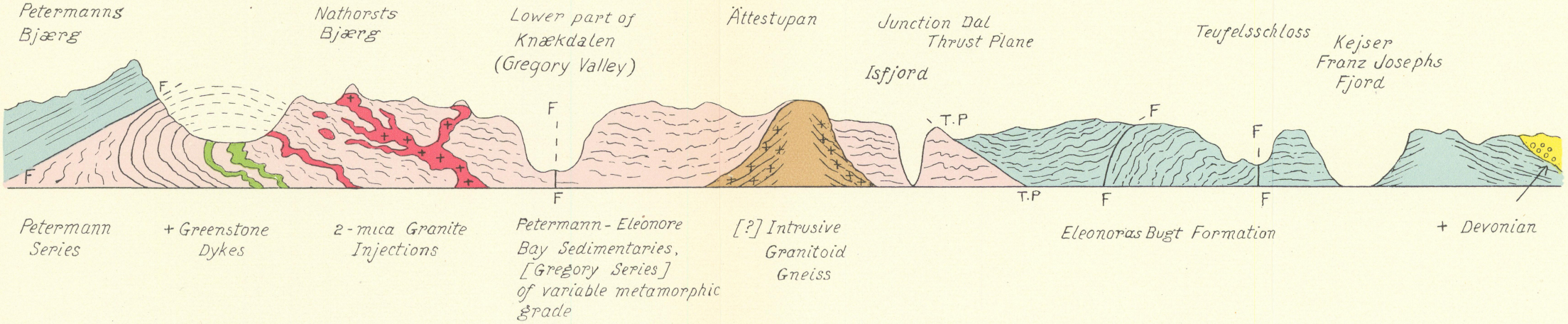
FROM PETERMANNS BJÆRG TO YMERS Ø

N.E. GREENLAND

Horizontal Scale 1 : 500,000 [7-9 mls. = 1 in.]

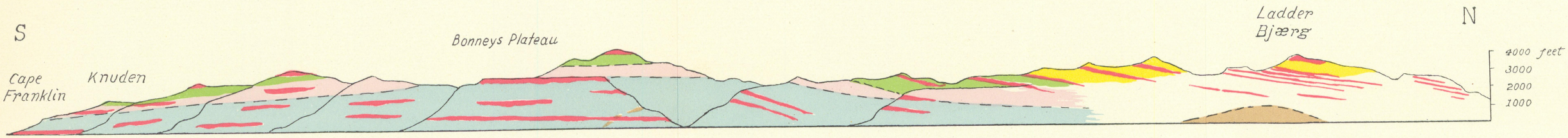
Vertical Scale exaggerated 4·3 times

W E



Generalised section through the Giesecke Bjærge.

Scale: 1 inch = 1·5 miles



? Tertiary

Cretaceous

Triassic and ? Permian

Upper Carboniferous

Basalt

Granite

MYSTERIESØER OVERFOLD

ca. 1600 - 1700 feet of beds involved in actual fold.

Diagrammatic only: horizontal scale 1 mile = ca. 1 inch

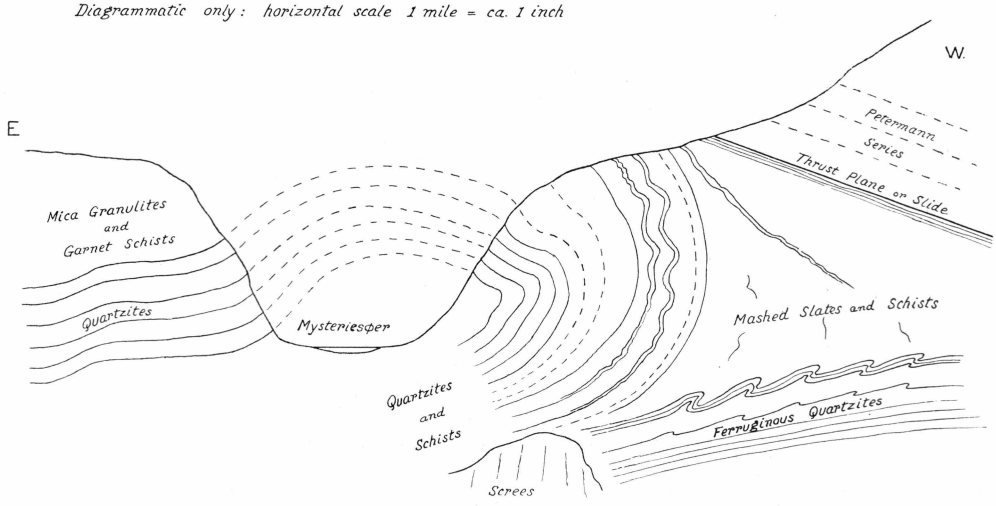


PLATE 6.

OVERTHRUSTS AND TEAR-FAULTS AT BLOMSTERBUGTEN, YMERS Ø