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UNDER LEDELSE AF LAUGE KOCH

GEOLOGICAL EXPLORATIONS
IN THE PETERMANN REGION, WESTERN
PART OF FRÆNKELS LAND,
EAST GREENLAND

BY

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WITH 33 FIGURES IN THE TEXT
AND 2 PLATES

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INTRODUCTION

In the present report some field-geological results are discussed which were obtained in July-August 1951 during the Danish East Greenland Expedition directed by Dr. LAUGE KOCH. The geological party of the authors had been instructed to map Frænkels Land, the peninsula situated between the innermost part of Kejser Franz Josephs Fjord and Isfjord. Our reconnaissance survey covered this peninsula from its eastern cape, called Svenskenæs, to the nunatak region west of the Petermann Range (see Fig. 1).

The results secured in the eastern part of Frænkels Land will be incorporated in a forthcoming paper by J. HALLER on the geology of Andrées Land and the adjacent part of Frænkels Land. The geology of the western part of Frænkels Land is roughly outlined in the present report. The publication of our field-geological results is justified, as this information is of immediate interest to our colleagues working in adjacent areas as well as to coming explorers. A more detailed study will be published when the petrological examination of the rock material collected has been finished.

The main object of our field-geological explorations was to solve the following problems:

1. the structure and stratigraphy of the Petermann Series,
2. the stratigraphical correlation between the Petermann Series and the Eleonore Bay Formation,
3. the relationship between the Petermann Series and the eastern adjoining Central Metamorphic Complex,
4. the rôle played by the late-tectonic to post-tectonic granite intrusions,
5. the alleged occurrence of a Western Metamorphic Complex between the inland ice cap and the Petermann Range.

The highly interesting petrological problems offered by the gradual and continuous transition from the slightly metamorphic sediments of

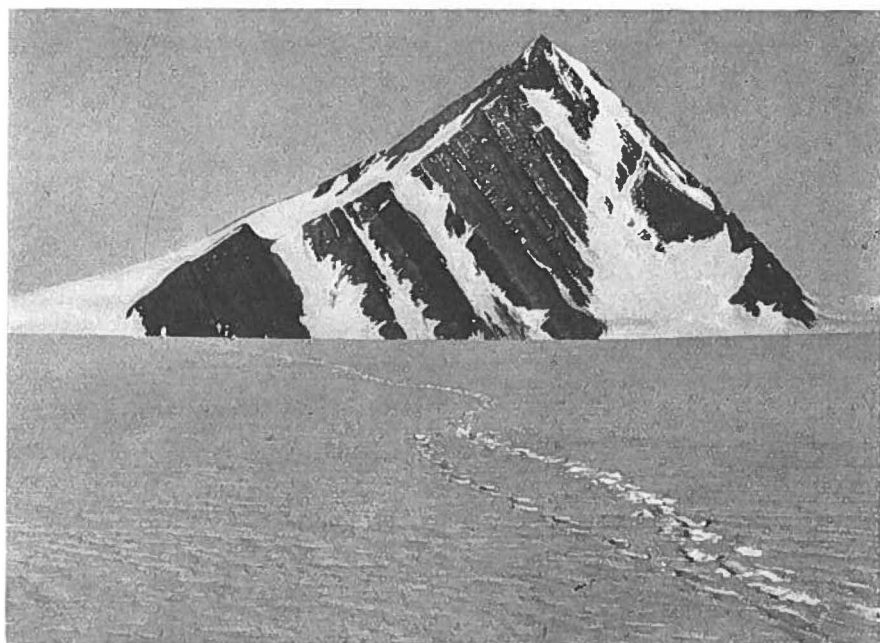


Fig. 2. Petermanns Bjerg, seen from Gregorys Gletscher (NE).

the Petermann Series to the high-grade metamorphic rocks of the Central Metamorphic Complex will be treated in a later paper, as soon as the microscopic and chemical study of the rocks is finished. These investigations are not only of considerable petrological interest, but also of great importance for the geological interpretation of the Central Metamorphic Complex.

Whoever knows the intricate character of the geological problems presented by the fjord region of East Greenland, will agree that only a carefully planned exploration campaign would have a chance of solving some of the delicate problems involved, especially in view of the comparatively short period of actual field-work (16th July—30th August 1951 in Frænkels Land). Of great importance for the success of our explorations were—apart from the unfailing help and advice offered by Dr. L. KOCH, and the local experience gained by J. HALLER during his work in Andrées Land (1949—1950)—the detailed study of the geological literature on the Kejser Franz Josephs Fjord region. Especially the papers by H. G. BACKLUND (1930, 1932) and C. E. WEGMANN (1935) on the fjord sections, those by N. E. ODELL (1939, 1944) and W. HUBER (1950) on Knækdalen (Gregory Valley), and the publications by J. M. WORDIE (1930), M. M. L. PARKISON and W. F. WHITTARD (1931) and D. H. WISEMAN (1932) on the area of Petermanns Bjerg proved to be very

useful for the planning of our campaign. Though we disagree with some of the opinions expressed therein, we gratefully acknowledge all the substantial information contained in these contributions.

The survey of Fränkels Land entailed the ascent of Petermanns Bjerg 2940 m (see Fig. 2), Gog 2607 m (both second ascents), and several other hitherto unknown summits of the Petermann Range (Kerberus 2575 m, Trappebjerg 2400 m a. o.). Moreover a long reconnaissance trip was made into the remote country W of Petermanns Bjerg, as far as Martin Knudsens Nunatak. All these excursions, which, apart from the usual mountaineering difficulties, offered considerable problems of transport, were made possible by the assistance of our comrades Dr. med. H. P. BUSS, Basel, and stud. ing. S. GÖRTZ, Zürich. They accompanied us on the badly crevassed inland glaciers and on all the major climbing tours; moreover they took the lead in transporting outfit and provisions. We are greatly indebted to our friends for their cheerful and unselfish cooperation, which enabled us, temporarily, to divide into two geological parties, and to stay away from our fjord-camp at the mouth of Knækelven for 23 days.

The strips of aerial photographs taken by E. HOFER, Berne, air-photographer of the expedition, were very useful for the extrapolation of our field observations to the unexplored neighbouring country. The pictures contained in this report (except Figs. 2 and 29) were likewise taken by him.

Our most cordial thanks are due to Dr. LAUGE KOCH, Copenhagen, the leader of the Danish East Greenland Expeditions, for offering us the opportunity to visit the highly interesting Petermann area, for his ready support and for the great personal interest he took in our field and laboratory work.

The field work, whose results are outlined in the present report, was made jointly by the two authors. Chapters I—IV were written by E. WENK, and Chapter V by J. HALLER, who also contributed all the graphical illustrations.



Fig. 3. Petermanns Bjerg, seen from NW; in background Goodenoughs Land.

I. STRUCTURE AND STRATIGRAPHY OF THE PETERMANN SERIES

In the region of Petermanns Bjerg (see Figs. 3 and 4) a well developed group of sediments was discovered by the geologists of the Cambridge East Greenland Expedition 1929. This zone of sediments of very low metamorphic grade, exposed to the west of the Central Metamorphic Complex, has been named the Petermann Series. According to J. M. WORDIE and W. F. WHITTARD (1930) as well as M. M. L. PARKINSON and W. F. WHITTARD (1931), these sediments consist of a series of black, brown, red or green quartzites, with ripple-marks and current-bedding unusually prominent, and they repose upon black shales. The quartzites of Petermanns Bjerg are reported to be at least 3500 ft thick.

In 1933 N. E. ODELL (1939, 1944), geologist of the Louise A. Boyd Expedition to East Greenland 1933, explored the Petermann sediments in the section of Gog 2607 m, in the northern part of the Petermann Range, and also those exposed in the mountainous country east of the Gregorys Gletscher. The Petermann Series was estimated to be upwards of 11,000 ft in thickness in the Petermann Range alone. The lower-

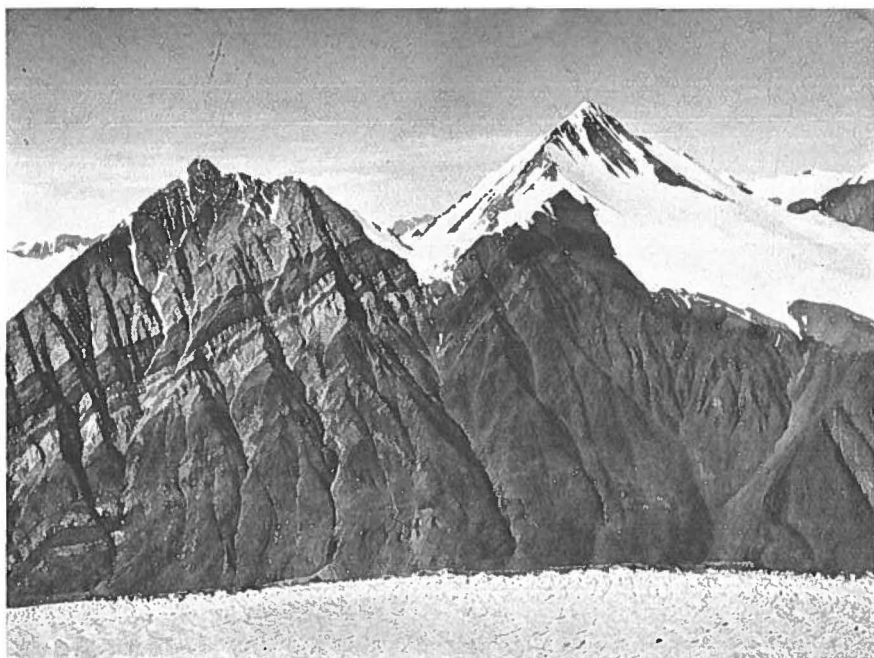


Fig. 4. Petermanns Bjerg (right) and Lille Petermann (left), seen from the SE; Petermann sediments (light-coloured Summit Series, banded and coloured Shoulder Series, dark-coloured Layered Series at base), exposed in rock walls above Norden-skiölds Gletscher.

grade metamorphic Petermann sediments are reported by ODELL (1944, pp. 222—223) to pass in downward succession, and without significant break, into an originally similar psammitic-pelitic group of higher metamorphic grade. This lower complex was named the Gregory Series, on account of its wide development in the Gregory Valley (Knækdalen), and it was estimated to be some 7000 ft thick. The stratigraphical succession of the whole sedimentary series is not mentioned; but a great number of rock samples are carefully described and their genesis discussed.

In 1948 W. HUBER (1950), member of the Danish Expedition to East Greenland under the leadership of Dr. LAUGE KOCH, re-examined the splendid section exposed in Knækdalen from Kejser Franz Josephs Fjord to Mysteriedalen and Magog 2512 m. In opposition to ODELL's results, HUBER found evidence for the gradual lateral transition of the Petermann sediments into the beds of the higher metamorphic Gregory Series; but he did not publish any petrological details regarding this transition. HUBER's paper includes a geological section superior to that of ODELL, and contains also a stratigraphical column of the Petermann



Fig. 5. Gregorys Gletscher, seen from NE; in background Shackletons Bjerg (left), uppermost part of Nordenskiöld's Gletscher, Petermanns Bjerg (right centre) and inland ice cap.

Series, comprising 11 different stages of a total thickness of 2400 m (7870 ft)¹).

All the previous explorers assumed that the sediments of the Petermann Series were of approximately the same age as those of the Eleonore Bay Formation found in the fjord region, especially the lower quartzitic part of this upper Pre-Cambrian formation. But an exact correlation of the two important sedimentary zones, adjoining the Central Metamorphic Complex to the east and west, was not possible. The stratigraphical sequence and the thickness of the different stages were, in fact, insufficiently explored.

The geological results of our explorations in July-August 1951 are compiled in the geological map and sections (Plates 1 and 2) and in the concise stratigraphical columns (Fig. 12a and 12b) and demand little comment. For the field work enlargements (1:100,000) of the official Danish map (1:250,000), sheet 73 Ø 3, Petermanns Bjerg, 1941, were used. Moreover, for Knækdalen (Gregory Valley) the excellent photogrammetrical map on a scale of 1:50,000, drawn by the surveyors of the Louise A. Boyd Expedition 1933 (L. BOYD 1935, Pl. 1), was at

¹) It may be added here that the thickness measured in HUBER's section exceeds this figure.

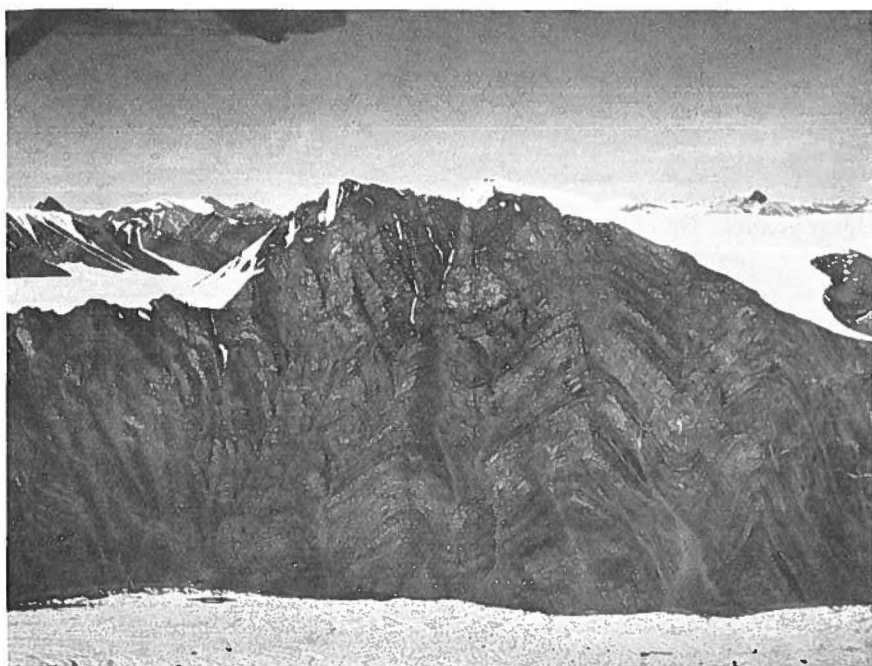


Fig. 6. Anticlinal core of Gregory Anticline in rock wall above Nordenskiöld's Gletscher, seen from S; in background part of Petermann Range and Gregorys Gletscher (left), Nathorsts Tinde (right).

our disposal. Our detailed geological map on a scale of 1:50,000 of this highly important valley extending from the summits Gog and Magog in the west to the innermost Kejser Franz Josephs Fjord in the south-east, will be published in a forthcoming petrological paper. The dips shown on Plate 1 indicate the routes actually surveyed; the geology of the neighbouring country was sketched according to aerial evidence.

1. Tectonics.

The structure of the area occupied by the Petermann Series and by its metamorphic equivalents is comparatively simple. It is governed by three principal folds:

Gregory Anticline: A broad anticline runs in a SSW—NNE direction along the Gregorys Gletscher and Mysteriedalen. It can be traced over a distance of 30 km, right across Fränkels Land, from the Nordenskiöld's Gletscher in the SSW as far as the Jættegletscher in the NNE. The axial crest is buried beneath the Gregorys Gletscher, from which the strata dip away on both sides (see Fig. 5). As is shown on Fig. 6, the complex anticlinal core is well exposed in the steep rock walls



Fig. 7. Anticlinal crest of Gregory Anticline in uppermost part of Knækdalen (bottom, draining to the right), Mysteriedalen (left) and Jættegletscher, seen from S.

SE of Petermanns Bjerg, which descend to the Nordenskiöld's Gletscher. The position of the crumpled anticlinal region is well borne out also by the many dips collected in the exposures near the tongue of the Gregorys Gletscher, in the ravines of the uppermost part of Knækdalen, and in the 'roches moutonnées' of the threshold separating Knækdalen and Mysteriedalen (see Fig. 7). The Mysteriesøer overfold, discovered by ODELL (1939, Fig. 2), forms part of the complicated anticlinal core of this Gregory structure, as correctly pointed out by HUBER (1950). In contrast to the broad and crumpled anticlinal core, the flanks of the Gregory Anticline show a very regular structure (see Figs. 5 and 10). Only the incompetent pelitic layers, interbedded between the competent psammitic strata, exhibit drag folds which, in the eastern adjoining metamorphic equivalents of the Petermann Series, give rise to the development of flow cleavage. The axes of these minor folds have the same direction and plunge as the anticlinal axis.

Petermann Syncline: At a distance of roughly 8 km to the WNW of the Gregory Anticline, and parallel to this tectonic line, runs the Petermann Syncline. This structure was first discerned from the top of Gog 2607 m. Its summit offers a splendid view of the northern precipices of Kerberus 2575 m, where the trough of the syncline is



Fig. 8. Petermann Syncline, seen from NNE; Kerberos in foreground, Petermanns Bjerg, Shackletons Bjerg and inland ice in background.

well exposed (see Fig. 8). Here the pelitic beds of the stratigraphically highest series are more compressed than the deeper parts of the Petermann Syncline. This observation supports WEGMANN's table (1935, Fig. 6, No. 2), based on similar observations in the fjord region of East Greenland. The synclinal area was subsequently explored in two sections. Like the Gregory Anticline, the Petermann Syncline, also, can be traced right across Fränkels Land. From the area immediately west of Petermanns Bjerg it can be followed in a NNE direction over a distance of 40 km as far as the south-western part of Louise Boyds Land, where the splendid section of the Jættegletscher shows the trough again (see Fig. 9).

Knækdalen Syncline: East of the Gregory Anticline a synclinal structure with a broad, flat bottom and rather steep flanks was ascertained in Knækdalen and in the mountains N of the lower part of Nordenskiöld's Gletscher. Actually in both sections this Knækdalen-Syncline appears to be divided into two troughs; but for the sake of convenience only one synclinal axis is shown on our map (Pl. 1). It can be traced over a distance of 15 km. Its southern and northern prolongations have not yet been ascertained. It is interesting to note that the late- to post-tectonic granite intrusions of Fränkels Land appear to be restricted



Fig. 9. Gog (centre), Magog (right), and Louise Boyds Land (background), seen from S; note the trough of the Petermann Syncline in Louise Boyds Land above Jættegletscher.

to the zone occupied by this synclinal structure (see Figs. 23 and 24, also Figs. 25 and 26).

Faults: Major faults are entirely absent in the area explored. In agreement with the observations of W. HUBER (1950), we did not find any support for the existence of an important fault-line at the base of the Petermann Range, as postulated by N. E. ODELL (1939, Plates 2 and 3; 1944 Figs. 3 and 4). The cataclastic and mylonitised rocks, mentioned by this explorer, correspond to those members of the Phyllite Series which show flow cleavage and occur in the drag folds mentioned above. This deformation is not confined to a definite tectonic line, such as the western flank of the Gregory Anticline. It occurs in the eastern limb of this structure as well. A fault-line of regional importance, as assumed by ODELL, would be visible in the fine sections offered by the Nordenskiöld's Gl. and Jættegletscher. However, no such feature was detected on the well overlapping series of aerial photographs of these distinctly banded rock walls. It is only in the area SW of Petermanns Bjerg that some minor faults are seen.

Thus, the sedimentary zone (Petermann Series) occurring to the west of the Central Metamorphic Complex is distinguished from the



Fig. 10. Gregorys Gletscher (foreground), Spaltegletscher (left), part of Petermann Range, and Martin Knudsens Nunatak (background), seen from ESE; the middle moraine in the foreground leads to the Nathorst Gletscher. The mountain ridge in the centre gives a continuous section from the Synclinal Series (1) of Kerberus (snow-clad mountain on the left), across the light-coloured Summit Series (2), the banded Shoulder Series (3), to the dark-coloured Layered Series (4) above Gregorys Gletscher; this section served as type section.

sediments situated to the east of the crystalline complex (Eleonore Bay Formation) by stronger folding and much fainter faulting.

2. Stratigraphy.

The thickness of the strata of the Petermann Series was determined in three ways: (1) by means of the 'Photogrammetrical Survey of the Gregory Valley, scale 1:50,000' (L. BOYD 1935, Pl. 1) and of many determinations of strike and dip in the section Gog-Knækdalen, (2) by altimeter readings, and (3) by chaining by the aid of our 40 m glacier rope. The latter method was adopted on Petermanns Bjerg (Fig. 2) and also during the survey of our type-section along Spaltegletscher, between Kerberus and Gregorys Gletscher (Fig. 10). The total thickness amounts to 6300 m.

For the subdivision of the Petermann Series natural lithological boundary lines were chosen, independent from any correlational specu-

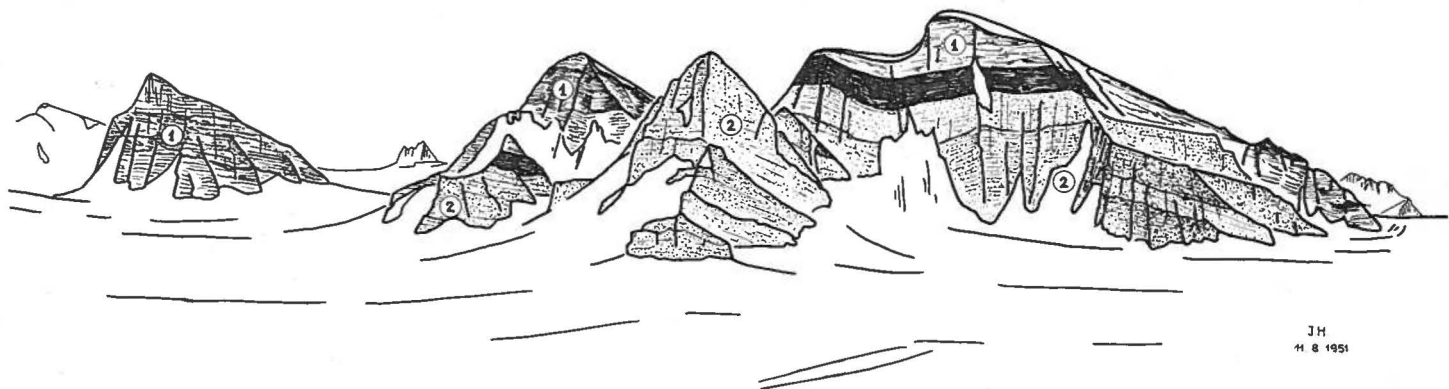


Fig. 11. Panorama of the nunatak region between Kerberus and Kalifbjerg, seen from W (N-end of Ulvekam); in foreground, gently dipping western limb of Petermann Syncline, with Synclinal Series (1) reposing upon Summit Series (2), in background summits of the Petermann Range.

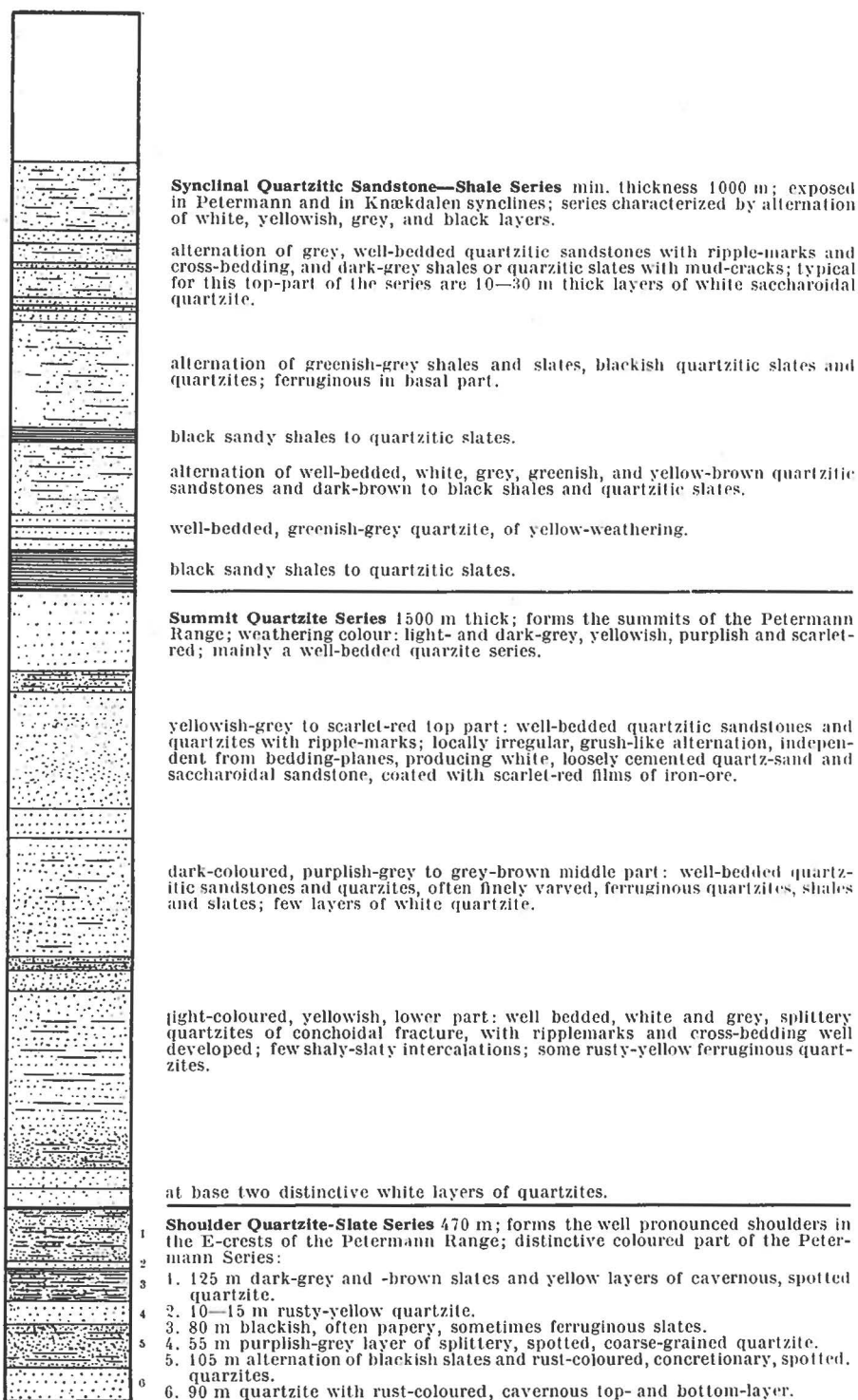


Fig. 12a. Stratigraphical column of the upper part of the Petermann Series.



Layered Quartzite-Slate-Dolomite Series 1400 m thick;
forms steep cliffs along Knækdalen and Gregory Glacier;
light-grey, dark-grey and yellow weathering colour.
rhythmical alternation of well bedded
dark-grey slates, quartzitic ferruginous slates and spotted phyllites with
biotite- and garnet-porphyroblasts;
light-grey quartzites with characteristic layers, lenses and streaks of grey
dolomite, showing chocolate- to coffee-brown weathering colour; white sac-
charoidal quartzites.
Metamorphism of series increasing in eastern direction;
transition into mica-schists and biotite-plagioclase-gneisses, garnet-quartzites
and garnet-hornblende-granulites.

white quartzite at base in Knækdalen

Phyllite Series approx. thickness 1250 m;
forms gentle, soft mountain slopes;
olive to brown weathering-colour.
monotonous series of tough, greenish-grey to silver-grey phyllites (sericite,
chlorite).
Grade of metamorphism increasing E of Petermann Range:
porphyroblasts of biotite and garnet; transition into garnet-chlorite- and garnet-
mica-schists with lenses of garnet-hornblende-fels; in lower part of Knækdalen
transition into garnet-staurolite-mica-schists and gneisses with lenses of garnet-
amphibolite and with pegmatite-veins.
Series shows pronounced incompetent folding and flow-cleavage.

Mystery Quartzite Series min. thickness 700 m:
forms steep cliffs E of Mystery Valley; yellowish-grey to rusty-yellow weathering-
colour; mainly a poorly bedded series of massive quartzitic sandstones with
ripple-marks very well developed.
Upper part: lenticular, light-grey quartzites and mica-quartzites of a rusty
weathering-colour, with ripple-marks and cross-bedding, alternating with slates
and mica-schists.
Lower part: massive, light-grey quartzites, purplish or yellow on weathering;
badly bedded, but sometimes finely varved by films and mm-thick beds of
slate and biotite-magnetite-schist.
Base of series not exposed; many boulders of carbonate-chlorite-actinolite-schists
and phlogopite-marbles in moraine near Lower Mystery Lake, at the base of
the Mystery Quartzites.

Fig. 12b. Stratigraphical column of the lower part of the Petermann Series.

lations. Fortunately the predominantly psammitic sediments are interbedded with pelitic and dolomitic-calcareous layers, which served as guide horizons. Some of the sediments are strikingly coloured, e. g. those of the Shoulder Series. But we carefully omitted terms adopted for the subdivision of the Eleonore Bay Formation (e. g. coloured series).

The stratigraphically youngest and hitherto unknown sediments of the Petermann Series were only found in the Petermann Syncline, especially in the vicinity of Mount Kerberus. This Synclinal quartzitic sandstone-shale Series shows a minimum thickness of 1000 m (see Fig. 11). It is underlain by a mainly psammitic series, 1500 m thick, which builds up all the prominent summits of the Petermann Range, from Lille Petermann in the SSW to Magog in the NNE. The direction of the Petermann Range is parallel to the synclinal and anticlinal axis of the folding, and this Summit Quartzite Series demonstrates the close relations between tectonics, lithology, and morphology in this region. The light-coloured and well bedded quartzitic sandstones and quartzites of the summit region rest upon a coloured, 470 m thick alternation of blackish to brown shales-slates and rusty-yellow to purplish massive quartzites, which everywhere form the pronounced shoulder in the eastern spur of the individual summits. These characteristic coloured layers were termed Shoulder Quartzite-Slate Series. Its stratigraphy was studied in more detail, and it became evident that the facies of this series varies distinctly within the Petermann Range. The stratigraphical column (Fig. 12a and b) refers to the division found in our type-section between Kerberus in the W and the Gregorys Gletscher in the E. In downward succession follows the 1400 m thick Layered Quartzite-Slate-Dolomite Series, exposed in the steep cliffs on both sides of the Gregorys Gletscher (see Fig. 5). It overlies the 1250 m thick Phyllite Series, which forms the gentle mountain-slopes around the tongue of Gregorys Gletscher, in Mysteriedalen, and in the uppermost part of Knækdalen. The lowermost part of the Petermann sequence is only exposed in Mysteriedalen, and consists of quartzites with very well developed ripple-marks. It was termed the Mystery Quartzite Series. Possibly this series is underlain by carbonate-chlorite-schists, carbonate-actinolite-schists and phlogopite-bearing marbles, which rocks form about 30 per cent. of the morainic block material found in the vicinity of the Nedre Mysteriesø. This region forms an axial culmination of the Gregory Anticline.

Diabase dikes, cutting across the Petermann sediments, are rare. Sporadic occurrences of these rocks were found in all closely examined sections of the Petermann Range, from Petermanns Bjerg to Gog.

II. STRATIGRAPHICAL CORRELATION BETWEEN THE PETERMANN SERIES AND THE ELEONORE BAY FORMATION

There are three lines of approach to the stratigraphical correlation of the sediments adjoining the Central Metamorphic Complex to the west (Petermann Series) and to the east (Eleonore Bay Formation):

1. Lithological arguments.

Quartzitic sandstones and quartzites showing very well preserved ripple-marks and cross-bedding are a common feature of both sedimentary groups. They are, in fact, characteristic of these geosynclinal shallow-water deposits. But, as far as our knowledge goes, psammitic beds with ripple-marks are abundant within the pre-Cambrian sediments of East Greenland, and are scattered throughout the stratigraphical sequence; they are of no use for the formational correlation of specific horizons.

Of far greater value are the pelitic intercalations. Argillaceous series of a thickness of several hundred metres are rarely met with in the pre-Cambrian sequence, and those of over 1000 m thickness, such as the Phyllite Series of the Petermann group, may serve as guide-horizons. They have an equivalent only in the lower part of the comprehensive Eremitdal Series of the Eleonore Bay Formation, as described by E. FRÄNKEL (1952) and J. HALLER (1952) from Andrées Land. The Phyllite Series can be followed (see Pls. 1 and 2) from the type area around the snout of Gregorys Gletscher in an eastern direction as far as Lavinegletscher in Knækdalen, where the garnet-phyllites and garnet-mica-schists dip down below the valley floor. In the eastern limb of the Knækdalen Syncline the Phyllite Series emerges, again in a higher metamorphic grade (garnet-staurolite-cyanite-mica-schists and -gneisses, alternating with garnet-amphibolites), in the gorge of Knækvelven between Portgletscher and Lystergletscher. Petrographically identical rocks occur farther eastward, in Engdalen, within the Central Metamorphic Com-



Fig. 13. Kerberus, Trappebjerg (centre) and type section above Spaltegletscher (right), seen from SE; Synclinal Series (1), Summit Series (2), Shoulder Series (3) and Layered Series (4); compare the stratigraphy seen in Fig. 14.

plex, as members of the metamorphic Eremitdal Series. They are found within the same series also along the Isfjord section of Frænkel's Land.

Another petrographical parallelisation is indicated by the remarkable bands, lenses, and streaks of grey dolomite with a coffee- or chocolate-brown-weathering crust which are scattered throughout the Layered Quartzite-Slate-Dolomite Series, covering the above-mentioned phyllites. Corresponding rocks are found in the upper part of the Eremitdal Series from the type localities in Andrées Land, as is documented by the collections made by E. FRÄNKEL.

Both parallelisations point to a correlation of the Phyllite Series + Layered Series = Eremitdal Series. It seems probable that the Shoulder Series, also, corresponds to the, in the type area of Andrées Land somewhat ill-defined, Eremitdal Series, and that it forms the uppermost part of this comprehensive group. This assumption is supported by the fact that the Summit Quartzite Series, covering the Shoulder Series, commences, at its base, with one, sometimes two distinctive white bands of quartzite (see Figs. 4 and 10), resembling those found at the bottom of stratum 1 of the Eleonore Bay Formation. The photographs Figs. 13



Fig. 14. N-side of Grejsdalen, East Andrées Land; seen from S; post-orogenic granite (bottom) in discordant contact with beds of the Eleonore Bay Formation; beds No. 3 of the Quartzite Series (1), beds No. 1 (2b) and 2 (2a) of the Quartzite Series, uppermost part of the Eremitdal Series (3), Eremitdal Series (4); figures entered in photograph agree with those of Fig. 13 and designate stratigraphically corresponding beds.

and 14 demonstrate the striking similarity of the respective sections of the Petermann Series and of the Eleonore Bay Formation.

2. Geological connection.

During the field campaign in Fränkels Land it became evident that the mica-schists, gneisses, migmatites and granites, exposed in the N—S running lower part of Knækdalen, build up, in their eastern prolongation, the mountain tops of Engdalen, and continue in a NE direction as far as Haredalen-Isfjord. These rocks together form a nappe-like, syntectonic, migmatite complex. The metamorphic equivalents of the Petermann Series, exposed in the E—W running part of Knækdalen, just above the confluence of Knækvelven and the river draining Lystergletscher, adjoin this migmatite complex to the W and NW and correspond to the parashists found along the Isfjord between Haredalen and the Jættegletscher. These metamorphic sediments of the Isfjord region have already been correlated with the Eleonore Bay Formation and were identified as

the metamorphic Eremitdal Series by HALLER (1952) in Andrées Land (cf. the geological maps 1:250,000 of Andrées Land in the forthcoming publications of E. FRÄNKEL and J. HALLER).

Thus, the field-geological connection points also to a correlation of the Phyllite Series + Layered Series + Shoulder Series = Eremitdal Series (see Fig. 15).

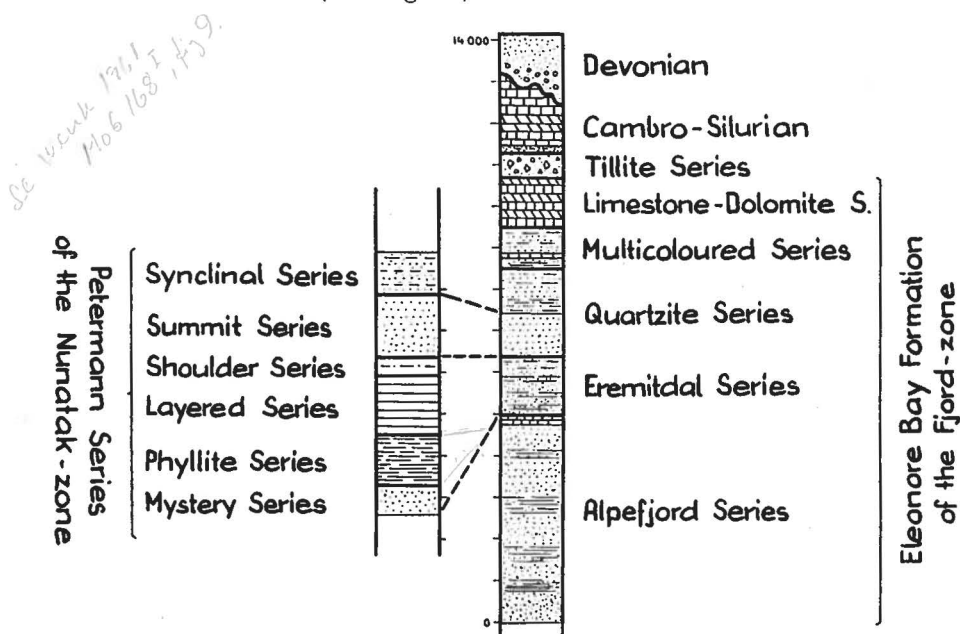


Fig. 15. Stratigraphical correlation table of Petermann Series and Eleonore Bay Formation.

3. Position of the top of the predominantly granitic crystalline.

In the fjord region of East Greenland the discordant, late- to post-tectonic granite intrusions are in contact with very different stratigraphical series. But the concordant gneisses and igneous-looking rocks of granitic composition, forming the migmatitic infrastructure of the covering sediments, usually touch with their roof a definite stratigraphical horizon. This means, to follow the terminology of WEGMANN (1935), that the 'migmatite front' within a given fjord region, by granitisation of the underlying sediments, has risen to a certain stratigraphical level. In a neighbouring area the migmatite front may have a somewhat different position, higher or lower in the stratigraphical sequence.

Throughout the area of the dome-like uplift, whose centre is situated in the Isfjord near Renbugten, between Fränkels and Andrées Land,

the roof of the conformable granitic basement is in contact with marbles, carbonate-bearing schists, green schists, and quartzites, which underlie the Eremitdal Series. This holds good also for the mountain Ättestupan in the innermost part of Kejser Franz Josephs Fjord, where the granite-dome plunges in a westward direction down below sea-level. 25 km farther to the west, W of Knækelven, the migmatitic infrastructure is in contact with the amphibolite-bearing gneisses and schists of the Phyllite Series described. As it is not reasonable to assume an important rise or drop of the migmatite front over this short distance, a correlation of the Phyllite Series of the Petermann beds, with the lower part of the Eremitdal Series of the Eleonore Bay Formation, seems probable from this point of view also.

Figure 15 indicates that, according to our correlation, 5200 m of the Petermann Series correspond to 2400 m of the Eleonore Bay Formation. The great difference in thickness means a certain obstacle to our correlation. But, as will be shown in the forthcoming publication of J. HALLER (1952), the thickness of the Eremitdal Series in Andrées Land increases considerably from E to W. The late pre-Cambrian sediments change more rapidly in facies and thickness in an E—W direction than they appear to do in a N—S direction.

Though the sediments of the Petermann Series are thicker than the corresponding stages of the Eleonore Bay Formation, they do not represent a more bathyal development of the late pre-Cambrian sedimentation. In our opinion the median part of the late pre-Cambrian geosyncline was situated in the belt now occupied by the Central Metamorphic Complex. It is in this zone of western Andrées Land and central Fränkels Land that the stratigraphically interpretable sediments, especially the Eremitdal Series, show a uniform, sandy-argillaceous development. The thick and monotonous sequence of the Eremitdal Series, found in central Fränkels Land, resembles the 'schistes lustrés' of the Alps and contrasts with the more differentiated development of the same beds in the Petermann Series. The Petermann Series and the Eleonore Bay Formation appear to represent the sediments deposited in the western and eastern marginal portions of the late pre-Cambrian geosyncline. Future investigations, on a regional scale, will have to deal with these problems.

III. RELATIONSHIP BETWEEN THE PETERMANN SERIES AND THE CENTRAL METAMORPHIC COMPLEX

As shown by the outcrops of Mysteriedalen and Gregorys Gletscher, and as was stated already by HUBER (1950), the sequence of the Petermann Series has its lateral eastward continuation in the succession of ODELL's metamorphic Gregory Series (= western part of the Central Metamorphic Complex). The Gregory Series represents the metamorphic equivalent of the Petermann Series. This result, borne out by the geological survey 1:50,000 of Knækdalen, is of great geological importance. It proves the gradual lateral transition of the beds of the Petermann Series into those of the Central Metamorphic Complex, and supports the views expressed by KOCH (1929), BACKLUND (1930, 1932) and WEGMANN (1935) in respect to the relations between the Eleonore Bay Formation and the Central Metamorphic Complex.

In the section of Knækdalen (see Plate 2) this transformation can be followed stepwise in different stratigraphical series. The Phyllite Series, the lowermost pelitic part of the Petermann sediments, is represented by chlorite-sericite-phyllites at the base of the mountains Gog and Magog, and here forms the western flank of the Gregory Anticline. In the eastern flank of this structure the same beds consist of spotted phyllites and schists, indicating incipient biotite and garnet crystallization. A few kilometers farther east, but still to the west of the Knækdalen Syncline, the rocks are crowded with mm-thick idiomorphic garnet porphyroblasts and contain occasional lenses of garnet-hornblende-rock. The chlorite disappears, and the phyllites gradually pass into garnet-mica-schists, dipping eastward beneath the valley floor. In the eastern limb of the Knækdalen Syncline, below Portgletscher and in the neighbourhood of Camp I of the Louise A. Boyd Expedition (see Plate 1 in L. BOYD 1935) the same stratigraphical series crops out again, now in the more highly metamorphic form of garnet-staurolite-cyanite-mica-schists and garnet-mica-gneisses with cm-large garnet porphyroblasts. From here towards the junction of Knækelven with the

stream draining Lystergletscher the schists and gneisses grow lighter in colour and are enriched with plagioclase and alkali-felspar, especially microcline. At first they contain only eyes of felspar, then lenses and veins of pegmatite, and finally layers of garnet-bearing granite. This border zone passes into the thick migmatite complex of the lower Knækdalen and of Engdalen—Haredalen. Evidently the rocks of the Phyllite Series have, during the metamorphism, here also been transformed metasomatically, mainly by addition of alkalis.

The Layered Quartzite-Slate-Dolomite Series, overlying the Phyllite Series, undergoes a similar progressive metamorphism. The quartzitic

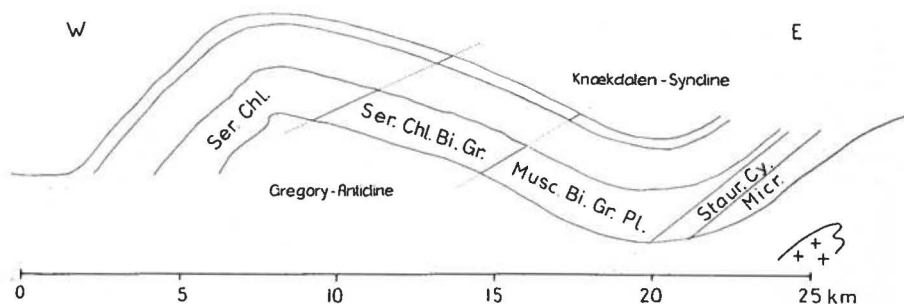


Fig. 16. Schematic section across metamorphic zones of Knækdalen. Ser. = sericite, Chl. = chlorite, Bi. = biotite, Gr. = garnet, Musc. = muscovite, Pl. = plagioclase, Staur. = staurolite, Cy. = cyanite, Micr. = microcline.

sandstones and quartzites with the characteristic streaks, lenses and layers of dolomite found in the Petermann Range, 12 km farther eastward are transformed into garnet-hornblende-granulites and -marbles. In the originally sandy layers of this series cross-bedding is often well preserved even in the felspatised rock types.

The pelitic members of the Shoulder Quartzite-Slate Series, the next higher division of the Petermann Series, also show a progressive metamorphism. The shales and slates of the Petermann Range pass into phyllites and schists in the middle part of Knækdalen. But, compared with the stratigraphically much deeper Phyllite Series, the grade of metamorphism is much less.

Field-geological evidence shows that the grade of metamorphism increases as one goes eastward, be it along the valley floor, or along the peneplained crest of the mountains. The metamorphism is progressive also if one descends the steep rock walls down into Knækdalen. The horizontal and vertical gradients indicate that the zones of comparable metamorphism are inclined, and dip towards the west. The results of the microscopical examination of the numerous rock samples collected lend support to this result. Though the petrographic investigations are



Fig. 17. Rock wall N of front of Nordenskiöld's Gletscher; dark-coloured metamorphic rocks of the Phyllite Series, covering banded and flow-structured gneisses of migmatite complex; in background mountains N of Knækdalen.

still in progress and will be treated in detail in a following publication, the results obtained so far are summarised in the schematic Fig. 16. It is evident that the zones of equal mineral facies cut across the bedding planes and across the whole structure. This puzzling result demands an explanation:

The interrelations between the crystallisation and the deformation phases recognisable in the fabric of the metamorphic sediments, indicate that the porphyroblasts were formed partly during, partly after the folding of the rocks. The differential movements during the folding and the load of the covering rocks were about the same throughout the section examined (Plate 2). The differential movement was, in fact, so negligible that it did not disturb the ripple-marks and cross-bedding of the psammitic beds; only in the pelitic beds was it of some importance. Thus, the pressure conditions cannot be made responsible for the progressive metamorphism. The temperature conditions, produced by the syntectonic migmatite and granite complex exposed in the lower part of Knækdalen, must have been essential for the grade of metamorphism increasing from W to E. The granitic solutions, ascended during the orogenesis, gave rise to thermal metamorphism of the country rock in



Fig. 18. Rock wall N of the head of Kejser Franz Josephs Fjord, between the front of Nordenskiöld's Gletscher and the mouth of Knækvelven (continuation of Fig. 17 to the right (E)); light-coloured gneissose granite in anticlinal core of migmatite fold.

the zones far outside the aureola of injection and metasomatic replacement. The zones with the same mineral facies represent segments of the same thermal metamorphism. This contact metamorphism was almost synchronous with the moderate folding. Figures 17 and 18 show the 2000 m high rock walls at the head of Kejser Franz Josephs Fjord, W of Knækdalen and N of the front of Nordenskiöld's Gletscher. The overlapping aerial photographs show the field relations between the dark-coloured original pelites of the Phyllite Series, metamorphosed without notable chemical exchange (seen on the mountain top in the upper left hand part of Fig. 17), and the light-coloured gneissose granite, emerging in the deepest anticlinal core exposed, just above sea-level (seen in Fig. 18, halfway between the front of Nordenskiöld's Gletscher and the mouth of Knækvelven). The transitional zone between the metamorphic sediments and the basal granite is well over 2000 m thick and forms a migmatite complex. Its well banded uppermost part is conformably overlain by the metamorphic sediments. It is composed of banded gneisses and contains lenses of pegmatite, sheets of granite, as well as layers of para-gneiss. The thick central part of the migmatite zone is characterised by flow-folding and contains streaky

augen-gneisses, rich in biotite, banded and veined gneisses, amphibolites and irregular, coarsely mixed migmatites, composed of a metamorphic sedimentary host rock and admixed granitic material. The basal part shows a more regular and shell-like structure, in which granitoid rocks prevail.

The migmatite zone with its characteristic flow-structures shows a style of folding different from that found in the covering sediments. A detailed study of the foliation and lineation of the different rocks showed, however, that the metamorphic sediments, the migmatites and the granite have the same structural directions. The axes of the major and minor folds, the direction of elongation of the mineral grains, and all other lineations observed in this section pitch $20\text{--}30^\circ$ N, farther northward, in the lower part of Knækdalen, $10\text{--}20^\circ$ N. The folding of the migmatite complex is more intense and often disharmonic; but it is homoaxial with regard to the deformation of the covering sediments and therefore contemporaneous with the folding of the suprastructure. Even the concordant gneissose granite at the base shares this homoaxial structure. The granite does not form the regional Archaean basement of the pre-Cambrian sedimentary sequence, as postulated by the British geologists, nor does it form part of a local Archaean threshold, as once assumed by BACKLUND (1930 pp. 236—246; 1932 p. 8, Fig. 1). The granitic solutions ascended during the orogeny, and, by intrusion, injection, assimilation and metasomatic replacement processes, they gave rise to the development of the migmatite complex, which still contains stratigraphically interpretable relics of the pre-Cambrian host rocks. In the more distant contact aureoles of the rising granitic core, the sedimentary country rock was transformed only by metamorphism and metasomatism. The field relations described and illustrated by figures 17 and 18 represent a striking example of BACKLUND's 'Magmaaufstieg im Faltengebirge' (1936) and of WEGMANN's 'Aufstieg der Migmatitfront' (1935).

In a structural respect, also, the migmatite complex discussed plays a special rôle. The geological survey of Fränkels Land made it evident that the $30^\circ\text{--}70^\circ$ W-dipping gneisses of the Knækdalen migmatite complex continue towards the east into the peneplained mountains between Knækdalen and Engdalen. They also build up the summit region of Engdalen, where the flat-lying, banded and veined gneisses, garnet-amphibolites, and intercalated sheets of granite repose upon the low-grade metamorphic para-schists of the Eremitdal Series. The migmatite complex extends in an eastern direction and with a reduced thickness, as elongated tongue, as far as the high-plateau NW of Ättestupan. From here on, according to aerial evidence, it must be connected with the composite gneisses and granites of Haredalen on

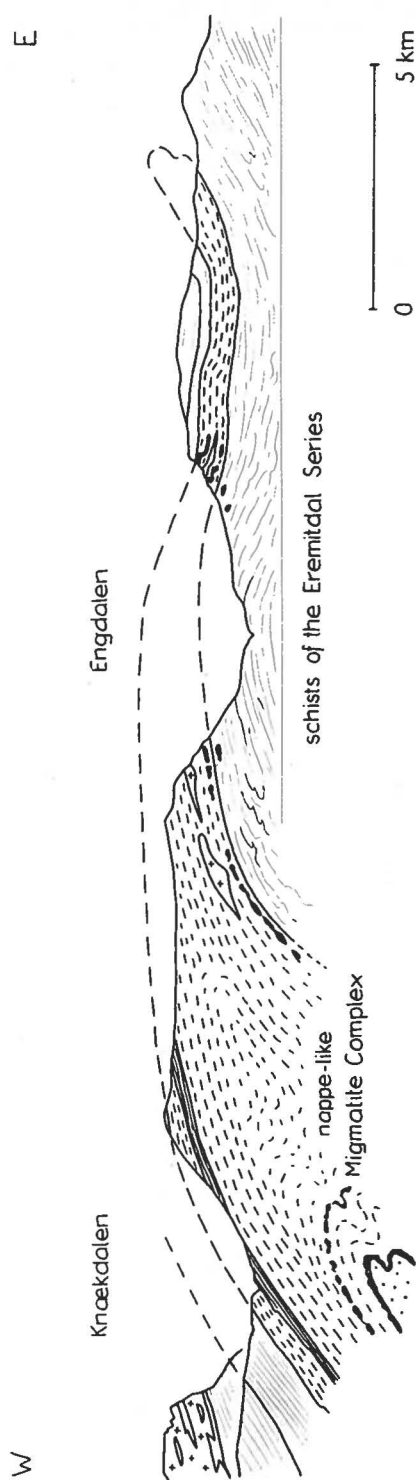


Fig. 19. Section across the central part of Fränkels Land, showing nappe-like migmatite complex.

the Isfjord side of Frænkels Land. The petrographically identical and steeply dipping migmatite zones of Knækdalen and Haredalen form the roots of the nappe-like sheet (see Fig. 19).

The nappe-structure of the migmatite complex is in striking contrast to the moderate folds of the metamorphic and non-metamorphic sedimentary cover on both sides of it. It would seem that this structure cannot possibly be explained by tangential compression. The tangential movements should have affected mainly the sedimentary cover and, to a much less degree, the crystalline basement; but here the relation is reversed. So far only one other nappe-like migmatite body is known from East Greenland, viz. a similar structure found in 1934 by H. G. BACKLUND and E. WENK on the NE-side of the innermost part of NW-Fjord (Scoresby Sund). It is significant that in the moderately folded mountain belt of East Greenland only migmatite complexes form recumbent flow-folds. We cannot believe that these structures are due to far-reaching tectonic transport, produced by tangential compression. Their mode of occurrence, especially their diapir-like character, indicates that we are here dealing with mobile masses of the infrastructure, which have ascended and intruded into the covering sedimentary series. We think that the rise was not only due to the mobility and the lower specific gravity of the hydrothermally activated and granitised rock material; it was also the consequence of the considerable increase in volume during the formation of the migmatite bodies. The migmatite complexes, composed of a solid phase of sedimentary origin, and of a liquid phase, permeating the pre-existing host-rock, were squeezed out from the infrastructure and pressed into the covering sedimentary series, where they took part in the general moderate folding.

The nappe-like migmatite sheet described is a challenge to the East Greenlandic geology. It was the greatest surprise of our campaign in Frænkels Land. The structure appears to continue in a southern direction, and probably the astonishing 'mushroom-fold', displayed on the S-side of the head of Kejser Franz Josefs Fjord, between Ridderborgen and Cambridge Toppe, forms part of it. The planned survey of Suess Land and Goodenoughs Land will, no doubt, yield further information on this phenomenon.

It is evident that our main conclusions are in line with the results obtained by BACKLUND and WEGMANN. The metamorphism of the sedimentary cover and the formation of the migmatites are contemporaneous and consequences of the same geological processes. They are mainly brought about by the action of granitic-pegmatitic solutions ascending during a phase of regional mountain building, and they are due to rising temperature fronts. The

granitic and migmatitic infrastructure, in its present state of preservation, is not older, but younger, than the pre-Cambrian sedimentary cover. The ascent of the granitic solutions, and associated thermal fronts, represented the most important act of the East Greenlandic orogeny.

The field observations, proving the existence of a conformable sequence from the late-pre-Cambrian sediments down into the migmatitic basement, and especially the numerous readings of the axial plunge (see Plate 1; a detailed map, showing all the observations made along Knækdalen, will follow in a later paper), indicate one major and slightly converging trend of deformation throughout the western part of Frænkels Land. However, the age of the folding cannot be dated in this innermost fjord and nunatak region. We must rely upon the observations made in the fossiliferous outer fjord region, which indicate a Caledonian age of the same folding.



Fig. 20. Nordenskiöld's Gletscher and Nathorst's Gletscher (right centre), seen from ENE; late-tectonic granite intrusion in centre; in background Shackleton's Bjerg (left), inland ice, and Petermann's Bjerg (right).

IV. LATE-TECTONIC TO POST-TECTONIC GRANITE INTRUSIONS

Apart from the above-mentioned concordant granites and migmatites, which form the infrastructure of the metamorphic sediments, a second generation of granite is found in the western part of Fränkels Land. It occurs in intrusive relationship within the sedimentary series and appears to be confined to the zone occupied by the Knækdalen Syncline. We are dealing here with a white, medium-grained muscovite-biotite-microcline-oligoclase-granite. This characteristic granular rock, rich in potash, is always very fresh and varies only little in its mineralogical composition. It belongs to WEGMANN's (1935) group of 'Marginal Granites'.

The centre of the granite intrusion is located in the region of Nordenskiöld's Gletscher, near the junction with its tributaries Disa, Rype, and Nathorst Glaciers (see Fig. 20). This granite complex was already known to the geologists of the Cambridge Expedition 1929, who assumed



Fig. 21. Granite intrusion at Disa Gletscher, N of Nordenskiölds Gletscher (bottom); in background (centre) Nathorsts Tinde.

the occurrence here of a batholith or a large subjacent stock, which obscured the junction between the Petermann Series and the Central Metamorphic Complex. The geology and petrology of the granite was well characterised by ODELL (1939, 1944), who had explored the western and northern parts of the intrusion. In contradistinction to the findings of WORDIE and WHITTARD (1930), ODELL described the occurrence as a complex sheet-intrusion.

The strips of aerial photographs, taken in 1951 by E. HOFER in the region of Nordenskiöld and Nathorst Gls., demonstrate, that in this coherent granite complex, at any rate, discordant as well as concordant contacts with the country rock exist. Some selected pictures of this remarkable intrusion are published here. The contact phenomena displayed along the northern Nordenskiöld section are represented in Figs. 21 and 22. Figure 21, bordering Figs. 6 (left) and 22 (right), shows the Disa Gletscher, where the Cambridge Expedition 1929 started their arduous ascent of Petermanns Bjerg. The contact between light-coloured granite and dark sediments of the Petermann Series is here sharp and discordant; dikes are seen, branching off into the sediments. The wall of the intrusion is steep and dips outward; there is no visible or inferable floor of the granite body. In the centre of Fig. 22 the gigantic floating masses of dark sedimentary rock, recorded by WORDIE and WHITTARD

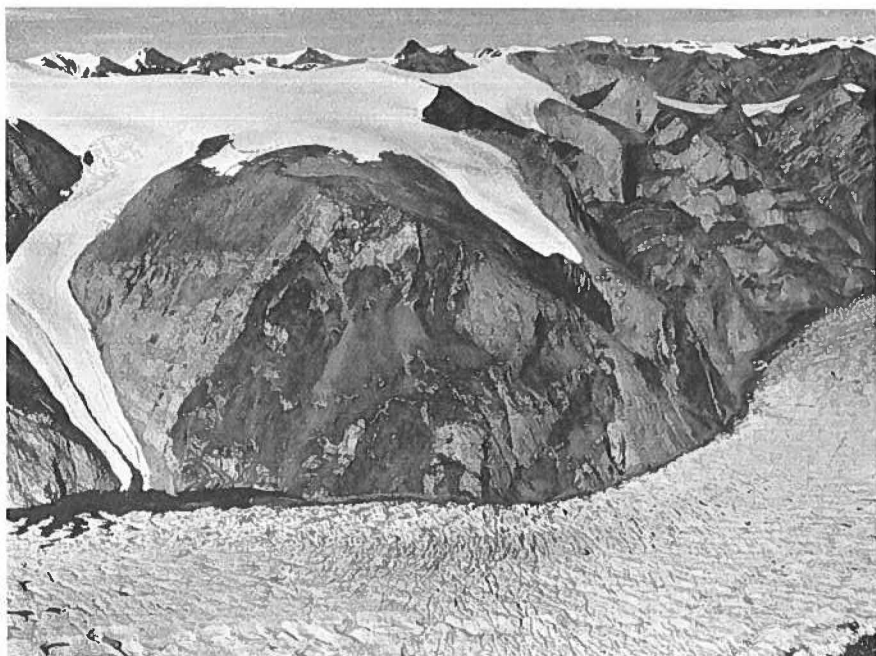


Fig. 22. Granite intrusion at bend of Nordenskiöld's Gletscher, E of Disa Gletscher; seen from S.

(1930), build up a large part of the 1500 high solid rock wall. Towards the east (right) these inclusions are more regular in shape and arrangement.

Fig. 23 shows the rock wall N of the upper part of Nathorst's Gletscher, by which the upper Gregory's Gletscher drains into the Nordenskiöld's Gletscher. The light-coloured granite is also here in discordant contact with the dark beds of the low-grade metamorphic Layered Series (left) and includes large xenoliths of the sediments. These inclusions are angular, and of irregular shape in the centre of the photograph. But farther to the E, as is seen in Fig. 24, the inclusions of sedimentary country rock form subparallel lenses and layers. Their parallel arrangement depicts the eastern limb of the Knækdalen Syncline, and passes, without interruption or disturbance, into the structure of the adjacent metamorphic sediments. Evidently, the coherent intrusion, which is clearly discordant in the S (Disa Gletscher) and W (upper Nathorst's Gletscher), towards the E—and, as we shall see, also towards the N—passes into a concordant sheet-intrusion. We are here dealing with a late-tectonic to post-tectonic Caledonian intrusion.

The granite complex, observed along the Nordenskiöld and Nathorst section, is exposed also in Knækdalen, where it was studied before us



Fig. 23. Discordant granite intrusion into metamorphic Petermann sediments, N of upper part of Nathorst's Gletscher, seen from S.



Fig. 24. Sheet-intrusion into metamorphic Petermann sediments, near junction of Nathorst's Gletscher (left) and Nordenskiöld's Gletscher (foreground), seen from S.



Fig. 25. Discordant contact between metamorphic Petermann sediments (left) and post-tectonic granite (right), N of Knækdalen, E of Lejrgletscher (left); compare background of Fig. 17.

by ODELL and by HUBER (1950, see Figs. 7 and 8). An excellent insight into the geological conditions along this valley is offered by Figs. 25 and 26, giving a panorama of the mountain range N of Knækdalen (cf. also the background of Fig. 17). The discordant contact of the granite with the Shoulder and Summit Series, seen in Fig. 25, forms the NE prolongation of a similar outcrop, observed along Nathorsts Gletscher (Fig. 23); while the sheet-like intrusions of Fig. 26 correspond to those of Fig. 24. These aerial photographs bear evidence, again, of the fact that the intrusive granites are confined to the Knækdalen Syncline. In contrast with the exposures along Nathorsts and Nordenskiölds Gletscher, the granite sheets in the mountains on both sides of Knækdalen are underlain by continuous layers of metamorphic Petermann sediments (Shoulder and Layered Series) and do not root here. In this regard the sections drawn by ODELL (1939) and HUBER (1950) will have to be modified. It is true that a minor intrusion, with branching dikes of micro-granite and pegmatite, is exposed at the floor of Knækdalen near Lavinegletscher and Lejrgletscher; but this granite is not connected with the sheets of the summit region. These thick upper sheets are united with the granite stock of the Nordenskiöld-Nathorst region, which forms the centre of the sheet-intrusions, directed N and E.



Fig. 26. Complex sheet-intrusions into metamorphic Petermann sediments, N of Knækdalen (bottom), SW of Lystergletscher (right); continuation of Fig. 25 to the E (right).

At whatever stratigraphical level the white granite occurs, it has about the same composition, and is homogenous over wide areas. The proportion of the micas may vary slightly from place to place, but even in the zones crowded with xenoliths, the granite is hardly contaminated by assimilation processes. Its structure, also, is but slightly altered. Typical granular rocks are by far predominant; slightly gneissose varieties are restricted to minor sheets. The parallel structure, according to our observations, is not due to metamorphism, brought about by subsequent folding; it is the result of primary mimetic crystallisation (*Abbildungskristallisation*) in the sheet-like intrusions. The contact metamorphism in the country rock is feeble, as already stated by ODELL and HUBER. All petrological indications point to a low-temperature intrusion congealed in the upper zones of the lithosphere. This matter of contact effects is of considerable importance with regard to the occurrence of the intrusive granites in the zones of progressive metamorphism discussed above. We agree perfectly with ODELL (1939, pp. 14—15), whom we may quote in this connection: "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 the wide-spread regional metamorphism."

The late-orogenic intrusive white granites have, no doubt, not developed 'in situ', by granitisation of pre-existing rocks. They were formed from a granitic magma, ascended along localised tectonic lines, forcing its way by magmatic stoping, and then intruding laterally, parallel to the stratification of the country rock. It appears probable that the late-orogenic granites to some extent displaced the structural pattern of the Caledonian folds: The general NE trend of the fold axes W of the granite complex contrasts with the NNW direction noted E of it (see Pl. 1). This divergence may be due to displacement by the wedge-shaped granite intrusion.

Nowhere in Fränkels Land are the post-tectonic granites in contact with the migmatite complexes. As far as the composition is concerned, the late-orogenic, white intrusive granites are related to the genuine granites of the synorogenic, migmatite-forming generation. The white granites, however, are richer in silica and potash than these, and represent a more advanced, later, differentiation stage of the 'Magmaaufstieg im Faltengebirge' (BACKLUND). The pegmatitic offsprings of the late granites are locally rich in volatile constituents.



Fig. 27. Nunatak region E (foreground) and SW (background) of the upper part of Victor Madsens Gletscher, seen from NE; on the left Kalifbjerg (centre) and uppermost part of Nordenskiölds Gletscher (background); on the right, part of Baselfjeld (foreground), Ulvekam (centre) and uppermost part of Victor Madsens Gletscher (background). The boundary between the Petermann Series and the Western Metamorphic Complex follows the morphological depression between Kalif Bjerg and Ulvekam.

V. THE "WESTERN METAMORPHIC COMPLEX"

On the basis of boulders found in the moraines of Nordenskiölds Gl. the presence of a crystalline zone in the area traversed by this glacier was supposed by the geologists of the Second Cambridge Expedition (WORDIE, WHITTARD, PARKINSON, WISEMAN). In contrast to the "Central Metamorphic Complex" in the area of the inner Kejser Franz Josephs Fjord, the supposed crystalline area west of the Petermann Range was called the "Western Metamorphic Complex".

During our ascent of Petermanns Bjerg on August 9th, 1951, we likewise found boulders of augen-gneiss, hornblende-gneiss, and amphibolite on the southeastern ridge of the mountain up to an altitude of 2,400 m. The favourable weather permitted us, in addition to the work in the Petermann Range, to undertake a trip for several days into the area of the upper Victor Madsens Gl. and the southern Martin Knudsens



Fig. 28. Stribethjerg (left), NW-corner of Fränkels Land, and SW-part of Louise Boyds Land (Boys Bastion), seen from S. The boundary zone between Petermann Series and Western Metamorphic Complex runs in diagonal direction across the picture, from the left bottom corner, to Boys Bastion in the right upper corner.

Nunatakker. Owing to the remoteness of this area, however, it was only possible for us to get a very summary idea of the geological conditions during the trip.

In the nunatak area immediately west of the Petermann Range the flatter western flank of the Petermann Syncline is cut off by a NNE—SSW running dislocation line. West of this line occurs a zone of crystalline rocks, the "Western Metamorphic Complex", which strikes perpendicular to the Petermann Syncline. The largely cataclastic contact zone between the sediment series of the Petermann Syncline and the crystalline series of the "Western Metamorphic Complex" is very prominent morphologically, and by means of numerous aerial photographs it could be traced northwards into the northwestern Louise Boyds Land (figs. 27 and 28).

The "Western Metamorphic Complex" is, in the main, built up of the following four rock groups:

- 1) Leucocratic migmatite-gneiss of granitic composition, which in the form of elongated tongues, issuing from the eastern foot of Martin Knudsens Nunatakker, rises towards the east. The leucocratic



Fig. 29. Outcrop at E-spur of Spalenhjerg (Martin Knudsens Nunatakter). Migmatite zone, showing inclusions of garnet-amphibolite, enstatite-fels, hornblende-gneiss layers of biotite-gneiss, floating in white tourmaline-biotite-pegmatite.

granitic biotite-gneiss often contains inclusions of amphibolite (fig. 29). The axes of the folds of this tongue-shaped gneiss complex all strike NW—SE, with a pitch of 10—25° towards the SE.

2) Para-gneiss and mica-schist enclose the horizontal granite-gneiss complexes described above. Petrographically these mantles of para-schists are very similar to the rocks of the metamorphic Eremitdal Series occurring under the same petrogenetic conditions in Isfjord. The regional geological connections of the "Western Metamorphic Complex" and the sediment series of the Petermann Syncline would suggest that the upper para-rocks should be regarded as members of the metamorphic Eremitdal Series (respectively its equivalents in the Petermann Series, see fig. 15).



Fig. 30. Martin Knudsens Nunatak W of middle part of Victor Madsens Gletscher, W of 'A' of 'Madsen'; intrusive white biotite-granite in foreground.

3) Slightly metamorphic quartzite and quartzitic shale. In the top region of the southern Martin Knudsens Nunatak a flat, westward-dipping series of light-grey banded massive rocks (probably quartzite) rests unconformably on dark-brown-weathering, poorly bedded to slaty rocks. The latter pass with increasing depth, and towards the east successively, into the above-mentioned mantles of para-schists of the granitic migmatite-gneiss complex. Judging by their appearance, these low-grade metamorphic sedimentary covering rocks might correspond to the Summit-Series and the Layered Series.

4) Younger intrusive granite. Between the lower crystalline series at the eastern margin of the "Western Metamorphic Complex" and the conformably covering, low-grade metamorphic members of the middle Petermann Series in Martin Knudsens Nunatak, intrusive granite occurs, namely white biotite-granite and tourmaline-biotite-pegmatite, which are, no doubt, younger than the above-mentioned migmatite-gneiss complex and in part pierce them. The younger granite is met with in the form of discordant, fairly large intrusive bodies, but also as concordant sheets, especially at the eastern foot of Martin Knudsens Nunatak (fig. 30), as also in the border mountains of NW-Frønkels Land (west of the large fault line).

The relations between the "Western Metamorphic Complex" and the folding structure of the Petermann Range suggested above are illustrated in the drawing (fig. 31). At the same time the structural conditions within the crystalline zone proper are also shown. As mentioned above, the axes of the folds as well as the lineation in the area of the granitic

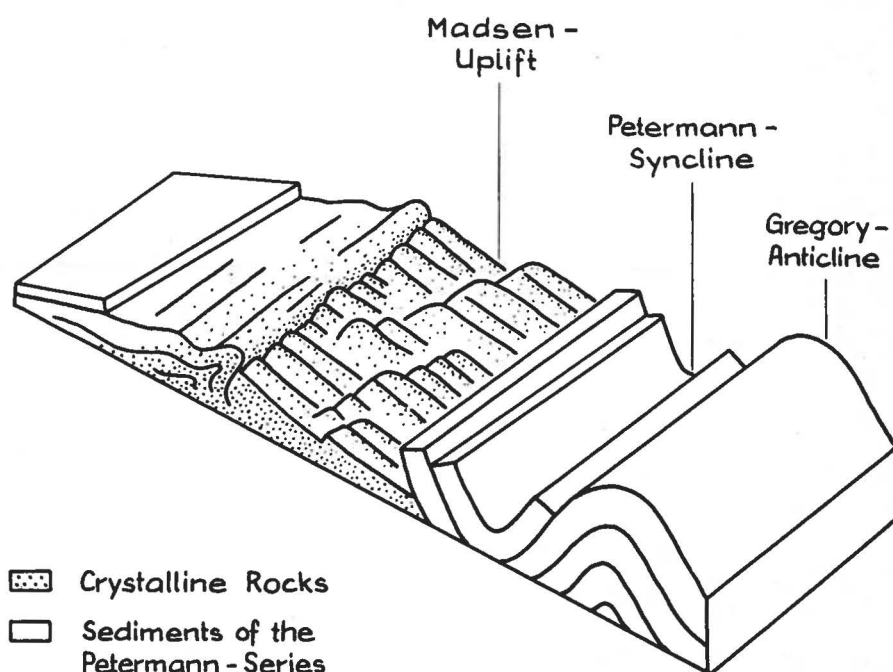


Fig. 31. Schematic sketch, showing structural relationships between Western Metamorphic Complex and Petermann Series.

migmatite-gneiss-tongues and their mantles of para-gneiss strike perpendicular to the anticlinal system of western Fränkels Land. Within the crystalline complex, e. g. at the eastern foot of Martin Knudsens Nunatak, the relationship between the two structures can be clearly recognised. There the transverse strike of the deeper crystalline series is restricted to the host-rock of the migmatite complex, which itself is overfolded by secondary movements producing a fold-axis parallel with the Petermann Syncline. This is clearly evidenced by the fabric of the migmatite-gneiss.

The remarkable transverse strike and the characteristic horizontal tongue- and nappe-like fold structure of the deeper portion of the "Western Metamorphic Complex" have probably some connection with the "Stockwerk"-folding widely distributed in the "Central Metamorphic Complex". It seems possible, therefore, that a not only

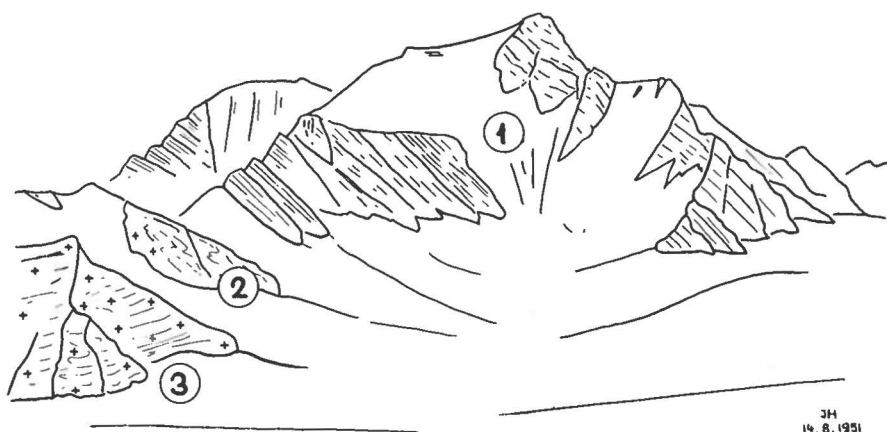


Fig. 32. Sketch of Baselfjeld, seen from SW (N-end of Ulvekam). Summit Series in W-limb of Petermann Series (1), contact zone between Western Metamorphic Complex and Petermann Series (2), migmatite-gneiss of Western Metamorphic Complex (3).

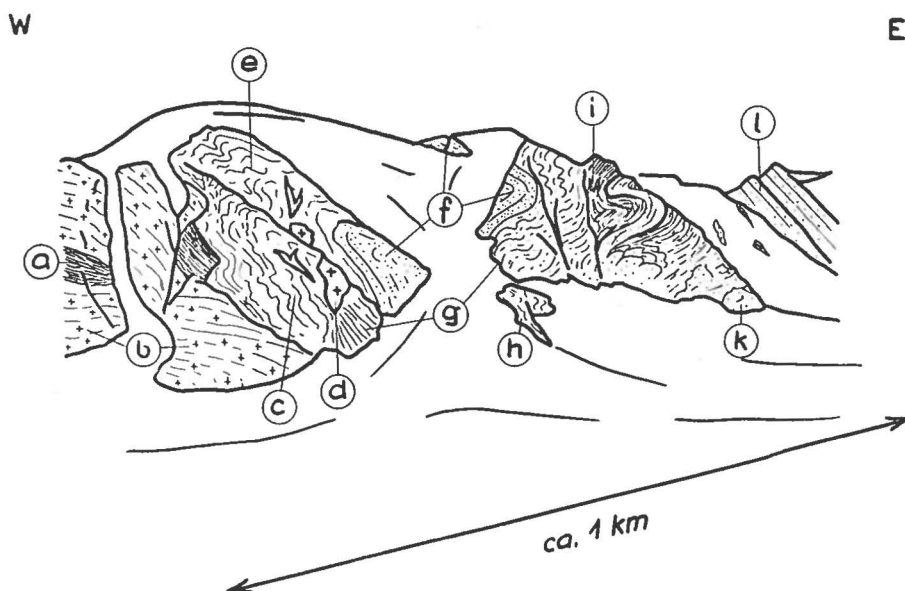


Fig. 33. Contact zone between Western Metamorphic Complex and Petermann Series in W-spur of Baselfjeld, see (2) in Fig. 32. Mica-schists (a), phlebitic, granitic biotite-gneiss (b), biotite-chlorite-schists and -gneiss (c), muscovite-pegmatite and quartz-veins (d), chlorite-schists (e), white quartzite, coated with haematite-films (f), alternation of grey quartzite and biotite-bearing phyllite (g), phyllonites with quartzitic layers and quartz-lenses (h), quartzitic slates and schists (i), breccia of greenish-grey quartzite and slate (k), white quartzitic sandstones of the Summit Series (l).

petrogenetically, but also structurally lower storey is exposed at the evidently elevated eastern margin of the "Western Metamorphic Complex". To the west (Martin Knudsens Nunatak) it is disharmoniously overlain by a higher folding structure, to the east, however, the deeper segment is unconformably bounded by the late- to post-orogenic fault line. The younger intrusive granite occurs in the area of the zone of transition between the lower and the upper folding structure.

Unfortunately the regional dislocation line, which separates the elevated block of the "Western Metamorphic Complex" from the sediment series of the Petermann Syncline, could only be studied in a single exposure (fig. 32). It is not possible, therefore, to give an accurate analysis of the phenomena of movement that are reflected along this line. No doubt, a post-crystalline upheaval of the western complex has taken place. The characteristic compression folding within the fault zone (fig. 33) is further suggestive of thrusting from the west, associated with the upheaval of the "Western Crystalline Complex" (Madsen-uplift).

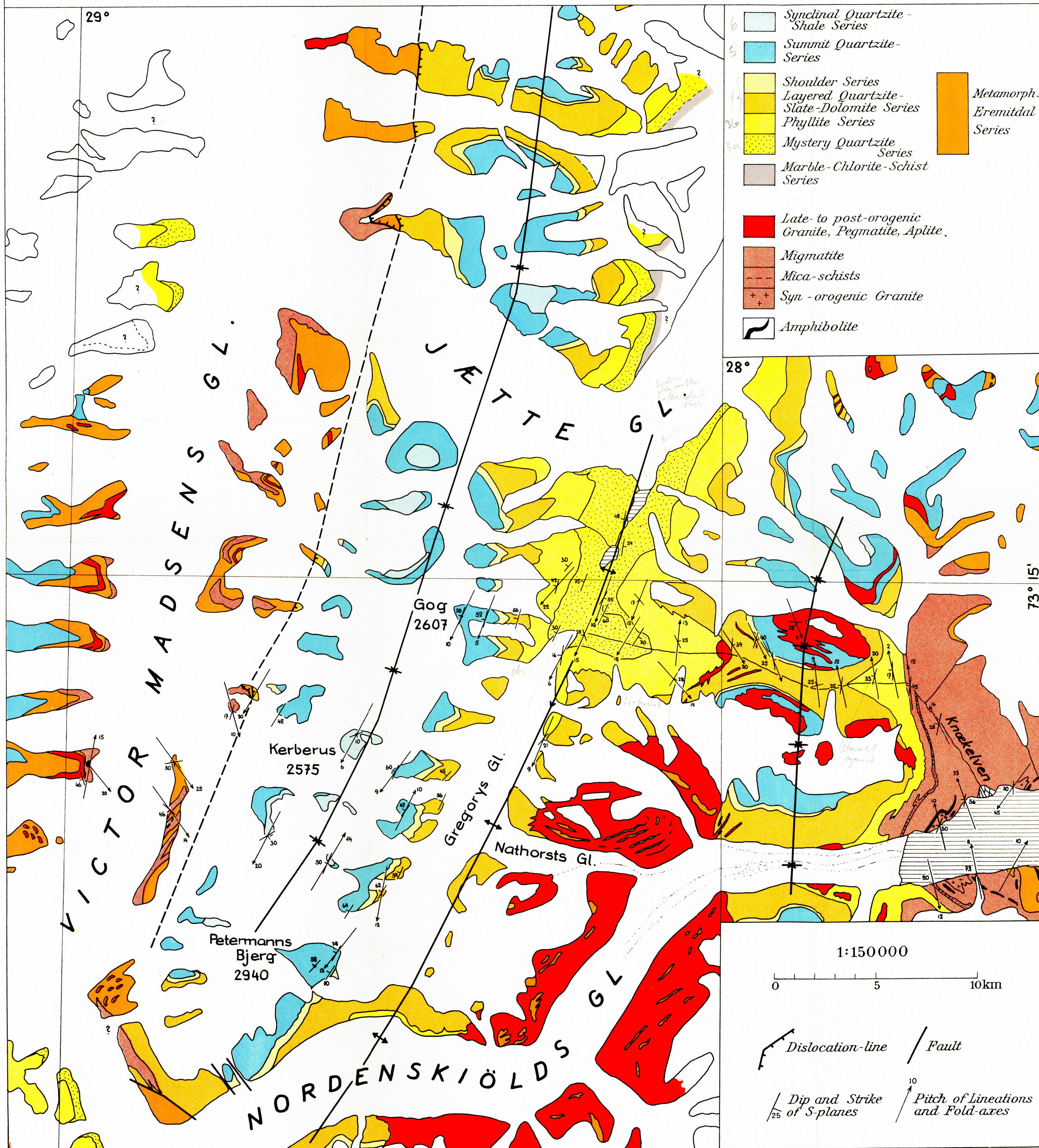
On the basis of the petrographic, stratigraphic, and tectonic observations it may be regarded as certain that also the origin and mise-en-place of the "Western Metamorphic Complex" should be referred to the Caledonian orogeny.

NOT
SUBSTANTIATED
ABOVE ?

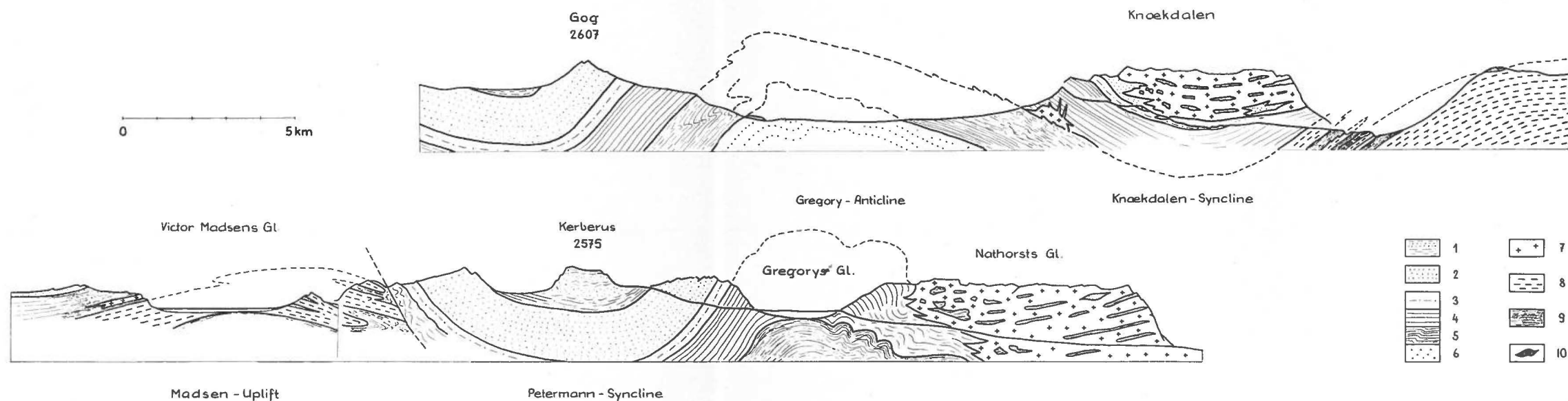
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GEOLOGICAL MAP OF THE PETERMANN REGION (NE - GREENLAND)



Geological Sections
across the
Petermann Region



Legend:

- 1 = Synclinal Quartzite-Shale Series,
- 2 = Summit Quartzite-Series,
- 3 = Shoulder Series,
- 4 = Layered Quartzite-Slate-Dolomite Series,
- 5 = Phyllite Series,

- 6 = Mystery Quartzite Series,
- 7 = Late- to post-orogenic Granite,
- 8 = Migmatite,
- 9 = Mica-scists,
- 10 = Amphibolite.