SKRIFTER NR. 178

YOSHIHIDE OHTA

HECLA HOEK ROCKS
IN CENTRAL AND WESTERN NORDAUSTLANDET

NORSK POLARINSTITUTT
OSLO 1982

DET KONGELIGE MILJØVERNDEPARTEMENT

NORSK POLARINSTITUTT

Rolfstangveien 12, Snarøya, 1330 Oslo Lufthavn, *Norway*

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ISBN 82-90307-23-3
Printed December 1982

Contents

The first two articles in this volume were ready for printing early in 1981. Unfortunately, due to economic difficulties and the work involved in starting Norsk Polarinstitutt's new series, *Polar Research*, publication of these articles was delayed until the third one was ready.

The last article was written in 1982. Therefore, use of stratigraphic terms in the first two articles and in the last one, is not entirely consistent, due to later development of the studies.

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YOSHIHIDE OHTA:

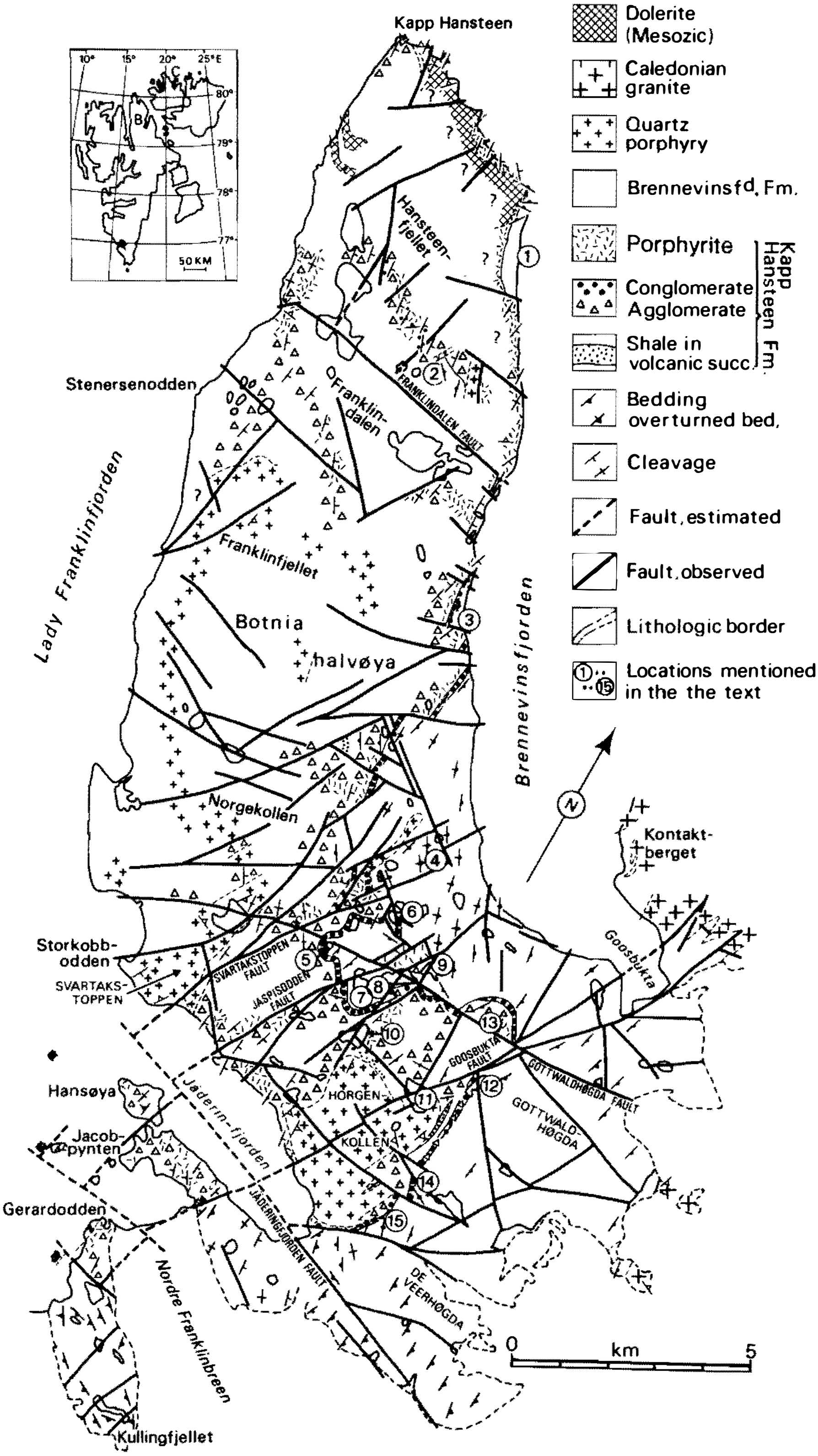
RELATION BETWEEN THE KAPP HANSTEEN FORMATION AND THE BRENNEVINSFJORDEN FORMATION IN BOTNIAHALVØYA, NORDAUSTLANDET, SVALBARD

Abstract

The conglomerate which lies at the boundary between the Kapp Hansteen and the Brennevinsfjorden Formations was traced throughout the whole length of Botnia-halvøya and the stratigraphical relations of the two formations were carefully examined. In the southern part of the peninsula it can be demonstrated that the conglomerate is situated at the base of the Kapp Hansteen Formation and unconformably overlies the folded shales of the Brennevinsfjorden Formation. Additional evidence to support this relationship was observed elsewhere in the peninsula. These observations imply that the stratigraphical order of the two formations is the reverse of that previously proposed, and thus correlations of the Kapp Hansteen volcanic rocks with other parts of Svalbard are influenced by this discovery. This angular unconformity, together with that at the base of the Franklinsundet Group in western central Nordaustlandet, provides evidence which implies a pre-Cambrian deformation phase in the late Lower Hecla Hoek period, about 800 m.y.

Introduction

Nordenskiöld (1863) was the first geologist to report the green phyllite and dolerite dykes (in his terminology 'talc schist' and 'hyperite') of Hansteenfjellet and the areno-argillaceous rocks and the limestone in south-eastern Brennevinsfjorden. Kulling (1934) described quartz porphyry and porphyrite-agglomerate-tuff along the north and west sides of Botnia-halvøya and used the term 'Cape Hansteen Formation' for this volcanogenic succession. He placed this formation lower in the succession than the Murchison Bay Formation. Sandford (1950, 1956) described the distribution of porphyrite in the Sabinebukta area, about 30 km to the east of Botnia-halvøya and used the term 'Cape Hansteen Formation' to include all vol-canogenic and areno-argillaceous successions below the quartzite succession



Kapp Hansteen
Dolerite (Mesozic)
Caledonian granite
Quartz porphyry
Brennevinsfd. Fm.
Porphyrite
Conglomerate
Agglomerate
Shale in volcanic succ.
Kapp Hansteen Fm.
Bedding
overturned bed.
Cleavage
Fault, estimated
Fault, observed
Lithologic border
Locations mentioned in the the text
50 KM
Hansteen-fjellet
Stenersenodden
Franklin-dalen
FRANKLINDALEN FAULT
Lady Franklinfjorden
Franklinfjellet
Botnia halvøya
Brennevinsfjorden
Norgekollen
Kontakt-berget
Goosbukta
Storkobb-odden
SVARTAKS-TOPPEN
SVARTAKSTOPPEN FAULT
JASPISODDEN FAULT
GOOSBUKTA FAULT
GOTTWALDHØGDA FAULT
GOTTWALD-HØGDA
HØRGEN
KOLLEN
Hansøya
Jacob-pynten
Jaderin-fjorden
JADERINFJORDEN FAULT
Gerardodden
Nordre Franklinbreen
DE VEERHØGDA
Kullingfjellet
0 km 5

→

of the Murchison Bay Formation. However, the porphyrite in Sabinebukta was later identified as quartz porphyry by Flood et al. (1969) who excluded this from the sedimentary column. Flood et al. gave the name 'Botniahalvøya Group' to Sandford's Cape Hansteen Formation, retaining the name 'Kapp Hansteen Formation' for the volcanogenic succession alone. The areno-argillaceous succession in the southern part of Botniahalvøya was called the 'Brennevinsfjorden Formation'. Russian geologists have not adopted this terminology but still use Sandford's broader definition of the Kapp Hansteen Formation (Krasil'ščikov 1973). Flood et al. (1969) deduced from field evidence that the Brennevinsfjorden Formation was younger than the Kapp Hansteen Formation.

The present author carried out geological mapping of Botniahalvøya in 1978 and 1979. New observations provide evidence which proves that the Kapp Hansteen Formation unconformably overlies the Brennevinsfjorden Formation (after the terminology of Flood et al. 1969). This observation fits very well with the successions found in central Nordaustlandet, about 50 km to the east of Botniahalvøya, where a volcanogenic succession occurs below a quartzite one and is in turn underlain by thick areno-argillaceous sediments. The generally hitherto accepted idea that the Kapp Hansteen Formation represents the oldest Hecla Hoek meta-sediments in Nordaustlandet has to be revised in the light of these discoveries. This requires a significant change of ideas concerning the Lower Hecla Hoek stratigraphy of Svalbard.

Field observations on Botniahalvøya

Botniahalvøya is composed of two rock formations: the volcanogenic Kapp Hansteen Formation in the north and west and the areno-argillaceous Brennvinsfjorden Formation in the southeast. There are many faults cutting both formations and the most important of these are named on the map (Fig. 1). The Svartakstoppen fault represents a large structural break and divides the southern and central areas, while the Franklindalen fault separates the central and northern areas. The two formations show different field relations in the three areas thus delineated, and each area will therefore be described in turn.

The northern area

Detailed observations were made along the eastern coast of the peninsula (Area 1, Fig. 1) and along the northern side of Franklindalen (Area 2, Fig. 1). Along the east coast, the Kapp Hansteen Formation consists predominantly of dark green to dark grey agglomerates, but porphyrite with plagioclase phenocrysts and some andesitic rocks occur in the east and south of Hansteenfjellet. About 3 km southeast of Kapp Hansteen (Area 1, Fig. 1)

Fig. 1. Incomplete geological map of Botniahalvøya. Nos. 1 - 15 are referred to in the text. White areas west of the conglomerate are not mapped yet. Inserted map: A - Hornsund, B - Ny Friesland, C - Sabinebukta, D - Rijpdalen.

a dark areno-argillaceous succession outcrops in the cliff for a distance of 1.5 km (Fig. 2). The northern part of the cliff, with a height of about 100 m, consists of a dolerite sheet of Mesozoic age on the top, which is about 50 m thick and dips gently to the northeast. Below this are 20-50 m thick porphyrites with agglomerate layers. The porphyrite reaches the top of the cliff in the middle of the section, and here the lower part of the cliff is composed of the sandstone-shale succession. The rocks of the latter are black shale and grey sandstone, showing laminations 5-10 cm thick. Well developed ripple marks and cross-bedding structures demonstrate that the beds are right-side up. These beds form an asymmetric anticline, the southeastern limb may be cut by a fault, with the axis near the steep eastern limb. The shale sandstone succession almost reaches the top of the cliff in the crestal part of the anticline and its maximum thickness is about 150 m. Overlying volcanogenic rocks are dark green porphyrites and agglomerates which include dark blocks. Andesitic rocks and brown tuff occur in the southern part and the latter contains some jasper veins.

No conglomerate has been seen here, but some agglomeratic blocks are rounded. There is no possibility by which this areno-argillaceous succession may be explained as an overturned fold limb, and this succession undoubtedly underlies the Kapp Hansteen porphyrite and agglomerate. The shale and sandstone bear no traces of volcanogenic material among their constituent detritals.

On the northern side of Franklindalen (Area 2, Fig. 1), a dark cliff about 700 m long with good exposure occurs about 1.5 km from the eastern coast. This cliff is composed of a laminated shale and sandstone succession similar to that of Area 1. The beds strike nearly N-S and dip moderately westwards in the eastern half of the cliff, while they show NW-SE strikes and gentle NE dips in the western part, that is to say, they form an open synclinal fold. All cross-bedding and lamination confirm that they are right-side up, and the thickness is about 150 m. Both limbs of this syncline are cut by dykes of quartz porphyry.

This locality is about 2 km south of the shale-sandstone anticline of the first area along the strike direction, and therefore these two areas are considered to be continuous under the surface cover of porphyrite and Mesozoic dolerite. The quartz porphyry cuts both the areno-argillites and the porphyrite.

Most rocks of the Kapp Hansteen Formation in Hansteenfjellet show a strongly developed cleavage with nearly N-S strikes and steep eastward dips. The areno-argillite succession has been involved in the same tight folding and is barely exposed on the surface in the two localities. This proves that there is an areno-argillaceous succession below the volcanogenic Kapp Hansteen Formation. It could be a part of the Brennevinsfjorden Formation, in which case the previously established stratigraphical relationship of these two formations is incorrect, or it could be a third and older formation.

The thickness of the Kapp Hansteen Formation in this area is roughly estimated to be about 2000 m, and is thus far thinner than estimated by Orvin (1940) and Flood et al. (1969). Some intraformational conglomerates have been observed in the agglomerate along the northern side of Franklindalen.

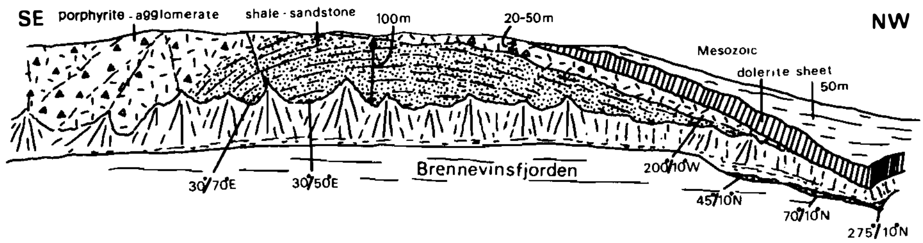


Fig. 2. Cliff section (about 1.5 km long) showing occurrence of the areno-argillaceous succession under the Kapp Hansteen porphyrite along the northeastern shore (Area 1, Fig. 1).

The central area

A characteristic rock association of conglomerate and columnar-jointed porphyrite occurs at the border between the volcanogenic Kapp Hansteen Formation and the areno-argillaceous Brennevinsfjorden Formation in this area. The conglomerate is monomictic with well rounded quartzite pebbles and boulders, the largest being one metre in diameter, and with very small amounts of quartz-rich matrix (Fig. 3a). The conglomerate occurs near the east coast in the southeastern part of Franklindalen, with roughly N-S strikes and steep to vertical eastward dips. This bed is often displaced by E-W trending faults in a step-wise manner. The thickness of the conglomerate is less than 20 m. Partial wedging out into associated sandstone is locally observed in the southeast of Franklindalen (Area 3, Fig. 1). The conglomerate bed and a sandstone, a few tens of metres thick, are here sandwiched between two porphyrite layers. The western one has typical columnar joints, while the eastern one is massive and is considered to be an intrusive sheet.

The bedding of the areno-argillaceous rocks along the east coast is vertical or dips steeply eastwards, and the cross-bedding shows that the beds are often overturned. For example, all observed cross-beddings around Area 4 (Fig. 1) are clearly overturned, so the beds decrease in age westwards. Accordingly, it is deduced that the conglomerate is younger than the areno-argillites and that the columnar-jointed porphyrite and agglomerate to the west are younger still. Not all sediments show cross-bedding. A few hundred metres east of the conglomerate occur black slates and tightly folded laminated shales where the way-up relation of the beds is impossible to establish.

Some observations show that the columns of the columnar jointed porphyrite are normal to the bedding surface of the underlying bed. The columns of the porphyrite always have gentle eastward dips and this indicates steep westward dips of the upper surface of the conglomerate bed below. Some westward dips are in fact observed in the agglomerate to the west, where it contains thin layers of cross-bedded tuff.

Steeply eastward dipping cleavages are developed very strongly in all the rocks of this area, and indicate eastward inclined axial planes of fold structures.

3a

3b

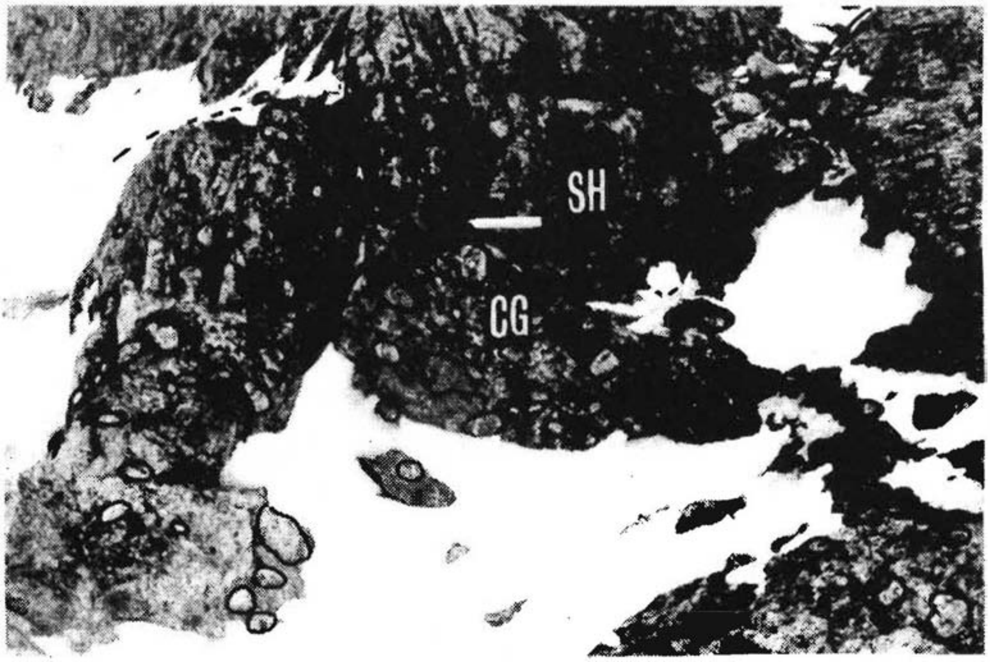


Fig. 3. a: Conglomerate containing round quartzite pebbles with very small amount of matrix, south of Area 3 (Fig. 1).
b and c: Angular-unconformity between the Kapp Hansteen conglomerate and the shale of Brennevinsfjorden Formation, at Area 14 (Fig. 1).
d: Sorted conglomerate with tuffaceous sandstone around Area 15 (Fig. 1).

3c

3d

←

These observations in the central area provide evidence that the Kapp Hansteen Formation is younger than the areno-argillaceous Brennevinsfjorden Formation.

A quartz porphyry dyke, 25-30 m wide, cuts the agglomerate in the west, passing through the columnar-jointed porphyrite and the conglomerate and into the eastern areno-argillites in the west of Area 4. It is about 3 km long with a NE-SW trend diagonal to the border of the two formations. Xenoliths of the porphyrite and the conglomerate are included in the quartz porphyry. A shaly sandstone bed occurs in the agglomerate in the northeast of Norgekollen, and is assumed to be a lensoid bed in the Kapp Hansteen Formation.

The southern area

This is the area southeast of the Svartakstoppen fault and is subdivided into three sub-areas by two more faults, the Jaspisodden fault and the Goosbukta fault, both trending NE-SW. Each of these sub-areas shows characteristic relations of the two formations.

S-I sub-area

In the area between the Svartakstoppen fault and the Jaspisodden fault, the Brennevinsfjorden Formation in the east consists of alternating dark shale and shaly quartzite and includes some thin calcareous beds. It has a constant dip to the east of about 45 degrees and cross-bedding indicates overturned sequence.

A conglomerate containing round quartzite and angular porphyrite boulders occurs southeast of Lake 6 (Fig. 1). This has nearly conformable dips with the shale, and is overturned. A fault occurs to the west of this conglomerate, and a siliceous shale containing persistent laminae, occurs to the west of the fault. From the west of Lake 6 to the south of Lake 5, the shale is overlain by a conglomerate with quartzite, shale, and porphyrite pebbles, interbedded with tuffaceous dark grey shale. The main body of agglomerate overlies this conglomerate and extends further to the west. The shale forms the flat terrain around Lake 7 and can be considered as a window of the Brennevinsfjorden Formation. The structural relation to the Kapp Hansteen agglomerate is apparently conformable in this area. The conglomerate to the south of Lake 6 extends southeast and is cut by a fault. Dark green tuff, agglomerate, and dense lava occur as fault blocks along the Jaspisodden fault to the north of Lake 8.

S-II sub-area

A large mass of the Kapp Hansteen agglomerate overlies a shale to the south of Lake 7, with a conglomerate and sandstone bed at the base. South of Lake 8, agglomerate and andesitic porphyrite pass laterally into a dark grey, gently dipping sandstone to the north. A steeply westward dipping shale and siliceous shale alternation occurs below the sandstone along the southern shore of Lake 8.

The Brennevinsfjorden Formation occupies most of the area north of the Gottwaldhøgda fault and is composed of alternating dark grey shale, siliceous shale and shaly quartzite with a constant N-S strike and steep to moderate dips to the east.

An isolated porphyrite occurs in Area 13, adjacent to the Gottwaldhøgda fault and is underlain by a 20-30 m thick agglomerate and a 5-10 m thick conglomerate. The conglomerate has many round and sub-angular boulders of white quartzite and porphyrite and a matrix of coarse-grained volcanogenic material. This rock outcrops along the northern boundary of the porphyrite, while the southern boundary is tectonic, being cut by the Gottwaldhøgda fault. The conglomerate, probably with a gentle dip, overlies moderately eastward dipping shales of the Brennevinsfjorden Formation on the east and north sides of the porphyrite. Although the contact was never seen, an angular unconformity can be deduced between the two formations in Area 13.

East of Lake 8 along the south of the Gottwaldhøgda fault, an agglomerate changes laterally into a coarse-grained tuffaceous sandstone with scattered round pebbles, suggesting that the basal conglomerate is very near the surface. This conglomeratic bed may be a continuation of that of Area 13 in the east, but it could also be an impersistent bed within the agglomerate succession.

The Gottwaldhøgda fault has some tens of metres of vertical throw (the northern side thrown up) and has several hundreds of metres right lateral displacement in this part of the area.

A large fault block of agglomerate and porphyrite occurs north of the Horgenkollen quartz porphyrite. A massive porphyry is dominant northeast of Lake 10, but shows rapid lateral transformation eastwards into agglomerate.

To the north of the Horgenkollen quartz porphyry a well bedded, in part strongly folded, coarse-grained sandstone and dark grey shale apparently overlies a conglomerate which shows coarsening-upwards structure and occurs in a local syncline which plunges gently to the southeast. The northern boundary of these rocks is a fault extending from Lake 10 to Lake 11, while the intrusive quartz porphyry is on the southern boundary. It is plausible that these beds show a local syncline structure produced by the emplacement of the quartz porphyry.

Flood et al. (1969) described 'a conglomerate including boulders of quartz porphyry from the place between the small lake and quartz porphyry body across the fjord (Jäderinfjorden) due east of Hansøya. This conglomerate which also carries boulders of the Kapp Hansteen volcanics, rests discordantly on fine-grained Kapp Hansteen tuffs' (Flood et al. 1969, p. 61). It is possible that this is the basal conglomerate of the overlying succession, i.e. the base of the Meyerbukta Formation (Ohta 1982), although the present author has not seen it and it is in a different horizon from that at the base of the Kapp Hansteen Formation.

SIII sub-area

The shale and shaly quartzite alternation of the Brennevinsfjorden Formation outcrops over the greater part of Gottwaldhøgda and De Veerhøgda and has constant NNE-SSW strikes with steep to moderate dips to the east. The conglomerate occurs around the eastern slope of Horgenkollen and has very steep dips from Lake 12 to Area 14 and moderate dips in Area 15. For two kilometres from Lake 12 to the south,the conglomerate has large round volcanic boulders and a volcanogenic matrix, and almost vertical bedding. A dark grey shale occurs a few hundreds of metres west of the conglomerate near the Horgenkollen quartz porphyry, but its structural relation to the surrounding agglomerate is not clear due to poor exposure.

A definite angular unconformity was observed in Area 14 (Figs. 3b and 3c). The conglomerate with round white quartzite pebbles overlies tightly folded alternating shale and siliceous shale without any trace of displacement, for a distance of about 50 m. Thus the existence of a deformation phase between the Kapp Hansteen Formation and the Brennevinsfjorden Formation is demonstrated.

A conglomerate with mostly volcanic pebbles and boulders occurs at the base of the agglomeratic Kapp Hansteen Formation in Area 15 and the sorting of pebbles and the cross-bedding show that this bed lies on the shale in a right-side up position (Fig. 3d). A small porphyrite dyke cuts both the conglomerate and the underlying shale for a few metres and all are again cut by a pegmatitic vein derived from the quartz porphyry (Fig. 4). Exposures of the conglomerate are found along the river bed from northern De Veerhøgda to Jäderinfjorden, where it has a black volcanogenic matrix. A conglomerate occurs under an andesitic rock at the mouth of the river, and a fault with right lateral displacement is assumed to follow the river valley.

It is clear in the southern half of the S-III sub-area, that the conglomerate is at the base of the Kapp Hansteen agglomerate and overlies unconformably the shale of the Brennevinsfjorden Formation.

The peninsula southwest of Jäderinfjorden

The southwestern extension of the Goosbukta fault passes through the middle of this peninsula and separates the shaly Brennevinsfjorden Formation in the east from the agglomerate of the Kapp Hansteen Formation in the west. Two small quartz porphyry bodies occur near the fault in the agglomerate. Some lavas with distinct flow structure occur in the agglomerate succession in the western part of the peninsula. The southwestern extension of the Jaspisodden fault separates Hansøya from the peninsula. No primary relation between the two formations was seen in this pensinsula.

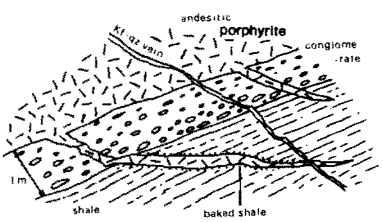


Fig. 4. Porphyrite dykes and a quartz porphyry vein cutting both the conglomerate and underlying shale around Area 15 (Fig. 1).

Gerardodden and Kullingfjellet

A small mass of quartz porphyry occurs at Gerardodden and a small island to the west shows a sharp intrusive contact of this porphyry with the schistose porphyrite in the southeast. The porphyrite and agglomerate are both strongly phyllitic and outcrop for about one kilometre towards the southeast from Gerardodden. They are penetrated by a number of sheared zones trending N-S and showing gossan-like weathering. The phyllitic agglomerate, with some round porphyrite boulders in the southern part, ends abruptly a few hundred metres west of the glacier (Nordre Franklinbreen) and well-bedded grey shales with gentle westward dips occur in the south. About 10 m at the contact is not exposed. A N-S trending fault is assumed to occur at the border between the two rock successions.

An E-W trending fault forms the southern boundary of the phyllitic agglomerate and the area from this fault to Kullingfjellet in the south is totally composed of alternating shale, shaly quartzite and sandstone. This southern area is cut by three faults all tending NNE-SSW, the southern two having associated breccia zones. The second from the north, and the southeasternmost, blocks have steeply dipping structures, while the other two have gentle to moderate dips to the south, showing gentle folds. Two thin conglomerates, containing both clastic and volcanic fragments, were reported in the southern area by Flood et al. (1969). The lithological characteristics of the shaly succession are very similar to those of the Brennevinsfjorden Formation on Botniahalvøya. No direct relation between the two formations can be established in this area. Flood et al. (1969) reported some variations of the axial plunges of small folds, which suggest refolding of older deformation axes, and this is consistent with the angular unconformity found in the S-III sub-area.

Discussion

Two conclusions are drawn from the present study:

1. The Kapp Hansteen volcanogenic succession overlies the areno-argillaceous Brennevinsfjorden Formation.
2. An angular unconformity has been established at the base of the Kapp Hansteen Formation.

These conclusions lead to a revision of the regional stratigraphic correlation of the Hecla Hoek succession as shown in Tables 1 and 2. Since the thickness of the Kapp Hansteen Formation was previously estimated to be about 4000 m (Orvin 1940, Flood et al. 1969), it was reasonable to correlate this formation to the Harkerbreen Group of Ny Friesland. Present studies show that the rocks of the Kapp Hansteen Formation form a large unit of volcanogenic piles and have almost no normal intercalated clastic sediment. Accordingly, this formation may be a product of a relatively short period of eruptive activities, unlike the Harkerbreen Group which consists of many basic rock beds separated by hundreds of metres with thick clastic beds.

Table 1
Correlation of lower Middle and upper Lower Hecla Hoek successions between Ny Friesland and Nordaustlandet

Ny Friesland				NW Nordaustlandet	Central Nordaustlandet
Lomfjellet SG	Veteranen Gr. (3790 m)	Kingbreen Fm. (1500 m)			
		Kortbreen Fm. (1200 m)	qt	Persberget Fm.	Persberget Fm.
			sh qt ls	Meyerbukta Fm.	Austfonna Fm.
Stubendorffbreen SG	Planetfjella Gr. (4750 m)	Vildadalen Fm. (3250 m)	ps pl		
			ps ls f-ps	Kapp Hansteen Fm.	Volcano-pelitic succession
			pl ls f-ps		
		Flåen Fm. (1500 m)	ps ls f-ps		
			pl	Brennevinsfjorden Fm.	Psamm-pelitic succession
				?	?
	Harkerbreen Gr. (4100 m)	Sørbreen Fm. (250 m+)			
	HARLAND et al. 1966			Present paper	

Table 2
Correlation of Lower Hecla Hoek in Svalbard

(BIRKENMAJER 1975)		(HARLAND et al. 1966)						Present paper		
Hornsund	Nordaust-landet	Ny Friesland			Nordaust-landet		Nordaust-landet		Hornsund
Deillega Fm.	Brennevins-fjorden Fm.	Stubendorffbreen Supergroup	Planetfjella Group	Vilda-dalen Fm.	Kapp Hansteen Fm.	Pelites	Murchison-fjorden Sgr.		
Eimfjellet Gr.	Kapp Hansteen Fm.			Flåen Fm.		Volcanics	Botniahalvøya Gr.	Kapp Hansteen Fm.	Eimfjellet Gr.
Gulliksen-fjellet Fm.								Brennevins-fjorden Fm.	Gulliksen-fjellet Fm.
								?	
Isbjørnhamna Gr.			Harkerbreen Group						
			Finland-veggen Gr.						

The angular unconformity observed in the southern part of Botniahalvøya provides evidence of a pre-Cambrian deformational phase in the late lower Hecla Hoek period. The Rb/Sr isochrone age of the quartz porphyry, which cuts the conglomerate, is 766 ±87 m.y. (Gorochov et al. 1977). Our preliminary results from the same rock suite, by the same method, show about 670 and 563 m.y. (Råheim pers. comm. 1980). Consequently, the deformation must be older than the radiometric ages.

No stratigraphic gap has been reported from the Middle and Lower Hecla Hoek successions of Ny Friesland (Harland et al. 1966), but an unconformity has been inferred at the base of the Franklinsundet Group in the western part of central Nordaustlandet (Flood et al. 1969) and a discontinuous conglomerate bed occurs at the base of the volcanic rock succession. In Botniahalvøya, conglomerate is set off on both the lower and upper borders of the Kapp Hansteen Formation and the thickness of the volcanogenic succession may change laterally rather rapidly. It may be reasonable to consider the Kapp Hansteen Formation to be the product of syn-tectonic igneous activities accompanying the pre-Murchisonfjorden Supergroup deformation event.

Acknowledgements

I am grateful to Messrs. J.E. Fortun and E. Nordby in 1978 and J.F.Fadnes and A. Ohta in 1979 for their excellent assistance in the field. Thanks are also due to Mrs. B. Jensen for her improvement of the English language.

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YOSHIHIDE OHTA:

MURCHISONFJORDEN SUPERGROUP OF LÅGØYA, NORTHWEST NORDAUSTLANDET, SVALBARD

Abstract

The Murchisonfjorden Supergroup of Lågøya at the northwestern corner of Nordaustlandet, Svalbard, is described. A new formation, the Meyerbukta Formation, is introduced at the lowest part of the supergroup. The successions from the Meyerbukta Formation to the Raudstup-Sälodd Formation represent three mega-cycles, each having orthoquartzite at the base and calcareous shale in the upper part. These cycles correlate very well with the successions in western Nordaustlandet and Ny Friesland. These cyclic successions constitute one of the three divisions of Hecla Hoek sediments lying between the lower eugeo-synclinal successions and the upper argillo-calcareous successions. The cyclic successions represent repeated transgressions in an unstalbe shelf environment.

The geological structures of this island have developed from concentric flexure folding, through flattening by flexure-slip folding, to rupturing by conjugate tear faults. The stress field in western Nordaustlandet during the Caledonian deformation shows a gentle curvature which suggests that the volcanogenic rocks and granite-migmatite complex in the east acted as a tectonic barrier against regional compressive stress from the west.

Introduction

Lågøya, an island 10 kilometres by 8 kilometres, with the shape of a parallelogram, is located at the northwestern edge of Nordaustlandet and is separated from the main island by Franklinsundet (Fig. 7b). It is mostly composed of rocks of the Murchisonfjorden Supergroup.

This island was visited by Sandford (1926) who landed on the northwest tip and described a 920 m thick succession mostly of quartzite and shale. Kulling (1934) made some observations at the southeastern point of this island where a shale succession was recorded. The southwestern part of the island was mapped by geologists of the Norsk Polarinstitutt's expeditions of 1957, 1962, and 1965, and successions corresponding to the sequence from the Hunnberg Formation to Persberget Formation in the Murchisonfjorden Supergroup were described (Flood et al. 1969).

The present author examined vertical aerial photographs of western Nordaustlandet and found some fold structures. The fracture patterns cutting the folds were also very clear. The intention was to make a detailed structural analysis in 1978, but strong frost action on the surface prevented any detailed measurement. However, the structures seen on the aerial photographs were confirmed by the surface mapping and further evidence was obtained. This paper deals with the lithostratigraphy and deformation of this island and of the Murchisonfjorden area. The sedimentary cycles of the Middle Hecla Hoek succession in northeastern Svalbard will also be discussed.

Stratigraphy

The succession of the middle and lower Murchisonfjorden Supergroup can be readily traced from Storsteinhalvøya across the 7 km wide Franklinsundet to Lågøya (Fig. 7b). The youngest succession in Lågøya belongs to the lower part of the Hunnberg Formation while the oldest is the newly defined Meyerbukta Formation. The geological mapping of Flood et al. (1969) was generally confirmed on this island, except for the eastern part where the new formation was established, though many minor improve-

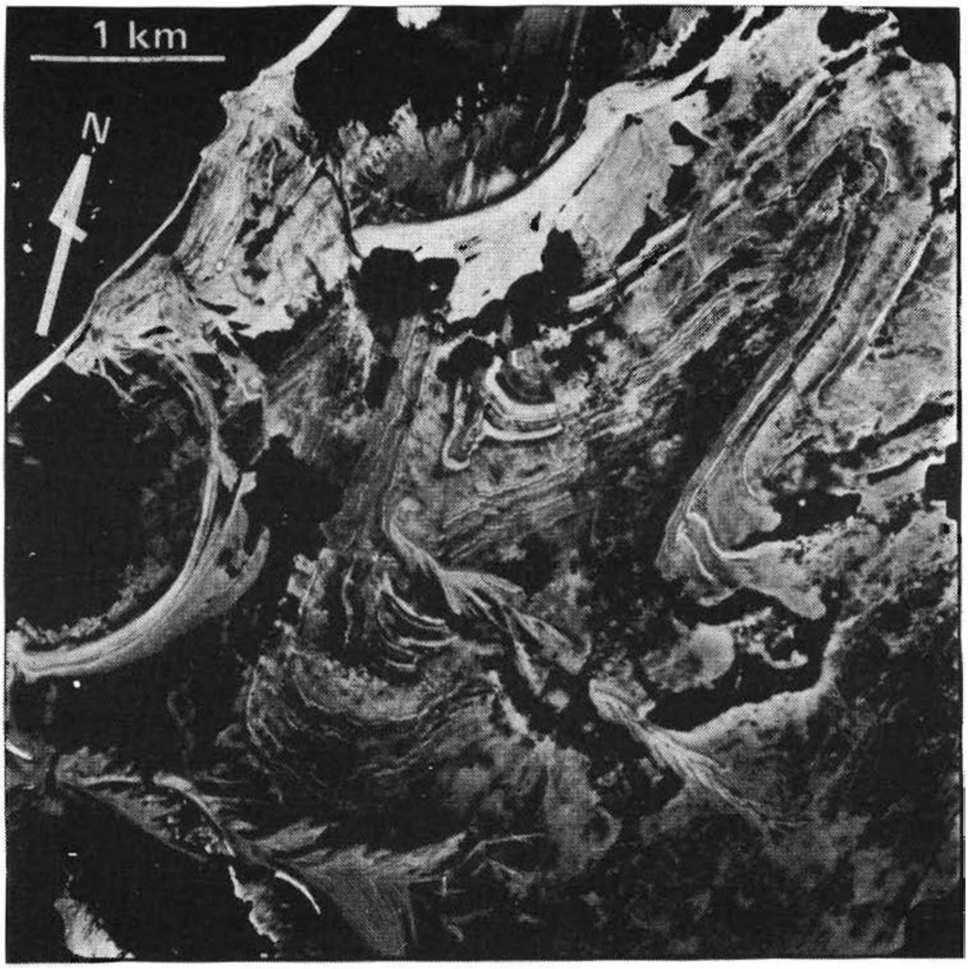

Fig. 1a. Vertical aerial photograph of the southwestern part of Lågøya.

ments have been made. The western half of the island consists of a synclinorium containing successions from the Hunnberg Formation to the Flora Formation, while the eastern half is made up of nearly vertical strata which are older than the Flora Formation (Figs. 1b and 2). The thickness of the formations varies considerably at different positions in the folds (Figs. 2 and 6). The stratigraphical columns described below (Figs. 3a and 3b) are mostly measured on the fold limbs. A Mesozoic dolerite sheet occurs along the northern side of the island.

The following is a lithostratigraphical description of the formations in the Murchisonfjorden Supergroup in descending order.

The Hunnberg Formation (lower Roaldtoppen Group)

This formation consists of a banded grey limestone containing thin siliceous films, and has a thickness of about 200 m. It occurs along the

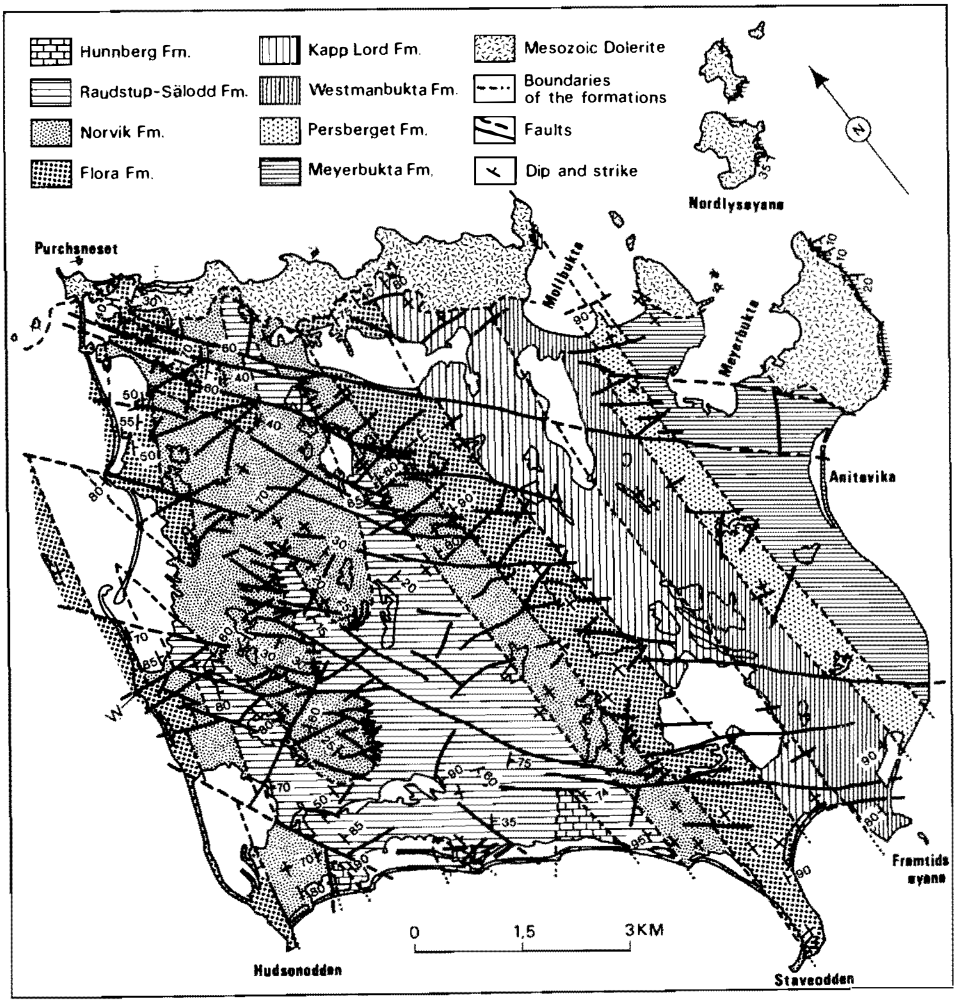

Fig. 1b. Geological map of Lågøya (locations refer to Fig. 7b). E-W: the profile line.

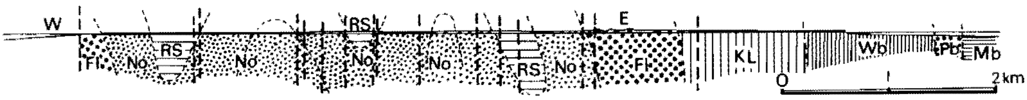

Fig. 2. Geological profile from W through E, to the east coast (W - E line of Fig. 1b). The legend is the same as for Fig. 1b.

southwestern shore, forming parasitic subordinate synclines of about 1 km wavelength in the core of the major synclinorium. The upper limit of this formation is not exposed, while its lower boundary is defined as the base of a few metres thick grey limestone bed, where the contact to the underlying shale is sharp and conformable. The geological map of Flood et al. (1969) showed this formation confined to the relatively large synclinorium core in the middle of the island, but new mapping proved that the grey limestone outcrops less than one kilometre from the coast.

The Raudstup-Sälodd Formation (upper Celsiusberget Group)

This is a dominantly shaly succession occupying the core of the major synclinorium and showing complex small parasitic folds which make stratigraphical mapping very difficult. The thickness differs considerably from the limbs to the hinges of the folds (400 m to 2200 m).

The upper 30-50 m is often interbedded with impure limestone beds less than one metre thick in the grey/green and red shales, but thin quartzite beds do occur rarely. This part of the succession corresponds to the Sälodd Formation of Kulling (1934). The middle part, accounting for more than half the total thickness of the formation here, is dominantly shale of red and grey/green varieties in alternating beds. The thickness of each bed varies from cm to dm scale. The borders between these beds are relatively sharp and the colour persists laterally over considerable distances. One colour may also predominate throughout a thickness of some hundreds of metres. A few black slate horizons of less than 100 m thickness occur too. This middle part also contains many thin quartzite beds less than one metre thick. The lower part of the formation is dominated by an alternation of grey and red coloured shale beds, but several thin white quartzite beds are also present. The quartzite comprises about 10 per cent of the middle and lower parts of this formation. The lower limit of the formation is defined as the top of the first thick white quartzite (5-7 m).

The shales show well developed small scale laminations, being composed of sandy-silty shale and fine-grained quartzose arenite, the latter consisting of well sorted sub-angular quartz grains with a carbonate cement. The quartzose arenite always shows distinct cross-bedding on a mm scale and forms incipient lenses of less than 5 cm thickness. These structures indicate a wave-dominated environment of sublittoral character.

It is possible to distinguish some fining-upwards cycles of a few hundreds of metres in scale in the lower and middle parts of this formation (cycles 10-13 of Fig. 3a), but it is difficult to distinguish any in the upper part because of structural disturbance.

A thin, 0.5 meta-porphyrite was found in the lower part of this formation, concordantly interbedded in the coloured beds of shales. The rock has plagioclase and mafic phenocrysts, the former are unaltered, while the latter have been totally converted into carbonate dusts. The latter still represent the traces of zonal structure and are thought to represent pseudomorphs after pyroxene on account of their rectangular outlines. The matrix consists of carbonates and unoriented mica flakes. It is unclear whether this rock represents an intrusive sheet or a lava flow, but since it had been altered and deformed together with the surrounding sediments, it is different from the Mesozoic dolerite.

The Norvik Formation (middle Celsiusberget Group)

This formation consists of an alteration of shales and quartzites located between the overlying shale-rich Raudstup-Sälodd Formation and an underlying thick quartzite of the Flora Formation. It has a thickness of about 900 m and is divided into two members - the upper shale and quartzite alternation (300-700 m) and the lower shale-dominated succession (200-550 m).

Five cyclic sequences consisting of quartz arenite and sandy-silty shale can be distinguished (cylces 5-9 of Fig. 3a) in the two members. The quartzite beds are 7-20 m thick at the base of each cycle, while they are less than 3 m thick in other parts. The rocks are almost pure quartz arenites with small amounts of oligoclase-andesine plagioclase and chert grains. The matrix is totally recrystallized into authigenic mantle quartz around well rounded detrital quartz grains. The opaque constituents increase in the coloured quartzites.

The shaly rocks are mostly dark grey silty shales and black slate, though a few thin beds of red shale occur in the middle of the uppermost cycle. These rocks have less distinct cross-bedding and less calcareous cement than those of the Raudstup-Sälodd Formation. There are infrequent occurrences of small incipient lenses of cross-bedded arenite, and relatively persistent wacke beds are sometimes associated with them. A few calcareous sandstone beds, 1-3 m thick, are interbedded in the upper two cycles. The thickest one, in the middle of the uppermost cycle, is oolitic. The detrital grains of the calcareous sandstone are quartz and dolomite. The former shows authigenic mantling and is partly replaced by the concentric outer shells of oolitic calcite.

The shale-slate succession of the lower member belongs to a cycle which starts with the thick quartzite of the upper Flora Formation (cycle 5 of Fig. 3a).

Laminated structures and weak cross-bedding in the shaly rocks suggest sublittoral wave-dominated conditions, whilst distinct cycles with cross-bedding and asymmetric wave-ripples with straight ridges in the quartzites indicate a high energy shelf environment.

Similar cycles can be recognized in the columnar sections described from the northern side of Murchisonfjorden by Kulling (1934) and Flood et al (1969, Fig. 7, column No. 9).

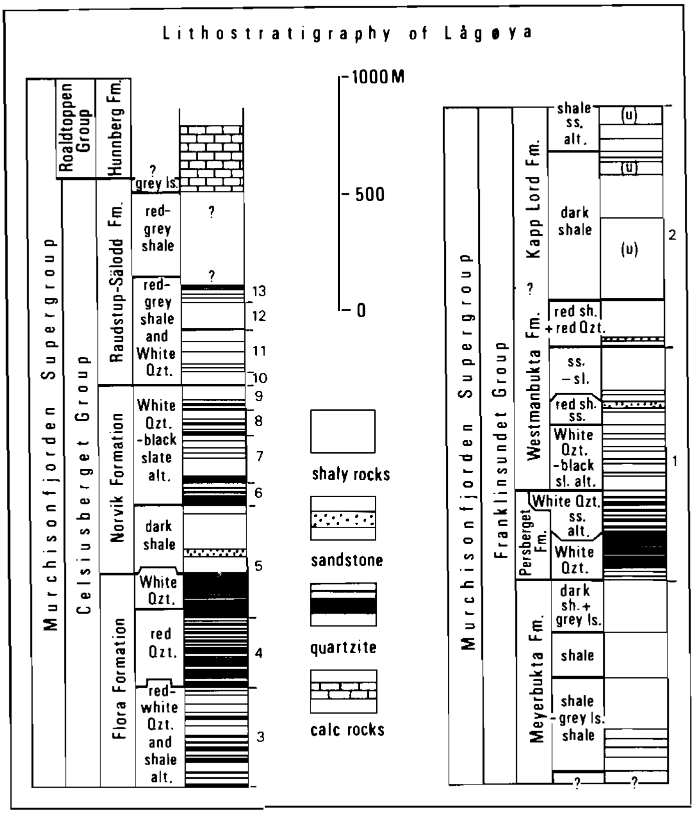

Fig. 3a
Stratigraphical columns of the Murchisonfjorden Supergroup. Lågøya: the numbers along the right side of the column represent the small cycles referred to in the text.

The Flora Formation (lower Celsiusberget Group)

This formation consists mainly of thick quartzite beds and some shales all having consistent thicknesses over long distance, and is subdivided into three members. The total thickness is about 910 m.

The upper member is a white-grey, banded orthoquartzite with thin flasers of dark grey shale and sandstone, and a thickness of about 50-150 m. Tabular cross-bedding and parallel laminations are well developed and many flattened black fragments of shale are pressed on the bedding planes of the quartzite.

The middle member is dominated by reddish quartzite and has many beds of dark slate/shale and sandstone varying from a few metres to 100 m in thickness. Some white quartzite beds also occur and the rocks include many small flattened red shale fragments.

The lower member consists of rapid alternations of dark grey sandstone and reddish-white quartzite. The latter are thinner than in the middle member and include abundant red shale fragments.

Both the reddish and the white quartzites in this formation are orthoquartzites with small amounts of round, green/brown tourmaline, zircon, and opaques, the latter increase in the reddish quartzite which has some shaly chert grains. Didirectional tabular cross-bedding of dm thick units and asymmetric ripple marks with straight ridges are abundant in all the quartzites.

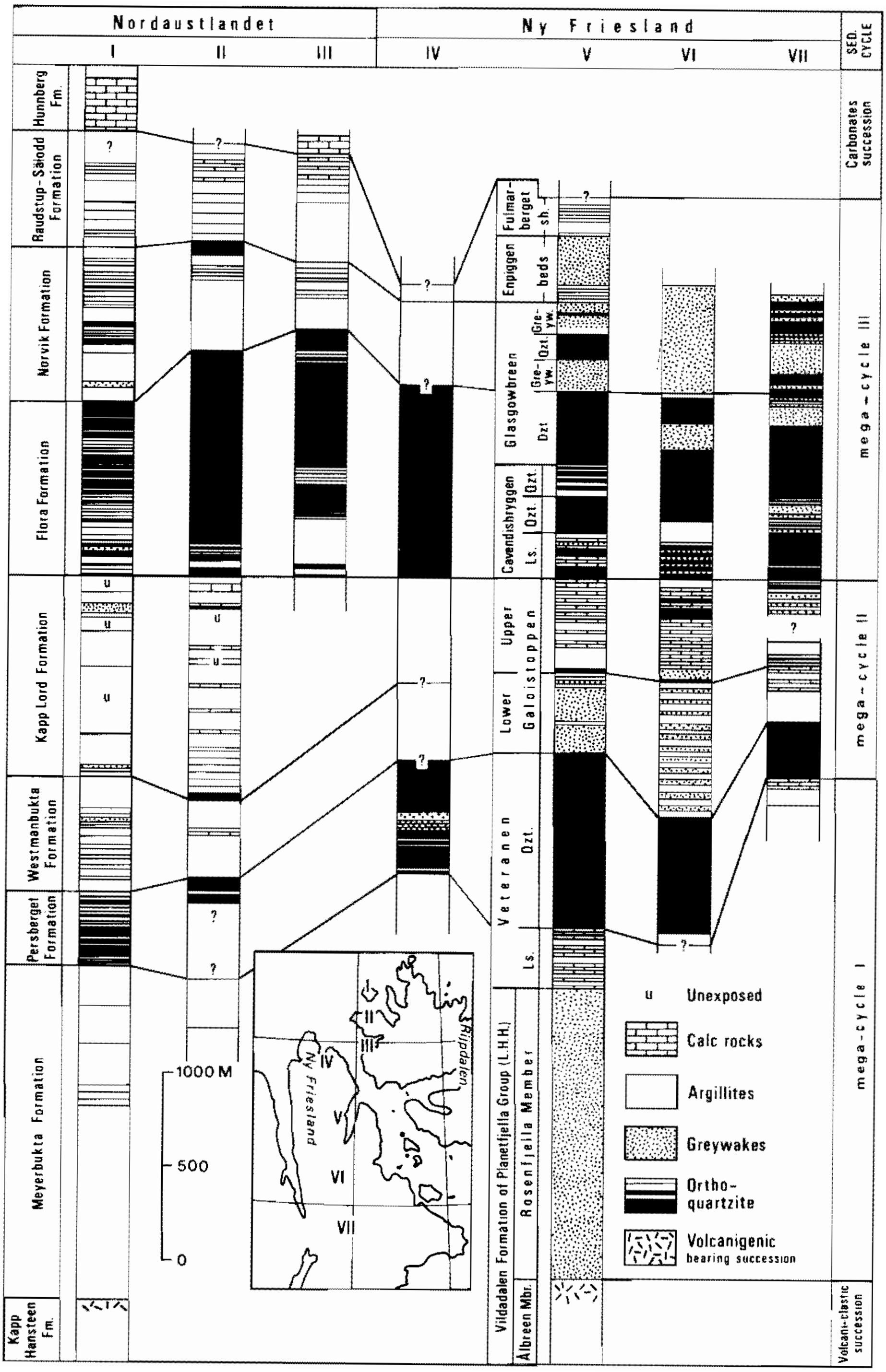

Fig. 3b. Stratigraphical column of the Murchisonfjorden Supergroup with the correlation of the mega-cycles in the Middle Hecla Hoek Supergroup of western Nordaustlandet and Ny Friesland. I: Lågøya (present paper). II: southern side of Franklinsundet (Flood et al. 1969). III. Murchisonfjorden (Kulling 1934, Flood et al. 1969). IV. Hecla Hoeken (Kulling 1934). V. Faksevågen (Kulling 1934, Wilson 1958). VI: Glasgowbreen (Wilson 1958). VII: Grusdievbreen (Wilson 1958, Hjelle 1965).

The sandstones in the middle and lower members are fine-grained quartzose wackes (matrix less than 15 per cent) with sericitic cementing material, partly overgrown by dolomite grains. Some, in the lower member, are feldspatic wackes with unaltered oligoclase-andesine plagioclase grains and the matrix is a mixture of very fine-grained quartz and sericite flakes. One sandstone near the base of this formation is lithic wacke, showing a gradational change from orthoquartzite and has disturbed sedimentary structures such as intrastratal brecciation and folding. Detrital biotite flakes are found in this wacke.

The sedimentary structures represented both in the quartzites and sandy rocks indicate that this formation was formed under higher energy fluvial conditions than the overlying formations. The lower and the middle members form two cycles (cycles 3 and 4 of Fig. 3a), while the upper member belongs to another cylce (cycle 5 of Fig. 3a).

The Kapp Lord and the Westmanbukta Formations (upper Franklinsundet Group)

These formations are in a calcareous-shaly succession occurring between the two thick quartzite successions of the Flora and the Persberget formations, total thickness about 1800 m. Due to poor exposure in the middle part of the succession, the border between the two formations has not been clearly defined.

The upper part was observed in the northern part of the island, where the uppermost 50 m is a calcareous shale with a thin quartzite and a 0.3 m thick grey limestone, below which is a 10 m thick white sandstone bed. Below these again is about 500 m of dark grey shale interbedded with thin white quartzite beds and four grey limestones, all less than 1 m thick. Three are oolitic and one has a brecciated texture. Some thin quartzites contain very thin fragments of red shale.

Red and dark grey shales dominate in a lower succession which has a total thickness of 400 m. This shaly succession is observed along the northern side of a lagoon in the northeast of Staveodden on the southern shore of the island, and is in turn underlain by a shaly succession including some white quartzite beds 5-10 m thick, the latter forming the peninsula north of Framtidsøyane. To the east of this peninsula is a 30 m thick grey and green shale with some carbonate beds, about 500 m, of red and dark green shale, and a grey/green silty shale several dm thick. The last named overlies the thick quartzite of the Persberget Formation which occurs on the eastern side of the lagoon at the southeastern edge of the island.

In the central and northern parts of Lågøya, the middle part of the shaly succession includes some pinkish white quartzite beds less than 5 m thick and red-grey sandstone beds 20-50 m thick, while the lower succession consists of black slate intercalated with thin, white quartzite beds. It may be reasonable to place the border between the Kapp Lord and the Westmanbukta Formations at the top of these quartzite intercalations in the central part of the island. Their extension southwards is represented by the quartzites of the peninsula north of Framtidsøyane. This quartzite succession can also be regarded as the beginning of a cycle which terminates at the top of the Kapp Lord Formation (cycle 2 of Fig. 3a), while the lower shaly-slaty succession belongs to the underlying cycle which starts with the orthoquartzite of the Persberget Formation (cycle 1 of Fig. 3a).

The shaly rocks in the upper part of the Kapp Lord Formation have carbonate cement and display thin laminations composed of mm to cm thick beds of muddy shale and fine-grained sandstone, the latter being a feldspathic wacke. The sandstone at the border between the two formations has sandy laminae of fine- to medium-grained feldspathic wackes with some detrital micas totally converted into chlorite.

The Persberget Formation (lower Franklinsundet Group)

This is dominantly a quartzite formation about 400 m thick, occurring in the eastern part of the island. The upper 100 m consists of alternating beds of white/grey quartzites and fine-grained dark grey/red sandstone. The middle 150 m is black slate and white/grey quartzite, again occurring in alternating beds. The lower 120 m is thick banded quartzite showing purple, red, and white colouration, while a 30 m thick slate and quartzite alternation comprises the base of this formation. The lower quartzites of this formation have calcareous spots of dark brown colour, a few cm across, while flattened dark shale fragments are abundant in the quartzites of the upper part. Tabular and platy types of cross-bedding and asymmetric ripple marks of a dm scale of wavelength and amplitude, are well developed at some localities. Graded bedding from quartzite to silty shale with transitional quartzose wacke is seen in the lower part of the formation.

The Meyerbukta Formation

This is a newly introduced formational name. Outcrops of the rocks of this formation occur in the easternmost part of the island and in Nordlysøyane below the Mesozoic dolerite sheet. A steeply dipping shaly succession about 600 m thick, located east of the Persberget quartzite along the southeastern shore of Mollbukta, is the type locality. Here, the upper 200 m and the lower 150 m include thin muddy grey limestone beds, and the middle part is dark grey calcareous shale. The succession below this is exposed at low tide under the Mesozoic dolerite sheet which covers three peninsulas in the northeast of the island and Nordlysøyane, and dips gently. The rocks are calcareous grey-black shale to fine-grained sandstone and impure limestone, the former showing cross-bedding and graded laminae of cm to dm thickness. The thickness of the lower rocks is estimated at about 800 m, accordingly the total observed thickness of this formation is 1400 m, though the base is not exposed. The overlying Mesozoic dolerite has less than 50 m observable thickness.

The coastal exposures of Tomboløya, about 5 km to the southeast of Lågøya, appear to be grey shaly limestone, very similar to that of northeastern Lågøya, though this statement is only based on observations made from a low-flying helicopter.

Around Persberget on the southeastern side of Franklinsundet, Kulling (1934) recorded a shale succession outcropping for a distance of one kilometre, to the east of a thick quartzite (which he classified as the Flora Formation). This succession was included in the Persberget Formation on the map of Flood et al. (1969). It occupies the core of an anticline according to the structural interpretation of that same map. Thus, this shale is lower than the Persberget quartzite and is correlatable to the Meyerbukta Formation of Lågøya.

Stratigraphic and sedimentological discussion

There is no problem in correlating the formations between Lågøya and the Murchisonfjorden area. The introduction of the Meyerbukta Formation makes it easier to correlate the successions within the Middle Hecla Hoek Supergroup of this area to those of Ny Friesland and central Nordaustlandet. The thick psammitic Vildadalen Formation of the upper Planetfjella Group and a calcareous succession at the base of the Veteranen Group in Ny Friesland (Harland et al. 1966), can be correlated to the Meyerbukta Formation. The Austfonna Formation in Rijpdalen, central Nordaustlandet (Flood et al. 1969), an about one kilometre thick pelitic succession with some quartzite beds occurring between the quartzite-rich succession above and the volcanics-bearing one below, corresponds to the Meyerbukta Formation.

Kulling (1934) was of the opinion that the quartzose sandstone succession with dolomite intercalations in the central part of Gerardodden, at the southern end of Lady Franklinfjorden, is of similar lithofacies to the lower part of the Murchisonfjorden Formation (his term). He did not find any conglomerate between this succession and the Kapp Hansteen Formation, but he believed that Kapp Hansteen rocks underlie this sandstone. Flood et al. (1969) recorded conglomerates on both sides of the NE-SW trending fault in Gerardodden. Two conglomerate beds in the south of the fault, with clastic and volcanic blocks occurring in a sandstone succession, were considered to be of the Brennevinsfjorden Formation, while a 10 m wide conglomerate in the north of the fault, with large volcanic boulders, was correlated to the conglomerate east of the Kapp Hansteen Formation on Botniahalvøya. They also described a conglomerate resting discordantly on fine-grained Kapp Hansteen tuff around the quartz porphyry body across the fjord due east of Hansøya, with boulders of quartz porphyry which cut both the Kapp Hansteen and the Brennevinsfjorden Formations. The present author considers that this could be the basal conglomerate of the Meyerbukta Formation. He also considers that the clastic succession in the south of Gerardodden is part of the Brennevinsfjorden Formation.

Most of the successions observed in Lågøya, except for the Hunnberg Formation, are composed of orthoquartzite and silty shale beds. Wackes and limestones are subordinate. The quartzite beds have constant thicknesses over long distances, and are well sorted, consisting of very well rounded quartz grains. This indicates steady wave action and a long period of weathering in the source area. Platy-tabular cross-bedding and asymmetrical wave ripples with straight ridges suggest a fluvial or a sublittoral origin. The few measurements made indicate palaeocurrents flowing from east to west. Peal-up and pull-apart structures are seen in the thin shaly films between quartzite beds, and flattened clay pellets occur abundantly in the quartzites. The silty shales often show fining-upwards lamination, mud cracks, small asymmetrical ripple marks, bounce casts and pull-apart structures. The sandstones are mostly fine-grained quartzose wackes with very small amounts of plagioclase and detrital micas. Most limestones are muddy, grey banded rocks, commonly having oolitic and brecciated textures, occurring as intercalated beds in the upper shaly part of the cyclic successions. All the lithological characteristics of these rocks suggest a sedimentary environment of shallow open water. The colours of the shale suggest their lacustrine origin.

These rocks make up repeated cycles of orthoquartzite-(sandstone)-shale-calcareous shale with limestone. Thirteen cycles are distinguished from the base of the Persberget Formation to the middle of the Raudstup-Sälodd Formation (Fig. 3a). Additional cycles are recognizable in the upper Raudstup-Sälodd Formation. The thickness of the cyclic units decreases upwards. It is in general about 1000 m in the lower cycles, 300-500 m in the middle ones, and less than 200 m in the upper cycles. Most of the cyclic units are of a fining-upwards type, but some (cycles 1, 4, and 13 of Fig. 3a) have thin quartzite beds around the top of the unit, indicating a weak tendency towards coarsening-upwards cycles.

Three mega-cycles on a large scale can be distinguished in Lågøya(Fig. 3b, column I):

Mega-cycle 1:	The Meyerbukta Formation, about 1.75 km thick.
Mega-cycle 2:	From Persberget Formation to the Kapp Lord Formation, about 2 km thick.
Mega-cycle 3:	From the Flora Formation to the Raudstup-Sälodd Formation, about 2.25 km thick.

Mega-cycles of similar scale can also be identified on the southern shore of Franklinsundet and in the Murchisonfjorden area from previous descriptions (Kulling 1934, Flood et al. 1969) (Fig. 3b, columns II and III). Wilson (1958) recognized two mega-cycles in the Veteranen Group of Ny Friesland while the third cycle is recognizable from the uppermost Planetfjella Group to the lowest part of the Veteranen Group (Fig. 3b, columns V and VI). The lower and middle Murchisonfjorden Supergroup of central Nordaustlandet has a similar cyclic nature (Sandford 1950, 1956, and 1962, Flood et al. 1969), but no detailed stratigraphical column is available.

In this way, the three mega-cycles can be correlated very well over wide areas (Fig. 3b) and characterize the clastic successions of the lower and middle parts of the Middle Hecla Hoek Supergroup. All three mega-cycles in western Nordaustlandet have calcareous silty shale in the upper parts of the cyclic sequences, while in Ny Friesland the corresponding parts are fine- to medium-grained greywackes. This fact indicates that during this period the Ny Friesland area was a more active, unstable basin, than the Nordaustlandet area.

Wilson (1958) attributed the origin of the mega-cycles to crustal elevation in the source area and climatic and oceanographic changes.

Krasil'ščikov (1973) referring to Wilson (1958), considered the successions above the Harkerbreen Group of Ny Friesland and the Kapp Hansteen Formation of Nordaustlandet (his term) as one large sedimentary cycle of Middle-Late Riphean period, from 1400 to 570 m.y., and regarded the mega-cycles as second-order cylces. He was of the opinion that the Lower Hecla Hoek below the cyclic successions is a pre-Riphean metamorphic complex constituting the basement of a Caledonian geosyncline. This last problem requires a more intensive radiometric age study of the Lower Hecla Hoek rocks.

From a tectonic point of view, successive layering of different lithologies is essentially dependent on the change of distribution width of the various lithological facies and the migration of the shore line (Belusov 1954). Since time-marker beds are lacking in the present case, it is impossible to know the lateral change of lithologic facies during a limited time span. However, the orthoquartzite successions at the base of the mega-cycles, which extend over 100 km from Lågøya to southern Ny Friesland, can not be coeval, but were undoubtedly formed by a sequence of transgressions over a longer period of time. If this is the case, the quartzite beds in the lower parts of the mega-cycles can be regarded as the fluvial progradational phases, while the silty shale and muddy limestone in the upper parts of the cycles reflect the agradational phases to fill up a basin. Small cycles distinguished within the mega-cycles represent intermittent advances of the main transgression and some coarsening-upwards cycles may represent limited regressive phases.

The cyclic nature of the Middle Hecla Hoek clastics contrasts strongly with the overlying carbonate-argillite (+ tilloids) successions of upper Middle to Upper Hecla Hoek, and with the underlying areno-argillo-volcanogenic successions of the Lower Hecla Hoek Supergroup. Therefore, from a sedimentological point of view, it is reasonable to divide the Hecla Hoek sediments into three large units with this cyclic clastic succession as the middle unit. The boundaries of formations within this succession described in previous literature, have often been chosen in the middle of a cycle. It is suggested that these should be reconsidered critically on the basis of more detailed analyses of the sedimentologcial pattern of the rock succession.

If this revised grouping is accepted, the Hecla Hoek successions on the west coast of Spitsbergen (Birkenmajer 1975) can be classified as Lower Hecla Hoek up to the Skalfjellet Subgroup and Upper Hecla Hoek from the limestone-dolomite successions just below the tilloids (Hjelle et al. 1979). Some conglomerates and unconformities already deduced in the Middle Hecla Hoek succession may be correlated with the base of the mega-cycles of the Nordaustlandet and Ny Friesland areas, which suggests that the west Spitsbergen area suffered stronger tectonism than the eastern areas during the Middle Hecla Hoek period (Fig. 4).

In contrast to the paired geosynclines of young geologic time, it is charactersitic of the Hecla Hoek geosyncline that the typical eugeosynclinal facies is restricted to the Lower Hecla Hoek Supergroup, while the Middle and Upper Supergroups are miogeosynclinal, and that only a very small lateral contrast of facies has been observed in the 400 km across the Svalbard Caledonides.

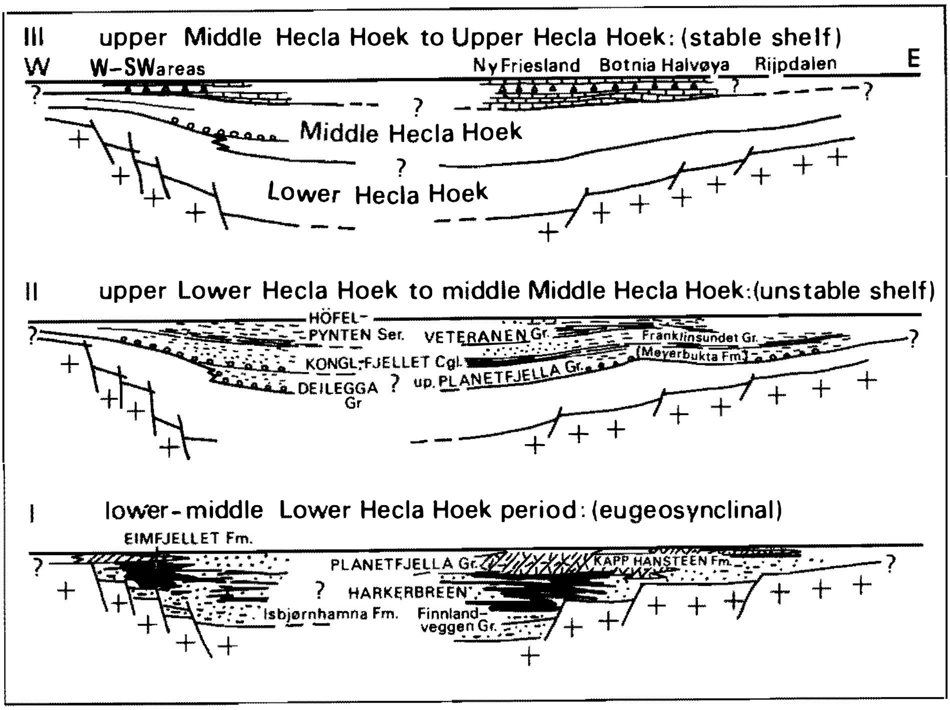

Fig. 4. Three stages in the development history of the Hecla Hoek geosyncline - a schematic representation.

These sedimentological discussions give the following development scheme for the Hecla Hoek geosyncline (Fig. 4). Starting probably before 1000 m.y. ago, though not more than 1200 m.y. (Edwards et al. 1974), more than 10 km of Lower Hecla Hoek sediments were formed on a continental basement in an active eugeosyncline bounded by deep fractures with associated initial magmatism of a non-oceanic type (Ohta 1978). This was probably related to a form of large scale rift tectonics with an asymmetrical active centre located to the west. This rapidly sinking broad riftgene-like geosyncline was nearly filled up at the time of the acidic volcanism of the Kapp Hansteen Formation and the Planetfjella Group, about 770 m.y. ago (Gorochov et al. 1977), and relatively stable epirogenic movements followed in the Middle and Upper Hecla Hoek periods.

Geological structures

The western half of Lågøya is a synclinorium composed of rocks of the Celsiusberget Group. This structure is the northern extension of the syncline found in the central Murchisonfjorden area. The eastern half of the island is composed of nearly vertical beds of Franklinsundet Group rocks (Fig. 2). An incomplete anticline occurs in the northeastern part of the island and on Nordlysøyane, and this structure is the northern extension of the anticline of the Westmanbukta and Persberget areas on the southern side of Franklinsundet. Some faults trending WNW-ESE are deduced along

Franklinsundet from a marked change of general strike in the fold structures on both sides of the strait (Fig. 7b).

Development of secondary cleavages is restricted to the shaly core of the synclinorium and the fold structures are very well revealed by the quartzite beds. The fold structures and faults at various scales are recognized very clearly on the aerial photographs (Figs. 1a and 5a).

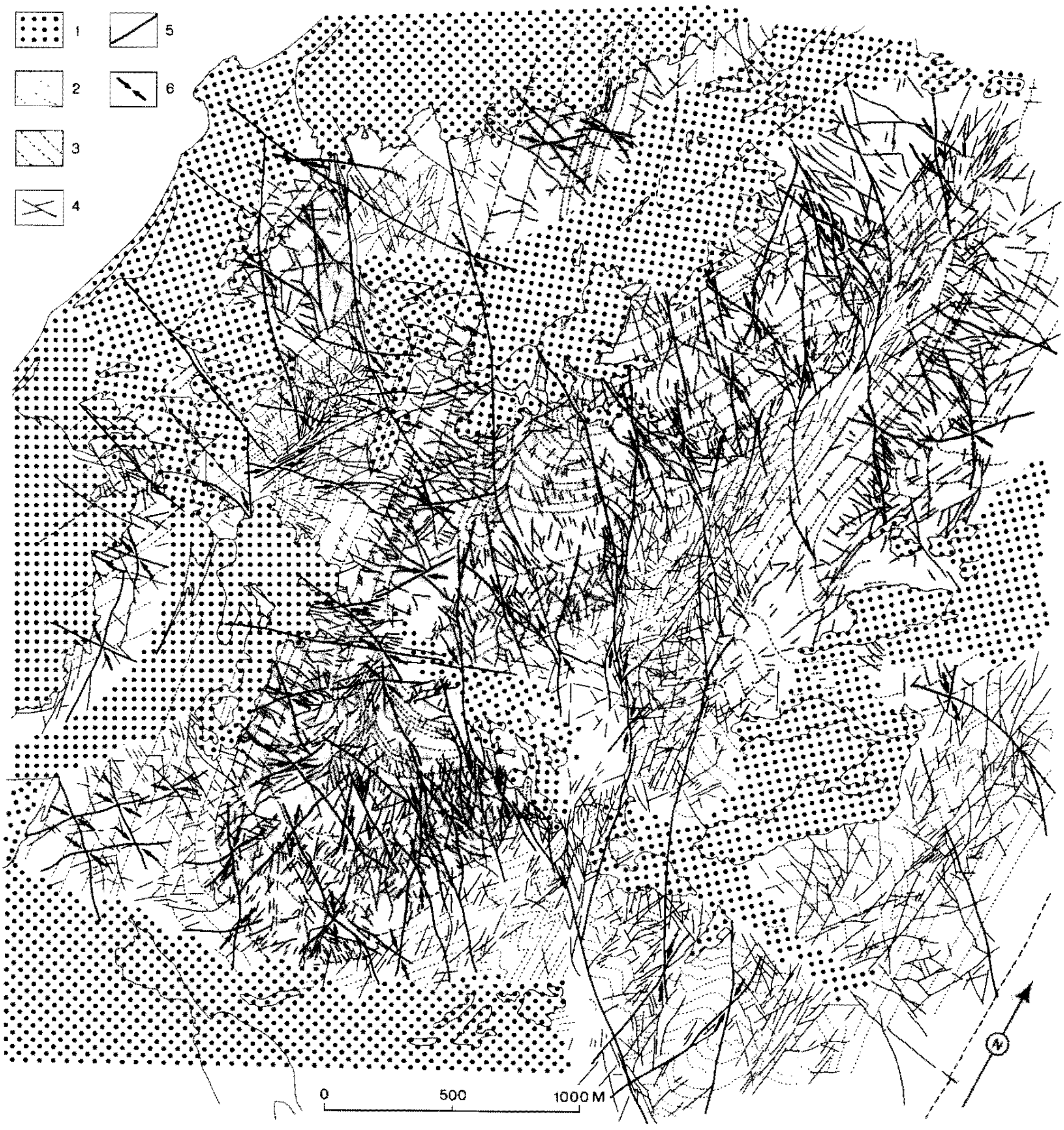

Fig. 5. Structural details of the western synclinorium of Lågøya.

5a. Structural map of western Lågøya. 1: sand dune, 2: upper Norvik Formation, 3: lower Norvik Formation, 4: tear faults, 5: major faults, 6: direction of maximum compressive stress.

The Eastern Anticline

The calcareous shales of the Meyerbukta Formation in northeastern Lågøya have E-W to NNW-SSE strikes and 10-30 degrees' dips to the south and southwest. This suggests the western limb of an anticline, the axis of which would be located a little off shore to the east and plunging to the south. Taking into account the fold structures on the southern side of Franklinsundet, this deduced anticline must be the northern continuation of the structure around Persberget (Fig. 7b). The shaly limestone of the Meyerbukta Formation on Tomboløya is near to the core of this anticline. Further to the southeast, a syncline is developed around De Geerfonna and the Persberget quartzite occurs in the eastern limb of the syncline along the west coast of Søre Franklinbreen (Fig. 7b).

The Central Monoclinal Structure

This zone strikes roughly N-S and is about 3 km wide. It is composed of rocks from the Meyerbukta Formation to the Flora Formation (Fig. 1b). This structure is backboned by two thick quartzite successions of the Persberget and the Flora Formations, and the cleavage of the shaly rocks is mostly parallel to the bedding surfaces. No isoclinal folding is involved in this zone. The oolites in the thin limestone beds of the Kapp Lord Formation show strong deformation into long ovoids, with short/long axis ratios of 1/4 to 1/5. However, the limestone accounts for less than a few per cent in the succession and the tectonic attenuation of the thick shaly succession can not be estimated from the deformation of the oolites.

The Western Synclinorium

This fold involves rocks ranging from the Flora Formation to the Hunnberg Formation and has a roughly N-S striking axis with a 25-30 degrees' plunge to the south (Figs. 1b and 5b). The Flora quartzite makes the outer wrap of the fold while the Raudstup-Sälodd shales fill the hinge area. Subordinate, homoaxial folds (two anticlines and three synclines) with wavelengths of about 1.3 km and amplitude of about 1 km, occur in the hinge area. The northern part of the synclinorium is obliquely cut by NW-SE trending faults with left-lateral displacements and the western subordinate anticline is cut by a cross fault in the south (Fig. 5a).

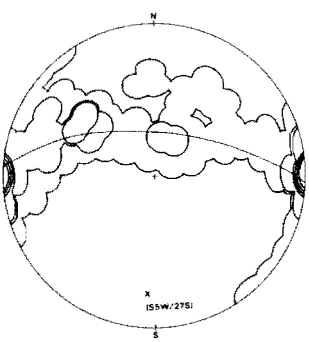

Fig. 5b. Projection of the bedding planes from the synclinorium, equal area lower hemisphere projection. Number of measurements = 103, contours: 1-5-10-15-20-25%, X: calculated modal axis of the synclinorium.

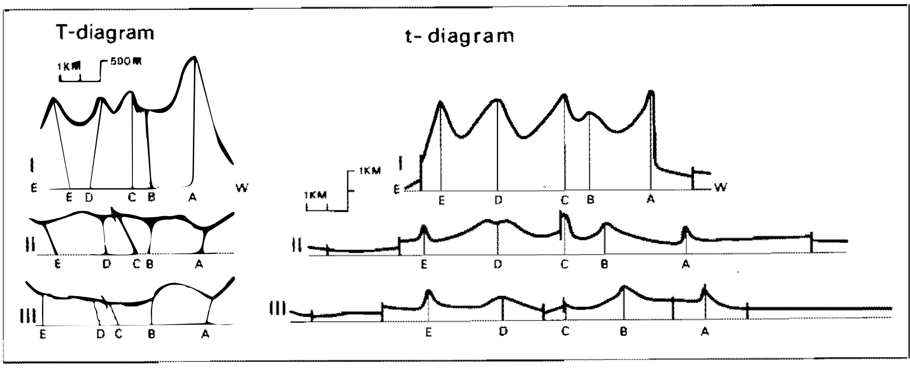

Fig. 6. T and t diagram for the Norvik and the Raudstup-Sälodd Formations in the western synclinorium. T: thickness parallel to the axial plane, t: thickness perpendicular to the bedding plane. These values are modified from Ramsay (1962), (see text). I: Raudstup-Sälodd Formation, II: upper Norvik Formation, III: lower Norvik Formation, A.....E: refer to the same points in the fold.

The synclinorium is nearly symmetrical and is a cylindroidal fold with little disharmonic style as a whole (Figs. 2 and 5b). The western subordinate anticline and syncline show symmetrical profiles and orthorhombic symmetry, while the eastern ones have asymmetric monoclinal profiles with curved axial surfaces, indicating weak westwards overturning.

The tectonic s-surfaces are mostly parallel to the bedding surfaces in the quartzites, having utilized thin shaly intercalations as slip surfaces. In the thick shale successions in the fold hinge area, penetrative axial plane cleavages of diverging types are strongly developed, showing direct componental movements with orthorhombic symmetry. The componental movement is observed to be a finite non-affine displacement of wedge-shaped microlithons. The whole shape of the synclinorium was essentially controlled by thick quartzite beds and the axial thickening is mainly due to the shaly successions, thus the folds are of an intermediate type between concentric and similar folding as shown in the T-t diagram (Fig. 6).

Due to the great thickness of the quartzite-rich succession of the Flora Formation, the folding must be expected to be controlled by the competent succession,in which the dominating fold mechanism was flexure folding to form concentric folds (Fig. 8a). By successive compression, flexure-slip folding advanced, with increasing effect of slip folding in the shaly successions via a mechanism of flattening (Ramsay 1962, Fig. 8b). The flattening ratio was originally defined for individual beds by Ramsay (1962), but here the same principle has been applied to the mappable units of the succession, each some hundreds of metres in thickness. The degree of flattening has been obtained from the ratio tw/th and α' (Fig. 8b) and the results are shown in Table 1. The degree of flattening is expected to be proportional to the amount of incompetent beds in the successions. The modification of fold style due to this flattening reached a limit when the limbs of the fold became parallel for certain lengths of the profile and the high competency of thick quartzite beds prevented furhter folding at the hinge.

TABLE 1

Degree of flattening by flexure-slip folding (modified from Ramsay 1962, see Fig. 8b)

	Raudstup-Sälodd Formation	Upper Norvik Formation	Lower Norvik Formation
Flattening degree	78%	30-38%	50-60%
% of quartzite in succession	10.6%	30%	9.4%

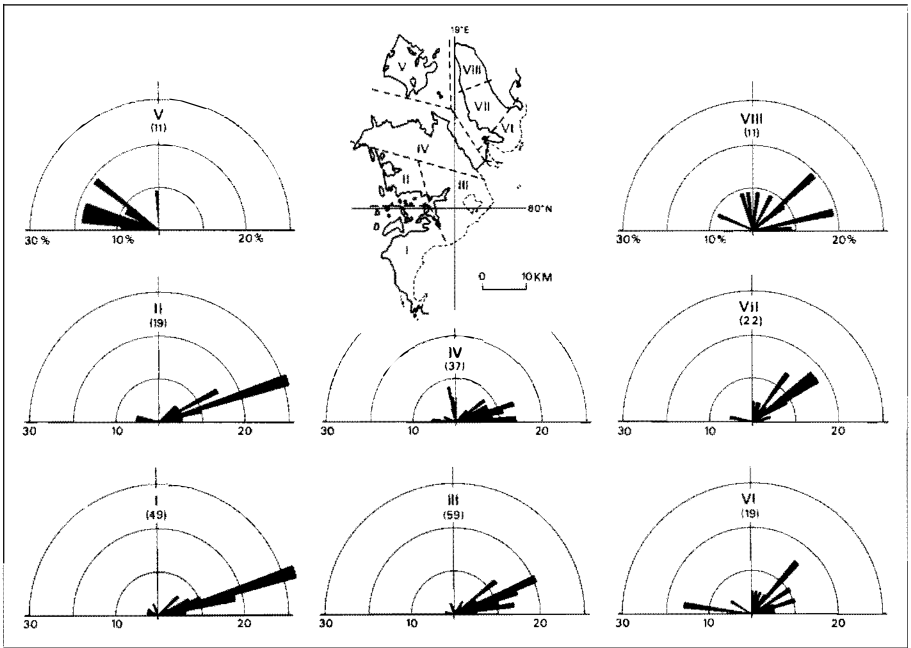

Fig. 7. Stress field calculated from conjugate pairs of tear faults, and fold axes on western Nordaustlandet.
a: Rosette diagrams showing the strikes of the σ_1 (maximum compressive stress) from the sub-areas.

Under further continued compression, the deformation mechanism changed into a ruptural type along a set of conjugate tear fractures of mostly vertical dips with lateral slip (Figs. 5a and 8c). This mechanism is similar to the 'Plattung' of Sander (1930) but on a larger scale than that discussed by him, and also to the small scale wrench faults (tear faults) of De Sitter (1956). The displacement made by each fault is only a few metres, but numerous sets of conjugate tear faults achieved a large 'Plattung'. The direction of maximum compressive stress calculated as the acute bisectrix of the conjugate fractures, referring observed displacement, is nearly E-W, i.e. perpendicular to the axial plane of the fold (Fig. 5a). The stress direction deviates, especially in the shaly hinge areas, and the axial plane cleavages developed in the previous stage, were utilized as one of the conjugate fractures.

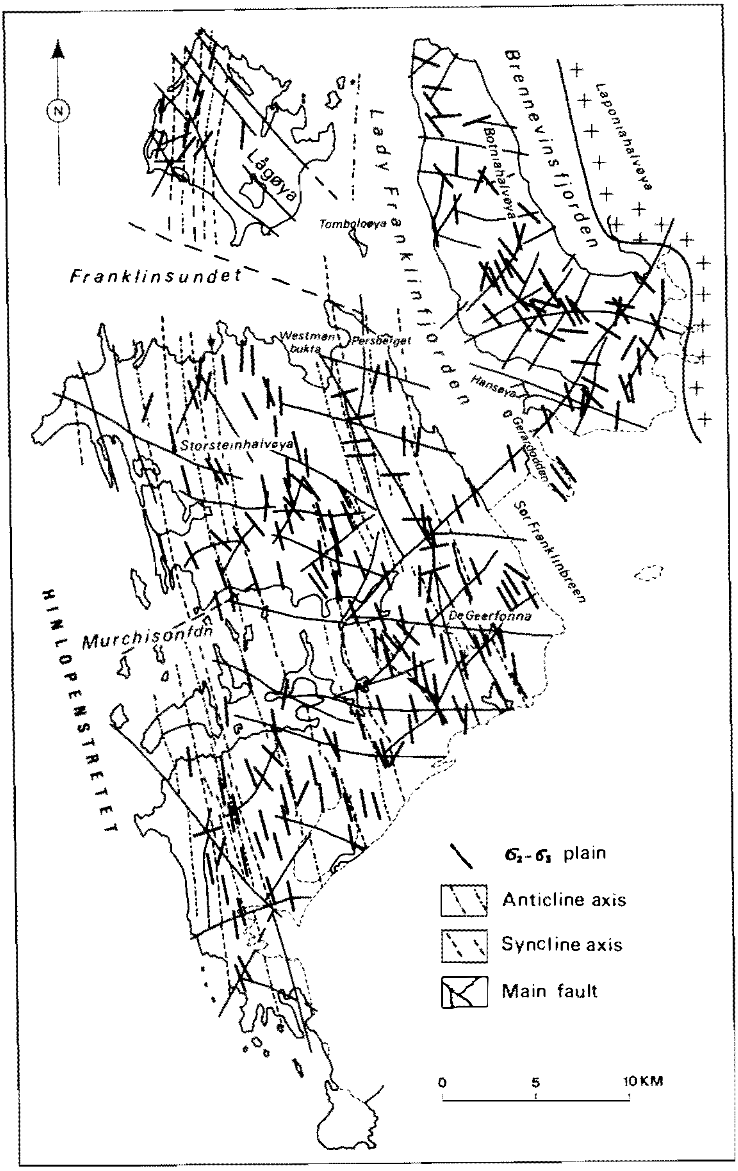

Fig. 7b: Anticline and syncline axes with the trend of σ_2-σ_3 planes (planes perpendicular to the maximum compressive stress).

A large displacement in the hinge of the western subordinate anticline was made by a peri-anticline cross-fault of normal tensional origin, which utilized some of the preceding conjugate fractures.

The NW-SE striking faults with relatively large left-lateral displacements in the north and south of the island have similar trends to one of the conjugate fractures and produced a similar effect as the cross-fault. However, constant left-lateral movement by these faults must have been caused by a regional coupled stress.

The fold structures observed in Lågøya continue into the Murchisonfjorden area and both the dimensions and styles of the folds are similar in both areas. The conjugate tear faults are very well developed in the Murchisonfjorden area and an extremely distinct fracture pattern has been obtained from

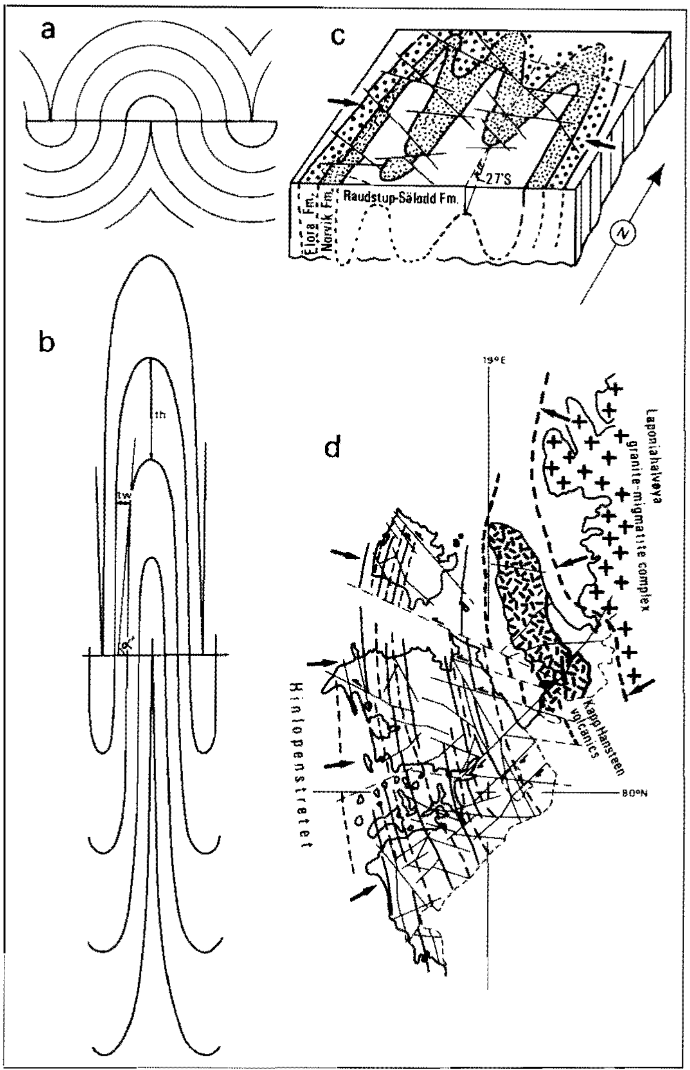

Fig. 8. Schematic illustration of the structural development.
a. Complete concentric folds formed by flexure folding.
b. 50% flattening of the concentric folds, keeping the volume constant as 8a. 'th', 'tw', and 'α' refer to the text and Table 1 (Ramsay 1962).
c. Further extension along the fold axis by conjugate tear faults and peri-anticlinal cross-faults by successive compression from the same direction as in the previous stages.
d. General stress field in western Nordaustlandet, showing a slow curvature. The volcanics of Botniahalvøya and the granite-migmatites of Laponiahalvøya acted as a tectonic barrier against the stress from the west.

vertical aerial photographs. The maximum compressive stress direction was calculated from the conjugate pairs (Figs. 7a and 7b), assuming most fractures to have nearly vertical dips. The deduced stress direction changes gradually from SW-NE in the south to WSW-ENE to the north of Murchisonfjorden and to E-W in Lågøya further north. This gradual change of the stress field suggests that a resistant mass existed to the east of this area. The Kapp Hansteen volcanic rocks in Botniahalvøya and the granite-migmatite complex of Laponiahalvøya may well correspond to this tectonically rigid barrier (Fig. 8d). The gentle swing of the fold axes along the whole length of the eastern shore of Hinlopenstretet tends to confirm this idea (Fig. 7b).

Several large faults of WNW-ESE trend and with left-lateral displacement, similar to those of Lågøya, occur over the entire Murchisonfjorden area (Fig. 7b). This widespread occurrence of left-lateral faults indicates that a common mechanism covering the whole metasediment area of western

Nordaustlandet was in operation later than the regional folding. A possible cause of this is the emplacement of the igneous and metamorphic complex of Laponiahalvøya. This would have had the effect of pushing the northern part of the folded metasediments towards the west. The fractures striking NW-SE, initiated as the conjugate fractures in preceding stage, was utilized as shear slip planes and produced step-wise non-affine block movements at a late stage in the orogenic period (Fig. 8d).

The regional folding might be around 530 m.y. ago as obtained by preliminary Rb/Sr whole rock isochron age determination from the metasediment of the Persberget Formation (Råheim pers. comm. 1979), and the emplacement of the granite-migmatite complex took place around 400 m.y. ago as shown by the K/Ar ages (Gayer et al. 1966). The age of the regional folding is roughly similar to the Finnmarkian phase of the Caledonian orogeny in the northernmost part of Norway (Sturt et al. 1978).

Conclusion

Lågøya, in spite of its only being a small island at the northwestern edge of Nordaustlandet, contains most of the succession of the Murchisonfjorden Supergroup, except for the Ryssø Formation. A new formation, the Meyerbukta Formation, more than 1500 m in thickness, has been defined in the eastern part of the island. This new formation occurs below the Persberget Formation (which was thought to be the lowest formation in the Murchisonfjorden Supergroup), and overlies unconformably the Kapp Hansteen Formation of Botniahalvøya (Ohta 1982). This could be classified as an independent group because of its great thickness.

The succession of the Celsiusberget and the Franklinsundet Groups, totalling 400-500 m in thickness, together with the Meyerbukta Formation of more than 1500 m, represent three mega-cycles each a few thousand metres in thickness, and the middle and upper cycles can be subdivided into more than thirteen small cycles. Each cycle, whether large or small, begins with orthoquartzite and ends with calcareous shale with some impure limestone beds. The mega-cycles represent transgressions during the Middle Hecla Hoek period, and similar cycles are recognized throughout the Hinlopenstretet synclinorium and in central Nordaustlandet. The stratigraphical discontinuities in the Middle Hecla Hoek successions of southwestern Spitsbergen can be correlated to the base of each of these mega-cycles in the Hinlopenstretet Synclinorium. Thus, the cyclic successions in the Middle Hecla Hoek Supergroup constitute one of the three divisions of the Hecla Hoek geosynclinal sediments. These consist of the lower volcano-arenoargillaceous eugeosynclinal successions, the middle cyclic areno-argillaceous sediments, and the upper argillo-calcareous epicontinental successions with tilloids. The middle cyclic successions represent unstable shelf conditions which followed the active riftgene eugeosynclinal development of the Hecla Hoek Geosyncline.

A detailed structural study of the fold and fault structures has been carried out with the help of vertical aerial photographs. Regional E-W trending compressive stress created concentric folds by flexure folding in the early stages, then flattening of the folds was produced by flexure-slip folding. After that, ruptural deformation developed as numerous conjugate tear faults and allowed further extension along the fold axis. The stress field along the western coast of Nordaustlandet shows a gentle curvature which indicates that the Kapp Hansteen volcanic rocks of Botniahalvøya and the granite-migmatite complex of Laponiahalvøya acted as a tectonically resistent mass to the orogenic stress from the west.

Acknowledgements

The author wishes to thank Mr. J.E. Fortun and Mr. E. Nordby for their helpful assistance during the field work. Thanks are also due to Mrs. Brenda Jensen for helping with the English language.

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YOSHIHIDE OHTA:

LITHOSTRATIGRAPHY OF THE HECLA HOEK ROCKS IN CENTRAL NORDAUSTLANDET AND THEIR RELATIONSHIPS TO THE CALEDONIAN GRANITIC-MIGMATITIC ROCKS

Abstract

The lithostratigraphy of the Hecla Hoek sediments of central Nordaustlandet is described with the contact relationships to the Caledonian granitic-migmatitic rocks. Three groups of the middle and lower Murchisonfjorden Supergroup form 1.3-1.5 km thick mega-cycles, starting with transgressive orthoquartzite and ending with regressive calcareous shale. Similar cycles have been recognized in western Nordaustlandet and eastern Ny Friesland (Ohta 1982b), and proved to have an extension of more than 100 km across the structural trend of the Caledonian area in northeast Svalbard. An unconformity is inferred at the base of the Murchisonfjorden Supergroup.

The Kapp Hansteen Group consists of diabasic and rhyolitic rocks in this area. They are mainly intrusive into the Brennevinsfjorden Formation (about 3 km in thickness), but some extrusive rocks also occur.

The Caledonian granites and migmatites have intrusive contacts to the Hecla Hoek rocks and form narrow zones of hornfels and schists. The metasedimentary rocks up to the Franklinsundet Group were involved in the migmatization in the northeastern part.

A Caledonian lamprophyre and Mesozoic dolerites occur as small dykes.

Introduction

The southern half of the ice free corridor in central Nordaustlandet between the Vestfonna and Austfonna ice caps, is one of the geologically least known areas in Svalbard (Fig. 1). Its southwestern part along Wahlenbergfjorden was first described by Sandford in 1926 and the northwestern and northeastern parts were discussed by him in 1950, 1956, and 1963. An extensive survey of northern Nordaustlandet was carried out by Norsk Polarinstitutt in 1965, and the results were published in 1969 (Flood et al.) but investigation of the present area was at that time still at a reconnaissance stage.

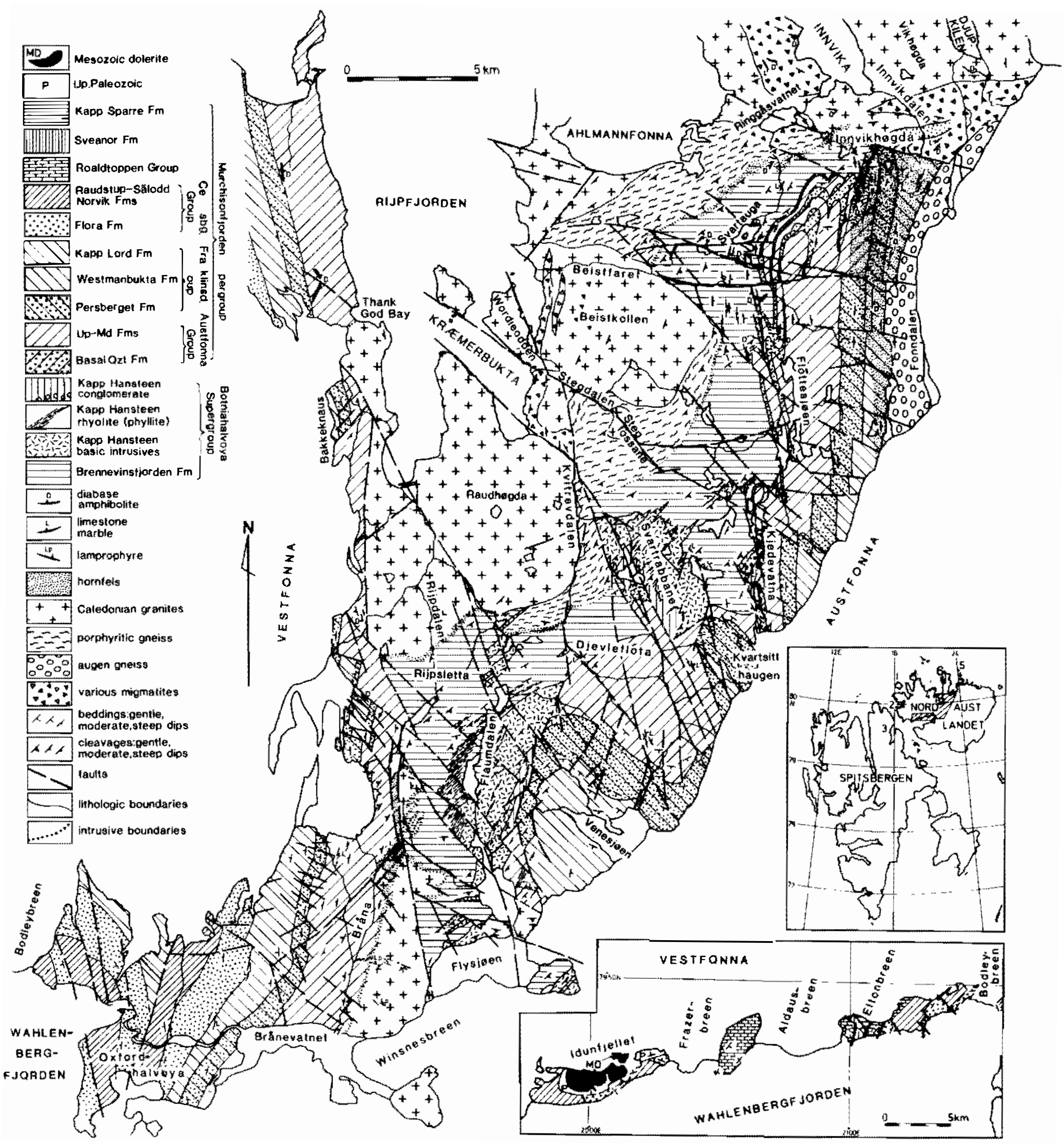

Fig. 1. Geological map of central Nordaustlandet. Inserted map: 1. Lågøya, 2. Murchisonfjorden, 3. Ny Friesland, 4. Sabinebukta, 5. Nordre Repøya, 6. Kapp Platen peninsula.

From 1976 to 1979, several geologists of Norsk Polarinstitutt were engaged in field work in this area:

1976 T. Gjelsvik: Innvikdalen and Rijpfjorden granite
A. Hjelle: Ahlmannfonna area
Y. Ohta: northern half of the metasediment area
T.S. Winsnes: east of Flysjøen
1978 Y. Ohta: Beistkollen granite
1979 Y. Ohta: southern half of the metasediment area

Although some important problems have still not been completely solved, and since there is no plan of extensive further geological field work in the area in the near future, it seems right to make a summary of the lithostratigraphy of this area.

This paper presents lithostratigraphic descriptions of the Murchisonfjorden Supergroup and the Botniahalvøya Group (previous name) and of the contact relationships of these rocks to the Caledonian granitic and migmatitic rocks. The structures will be mentioned only when they are relevant to lithostratigraphy. Some new proposals will be made on the stratigraphic nomenclatures, and the successions obtained will be compared to those of the western Nordaustlandet and Ny Friesland areas from the view point of sedimentary cycles. Contact metamorphism around the Caledonian granitic-migmatitic rocks will be described, mainly based on the field observations.

More than ten place names used in Fig. 1 are recently proposed and authorized by the Norwegian Polar Research Institute.

Structural outline

The major structures of the map area are a N-S trending anticlinorium from Rijpfjorden in the north to Winsnesbreen in the south, with granitic masses in the axial zone, and a NNE-SSW trending synclinorium on the northern coast of Wahlenbergfjorden, the axis of which is located in the southern part of Eltonbreen (Sandford 1963, Flood et al. 1969).

The western side of the anticlinorium is cut by faults in the upper Rijpdalen area and intruded by granitic masses in the south and the north. The youngest two formations of the Murchisonfjorden Supergroup occur in the sunclinal trough, while rocks younger than the upper Celsiusberget Group occur in the western limb of the synclinorium as far as Idunfjellet where they are covered unconformably by Carboniferous beds and Mesozoic dolerite. Rocks from the Roaldtoppen Group to the upper Austfonna Group occur in the eastern limb as far as Bråna, showing some repetitions by subordinate folds with NNE-SSW axial trends. These rocks extend northwards along the eastern side of Vestfonna to the west coast of Rijpfjorden and to the Sabinebukta area.

The eastern flank of the major anticlinorium includes some subordinate synclines along the western side of Austfonna: the Venesjøen syncline, the Kvartsitthaugen syncline, and the Innvikhøgda syncline. The axial trends of these synclines are different south (NNE-SSW) and north (NNW-SSE) of the fault zone (NNW-SSE) from Kvitrevdalen to Djevleflota. These subordinate folds are clearly illustrated by the distribution patterns of quartzite-rich formations of lower groups of the Murchisonfjorden Supergroup. Incompetent beds are often squeezed out in the fold limbs and the complete successions are only observed in the axial zones, although they are tectonically thickened. The thicknesses of the formations from the present area quoted in Table 1, are mostly from the axial parts. These figures may thus be somewhat greater than the primary thicknesses.

The rocks of the Botniahalvøya Supergroup (revised name, see next chapter) occur along the eastern side of granitic masses, along the eastern side of the major anticlinorium. Cleavages are very strong in these rocks, being roughly conformable to the borders of the granitic masses, and often make it difficult to establish the fold structures of the metasedimentary rocks.

Judging from the gentle eastward dips of gneissosities in the granitic and migmatitic rocks west and north of the metasediments area, and in the augen gneiss along Fonndalen in the east, the metasediments to the north of Stegdalen are sandwiched between the granitic and migmatitic rocks as a large wedge and have suffered stronger migmatization and metamorphism than those in the southern part. This structural interpretation is supported by the magnetic study by Åm (1975) who suggested a sheet-like structure for the granitic and migmatitic rocks.

TABLE 1 - Hecla Hoek meta-sediments in Nordaustlandet
(The Murchisonfjorden area is after Flood et al. 1969 and Ohta 1982b)

Sup. gr.	Group	Formation	Murchi-sonfj.	W side: Wahlen-bg.fj.	W side: UpRijp-dalen	W side: Bakke-knaus.	E side: Venesj.	E side: Kvartst-haugen	E side: Flöttesj.	E side: Innvikh-øgda
(L-Paleoz.)		K.Sparre	1100	+50						
(Eocamb.)		Sveanor	330	175						
Murchisonfjorden	Roald toppen	Ryssø	750	+400						
		Hunnberg	500							
	Celsius berget	Raudstup -Sälodd	550	800						
		Norvik	340							
		Flora	1250	850						
	Franklin sundet	K.Lord	1000	850			390		600	+516
		Westman-bukta	625			+400	687	+120	360	510
		Persbergt	+150	300	420	500	353	440	310	280
	Meyerbukta and Austfonna	Innvik-høgda	+400	465	250	250	+250	320	420	320
		Djevle-flöta	+800	900	+500	+400	1200		980	650
		Basal Qtz.					+50		100	110
Botniahalvø.	Kapp Hansteen		c2000					extrusives: 200 300 intrusives: c.2000		
	Brennevinsfjorden		+3000	c 3000						

General stratigraphy

The lithostratigraphy of the Hecla Hoek rocks of Nordaustlandet, especially the Murchisonfjorden Supergroup, was established by Kulling (1934) and was supplemented by Flood et al. (1969). Some modifications have recently been made by Ohta (1982 a and b).

Table 1 shows the general stratigraphy with these recent modifications. The Meyerbukta Formation was established on Lågøya, northwest of Nordaustlandet (Ohta 1982b). An upper shaly division and a middle calc-argillaceous division were distinguished. This formation can be correlated with the Austfonna Formation of the present area (Flood et al. 1969) where a basal quartzite, middle areno-argillaceous succession and an upper argillaceous succession with some limestone and basic rock layers have been distinguished. These three divisions have been designated as formations and their total thickness, more than 1.5 km, is comparable to that of other groups within the Murchisonfjorden Supergroup. The lithologies of the Austfonna Formation show a mega-cycle similar to those revealed by the Franklinsundet and Celsiusberget Groups. For these reasons, the Meyerbukta/Austfonna Formation has been defined as a group and is included in the Murchisonfjorden Supergroup.

The Kapp Hansteen Formation of Botniahalvøya is composed of several lithological units: a basal conglomerate, a porphyrite with well developed columnar joints, stratified tuff and tuff-breccia, agglomerates and massive porphyrites (Ohta 1982a). They have not yet been mapped comprehensively over the entire peninsula, but each can be defined as a formation. Accordingly, the Kapp Hansteen Formation must be a group, and the Botniahalvøya Group then becomes a supergroup. The total thickness, more than 5 km, is comparable with the Murchisonfjorden Supergroup in the region.

Description of lithostratigraphy

I. THE LOWER PALAEOZOIC AND EOCAMBRIAN FORMATIONS

The Cambro-Ordovician Kapp Sparre Formation and the Eocambrian Sveanor Formation occur along the northern coast of Wahlenbergfjorden, to the east of Aldousbreen (Fig. 1, lower right map). The lower part of the Kapp Sparre Formation here is only 50 m thick and the upper part is missing. The Sveanor Formation is composed of six thick tillite units of subglacial origin, thin mudstones of subaqueous origin and deposits of wind-blown loess (Edwards 1976). Its thickness here is less than in the Murchisonfjorden area, and the proportion of tillites to mudstones is greater.

II. THE MURCHISONFJORDEN SUPERGROUP

II.A. Successions younger than the Franklinsundet Group.

The upper formation of the Roaldtoppen Group is missing and the distinctive stromatolites of the group are not so well developed as in the Murchisonfjorden area. The Celsiusberget Group is not as thick here as it is in the Murchisonfjorden area, mainly due to the small thickness of the Flora quartzite Formation. These successions occur on the northern coast of Wahlenbergfjorden . The constituent rocks are very similar in both areas.

A red shale succession occurs under the Middle Carboniferous on the southern coast of Wahlenbergfjorden (Lauritzen 1981) and this can be correlated with the Raudstup-Sälodd Formation of the Celsiusberget Group.

II.B. Franklinsundet Group (Fig. 2)

A thick quartzite succession within the Persberget Formation clearly separates this group from the underlying succession.

II.B.1. Westmanbukta and Kapp Lord Formations. - These two formations are difficult to separate in the present area, except in the north-eastern part. An argillite-dominated succession occurring above the Persberget quartzite is therefore designated to both formations without attempting to subdivide further.

West of Bråna, the lower part of the succession contains many beds of quartzite, less than five metres in thickness. The dominating shale beds have black, chocolate, purple, and greenish colours. Sandstone and quartzite beds are also interbedded in the middle part and have a dolomitic matrix. The upper part is black slate.

The lower part occurs in Bakkeknausen on the west side of innermost Rijpfjorden. The rocks are graded black shales and the transition to the underlying quartzite is very sharp.

Equivalent successions occur in three areas in the east along the edge of Austfonna. The rocks are unmetamorphosed in the two southern localities, while they are recrystallized into crystalline schists in the northern locality. The rocks of this succession occupy the cores of two synclines in the Venesjøen and Kvartsitthaugen areas and include characteristic chocolate and green coloured shales. A thick laminated succession (500 m) of black shale-sandstone occurs in the Venesjøen syncline below the chocolate shale. The contact to the underlying quartzite is very sharp in both synclines.

In the northern locality from east of Flottesjøen to Innvikhøgda, the pelitic rocks of these formations have been metamorphosed into garnet-two-mica schists and the grade of metamorphism and degree of recrystallization increase eastwards. A thin marble bed occurs in the schists east of Flotte-

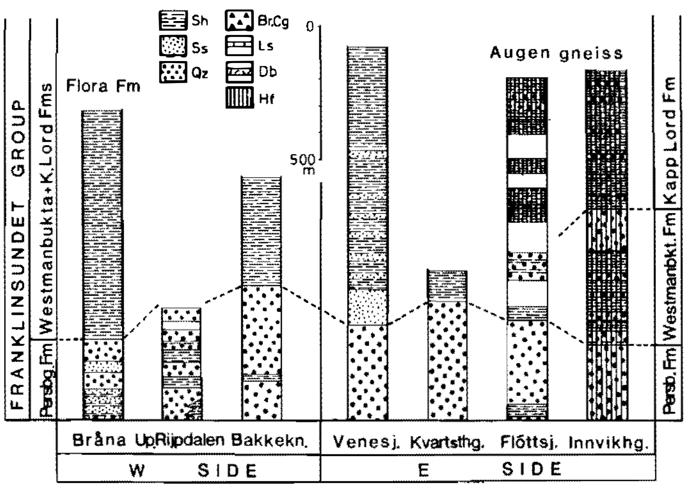

Fig. 2.
Lithological sections in the Franklinsundet Group.

sjøen and Innvikhøgda and a schistose amphibolite layer a few metres thick is associated with the marble at the latter locality.

The lower 310 m to the east of Flottesjøen and 510 m in the Innvikhøgda section contain some quartzite beds which have been recrystallized into two-mica quartz schist. These parts of the succession can be correlated with the Westmanbukta Formation, and distinguished from the overlying pelitic schists-rich parts of the Kapp Lord Formation.

II.B.2. Persberget Formation. - A breccia bed occurs at the base of this formation in the western limb of the anticline along Vestfonna. Just southwest of upper Rijpdalen this bed contains angular blocks of quartzite, banded dark sandstone-shale, and dolomite rocks in brown dolomitic and grey quartzitic sandstone matrices. The maximum fragment size of breccias is up to 20 cm, and many fragments are flattened. Equivalent beds west of Bråna have small white quartzite fragments, 3 cm or less in size, and a grey quartzite sandstone matrix which often shows faint graded bedding of dm thickness. A similar breccia bed has been reported from the eastern part of Oxfordhalvøya (Sandford 1926). Breccia or conglomerate beds were not observed at the base of the quartzite in the Bakkeknausen area. However, from its northern extension to the northwest of Thank God Bay, Flood et al. (1969) describes a quartzite overlying the Austfonna Formation (their term) and separated from it by an unconformity with a conglomerate. The pebbles are mostly angular (T.S. Winsnes pers. comm.). No basal conglomerate or breccia bed has been seen in the eastern localities along Austfonna.

This formation consists almost entirely of a single quartzite layer 350-500 m thick in the northwestern and eastern localities. In the southwestern localities it contains some shaly and sandy beds. The thickness of the formation increases northwards in the western localities.

The quartzites are white and grey and sometimes pink, and often show wedge-shaped cross laminae and ripple marks. The rocks are well sorted

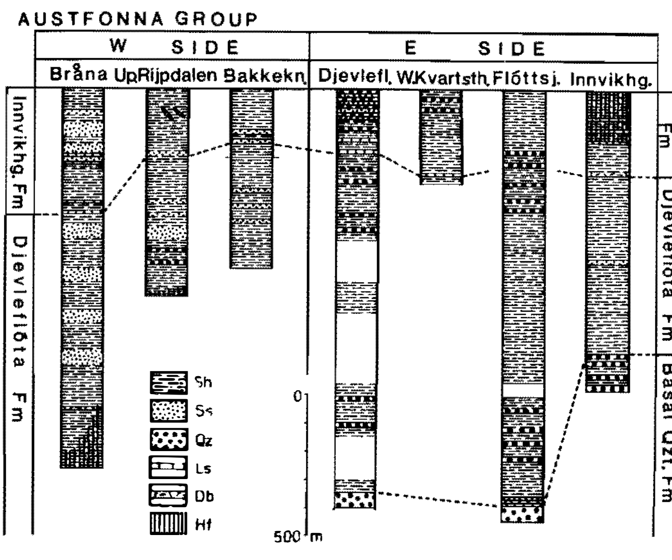

Fig. 3.
Lithological sections in the Austfonna Group.

orthoquartzite, some have up to 30 per cent feldspar grains which are now totally converted into sericite aggregates. Weak banding less than two metres thick, is often observed, and pink coloured rock becomes more frequent in the lower part of the succession. The quartzites are recrystallized into muscovite-quartz schists in the Innvikhøgda area near the contacts to migmatitic rocks to the north and augen gneiss to the east.

The intercalated shales and sandstones show graded bedding, all are dark coloured to the west of Bråna, while southwest of upper Rijpdalen the upper beds are chocolate coloured.

II.C. Austfonna Group (Fig. 3)

This is a thick areno-argillaceous succession below the Persberget quartzite and is distinguished from the underlying succession by the lack of volcanogenic rocks. The group is composed of three formations: the Basal Quartzite (40-110 m), a middle areno-argillaceous succession of the Djevleflota Formation (max. = 1,300 m), and an upper argillaceous succession (max. = 465 m) with some limestone and basic rock, the Innvikhøgda Formation.

Along its western side, this group outcrops as a broad zone from Bråna to Bakkeknausen. Its eastern side is cut by the Winsnesbreen granite in the south and by a fault along the western side of the Raudhøgda granite in the north, where the lower part of the group is absent.

This group has a 1,370 m thick sandstone-shale succession in the Bråna area. This thickness is based on the simplest structural assumption of monoclinal structure, so it may include some repetitions. The upper 460 m belong to the Innvikhøgda Formation and comprises four thin lenses of limestone and a shale bed containing Mn-Fe oxide concretions with reniform surfaces. The uppermost 80 m are red coloured shale. The thick succession to the east is the Djevleflota Formation, and the lowest few hundreds of metres are pelitic hornfels with a few intercalated calcareous beds, which had suffered contact metamorphism during the Winsnesbreen granite intrusion to the east. The middle part is mainly shale and sandstone, with some black slate, showing graded bedding units a few cm thick.

In the upper Rijpdalen area this group is composed of graded beds of slate, shale and sandstone. About 100 m of the lower part is hornfels. A fault separates the hornfels from slate (with some thin quartzite beds) to the west. The upper part comprises grey and black slates, and the Innvikhøgda Formation could not be distinguished.

In the northern half of Bakkeknausen this group has a dark green shale at the top and shale-sandstone in the middle. Together these constitute about 250 m, and are considered to represent the Innvikhøgda Formation. The lower black slate here, and a thick laminated sandstone-shale succession in the southern half, belong to the Djevleflota Formation.

This group occurs widely along the edge of Austfonna, in Djevleflota and Innvikhøgda, but is pinched out in the northeast and has a fault contact to the granite in the south. The thickness of the group changes considerably from the crests to the limbs of the folds.

West of the Venesjøen syncline, a 250 m thick representative of the Innvikhøgda Formation occurs below the Persberget quartzite. It is composed of an alternation of sandstone and quartzite beds, the latter with dolomitic cement, two brown dolomites and some white quartzite. This formation consists of a shale-sandstone succession with many thin quartzite beds in the anticline crest to the northeast of the Venesjøen syncline. A grey limestone lens, 30 m thick and 200 m long, occurs to the west of the Kvartsitthaugen syncline. The approximately 300 m thick shale succession above this lens belongs to the Innvikhøgda Formation.

This formation is not clearly defined between Kjedevatna and Flottesjøen since the area constitutes a thinned fold limb with longitudinal faults. However, it is then found as a 320 m thick succession in the fold crest at Innvikhøgda. The rocks are metamorphosed into schists and phyllites near migmatitic rocks to the east and north. Two thin, banded marble beds occur in the middle. They show very strong intra-bed folds and are partly split into boudins. A schistose amphibolite 5 m thick occurs about 100 m below the marbles. The rock retains a faint doleritic texture.

The Djevleflota Formation outcrops on the flat area of Djevleflota, and consists mainly of shale and sandstone with some quartzite beds. The thickness is 1,250 m, possibly including tectonic thickening. A grey limestone lens less than 10 m thick occurs along the middle stretch of Kvitrevdalen, and has a strange NW-SE strike in shales having NE-SW striking cleavages. This formation is 980 m and 650 m thick in the Flottesjøen and Innvikhøgda areas, respectively, and the rocks have been metamorphosed in the northeast. The pelitic sediments have been converted into garnet-biotite schists and black phyllite, the grade of metamorphism decreasing towards the west and south.

The Basal Quartzite Formation forms a synclinal trough south of Svartrabbane and outcrops along Kjedevatna, via Flottesjøen to Innvikhøgda. The thickness is 40-50 m in the south and 110 m in the north and comprises several quartzite beds and shales in the latter localities. West of Flottesjøen, a 5 m thick brown dolomite and a 30 m thick calcareous sandstone occur above the quartzite succession, and a green phyllitic agglomerate bed occurs between the calcareous beds. The upper part of the quartzite has a somewhat calcareous cement.

III. THE BOTNIAHALVØYA SUPERGROUP

III.A. Kapp Hansteen Group

A succession including a large volume of volcanogenic rocks in the central and southern parts of the map area (Fig. 1) was identified in 1965 and correlated with the Kapp Hansteen Formation of the Botniahalvøya Group (terms after Flood et al. 1969). The volcanogenic rocks have now been mapped in their full extent from Flysjøen in the south to Svartauga in the north.

There are both basic and acidic volcanogenic rocks. Strong cleavages have developed in thin layers and at the margins of large masses, and have obliterated the primary relationship to the surrounding sediments.

Two large masses of basic rocks occur along the east of Flaumdalen and Svartrabbane. The rocks are mainly fine-grained diabase together with a subordinate amount of dioritic rock. The latter occasionally includes blocks of the former as cognate breccias. Small amounts of andesitic rock and medium-grained hornblende gabbro are locally associated with the diabase. The central parts of large masses are relatively massive. The rocks have lost their primary igneous textures and have suffered a low grade metamorphism. Thin intercalations of clastic sediments are often observed in the Flaumdalen mass.

A thin limestone lens, which is in contact with the schistose diabase at the northeastern margin of the Svartrabbane mass, is tightly folded and has suffered thermal metamorphism to form epidote. Small fragments of calcareous shale are included in the diabase as shadow-like xenoliths.

A conglomerate was reported from the southwestern part of the Flaumdalen mass (Flood et al. 1969), but is actually a diabase incorporating large numbers of xenoliths of weakly digested sedimentary rocks. The shale and sandstone to the north of the diabase are silicified.

Basic rocks occur only in very small amounts in the area north of Svartrabbane, but some layers and sheets less than 10 m thick occur roughly concordant with the cleavages of the metasediments. Thin diabasic layers between Svartrabbane and Stegdalen are evidently intrusive, cutting the folded metasediments which have in consequence been hardened by silification. This could also be the case for thin diabases in the area between Beistfaret and Svartauga, though these are apparently concordant with metasediments and have schistose margins.

The contact phenomena described above indicate an intrusive placement of the diabasic rocks, but there is also some evidence indicating extrusion. A lense of conglomerate, about 50 m thick, containing shale boulders and pebbles of round and subangular form, occurs at the lower side of the diabase along Kjedevatna. An agglomerate structure was clearly observed near the eastern margin (upper part) of the Flaumdalen diabase mass.

The acidic rock is a rhyolite, having a grey dense matrix with scattered quartz phenocrysts. The largest occurrence is along the western side of Flaumdalen. One exposure illustrates that this rock intruded along the joint planes of the surrounding metasediments. This rock often occurs as thin layers, sometimes piled up to form a thick succession, and is mostly converted into grey phyllite with clayish and silky luster. The original texture has been totally destroyed, except for some corroded quartz phenocrysts. The surrounding metasediments are mainly graded shale and sandstone with subordinate slate. The phyllitic rhyolite also occurs within the diabase masses as thin layers. Some such layers traverse the Svartrabbane diabase mass along sheared zones with NE-SW strike. This gives the impression that the rhyolite is younger than the diabasic rocks, but the primary relationship has been completely lost.

The phyllitic rhyolite also occurs as a few thin layers in the metasediments between the Beistkollen granite and Flottesjøen.

The thickness of volcanogenic rocks, including both basic and acidic rocks, is about 2 km in the Flaumdalen area and 1-2 km in the Svartrabbane area.

III.B. The Brennevinsfjorden Formation

A thick monotonous shale-sandstone succession occurs to the west of the volcanogenic succession (Fig. 1) and is correlated with the Brennevinsfjorden Formation of Botniahalvøya (Flood et al. 1969). Small scale sedimentary structures are often observed, but they are mostly obliterated by strong cleavages and are of no help for mapping fold structures. The width of outcrops is up to 4.5 km in the area south of the Raudhøgda granite, from Stegdalen to Kjedevatna and along Beistfaret. Considering moderate dips (about 50°) to the east, the thickness is calculated to be about 3 km, possibly including some structural repetitions.

An isolated exposure to the east of Flysjøen was marked as syntectonic granite on the geological map of Flood et al. (1969), but is composed of black slate of the Brennevinsfjorden Formation intruded by diabase sheets of the Kapp Hansteen Group. The moraines around this exposure consist entirely of fossiliferous Carboniferous rocks, indicating that Upper Palaeozoic rocks occur beneath the Austfonna ice sheet to the east.

The rocks of this formation are mainly graded shales, fine-grained sandstone, and some gritty beds. Locally, black slate dominates in a one kilometre wide area to the north of Svartrabbane and in upper Rijpdalen. A few impure limestone lenses occur in the higher part of the succession north of Svartrabbane. A local conglomerate lens less than five metres thick with dolomite pebbles, occurs southwest of Svartrabbane. The upper part of the formation is intruded by the Kapp Hansteen igneous rocks in the areas of Svartrabbane and Flaumdalen. These rocks display chlorite zone regional metamorphism.

A distinct hornfels zone a few hundreds of metres wide occurs along the contacts with the granite and migmatite complex, and will be described in a later chapter. Many angular and sub-angular blocks of the metasediments are included in the granite and gneissic rocks near the contacts.

IV. STRATIGRAPHICAL DISCUSSION

Some modifications of the formation and group names are proposed in the former chapter, based on lithological subdivisions and comparison of their thicknesses (Table 1).

IV.A. The Murchisonfjorden Supergroup

The present area is located about 40-50 km east of the Murchisonfjorden area where the type succession of the supergroup was established (Fig. 1, inserted map).

Rough estimates suggest that the formations of the upper groups are thinner here than in the type localities of the Murchisonfjorden area (Table 1), except for the Persberget Formation which is nearly twice as thick in the present area.

The Celsiusberget and the Franklinsundet Groups consist of respectively 1.5 and 2.0 km thick mega-cycles, starting with a transgressive thick orthoquartzite and ending with calcareous shales of regressive origin. The Austfonna Group, a 1.3 to 1.5 km thick succession correlated with the Meyerbukta Group, represents another mega-cycle of similar lithological nature.

These three mega-cycles are correlatable over large areas from eastern Ny Friesland, through the Murchisonfjorden area, to central Nordaustlandet (Ohta 1982b). This means that these areas were under the same tectonic regime of gentle rhythmic crustal undulation during the Middle Hecla Hoek period.

An unconformity has been inferred by Flood et al. (1969) at the base of the Persberget Formation in the western localities of the present area. This break could not be confirmed in the eastern localities. The Austfonna Group shows a conformable fold pattern with the Persberget quartzite in the eastern part of this area. The breccia-conglomerate at the base of the Persberget Formation can be considered as marking the beginning of the new transgression of the second mega-cycle. No conglomerate or breccia bed has been seen at the base of the Persberget Formation in the Murchisonfjorden area. This means that the second mega-cycle started with a stronger event in the present area than in the Murchisonfjorden area, producing a thicker orthoquartzitic succession.

The relation between the Austfonna Group and the Kapp Hansteen Group is not clear due to strong cleavages. West of Flottesjøen, a few layers of diabase from the north terminate abruptly against the Basal Quartzite Formation of the Austfonna Group. About one kilometre farther south, the quartzite is underlain by a shale in the east, but by a diabase in the west for a distance of two kilometres. These observations suggest an unconformity at the base of the Austfonna Group. The lack of extrusive rocks of the Kapp Hansteen Group in the area north of Stegdalen can be cited as further evidence in support of this unconformity. More detailed surveys along the base of the Austfonna Group are necessary before this can be confirmed.

IV.B. The Botniahalvøya Supergroup

The Kapp Hansteen Formation (former term) was defined as a volcanogenic succession on Botniahalvøya (Kulling 1934, Flood et al. 1969). In the present area, the majority of the volcanic rocks have intrusive relations to the surrounding metasediments, although the upper part includes extrusive rocks. The larger masses of volcanogenic rocks show folded structures roughly conformable with the overlying metasediments. The name Kapp Hansteen Group will stratigraphically be restricted to the upper part, i.e., that containing extrusive volcanic rocks. The total thickness of volcanogenic rocks is up to two kilometres though the extrusive Kapp Hansteen Group has a thickness of a few hundred metres in the Flaumdalen and the Kjededalen areas, while it is difficult to evaluate in the Svartrabbane area. Extrusive rocks are apparently lacking in the northern part of the map area.

The Kapp Hansteen Group of Botniahalvøya consists mainly of extrusive intermediate, and subordinate acidic rocks, while the present area has mainly basic intrusive rocks with smaller amounts of acidic rocks. These rocks occur as local, but thick, piles in the south and central parts of the map area. Their maximum thickness of two kilometres is comparable to that found in the Botniahalvøya area (Table 1).

The rocks intruded by the Kapp Hansteen igneous rocks are a monotonous shale-sandstone succession similar to those of the underlying Brennevinsfjorden Formation. An unconformity was discovered at the base of the Kapp Hansteen Group on southern Botniahalvøya (Ohta 1982a). However, such a relationship is difficult to observe in the present area, because the dyke/sheet-swarm of diabasic rocks intruded around the boundary has obliterated the primary relations.

Contact relationships to the granite and migmatites

The granitic and migmatitic rocks occur in the northern and southern parts of the map area. The post-tectonic granite around Rijpfjorden has been named the Rijpfjorden granite by Hjelle (1969), and includes the granites around Flysjøen in the south. These rocks are here divided into several structural units (Fig. 1):

Ahlmannfonna-Innvikhøgda migmatite complex
Mefjordheia granite } Rijpfjorden granite
Beistkollen granite } Rijpfjorden granite
Raudhøgda granite } Rijpfjorden granite
Winsnesbreen granite } Rijpfjorden granite
Flysjøen granite } Rijpfjorden granite
Fonndalen augen gneiss

The lithology of the granitic rocks was already given by Hjelle (1969) and the modal compositions show that the rocks from all units of the Rijpfjorden granite are two-mica granites with local variations to alkali-feldspar granite and granodiorite, according to the classification of Streckeisen (1967).

The contact relationships between the granitic and migmatitic rocks and the Hecla Hoek metasediments will be presented here, mainly based on field observations. The Mefjorden granite lies outside the map area and is not included.

I. THE AHLMANNFONNA - INNVIKHØGDA MIGMATITE COMPLEX

This complex forms the northern boundary of the metasediment area and is a mixture of gneisses, granites, and granitic migmatites. More descriptions on these rocks have been given by Hjelle et al. (1978) and Hjelle (1978). On the eastern side around Innvikhøgda, a grey homogeneous granite intrudes the metasediments, the contact often following joints in the latter. The metasediments have been metamorphosed to garnet-biotite hornfels for a few tens of metres from the contact, and large andalusite idioblasts are occasionally present. To the east the areno-argillaceous metasediments are rapidly digested in the migmatites, while quartzite persists for some kilometres as xenolithic quartz schists with two micas.

From south of Ringgåsvatnet to south of Ahlmannfonna a zone of homogeneous porphyritic gneiss, a few kilometres wide and of quartz diorite composition, occurs along the contact. This gneiss contains angular blocks of metasediments, which are silicified and converted into hornfels. Along the contact in a zone less than 10 m wide there is a spotted hornfels with idioblastic andalusite and poikiloblastic staurolite. Then, outwards for about 100 m, there is a garnet-biotite hornfels zone, followed by a biotite-muscovite assemblage, which can be traced in pelitic rocks for a few hundreds of metres. A zone of distinct kink folds occurs around the boundary between the biotite-muscovite hornfels and the chlorite-sericite rocks which occur farther off from the contact.

In the southern part near Beistfaret the gneiss has interfingered with the metasedimentations to form local feldspar porphyroblastic textures in the latter. Some detailed local descriptions of the contact have been given in Flood et al. (1969).

II. THE BEISTKOLLEN GRANITE

This is a coarse-grained, pink granite mass, the northern and southern boundaries of which are faults. A zone of agmatitic migmatite occurs in the western part of the granite near the Rijpfjorden coast, and the palaeozomes are sillimanite-garnet-biotite gneiss and siliceous banded gneiss. Idiomorphic feldspar shows strong porphyroblastic texture.

A thick porphyritic gneiss, which is similar to that south of Ahlmannfonna, occurs along the eastern margin of the granite forming a layer overlying the granite. A pink granite window occurs around Stegfossane under the gneiss.

The metasediments in contact with the gneiss have been converted into biotite hornfels in a zone up to 250 m wide. A black slate is in contact with the gneiss on a sheared boundary in the area between Stegdalen and Kvitrevdalen, and the slaty cleavages are parallel to this contact. The gneiss contains small angular blocks of metasediments as silicified dark inclusions.

III. THE RAUDHØGDA GRANITE

Lithologically, this granite is similar to the Beistkollen granite, although it contains less supracrustal inclusions. A porphyritic gneiss occurs along the east to southeast margins, but is lacking along the southern border.

The contact between the porphyritic gneiss and the diabasic rocks of Svartrabbane is essentially a fault, but some interfingering is observed locally. Some sheet-like diabase masses occur in the gneiss, having hornfelsic margins. Small angular blocks of pelitic hornfels are also found within the gneiss.

Along the southeastern margin on the west side of Kvitrevdalen, a narrow zone of porphyritic gneiss is in contact with a black slate and a relatively massive diabase. The slate carries garnet for several metres from the contact in some parts, while the rest of the contact is tectonic.

In the south, around the middle stream of Rijpdalen a pink massive granite is in contact with the slate and an andalusite-biotite hornfels zone occurs about 50-80 m in width. The western border of the granite is a fault.

IV. THE WINSNESBREEN GRANITE

This is a wedge-shaped, muscovite-rich, two-mica granite, extending northwards from Winsnesbreen in the southern part of the map area (Fig. 1). The eastern border is a well defined fault, and two small satellite masses occur to the east and north. Some dykes of muscovite granite, potash feldspar-muscovite pegmatite and aplite occur to the north of the main mass.

A 200-300 m wide hornfels zone is developed along the western margin of the main mass and on the northern side of the eastern satellite body. The hornfelses have andalusite poikiloblasts, granular staurolite, poikiloblastic garnet and unoriented flakes of biotite, and are cut by muscovite-albite-quartz veins. Some calcareous beds have been recrystallized into garnet-actinolite-biotite hornfels. A zone of rock with distinct kink folds occurs to the west of the hornfels zone. It is a few hundred metres wide and is associated with some gossan zones. The hornfels zone is either narrow or totally lacking along the southwestern margin of the main granite mass. Narrow biotite hornfels zones are developed along the southern side of the eastern mass and along the southern border of the northern satellite body.

V. THE FLYSJØEN GRANITE

This is a potash feldspar porphyritic gneissose granite, including small hornfelsic xenoliths. A local porphyritic gneiss facies may represent a sheared part of the granite. This granite shows stronger gneissic structure and more heterogeneity than the other Rijpfjorden granite and has similar lithology to a porphyroblastic granite in the Ahlmannfonna-Innvikhøgda migmatite complex, but the present setting is tectonic.

The northern boundaries on both sides of Flysjøen are shear zones, in which both the granite and metasediments were crushed and no hornfels has been seen. The western boundary to diabasic rocks is also sharp, but is thought to be an intrusive contact.

VI. THE FONNDALEN AUGEN GNEISS

A more than one kilometre wide zone of augen gneiss occurs along the northwestern margin of the Austfonna ice sheet and was described as foliated quartz monzonite by Flood et al. (1969). This is a very coarse-grained, muscovite-biotite gneiss, having granite composition and large feldspar augen, and it resembles a porphyroblastic facies of the granitic migmatite widely distributed to the north of Austfonna (Hjelle et al. 1978).

The contact to the pelitic and quartzitic metasediments to the west is relatively sharp, though small scale interfingering of porphyroblastic layers into the metasediments is often observed. The metasedimentary rocks at the contact are mainly garnet-biotite schists and muscovite-quartz schist. Staurolite poikiloblasts occur in some strongly pelitic schists. The metamorphic grade decreases rapidly to the west, the garnet isograd is about 1.5 km, and the biotite isograd is at about 2 km, from the contact. The pelitic schists have stronger schistosity than the hornfelses occurring along the southern margin of the Ahlmannfonna-Innvikhøgda migmatite complex, but their matrices show hornfelsic texture in less schistose parts.

Small bodies of amphibolite occur in the area of the biotite isograd, the hornblende has been fragmented and converted into actinolite around the grain margins, while primary doleritic texture can still be recognized in some places. No calc-silicate mineral was formed in the small marble lenses in the biotite zone.

All these schists belong stratigraphically to the upper part of the Austfonna Group and the Franklinsundet Group. The width of contact metamorphism is about ten times greater here than of the hornfels zones around other granite masses. The width of the schist zone decreases southwards to a few hundred metres, to the east of Flottesjøen. This means that the metasediments of the Innvikhøgda area form a large wedge, piercing the migmatites to the northeast. A zone of abundant palaeozome in the migmatites occurs on the northeastern extension of the thick quartzites from Innvikhøgda.

Sandford (1956) inferred a large fault from aerial photographs, separating the supracrustals and basement migmatites around the position of the western border of the augen gneiss. Harland and Wright (1975) placed great emphasis upon it, calling it the North East Fault Zone, and making it one of the major fault zones of Svalbard. However, no evidence to confirm this fault has been found, either in the map area or on its northern extension in the Duvefjorden and eastern Kapp Platen peninsula areas (Flood et al. 1969).

Basic dykes and gossan zones

I. LAMPROPHYRE

This rock has a dark coloured, fine-grained massive matrix and carries large idiomorphic phenocrysts of biotite and plagioclase glomero-phenocrysts. The plagioclase shows corroded texture. This rock cuts both the black slate of the Austfonna Group and the Winsnesbreen granite (Fig. 1). The dykes are 2-5 m thick and 50-100 m long, and aligned en echelon. A narrow hornfels zone less than 50 cm, is developed at the contact to the slate with idioblastic garnet and unoriented biotite flakes. Prehnite aggregates with reniform surfaces occur in veins.

This dyke rock was dated by the K/Ar method by Firsov (in: Krasil'ščikov 1969) to 362-376 Ma, thus it is a late Caledonian intrusion. Similar basic rocks with abundant large biotite flakes occur in the migmatites of northeastern Nordaustlandet and Kvitøya (Hjelle et al. 1978),but they are strongly metamorphosed.

II. DOLERITE DYKES

Three massive diabase dykes, each about 50 m long, occur west of upper Rijpdalen, aligned en echelon. They cut the slate of the Austfonna Group and are roughly parallel to the faults in the area. No thermal influence has been observed at the contact. These dykes are considered to be Mesozoic dolerites similar to those on the west side of Rijpfjorden northwest of Thank God Bay (Flood et al. 1969).

III. GOSSAN ZONES

III.A. Marcasite

A marcasite-quartz vein occurs along a sheared zone in the slate of the Brennevinsfjorden Formation between two relatively large lakes in the upper Rijpdalen area. The sheared zone is the northern extension of the fault bounding the eastern margin of the Winsnesbreen granite in the south. The marcasite-bearing vein was observed at two localities along the zone, 500 m apart. The rock is a quartz-impregnated breccia rock with spherical druses filled by marcasite. Small cubes of pyrite are also seen under the microscope. Marcasite constitutes about 35-48 per cent of the rock. It seems that this ore is a post-magmatic hydrothermal product relating to the granite in the south, and may follow the whole length of the sheared zone.

Two gossan zones occur just northeast of Bråna, about 1.5 km west of the Winsnesbreen granite, forming a discontinuous sheared zone in the area of strong kink folds outside the hornfels zone. They are also related to the emplacement of the granite and no ore minerals were seen.

III. B. Pyrite and chalcopyrite

East of the northern branch of Flysjøen, narrow gossan zones occur in the slate-diabase complex of the Botniahalvøya Supergroup. The weathered surface shows green copper hydroxide coating, and sulphide grains constitute less than one per cent of the volume. The gossan zones cannot be traced more than 50 m along the strike.

Discussion of the granitic and migmatitic rocks

The granitic rocks have been divided into several structural units and all show sharp intrusive contacts, or locally fault/sheared contacts, and have narrow hornfels zones. The augen gneiss of Fonndalen has a wider metamorphic zone than the others.

Several K/Ar ages have been reported from different parts of the Rijpfjorden granite, ranging from 330 to 380 Ma. (Gayer et al. 1966). A biotite gneiss from east of Wordiebukta gave 430 Ma. The Rb/Sr ages from a biotite schist are 581, 618, and 636 (whole rock, biotite, and muscovite, respectively). The exact locality of this schist is not clear (Hamilton and Sandford 1964), but it must be from the porphyritic gneiss or agmatite palaeozomes in the Beistkollen granite mass. The metasediments to the east of the granite have no biotite or muscovite large enough to separate for dating, even when they occur as xenoliths in the granite. It is likely that these ages represent pre-Cambrian rocks modified by the Caledonian granite. The apparently oldest rocks could contain relics of the metasediments of the Botniahalvøya Supergroup, or even older sediments. The age of the Kapp Hansteen quartz porphyry in Botniahalvøya has been given as 760 Ma. (possibly 970 Ma.) by Gorochev et al. (1977). Therefore, these ages for the schist do not indicate decisively the existence of pre-Cambrian crystalline basement.

Two Rb/Sr isochron ages from the Ahlmannfonna-Innvikhøgda migmatite complex were obtained recently (Ohta et al. in prep.), and both are 350 Ma., coinciding with the majority of the K/Ar ages.

A granite dyke cutting migmatites in Nordre Repøya, 40 km north of the present area (Fig. 1, inserted map) gives a Rb/Sr isochron age of 600 Ma and initial Sr 87/86 ratio of 0.702 (Ohta et al. in prep.). This indicates pre-Cambrian granite activity and the existence of crystalline rocks older than the granite.

Conclusion

The middle and lower successions of the Murchisonfjorden Supergroup of this area form three mega-cycles, each a few kilometres in thickness, similar to those observed in western Nordaustlandet (Ohta 1982b). The cyclic sedimentation of the Middle Hecla Hoek period is now proved to extend for more than 100 km across the structural trend from eastern Ny Friesland to central Nordaustlandet. The lower two cycles have coarser and thicker quartzites at their bases in the present area than in the western areas.

The Kapp Hansteen igneous rocks are mainly intrusive in this area, though small amounts of extrusive rocks have also been distinguished. These rocks can be correlated with the basic and acidic rocks in the middle Lower Hecla Hoek (Lower Planetfjella Group and the Harkerbreen Group of the Stubendorffbreen Supergroup) of Ny Friesland (Harland et al. 1966).

An inferred unconformity at the base of the Persberget Formation (Flood et al. 1969) seems to be of limited significance. However, a disconformity inferred at the base of the Austfonna Group may have regional importance, although this is not yet established with certainty. The unconformity at the base of the Kapp Hansteen Group of Botniahalvøya (Ohta 1982a) may be correlated with this disconformity and the Kapp Hansteen igneous rocks (760/970 Ma.) could be the products of a syntectonic magmatic activity associated with the sub-Murchisonfjorden Supergroup diastrophism.

The granites and migmatites show essentially intrusive contacts to the metasediments, partly modified by faults. The metasediments wedge into plutonic rocks to the northeast. The plutonic rocks produced narrow hornfels zones in the metasediments. A relatively wide metamorphic zone has been developed around the augen gneiss in the northeast, where pelitic schists similar to regional metamorphic rocks were formed in the rocks of the Franklinsundet Group. This is the only area in Svalbard where the Caledonian migmatization reached the lower part of the Middle Hecla Hoek succession.

The base of the metasediments has not been observed. An additional evidence for the existence of pre-Cambrian crystalline basement has been reported from the granite-gneiss clasts of the Sveanor tillite, i.e. 1,275 ±45 Ma. (Edwards and Taylor 1976) from the northern side of Wahlenbergfjorden.

Acknowledgements

I am indebted to Messrs. J.E. Fadnes and A. Ohta for their assistance during the field surveys, and to the geological staff of Norsk Polarinstitutt for supplying the data from their field work.

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