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The pre-basaltic sediments and the Lower Basalts at Kangerdlugssuaq, East Greenland: their stratigraphy, lithology, palaeomagnetism and petrology

T. F. D. Nielsen, N. J. Soper, C. K. Brooks, A. M. Faller, A. C. Higgins and D. W. Matthews

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The pre-basaltic sediments and the Lower Basalts at Kangerdlugssuaq, East Greenland: their stratigraphy, lithology, palaeomagnetism and petrology

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This paper presents a new 1:40 000 topographic and geological map of the area around Miki Fjord and I. C. Jacobsen Fjord, East Greenland. The post-Precambrian sedimentary succession, the Kangerdlugssuaq Group, begins with the Ryberg Formation (Campanian to Danian (?)) and continues into the Vandfaldsdalen Formation of Late Paleocene age. These sediments were laid down in a basin which subsequently became filled and covered by basaltic rocks of the Blosseville Group, including lavas, hyaloclastites, tuffs and breccias. Considerable facies variations are apparent in both the sediments and volcanics indicating that the basin deepened in an easterly direction. Palaeomagnetic measurements confirm previous results for the Blosseville Group on the Lower Basalts but do not yet entirely eliminate the possibility that some of the succession has normal polarity. Petrographically the volcanics include picrites (oceanites and ankaramites), olivine tholeiites, tholeiites and tholeiitic andesites. They have almost all suffered alteration up to greenschist facies and some show evidence of sedimentary contamination. They are all of tholeiitic affinity and are Fe and Ti enriched when compared to normal ocean ridge basalts. They are however much more variable in composition than the overlying Plateau Basalts and have not been produced in such large volumes. It is suggested that a primary picritic magma gave rise to the oceanites and ankaramites by olivine and clinopyroxene fractionation and accumulation. The olivine tholeiites, which appear to be separated from the picrites by a compositional gap, may be derived from a different parental magma. Petrological parallels are drawn with other provinces.

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The work reported in this paper stems largely from an approximately one month stay in the area in the summer of 1977 by a combined party from the universities of Sheffield and Copenhagen. It has been supplemented by observations made both in earlier years and during a short visit to the area in 1979.

Previous work in this part of East Greenland has been largely of a reconnaissance nature (Wager 1947, Soper et al. 1976 a) or has focussed on the igneous intrusions (e.g. Wager & Deer 1939). In the last decade, however, most of the publications from the area have emphasized the relationship between the Tertiary volcanic activity and plate separation in this part of the North Atlantic. It has become increasingly clear that a more detailed knowledge of the geology of the country rocks would increase our understanding of the timing and the magmatic and tectonic processes during the continental break-up. To this end a detailed topographic map was prepared to serve as a basis for the geological mapping.

The chosen area, which covers approximately 240 km^2 and extends from the western side of Miki Fjord to just west of the head of I. C. Jacobsen Fjord, includes the pre-basaltic sediments of the Kangerdlugssuaq Group and the lower part of the basalts of the Blos-

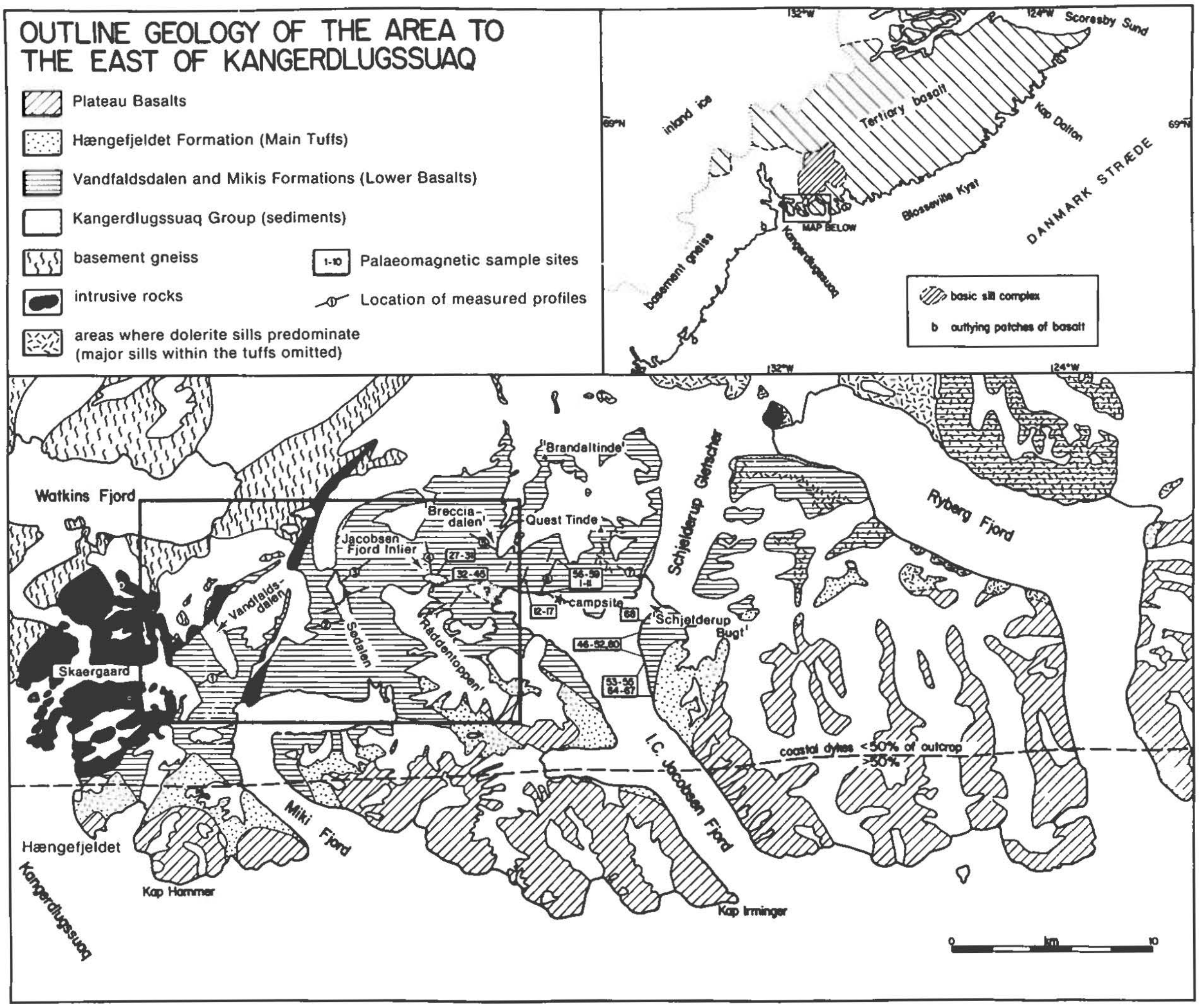


Fig. 1. General geology of the southern part of the Blosseville Kyst showing the area covered by the geological map (Plate 1). Place names in inverted commas as yet not authorized.

seville Group (Fig. 1). The stratigraphy of these formations was originally described by Wager (1934, 1947) and later refined by Soper et al. (1976a) while some palaeomagnetic information was published by Faller (1975). The petrology of the basalts has so far received little attention although a general description of the whole Blosseville Group was presented by Brooks et al. (1976). These authors made the important observation that picritic lavas are present in the lower part of the Blosseville Group although they lacked sufficient data to give any impression of abundances or any coherent picture of the chemical stratigraphy of the lower part of the lava pile. They were however able to indicate significant petrological differences on a broad scale between the earlier and the later lavas. Palaeomagnetic measurements of Tarling (1967), Faller (1975) and Hailwood et al. (1973) suggested that the entire Blosseville Group is reversely magnetized, which has important implications for the rate of lava production. However, large thicknesses of the Blosseville Group remained unsampled and one of the major objectives of the present work was to extend this sampling.

The map resulting from this work and accompanying this report is a continuation of that of the Skaergaard intrusion (McBirney & others, in prep.). Together these cover a classic area which illustrates the geological processes operating during continental break-up, although the present map lies to the N of the locus of most intense dike injection. An outline map of the area from Kangerdlugssuaq to Ryberg Fjord is shown in Fig. 1. Geological formations include sediments, lavas, hyaloclastites and breccias as well as minor intrusions and the Precambrian gneiss. It is with the first four of these that this paper is concerned.

Pre-basaltic sedimentary succession

Approximately 300 metres of pre-basaltic sediment have been recorded on the Blosseville Kyst over a distance of 100 km along the coast and 80 km inland. The sequence is commonly interrupted by sills and dikes and these may be so frequent that the sediments occur as rafts, a few metres in thickness, floating in a sequence of sills. Careful logging of all sections, together with assiduous collecting of trace-, body- and microfossils has led to the construction of a sequence, although contact alteration renders fossil identifications difficult. Fossils occur sparsely throughout the sequence and are still present in the volcanoclastic sediments 1000 m above the base of the volcanic succession. They can be used to determine both the age and the depositional environment of the sediments.

An embayment in the basement gneiss was the site of deposition of the sediments. It was initially small in area during the Lower Cretaceous but expanded to the east, west and north during the Paleocene when the later sediments onlapped and in some instances overstepped the earlier ones to come to rest on the basement gneiss. The sedimentary base is therefore both unconformable and diachronous, and ranges in age from the Lower Cretaceous to late Paleocene or early Eocene. Most of the sequence is marine but the latest sediments, including at least part of the early volcanics, occurring just beneath the plateau basalts, are non-marine, and probably mark the termination of the basin as a site of deposition. The base, although rarely observed, also appears to be irregular and indicates the infilling of an irregular landscape of basement gneiss, although the relief was not so great as that of the pre-basaltic surface around Gåsefjord (Watt & Watt 1971).

Soper et al. (1976a) outlined the sedimentary sequence beginning in the Lower Cretaceous (Albian) with the Sorgenfri Formation, a *c.* 30 m thick succession of black shales with marine fossils which occur in a sedimentary raft. These sediments range upwards into the Upper Cretaceous, Cenomanian, but are not continuous with the overlying sediments of the Ryberg Formation and the relationship between the two formations is therefore unknown. The latter ranges in age from the Campanian? to at least the Danian stages. The absence of the Turonian may be due to lack of exposure rather than unconformity. The Ryberg Formation is characterized by coarser sediments than the Sorgenfri Formation and consists of micaceous shales and thin planar sandstones, the two often alternating, with an influx of coarse feldspathic sandstones on the margins of the basin at the beginning of the Paleocene. These latter may be the first indications of the later, more widespread, uplift which affected the whole of the basin during the late Paleocene. The Montian and Thanetian stages have not been recognised and they may be absent in the margins of the basin where an unconformity occurs beneath the Sparnacian, but in the centre of the basin they may be represented by unfossiliferous sediments.

In late Paleocene (Sparnacian) times sediments represented by the Vandfaldsdalen Formation mark the beginning of a phase of uplift and volcanic activity. Coarse, often conglomeratic, feldspathic sandstones, micaceous shales and siltstones often rich in organic detritus, tuffaceous sediments and basalts signify the

Fig. 2. Sediments below the lavas, exposed in fault scarp at "Canyondal" east of the lake in Sødalen. The profile is *c.* 140 m high and exposes sediments of the Ryberg and Vandfaldsdalen Formations ranging in age from Campanian to uppermost Paleocene.

changes and an unconformity at least on the western margin of the basin is indicative of tectonic activity at this time. At least two marine bands with macrofossils within the Lower Basalts, a horizon with marine dinoflagellates and the development of hyaloclastic flow foot breccias up to 100 m in thickness point to the marine nature of the sediments and the eruption of some of the early lavas into an aquatic environment. A detailed account of the stratigraphy and the environment of deposition is given by Higgins & Soper (1981).

Within the investigated area sediments occur at the base of the volcanic sequence in Vandfaldsdalen to the east of the Skaergaard intrusion, in Sødalen, as a valley inlier in I. C. Jacobsen Fjord and adjacent to the west Schjelderup Gletscher (see Fig. 1). The Sorgenfri Formation is unknown in this area although it may be present at depth in the more easterly outcrops.

Sødalen section

The oldest rocks in the area occur at "Canyondal", Sødalen, (place names in inverted commas as yet not authorized) where the section is as follows (Fig. 2):

Vandfaldsdalen Formation		Metres
(Schjelderup Member – lower part)	Parallel laminated sandstone	2
	Coarse sandstone, conglomeratic at base	8
	Erosional contact	
Ryberg Formation	Siltstone, flaser and lenticular bedded	5
	Calcareous sandstone	3
	Micaceous blue shales with Danian fossils	17
	Thin graded sandstones interbedded with micaceous shales	20
	Black micaceous shales with Campanian fossils	10+

The lower part of Ryberg Formation in this section is principally shales with influxes of thin (up to 30 cm) sand layers which are graded. Dinoflagellates from the shales have been identified by Dr. L. I. Costa as of probable Campanian to Danian age and also indicate that the sediments are marine. Trace fossils are common in the sandstone units and are principally trails such as *Cochlichnus* and also include a possible resting trace. The upper beds are coarser, flaser and lenticular bedded siltstones and a calcareous sandstone bed, in this section somewhat leached, which are probably a shallower water facies. The beds are unfossiliferous.

I. C. Jacobsen Fjord section

Here the sediments crop out as an inlier near the head of the valley. Only the upper part of the Ryberg Formation is exposed compared to the Sødalen section. The sequence is as follows (Fig. 3):

Vandfaldsdalen Formation		Metres
(Schjelderup Member – lower part)	Dark grey medium sandstone with thin (5 cm) shale partings	12
	Coarse feldspathic sandstone, conglomeratic at the base	10
	Erosional contact	
Ryberg Formation	Laminated grey medium sandstone	3
	Interlaminated siltstone and sandstone	10
	Laminated calcareous sandstone	8+

The white calcareous sandstone at the base is less leached than in Sødalen and the internal structures are consequently more apparent. The basal 3 m is a pale grey medium sandstone rich in ironstone concretions up to 30 cm diameter. Small scale cross-lamination is present in units up to 3 cm thick and the bed grades up into finely laminated units at the top. Planolitid burrows are common in the basal 30 cm. The next 5 m consists of cross-laminated beds in 10 cm units with less common ironstone concretions. At 3 m above the base a 10 cm thick lens of bivalves and gastropods occurs: the lack of life orientation of either fossil group points to this being a transported assemblage which accumulated in a hollow. Such lenses are common in loose blocks of the calcareous sandstone in other parts of I. C. Jacobsen Fjord. Thin laminae of black micaceous shale, heavily bioturbated, occur at irregular intervals throughout this upper unit.

The calcareous sandstone passes upwards into interlaminated thin sandstones and siltstones which are

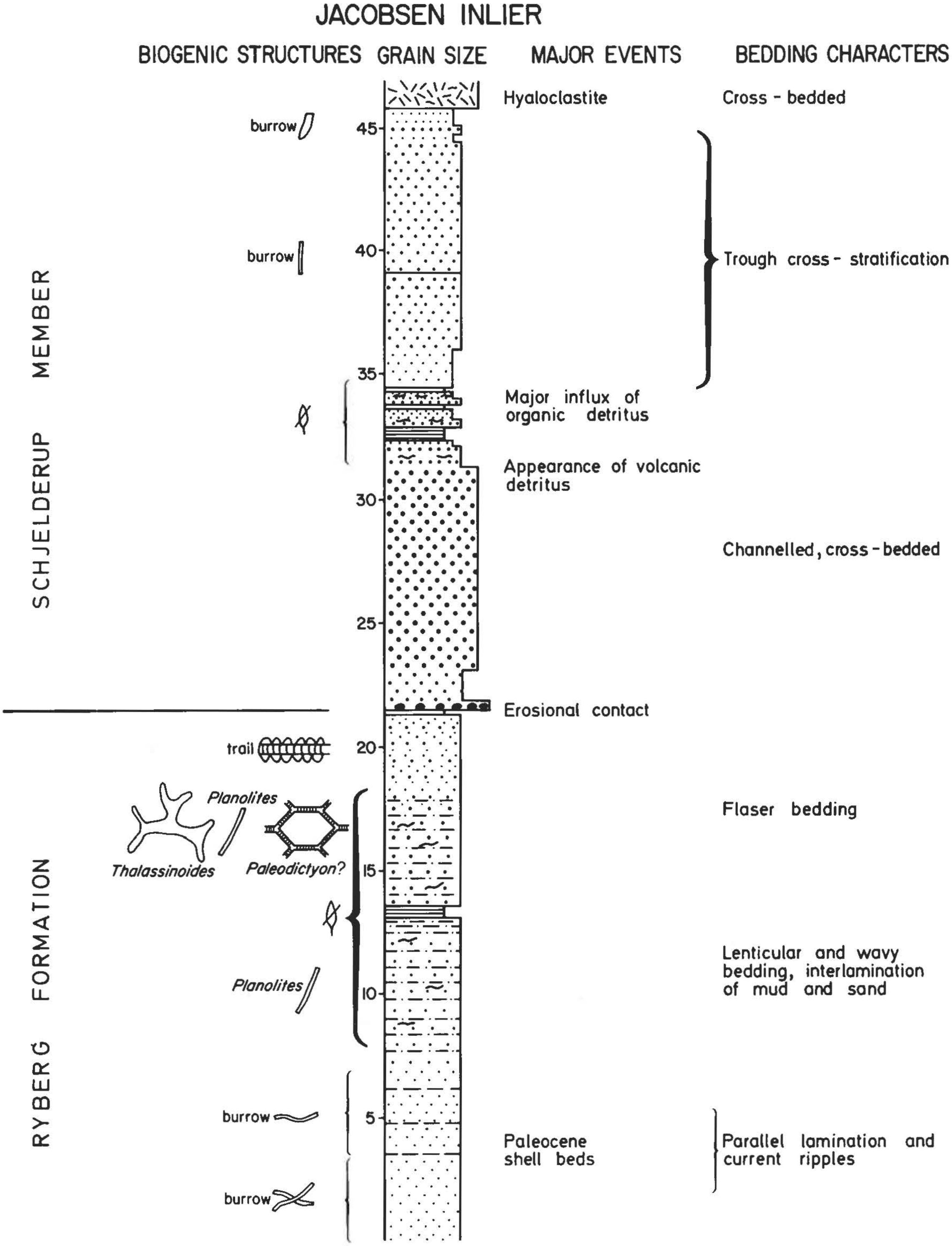


Fig. 3. The Jacobsen inlier section in the pre-basaltic sediments as described in the text.

flaser and lenticular bedded. The more silty and shaly beds are rich in plant detritus and are heavily bioturbated. The trace fossil suite in the sandstones is varied and includes *Thalassinoides*, a large network of burrows which may be referred to *Paleodictyon* and subvertical burrows of a planolitid type. The *Paleodictyon* is larger than most described forms: each hexagon is 26 cm in diameter and individual tubes are 2 cm in diameter. The network consists of regular hexagons in which the tubes are ornamented by coarse ribs 1 cm apart at right angles to the length of the tube. The thalassinoidid and planolitid traces are most common in a sandstone bed near the top of the unit. Where this bed forms the top of the Ryberg Formation, due to the erosion of the highest bed of the formation, the trace fossils are infilled by the coarse feldspathic sandstone of the overlying Schjelderup Member, possibly implying that the highest beds of the Ryberg Formation were lithified before the overlying sediments were deposited, and indicating the presence of a significant break between the two units.

The highest bed of the Ryberg Formation is often absent due to erosion, but when present indicates a return to earlier conditions of deposition, for it consists of 3 m of grey sandstone which is very similar to the earlier calcareous sandstone.

The age of the Ryberg Formation in I. C. Jacobsen Fjord is difficult to determine precisely as the gastropods and bivalves are unidentifiable but correlation of the succession with that of Sødalen suggests that it is early Paleocene.

The Gabbrofjeld and Vandfaldsdalen sections

Two sections of the Ryberg Formation crop out around the Skaergaard intrusion, one to the north at Gabbrofjeld and one to the east in Vandfaldsdalen. At Gabbrofjeld the sediments are baked by their proximity to the intrusion, but the 80 m exposed appear to consist of two units of feldspathic sandstone alternating with planar sandstones and unconformably overlain by 4 m of conglomerate belonging to the overlying Vandfaldsdalen Formation. Foraminifera from near the base of the Ryberg Formation, identified by Dr. C. G. Adams (Soper et al. 1976a), indicate a Paleocene age for the beds. The 80 m thickness and the general coarseness of the sediment contrasts with 25 m at Sødalen and 21 m at the Jacobsen Fjord inlier and the finer grained nature of beds which must be of the same age. In recognition of the differences this part of the Ryberg Formation was named the Feldspathic Sandstone Member by Higgins & Soper (1981). Although relationships are obscured by ice, basement gneiss crops out near the exposed base of the Ryberg Formation at Gabbrofjeld suggesting that little more sediment can be present and that Cretaceous beds may well be absent. This, together with the general coarseness of the sediment, suggests close proximity to the western margin of the basin. No outcrops of the Ryberg Formation are known to the west of this locality.

The section in Vandfaldsdalen was first described by Wager & Deer (1939) and later revised by Wager (1947) and Higgins (*in* Soper et al. 1976a). White, coarse feldspathic sandstones alternate with shales and thin siltstone bands in the Feldspathic Sandstone Member which is 85 m thick. At the top of the formation are 45 m of medium planar sandstones which are overlain by the feldspathic conglomerate at the base of the Vandfaldsdalen Formation. This sequence correlates well with the section at Gabbrofjeld and, as at the latter locality, the basement gneiss is nearby and would not leave room for more than a few metres of additional sediment.

Stratigraphy of the Lower Basalts

Wager (1947) adopted a threefold subdivision of the Blosseville Kyst basalt comprising the Lower Basalts, Main Tuffs and Main Basalts. Soper et al. (1976a) recognised five formations in the Kangerdlugssuaq–Ryberg Fjord region constituting the Blosseville Group. On the basis of more detailed work carried out in 1977 we now retain and formalize the two lower formations Vandfaldsdalen and Mikis, which equate approximately with Wager's Lower Basalts, (a useful informal term) and the Hængefjeldet Formation which equates with Wager's Main Tuffs in the west only.

At Ryberg Fjord, basalts of the Mikis Formation pass eastwards into tuffs, which form the lower part of Wager's Main Tuffs in this area. West of Ryberg Fjord the Main Tuffs directly overlie the Mikis Formation lavas as redefined here. We abandon the Jacobsen Formation, which is included in the redefined Mikis Formation and we use the term the Plateau Basalts for Wager's Main Basalts and the Irminger Formation of Soper et al. (1976b). The lithofacies and internal correlation of the Vandfaldsdalen Formation are shown in Fig. 4.

Vandfaldsdalen Formation

The lowest 550 m or so of the basalt pile are assigned to the Vandfaldsdalen Formation. This commences with a thin, non-volcanic sedimentary sequence termed the Schjelderup Member which at Kangerdlugssuaq rests unconformably upon sediments of the Ryberg Formation and passes, from west to east, up into flows, hyaloclastic breccias and marine tuffs.

Schjelderup Member. – The base of the member is an unconformity in the west, between Skærgården and I. C. Jacobsen Fjord. Elsewhere there is evidence of erosion and non-sequence at this level and, in view of the lack of

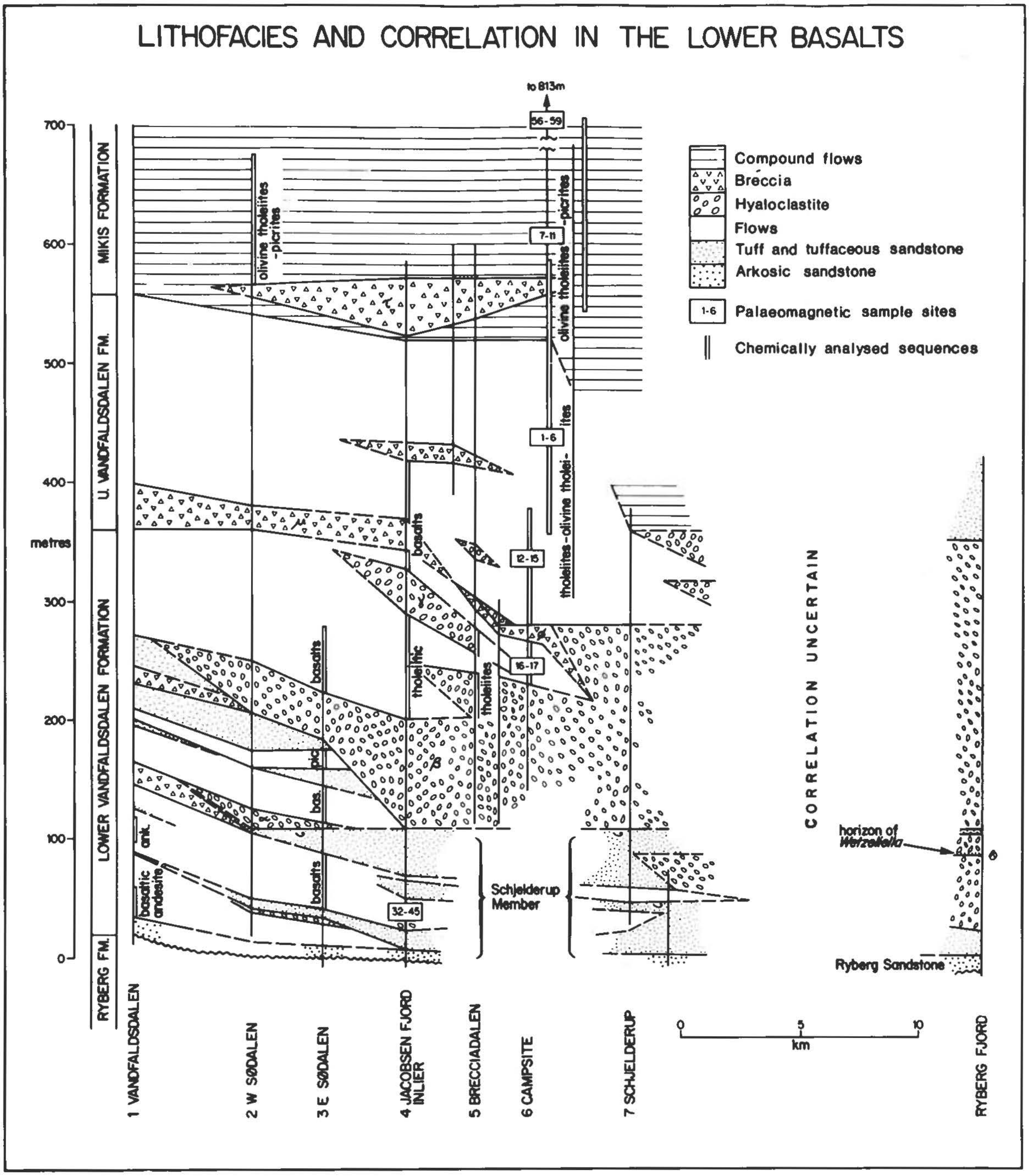


Fig. 4. Lithofacies variation and correlations in the lower part of the Lower Basalts as interpreted from the sections shown in Fig. 1.

proof that the Thanetian Stage is present, the break may be considerable. In the extreme west, around the Skaergaard intrusion, the sequence begins with a conglomerate composed of basement gneiss fragments in an arkosic matrix. This passes eastwards into a finer feldspathic sandstone. In the west, basalts follow immediately above the conglomerate and in Vandfaldsdalen the lowest flow appears to have been erupted before the underlying sediment was lithified. Further east there is an upward passage into progressively darker sediments whose colour is due in part to an influx of organic detritus and in part to the appearance of volcanic debris in increasing abundance. Two faunal horizons about 50 m and 100 m above the base are useful markers and contain marine bivalves. The upper, which is overlain by thick hyaloclastites of the Vandfaldsdalen Formation, is taken to be the top of the Schelderup Member.

The stratigraphy of the entirely volcanic part of the Vandfaldsdalen Formation, above the Schjelderup Member, was described in outline by Soper et al. (1976a, Fig. 4). Sections measured in Sødalen (Fig. 5) and the I. C. Jacobsen Fjord area in 1977 have improved correlation and added much detail. Fig. 4 is a correlation diagram illustrating the internal stratigraphy and facies changes within the Vandfaldsdalen Formation derived from the measured profiles located on Fig. 1. The principal rock types are described below.

Lavas. – Flows constitute about 75 percent of the formation in Vandfaldsdalen (Miki Fjord), the type area. As shown in Fig. 4, this proportion diminishes eastward as the flows pass into hyaloclastic breccias. As reported by Brooks et al. (1976) these basalts show much greater compositional and morphological diversity than the tholeiitic plateau basalts higher in the pile which outcrop extensively along the Blosseville Kyst and inland.

Flows seldom exceed 20 m in the Vandfaldsdalen Formation and are commonly about half this thickness, contrasting markedly with an average of about 50 m for the massive, columnar jointed plateau basalt flows of the northern Blosseville Kyst (Fawcett et al. 1973), where the thickest examples attain 100 m. As noted by Brooks et al. (1976) the average erupted volume per flow is thus likely to be much smaller for the Lower Basalts than the plateau lavas, although we have no data on the areal extent or volumes of individual flows. Some multiple units in the lower lavas consist of numerous lobes, a metre or less in thickness, overlapping each other to form in effect a single flow. Conversely, thicker units of around 30 m are occasionally encountered, which show no internal chills and appear to be single flow units. Such morphologies are described by Walker (1972) respectively as compound and simple flows. The compound flow type is believed to be of moderate volume and extrusion rate and is probably restricted to near-vent environments, which are subjected to a continuous supply of volumetrically restricted magma pulses. In contrast the simple flows are found to be voluminous, rapidly extruded lavas, which spread far from the source area.

Petrographically the Vandfaldsdalen flows are distinct from the dominantly feldspar-phyric Plateau Basalts. Olivine-phyric flows predominate, but the phenocrysts are usually small and invariably pseudomorphed. A few flows are strongly olivine-phyric and show distinctive dark brown "rubbly" weathering. There are a few pyroxene-bearing flows towards the base of the sequence, but plagioclase phenocrysts are absent except in one distinctive basaltic andesite which is recorded only as blocks in the breccias. The lower flows of the Vandfaldsdalen Formation range from picrites to andesitic tholeiites, with olivine tholeiites perhaps predominating. The major element composition and affinities of the basalts are discussed subsequently; their field characteristics are briefly described here.

Fig. 5. General view from Miki Fjord to the north along Sødalen. The lower part of the Vandfaldsdalen Formation is exposed in the valley floor and includes lavas, breccias, tuffs and hyaloclastites (see the geological map, Plate 1). The upper part of the Vandfaldsdalen Formation and the Mikis Formation are exposed in the sides of the valley. The steep mountains in the background are composed of basement gneisses uplifted in the centre of the Kangerdlugssuaq dome (Brooks 1973a).

Detailed field characteristics, which are sometimes of correlative value, reflect both composition and depositional conditions. Many flows are vesicular, with vesicles concentrated towards the top, in horizontal layers, or as pipe vesicles at the base. In addition to pipe vesicles there occur pipe-like cylindrical zones a few centimetres in diameter which are crowded with spherical vesicles. Both structures are attributed to the escape of vapour and regarded as evidence for subaqueous emplacement or flow over a wet surface. Pillow bases are not common, even in flows which overlie tuffs with marine bivalves or submarine debris flows. On the other hand, weakly oxidised tops occasionally occur and indicate subaerial conditions, although there is no extensive red bole development as at many levels in the Plateau Basalts (Fawcett et al. 1973). Studies of the vesicle mineralogy have not been made but vugs and amygdales are common and contain quartz, epidote and prehnite, in contrast to the chalcedony – scolecite – stilbite assemblage characteristic of the Plateau Basalt tholeiites. The former assemblage indicates a higher metamorphic grade, as would be expected for the deeper burial in the volcanic succession.

Columnar jointing is uncommon in the Vandfaldsdalen lavas, another distinction from the Plateau Basalts, and, as already noted by Wager (1934), the Lower Basalts do not exhibit the trap topography so characteristic of plateau basalt areas. The basal flow in Vandfaldsdalen is however strongly columnar, thicker than the average and resembles a sill. It incorporates the underlying Schjelderup Member sandstone in a manner suggesting that this sediment was unlithified at the time. Some flows, usually in groups, show yellow rather than brown weathering and have a massive flinty appearance. These are tholeiitic basalts and basaltic andesites and one group of these contains dark, rather indistinct layers, termed in the field 'wispy banding'. This structure allows the flow group to be correlated over some 20 km. Thin section studies suggest that the bands represent the chilled skin, disrupted and re-incorporated into the liquid and then overgrown by clinopyroxene.

Hyaloclastites. – Hyaloclastic breccias are not represented in the Vandfaldsdalen section but appear at three levels in Sødalen and increase in importance eastwards. The major unit (β on Fig. 4) thickens to the east at the expense of basalt flows and attains a thickness of over 300 m at Ryberg Fjord.

The hyaloclastic units consist of basalt pillows up to a metre or so in size (Fig. 6) and small pillow fragments, set in a matrix of palagonite shards and secondary minerals. Excellent cliff exposures of unit (β) around "Brecciadalen" and Sødalen show massive cross-stratification defined by the orientation of pillows and variations in the size of the fragments, inclined east and north. In a passage zone at the top of this unit, horizontal basalt flows are seen to pass into trains of pillows defining the cross-strata. Unit (β) is interpreted as a flow-foot breccia (Jones & Nelson 1970) produced by flows which entered water and built out prograding deltas of hyaloclastic material. The passage zone marks the water level at the time and the thickness of the unit indicates the water depth. This was approximately 100 m in Brecciadalen and increased eastwards. The unit directly overlies marine tuffs and at Ryberg Fjord, as previously recorded, contains interbedded shale with the dinoflagellate *Wetzeliella* and is without doubt of submarine origin. In Sødalen the hyaloclastites rest on subaerial lava flows, occasionally separated by minor waterlain tuff. The distribution of this hyaloclastite indicates eastwardly increasing water depth, progressive subsidence and a source area of the breccias to the S of the present exposures at the coast or on the shelf (Fig. 4).

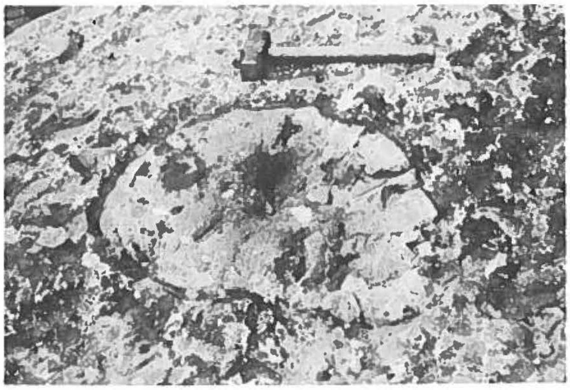


Fig. 6. Typical basaltic pillow in hyaloclastite unit β, Vandfaldsdalen Formation, Sødalen. The pillow is *c.* 1 m across.

Tuffs. – In the central and eastern parts of the area, basement-derived sediments of the Schjelderup Member pass up into tuffs by a rapid increase in the volcanogenic component, whereas flows directly overlie the basement-derived sandstones of the Schjelderup Member in the Vandfaldsdalen section. The waterlain basaltic tuffs together with the hyaloclastites replace the subaerial flows away from the basin margins. No more than about ten percent of waterlain tuffs are included in the succession (Fig. 4). They are well bedded with frequent cross-stratification and individual units often grade up into ripple-laminated purple and green silts. One horizon in Sødalen contains the marine bivalve *Hippopodium* and it is probable that most of the tuff units in the lower part of the sequence in Sødalen and eastwards are of shallow marine or deltaic deposition, representing material eroded from nearby subaerial flows. They are therefore volcanogenic sediments (s.s.) rather than true tuffs.

Breccias. – Three polymict breccia units are present in the Vandfaldsdalen section and comprise about 15 percent of the formation. The Main Breccia of Wager

Fig. 7. Lower contact of breccia unit β, Vandfaldsdalen Formation, Sødalen. The underlying sediment is a well bedded waterlain tuff. The hammer is *c*. 30 cm long.

(1947) (μ in Fig. 4) has now been traced eastwards for about 12 km and a higher unit (τ) attains 50 m in thickness and can be followed for a similar distance. These are invaluable marker horizons. As briefly described by Soper et al. (1976a) the matrix supported fragments consist of angular to sub-rounded blocks up to 0.5 m, occasionally larger, of basalt, pillow fragments and breccia and rare hypabyssal types. Most types of flows are present, together with varieties not recorded as flows – in particular the plagioclase and pyroxene porphyritic basaltic andesite already mentioned and characteristic of breccia unit (τ). The smaller blocks are often well rounded. The matrix consists of medium-grained basaltic detritus with abundant clinopyroxene fragments. It can sometimes be seen to be continuous with underlying or overlying lenses of well bedded tuffs (Fig. 7). The breccia units are generally not internally bedded but often show a decreasing block size towards the top and may contain well stratified tuff lenses.

These characteristics led Soper et al. (1976a) to interpret these breccias as subaqueous mass-transport deposits. In Vandfaldsdalen, however, the lavas show no subaqueous characteristics and the breccias here may represent subaerial debris-flows, possibly lahars. Nevertheless, the marine environment of at least one unit in I. C. Jacobsen Fjord (∮ in Fig. 4) is proved by the presence of a planolitid-like trace fossil showing that the debris-flows entered the water at least in this area.

Mikis Formation

The base of the overlying Mikis Formation is taken at the incoming of a thick sequence of grey compound olivine tholeiite flows with rubbly-weathering centres which forms a prominent topographic discontinuity. A few compound units of this type occur in the Vandfaldsdalen Formation but the lower part of the Mikis Formation is composed almost entirely of them together with more massive groups of picritic flows. The upper part of the formation is dominated by massive simple olivine tholeiite flows and was formerly termed the Jacobsen Formation. This formation has been abandoned as the transition from the upper to the lower parts of the Mikis Formation is gradual. In the area of Miki Fjord the base of the formation almost coincides with the highest breccia (unit τ, Fig. 4) which presumably approximates to a time plane. At I. C. Jacobsen Fjord the base becomes markedly diachronous and it is thought that the whole formation rapidly decreases in thickness and passes into water-lain tuffs further east in the Ryberg – Nansen Fjord area.

The olivine tholeiite flow units in the Mikis Formation are typical compound lava flows (Fig. 8) and are highly vesicular usually with a zone of pipe amygdales at the base and often with internal layers, anastamosing zones or networks of vesicles. Ropy surfaces occur but oxidized tops are absent. The form of the flow units,

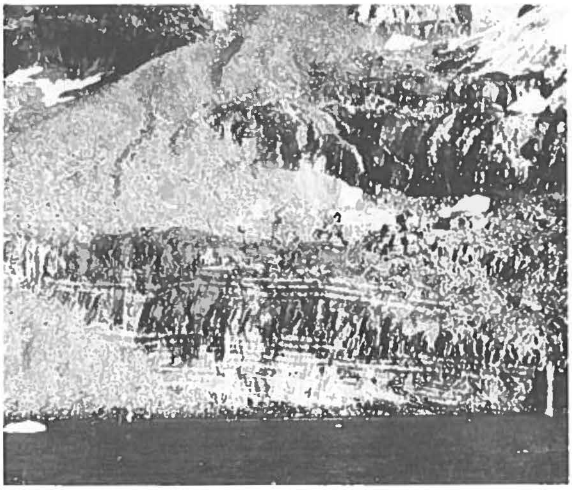


Fig. 8. Typical section from the compound flows in the lower part of the Mikis Formation. Single units are mostly less than 1 m thick. Southern shore of Miki Fjord.

which is typical of pahoehoe lavas, is thought to arise from high mobility of the lava rather than necessarily a submarine origin as previously supposed. Subaqueous deposition is indicated by a conglomerate and shales overlying the thick breccia (unit τ) near the base of the formation. A few horizons of sedimentary tuff and one 0.5 m bed of entirely basement-derived sandstone are also observed in this part of the succession. Hyaloclastic deposits are absent in the lower part of the Mikis Formation. Groups of two to four picritic flows are interspersed among the dominant olivine tholeiites and amount to about 150 m, equivalent to approximately a fifth of the Mikis Formation.

The thickness of the formation is not known with accuracy because no complete section has been recorded. A 445 m profile was measured on "Rådentoppen" SE of the Jacobsen Fjord inlier (Fig. 1). A 480 m profile was recorded in the opposite side of the valley to an altitude of 800 m with a further 150–200 m visible above, giving about 650 m exposed in this area, above the Vandfaldsdalen Formation. It is unlikely that a significantly greater thickness is represented on the "Brandaltinde" (1700 m altitude) which exposes Mikis Formation to the summit but lies up-dip. The top of the formation is seen on the NW side of I. C. Jacobsen Fjord east of the Schjelderup Gletscher where it is followed by a great thickness of water-lain tuff of the Hængefjeldet Formation. Here an estimated 563 m section in the Mikis Formation was sampled for palaeomagnetic study along the fjord shore. No correlation can be made between the sections east and west of "Schjelderup Bugt" because of the lack of distinctive markers. In the field a large overlap was thought probable. Subsequent analytical work has failed to identify picritic flows in the fjord section east of the Schjelderup Gletscher, which are characteristic of the lower part of the formation to the west. Thus although a minimum thickness of 650 m is adopted for the Mikis Formation in this area, thicknesses between 750 and 900 m have been estimated from the geological maps. The variations in the estimates are in part due to variation in the total thickness of sills injected in the successions. The total thickness of the Vandfaldsdalen, Mikis and Hængefjeldet formations at their maximum observed development lies between 1.8 and 2.5 km.

Palaeomagnetism

The main purpose of the palaeomagnetic study was to determine the polarity of the stable remanence of the basalts in the I. C. Jacobsen Fjord region. All previous palaeomagnetic studies of the East Greenland basalt pile have found the flows to be reversely magnetized (Tarling 1967, Faller 1975, Hailwood 1977). It has been suggested that the whole pile may have been erupted within the geomagnetic reversed interval immediately prior to ocean floor magnetic anomaly 24 (Faller 1975, Soper et al. 1976a). However the eruption of the Faeroese basalts, believed by some workers (e.g. Brooks 1973a, Soper et al. 1976b) to have been synchronous with that of the East Greenland pile, appears to have spanned more than one polarity period. Tarling (1970) found normally magnetized flows in the Lower Series of the Faeroese basalts overlain by reversely magnetized Middle and Upper Series.

The previous palaeomagnetic studies of the East Greenland basalts do not represent systematic sampling through the whole pile. Tarling and Hailwood worked in the Scoresby Sund area where they sampled what is probably the upper part of the total pile whereas Faller carried out a pilot study on the base of the pile in the Kangerdlugssuaq area. There remained the possibility that a portion of the pile may have been erupted during the geomagnetic normal interval which produced magnetic anomaly 25. If a sequence of normally magnetized basalt were found higher in the pile than the sites of Faller's pilot study, the palaeomagnetic evidence would imply that the eruption of the pile had commenced before anomaly 25 time and continued after it.

Sampling and experimental procedure

A site was drilled in each of forty-two basalt flows. Each site comprised at least six cores which were taken from the lower half of the flow and oriented by sun compass. Six pillows and a number of pillow fragments in hyaloclastic breccia γ were also sampled, as were four sills with one site per sill. Thirty-three of the dikes which intrude the basalts were sampled; this study is reported elsewhere (Faller & Soper 1979).

The sites in the basalts are indicated on Figs 1 and 4. Sites 41–45 are in the Schjelderup Member of the Vandfaldsdalen Formation, with each site in one of five well-defined flows immediately overlying the sediments in the Jacobsen Fjord inlier where the dip is 7° to the south. They span about 120 m of the sequence. Sites 1–17 and 56–59 (not the stratigraphic order) were drilled in the basalts which outcrop to the north of I. C. Jacobsen Fjord west of the "Schjelderup Bugt". These are in the continuation of the Vandfaldsdalen Formation and extend into the Mikis Formation, but because parts of the sections were poorly exposed it is not known how many flows were not sampled. An estimated 480 m of the pile was sampled here. The remaining sites were sampled on the north shore of I. C. Jacobsen Fjord south of "Schjelderup Bugt" where the strata dip seawards at 10°–12°. They are all in the Mikis Formation where it is not always possible to distinguish between separate flow units and cooling units but the total thickness sampled was approximately 600 m. Site 68 was in the flow immediately below a thick sill; the other sites south of "Schjelderup Bugt" were stratigraphically above this sill. It is not possible to correlate flows in the Mikis Formation across "Schjelderup

Bugt", but any overlap or hiatus is believed to be minor.

Palaeomagnetic measurements were made on 1-inch cores using a Digico balanced flux-gate spinner magnetometer. One sample from each site was subjected to step-wise alternating field (AF) demagnetization using a two-axis tumbler and one was saved for thermal demagnetization in a field of less than five gamma in an inert atmosphere with temperature increments of around 50°C. The remaining samples were cleaned by the AF method, using the lowest peak field at which the pilot sample for the site had given a stable direction. Initial susceptibilities were measured on a commercial bridge.

Results

The results are presented in Table 1 and Fig. 9. Thirty-nine of the basalt flows have stable reversed magnetiza-

Table 1. Palaeomagnetic results.

Site	N	$\bar{J}_o$	$\bar{\chi}$	$\bar{Q}$	D_o	I_o	α_{95}	D	I	α_{95}
41	7	0.044	0.6	1.9	148	–70	8	150	–71	4
42	8	0.021	0.8	0.7	155	–73	3	158	–75	2
43	8	0.028	0.9	0.8	161	–72	2	160	–73	2
44	5	0.079	0.7	3.0		not significant		178	–65	11
45	7	0.053	0.9	1.5	141	–67	5	134	–74	3
γ	7	0.003	0.7	0.1		not significant		152	–68	10
17	9	0.007	0.6	0.3	163	–62	5	165	–67	3
16	8	0.020	0.7	0.9	139	–57	11	140	–68	2
15	8	0.077	2.0	1.0	185	–14	13	189	–34	6
14	7	0.020	0.7	0.7	189	–35	16	192	–58	9
13	8	0.002	0.45	0.1		not significant		175	–62	10
12	8	1.90	9.5	5.3	162	–54	3	168	–59	3
1	6	0.035	0.7	1.2		not significant		183	–63	9
2	7	0.041	0.8	1.2		not significant		170	–71	4
3	6	0.370	11.0	0.8		not significant		167	–54	3
4	5	0.930	50.0	0.4		not significant		167	–48	14
5	7	0.004	0.07	1.5	184	–64	4	173	–66	4
6	7	0.450	6.0	2.0	139	–23	9	139	–39	5
7	8	0.093	2.4	1.0		not significant			not significant	
8	5	0.200	5.0	1.1		not significant		152	–34	13
9	8	0.070	1.1	1.7		not significant		153	–16	14
10	7	0.160	2.0	2.1		not significant		166	–66	13
11	8	0.024	0.5	1.3	183	–64	4	179	–66	4
56	4	0.010	0.6	0.4		not significant		158	–40	18
57	6	0.003	0.4	0.2	356	69	8	354	61	8
58	6	0.032	0.6	1.4	150	–65	4	150	–68	4
59	6	0.006	0.8	0.2	157	–24	19	159	–51	14
68	6	18.10	30	14.4	118	–20	2	118	–21	2
60	6	0.120	0.5	5.7	130	–25	5	132	–33	3
46	8	0.170	0.8	5.6	125	–30	3	126	–34	2
47	7	1.350	1.2	3.0	126	–09	11	124	–25	6
48	9	0.009	0.8	0.3	168	–10	9	166	–44	4
49	5	0.001	0.6	0.04		not significant		162	–40	8
50	6	0.020	1.0	0.5	142	–52	16	148	–63	9
51	6	1.160	30	0.9		not significant		160	–59	11
52	6	0.210	2.0	1.7		not significant		145	–50	8
64	6	0.700	38	0.5		not significant			not significant	
65	6	0.130	7.0	0.5		not significant		193	–79	5
55	6	0.030	0.7	1.1	174	–57	5	173	–63	3
54	6	0.040	0.7	1.5	166	–34	9	167	–40	8
53	5	0.640	25	0.6		not significant		154	–36	8
66	6	0.110	11	0.3	205	–77	3	205	–73	2
67	6	0.780	65	0.3	159	–23	13	170	–59	6
62	6	0.800	18	1.2		not significant		127	–27	7
105	5	0.300	6.5	1.2	165	–42	3	166	–60	3
106	5	0.080	1.2	1.8	315	70	5	317	65	4
107	5	0.120	5.0	0.6	167	–64	8	165	–70	5

Mean stable tilt-corrected palaeomagnetic direction for the flows: D = 157°, I = –56°, N = 39, α_{95} = 5° (ignoring site 57).
Corresponding palaeomagnetic pole position: 60°N, 183°E (dp = 8°, dm = 5°).
Key to palaeomagnetic symbols:
N = number of samples; $\bar{J}_o$ = mean NRM intensity (Am^{-1}); $\bar{\chi}$ = mean initial volume susceptibility (SI units); $\bar{Q}$ = mean Königsberger ratio; D_o = initial declination; I_o = initial inclination; D = stable declination; I = stable inclination (all directions corrected for tilt); α_{95} = semi-angle of cone of 95% confidence of preceding direction. Sites are arranged in stratigraphic order and in groups as follows: Inlier, Vandfaldsdalen Formation, Mikis Formation and sills.

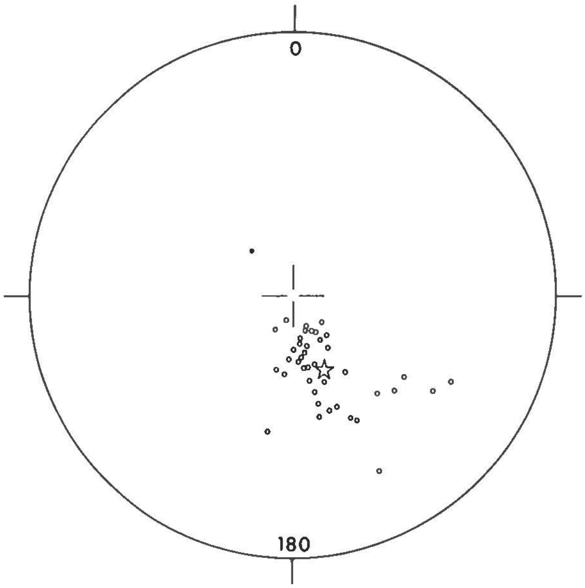
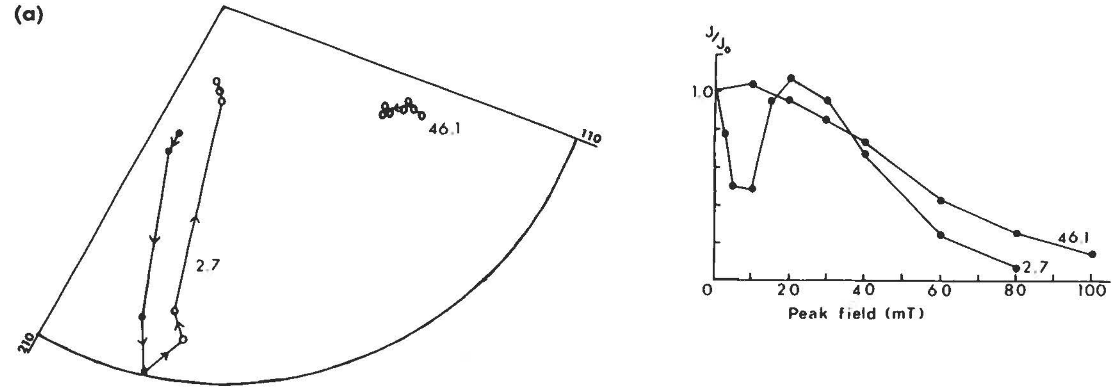


Fig. 9. Stereographic projection of stable tilt corrected site mean palaeomagnetic directions of the lavas. *Open circles* denote the upper hemisphere (reversed) and *solid symbols* the lower hemisphere (normal). The *star* is the mean direction of the reversely magnetized sites. Its points lie on the circle of 95% confidence.

tion, one (site 57) appears to be normally magnetized, and two fail to give significant results. Hyaloclastic breccia γ is reversely magnetized with a very weak stable component. At about half the sites there is no significant mean direction before cleaning. AF cleaning commonly removes an unstable normal component of magnetization which may have been acquired during the present normal geomagnetic epoch. At many sites samples in which this normal component dominates the NRM were obtained within a meter of samples in which it is entirely absent (Fig. 10a).

The initial remanence intensities of the flows vary over three orders of magnitude with great differences between the mean values for adjacent flows, e.g. sites 12 and 13. The site mean NRM intensities follow an approximately log-normal distribution about a geometric mean of 0.07 Am^{-1} (Fig. 11). The arithmetic mean from all the sites (excluding 68) is 0.24 Am^{-1}. Site 68, in the flow immediately beneath a thick sill, is extremely strongly magnetized, comparable in intensity to some of the dikes in the area rather than to any of the other flows. In thin section it can be seen to have a very high proportion of opaque oxides, whereas the very weakly magnetized samples from other sites show only minor contents of opaque minerals in thin section. The Königsberger ratios (Q) are often close to or less than



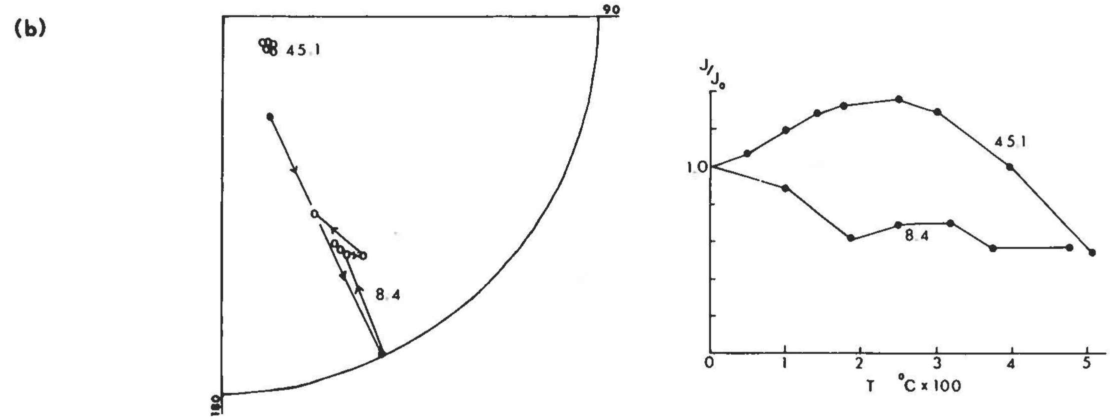


Fig. 10a. Examples of AF demagnetization (see text).

Fig. 10b. Examples of thermal demagnetization (see text).

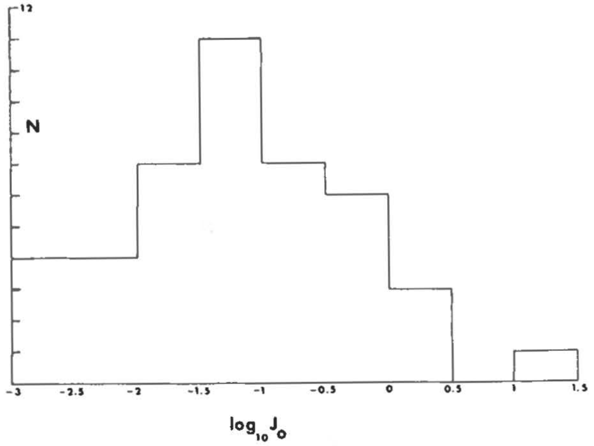


Fig. 11. Logarithmic histogram of the site mean NRM intensities from the lavas.

unity, indicating that the induced magnetization in the Earth's present field is comparable with the remanence or dominates it. Response of the basalt samples to thermal demagnetization varies; some have only high blocking temperatures in the range between 450°C and the Curie temperature of magnetite, others show additional lower blocking temperatures (Fig. 10b). Three of the sills are reversely magnetized and one (site 106) is normal (Table 1). This normal sill intrudes its neighbouring sill (site 105).

Discussion

The magnetic directions reported above are believed to be primary for the reasons discussed by Faller & Soper (1979). The mean stable tilt-corrected palaeomagnetic direction for the thirty-nine reversely magnetized flows and the hyaloclastic breccia is D = 157°, I = –56°, α_{95} = 5°. This result substantiates the previous result from the Vandfaldsdalen Formation, D = 159°, I = –63°, α_{95} = 9° (Faller 1975) and is statistically identical with the results of Tarling (1967) and Hailwood (1977) according to the test of Watson (1956). Apart from one isolated flow (site 57) in the Mikis Formation all the basalts sampled within an approximate 1200 m thickness of the pile are reversely magnetized. Although both the declination and inclination of site 57 suggest magnetization in a normal field, the result is surprising, as the site was in one of a group of thin flows, and is therefore stratigraphically very close to sites 56 and 58, which are both undoubtedly reversed. Whether site 57 is anomalous or not, it may be disregarded, as it could only represent a brief excursion of the geomagnetic field rather than a normal epoch.

The between-site variations of the stable directions are within the range expected to result from the secular variation of the geomagnetic field. Their existence suggests that each site was sampled in a position where it records the field direction at the time when the flow cooled. No overprinting due to re-heating by the next flow is shown by the present data. Unfortunately the sampling density is inadequate to use the secular variation for correlation of the sections on opposite sides of the "Schjelderup Bugt" inlet.

Although we have established that the lowest 1200 m of the basalt pile in the I. C. Jacobsen Fjord (Kangerdlugssuaq) region is reversely magnetized, we are still not in a position to decide whether the whole pile was erupted in the same reversed epoch. It was not possible to sample higher in the sequence because of the terrain and the dense intrusion of the dike swarm on the outer coast. We have narrowed the gap between the basalts sampled here and in the Scoresby Sund region, but the question of whether a normal polarity epoch is recorded within the pile must remain open. Future plans for further sampling of the main basalt pile must await stratigraphic correlation between the two regions.

The other properties of the lavas, namely NRM intensity, initial susceptibility, Q-value, stability of AF demagnetization and behaviour on thermal demagnetization, are characterized by high variability from one flow to the next. Examples are noticed of all the types of behaviour recorded by Deutsch & Kristjansson (1974) on the Tertiary lavas from Disko island, West Greenland, and explained by them in terms of variations in oxygen fugacity during cooling and variations in titanomagnetite domain size distribution. Similar variation has been observed among the basalt samples drilled from the Atlantic ocean floor during DSDP Leg 49 (Faller et al. 1979). However our mean NRM intensity for the East Greenland basalts is at least an order of magnitude lower than the mean for Atlantic ocean floor basalts (Faller et al. op. cit.) and for ocean floor basalts in general (Lowrie 1977).

Petrology of the Lower Basalts

In contrast to the Plateau Basalts (Fawcett et al. 1973, Brown & Whitley 1976, Brooks et al. 1976) which are Fe- and Ti-rich tholeiites having a small compositional range, the lower basalts are much more diverse. Brooks et al. (op.cit.) recognised the presence here of more mafic picritic types. However all these lavas prove to be of tholeiitic affinity. In the present study stratigraphically controlled sampling has given some indication of compositional changes with time. However, most of these lavas are strongly altered and many of the lowest flows in the succession contain partly digested xenoliths of basement rocks and sandstone. Data on the compositions of these lavas must therefore be treated with caution and attention is here limited to a general characterization of the rocks in terms of major elements and phenocryst mineralogy determined by microprobe.

Lavas of the Vandfaldsdalen Formation and especially those between 0 m and 275 m in the Miki Fjord sections (Fig. 4) form the most variable group, ranging from picritic to andesitic in composition. The upper Vandfaldsdalen Formation lavas, from 275 m to the base of the Mikis Formation at about 600 m in the Miki Fjord section, are more uniform and include the massive yellow weathering flows described above.

The dominant flow types in the lower part of the Vandfaldsdalen Formation are ophitic to subophitic basaltic to andesitic flows with occasional pilotaxitic texture (Figs 12 & 13). They are generally aphyric except for rare microphenocrysts and phenocrysts of olivine (pseudomorphed) and plagioclase. Their groundmass is fine-grained and composed of plagioclase, clinopyroxene, magnetite and sometimes olivine, with alteration products. Fewer picritic flows have been found; these are both oceanites and ankaramites (Sørensen 1974). The oceanites (Figs 14 & 15) are composed of up to 30 percent 1–0.5 cm sized euhedral olivine phenocrysts rich in euhedral chromite inclusions, sparse grass-green clinopyroxene, minor euhedral

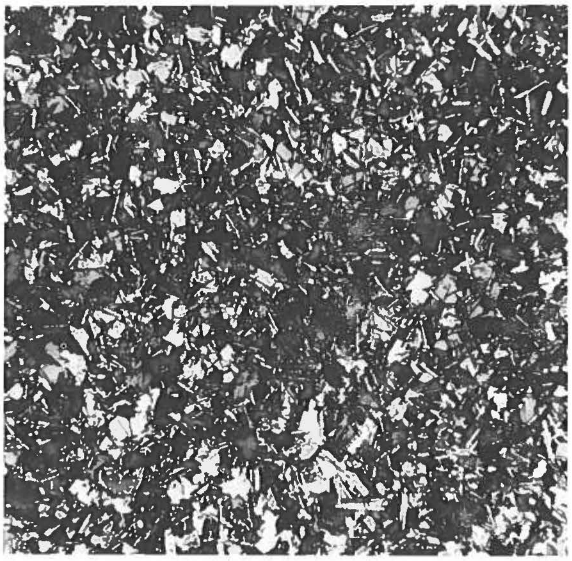


Fig. 12. Tholeiitic basalt, lower Vandfaldsdalen Formation GM 40636, Sødalen. Field of view *c.* 10×10 mm. Crossed nicols.

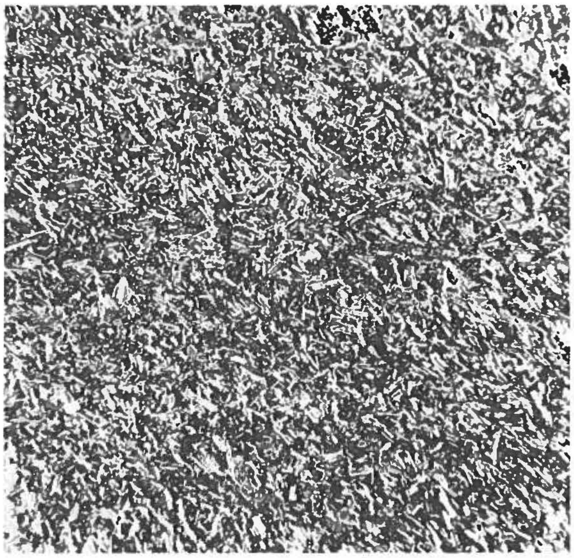


Fig. 13. Tholeiitic andesite, lower Vandfaldsdalen Formation, GM 40632, Sødalen. Field of view *c.* 10×10 mm.

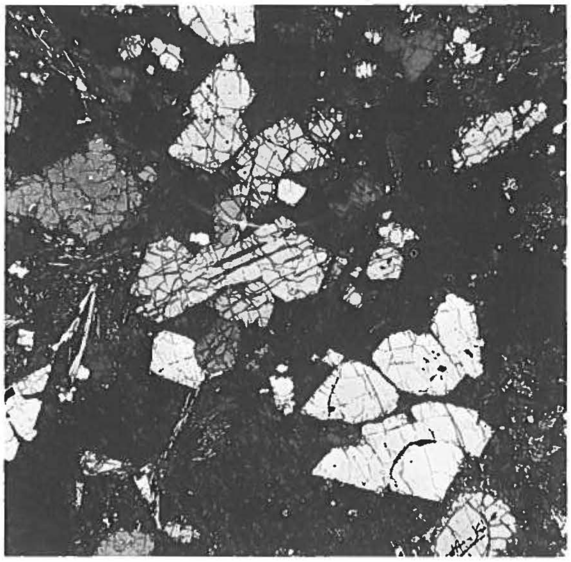


Fig. 14. Oceanite, Mikis Formation, GM 40646, inner I. C. Jacobsen Fjord. Note partly skeletal olivines. Field of view *c.* 10×10 mm. Crossed nicols.

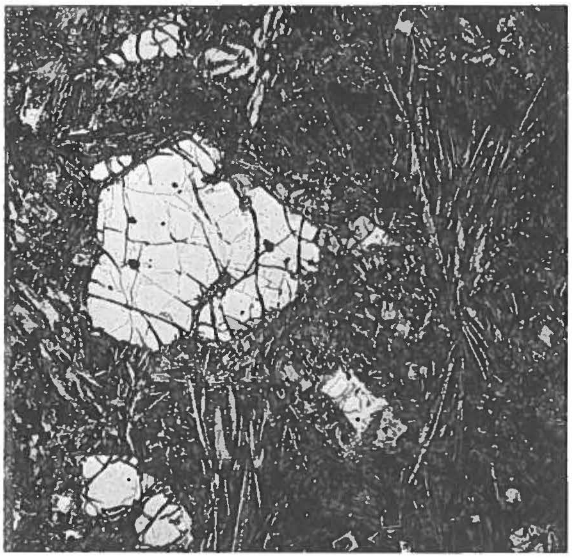


Fig. 15. Oceanite (same as in Fig. 14). Note the feathery quench intergrowth of clinopyroxene and plagioclase. Field of view *c.* 4×4 mm.

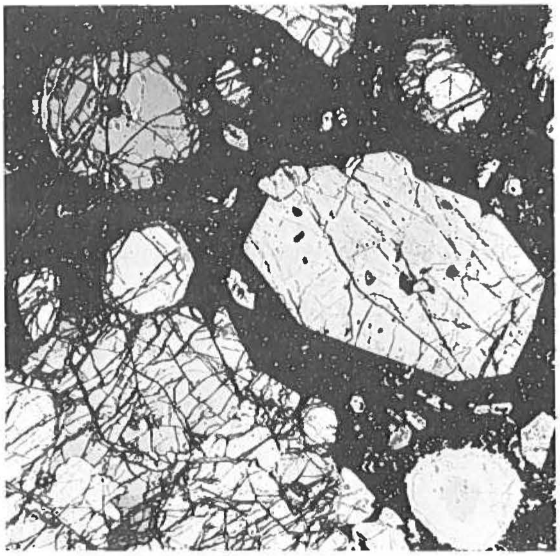


Fig. 16. Ankaramite, Mikis Formation, GM 40637/1, I. C. Jacobsen Fjord north of inlier locality. Note dunitic nodule (lower left) and twinned euhedral Cr-endiopside phenocryst (right centre). Field of view *c.* 10×10 mm. Crossed nicols.

chromite phenocrysts in a quenched base of clinopyroxene needles, plagioclase and altered glass which is dusted with oxides. A few resorbed olivine crystals rich in euhedral chromite were observed. The ankaramites (Fig. 16) are rich in the grass-green euhedral clinopyroxene phenocrysts and olivine phenocrysts and have rare euhedral zoned chromite phenocrysts and dunite and wehrlite nodules. The base is finely crystalline and composed of clinopyroxene, altered olivine, plagioclase, oxides and glass. Accordingly the chemical variation in the lower part of the Vandfaldsdalen Formation is considerable (Fig. 17. Table 2).

The more uniform upper Vandfaldsdalen Formation lavas include less altered olivine tholeiites and

Table 2. Examples of lava compositions.

	1	2	3	4	5	6	7	8	9
SiO_2	43.99	48.08	46.62	50.90	50.89	51.32	46.04	47.06	48.86
TiO_2	2.30	2.68	1.65	3.39	2.06	2.25	2.01	2.12	2.36
Al_2O_3	6.39	7.94	12.41	12.69	12.47	13.03	8.60	10.72	12.43
Fe_2O_3	4.60	4.18	2.22	4.29	3.80	3.88	4.38	7.59	4.29
FeO	9.15	8.90	7.76	7.73	7.10	6.28	7.60	5.64	7.08
MnO	.17	.16	.15	.17	.15	.15	.18	.16	.17
MgO	18.51	11.01	7.88	4.45	8.38	6.18	18.50	11.80	8.45
CaO	9.00	10.77	11.14	9.16	8.71	9.53	7.60	9.44	10.70
Na_2O	.83	1.48	1.48	2.16	2.36	3.07	1.30	2.00	1.97
K_2O	.22	.38	.13	1.12	.76	.81	.15	.38	.54
P_2O_5	.20	.27	.16	.33	.18	.19	.17	.31	.17
L.O.I.	3.97	3.20	7.88	3.02	2.72	2.92	3.37	3.09	2.73
SUM	99.34	99.05	99.48	99.41	99.58	99.61	99.91	100.31	99.75
Q	.00	.63	2.67	7.84	2.30	1.87	.00	.00	.56
or	1.30	2.25	.77	6.62	4.49	4.79	.89	2.25	3.19
ab	7.02	12.52	12.52	18.28	19.97	25.98	11.00	16.92	16.67
an	13.06	13.90	26.84	21.62	21.19	19.38	17.19	19.15	23.48
di	24.30	30.66	22.32	17.99	16.98	21.83	15.57	20.81	23.21
hy	19.16	27.50	21.01	14.35	25.34	15.99	25.18	18.36	22.65
ol	22.69	.00	.00	.00	.00	.00	20.01	12.00	.00
mt	2.55	2.43	1.87	2.22	2.02	1.87	2.21	2.39	2.10
ilm	4.37	5.09	3.13	6.44	3.91	4.27	3.82	4.03	4.48
ap	.47	.63	.37	.76	.42	.44	.39	.72	.39

L.O.I. = Loss on ignition.
C.I.P.W. norms are calculated after reduction of $Fe_2O_3/FeO + Fe_2O_3$ to .15.

Column 1–4: Lower part of the Vandfaldsdalen Formation:
1: Oceanite flow, inner Sødalen, Miki Fjord (CKB 70–24).
2: Ankaramite flow, Vandfaldsdalen, Miki Fjord (GM 20351).
3: Chilled tholeiite from neck in sediments, Jacobsen inlier (GM 40031).
4: Andesitic basalt, section above lake in Sødalen (265 m), Miki Fjord (GM 40632).
Column 5–6: Upper part of the Vandfaldsdalen Formation:
5: Tholeiite flow, section above lake in Sødalen (449 m), Miki Fjord (GM 40634).
6: Tholeiite flow overlying hyaloclastite unit at 440 m in Jacobsen inlier section (GM 40041).
Column 7–9: Mikis Formation:
7: Oceanite flow at the base of the Mikis Fm. at 450 m between Campsite and Schjelderup Gletscher sections, I. C. Jacobsen Fjord (GM 40645).
8: Olivine tholeiite flow, head of Miki Fjord in type section of Miki Fjord type basalts, Brooks et al. 1976, (GM 20332).
9: Tholeiite flow, section south of Schjelderup Gletscher, I. C. Jacobsen Fjord (GM 40640).

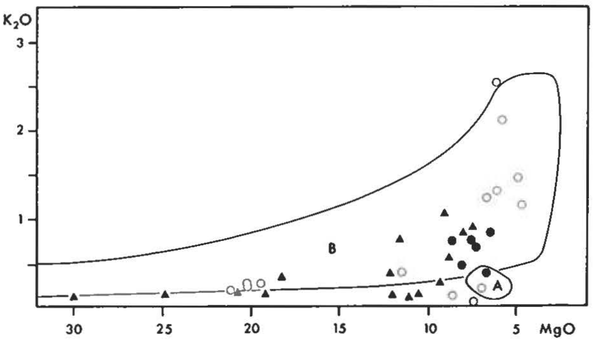


Fig. 17. K_2O *vs* MgO diagram. *Circles:* Lavas from the lower part of Vandfaldsdalen Formation, *filled circles:* upper part of Vandfaldsdalen Formation and *triangles:* Mikis Formation. *Field A* encloses the lowermost Plateau Basalts (lavas collected at Nansen Fjord, see Brooks et al. 1976) and *field B* enclosed the lower picritic to basaltic lavas of the Deccan Traps (Krishnamurthy & Cox 1977).

tholeiites. The less marked alteration is reflected in the diminished K_2O-range, probably due to the more massive and vesicle-free flow type. No picritic or andesitic flows have so far been observed in this part of the sequence. These rocks are fine-grained, phenocryst-free and composed of plagioclase, clinopyroxene, magnetite and olivine. Most of the compositions show 6 to 8 wt. percent MgO (average 7.43%) with a FeO*/FeO* + MgO ratio of 0.60 and a K_2O value of 0.65%.

The clear morphological change at the base of the Mikis Formation is also reflected in the composition of the lavas. The lower Mikis Formation includes a dominant group of compound olivine tholeiite and tholeiite lavas and subordinate massive picrite flows. Towards the base of the formation the picritic types form repeated sequences of two to four flows and may constitute up to 20 percent of the outcrop. They are similar to the picritic flows in the underlying Vandfaldsdalen Formation and show distinct quench textures. A single ankaramitic type was observed. The compound flows

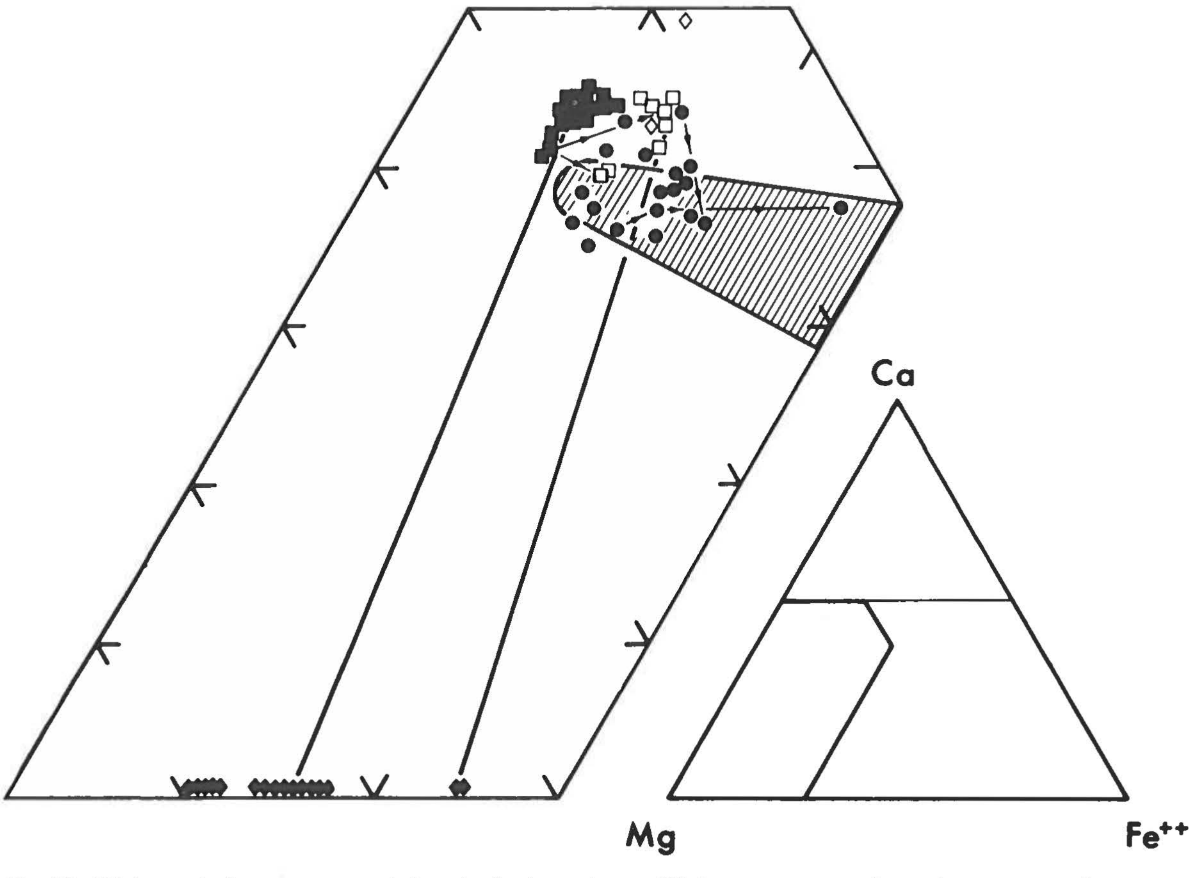


Fig. 18. Olivine and clinopyroxene variations in the lower lavas. *Filled squares:* cores of zoned grass-green clinopyroxene phenocrysts from the ankaramitic varieties in the picritic lavas, and *open squares:* rims. *Open diamonds:* quench clinopyroxenes of oceanites. *Filled circles:* clinopyroxenes of Ol-tholeiites to andesites. *Arrows* connect compositions of zoned microphenocrysts in the Ol-tholeiite to andesite lavas. *Ruled field:* groundmass clinopyroxenes in lavas of the Thingmuli volcano (Carmichael 1967). *Filled diamonds:* olivine from picrites. The most Fo-rich represent the resorbed olivine phenocrysts and the most Fa-rich the olivine of wehrlite inclusions, which coexists with clinopyroxene similar to that of the rims of the grass-green phenocrysts of the ankaramites. Tie-lines connect normal stable olivine phenocrysts (Fo_{85-82}) with coexisting clinopyroxene phenocryst cores.

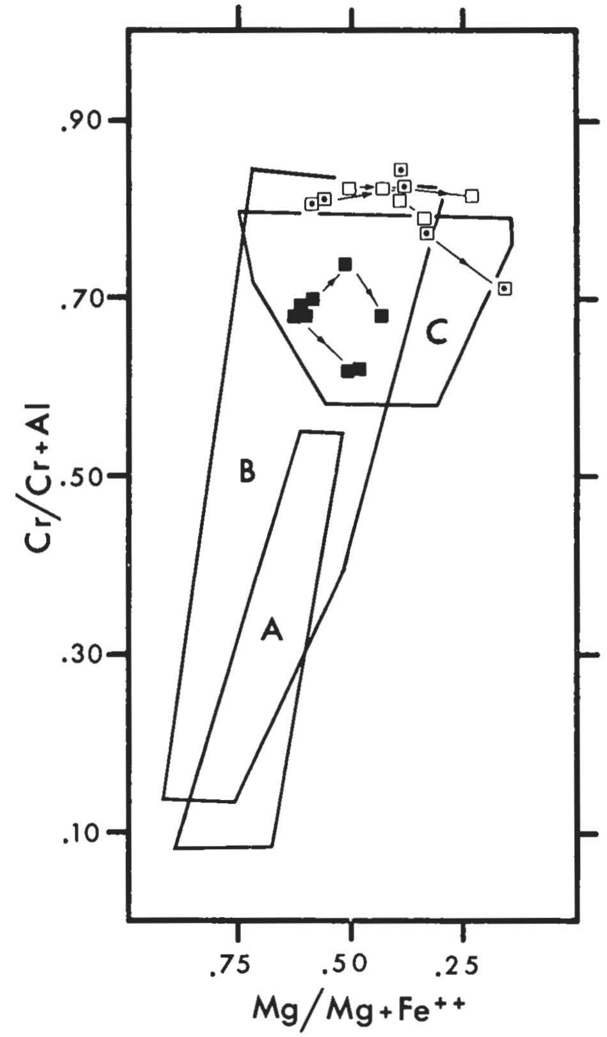


Fig. 19. Chrome-spinel variation in picrites. *Open squares:* zoned phenocrysts, *open squares with dots:* zoned euhedral crystals enclosed by olivine (Fo_{85-82}) and *filled squares:* zoned euhedral spinel enclosed in resorbed Fo-rich olivine phenocrysts. Compositional fields A, B & C from Irvine & Findlay (1972).

which are dominant in the lower part of the formation include olivine-phyric olivine tholeiites and tholeiites together with nearly aphyric tholeiites (such as those described by Brooks et al. (1976)). The more massive tholeiites increase in number in the upper part of the formation. The olivine-phyric flows form a restricted group of often very vesicle-rich and altered flows with an average of 11.47% MgO, FeO*/FeO* + MgO = 0.51 and 0.32% K_2O. The nearly aphyric flows show a slightly larger variation with MgO ranging from 9.30 to 7.39% and an average MgO of 8.49%, FeO*/FeO* + MgO = 0.57 and 0.72% K_2O.

The available mineral data is summarized in Figs 18 and 19 which show the compositional variation of clinopyroxenes, olivines and oxide phenocrysts. The clinopyroxenes are readily divided on a chemical basis. The grass-green phenocrysts of the picrites are chrome-rich diopsides or augites rimmed towards higher Fe (Fig. 18. Table 3). The clinopyroxene of the wehrlite inclusions is similar to the Fe-enriched rims. Quench pyroxenes of the picritic flows have most variable compositions, and two are shown in Fig. 14. The groundmass clinopyroxenes of the olivine tholeiites, the tholeiites and andesites are chemically variable and cover a field of more or less Mg- and Ca-rich groundmass clinopyroxenes of the olivine tholeiites, tholeiites and basaltic icelandite lavas of the Thingmuli volcano in Iceland (Carmichael 1967).

Olivine is only preserved in the oceanites and ankaramitic flows and the large stable phenocrysts have compositions in the range Fo_{85-82} (Fig. 18). The partly resorbed olivines of oceanitic flows have compositions up to Fo_{90} and the olivines of wehrlitic nodules have compositions down to Fo_{75}. The dunitic nodules cover a range similar to that of the stable phenocrysts (Table 3), possibly suggesting a cognate origin.

The oxide phenocrysts are all chromites and in most of the mafic flows the euhedral chromites enclosed by olivine and the euhedral phenocrysts have relatively Mg-rich and Al-poor cores zoned towards more Fe-rich variaties (Fig. 19). They lie in the upper part of the field of chromites from stratiform complexes and the field of alpine peridotites. The chromites enclosed by the olivines of the oceanites are distinct in having higher Al, but are also zoned towards more Fe-rich compositions.

As shown in Fig. 17 only two of the lavas in the Vandfaldsdalen and Mikis Formation correspond compositionally to the Plateau Basalts, here represented by the Nansens Fjord lavas (Brooks et al. 1976). Even though the individual lava composition may be affected by alteration and contamination processes and can only tentatively be compared with the lavas of the other plateau basalt areas, the chemical spread (Fig. 17) is found to be comparable with that of the lower Deccan Traps (Krishnamurthy & Cox 1977). The lower part of this succession includes large amounts of oceanitic and ankaramitic and related three-phenocryst and basalt flows, which are suggested to have formed by complicated fractionation, accumulation and flotation processes from common Mg-rich picritic primary magmas. Similar processes could be suggested for the Lower Basalts of East Greenland. Not only in petrography and chemistry are similarities apparent, but the resorbed olivine phenocrysts and the chromites enclosed by olivine in the oceanite and ankaramite flows are almost identical to the phenocrysts of the flows in the lower part of the Deccan succession. However an origin of all the lower lavas from a single Mg-rich parental composition may not be applicable in view of the compositional break between 17 and 13% MgO and the clear division of the analysed flows into several trends (Fig. 20). The model also excludes: a) possibilities for chemical alteration during burial metamorphism, evidenced by the low

Table 3. Selected mineral compositions.

	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	53.54	50.57	49.64	52.05	52.17	52.13	40.09	39.46	37.81	.00	.00	.00
Al_2O_3	1.30	3.29	4.68	2.61	.84	1.38	.00	.00	.00	8.33	6.16	11.77
TiO_2	.65	1.70	1.85	.57	.68	.62	.00	.00	.00	2.11	9.59	1.85
Cr_2O_3	1.01	.27	.54	.69	.00	.24	.00	.00	.00	53.16	22.70	50.25
V_2O_5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.07	.49	.06
Fe_2O_3	.00	.00	.00	.00	.00	.07	.00	.00	.00	7.67	21.80	6.21
FeO	5.20	8.98	8.29	8.65	15.62	10.46	10.71	14.87	22.53	15.70	35.33	18.32
MnO	.00	.00	.02	.12	.14	.08	.04	.08	.24	.24	.27	.13
NiO	.00	.00	.00	.00	.00	.00	.25	.21	.08	.00	.00	.00
MgO	16.90	14.91	14.81	18.04	12.21	16.38	48.56	45.12	39.15	12.55	3.74	11.03
CaO	21.54	20.36	19.94	17.02	17.77	18.30	.06	.10	.10	.00	.00	.00
Sum	100.14	100.08	99.77	99.75	99.43	99.66	99.71	99.84	99.91	99.83	100.08	99.62
Si	1.958	1.880	1.846	1.918	1.991	1.945	.991	.993	.987	.000	.000	.000
Al	.056	.144	.206	.114	.038	.061	.000	.000	.000	2.580	2.059	3.631
Ti	.018	.048	.051	.016	.019	.018	.000	.000	.000	.419	2.048	.362
Cr	.029	.008	.016	.021	.000	.007	.000	.000	.000	11.050	5.096	10.409
V	.000	.000	.000	.000	.000	.000	.000	.000	.000	.013	.088	.013
Fe^{3+}	.000	.000	.000	.000	.000	.000	.000	.000	.000	1.519	4.661	1.225
Fe^{2+}	.158	.279	.257	.266	.497	.323	.221	.313	.493	3.458	8.393	4.018
Mn	.000	.000	.000	.004	.005	.002	.002	.002	.005	.048	.068	.031
Ni	.000	.000	.000	.000	.000	.000	.005	.005	.002	.000	.000	.000
Mg	.921	.826	.820	.990	.694	.910	1.789	1.692	1.524	4.913	1.587	4.313
Ca	.844	.812	.796	.671	.726	.731	.002	.003	.003	.000	.000	.000

Atomic proportions calculated assuming 4 cations to 6 O in clinopyroxenes, 3 cations to 4 O in olivines and 24 cations to 32 O in chromites. Analytical method as described by Nielsen (1978).

1: Grass-green chrome-rich clinopyroxene phenocryst, core, ankaramite, Lower Vandfaldsdalen Fm. (GM 40032).
2: Rim of previous.
3: Quench clinopyroxene, oceanite flow, lower Vandfaldsdalen Fm. (GM 40633).
4: Augite phenocryst, core, Ol-tholeiite, Upper Vandfaldsdalen Fm. (GM 40634).
5: Rim of previous.
6: Groundmass augite, Ol-tholeiite flow, Upper Vandfaldsdalen Fm. (GM 40634).
7: Resorbed olivine phenocryst, oceanite flow, Lower Vandfaldsdalen Fm. (GM 40633).
8: Core of euhedral and stable olivine phenocryst, oceanite flow, Lower Vandfaldsdalen Fm. (GM 40633).
9: Olivine of wehrlitic inclusion in ankaramite, Lower Vandfaldsdalen Fm. (GM 40637).
10: Chromite phenocryst, core, ankaramite, Lower Vandfaldsdalen Fm. (GM 40637).
11: Rim of previous.
12: Euhedral chromite in resorbed olivine phenocryst, oceanite flow, Lower Vandfaldsdalen Fm. (GM40633).

O^{18}-values (Taylor & Forester 1979) which are regarded as due to exchange with circulating meteoric water, and b) possibilities of contamination as evidenced by the partly digested basement and sandstone inclusions. The spread in K_2O shown in Fig. 17 may well be due to such processes, though Carter et al. (1979) found no isotopic evidence of crustal contamination in an olivine tholeiite from the lower part of the Mikis Formation. This sample, from our collection and having 11.80% MgO and 0.38% K_2O, similarly shows no petrographic signs of contamination and is relatively well preserved. Accordingly this sample does not give any information on the effects of alteration and contamination. Some indication of progressive alteration with depth comes from sparse data on initial Sr-isotope ratios, which show a regular decrease from 0.70392 in the olivine tholeiite of the Lower Lavas to 0.70330 in the uppermost flows of the Plateau Basalts (Carter et al. 1979).

The MgO *vs.* FeO*/FeO* + MgO variation is believed to be primary. It can be divided into three and possibly four trends (Fig. 20). The most Mg-rich trend (A) include oceanites of both Vandfaldsdalen and Mikis Formation and appears to be governed by accumulation or fractionation of the stable olivine phenocrysts (Fo_{85-82}). Trend B includes all flows carrying the grass-green clinopyroxene and olivine phenocrysts (Fo_{85-82}) and constitutes an ankaramite trend. The most Mg-poor trend (C) includes all aphyric or clinopyroxene- and/or plagioclase-phyric tholeiites and andesitic basalts. The fourth trend (D) is weakly defined and includes the olivine-phyric olivine tholeiites of the Mikis Formation. It is readily seen that the picrites of trend (A) cannot have formed by olivine accumulation in any of the olivine tholeiites or tholeiites, which would then be expected to lie on the prolongation of trend A. Assuming the intimately related oceanites and ankaramites to have formed from a common primary liquid, the chrome-diopside-free picrites represent compositions that are quenched from temperatures exceeding those of chrome diopside/augite crystallization. Accordingly the picrites at the junction of trends A and B in Fig. 20 are the most MgO-poor possible primary parental picritic liquids. The few more MgO-rich picrites on the olivine control line are believed to be cumulative. Many workers, notably O'Hara (1965) advocated the existence of primary picrite liquids and such have been described from West Greenland (Clarke 1970), the Reykjanes Peninsula (Jakobsson et al. 1978), Réunion (Upton & Wadsworth 1972), the Deccan Province (Krishnamurthy & Cox 1977), the Nuanetsi area (Cox & Jamieson 1974) and Hawaii (Macdonald 1968). Thus, it seems characteristic that volcanic cyles in areas of intense magmatism are initiated by subordinate picrite activity prior to the much more voluminous basaltic activity just as in the case of East Greenland where the Lower Basalts correspond to the initial magmatism followed by the much more voluminous tholeiitic Plateau Basalts (Brooks et al. 1976, Nielsen & Brooks, 1981). Suggested primary picritic compositions close to the junction of trends A and B are given in Table 4. There is a strong similarity between the suggested primary picrite composition from East Greenland and the average primary oceanite from Hawaii.

Although the sampling in East Greenland may not be representative, the lack of chrome-rich clinopyroxene phenocrysts in the olivine tholeiites close to the Mg-poor part of trend B and the compositional gap between 17 and 13% MgO strongly suggests the existence of several parental liquids. A simple accumulation of olivine in the olivine tholeiites, as illustrated by trend (D) explains the apparent position of these rocks on the MgO-poor part of trend (B). It thus appears that, as on the Reykjanes Peninsula (Jakobsson et al. 1978), picritic as well as at least one type of olivine tholeiite liquid at the junction of trend (C) and (D) are parental to the observed chemical variation in the lower lavas. This composition is represented by a sample situated at the

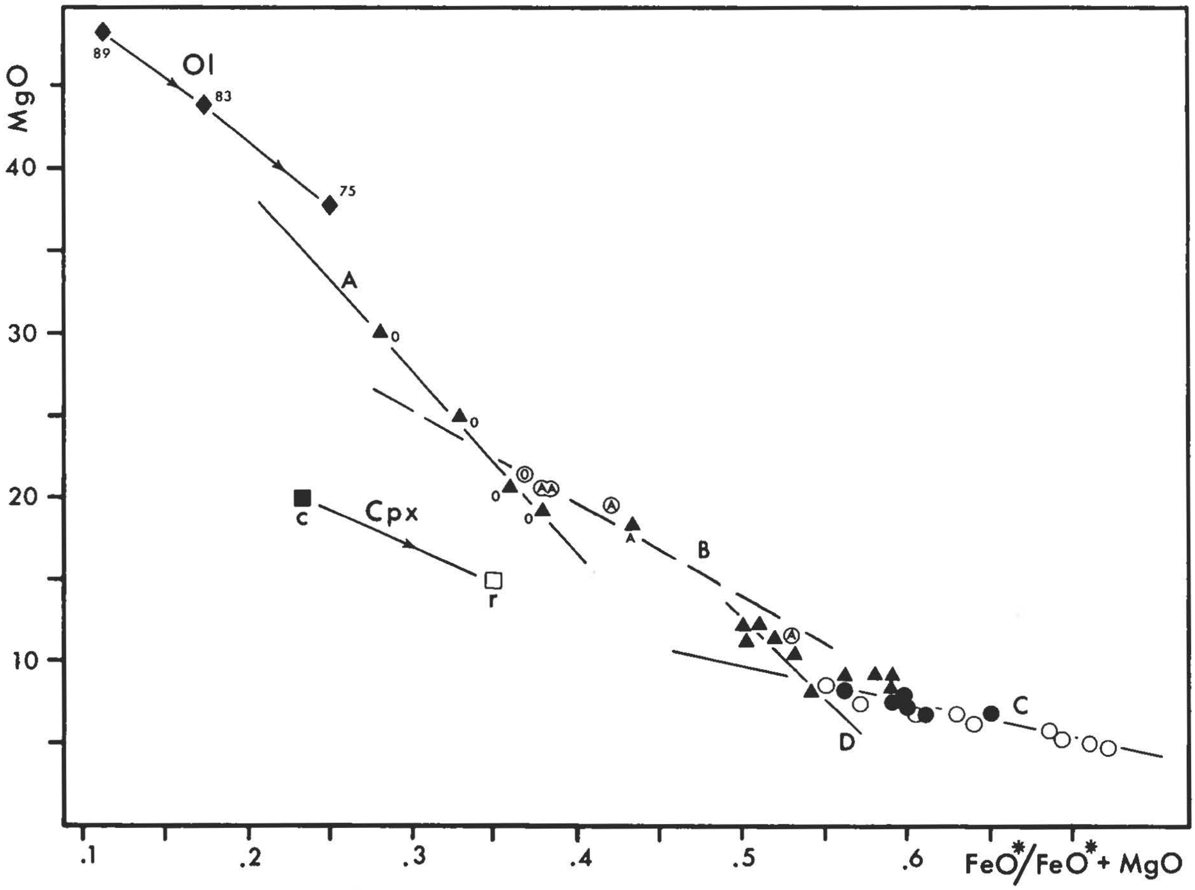


Fig. 20. MgO *vs.* FeO*/FeO* + MgO diagram showing the picrite and tholeiite lava groups and possible evolutionary trends (see discussion in the text). All compositions recalculated volatile-free and symbols as in Fig. 17 with O and A denoting oceanite and ankaramite respectively. *Trend A:* Oceanite trend. *Trend B:* Ankaramite trend. *Trend C:* Tholeiite trend and *Trend D:* Ol-tholeiite trend. Olivine and clinopyroxene compositions from the picrites shown. Numbers adjacent to olivine points indicate Fo-contents, and clinopyroxenes cores and rims are indicated.

Table 4. Selected possible primary picrite liquids for comparison.

	1	2	3	4	5	6	7	8	9	10
SiO_2	47.28	47.46	46.7	46.93	46.4	45.87	46.43	47.70	46.52	48.7
TiO_2	2.12	1.62	2.0	1.53	.78	1.22	1.78	2.04	.41	2.59
Al_2O_3	7.56	9.11	8.5	6.75	11.1	10.54	10.50	12.13	13.78	6.93
FeO§	12.26	11.76	12.12	10.67	10.6	11.26	11.47	11.55	8.45	11.8
MnO	.21	.13	.2	.18	.19	.18	.18	.18	.15	.16
MgO	20.47	20.05	20.9	23.78	20.3	19.2	18.76	14.05	18.27	19.6
CaO	8.43	7.92	7.4	8.85	9.5	10.0	8.37	9.32	6.94	6.97
Na_2O	1.27	1.39	1.6	.68	1.07	1.42	1.82	2.18	1.33	1.32
K_2O	.21	.35	.3	.43	.08	.13	.50	.60	.01	1.53
P_2O_5	.19	.21	.2	.18	.09	.14	.18	.21	.02	.39

All analyses recalculated to 100% of the listed elements and with all Fe as FeO.
1: Average of 5 oceanites and ankaramites from the lower lavas of East Greenland.
2: Picrite basalt flow 1840, Nanawale Bay, Kilauea, Hawaii (Cross 1915, p. 44).
3: Average oceanite, Hawaii (MacDonald 1968, Table 8, column 1).
4: Picrite lava (W-1), Deccan (Krishnamurthy & Cox 1977, Table 5, column 1).
5: Average groupe II picrite, Baffin Island, Canada (Clarke 1970, Table 1, column 3).
6: Average groupe II picrite, Svartenhuk, West Greenland (Clarke 1970, Table 1, column 4).
7: Olivine phyric center of dike (Re 604) Piton de Neiges, Réunion (Upton & Wadsworth 1972, Table 1, column 7).
8: Chilled margin of previous (Upton & Wadsworth 1972, Table 1, column 9).
9: Lava from picrite shield (RE-78), Reykjaness, Iceland (Jakobsson et al. 1978, Table 3, column 3).
10: Average picrite, Nuanetsi (Cox & Jamieson 1974, Table 8, column B).

junction of trends (C) and (D) from the Vandfaldsdalen Formation which is a chilled aphyric olivine tholeiite from a neck in the sediments at the inlier locality (Fig. 1). A genetic link between the parental picrite and olivine tholeiite liquid may exist at depth but does not seem possible at lower pressures. However the poor preservation of the Lower Basalts is a servere hindrance to any detailed fractionation calculations and a more precise identification of the parental liquids.

Conclusions

The observations described above confirm and amplify the picture of the depositional environment arrived at previously by Soper et al. (1976a). It shows that towards the end of the Mesozoic the southern part of the Blosseville Kyst began to sink and became the site of a depositional basin, which received shallow water marine sediments. Relative uplift in neighbouring areas occurred in late Paleocene, when coarser sediments made their appearance and were closely followed by volcanogenic material which marks the onset of volcanism. Although the bulk of the Blosseville Group volcanics are subaerial, marine horizons and important hyaloclastites up to 100 m in thickness in the mapped area, show that sinking still occurred but was largely compensated by the deposition. In the Ryberg-Nansen Fjord area immediately adjacent to the east however, volcanism was more restricted and considerable thicknesses of water lain tuffs (in part equivalent to the lavas of the area in question) were deposited.

Likewise our observations bear out those of Brooks et al. (1976) that the lava flow was much less voluminous in these Lower Basalts than higher up in the Plateau Basalts and was much more variable petrographically. Palaeomagnetic directions are generally similar throughout the sampled lava pile conforming the earlier results of Faller (1975). However, there still remains a possibility that normally magnetized material may be present in the hitherto unsampled lower part of the Plateau Basalts but this possibility has been considerably reduced and the Plateau Basalts are still believed to have formed entirely in the short (3 Ma) reversed period prior to ocean floor anomaly 24.

The detailed mapping shows that picrites make up only a small proportion of the Lower Basalts, but they are of importance due to the significance attached to such rock types in some petrogenetic schemes (e.g. O'Hara 1965). The presence of picrites in the lower horizons in this province amplifies the similarities already noted to other areas of plateau basalt volcanism, such as West Greenland, Deccan and Lebombo-Nuanetsi. Picritic lavas are also found in tholeiitic volcanic islands (e.g. Hawaii, Réunion) while in Iceland magmatic cycles are initiated by small picritic shields succeeded by more voluminous olivine tholeiite and tholeiite shield and fissure eruptions. Similarly, the Lower Basalts of East Greenland, which are believed to represent early stages of ocean rifting (Brooks 1973, Nielsen 1975, 1978, Soper 1976a + b) show many similarities to ophiolite complexes, where tholeiitic picrites also occur (e.g. Gass 1958) and there is evidence for an overall picritic composition (Elthon 1979).

The work described here considerably increases our knowledge of the Kangerdlugssuaq and Blosseville Group, but much work still remains before this survey can be coordinated with that of the Geological Survey of Greenland in the Scoresby Sund district. It is recommended that further work extends the field of observation to the NE and concentrates on the collection of fresher material from the Lower Basalts which may possibly be encountered in this direction or inland.

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Appendix

Preparation of topographic map of the Miki Fjord – I. C. Jacobsen Fjord area at 1:20 000.

The topographic map that forms the basis of the geological map of the Lower Lavas in Plate 1 has been prepared from vertical aerial photographs (diapositives) at about 1: 27 000 which were made available by Professor A. R. McBirney, University of Oregon. The geology was mapped on the photographs during several field seasons and subsequently transferred to the topographic map, which has been reduced to 1:40 000. A second order photogrammetric plotting instrument, Aviograph B8 (Wild) at the Institut for Landmåling og Fotogrammetri, Danmarks Tekniske Højskole was used for continuous drawing of the topography (see Dueholm 1979).

The precision of the map prepared by this method is highly dependent of the quality of the ground control, which in the area in question has proved to be very poor. Fixed points given on existing maps of the area have been used in an attempt to perform a combined geodetic/photogrammetric triangulation. However, the errors obtained during least squares refinement of models were so large and unsatisfying that the present map has been prepared without any triangulation. Baselines in the fjords at elevation 0 m were transferred from the existing maps at 1:250 000 to the maps prepared from the aerial photographs and at least 3 fixed points in each model, arrived at using the baselines in the fjords, were transferred to the adjacent models.

It is very difficult to give any exact data for the precision of the map, but an accumulated error of 8 m in elevation through 5 models from Miki Fjord to Watkins Fjord was found. Within each model the relative error is believed to be much smaller. This is confirmed by the elevations obtained for the peaks along the fjord, which compare well with the heights given in the existing maps, whereas large variations were observed in the inland area. During the fieldwork profiles were measured with pocket aneroids and deviations of no more than ± 5 m from the heights on the topographic map were observed. Longitude and latitude have been transferred from the existing maps (sheet 68 Ø 3 Geodætisk Institut, København).

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Meddelelser om Grønland, Geoscience

1979.

1. C. K. Brooks:
»Geomorphological observations at Kangerdlugssuaq, East Greenland«. 24 pp.

The Kangerdlugssuaq area is mainly comprised of two contrasting rock groups: on the one hand the easily-eroded lavas and sediments of late Mesozoic to early Tertiary age and on the other the highly resistant Precambrian gneisses. Intermediate between these two types in terms of behaviour with respect to erosion are the Tertiary plutonic complexes and the basaltic areas along the coast which have been intruded by intense dyke swarms.

In the late Mesozoic the area was a peneplain, and low relief apparently persisted throughout the volcanic episode as there is good evidence that the lava plateau subsided during its formation. During this period ocean-floor spreading gave rise to the embryonic Danmark Stræde. Shortly after the volcanic episode the Kangerdlugssuaq area became the centre of a massive domal upwarping which has been a dominant feature of the land-forms up to the present day. The original surface of the dome has been reconstructed on the basis of topographic and geological evidence to show that it was elliptical in form with a major axis of at least 300 km in length and a height above present sea-level of about 6.5 km. However, subsequent isostatic effects are not considered in deriving these figures. The updoming is estimated to have occurred about 50 m.y. ago.

Several kilometres thickness of sediments and lavas were eroded off this dome at an early stage exposing the gneissic core, which still stands in alpine peaks up to about 2.7 km altitude in the central part, and dumping ca. 50000 km^3 of sediment on the continental shelf. The erosion was effected by a radial, consequent drainage system, relicts of which can still be found. Kangerdlugssuaq itself may owe its origin to a tectonic line of weakness formed in response to doming, but there are also good arguments for its being purely erosional. The erosion of the dome was probably fluviatile but all trace of this stage has been obliterated by the subsequent glaciation.

In the period between the Eocene and the early Miocene, possibly around 35 m.y. ago, the entire area underwent epeirogenic uplift raising the undeformed parts of the original lava plateau to around 2.5 km above sea-level. At present this plateau is undergoing dissection from the seaward side, but considerable areas are still preserved under thin, horizontal ice-caps.

A brief description of the various types of glaciers, an impermanent, ice-dammed lake and the areas of ice-free land is given. In the Pleistocene, the Kangerdlugssuaq glacier was considerably thicker than at the present time and extended far out over the shelf, excavating a deep channel here. Finally some observations on the coastlines are presented.

1979

2. Sven Karup-Møller and Hans Pauly:
»Galena and associated ore minerals from the cryolite at Ivigtut, South Greenland«. 25 pp.

Silver- and bismuth-rich galena concentrates have been produced for more than 70 years as a byproduct in the dressing of the crude cryolite from Ivigtut, South Greenland.

Concentrates from the years 1937 to 1962 contained from 0.44 % Ag and 0.74 % Bi to 0.94 % Ag and 1.93 % Bi. Conspicuous increases in the content of these elements appeared twice within this time interval, namely in 1955 and in 1960. Thus it seems that crude cryolite from specific areas within the mine carried galena high in silver and bismuth. This promoted a detailed study of the common Ivigtut galena and associated sulphides.

An outline of the geological setting of the deposit is given. The deposit is divided into two main bodies – the cryolite body and the quartz body. Both are subdivided into units characterized by their content of siderite and fluorite. Galena samples from these units and from rock types surrounding the deposit have been studied.

Galena from units characterized by siderite follows the compositional pattern found in the galena concentrates, whereas the sparse galena mineralizations from units characterized by fluorite contain much smaller amounts of silver and bismuth, less than 0.2 %. However, within the fluorite-bearing units, two peculiar parageneses reveal high contents of silver and bismuth expressed by the presence of particular minerals such as matildite-aikinite and gustavite-cosalite respectively.

Further trace element studies on selected galena samples emphasize Sn and Te as chemically characteristic of the galena and of the sulphide-carbonate phase of the deposit.

The temperature of formation of the main part of the deposit is placed at 550–400°C, and between 300 and 200°C for certain parts of the fluorite cryolite and the fluorite zone.

1980

3. John C. Rucklidge, Charles Kent Brooks and Troels F. D. Nielsen: »Petrology of the coastal dykes at Tugtilik, southern East Greenland«. 17 pp.

Dolerite and lamprophyre dikes from Tugtilik in the southern part of the onshore exposure of the East Greenland coastal dike swarm are described. The dolerites, which are earlier, are similar to other tholeiites from the dike swarm and the plateau basalts and also to many Icelandic tholeiites. Transitional varieties have been identified from the Angmagssalik district. The lamprophyres have a nephelinitic composition and are rich in phenocrysts and xenocrysts. In one case, abundant low pressure inclusions occur. Rocks identical to these lamprophyres have not previously been described from Greenland but are well known, for instance, in the African Rift.

1981

4. Barbara H. Scott: »Kimberlite and lamproite dykes from Holsteinsborg, West Greenland«. 24 pp.

Numerous kimberlite and lamproite dykes occur to the south and east of Holsteinsborg in Central West Greenland. This paper gives details of the petrography, mineral chemistry, age relations and geochemistry of the dykes.

The kimberlites are composed of macrocysts of olivine, phlogopite, rare ilmenite and garnet in a matrix of olivine, phlogopite, diopside perovskite, spinel, serpentine, carbonate and apatite. They can mostly be classified as clinopyroxene-phlogopite hypabyssal kimberlites. Mantle-derived inclusions are found in some of the dykes and include lherzolites, wehrlites, harzburgites and, most commonly, dunites. Both coarse and porphyroclastic inclusions occur. Garnet-granulites and eclogites, although rare, are present.

The lamproites have variable mineral assemblages and textures but the main constituents are phenocrysts of pseudoleucite, olivine, phlogopite and clinopyroxene set in a groundmass of phlogopite, potassic richterite, diopside, pseudoleucite and potassium feldspar. The mineralogy of these dykes is a reflection of unusual ultrapotassic, magnesian whole-rock compositions.

Meddelelser om Grønland, Man & Society

1980

1. Isi Foighel: »Home Rule in Greenland«. 18 pp.

By Danish Act of 29 November, 1978, Home Rule was established in Greenland within the Unity of the Danish Realm. The Act was prepared by a Danish-Greenlandic Commission.

The Act on Home Rule is discussed with special reference to the historical and political background.

By the establishing of Home Rule, powers which hitherto had been vested in the Danish Government and Parliament were transferred to the Greenlandic authorities. The scope of these powers and their legal characteristics are outlined.

Home Rule makes no changes in the international competence or in the relationship between Greenland and the international or interregional organizations. Greenland's membership of the EEC creates some special problems.

The question of ownership of the natural resources was of great importance in the debate in the Home Rule Commission. The Act contains a solution which seeks to give the Danish Government as well as the Greenlanders equal rights in the decision-making procedure, in the administration, and in the sharing of the revenue.

Furthermore, the financing of the Home Rule system, the language problem, the organizing of fishing and trade are being dealt with.

1981

2. H. O. Bang & Jørn Dyerberg:
»The Lipid Metabolism in Greenlanders.« 18 pp.

In the years 1970, 1972 and 1976 the blood lipids in Greenlanders living in the Umanak district and the composition of their food, especially that of their dietary fat were examined in an attempt to explain the rarity of ischaemic heart disease in Greenlanders.

Decreased concentrations of serum cholesterol, triglycerides, low density and very low density lipoproteins and increased concentration of high density lipoprotein in male Eskimos were found. The fatty acid pattern of the serum lipids was different from that of Danes. Especially remarkable was the high concentration of eicosapentaenoic and low concentration of arachidonic acids compared with Danes. The serum lipids of Greenlanders living in Denmark were found similar to that of Danes.

The Eskimo food was found rich in protein and poor in carbohydrate. The fatty acid pattern of the dietary fat was similar to that found in their blood.

We could show – by in-vitro experiments – that eicosapentaenoic acid can act as precursor for thrombocyte active prostaglandins instead of arachidonic acid in Europeans, giving rise to an anti-aggregatory prostaglandin, probably PGI_3, but to no pro-aggregatory thromboxane. This causes a shift in the balance towards the anti-aggregatory – and consequently anti-thrombotic – side.

During a fourth expedition in 1978 to the Umanak district our theory from the in-vitro experiments was confirmed by in-vivo observations in the Eskimos. We found decreased platelet aggregability and increased bleeding time.

The rare incidence of ischaemic heart disease and other thrombotic diseases in Greenlanders can be explained by their low serum lipids, their high content of α-lipoprotein and – probably most important – by their special serum fatty acid pattern giving rise to a decreased platelet aggregability and consequently a decreased tendency to thrombosis.

1981

3. Jens C. Hansen:
»A survey of human exposure to mercury, cadmium and lead in Greenland.« 36 pp.

Analyses of lead, mercury and cadmium in tissues from seal and fish have shown high concentrations of mercury and cadmium. A toxicological evaluation of the actual concentrations has revealed that in some districts of Greenland, the population may exceed the provisionally tolerable weekly intake (WHO, 1977) of cadmium with from 2 to 20 times and of mercury with from 2 to 40 times. Lead intake was below the provisionally tolerable weekly intake. As these high dietary intakes might have adverse health effects in the consumers, an investigation was undertaken in order to evaluate the human exposure as reflected in blood and hair concentrations. Five districts in Greenland and a control group of Greenlanders living in Denmark have been examined.

A total of 144 persons (including the control group) have participated.

Samples were taken in September and October 1979.

Mercury. Strong evidence was found for a connection between mercury exposure and seal-eating. The mercury levels found indicate that the exposure calculated from food analyses is overestimated, but still the most highly exposed groups are on an exposure level where subclinical effects may be anticipated.

Cadmium. In general the blood cadmium concentrations are higher in Greenland than in Denmark, but the groups in Greenland were found to be very similar. In hair concentrations no differences between the groups were observed. Separation of data on blood cadmium between smokers and non-smokers showed the differences between the mean values to be highly significant. In spite of the presumably higher dietary intake, no influence on blood concentrations could be observed. Contrary to blood, hair reflected dietary intake but not smoking. The results indicate that neither blood nor hair as only parameter reflects total cadmium exposure.

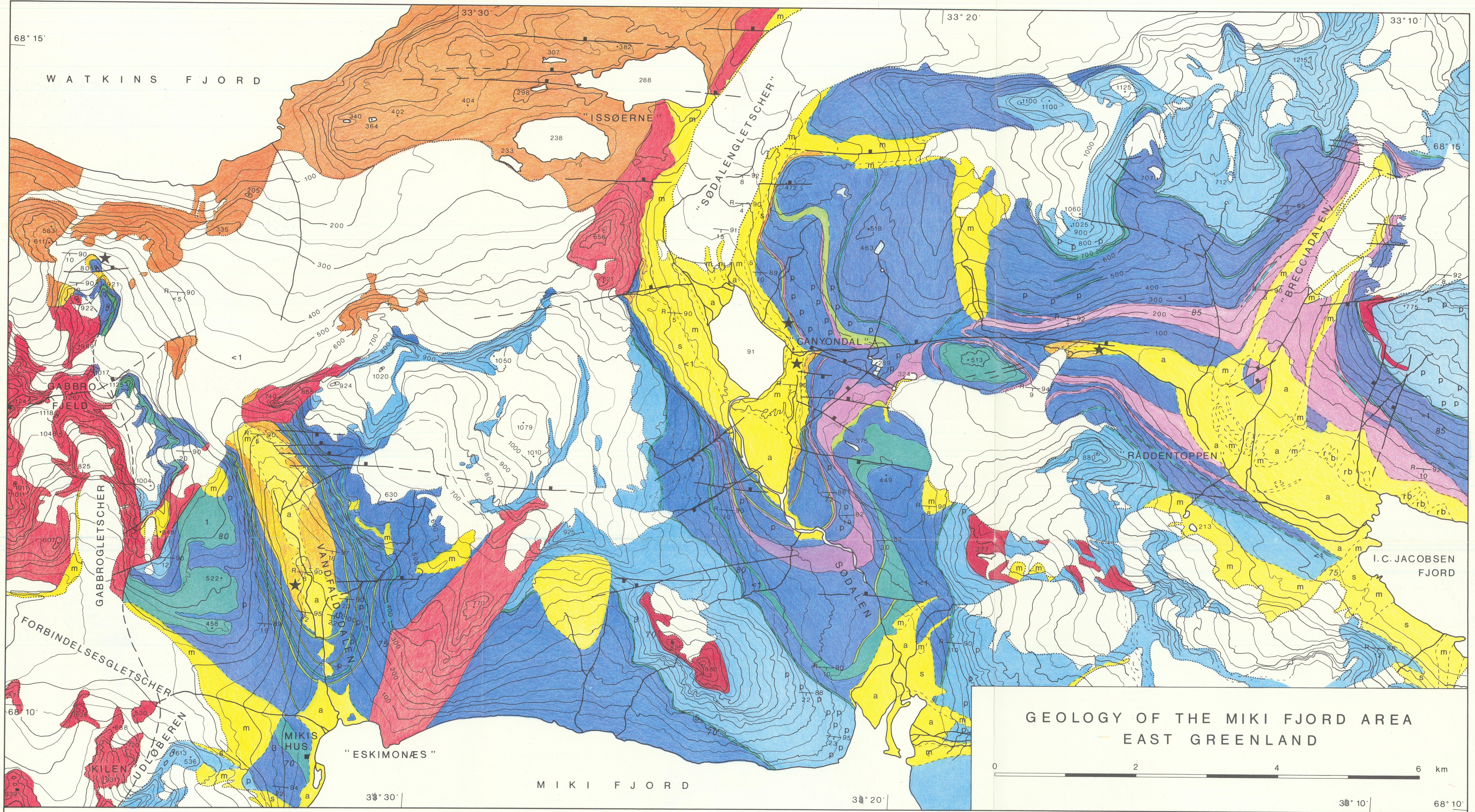
A positively significant correlation was demonstrated between lead and cadmium concentrations in hair, but not in blood.

Lead. Blood concentrations were found to be at the same level as found in Western European countries, but all to be below the limit of 35 μg/100 ml which is the upper individual limit in the EEC-countries.

The highest blood-values were found in the two northern districts, where the level is significantly higher than the level in the two southern districts. The difference was found to be related to varying eating habits, also smoking habits were found to be reflected in blood and hair. Blood was found to be a better index medium than hair for evaluating lead exposure.

Selenium. A potentially toxicity-modifying micronutrient selenium was determined in a limited number of hairsamples. No evidence of a high selenium intake could be provided.

Further research is needed especially concerning mercury exposure. Concerning lead and cadmium, the levels found are well below what is regarded a critical level. As, however, the concentrations are on the same level as those found in industrialized countries, follow-up studies seem to be needed in order to observe trends of exposure.



GEOLOGY OF THE MIKI FJORD AREA EAST GREENLAND

QUATERNARY
🟨 a:alluvium, m:moraine
rb:raised beach, s:scree

GABBRO INTRUSIONS
🟥 major sills
🟥 Skaergaard intrusion and macrodikes

MIKIS FM.
🟦 subaerial lavas
p:picrites (oceanites and ankaramites)

VANDFALDSDALEN FM.
🟦 subaerial lavas
🟪 hyaloclastites
🟩 breccias
🟨 tuffs, volcanogenic sediments

SEDIMENTS
🟧 Kangerdlugssuaq Group and Schjelderup Member

BASEMENT
🟧 undifferentiated

★ Fossil localities

Fault, direction of dip indicated
Inferred fault or boundary
Dip of bedding
Regional dip
5 Relative dike intensity
70 Average northerly dike dip

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Chapter (part): Wolfe, J. A. & Hopkins, D. M. 1967. Climatic changes recorded by Tertiary landfloras in northwestern North America. – In: Hatai, K. (ed.), Tertiary correlations and climatic changes in the Pacific. – 11th Pacific Sci. Congr. Tokyo 1966, Symp.: 67–76.

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1981

Meddelelser om Grønland

Bioscience
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