Re-appraisal of the Ikermit supracrustal suite of the Ketilidian border zone in South-East Greenland

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Previous workers in the Ketilidian orogen of South-East Greenland reported extensive outcrops of acid volcanic rocks and related gneisses which they described as the Ikermit supracrustal suite. The suite was regarded as a favourable host for sulphide mineralisation. New field and petrographic data show that the 'acid volcanic rocks' from the type locality on Ikermit island are entirely Archaean orthogneisses with abundant, but local, mylonites. These gneisses and mylonites occur within the wide border zone between the Ketilidian orogen and the Archaean foreland to the north. The name 'Ikermit supracrustal suite' should be abandoned.

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The Early Proterozoic Ketilidian orogen (*c.* 1750–1850 Ma) and its foreland of Archaean high-grade gneisses occupy the extreme south of Greenland (Fig. 1; Allaart, 1976). Recent interest in the Ketilidian of South-East Greenland was attracted by a statement by Andrews *et al.* (1971, p. 37) who emphasised that: "... the considerable thickness of gneisses derived from acid volcanic successions are favourable hosts for sulphides and that geologically the area mapped is more likely to yield ore minerals than most of the gneissose terrains so far described from Greenland".

No field investigations had been conducted along most of the south-east coast of Greenland since 1970 and confirmation of the existence and extent of the acid volcanic rocks and related gneisses was a prime objective of the SUPRASYD programme beginning in 1992 (Nielsen *et al.*, 1993). The lithological and chronological conclusions and the evaluation of the economic potential by Andrews *et al.* (1971, 1973) were largely based on supposedly well-preserved 'acid volcanic rocks' on Ikermit island, a related 'flat-lying gneiss complex' on the mainland to the west of Ikermit and a lithological correlation with extensive areas of Ketilidian supracrustal gneisses further south (Figs 1,2). The correlation with the supracrustal rocks in the south was subsequently discarded by Pedersen *et al.* (1974), but 'acid volcanic rocks' and gneisses derived therefrom were still believed to be of major importance in the supracrustal successions and paragneisses in the Ketilidian orogen of South-East Greenland.

The Ketilidian orogen of South Greenland

The Ketilidian orogen has been described in some detail by Allaart (1976) and more recently reviewed by Kalsbeek *et al.* (1990). Traditionally, the orogen has been divided into four broad east–west zones:

(a) a Border Zone in the north consisting of the Archaean foreland which, in the west, is overlain unconformably by Ketilidian sedimentary and mafic volcanic rocks; the underlying Archaean gneisses are cut by Early Proterozoic dolerite dykes which are increasingly metamorphosed and deformed towards the south; these dykes are correlated with the 'MD' dykes in the Archaean block further north (Bridgwater *et al.*, 1976); dolerite dykes which are presumed to be part of the MD swarm are found cutting the Archaean orthogneisses in the coastal outcrop of the foreland in South-East Greenland; the dolerite dykes are cut by appinite dykes which occur in the foreland gneisses up to *c.* 80 km north of the bound-

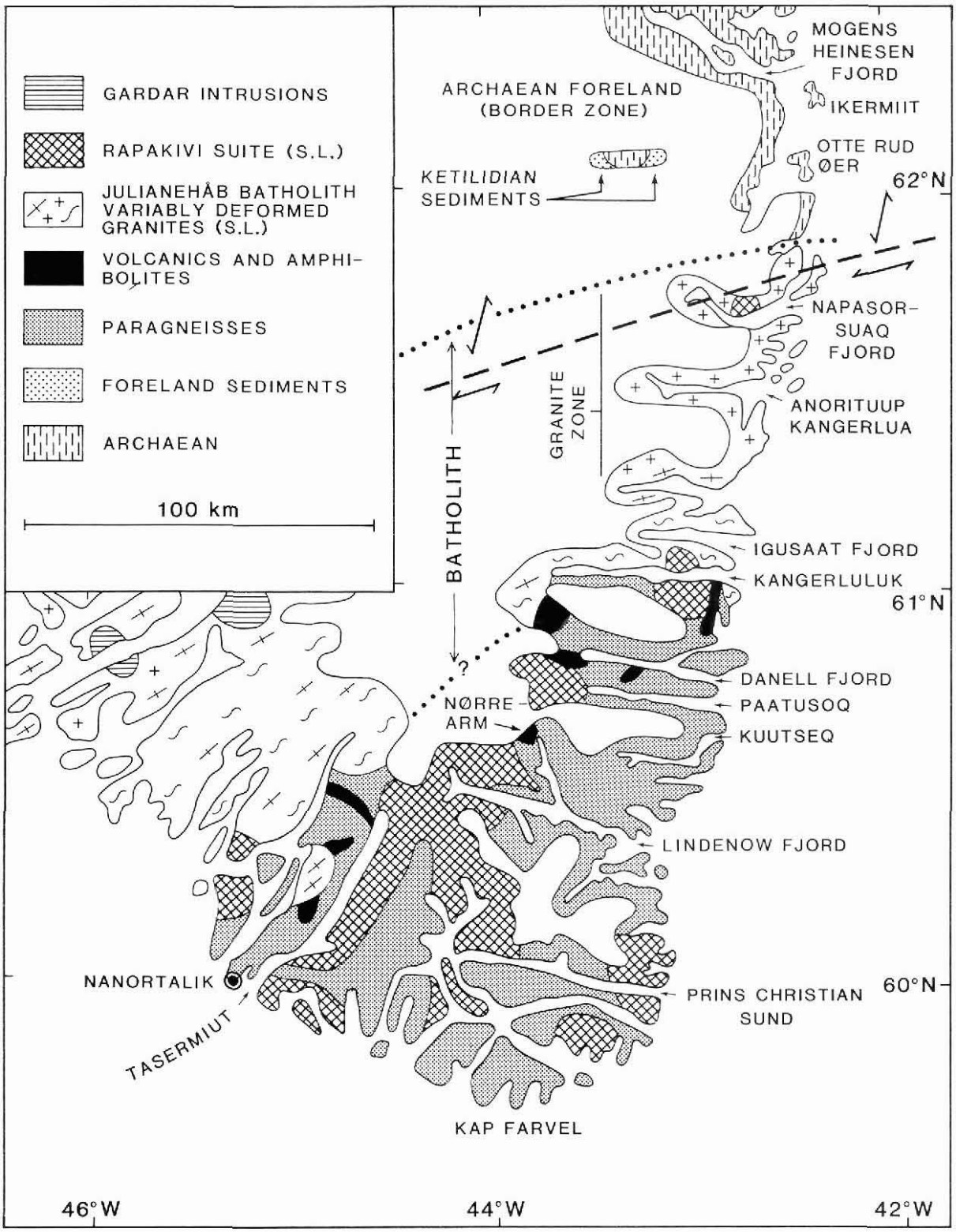

Fig. 1. Outline geological map of the south-east coast of Greenland between Mogens Heinesen Fjord and Kap Farvel. *Heavy dashed line:* presumed tectonic boundary between the Archaean foreland and the Ketilidian orogen (after Nielsen *et al.*, 1993).

ary of the Ketilidian orogen; the appinite dykes are presumed to be members of the abundant suite in the Ketilidian orogen itself;

(b) a Granite Zone with a wedge-shaped outcrop which widens from *c.* 50 km on the east coast to *c.* 150 km on the south-west; the zone comprises variably deformed granitic to dioritic plutonic rocks and a range of hornblende-bearing dykes of the appinite suite (*sensu* Pitcher, 1993); Chadwick *et al.* (1994) provide further details of the granite zone and they recommend that it be called the

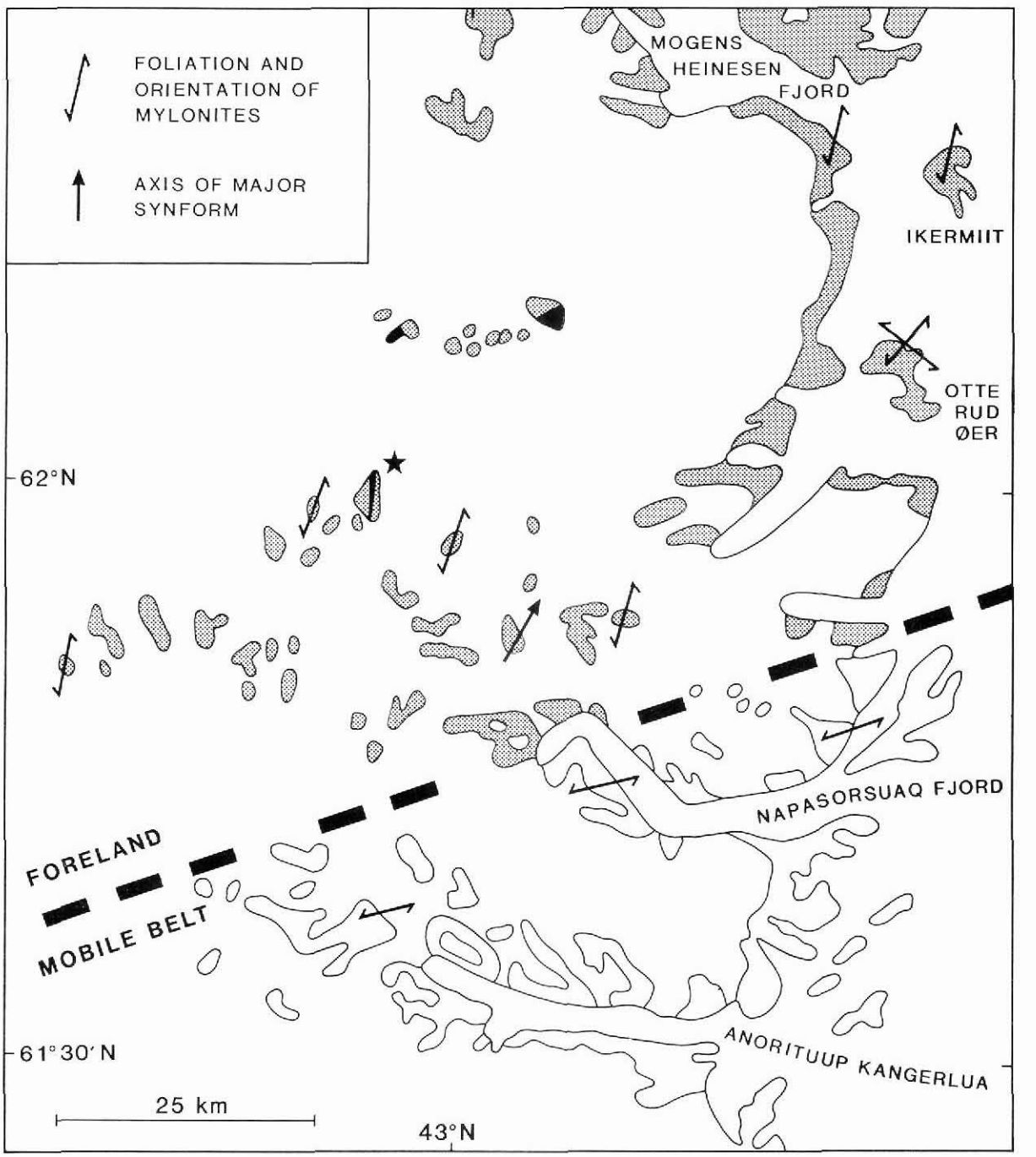

Fig. 2. Outline geological map of the area between Mogens Heinesen Fjord and Anorituup Kangerlua. *Grey:* Archaean orthogneisses and supracrustal rocks; *blank:* Ketilidian granite, syenite, granodiorite and related rocks; *black:* Ketilidian metasedimentary rocks; *star:* nunatak with weakly metamorphosed possible MD dolerite.

'Julianehåb batholith'; the central, western part of the batholith forms the foundation for the Gardar rift and its related alkaline dykes and plutons 1120–1300 Ma (Emeleus & Upton, 1976);

(c) a Folded Migmatite Zone comprising a range of deformed, psammitic-pelitic metasedimentary rocks, basaltic amphibolites and suites of appinitic dykes (*sensu* Pitcher, 1993); andalusite, cordierite, sillimanite and variable degrees of anatexis of the metasedimentary rocks indicate H*T* / L*P* metamorphism, but details of the structure of this zone remain largely unknown, particularly on the south-east coast;

(d) a flat-lying migmatite complex which occurs in the extreme south of the orogen; the zone is dominated by intensely migmatised pelites with broadly concordant sheets and discordant bodies of rapakivi granites, *c.* 1740 Ma.

Previous investigations of the Ketilidian orogen

Until the reconnaissance investigations of D. Bridgwater and his co-workers in the 1960s (Bridgwater & Gormsen, 1969; Bridgwater, 1970; Bridgwater *et al.*, 1973; Andrews *et al.*, 1971, 1973), the geology of most of the coast of South-East Greenland (Fig. 1) was largely unknown. The Ketilidian terrain between Mogens Heinesen Fjord and Prins Christian Sund was examined only during one boat-supported reconnaissance (Andrews *et al.*, 1971).

Andrews *et al.* (1971) identified little-deformed and little-metamorphosed 'acid volcanic rocks' on the southwest of Ikermit (Figs 1,2). The quartzo-feldspathic 'flat-lying gneiss complex' on the mainland west of Ikermiit appeared less deformed and metamorphosed and thus younger than the high-grade Archaean terrain to the north. The 'flat-lying gneiss complex' was also interpreted to have formed from 'acid volcanic rocks' and related sediments, and together with the 'acid volcanic rocks' on Ikermiit they were collectively defined as the 'Ikermit supracrustal suite' (Allaart, 1976). The 'acid volcanic rocks' and possible porphyries on Ikermiit were thought to have been transformed locally into grey quartzo-feldspathic gneisses similar to those of the 'flat-lying gneiss complex'.

The 'flat-lying gneiss complex' on the mainland is cut by 'green dykes' which were interpreted as metamorphosed Proterozoic MD dykes. These relationships led Andrews *et al.* (1971) to conclude that the 'acid volcanic rocks' and the gneisses derived therefrom were older than the dykes (Late Archaean or Early Proterozoic) and that they pre-dated the Ketilidian events, but post-dated the Archaean events. Pedersen *et al.* (1974) proposed that the 'acid volcanic rocks' represented an early Ketilidian magmatic event which predated the peak of Ketilidian activity by as much as 700 Ma.

The 'flat-lying gneiss complex' in the Border Zone is separated from quartzo-feldspathic and siliceous supracrustal rocks further south (Fig. 1) by the Julianehåb batholith. Andrews *et al.* (1973) correlated the supracrustal rocks north and south of the batholith, but they described the supracrustal rocks to the south as "pelitic, psammitic and basic units ... within grey gneisses of uncertain origin". The description appears to place less importance on the volcanic component in the supracrustal rocks south of the batholith, and it raises questions concerning the lithological correlation with the 'Ikermiit supracrustal suite'. Andrews *et al.* (1971), however, suggested a broad correlation between the 'acid volcanic rocks' of the Border Zone, the batholith and the supracrustal gneisses to the south. This correlation indicates an Archaean age for the supracrustal rocks in the south.

Isotopic dating of the acid volcanic rocks and the presumed related gneisses from north and south of the Julianehåb batholith by Pedersen *et al.* (1974) failed to confirm the correlation. Their results showed that the 'acid volcanic rocks' on Ikermiit are Archaean, i.e. 2665 ± 75 Ma (recalculated by Kalsbeek *et al.*, 1990, with λ ^{87}Rb $1{\cdot}42 \times 10^{-11}a^{-1}$), and the quartzo-feldspathic and siliceous gneisses south of the batholith were confirmed as Ketilidian, *c.* 1810 Ma.

The Border Zone in South-East Greenland

Ikermiit and Otte Rud Øer

We found neither acid volcanic rocks nor gneisses derived from such rocks on Ikermiit, although we were equipped with field maps from the earlier reconnaissance investigation. Areas on southern Ikermiit specifically marked as 'acid volcanic rocks' proved to be dominated by grey orthogneiss. The grey gneiss contains scattered inclusions of gabbro and leucogabbro(?), amphibolite and banded gneiss and is closely similar to the Archaean gneisses at Tingmiarmiut weather station to the north (north of area shown in Figs 1,2). Shear zones with mylonites are common on Ikermiit. In hand specimens the mylonites could be misinterpreted as little-deformed volcanic rocks. Mylonites with porphyroclasts of feldspar, in particular, resemble porphyritic volcanic rocks. The shear zones are cut by undeformed irregular sheets of granite and aplite.

The islands of Otte Rud Øer, 25 km further south, are comprised mainly of similar gneisses, including coarse-grained granodiorite *s.l.* Some of the gneisses there have a white 'bleached' aspect with 'blebby' mica textures. This 'blebby' texture may have formed by retrogression of granulite facies minerals. The leucocratic aspect of the

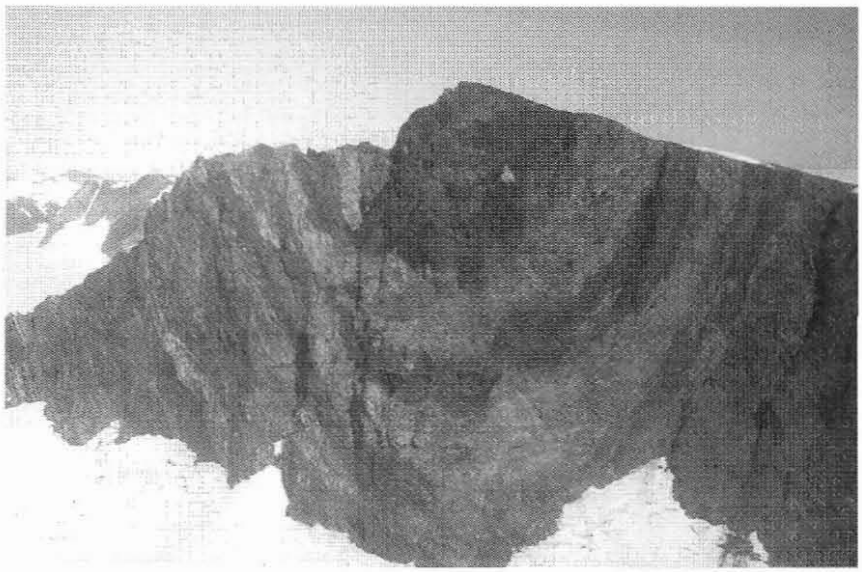

Fig. 3. Synform of Archaean orthogneisses and supracrustal layers in a nunatak north of Napasorsuaq Fjord. Height of cliff face is *c.* 500 m.

gneisses, especially on Otte Rud Øer, may be a function of intense shearing and fluid activity. Dark, foliated, granodioritic orthogneiss on the most southerly island of the Otte Rud Øer group contains enclaves of metagabbro and amphibolite like the gneiss on Ikermiit. The gneisses on the Otte Rud Øer are invaded by major masses of brecciated mafic diorite which we correlate with the appinite suite in the Julianehåb batholith immediately to the south.

Shear zones are abundant on the islands of the Otte Rud Øer group. Some appear to form a conjugate set of NW- and NE-trending structures up to 25 m wide. They contain mylonites, blastomylonites and ultramylonites. As on Ikermiit, the shear zones are cut by undeformed and irregular sheets of granite or aplite of possible Ketilidian age and by brown dolerite dykes of possible Gardar age.

Mainland

We made several helicopter surveys of the mainland west of Ikermiit in 1987 and 1992. Orthogneisses similar to those in the Archaean terrain in the Tingmiarmit region to the north were found on the south side of the mouth of Mogens Heinesen Fjord. Orthogneisses on the mainland due west of Ikermiit contain complexly folded, steeply dipping supracrustal units of amphibolite and sillimanite-quartz schist which weather to a rusty colour. The schists

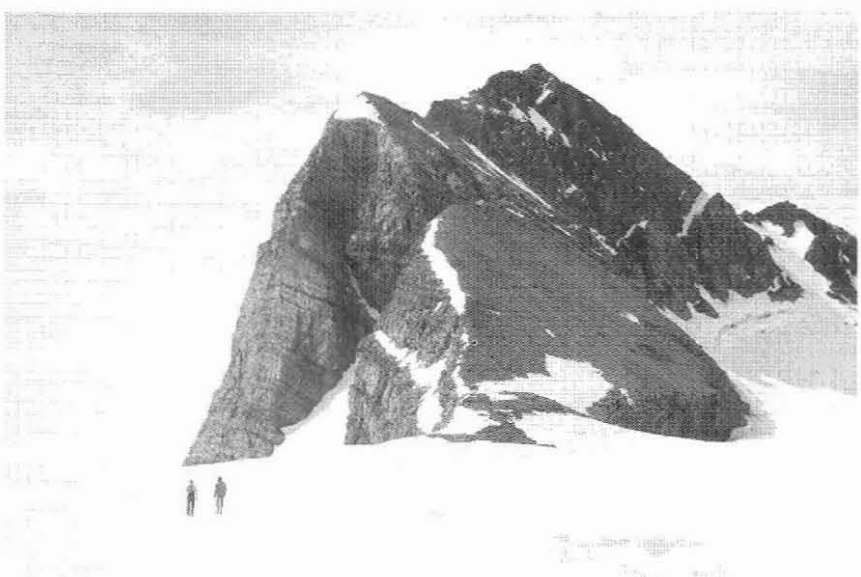

Fig. 4. Weakly deformed and metamorphosed north-dipping metasedimentary rocks in nunataks west of Ikermiit.

Fig. 5. Cross-bedded meta-arkose in the nunataks west of Ikermuiit.

are locally enriched in secondary carbonates and sulphides. These supracrustal rocks are closely comparable with the Archaean supracrustal rocks of the Tingmiarmit region (Bridgwater *et al.*, 1973). We have found similar supracrustal rocks as far south as Napasorsuaq Fjord (Fig. 2).

On the south of the entrance to Mogens Heinesen Fjord the orthogneisses are cut by 1–3 m wide 'green dykes' with many irregular apophyses and enclaves of host rock. The dykes are multiple injections with plagioclase or clinopyroxene phenocrysts and several contain ocelli typical of lamprophyric dykes. Moreover, their mineralogical and chemical compositions closely resemble those of calc-alkaline lamprophyres. This resemblance suggests that the green dykes are not part of the Early Proterozoic MD dyke swarm. Consequently, their greenschist facies assemblages may not be products of Ketilidian metamorphism in this part of the Border Zone. However, possible metamorphosed MD dykes which are cut by appinite dykes have been observed as far north as the Tingmiarmit region, but correlation with the Proterozoic MD dykes of West Greenland has not been proved.

The nunatak zone north, north-west and west of Napasorsuaq Fjord (Fig. 2) was visited during several reconnaissance flights in 1987 and 1992. As on Otte Rud Øer, the gneisses are characterised by intense shearing and bleaching, and in some places by intense localised reddening. Shear zones appear to form a conjugate set of NW- and predominant NNE–NE-trending structures. Some shear zones are several tens of metres wide and contain blastomylonites and mylonites.

Layers of amphibolites and metasedimentary rocks with rusty red weathering colours define a major synformal structure in one nunatak (Fig. 3). The axial trace trends NNE parallel to a major antiformal structure in the Tingmiarmit region. A single N-trending dolerite dyke was observed. It is not deformed, and although it is fractured, it is not significantly altered. This dyke may be a member of the MD swarm.

Well-preserved, weakly metamorphosed sedimentary rocks occur in nunataks *c.* 50 km west of Ikermiit (Kalsbeek *et al.*, 1990). They are several hundreds of metres thick (Fig. 4) and include cross-bedded meta-arkose and polymict conglomerates. Some of the finer grained quartzites contain carbonate and azurite. The sedimentary rocks dip to the north and are cut by undeformed sheets of granite and possible appinite and veins composed of quartz, titanite, epidote and green amphibole. Further west the sedimentary rocks appear to be intruded by a large body of granite. The conglomerates are poorly sorted and contain rounded to angular clasts up to 20 cm in size. The clasts include grey gneiss, grey granite, vein quartz and siliceous metasedimentary rocks. Some of the quartzites and polymict comglomerates display trough cross-bedding (Fig. 5). The conglomerates may correlate with similar conglomerates further south at the head of Danell Fjord (Nielsen *et al.*, 1993), conglomerates in inner Lindenow Fjord and in the Tasermiut area on the west coast. Alternatively, they may be equivalents of the Early Proterozoic Ilordleq Group in the Ketilidian border zone in West Greenland (Watterson, 1965). No firm conclusions can be drawn at this stage of our investigation.

The gneisses in the nunatak zone north of Napasorsuaq Fjord are intruded by a major complex of mafic dykes

and sills and felsic plutons. From the air dykes, sills and plutons appear little deformed; south of the fjord similar plutons are variably deformed and appear to form part of the Julianehåb batholith.

Petrography of the 'acid volcanic rocks' of Ikermiit

No outcrops of acid volcanic rocks were found on Ikermiit in 1987 or 1992. Thin sections of the samples of the 'acid volcanic rocks' that were dated by Pedersen *et*

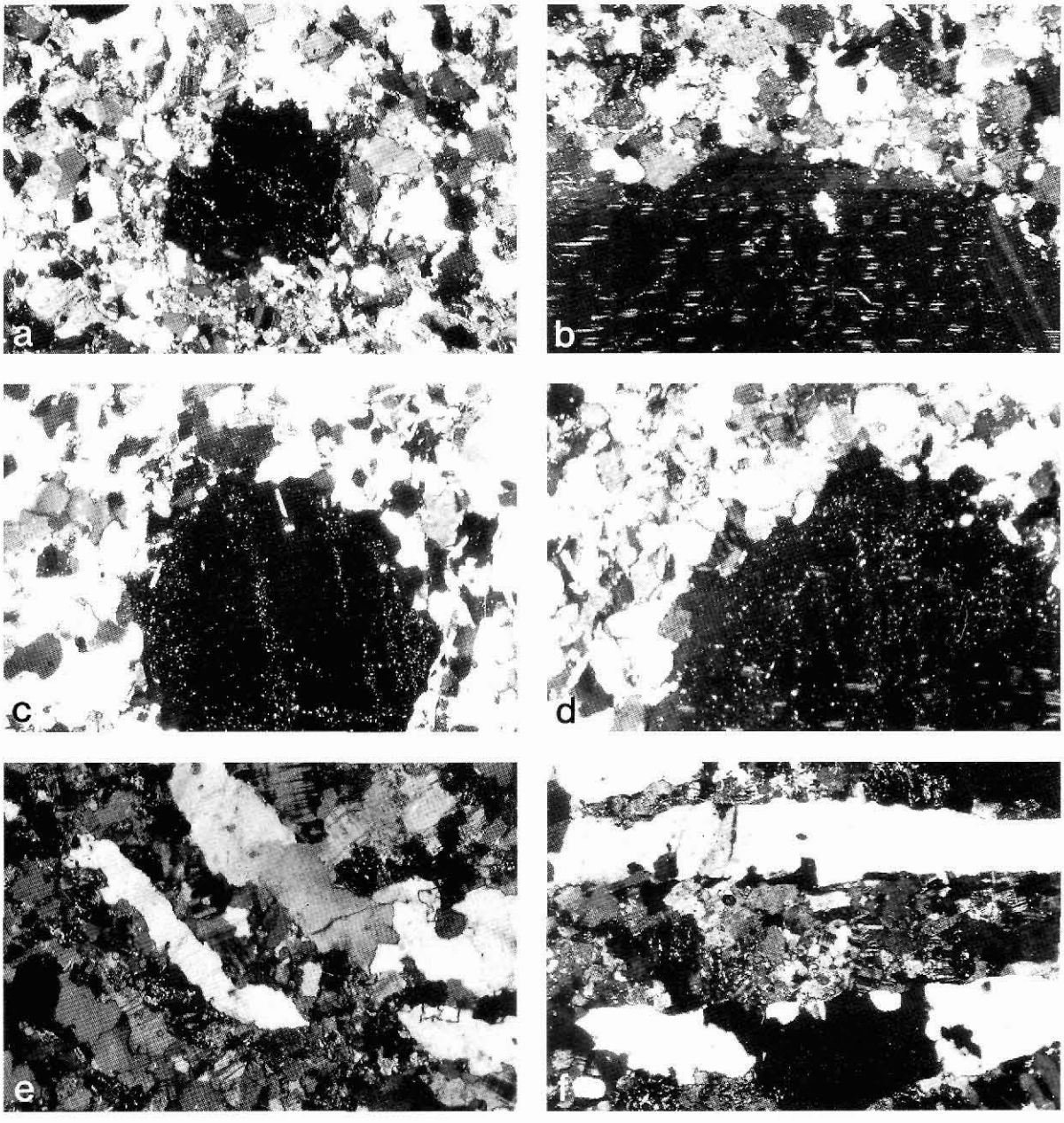

Fig. 6. Photomicrographs of textures in rocks originally described as acid volcanic rocks by Andrews *et al.* (1971). (a) Mylonite from Ikermiit, dated as 'acid volcanic rock', GGU 126181, by Pedersen *et al.* (1974); (b) mylonite from Ikermiit, dated as 'acid volcanic rock', GGU 126180, by Pedersen *et al.* (1974); (c) mylonite from shear zone in orthogneiss, Ikermiit, GGU 300179; (d) same as 6c; (e) mylonitised orthogneiss from Ikermiit dated as a 'transitional metavolcanic rock', GGU 126184 (Pedersen *et al.*, 1974), with ribbon quartz texture; (f) mylonitised orthogneiss from Ikermiit dated as 'acid volcanic rock' GGU 126185 (Pedersen *et al.*, 1974).

al. (1974) show that they are fine-grained and laminated, with broken and recrystallised grains of quartz, plagioclase, alkali feldspar, biotite and opaque minerals and probable original euhedral-subhedral zircon and apatite. Several samples which were described as metavolcanic rocks contain large feldspar grains which enclose matrix grains, i.e. a blastomylonitic texture (Figs 6a,b). A similar rock with similar textures was collected from a shear zone in orthogneiss on Ikermiit during reconnaissance in 1987 (Figs 6c,d). So-called 'transitional' and granitic gneisses derived from 'acid volcanic rocks' dated by Pedersen *et al.* (1974) have parallel ribbons of quartz with strong wavy extinction which is characteristic of dynamic recrystallisation in mylonites (Figs 6e,f). The term 'transitional' was used by Pedersen *et al.* (1974) for rocks which they believed were moderately deformed acid volcanic rocks. The precursors of the mylonites cannot be identified in thin section, but our field observations lead us to conclude that the 'acid volcanic rocks' dated by Pedersen *et al.* (1974) are mylonitised Archaean orthogneiss.

Discussion

Our field observations and petrographic data show that all of the areas on Ikermiit where Andrews *et al.* (1971) recorded 'acid volcanic rocks' are composed of orthogneisses which compare closely with those in the Archaean terrain to the north. Moreover, samples of 'acid volcanic rocks' collected by Andrews *et al.* (1971) and dated by Pedersen *et al.* (1974) are mylonitic or blastomylonitic rocks which compare closely with mylonitised orthogneiss that we collected from shear zones on Ikermiit. Finally, the 'flat-lying gneiss complex' on the mainland which was presumed by Andrews *et al.* (1971) to have been derived from acid volcanic rocks is composed of orthogneisses and supracrustal units which are similar to those in the Archaean terrain to the north. Some of the orthogneisses were intensely sheared and bleached by presumed Ketilidian effects within the Border Zone. Because of the lack of evidence of acid volcanic rocks or their gneissic equivalents in the Border Zone, we recommend that the term 'Ikermit supracrustal suite' be abandoned.

The Archaean age of the 'acid volcanic rocks' (2565 ± 75 Ma, Pedersen *et al.*, 1974; Kalsbeek *et al.*, 1990) is compatible with ages from the Archaean terrain to the north (Kalsbeek & Taylor, 1993).

At this stage in our investigations, we conclude that the Archaean terrain of the Ketilidian foreland extends as far south as Napasorsuaq Fjord (Fig. 1), but more data are required before the lithological and tectonic Ketilidian boundaries can be firmly established in South-East Greenland. We suggest that the lithological and structural boundaries of the Ketilidian orogen in South-East Greenland lie within the areas immediately north and south of Napasorsuaq Fjord. This view is supported by the apparent lack of significant deformation of granite plutons and mafic dykes and sills in the nunatak area north of Napasorsuaq Fjord and the occurrence of little-deformed sedimentary rocks in the nunataks west of Ikermiit. At present, we have insufficient information on the chronology and metamorphism of dykes to assess the Ketilidian metamorphism north of the lithological and structural boundary of the orogen.

Our field and petrographic data do not support the previous claim that a potential for sulphide mineralisation is indicated by acid volcanic rocks on Ikermiit and their correlation with supracrustal gneisses further south in the Ketilidian orogen. However, areas of sulphide mineralisation are indicated by the abundance of transition and precious metal in stream sediment samples in areas of metasedimentary rocks south of the Julianehåb batholith (Steenfelt *et al.*, 1993).

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