New insights on the north-eastern part of the Ketilidian orogen in South-East Greenland

Adam A. Garde, John Grocott and *Ken J.W. McCaffrey*

During a five week period in August–September 1998 the poorly known north-eastern part of the Palaeoproterozoic (*c.* 1800 Ma) Ketilidian orogen between Kangerluluk and Mogens Heinesen Fjord in South-East Greenland (Fig. 1) was investigated in continuation of recent geological research in other parts of the orogen. The north-eastern part of the orogen is remote from inhabited areas. It is mountainous and comprises a wide nunatak zone which can only be reached easily by helicopter. Furthermore, access to coastal areas by boat is difficult because many parts of the coast are prone to be ice-bound even during the summer months, due to wind- and current-driven movements of the sea ice.

Transport was provided by a small helicopter (Hughes MD 500) on charter from Greenlandair, which allowed effective reconnaissance of large areas and identification of localities where detailed ground traverses could be carried out. The expedition was based at the abandoned

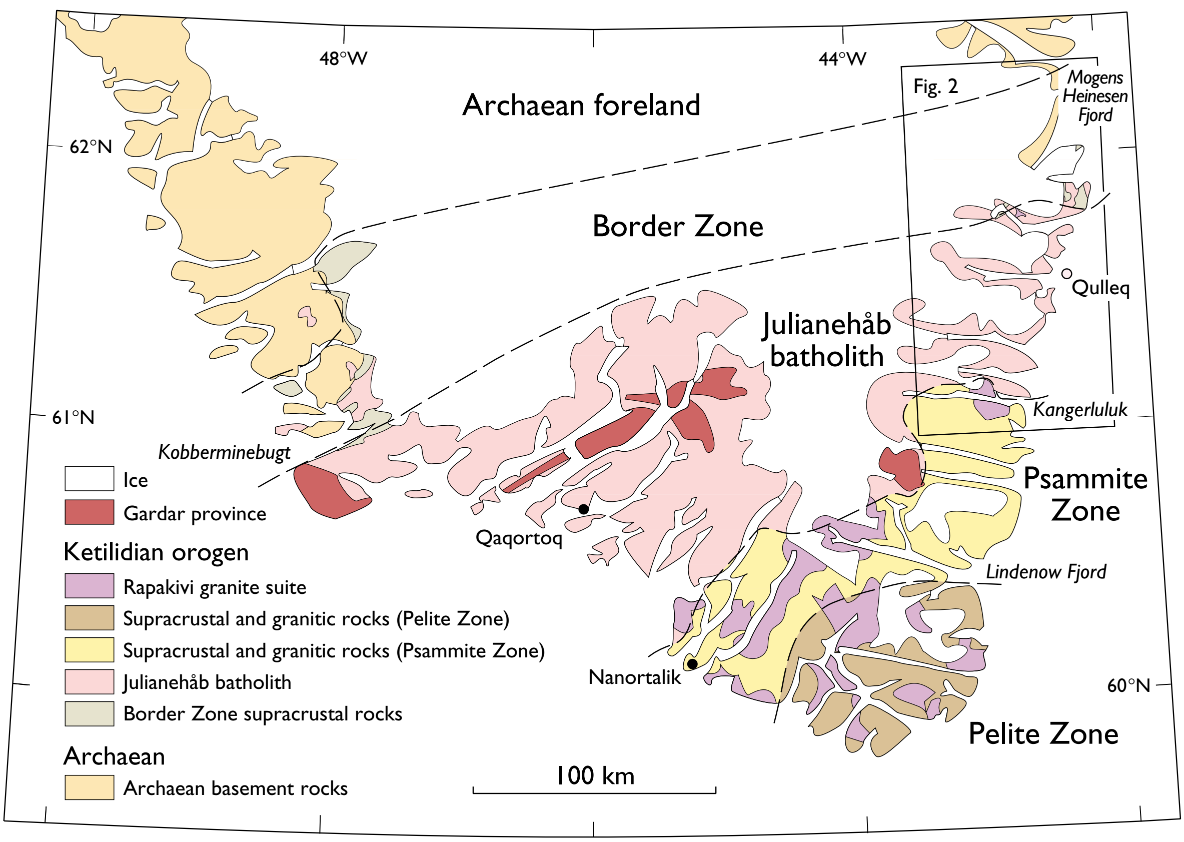
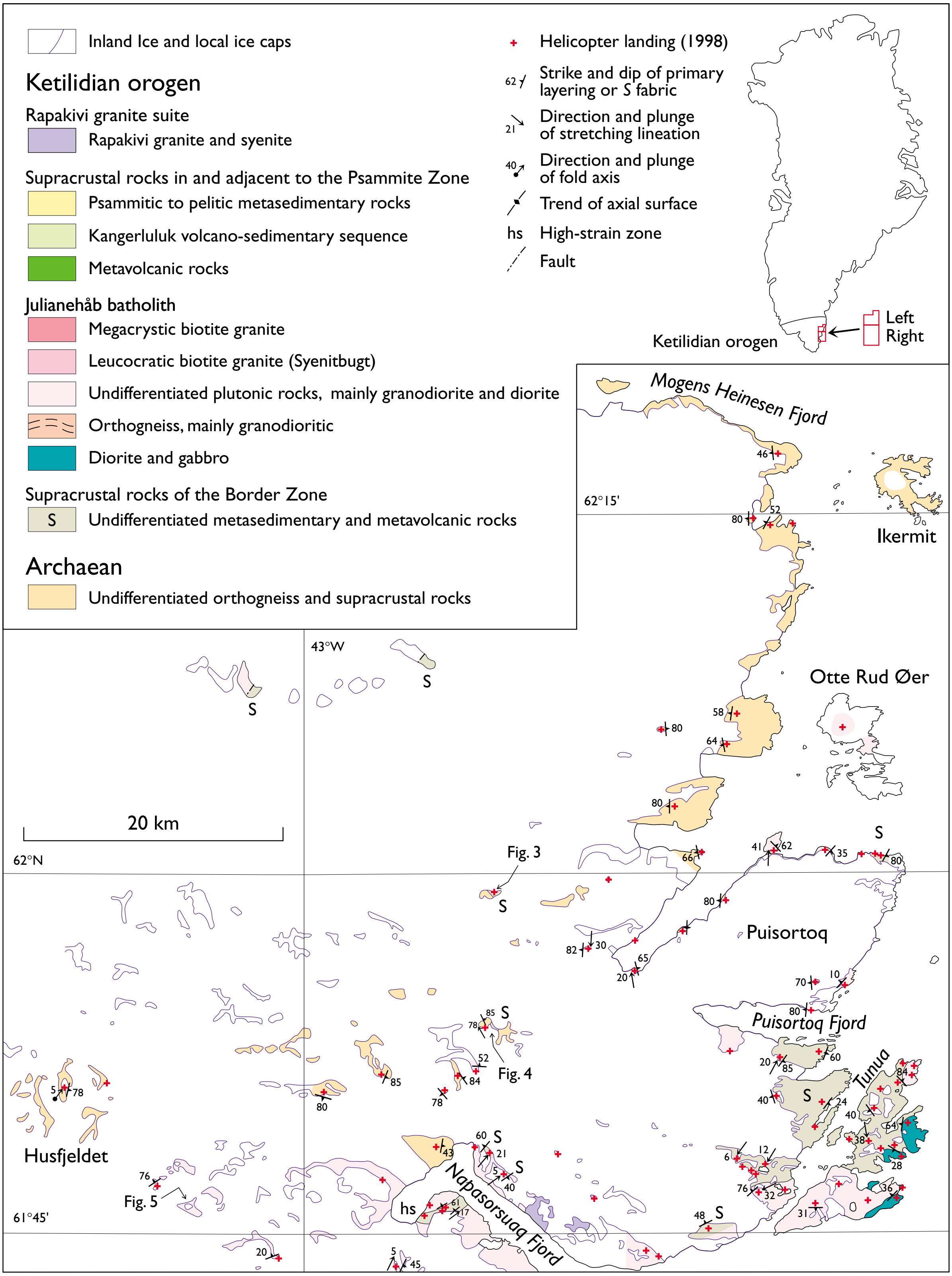


Fig. 1. The Ketilidian orogen in South Greenland, with the principal divisions according to Chadwick & Garde (1996). The frame indicates the location of Fig. 2, the region along the east coast covered by the investigation in 1998. An index map of Greenland is included in Fig. 2.


Inland Ice and local ice caps
Ketilidian orogen
Rapakivi granite suite
Rapakivi granite and syenite
Supracrustal rocks in and adjacent to the Psammite Zone
Psammitic to pelitic metasedimentary rocks
Kangerluluk volcano-sedimentary sequence
Metavolcanic rocks
Julianehåb batholith
Megacrystic biotite granite
Leucocratic biotite granite (Syenitbugt)
Undifferentiated plutonic rocks, mainly granodiorite and diorite
Orthogneiss, mainly granodioritic
Diorite and gabbro
Supracrustal rocks of the Border Zone
S Undifferentiated metasedimentary and metavolcanic rocks
Archaean
Undifferentiated orthogneiss and supracrustal rocks
Helicopter landing (1998)
Strike and dip of primary layering or S fabric
Direction and plunge of stretching lineation
Direction and plunge of fold axis
Trend of axial surface
hs High-strain zone
Fault
Ketilidian orogen
Left
Right
Mogens Heinesen Fjord
Ikermit
Otte Rud Øer
Puisortoq
Puisortoq Fjord
Tunua
Napasorsuaq Fjord
Husfjeldet
62°15'
62°N
61°45'
43°W
20 km
Fig. 3
Fig. 4
Fig. 5

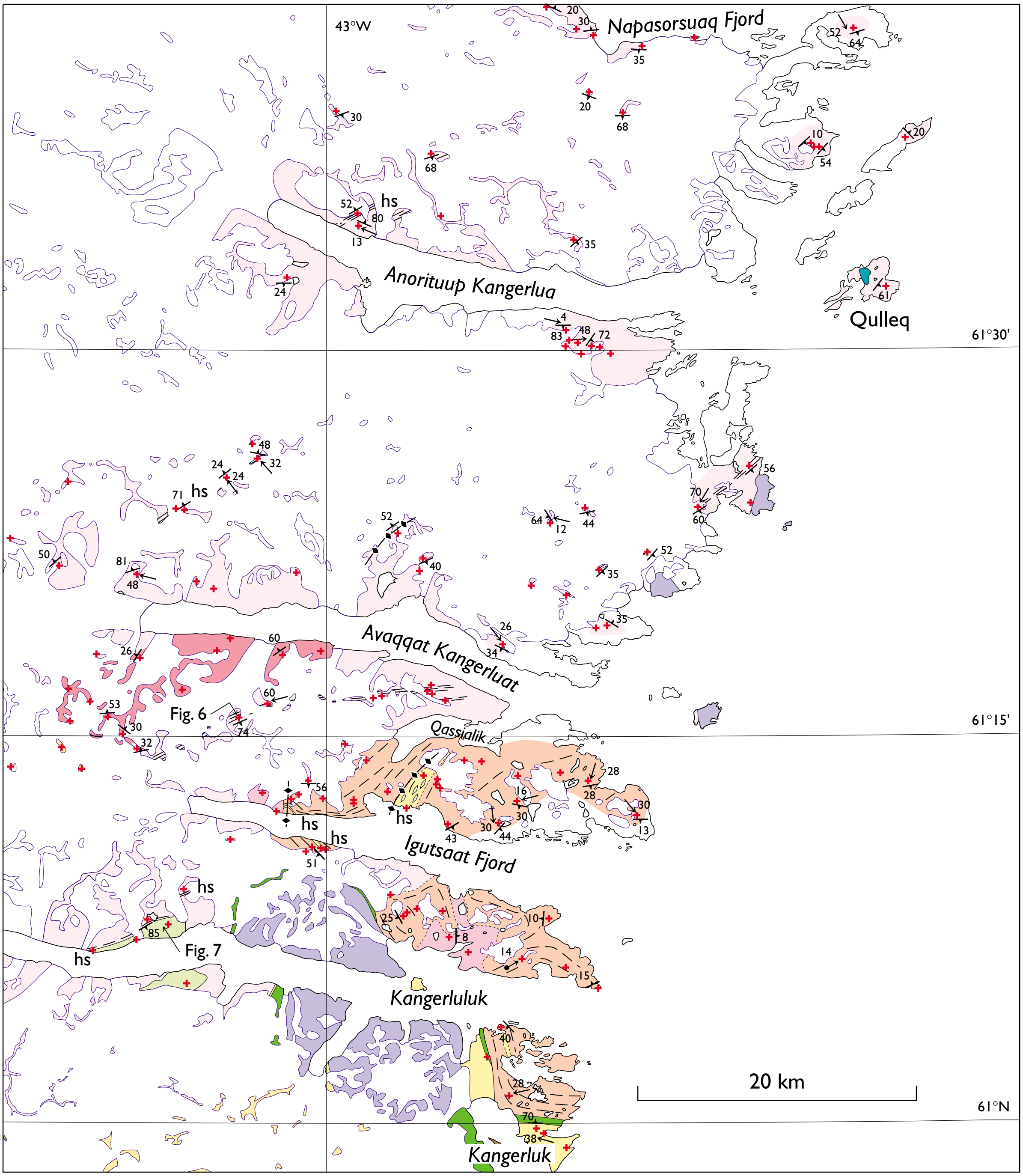


Fig. 2. **Left–right**. Geological sketch map of the north-eastern part of the Ketilidian orogen between Mogens Heinesen Fjord and Kangerluluk. The geological information is primarily based on observations made in 1998 (with helicopter landings shown by small red crosses), with a few additions in coastal areas based on an unpublished field map from 1970 by J.R. Andrews in the Survey's archives, and on personal communications with B. Chadwick and T.F.D. Nielsen in 1999. Nunataks and other areas lacking colour have not been visited. The area south of Kangerluluk was mapped in 1994 and 1996 (Garde *et al.* 1997). The positions of Figs 3–7 are shown with long arrows.

Loran station on the island of Qulleq (Figs 1, 2), and all observations were made during day trips with the helicopter. With a staff of just three geologists this proved to be a very effective way of using the limited field period and economic resources available for the project, and at the same time the amount of necessary field equipment was substantially reduced.

The principal aims of the 1998 field programme were: (1) to locate the north-eastern boundary of the Ketilidian orogen against the Archaean craton and study the nature of this boundary; (2) to study magmatic and tectonic accretion processes in the north-eastern part of the Julianehåb batholith which forms the central part of the orogen (see below); (3) to establish and correlate structural relationships in the batholith with those previously studied in the fore-arc basin to the south; (4) to study the nature and extent of a major mylonite zone which had previously been located at Igutsaat Fjord. Some 175 localities were visited (Fig. 2), many only briefly for reconnaissance purposes, but about half involved longer stops at which detailed observations were made or traverses carried out.

Previous work

On the basis of systematic investigations of the western and southern parts of the Ketilidian orogen in the 1950s and 1960s, Allaart (1976) divided the Ketilidian orogen into four different zones, which were revised by Chadwick & Garde (1996) into (1) the *Border Zone* of reworked Archaean basement and Ketilidian supracrustal rocks in the north-western part of the orogen, (2) the juvenile, calc-alkaline *Julianehåb batholith* in the central part, and (3–4) the *Psammite and Pelite Zones* in the south-east, consisting of deformed and metamorphosed supracrustal rocks largely derived by erosion of the Julianehåb batholith and interpreted as a fore-arc basin. A short updated outline of the orogen was published by Garde *et al.* (1998a), and Fig. 1 shows the fourfold division of the orogen.

Coastal areas in the north-eastern part of the Ketilidian orogen were visited by boat in 1970 (Andrews *et al.* 1971, 1973), when extensive areas of granitic rocks were observed and correlated with the Julianehåb batholith on the west coast of South Greenland. Extensive areas of leucocratic gneisses were also reported and interpreted as acid metavolcanic rocks. In 1987, low-grade sedimentary rocks of presumed Ketilidian age were discovered on nunataks west of Otte Rud Øer (Fig. 2 left; B. Chadwick and M. Rosing, personal communications 1995). In 1992, the first year of the Survey's SUPRASYD project (1992–1996), a stream sediment survey and a few days of geological reconnaissance were carried out by helicopter in the north-eastern part of the orogen (Chadwick 1992; Steenfelt *et al.* 1992; Nielsen *et al.* 1993). The field work in 1992 led to a re-interpretation of the previously reported acid metavolcanic rocks on the island of Ikermit (Fig. 2) as Archaean gneisses, reworked by intense deformation in a Ketilidian shear zone (Chadwick *et al.* 1994a), and it was considered that the existence of extensive areas of supracrustal rocks in the north-eastern part of the orogen previously reported by Andrews *et al.* (1971, 1973) was questionable. However, the more thorough study in 1998 firmly established the presence of a more than 5 km thick sequence of migmatised psammites to the north of Napasorsuaq Fjord (see below).

The north-eastern Border Zone

The north-eastern Border Zone is best addressed in the light of its well established counterpart on the west coast in the north-western part of the orogen (Fig. 1). The Border Zone in the north-west comprises Archaean basement rocks unconformably overlain by Ketilidian metasedimentary and basic metavolcanic rocks (the Vallen and Sortis Groups: Bondesen 1970; Higgins 1970), which become progressively involved in Ketilidian metamorphism and deformation towards the south (Henriksen 1969; Allaart 1976) and intruded by Ketilidian granites. It was firmly established during the 1998 field work that the north-eastern Border Zone, in South-East Greenland, is of a broadly similar nature. However, there is no equivalent to the metavolcanic Sortis Group and, in the short time available, we were unable to locate unequivocal exposures of any basal unconformity to the metasediments.

Archaean basement

The south-eastern boundary of the Archaean basement extends from north-west of Otte Rud Øer along the north-western side of Puisortoq and continues through the head of Napasorsuaq Fjord to the nunataks around Husfjeldet (Fig. 2). The basement largely consists of tonalitic orthogneiss with deformed and metamorphosed fragments of anorthosite, leucogabbro and gabbro, and numerous layers and lenses of supracrustal amphibolite and pelitic metasediment. The Archaean rocks contain a series of large N–S trending, upright, open to tight folds accompanied by a N–S tectonic fabric of variable intensity. The gneiss commonly has blebby textures characterised by clusters of secondary biotite or actinolitic hornblende, indicative of retrogression from granulite facies; relict hypersthene was found in basic lithologies north of the head of Napasorsuaq Fjord. According to previous observations by B. Chadwick (personal communication 1999), the retrogression took place in the Archaean, prior to or during the latest phase of deformation which produced the above mentioned upright folds. These structures are Archaean because they are cut by early Proterozoic (pre-Ketilidian) dolerite dykes.

Small intrusions of Ketilidian granite, diorite and gabbro, typically in the form of 5–100 m wide inclined sheets, are common together with dykes and low-angle sheets of appinite up to a few metres thick. Similar dykes have previously been observed in the Archaean foreland as far north as 63°N (Chadwick & Walton 1988; Chadwick & Garde 1996). Close to the Archaean basement some of the Ketilidian intrusive rocks contain N–S fabrics with steep internal strain gradients parallel to their margins. This indicates that localised Ketilidian reworking in these areas followed the Archaean N–S structural grain. Brown, undeformed, mostly E–W trending dolerite dykes of presumed Gardar age cut the Archaean and Ketilidian rocks. Some of the Gardar dykes contain conspicuous plagioclase megacrysts several centimetres across.

Low-grade Ketilidian supracrustal rocks overlying Archaean basement

Three new occurrences of low-grade Ketilidian metasedimentary rocks were discovered in the region underlain by Archaean basement, south and south-east of the previously visited exposures on nunataks *c.* 40 km west of Otte Rud Øer (Chadwick 1992). On the north face of nunatak 1120 m, 15 km south of the above mentioned nunataks and 20 km north of the head of Napasorsuaq Fjord (Fig. 2 left), an isolated sequence of shallowly NW-dipping conglomerate is present (Fig. 3). The sequence is more than 100 m thick and is in faulted contact with amphibolite and diorite, and cut by thin (*c.* 50 cm) Ketilidian diorite sheets. The cross-bedded and graded conglomerate beds are facing right way up and consist of up to cobble-sized clasts of vein quartz and granite, and dark, fine-grained clasts which are probably of sedimentary origin. The base of the conglomerate is not exposed. It may have been deposited

Fig. 3. Flat-lying Ketilidian conglomerate at base of nunatak 20 km north of the head of Napasorsuaq Fjord, within the region underlain by Archaean basement. Ken McCaffrey seen from the helicopter for scale. Position shown on Fig. 2.

Fig. 4. Flat-lying, fault-bounded Ketilidian sedimentary rocks at the base of nunatak 9 km north of the head of Napasorsuaq Fjord, within the region underlain by Archaean basement. The exposure is *c.* 50 m high. Location is shown on Fig. 2.

close to the Archaean–Proterozoic unconformity, and was faulted and intruded during subsequent Ketilidian events.

The second occurrence of low-grade Ketilidian supracrustal rocks was identified from the helicopter on the vertical south face of nunatak 1171 m, 9 km north of the head of Napasorsuaq Fjord (Fig. 2 left), where two fault-bounded blocks of flat-lying Ketilidian metasedimentary rocks occur (probably quartzite and semipelite, Fig. 4). The nearest landing spot some 100 m west of and below the cliff consists of migmatised Archaean orthogneiss with a distinct, vertical NNW-trending *S* fabric and a NNW-plunging stretching lineation, which we believe is of Archaean age.

The third occurrence is located on nunatak 1650 m, 9 km west-south-west of the head of Napasorsuaq Fjord, where a *c.* 5 m thick Gardar dyke emplaced into Ketilidian granites contains closely packed, angular xenoliths of low-grade Ketilidian psammite up to 20 cm across.

Deformed Ketilidian supracrustal rocks in the southern part of the Border Zone

South of the Archaean basement an up to *c.* 20 km wide zone occurs within which up to 5 km thick screens of generally highly deformed Ketilidian supracrustal rocks are embedded within intrusive members of the Julianehåb batholith. Arkosic and quartzitic, medium-grained psammitic rocks predominate, but thin horizons of polymict conglomerate, (semi)pelitic and metavolcanic rocks also occur. The rocks in this zone generally possess a NE–SW trending, steep to moderately NW-dipping tectonic fabric (*S1*), commonly combined with a subhorizontal stretching lineation. Sigmoidal feldspar porphyroclasts and other asymmetric kinematic indicators locally provide clear evidence of sinistral displacement. Between the outer parts of Napasorsuaq Fjord and Puisortoq Fjord, the steep *S1* fabric is deformed by recumbent minor folds and a weak to intense crenulation cleavage (*S2*) with subhorizontal or gently W-dipping axial planes. No related major structures have yet been identified. On the north coast of Puisortoq, on the island east of Tunua and north of inner Napasorsuaq Fjord (Fig. 2), the psammitic rocks are migmatised and in places partially melted to yield S-type granites. The partial melting indicates that some of the psammitic rocks have arkosic compositions, as in the Psammite Zone further south, where it has been shown that the detrital source of the metasediment was largely Ketilidian (Hamilton *et al.* 1996; Hamilton 1997; Garde *et al.* 1998a). An ion probe U–Pb age determination study of detrital zircon grains and their overgrowths from samples of migmatised psammite and S-type granite is in progress, and is expected to yield information with respect to the provenance of the detritus and the age of the Ketilidian thermal event.

Fig. 5. Nunatak 1480 m about 17 km west of the head of Napasorsuaq Fjord exposing granitic rocks of the Julianehåb batholith cut by flat-lying (Ketilidian) appinite sheets and a vertical Gardar dyke. The exposure is *c.* 200 m high. Position shown on Fig. 2.

Fig. 6. High-strain zone in the Julianehåb batholith: mylonitic Ketilidian orthogneiss cut by a thin, flat-lying granite sheet with a very weak *S* fabric (upper central part of the picture). Inner part of the peninsula between Avaqqat Kangerluat and Igutsaat Fjord (position shown on Fig. 2).

Julianehåb batholith

The Julianehåb batholith between Napasorsuaq Fjord and Kangerluluk (Figs 2, 5) largely consists of biotite (-hornblende) granite and granodiorite plutons and hornblende-bearing, less voluminous and more mafic lithologies. The survey of much of the batholith zone was of a reconnaissance nature, and the isolated exposures on nunataks and between glaciers made it difficult to identify and outline individual plutons in the short time available.

In contrast to the southern and north-western parts of the Julianehåb batholith, where steep magmatic and tectonic fabrics with subhorizontal stretching lineations and sinistral transpressive displacement patterns predominate (Chadwick *et al.* 1994b; Garde *et al.* 1998b; McCaffrey *et al.* 1998), we found considerable evidence in the north-eastern part of the batholith that many of its intrusive members were emplaced as moderately inclined sheets. The original magmatic fabrics are commonly retained, generally with orientations parallel to the margins of the intrusions, without overprinting by younger solid-state fabrics. Swarms of subhorizontal to gently inclined, undeformed appinite sheets are common in some parts of the batholith (Fig. 5) and reinforce the impression that the overall batholith structure is subhorizontal. In detail, however, some of the subhorizontal appinite sheets are discordant to the less obvious but moderately inclined intrusive sheeting of their host rocks and the magmatic layering within them.

As in other parts of the batholith, the magmatic fabrics have been overprinted by steep solid-state planar fabrics post-dating the magmatic emplacement in a number of NE–SW trending high-strain zones. These are spaced some 10–15 km apart from each other and are commonly cut by thin granite sheets with weak fabrics (Fig. 6), which indicate that the high-strain zones were developed before the magmatic activity completely ceased. U–Pb zircon dating of two discordant granite sheets and of a few large plutonic complexes within the batholith, is under way.

Stretching lineations in the high-strain zones have oblique plunges (most commonly to W or NW), which combined with reverse slip indicators show that a significant component of vertical displacement is present on some of the shear zones. It is possible that at least some of the high-strain zones in the batholith are synplutonic, and steeply plunging stretching fabrics may reflect elements of roof uplift or floor depression during emplacement of subhorizontal batholith components. Roof uplift during magmatic emplacement can only take place in the uppermost part of the crust, and if this emplacement mechanism was involved, it would therefore imply that a relatively high crustal level is exposed in this part of the batholith. However, independent supporting evidence for this, such as subvolcanic magmatic textures in the plutonic complexes, has not been found. Furthermore, at this stage of our investigation we are unable to readily distinguish between high-strain zones, which are related to emplacement mechanisms of individual batholith intrusions, and high-strain zones which are part of a regional deformation system.

Supracrustal enclaves, flat-lying tectonic fabrics and upright folds in the south-eastern part of the batholith

The south-eastern part of the Julianehåb batholith between outer Kangerluluk and Avaqqat Kangerluat (Fig. 2 right) largely consists of granitic (*s.l.*) orthogneisses with an intense flat-lying planar fabric, which at least locally reflects more than one phase of deformation. On both sides of Igutsaat Fjord the orthogneisses are interleaved tectonically with thinner screens (up to a few hundred metres thick) of intensely deformed psammitic paragneiss. The 1998 field work revealed that the mylonites found on the south and north coasts of inner Igutsaat Fjord during reconnaissance in 1994 and 1996 (Chadwick *et al.* 1997) represent a local intensification and re-orientation of the regional planar fabric. A screen of intensely deformed, predominately psammitic and semipelitic supracrustal rocks, up to almost 1 km thick and dilated by intrusive granite sheets, occurs within the orthogneisses south of Qassialik (Fig. 2 right, 61°15´N). Panels of supracrustal rocks up to two hundred metres thick have also been identified within the mylonites at Igutsaat Fjord. These supracrustal rocks are tentatively loosely correlated with the Psammite Zone to the south.

The flat-lying orthogneisses and their enclaves of supracrustal rocks have been folded by upright folds. The largest of these is an upright, tight antiform south of Qassialik, while another prominent antiform fold affects the mylonite north of Igutsaat Fjord (Chadwick *et al.* 1997). It is possible that both of these folds are contemporaneous with the NE–SW trending shear zones described in the foregoing section, but the structural relationships are complex and further discussion is beyond the scope of this short overview.

Structural and age correlation with the Psammite Zone

In order to correlate observations in 1998 from north of Kangerluluk with earlier work in the Psammite Zone to the south, a number of localities were visited along a traverse from the orthogneisses towards the south into the previously mapped northern part of the Psammite Zone between outer Kangerluluk and Kangerluk (Chadwick 1996). Our observations indicate that the intense foliation in the southern part of the Julianehåb batholith in South-East Greenland is continuous with the main planar fabric in the northern part of the Psammite Zone. In the metasedimentary rocks south of Kangerluluk, which were deposited on early batholith members and intruded by late batholith members, the main planar fabric is a composite *L-S* schistosity (*S1* + *S2*) resulting from transposition of bedding and a locally recognised first cleavage (*S1*) during an intense second deformation phase (Chadwick *et al.* 1997; Garde *et al.* 1997). Kinematic evidence suggests that the sense of shear is broadly parallel to the length of the orogen and consistent with that found in the Psammite Zone to the south, i.e. top to NE on shallow NE-plunging stretching lineations.

U–Pb zircon geochronology by Hamilton *et al.* (1996) and Hamilton (1997) helps to correlate the deformation events. Age determination of an orthogneiss east of Kangerluk yielded an age of 1845 ± 3 Ma (2σ confidence interval), and a statistically identical age (1846^{+2}_{-1} Ma) was obtained from a weakly deformed granodiorite at Kangerluluk. These results imply that the orthogneisses are part of the basement to the Psammite Zone, since most detrital zircon ages obtained from the metasedimentary rocks have younger ages. The age of the second deformation phase in the Psammite Zone has been determined as 1792 ± 1 Ma by dating of a synkinematic hornblende granite. A minimum age has also been obtained for the mylonite north of Igutsaat Fjord: a 2 m wide, NNE–SSW trending granite sheet which cuts the folded mylonite and is axial planar to the above mentioned antiform fold, yielded a U–Pb zircon age of 1794 ± 1 Ma. With support from the new observations around Igutsaat Fjord and Kangerluluk these age determinations imply that the *D1/D2* event in the Psammite Zone can probably be extended northward to north of Igutsaat Fjord. The deformation was either contemporaneous and took place at 1793 Ma (within error of the age determinations from each region), or it was diachronous and slightly earlier in the north.

Supracrustal rocks at the northern margin of the Psammite Zone

A well-preserved volcano-sedimentary sequence in low amphibolite facies, which unconformably overlies granodiorites of the Julianehåb batholith on the south coast of Kangerluluk, was briefly described by Stendal *et al.* (1997) and in more detail by Mueller *et al.* (in press). The supracrustal rocks were discovered during reconnaissance in 1994, early in the summer when much of the region was still covered by snow. In 1998, when the snow cover was at its minimum in late August, it was found that a higher stratigraphic level of the same volcano-sedimentary sequence is well exposed on the north coast of Kangerluluk (Fig. 2), but the short time available only allowed a very cursory investigation.

The internal structure consists of alternating zones of low deformation with moderate northerly dips, and more intensely deformed zones with steep NW dips. The lower exposures on terraces and slopes dropping off towards the fjord appear from the air to consist of deformed pillow breccia, which is also the dominant lithology in the southern part of the plateau *c.* 400 m above sea level, where cuspate bottoms of intact pillows show that the sequence is younging upwards. Plagioclase-phyric mafic dykes and zones of fine-grained, intermediate to basic sills or flows a few metres thick were also observed, and common zones of intense epidote alteration resemble those described from south of the fjord. The pillow breccia is overlain by several hundred metres of clast-supported conglomerate beds with boulders of fine-grained, dark, porphyritic basaltic rocks and smaller clasts of fine-grained felsic rocks (Fig. 7), interleaved with few metres thick, ?tuffaceous horizons with numerous small basaltic rock fragments and weathered-out vugs. The upper part of the sequence is dominated by plane-bedded and trough cross-bedded, dark grey psammitic rocks with primary load structures formed by liquefaction of wet sediment; these rocks are likely to have been formed by redeposition of volcanic material. The uppermost exposures are intruded by undeformed, homogeneous, medium-grained granitic sills of batholith affinity.

The volcano-sedimentary rocks exposed on the south side of Kangerluluk host a high-grade gold mineralisation in a rusty-weathering alteration zone with vein quartz and copper sulphides (Stendal 1997). During the short visit to the north coast of Kangerluluk no major alteration zones of this kind were encountered, but local rust-weathering was observed in the pillow breccias and volcanogenic conglomerates, and the area is considered to have potential for gold mineralisation.

Fig. 7. Undeformed, polymict conglomerate with large volcanic boulders in the northern part of the Kangerluluk volcano-sedimentary sequence. Hammer, 45 cm long, for scale. North of central Kangerluluk, position shown on Fig. 2.

Conclusions

The short and relatively inexpensive expedition to the north-eastern part of the Ketilidian orogen described above has firmly established for the first time that the north-eastern Border Zone of the orogen, like the north-western Border Zone, comprises Archaean basement unconformably overlain by extensive Ketilidian supracrustal rocks, progressively reworked towards the south and intruded by Ketilidian igneous rocks dominated by granites (*s.l.*), diorites and appinites. There is, however, no equivalent of the basic metavolcanic Sortis Group found in the north-west.

In contrast to the southern and north-western parts of the Julianehåb batholith, where steep magmatic and tectonic fabrics with subhorizontal stretching lineations and sinistral displacement patterns predominate, many of the plutons in the north-eastern part of the batholith were emplaced as moderately inclined sheets. As elsewhere in the batholith, several late- to post-magmatic, NE–SW trending high-strain zones were identified, but their stretching lineations have oblique plunges and there is evidence of reverse slip.

In the south-eastern part of the batholith, a regional flat-lying tectonic fabric is provisionally concluded to be structurally contiguous with mylonites at Igutsaat Fjord and with the previously established *S1/S2* fabric in the Psammite Zone to the south. There are also younger upright folds. Existing U–Pb zircon age data suggest that the intense deformation took place relatively late in the magmatic and tectonic accretion of the batholith.

A relatively well-preserved continuation of the Kangerluluk volcano-sedimentary succession, previously described from the south coast of Kangerluluk, was found north of the fjord and presents a new potential target for gold exploration.

Acknowledgements

Financial support from the Carlsberg Foundation and the Danish Natural Science Research Council which made this study possible is gratefully acknowledged. Kingston University, England, is thanked for a travelling grant to the British expedition members. We also thank Brian Chadwick, University of Exeter, England, for discussions and advice based on his reconnaissance in previous years. Helicopter pilots Bent Hvidberg and Flemming Bisgaard are thanked for their significant contributions to the realisation of the field study, and Grønlandsfly A/S for repeated technical support under difficult conditions.

References

Allaart, J.H. 1976: Ketilidian mobile belt in South Greenland. In: Escher, A. & Watt, W.S. (eds): Geology of Greenland, 120–151. Copenhagen: Geological Survey of Greenland.

Andrews, J.R., Bridgwater, D., Gulson, B. & Watterson, J. 1971: Reconnaissance mapping of South-East Greenland between 62°30´N and 60°30´N. Rapport Grønlands Geologiske Undersøgelse **35**, 32–38.

Andrews, J.R., Bridgwater, D., Gormsen, K., Gulson, B., Keto, L. & Watterson, J. 1973: The Precambrian of South-East Greenland. In: Park, R.G. & Tarney, J. (eds): The Early Precambrian of Scotland and related rocks of Greenland, 143–156. Birmingham: Birmingham University Press.

Bondesen, E. 1970: The stratigraphy and deformation of the Precambrian rocks of the Grænseland area, South-West Greenland. Bulletin Grønlands Geologiske Undersøgelse **86**, 210 pp. (also Meddelelser om Grønland **185**(1)).

Chadwick, B. 1992: Lightning report on reconnaissance surveys in the Ketilidian mobile belt and its foreland in South-East Greenland, summer 1992, 23 pp. Unpublished report, Geological Survey of Greenland, Copenhagen.

Chadwick, B. 1996: Report on field work in the Psammite Zone of the Ketilidian orogen in SE Greenland during the summer of 1996, 15 pp. Unpublished report, Geological Survey of Denmark and Greenland, Copenhagen.

Chadwick, B. & Garde, A.A. 1996: Palaeoproterozoic oblique plate convergence in South Greenland: a re-appraisal of the Ketilidian orogen. In: Brewer, T.S. (ed.): Precambrian crustal evolution in the North Atlantic region. Geological Society Special Publication (London) **112**, 179–196.

Chadwick, B. & Walton, B.J. 1988: Preliminary report on the geology of the area between latitudes 60°30´–63°00´ (Tingmiarmiut), Southeast Greenland. In: Nielsen, T.F.D. (ed.): The Archaean terrains in South-East Greenland, 3–16. Unpublished report, Geological Survey of Greenland, Copenhagen.

Chadwick, B., Erfurt, P., Frith, R.A., Nielsen, T.F.D., Schønwandt, H.K. & Stendal, H. 1994a: Re-appraisal of the Ikermit supracrustal suite of the Ketilidian border zone in South-East Greenland. Rapport Grønlands Geologiske Undersøgelse **163**, 23–33.

Chadwick, B., Erfurt, P., Frisch, T., Frith, R.A., Garde, A.A., Schønwandt, H.K., Stendal, H. & Thomassen, B. 1994b: Sinistral transpression and hydrothermal activity during emplacement of the Early Proterozoic Julianehåb batholith, Ketilidian orogenic belt, South Greenland. Rapport Grønlands Geologiske Undersøgelse **163**, 5–22.

Chadwick, B., Garde, A.A., Grocott, J. & Swager, C.[P.] 1997: Batholith-forearc structure in the Palaeoproterozoic Ketilidian orogen, South-East Greenland. In: Wardle, R.J. & Hall, J. (compilers): Eastern Canadian Shield Onshore–Offshore Transect (ECSOOT), Report of 1997 Transect Meeting. University of British Columbia, Lithoprobe Report **61**, 27–35.

Garde, A.A., Chadwick, B., Grocott, J. & Swager, C.[P.] 1997: Metasedimentary rocks, intrusions and deformation history in the south-east part of the *c.* 1800 Ma Ketilidian orogen, South Greenland: Project SUPRASYD 1996. Geology of Greenland Survey Bulletin **176**, 60–65.

Garde, A.A., Chadwick, B., Grocott, J., Hamilton, M.[A.], McCaffrey, K.[J.W.] & Swager, C.P. 1998a: An overview of the Palaeoproterozoic Ketilidian orogen, South Greenland. In: Wardle, R. J. & Hall, J. (compilers): Eastern Canadian Shield Onshore–Offshore Transect (ECSOOT), Report of 1998 Transect Meeting. University of British Columbia, Lithoprobe Report **68**, 50–66.

Garde, A. A., Chadwick, B., McCaffrey, K.[J.W.] & Curtis, M. 1998b: Reassessment of the north-western border zone of the Palaeoproterozoic Ketilidian orogen, South Greenland. Geology of Greenland Survey Bulletin **180**, 111–118.

Hamilton, M.A. 1997: Synopsis of new U-Pb geochronological results from the Ketilidian orogen, South Greenland. In: Wardle, R.J. & Hall, J. (compilers): Eastern Canadian Shield Onshore–Offshore Transect (ECSOOT), Report of 1997 Transect Meeting. University of British Columbia, Lithoprobe Report **61**, 118–134.

Hamilton, M.A., Garde, A.A., Chadwick, B. & Swager, C.[P.] 1996: Observations on Palaeoproterozoic fore-arc sedimentation and deformation: preliminary U-Pb results from the Ketilidian orogen, South Greenland. In: Wardle, R.J. & Hall, J. (compilers): Eastern Canadian Shield Onshore–Offshore Transect (ECSOOT), Report of 1996 Transect Meeting. University of British Columbia, Lithoprobe Report **57**, 112–122.

Henriksen, N. 1969: Boundary relations between Precambrian fold belts in the Ivigtut area, Southwest Greenland. Geological Association of Canada Special Paper **5**, 143–154.

Higgins, A.K. 1970: The stratigraphy and structure of the Ketilidian rocks of Midternæs, South-West Greenland. Bulletin Grønlands Geologiske Undersøgelse **87**, 96 pp. (also Meddelelser om Grønland **189**(2)).

McCaffrey, K.[J.W.], Chadwick, B., Garde, A.A., Hamilton, M.[A.] & Curtis, M.[L.] 1998: New structural and isotopic age data from the north-western border zone of the Ketilidian orogen, South Greenland. In: Wardle, R. J. & Hall, J. (compilers): Eastern Canadian Shield Onshore– Offshore Transect (ECSOOT), Report of 1998 Transect Meeting. University of British Columbia, Lithoprobe Report **68**, 103–114.

Mueller, W.U., Garde, A.A. & Stendal, H. in press: The 1.8 Ga Ketilidian rocks, Kangerluluk, South-East Greenland: pyroclastic deposits in a subaerial-subaqueous transition zone. Precambrian Research.

Nielsen, T.F.D., Chadwick, B., Dawes, P.R., Frith, R.A. & Schønwandt, H.K. 1993: Project SUPRASYD 1992: opening season in the Ketilidian of South Greenland. Rapport Grønlands Geologiske Undersøgelse **159**, 25–31.

Steenfelt, A., Dam, E. & Erfurt, P. 1992: Reconnaissance geochemical mapping of eastern South Greenland (60°30´ to 62°30´N). Open File Series Grønlands Geologiske Undersøgelse **92/10**, 12 pp.

Stendal, H. 1997: The Kangerluluk gold prospect. Shear zone hosted gold mineralization in the Kangerluluk area, South-East Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport **1997/53**, 18 pp.

Stendal, H., Mueller, W., Birkedal, N., Hansen, E.I. & Østergaard, C. 1997: Mafic igneous rocks and mineralisation in the Palaeoproterozoic Ketilidian orogen, South-East Greenland: project SUPRASYD 1996. Geology of Greenland Survey Bulletin **176**, 66–74.

Authors' addresses:

A.A.G., *Geological Survey of Denmark and Greenland, Thoravej 8, DK-2400 Copenhagen NV, Denmark.* E-mail: *aag@geus.dk*

J.G. & K.J.W.McC., *School of Geological Sciences, Kingston University, Penrhyn Road, Kingston-upon-Thames, Surrey KT1 2EE, UK.*