Archaean and Palaeoproterozoic orogenic processes: Danish Lithosphere Centre studies of the Nagssugtoqidian orogen, West Greenland

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The Danish Lithosphere Centre (DLC) was established in 1994 and one of its principal objectives in the first five-year funding cycle is the study of Precambrian orogenic processes. This work initially focused on the thermal and tectonic evolution of the Nagssugtoqidian orogen of West Greenland.

During the first two field seasons (1994 and 1995) most efforts were concentrated in the southern and central portions of the orogen. The 1997 field season was the third and final in the project in the Nagssugtoqidian orogen and emphasis was placed on the central and northern parts of the orogen in order to complete the lithostructural study of the inner Nordre Strømfjord area and to investigate the northern margin of the orogen (NNO in Fig. 1).

This report is partly a review of selected research results obtained since publication of the last Review of Greenland activities (van Gool *et al.* 1996), and also partly a summary of field activities in Greenland during the summer of 1997.

Background for project

The overall aim of DLC's Nagssugtoqidian project is to establish the large-scale geometry of the orogen, to identify the lithotectonic components and their age and to characterise the dynamic aspects of the evolution, including the structural, metamorphic and magmatic variations.

The southern boundary of the orogen (southern Nagssugtoqidian front, SNF in Fig. 1), was defined by Ramberg (1949) on the basis of progressive structural reworking of the Palaeoproterozoic Kangâmiut dyke swarm. South of the SNF, the dykes are discordant with respect to the structures in the Archaean granulite facies gneisses. North of the SNF, the dykes and their country rocks are deformed and metamorphosed together. The geometry of the SNF was first described in detail by Escher *et al.* (1970, 1975), and was viewed as a frontal thrust, across which the southern Nagssugtoqidian orogen was translated towards the southern foreland.

Figure 1 shows the main lithotectonic units of the Nagssugtoqidian orogen (from Marker *et al.* 1995; van Gool *et al.* 1996). The southern foreland consists of Archaean granulite facies tonalitic-granodioritic gneisses cut by mafic dykes of the Palaeoproterozoic Kangâmiut swarm. In the SNO (southern Nagssugtoqidian orogen) gneisses and dykes from the foreland were deformed and metamorphosed in amphibolite facies and transposed into NNW-dipping structures during SSE-directed ductile thrusting. Towards the contact between the SNO and CNO (central Nagssugtoqidian orogen), the metamorphic grade increases to granulite facies (Korstgård 1979). The SNO–CNO boundary is defined by the Ikertooq steep belt, a regionally pervasive high strain zone which also marks the northernmost occurrence of the Kangâmiut dyke swarm. The CNO is characterised by a southern part with a generally steep and penetrative ENE-trending structural grain, whereas the northern CNO comprises alternating steep and shallow-dipping structures ('steep' and 'flat' belts, respectively). Northwards, the CNO is delimited by the Nordre Strømfjord steep belt (Bak *et al.* 1975a, b; Hanmer *et al.* 1997), a regionally penetrative zone of steeply dipping gneisses, including zones of localised high strain. Palaeoproterozoic calc-alkaline intrusions occur in the north-eastern CNO (*c.* 1.92 Ga Arfersiorfik quartz diorite; Kalsbeek *et al.* 1987; Kalsbeek & Nutman 1996) and south-western CNO (*c.* 1.92 Ga Sisimiut charnockite; Kalsbeek & Nutman 1996). The northern Nagssugtoqidian orogen (NNO) is dominated by variably deformed Archaean granitic to granodioritic gneisses that include units of supracrustal sequences.

Both intra- and inter-cratonic settings have been proposed to explain the development of the Nagssugtoqidian orogen in terms of a large-scale tectonic model. Bridgwater *et al.* (1973) hinted at an inter-cratonic origin and interpreted the ductile thrusting in the south-

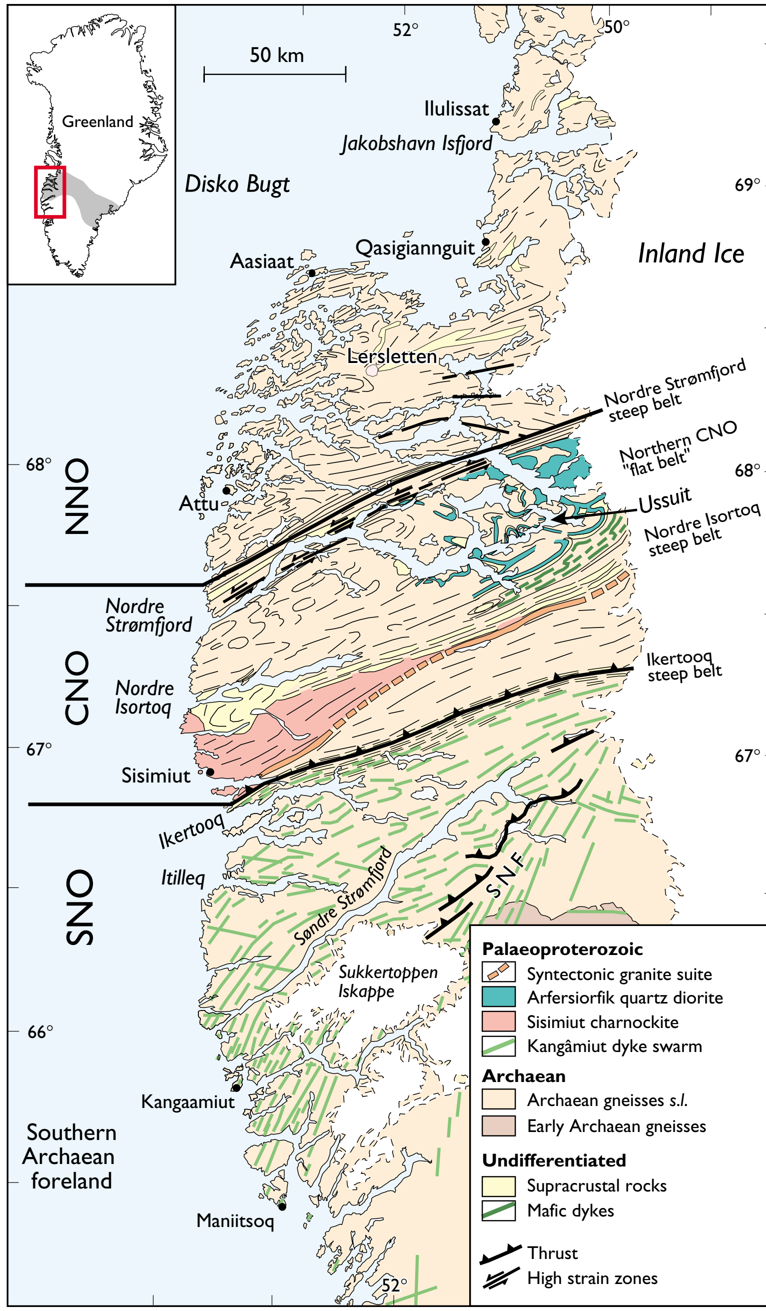


Fig. 1. Lithotectonic sketch map of the Nagssugtoqidian orogen and its southern and northern forelands. This figure includes information from Escher (1971), Allaart (1982), Marker *et al.* (1995) and van Gool *et al.* (1996). NNO, CNO and SNO are the northern, central and southern Nagssugtoqidian orogen, respectively. SNF: southern Nagssugtoqidian front. Shading on insert map shows regional extent of the Nassugtoqidian orogen across Greenland.

ern margin as indicative of a collisional origin. They had, however, insufficient data to constrain the extent of the postulated oceanic basin between the two continents. Later workers, however, focused on the large-scale transcurrent structures in the orogen, and favoured intracratonic settings to explain the geometries (e.g. Bak *et al.* 1975a, b). Geochemical and isotopic investigations of the Arfersiorfik quartz diorite (AQD) in the central part of the orogen led Kalsbeek *et al.* (1987) to revive the intercratonic model. The AQD is a calc-alkaline intrusion with geochemical and isotopic signatures similar to subduction-generated arc magmas. Based on this data, Kalsbeek *et al.* (1987) suggested that the central part of the Nagssugtoqidian orogen could contain a suture as a result of convergence, subduction and collision between two Archaean cratonic blocks.

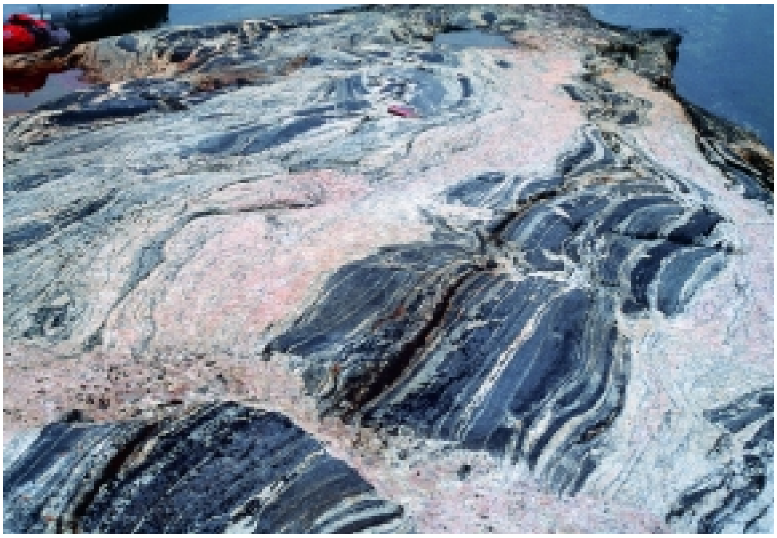


Fig. 2. Archaean basement gneisses from western Ussuit (Fig. 1). The older, mafic gneisses occur as disrupted layers in a dominantly tonalitic-granodioritic granitoid gneiss. In the foreground, a granitic pegmatite cuts both units. Notebook for scale.

Recent work by DLC in the Nagssugtoqidian orogen has partly been aimed at testing the continent–continent collision model and has been concentrated in the central and southern parts of the orogen. The work has involved an investigation of the AQD and its host-rocks in more detail, but also a characterisation of the two 'continents' in order to verify that they represent distinct blocks that were unrelated prior to collision (summarised in Marker *et al.* 1995; van Gool *et al.* 1996).

The 1997 field season focused on the central and northern parts of the Nagssugtoqidian orogen. The northern margin is poorly defined at present. There is no well-defined structural front similar to the southern margin, hence the overall geometry of the orogen is asymmetric. The northward extent of Nagssugtoqidian metamorphism is not known at present. Kalsbeek *et al.* (1987) reported undisturbed Rb-Sr and Pb-Pb isotope systems at Akulleq (25 km south-west of Aasiaat) and Aasiaat, respectively, whereas geochronological data from 15 km south-east of Aasiaat (Connelly & Mengel 1996) suggest minor thermal overprints of Palaeoproterozoic age at this latitude (Figs 1, 2).

With the above as background and framework, the main aims of the 1997 field season were:

1. To characterise the northern margin of the Nagssugtoqidian orogen and to collect data and samples necessary for outlining the northward extent of Palaeoproterozoic magmatism(?) and structural and metamorphic overprints;

2. To establish the three-dimensional geometry of structures in the inner Ussuit area (Fig. 1) in order to (1) test the thrust stack model for the interleaving of Archaean and Proterozoic gneisses (van Gool *et al.* in press); and also (2) to understand the dynamic relationships between 'steep' and 'flat' belts in the central part of the orogen;

3. To further investigate the compositional, geochronological and structural characteristics of the pre-Nagssugtoqidian basement, both internal and external to the orogen, in order to address these questions;

   a. Can a northern and southern 'continent' be identified?
   b. What are the linkages between Archaean units within the orogen and Archaean gneisses in the forelands, i.e. where is the suture?
   c. What is the control of pre-Nagssugtoqidian structures on the Nagssugtoqidian structural development?

Archaean basement rocks in the Nagssugtoqidian orogen and its forelands

Based on detailed field observations, a picture is emerging of a basement gneiss complex comprising at least three components that can be recognised throughout the orogen and within its marginal zones.

The oldest, and volumetrically least significant components are complex, polydeformed felsic to mafic

Fig. 3. Archaean basement gneisses from Kangersuneq (15 km south-east of Qasigiannguit; Fig. 1). The tonalitic-granodioritic component contains small, irregular inclusions of older, structurally more complex, mafic gneisses. Hammer for scale.

Fig. 4. Archaean basement gneisses from Orpissooq (20 km south-south-east of Qasigiannguit; Fig. 1). In this outcrop, the youngest, granitic component is dominant. The granite, locally megacrystic, contains inclusions of layered tonalitic-granodioritic gneisses (Fig. 3) and (just in front of the hammer) older mafic gneisses.

gneisses (Fig. 2). These units occur as layers, lenses or angular enclaves (centimetre- to metre-scale) included in grey tonalitic layered gneiss. Contacts are generally parallel to layering and foliation in both units, but the intrusive contacts between the older components and the younger grey gneiss are locally preserved.

This grey, tonalitic to granodioritic gneiss forms the dominant background lithology throughout the Nagssugtoqidian orogen (Fig. 3). The unit may be variably migmatitic and record several generations of migmatisation and deformation, often preserved as ghost structures in relatively homogeneous rocks.

The youngest, recognisably Archaean component of the basement gneiss complex is a granite to granodiorite which occurs as veins, sheets or larger discordant bodies (Fig. 4). The discordant boundaries are commonly transposed, but discordant relationships are locally preserved.

The zircon geochronology of the Archaean gneiss complex has been investigated both in a reconnaissance fashion (U-Pb SHRIMP: Kalsbeek & Nutman 1996) and in more detailed studies (conventional U-Pb TIMS: Connelly & Mengel 1996). The reconnaissance survey found clusters of ages around 2750–2700 Ma and 2850–2800 Ma in the dominant tonalitic-granodioritic gneisses, whereas the older components were not analysed. Similar age ranges were reported by Kalsbeek *et al.* (1987). By analysing small zircon fractions or single grains, Connelly & Mengel (1996) found that in the central and southern part of the orogen, the tonalitic-granodioritic gneisses contain igneous zircons with ages of 2870–2813 Ma and metamorphic zircons with ages between 2808 and 2750 Ma. Granitic rocks in the northern part of the orogen show intrusive ages of 2788 Ma, but apparently did not experience the post-2788 Ma deformation and metamorphism recorded elsewhere. In the southern foreland, granitic magmatism took place at *c.* 2717 Ma and at *c.* 2500 Ma (Ikertooq–Itilleq area; Connelly & Mengel 1996, unpublished data; Kalsbeek & Nutman 1996).

Albeit limited, this dataset is interpreted by Connelly & Mengel (1996, unpublished data) to show that a major intrusive event contributed new granitoid magma to the crust at 2870–2813 Ma, and that deformation and metamorphism at 2808–2750 Ma affected only the central and southern portions of the presently exposed Nagssugtoqidian orogen. Post-kinematic granite emplacement was widespread and affected an area larger than that experiencing deformation and metamorphism.

The oldest ages obtained from the Nagssugtoqidian orogen and its forelands are from immediately south of Søndre Strømfjord (Fig. 1), where zircons from gneisses in what is now defined as the Aasivik terrane have yielded U-Pb SHRIMP ages of 3784–3550 Ma (Rosing *et al.* 1997, in press). The oldest age from within the Nagssugtoqidian orogen is *c.* 3.1 Ga (F. Kalsbeek & A.P. Nutman, personal communication 1995; Nutman 1997) and was obtained from a unit of leucocratic granodioritic to granitic gneisses immediately south of inner Ussuit (Fig. 1). Sr-Nd data from a regional radiogenic isotope study (Whitehouse *et al.* 1998) also show the presence of crustal components with ages slightly in excess of 3.1 Ga.

The present geochronology dataset is incomplete, but it clearly shows that regional differences with respect to geochronologial, structural and metamorphic histories exist. The data furthermore suggest that the CNO–SNO boundary may represent a fundamental boundary, possibly separating the 'continents' which collided to form the Nagssugtoqidian orogen. During the 1997 field season, data and samples were collected with these issues in mind.

The stream-sediment data presented by Steenfelt (1994) also suggest overall geochemical differences between the crustal blocks north and south of Nordre Strømfjord. These differences largely coincide with the distribution of amphibolite and granulite facies, but may also reflect more fundamental differences, such as those indicated above.

Palaeoproterozoic lithologies and structural and metamorphic signatures

Southern Nagssugtoqidian front

Based on the rotation of structures in the southern Nagssugtoqidian front zone (SNF in Fig. 1) Bridgwater *et al.* (1973) and Escher *et al.* (1975, 1976) suggested that shortening in excess of 100 km was accommodated across the southern Nagssugtoqidian front (SNF). As a result of recent detailed work along the length of the exposed part of the front, Hageskov (1995) has shown the SNF to consist of segments of non-linked high-strain zones, thus suggesting that the total shortening across the front may be moderate. Two M.Sc. theses projects are at present being carried out on the structural and metamorphic contrasts across the SNF (H.E. Olsen, Geological Institute, Copenhagen University and P.S. Jensen, Geological Institute, Aarhus University) in order to constrain its development.

Structural styles in the central Nagssugtoqidian orogen

In the eastern part of CNO (Ussuit in Fig. 1), a complex thrust system separates the underlying Archaean basement gneisses from the overlying supracrustal rocks which are intruded by the the Arfersiorfik quartz diorite (Fig. 5). Due to the potential importance of this zone as representing the tectonic contact (i.e. suture) between the continent and a colliding arc, the tectonic development and structural style in the Ussuit area have received considerable attention (e.g. Passchier *et al.* 1997; Manatschal *et al.* in press; van Gool *et al.* in press).

In the Ussuit area, it can be shown that an early phase of W–NW vergent thrusting brought a lithotectonic unit consisting of supracrustal rocks intruded by the Arfersiorfik quartz diorite into tectonic contact with the underlying Archaean gneissic basement, and that this contact was repeated by subsequent thrust imbrication (van Gool *et al.* in press). These thrusts were then folded into kilometre-scale upright folds with overall ENE-trending axial planes. Based on observations in the eastern Ussuit area, Manatschal *et al.* (in press) suggest that this phase of folding was accompanied by extension along E- to ENE-dipping shear zones.

The early contractional thrust structures, which provide crucial information about the geometry and dynamics of early phases of the collisional event, are only rarely preserved; generally the thrusts are overprinted and obliterated by later open to tight upright folds, which dominate the present day structural grain.

Fig. 5. Tectonic contact between Archaean basement gneisses and a Palaeoproterozoic package consisting of supracrustal rocks intruded by the Arfersiorfik quartz diorite (see text for discussion). Bow of *Kissavik* indicates the south-dipping contact between Archaean gneisses (lower left) and Palaeoproterozoic rocks (upper right). Cape behind *Kissavik* is 380 m high. Locality: western Ussuit (Fig. 1).

Structures and lithologies in the northern Nagssugtoqidian orogen and foreland – linkage with the Rinkian?

The reconnaissance carried out in the Disko Bugt area (between 68°30′ and 69°30′N; Fig. 1) was aimed at characterising the poorly known northern margin of the Nagssugtoqidian orogen and at studying the relationships between the NNO and the better understood Rinkian belt farther north (e.g. Henderson & Pulvertaft 1987; Grocott & Pulvertaft 1990).

The basement in the Disko Bugt area south of Jakobshavn Isfjord is composed of layered amphibolite facies gneisses, comprising the three main components also described from elsewhere in the Nagssugtoqidian orogen. The oldest, mafic component is represented by layers, as well as blocks and fragments occurring in agmatitic zones, enclosed within the dominant grey, tonalitic to granodioritic layered gneiss (Fig. 3). The youngest granitic component is locally dominant, and occurs as sheets and dykes or as large, megacrystic bodies (Fig. 4). The larger bodies contain inclusions of both the mafic and tonalitic components, both showing a complex pre-granite structural history (Fig. 4). Discordant relationships between the granite and its host rocks are generally preserved, but the granitic layers and bodies are always folded along with its host rocks and have a variably developed foliation. The ‘younger granitic’ component described above, is presumably temporally and compositionally similar to the Rodebay granodiorite (Garde 1994), which occurs mainly north of Jakobshavn Isfjord and which is characterised by a single, simple fabric.

Two groups of supracrustal rocks occur as units interleaved with the Archaean gneiss complex. The first group is abundant near Jakobshavn Isfjord (Fig. 1) and is dominated by layered amphibolites (see also Henderson 1969; Escher 1971; Garde 1994). These rocks are intruded by grey tonalitic sheets assumed to belong to the Archaean complex.

The other group of supracrustal rocks occurs south of Jakobshavn Isfjord and is apparently similar to the supracrustal rocks from Lersletten (Fig. 1) farther south (e.g. Henderson 1969; Marker *et al.* 1995). This package is dominated by psammitic to pelitic lithologies and amphibolites with minor marbles, calc-silicate rocks and quartzites. Locally, these rocks are cut by two-mica granite sheets. Preliminary petrographic and thermobarometric studies (F. Mengel & M. Marker, unpublished data) on samples from Lersletten show staurolite-garnet-sillimanite-biotite-muscovite assemblages (kyanite found near Qasigiannguit, Fig. 1), with clear evidence of advanced replacement of staurolite in some lithologies. The stable parageneses suggest metamorphic peaks at lower to middle amphibolite facies conditions. The age of sources, deposition and metamorphism(s) of the supracrustal rocks is at present not known. The supracrustal rocks and the basement gneisses are cut by mafic dykes, which appear similar to the Kangâmiut dykes much farther south. This correlation is tentative, and awaits geochronological and geochemical confirmation.

The contact between Archaean gneisses and felsic supracrustal rocks is commonly mylonitised with subhorizontal, ENE-trending stretching lineations. Although a consistent sense of motion has not been determined so far, a top-to-east movement sense seems predominant. The earliest folds recognised in the area south of Ilulissat are mesoscopic, tight to isoclinal folds, generally recumbent. These are overprinted by large-scale, open, upright, shallowly ENE-plunging folds.

Although based only on a short visit (about one week) it appears that both the style and sequence of structural events in the northern NNO up to Ilulissat are comparable to that described for CNO (see above), namely involving (1) early shearing and thrusting along contacts between basement gneisses and supracrustal rocks, and (2) recumbent folding followed by (3) large scale upright folding with ENE-trending axial planes. If this correlation is correct, it follows that many of the observed structures in the NNO are of Nagssugtoqidian age, however, geochronological confirmation is clearly needed.

North of the Nagssugtoqidian orogen, the Rinkian belt is characterised by large-scale, west vergent recumbent folds (fold nappes) and dome structures which are considered to be Proterozoic (e.g. Grocott *et al.* 1987; Henderson & Pulvertaft 1987; Garde & Steenfelt, in press). The structural characteristics of the NNO are transitional between those in the CNO and the Rinkian. The NNO does not, however, contain structural evidence for the presence of gneiss domes.

It is worth re-emphasising that while the southern margin of the Nagssugtoqidian orogen is structurally well-defined (see above), the northern limit of clearly Nagssugtoqidian structural and metamorphic signatures cannot be precisely delineated and appears to grade, via a transitional zone, into the southern part of the Rinkian belt. The Nagssugtoqidian orogen and Rinkian belt may thus represent different responses to the same tectonic forces, and should not be viewed as unrelated orogens, but rather as different expressions of the same orogenic event.

Proterozoic mafic dykes – age data for the Kangâmiut dyke swarm

The Kangâmiut dyke 'swarm', which played a key role in the identification and definition of the Nagssugtoqidian orogen (Ramberg 1949), has long been known to include several generations of dykes (e.g. Windley 1970; Escher *et al.* 1975; Jack 1978; Nash 1979a, b; Mengel *et al.* 1997 and many others). The earliest generation is E–W trending, and normally orthopyroxene- or olivine-bearing and is cut by the NNE- to NE-trending main suite. Locally, there is evidence of an intervening suite with broadly the same composition and trend as the main swarm.

Kalsbeek *et al.* (1978) presented Rb-Sr data showing a 1950 ± 60 Ma intrusive age for the main swarm, and later U-Pb zircon (SHRIMP) analyses on the same and similar samples broadly confirmed this age (*c.* 2.04 Ga; Kalsbeek & Nutman 1996; Nutman *et al.* in press).

Recently, Willigers *et al.* (1998) presented ^{40}Ar-^{39}Ar hornblende cooling age data from Kangâmiut dykes in the southern foreland. The data fall in two groups clustering around *c.* 2.02 Ga (Kangaamiut–Itilleq area; Fig. 1) and *c.* 2.4 Ga (near Maniitsoq; Fig. 1). These ages are interpreted by Willigers *et al.* (1998) to show (1) the presence of > 2.4 Ga mafic dykes in the Kangâmiut dyke 'swarm' in the Maniitsoq area, (2) that the dykes in the southern foreland were affected by a phase of metamorphism pre-dating (and unrelated to) Nagssugtoqidian magmatism and metamorphism (*c.* 1.92–1.80 Ga), (3) that the area around Maniitsoq was not heated above *c.* 530°C (closure temperature for the diffusion of Ar in hornblende; Harrison 1981) after 2.4 Ga, and (4) that hornblendes from the area between Kangaamiut and Itilleq were not reset after 2.02 Ga, from which it follows that the Nagssugtoqidian metamorphic temperatures in this region never exceeded *c.* 530°C. It is notable, that the *c.* 2.02 Ga Ar-Ar cooling ages overlap within error with the *c.* 2.04 Ga U-Pb zircon ages referred to above.

The thermobarometric data presented by Mengel *et al.* (1997) showed that metamorphic garnet-bearing assemblages in dykes in the foreland between Maniitsoq and Itilleq (Fig. 1; including many of those studied by Willigers *et al.* 1998) equilibrated at pressures up to 10 kbar. Mengel *et al.* (1997) assumed that these overprints were of Nagssugtoqidian age. However the new ^{40}Ar-^{39}Ar data suggest that pre-Nagssugtoqidian thermal events are involved.

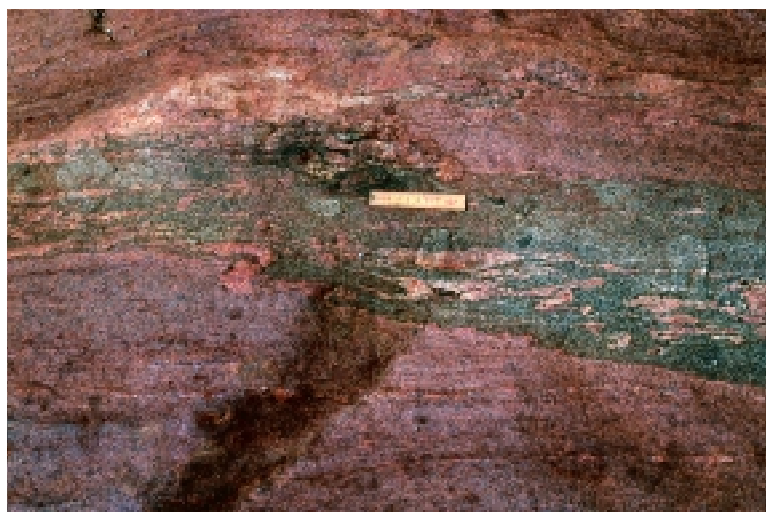
Work in progress is aimed at confirming these crucial new data and at evaluating the consequences for previous models for the pre-Nagssugtoqidian evolution of this area.

Proterozoic mafic dykes – relation to supracrustal rocks

Prior to the 1997 field season, Kangâmiut dykes had only been observed cutting supracrustal rocks in a few places (e.g. at the mouth of Itilleq: Jack 1978), and consequently this had been interpreted to indicate that deposition of some of the supracrustal packages, e.g. in the Ikertooq area, post-dated emplacement of the Kangâmiut dykes at *c.* 2.04 Ga, which is consistent with results from provenance studies (Nutman *et al.* in press).

Fig. 6. Two sets of mafic dykes from Tasersuaq (*c.* 20 km east-north-east of inner Ikertooq; Fig. 1). The earlier dykes and the layered host gneiss are folded in an overturned antiform which is cross-cut by a shallow-dipping dyke. Note slight off-set along younger dyke (e.g. just left of the centre of the photograph). Wall is *c.* 200 m high.

Fig. 7. Discordant mafic dyke in inner Ikertooq (Fig. 1). Detail of migmatised mafic dyke (grey) cutting pelitic supracrustal rocks (brown). The contact and the migmatitic veins are intensely folded. The foliation in the dyke is parallel to foliation and layering in the supracrustal gneiss. Scale bar is 10 cm.



Mafic dykes, tentatively correlated with the Kangâmiut dyke swarm, are found throughout Ikertooq. In the Avalleq and Akulleq areas (southern and central arms of inner Ikertooq; Fig. 1) most dykes are clearly discordant, while the majority of the dykes in Maligiaq (northern arm of inner Ikertooq; Fig. 1) appear to have been transposed into parallelism with the strong E–W structural grain characterising the SNO-CNO boundary zone.

Clearly discordant dykes of mafic composition were found cutting concordant mafic layers and dykes in penetratively foliated gneisses in 1995 (Fig. 6; van Gool *et al.* 1996), and during the 1997 field season discordant dykes were observed in the supracrustal rocks in Maligiaq (inner Ikertooq). The dykes cutting metapelitic supracrustal rocks are up to 0.5 m wide, highly irregular and strongly deformed, with a foliation that is parallel to that in the supracrustal rocks (Fig. 7). As a result of interaction between the hot dyke-magma and the hydrous pelite, the contact zone is strongly migmatised, and locally the dykes occur as irregular fragments, lenses or layers in delicately folded melt-rich migmatites, thus rendering identification difficult. Disrupted mafic to intermediate lenses occurring in migmatitic supracrustal rocks in Maligiaq are comparable in all aspects to the clearly discordant dykes, and may well represent dyke fragments. Preliminary geochemical analysis of one such dyke shows a composition different from average Kangâmiut dykes, and even disregarding the strong contamination from the supracrustal host-rock (enrichment in e.g. Na, K, Ba) this dyke is unlikely to belong to the main Kangâmiut swarm.

The observations show that not all mafic dykes in the Ikertooq area are the same age. It is, however, not clear whether the discordant dykes post-date the development of Nagssugtoqidian fabrics, or whether they are Kangâmiut dykes cutting Archaean penetrative fabrics in areas with older dykes (Archaean?) that escaped thorough Nagssugtoqidian deformation. Answers to these questions are presently being pursued by a combination of geochemical and geochronological methods.

Age of supracrustal rocks in the Nagssugtoqidian orogen

Supracrustal rocks occur in several distinct settings within the Nagssugtoqidian orogen (see also Fig. 1) and correct interpretations of their sources and ages are important for understanding the dynamic evolution of the orogen. Recently, an analytical programme was initiated in order to study the sources and ages of deposition of the various supracrustal suites in the SNO and CNO (Marker *et al.* 1997). The analytical methods employed include U-Pb analysis of zircons by NORDSIM ionprobe (M. Whitehouse) and by ICP-MS laser ablation (D. Scott), and Sm-Nd and Rb-Sr whole-rock isotope analysis (O. Stecher). The preliminary results of this study are summarised below (mainly from Marker *et al.* 1997).

The metasediments occurring along the SNO–CNO boundary (along Ikertooq; Fig. 1) have Sm-Nd model ages (T_{DM}, DePaolo 1981) of *c.* 2.8 Ga which indicate that their likely provenance are the surrounding *c.* 2.8 Ga Archaean gneisses. Zircons, on the other hand, have a range of $^{207}Pb^*/^{206}Pb^*$ ages, including an important component, probably metamorphic in origin, at 1.84 Ga. In a SHRIMP U-Pb zircon study of a metasediment from the same area, Nutman *et al.* (in press) also found ages around 2.8–2.7 Ga and 1.85 Ga, but in addition they obtained a cluster of $^{207}Pb^*/^{206}Pb^*$ ages at *c.* 2.4 Ga, which they interpreted to represent a Palaeoproterozoic component. Sediments immediately south of the SNO–CNO boundary show slightly younger T_{DM} ages (*c.* 2.4 Ga), also suggesting substantial contributions from Palaeoproterozoic sources (Marker *et al.* 1997).

The supracrustal package occurring along Nordre Isortoq (Fig. 1) was known from earlier work to be cut by *c.* 2.8 Ga orthopyroxene-bearing granitoid rocks (J. Connelly, unpublished data). T_{DM} ages are in agreement with an Archaean source for the Nordre Isortoq supracrustal rocks. In contrast, T_{DM} ages from supracrustal rocks in the eastern extension of the belt suggest a substantial Palaeoproterozoic component. It should be noted that the supracrustal units in the belt are not continuous (as also indicated schematically in Fig. 1), however, the lateral change in source-ages indicates either that two different supracrustal packages were tectonically juxtaposed, or reflects significant along-strike variations in the source rocks at the time of deposition.

Detrital zircon studies of allochthonous supracrustal units in inner Nordre Strømfjord have yielded mainly Palaeoproterozoic ages around 2100–2000 Ma (Nutman *et al.* in press). T_{DM} ages (*c.* 2.3 Ga) also suggest the presence of a significant Palaeoproterozoic component in the source. However, rocks of these ages are not known from the central part of the orogen, so the Palaeoproterozoic component must be distally derived. Sediments in the western and central part of the Nordre Strømfjord steep belt (Fig. 1) show similar detrital zircon age spectra and T_{DM} ages as the sediments farther east.

The first-order pattern emerging above is that supracrustal rocks in the SNO–CNO boundary region are largely derived from Archaean precursors, whereas those in the northern CNO are dominated by distally derived Palaeoproterozoic material.

Concluding remarks

This report presents the current status of work on the Nagssugtoqidian orogen being carried out by a large group of researchers (including participants of 1994 and 1995 field work; see Marker *et al.* 1995; van Gool *et al.* 1996).

Data at present available are in accord with the model describing the development of the Nagssugtoqidian orogen in terms of an early phase of closure of an ocean basin through subduction, and a second phase of collision, crustal thickening and later exhumation. It has also become clear that the Archaean basement experienced an orogenic cycle, including magmatism, deformation and metamorphism, prior to Nagssugtoqidian orogeny.

Ongoing efforts will focus on some of the geochronological, structural and metamorphic problems outlined above, and will allow us to address some of the following important topics:

1. Characterisation of the Archaean basement, including the geometry and dynamics of crustal blocks prior to Nagssugtoqidian orogeny;

2. Emplacement ages and exhumation history of mafic dyke swarm(s) in the southern foreland;
3. Sources and timing of deposition of supracrustal rocks: geodynamic significance;
4. Establishment of a detailed structural chronology for the multiply thrust-imbricated and folded tectonic contact between Archaean and Palaeoproterozoic units in the CNO;
5. Linkages with the Rinkian belt to the north;
6. Westward correlations with the Torngat–Baffin orogens in north-eastern Canada;
7. *T-t* evolution of the Nagssugtoqidian orogen subsequent to peak metamorphism.

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