

The Precambrian supracrustal rocks of Nunataq, north-east Disko Bugt, West Greenland

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Supracrustal rocks preserved in a major syncline in southern Nunataq comprise an Archaean and a Proterozoic sequence. An angular discordance between the two sequences is preserved locally. The basal development of the younger sequence shows similarities with that of the lower Proterozoic Marmorilik Formation of the Uummannaq region north of Nuussuaq.

The major syncline–anticline fold pair of southern Nunataq is part of a regional system of E–W-trending Proterozoic folds which also deform the supracrustal rocks of Anap Nunaa, south of Nunataq. Recognition of a major syncline in southern Anap Nunaa, largely obliterated by albitisation, permits a simpler structural interpretation than previously suggested.

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The area north-east of Ataa, north-east Disko Bugt (Fig. 1), contains a major Archaean supracrustal belt which is overlain by Proterozoic supracrustal rocks of significantly lower metamorphic grade (Kalsbeek *et al.* 1988; Kalsbeek 1989, 1990). In some areas the contact between the two supracrustal sequences is markedly discordant, but in other areas (as on Nunataq) the sequences are folded together and their contact relationships are not immediately obvious.

Nunataq is a semi-nunatak at the head of the fjord Torsukattak, surrounded on three sides by ice and with a 4 km fjord coast in the south-west (Fig. 1). Supracrustal rocks occur in two areas, a small area in the extreme north-east (not shown in Fig. 1), and a very large area in the southern part of the nunatak (Fig. 2). Between the two is an area of banded gneisses of presumed Archaean age. The obvious structure is an E–W-trending anticline deforming the southern area of supracrustal rocks, and cored by homogeneous granitic gneiss comparable with the Atâ tonalite (2800 Ma; Kalsbeek *et al.* 1988). This structure had been recognised in early photogeological studies by Escher & Burri (1967). Much

less obvious is a complementary syncline within the same area of supracrustal rocks, whose existence was deduced by Adam A. Garde during reconnaissance work by helicopter in 1989, from the repetition of a thin unit of marble. The marble and low-grade metasediments occupying the core of the syncline were compared by A.A. Garde (personal communication 1991) to the well-known Proterozoic supracrustal sequences farther north in the Marmorilik – Karrat Isfjord region (71°05′–71°35′N; Garde 1978; Henderson & Pulvertaft 1987). High-grade metasedimentary rocks surrounding the assumed Proterozoic rocks, and folded by both anticline and syncline, form part of the belt of Archaean supracrustal rocks exposed along Torsukattak, and extending southwards to Ataa and Eqi (Kalsbeek 1989, 1990; Garde & Steenfelt 1999, this volume).

One of the tasks assigned to the writers in the summer of 1991 was the geological mapping and structural interpretation of the supracrustal rocks of Nunataq with a view to testing Garde's hypothesis; Garde's basic interpretation was, in fact, verified. This paper gives a brief description of the rock units encountered dur-

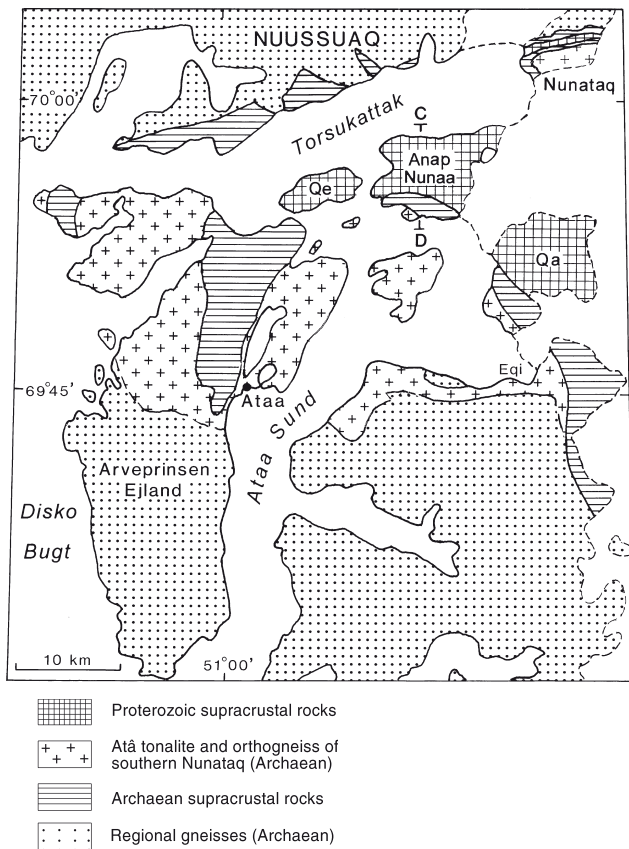


Fig. 1. Geological map of the Precambrian area north-east of Disko Bugt. Qe: Qeqertakassak; Qa: Qapiarfuit; C–D: Section line across Anap Nunaa, see Fig. 5. After Kalsbeek (1990).

ing the mapping, and a discussion of the structural setting.

Archaean gneisses

The gneisses on the north side of the main supracrustal zone are inhomogeneous, in places showing regular banding of light and dark layers with occasional thin amphibolite units. Foliation is generally E–W striking with southerly dips of 30–60°, approximately parallel to the contact with the supracrustal zone. At the contact sheets of aplite and muscovite granite invade both the gneisses and the supracrustal rocks in a zone up to 20 m wide. No basal conglomerate has been observed in the supracrustal rocks adjacent to the gneisses. In places a thin amphibolite is present at the contact. The supracrustal rocks are considered to be younger than the surrounding gneisses, but it is not clear whether the contact is depositional or tectonic.

The gneisses in the core of the major anticline in

the southern part of Nunataq (Fig. 2) consist of very homogeneous grey-white orthogneiss. A few conformable leucocratic veins are present, and locally there are late cross-cutting quartz veins. Foliation in the gneiss is parallel to the contact with the supracrustal rocks, and pre-dates the main folding as it is folded by the main anticline; in two traverses across the main structure the turnover of the anticline was located by a narrow zone of shallow foliation orientations. The supracrustal unit next to the orthogneiss is an amphibolite which, as described below, can be traced right round the anticline with no discordance at map scale. The contact is sheeted, with concordant granitic veins present in a zone a few metres wide in the amphibolite. This is taken to indicate an intrusive relationship of the orthogneiss protolith into the Archaean amphibolite.

The orthogneiss of southern Nunataq has a general resemblance to the Atâ tonalite, but lacks the vast number of cross-cutting veins and dykelets so conspicuous around Ataa (Kalsbeek *et al.* 1988). However, north-west of Ataa the tonalite forms agmatites with amphibolitic supracrustal rocks interpreted as an intrusive relationship, as in the case for the orthogneiss of Nunataq. As the Atâ tonalite has yielded an isotopic age of 2800 Ma (Kalsbeek *et al.* 1988), it is likely that the very similar orthogneiss of southern Nunataq is the same age and that the amphibolitic supracrustal rocks veined by the orthogneiss are also Archaean.

The boundary between the inhomogeneous banded gneisses of northern Nunataq and the orthogneiss (tonalite) of southern Nunataq is presumably hidden beneath the major syncline of supracrustal rocks. This boundary may trend ENE–WSW along Torsukattak; tonalites are not recorded north of the fjord (Fig. 1).

Archaean supracrustal rocks

Supracrustal rocks occur in two main strips, respectively north and south of the assumed Proterozoic supracrustals occupying the core of the main syncline (Fig. 2). It is likely that the rock units in the two strips are at least partly equivalent, although one prominent component of the southern sequence (amphibolite) is poorly represented in the northern sequence. In the extreme north-east of Nunataq a small area of amphibolite facies supracrustal rocks, mainly hornblende-rich psammites and semipelites with some amphibolite and locally massive pyrite mineralisation, is probably also Archaean in age.

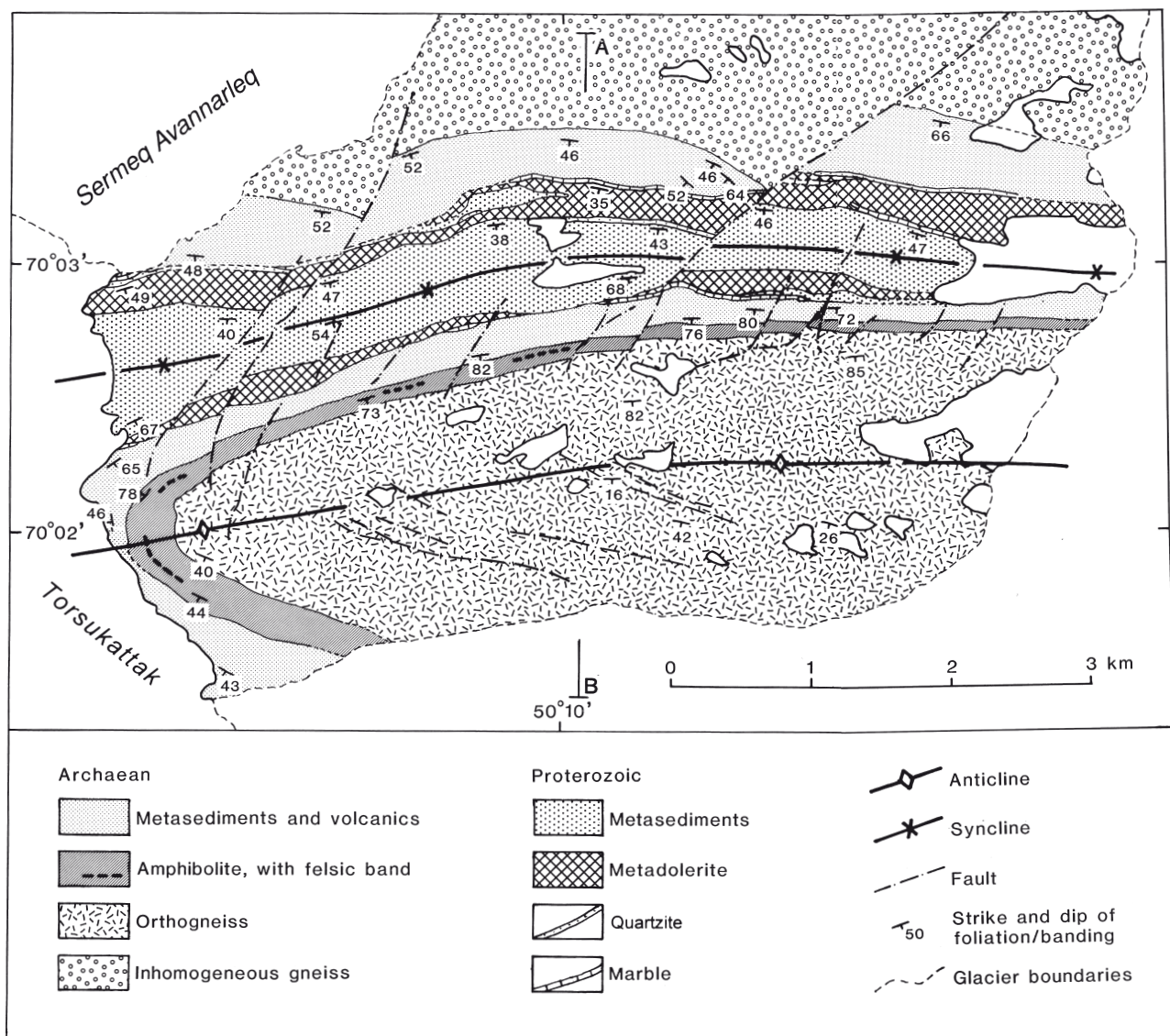


Fig. 2. Geological map of southern Nunataq. A-B: section line, see Fig. 3.

The southern sequence in the main supracrustal outcrop (Fig. 2) comprises two main mappable units, the amphibolite unit which lies next to the orthogneiss, and a structurally higher unit of mixed metasediments and metavolcanics. The two units can be traced for over 10 km along the north limb and around the nose of the main anticline. The amphibolite is strongly foliated, platy to schistose garnet amphibolite. It has a constant thickness of 200–300 m, reaching perhaps 500 m around the nose of the anticline. About 100–150 m from the top of the amphibolite occurs a thin but very persistent light coloured felsic band 1–2 m thick, which may be an acid volcanic rock. It is not known whether the protolith of the amphibolite was intrusive or extru-

sive, but both basic and acid metavolcanic rocks are reported in the Archaean supracrustal belts in nearby areas.

The overlying unit includes rocks described in the field as brownish weathering garnet-mica schist, greenish biotite psammite and undifferentiated greenstone and metasediments. At several localities, notably near the coast north-west of the main anticline, static recrystallisation of actinolitic amphibole was noted, often selectively developed in layers. It appears to post-date the Archaean foliation, but pre-dates Proterozoic crenulation associated with the main antiform.

The northern sequence, along the north side of the main syncline, is disrupted by two major faults with

marked sinistral displacements of 1–2 km. Amphibolite is limited to a few thin discontinuous bands within this unit, which has been mapped as an undivided sequence of metasedimentary and metavolcanic rocks. Field descriptions of rock types encountered include: platy quartzite, garnetiferous semipelite, garnet-muscovite-chlorite schist, veined greenstone and amphibole-rich schist. Random actinolitic amphibole is sporadically developed on bedding planes.

Proterozoic supracrustal rocks

The presumed Proterozoic supracrustal sequence is found only in the core of the main synclinal fold on Nunataq, and is bounded on both sides by higher grade supracrustal rocks of presumed Archaean age (Fig. 2). The contact between the two sequences on the south flank of the syncline is conformable. However, on the north flank of the syncline there is a marked angular discordance at two localities. The most prominent of these occurs on the west side of the eastern of two major NE–SW-trending faults, where there is a difference in strike of up to 40° between the two sequences. These two faults displace both supracrustal sequences in a sinistral sense, but the principal displacement of 1–2 km seems to affect only the Archaean rocks; reactivation on the faults subsequent to deposition and folding of the Proterozoic supracrustal rocks amounts only to a few hundred metres. These differential displacements are reflected in the present variable outcrop width of the northern Archaean supracrustal sequence.

Four lithological mapping units are recognised within the Proterozoic sequence: marble, quartzite, metadolerite (amphibolite), and an undifferentiated metasedimentary unit dominated by psammitic and semipelitic rocks.

The marble unit forms a conspicuous and persistent marker at the base of the Proterozoic sequence on both sides of the syncline. Even when not exposed its presence is suggested by a vegetation-covered depression. The marble is best exposed on the northern flank of the syncline, where thicknesses of 20–25 m were recorded locally. It varies in colour from grey to creamy white. Minor mineralisation has been noted in siliceous bands within the marble, and at contacts with the massive metadolerite body. The marble unit on the south limb of the syncline is less continuously exposed, and usually (when seen) only 2–5 m thick.

Quartzitic rocks are often associated with the mar-

ble, notably the unit on the north flank of the syncline where a conspicuous 3–4 m wide white quartzite bounded by rusty psammities overlies the marble for a distance of several kilometres (sometimes split up by intrusion of the metadolerite). Locally a muscovite-quartz psammite underlies the marble unit, and it is this association which shows resemblance to the lower divisions of the Proterozoic sequence in the Maarmorilik area (71°08'N; Garde 1978; A.A. Garde, personal communication 1991).

A massive unit of amphibolitic metadolerite occurs on both limbs of the synform; its variable thickness and the manner in which it sometimes splits up the marble and quartzite units strongly suggests it was emplaced as a sill. It is very homogeneous, and at the margin grades from very fine to coarse grain size over about 5 m. It is weakly foliated, and notably lacks the platy texture developed in the higher grade Archaean amphibolite.

The main part of the Proterozoic sequence comprises psammitic and semipelitic rock types, which occupy the core of the syncline. A sequence about 390 m thick was measured in the well-exposed western coastal outcrops. This is the only area where way-up criteria (sedimentary structures, bedding-cleavage relationships and vergence of minor folds) are preserved and the main structure can be demonstrated to be a syncline. The dominant rock types are micaceous and non-micaceous pale coloured psammities in beds from a few centimetres to 2.7 m in thickness, interbedded with subordinate dark coloured semipelite and psammite. Lenses and thin layers of spotted calc-silicate rocks are present.

The Proterozoic supracrustal rocks of Nunataq, Anap Nunaa and adjacent areas are ascribed to the Anap nunâ Group (Garde 1994; Garde & Steinfelt 1999, this volume). Low metamorphic siltstones collected on the island of Qeqertakassak (Fig. 1) have yielded a Rb–Sr whole-rock isochron age of 1760 ± 180 Ma, interpreted as the time of closure of the Rb–Sr isotope systems after metamorphism (Kalsbeek *et al.* 1988).

Structure

There is a marked contrast in strain state between the Archaean and Proterozoic supracrustal rock groups preserved in southern Nunataq. Although in many places both appear to contain only one dominant foliation, in clean coastal exposures bedding and cleavage or schistosity can often be distinguished in the

Fig. 3. N-S cross-section of the syncline-anticline fold pair in southern Nunataq; section line is shown on Fig. 2. For key to rock types see Fig. 2.

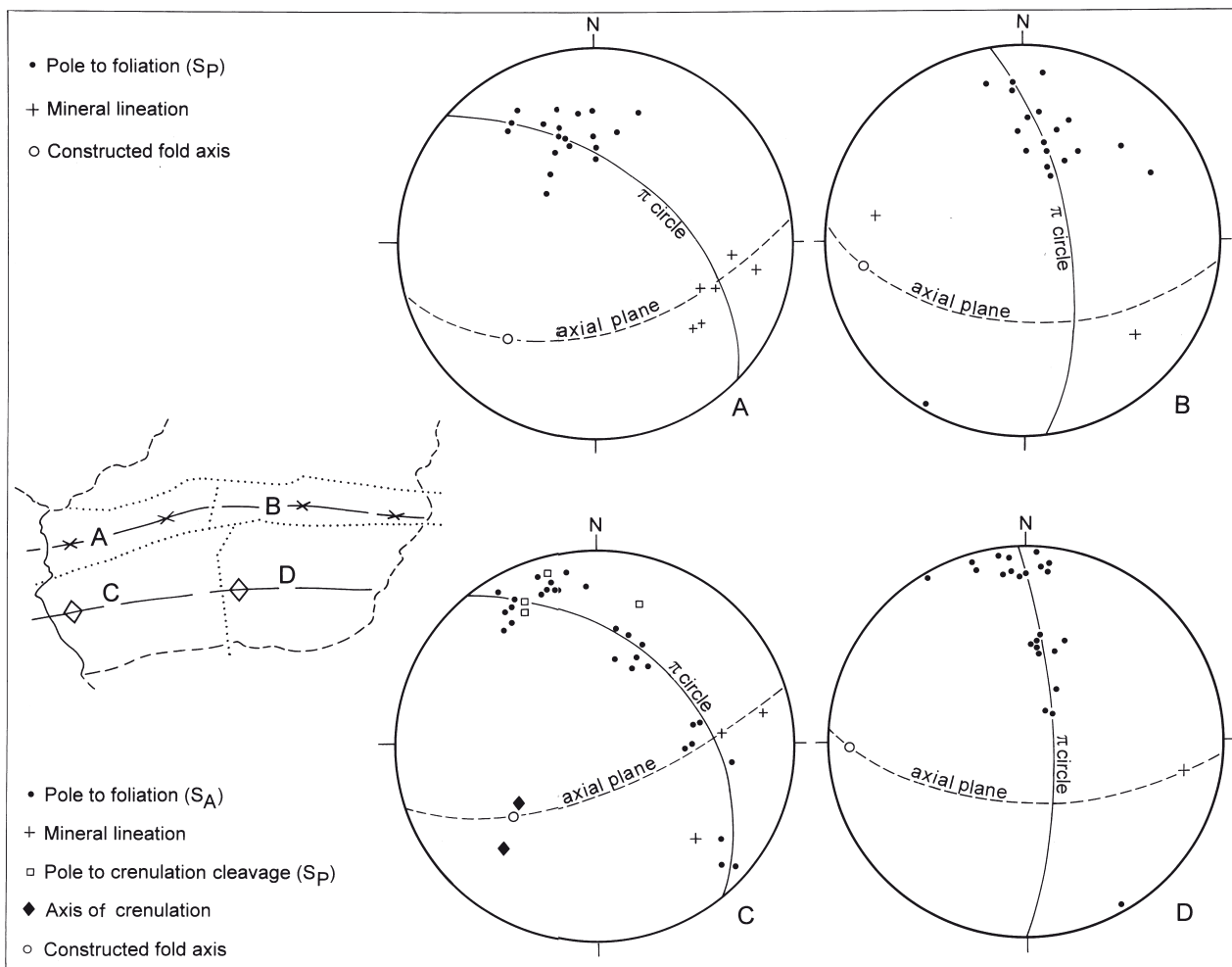
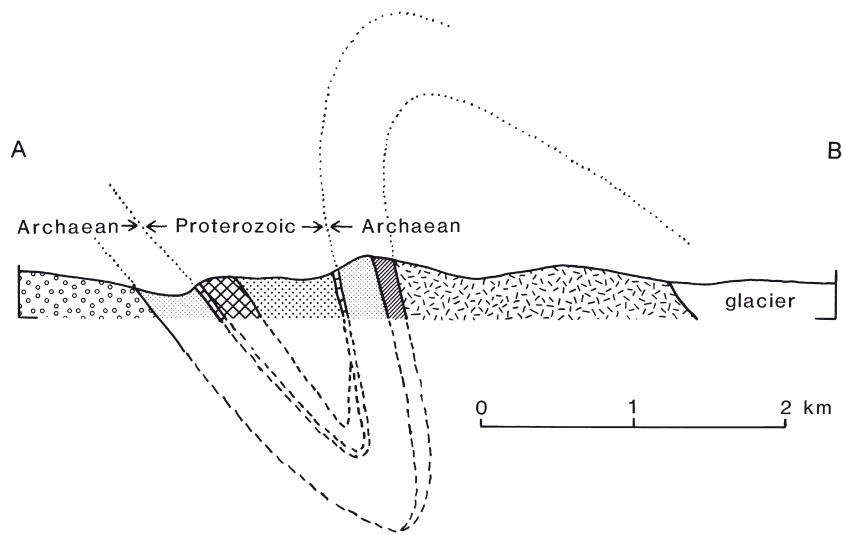


Fig. 4. Lower hemisphere equal area projections of structural data. A & B: Proterozoic supracrustal areas in syncline. C & D: Archaeane supracrustal and orthogneiss areas in anticline.

Proterozoic metasediments, while the Archaean rocks have a single pervasive foliation which is both a schistosity and compositional layering; the original bedding has evidently been completely transposed. As mentioned above, the contrast in fabric development in the older amphibolites and younger metadolerites is particularly marked. Only in the axial region of the main anticline can a younger, presumably Proterozoic fabric (a crenulation cleavage), be seen to deform the earlier foliation. The latter must be of Archaean age if the correlation of the orthogneiss with the Atâ tonalite is correct, because it affects both the gneiss and its metasedimentary envelope. This foliation is parallel to the contact and is folded around the anticline. We would therefore assign the earlier foliation to the Archaean (S_A), the later to the Proterozoic (S_P).

A difference in metamorphic grade is less obvious in the field, although micaceous lithologies within the older sequence tend to be more coarsely recrystallised, with a greater development of garnet. A phase of static amphibole crystallisation has been recorded locally in the Archaean supracrustals but not in the Proterozoic rocks. It post-dates S_A but is deformed by S_P in the axial region of the main anticline.

The two main folds comprise an anticline-syncline pair and are presumably both of Proterozoic age; the syncline contains upward younging Proterozoic rocks in its core (Fig. 3). The folds trend approximately E–W, and are overturned northwards such that both limbs of the structures dip southwards. The mutual limb of the fold pair dips southwards generally at 70–80°, whereas the northern limb of the syncline dips south at angles for the most part between 30° and 45°; the south limb of the anticline is incompletely exposed, much of it being hidden beneath a glacier.

Planar foliations have been measured throughout the supracrustal area (Fig. 4). In the Proterozoic rocks (Fig. 4 A,B) this foliation is likely to have been a mixture of original bedding and the Proterozoic (S_P) cleavage as, due to the rarity of original sedimentary structures, these two elements could only be distinguished locally in the well-exposed coastal outcrops.

Plots of planar orientations in the Archaean supracrustal rocks (Fig. 4 C,D) show two maxima corresponding to the steep and shallow limbs of the fold pair, but the planar features may be in part Archaean and in part Proterozoic in origin. It is only in the nose region of the anticline that the early Archaean foliation (S_A) can be clearly distinguished from the superimposed Proterozoic crenulation folds and associated cleavage.

Foliation in the orthogneisses forming the core of the anticline is clearly Archaean; it appears to be conformable to the envelope of supracrustal rocks and parallels that boundary as it is deformed in the nose of the anticline. Proterozoic crenulation fabrics are found superimposed on the foliation only rarely.

Mineral lineations in both the Archaean and Proterozoic sediments plunge generally into the SE quadrant at angles of 10–30°, and may be interpreted as cleavage-bedding intersections. Axes of the Proterozoic crenulation folds, congruous with the nose of the main anticline, plunge SW at about 40°. Few minor or mesoscopic Proterozoic folds have been recorded in the core of the syncline. Inland the approximate trace of the axial surface of the main syncline can be determined from the change in dip orientation of the two fold limbs. At the coast the occasional preservation of original way up criteria (cross-bedding) and of bedding-cleavage intersections demonstrate clearly that a major fold is present, although the fold core coincides with an area of non-exposure.

The Archaean supracrustal rocks were displaced by two major faults prior to peneplanation and deposition of the Proterozoic sequence. Subsequent to deformation of the Proterozoic sequence the two faults were reactivated, and together with numerous parallel faults show minor sinistral displacements of tens to a few hundred metres (Fig. 2).

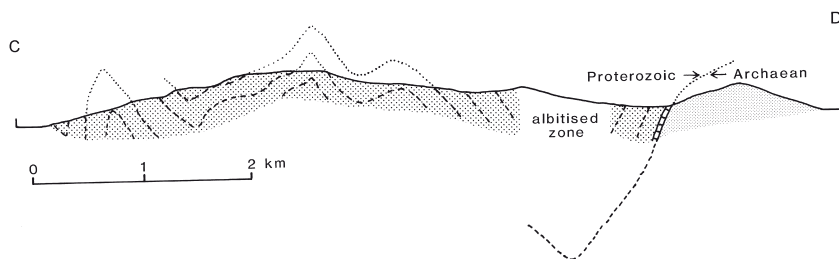
Regional Proterozoic deformation

Proterozoic supracrustal rocks consisting mainly of a very thick sequence of shallow water arenites are well exposed south of the fjord Torsukattak in a broad belt extending from Qeqertakassak through Anap Nunaa to Qapiarfuit (Fig. 1).

There is a general northward increase in the intensity of Proterozoic strain, from Qapiarfuit and the small nunatak east of there where the Proterozoic rocks are in general weakly deformed, through Qeqertakassak (Kalsbeek 1992) and Anap Nunaa (Andersen 1991) where there is upright E–W folding with cleavage, to Nunataq where the folds verge north and there is strong fabric development as described above. There is a zone of albitisation running through Qeqertakassak and Anap Nunaa which when most intense obliterates bedding and cleavage, rendering structural interpretation difficult. The writers visited Anap Nunaa (Fig. 1) in an attempt to clarify the structural interpretation.

On Anap Nunaa it is generally possible to distin-

Fig. 5. N-S cross-section through central Anap Nunaa (Fig. 1) showing structure interpretation and position of albitised zone. See Fig. 2 for key to rock types.



gish bedding and cleavage, except where albitisation is pronounced, and their relationships taken in conjunction with a limited number of sedimentary way-up observations enabled a coherent structural interpretation to be made (Fig. 5). A significant element in this interpretation is a major syncline whose presence was inferred from adequate younging evidence on the limbs, although its axial region is obliterated by a zone of intense albitisation; the total lack of foliation in the albitised region suggests the process post-dated deformation. The folds are upright and the cleavage strikes E-W and is subvertical. In the extreme north-east of Anap Nunaa, vertical common limbs of fold pairs are encountered, an indication of the northerly vergence of the Proterozoic folds which is more pronounced on Nunataq (Fig. 3).

The structural interpretation of Figure 5 differs from that of Andersen (1991) in some respects. He recognised additional major folds in areas not visited by the writers, but not the major syncline in the albitised zone of central south Anap Nunaa. As a result, he interpreted a synform in western Anap Nunaa as an overturned nappe-like anticline with a major inverted limb occupying the central part of the area. From a few

unambiguous younging observations the writers were able to establish that the synform is in fact a syncline, and to develop the simpler structural interpretation without recourse to the multiple deformation phases inferred by Andersen. However, when traversing western Anap Nunaa the writers did encounter a problematic area with divergent foliation orientations in which way-up criteria and cleavage-bedding intersections were ambiguous. On Qeqertakassak, due west of Anap Nunaa, a curious overturned anticline, enveloped by albitised rocks, has been mapped by Kalsbeek (1992).

Two lines of evidence suggest that the Proterozoic deformation involved dextral transpression. In the two areas examined in some detail, north-east Anap Nunaa and coastal exposures of the main syncline on Nunataq, the cleavage strikes a few degrees anticlockwise to bedding on steep overturned fold limbs. This indicates anticlockwise transection of the folds by the cleavage, and if the two are related by a 'flattened buckle' mechanism, that the deformation took place by a dextrally transpressive mechanism (Soper 1986).

The second line of evidence is provided by deformed trough cross-bedding in vertical beds beautifully exposed in glacially smoothed coastal exposures in north-

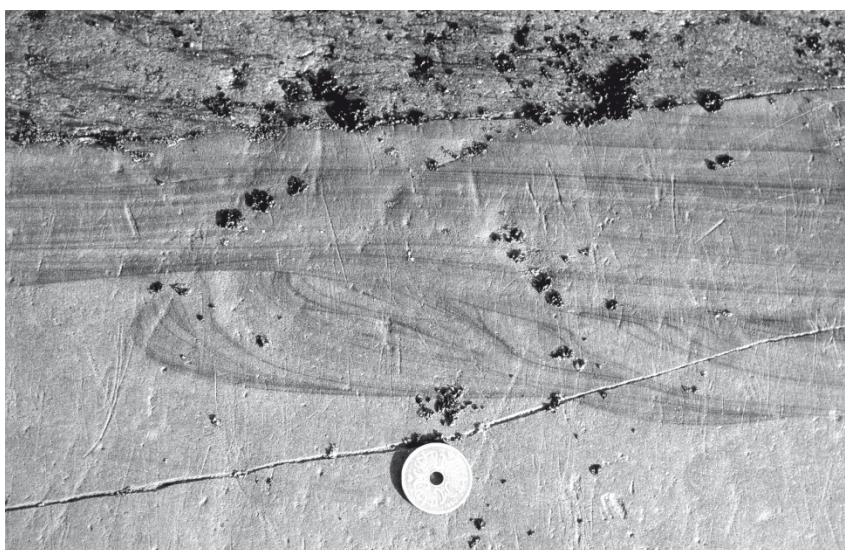


Fig. 6. Deformed trough cross-bedding in north-east Anap Nunaa.

east Anap Nunaa (Fig. 6). The manner in which the troughs are consistently deformed into 'Z' shapes requires a component of top-to-right shear strain, that is, dextral.

Summary of geological events

The following minimum sequence of Precambrian events can be inferred from the evidence on Nunataq and Anap Nunaa:

Archaean

1. Development of the banded gneiss complex
2. Erosion to mid-crustal levels
3. Deposition of sediments and volcanics
4. Emplacement of dolerite sills
5. Emplacement of the orthogneiss protolith (? 2.8 Ga)
6. Metamorphism and deformation to produce the S_A fabric
7. Static metamorphism

Proterozoic

8. Erosion; faulting on lines which now trend NE–SW
9. Subsidence and deposition of the Anap nunâ Group
10. Emplacement of the younger sills
11. Folding and cleavage development (S_p) under dextral transpression
12. Albitisation
13. Faulting, including sinistral reactivation of earlier faults

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