graphic representations from these areas should therefore be viewed with reservation.

A new topographical map of Greenland at a scale of 1:2 500 000 was published by KMS in 1994 (KMS 1994). The new Geological map of Greenland at the same scale uses an identical topographic base map with the same projection; the only significant topographical difference is the omission of contour lines on the land areas.

Based on the digital data for the new topographic map, the size of Greenland and its ice cover has been computed by Weng (1995). The new area figures are:

Ice-free land area	410 449 km^2
Ice-covered area	1 755 637 km^2
Total area	2 166 086 km^2

Crystalline rocks older than 1600 Ma: the Greenland Precambrian shield

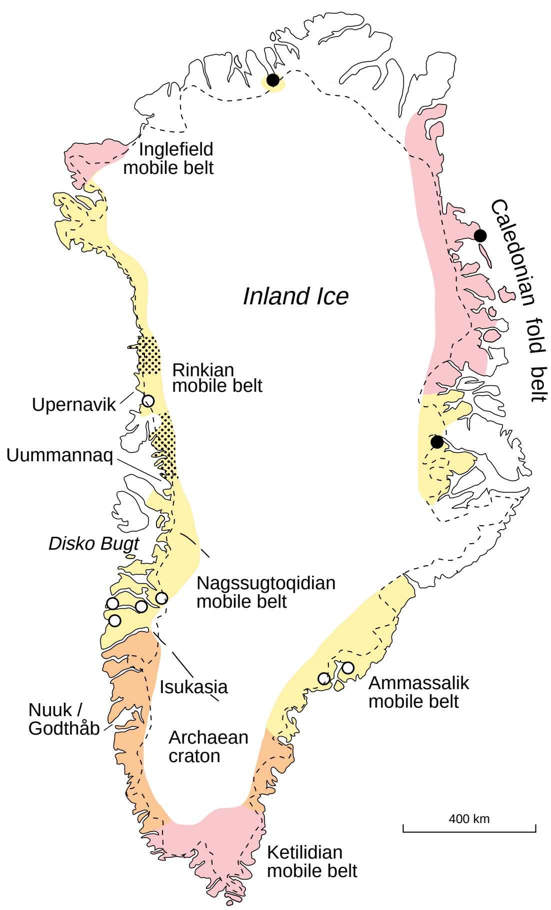

Fig. 3. Simplified map showing the distribution of Archaean and early Proterozoic basement provinces in Greenland. **Orange**: preserved Archaean (southern Greenland). **Yellow**: Archaean rocks reworked during the early Proterozoic (areas dominated by early Proterozoic metasediments are dotted). **Pink**: Dominantly juvenile early Proterozoic rocks. **White**: Younger formations and ice. **Large Dots** and **open circles** indicate schematically localities where the presence of, respectively, Archaean and early Proterozoic rocks have been documented in poorly known areas, and in cases where these ages are in contrast to the age of the surrounding rocks. Slightly modified from Kalsbeek (1994).

About half of the ice-free area of Greenland consists of Archaean and early Proterozoic crystalline basement rocks, mainly orthogneisses with some enclaves of supracrustal rocks. They belong to three distinct types of basement province (Fig. 3): (1) Archaean rocks (3100–2600 Ma old, with local older units), almost unaffected by Proterozoic or later orogenic activity; (2) Archaean terraines reworked during the early Proterozoic around 1850 Ma ago; (3) terraines mainly composed of juvenile early Proterozoic rocks (2000–1750 Ma old). Terranes of categories (2) and (3) often contain high grade early Proterozoic metasedimentary successions.

Nearly all unreworked Archaean gneisses occur within the Archaean craton of southern Greenland (Fig. 3). They are cut by swarms of basic dykes (see Fig. 18), most of which belong to a *c.* 2000–2200 Ma suite; the dykes are undeformed and unmetamorphosed, so the gneisses of the Archaean craton cut by the dykes cannot have been significantly affected by early Proterozoic orogenic activity around 1850 Ma ago.

Reworked Archaean gneisses are prominent in the Nagssugtoqidian and Rinkian mobile belts that occur north of the Archaean craton in West Greenland, and in the Ammassalik mobile belt of East Greenland (Fig. 3). Juvenile early Proterozoic gneisses and granitoid rocks (2000–1750 Ma) make up most of the Ketilidian mobile belt of South Greenland, and they also form a large proportion of the crystalline basement within the Caledonian fold belt of North-East Greenland; they are also present in the Inglefield mobile belt in North-West Greenland.

Before the opening of the Labrador Sea and Baffin Bugt the Precambrian basement of Greenland formed an integral part of the Laurentian Shield, and correlations between tectonic units in Canada and Greenland have been proposed (e.g. Hoffman 1989, 1990). However, the pre-drift fit of Greenland to Canada is still not accurately known and correlations are thus rarely straightforward; a detailed discussion of these relationships is outside the scope of this map sheet description.

Archaean craton

Most rocks of the Archaean craton (Kalsbeek & Garde 1989) were formed during the late Archaean 3100–2600 Ma ago. Early Archaean gneisses and supracrustal rocks (3900–3600 Ma old) have been found in the Godthåbsfjord region of South-West Greenland, where three distinct tectonic terranes have been recognised (Fig. 4). Each terrane has a characteristic rock association and tectonic history (Friend *et al.* 1987) and they were brought together by thrusting *c.* 2600 Ma ago; they are separated by mylonite zones. It is likely that the Archaean craton elsewhere is also built up of distinct terranes, which may explain why gneisses and supracrustal rocks in different parts of the Archaean craton often have different ages.

Fig. 4. Map of the Godthåbsfjord region, southern West Greenland, showing different tectonic terranes (plates). **1**: Akia terrane; **2**: Akulleq terrane; **3**: Tasiusarssuaq terrane. Modified from McGregor (1993).

Fig. 5. Early Archaean banded iron formation comprising interbanded magnetite (dark coloured) and chert (light coloured). Isua supracrustal sequence, Isukasia, inner Godthåbsfjord, southern West Greenland. Pen for scale. Photo: A.A. Garde.

Early Archaean supracrustal rocks

The Isua supracrustal sequence [69] (3700–3800 Ma old, Moorbath *et al*. 1973), which occurs in the Isukasia area at the head of Godthåbsfjord (Nuup Kangerlua) in West Greenland (Fig. 4), is the most extensive occurrence of early Archaean supracrustal rocks known on earth. It forms a zone up to 4 km wide and up to *c*. 35 km long and has been investigated in considerable detail. A recent review of earlier studies together with new data is presented by Appel *et al.* (1998, see also Nutman 1986). The sequence contains: (1) Layered and massive amphibolites with Fe-rich tholeiitic compositions, within which pillow structures are locally preserved; (2) Metacherts and a major body of banded iron formation thought to have originated as chemical sediments (Fig. 5); (3) Biotite-muscovite schists, some of which preserve graded bedding; (4) Units of talc schist, up to 100 m wide, with relics of dunite; (5) Banded carbonate and calc-silicate rocks, probably metasomatic in origin; (6) Bodies of chloritic leuco-amphibolite (garbenschiefer) up to 1 km wide which form *c*. 25% of the supracrustal belt and probably represent metasomatically altered metavolcanic rocks. All these rocks are strongly deformed and at high metamorphic grade, and the nature of their protoliths as well as their precise ages are under continuous debate.

Recent investigations have shown that the Isua supracrustal belt consists of at least two temporally distinct and unrelated sequences of supracrustal rocks, one about 3710 Ma and the other probably around 3800 Ma old, separated by thrusts (Nutman *et al*. 1997). Parts of the belt were isoclinally folded before intrusion of 3750 Ma old tonalites, while the arcuate trend of the belt as a whole is the result of at least two phases of later deformation (Nutman 1986).

Outside the Isukasia area inclusions of supracrustal rocks, mainly amphibolites of tholeiitic or komatiitic composition, occur within early Archaean gneisses as thin units. These supracrustal rocks have been collectively termed the Akilia association [69], and are thought to represent fragments of a disrupted greenstone belt (McGregor & Mason 1977).

Studies of graphite particles in samples of Isua and Akilia metasedimentary rocks have yielded evidence of very early life on earth (Mojzsis *et al.* 1996; Rosing 1999).

Fig. 6. Heterogeneous, polyphase Amîtsoq gneiss in the central part of northern Godthåbsfjord, southern West Greenland. Fragments of dark homogeneous amphibolite are interpreted as remnants of disrupted Ameralik dykes. The hammer is *c*. 45 cm long. Photo: A.A. Garde.

Early Archaean Amîtsoq gneisses

The early Archaean Amîtsoq gneisses [76] (Fig. 6) occur in an area stretching north-east from Nuuk/Godthåb to Isukasia. They are characterised by the presence of abundant remnants of metamorphosed basic dykes, known as the Ameralik dykes (see Fig. 18; McGregor 1973). The gneisses were formed during a number of distinct intrusive events that occurred between 3900 and 3600 Ma ago (Moorbath *et al.* 1972; Nutman *et al.* 1993).

Two main types of Amîtsoq gneiss can be recognised: (1) Grey, layered to homogeneous tonalitic to granitic orthogneisses of calc-alkaline affinity (commonly with secondary pegmatite banding) which form at least eighty per cent of the outcrop; (2) Microcline augen gneisses with associated subordinate ferrodiorites (*c.* 3600 Ma old), which have been referred to as the 'Amîtsoq iron-rich suite' (Nutman *et al.* 1984). The latter resemble Proterozoic rapakivi granites and were intruded after the strong deformation in the surrounding grey banded gneisses. Most Amîtsoq gneisses are in amphibolite facies, but locally the rocks have been affected by a *c.* 3600 Ma old granulite facies metamorphism possibly related to emplacement of the Amîtsoq iron-rich suite.

Late Archaean supracrustal rocks

Ten to twenty per cent of the Archaean craton is made up of a variety of supracrustal rocks [68], mainly amphibolites with subordinate paragneisses (often garnetiferous ± cordierite ± sillimanite) and ultramafic layers and pods. No reliable age determinations for these rocks are available, and they may belong to different age groups. Amphibolites locally show well-preserved pillow structures indicating a submarine volcanic origin. Intense deformation, however, has generally obliterated all primary structures and produced finely layered amphibolites. More massive amphibolites may represent original basic sills within the volcanic pile. Chemically the amphibolites range from low-K tholeiitic to komatiitic in composition.

Major units of garnetiferous paragneisses occur only locally, for example in the northern part of the Archaean craton north of Maniitsoq/Sukkertoppen; while these may be younger than most of the late Archaean gneisses, they were intruded by younger Archaean granitoid sheets. The late Archaean evolution of the craton was evidently very complex.

Supracrustal units are usually folded, and as they form good marker horizons they often reveal the intricate structure of the enveloping gneiss complexes. Primary cover–basement relationships with earlier gneisses have not been observed.

Anorthositic rocks

Metamorphosed calcic anorthosites and associated leucogabbroic and gabbroic rocks [85] form one of the most distinctive rock associations in the Archaean craton. They occur as concordant layers and trains of inclusions, and provide some of the best marker horizons for mapping structures on a regional scale. Anorthositic rocks are generally bordered by amphibolite units into which they are believed to have been intruded.

Anorthosites and associated rocks are most spectacularly developed in the Fiskenæsset area of West Greenland where they form *c.* 5% of the total outcrop. Here they appear to belong to a single stratiform intrusion, the Fiskenæsset complex (Myers 1985), which has been dated at *c.* 2850 Ma (Ashwal *et al.* 1989). The main rock types are metamorphosed anorthosite (< 10% mafics), leucogabbro (10–35% mafics) and gabbro (35–65% mafics), together with minor amounts of ultramafic rocks and chromitite. Magmatic structures are often preserved: cumulus textures with plagioclase up to 10 cm in size are common and igneous layering can be observed at many localities.

The Fiskenæsset complex has undergone complex folding. The earliest major folds were recumbent isoclines; these were refolded by two later fold phases producing structures with steeply inclined axial surfaces (Myers 1985).

Late Archaean gneisses

Most of the Archaean craton is composed of grey orthogneisses [72, 73] which were mainly generated 3000–2600 Ma ago. In the Nuuk/Godthåb region of West Greenland they are up to 3100 Ma old, whereas in the Fiskenæsset area to the south isotopic ages are generally less than 2900 Ma. It is believed that the precursors of the gneisses were intruded as sub-concordant sheets and larger complexes that penetrated and disrupted ('exploded') pre-existing basic volcanic units and anorthositic rocks; the gneisses commonly occupy much larger volumes than the older rocks into which they were intruded. Individual gneiss sheets range from

Fig. 7. Amphibolite agmatite with numerous sheets of tonalite, granodiorite, granite and pegmatite, dated at 3.0–2.97 Ga. South-facing, *c.* 40 m high cliff in central Godthåbsfjord, southern West Greenland. Person in red anorak for scale. Photo: A.A. Garde.

a few metres to several kilometres in thickness (Fig. 7). It has been suggested that intrusion of granitoid magma took place during periods of thrusting (Bridgwater *et al.* 1974).

Most of the gneisses are tonalitic to granodioritic in composition. In the Fiskenæsset area gneisses form *c.* 85% of the outcrop with tonalitic gneisses as the dominant component. In amphibolite facies gneisses biotite is the most important ferromagnesian mineral.

About half of the craton north of Fiskenæsset is occupied by granulite facies gneisses [73]. Granulite facies metamorphism, however, was not synchronous throughout the area: north of Nuuk/Godthåb it is 3000–3100 Ma old (Garde 1990; Friend & Nutman 1994), whereas in the Fiskenæsset area it is *c.* 2800 Ma old (Pidgeon & Kalsbeek 1978) and north of Maniitsoq/Sukkertoppen *c.* 2750 Ma old (Friend & Nutman 1994). In granulite facies terraines hypersthene is most common in amphibolites, whereas in the gneisses its presence depends on chemical composition; parts of the amphibolite facies gneisses in the northern part of the craton were formed by retrogression of granulite facies rocks (e.g. Garde 1990).

Commonly the gneisses show complex fold interference structures (e.g. Berthelsen 1960; Fig. 8). Formation of the gneisses by deformation and migmatisation of their igneous precursors has been described in detail by Myers (1978), and a detailed description of the complex evolution of the Fiskefjord area, north of Godthåbsfjord, was recently presented by Garde (1997).

Intrusive rocks

Within the late Archaean gneisses a variety of homogeneous granitic to tonalitic rock units have been differentiated on the map as felsic intrusions [80]. These rocks were emplaced at various times during the tectonic evolution of the areas in which they occur. Some (e.g. the *c.* 3000 Ma old Taserssuaq tonalite north of inner Godthåbsfjord) represent late phases of the igneous precursors of the gneisses in areas where deformation was less intense than elsewhere. Others (e.g. the 2800 Ma old Ilivertalik augen granite north-east of Fiskenæsset) are younger than the surrounding gneisses, but have been strongly overprinted by later deformation. One rock unit, the 2550 Ma old Qôrqut granite complex [79] (Friend *et al.* 1985), is clearly post-tectonic.

A distinct 2700 Ma old suite of very well-preserved post-tectonic intermediate and mafic intrusions, including gabbros and diorites [82] as well as syenites and granites [80], occurs within late Archaean gneisses in the Skjoldungen district of South-East Greenland (Nielsen & Rosing 1990; Blichert-Toft *et al.* 1995). It is associated with older syenitic gneisses [80] and with a late nephelinite body, the 2670 Ma old Singertât complex [83].

Small norite bodies [82] occur within an arcuate belt east of Maniitsoq/Sukkertoppen (Secher 1983), and a small carbonatite sheet *c.* 2650 Ma old [84] has been found at Tupertalik, 65°30′N in West Greenland (Larsen & Pedersen 1982; Larsen & Rex 1992).

Proterozoic orogenic belts

About forty per cent of the ice-free area of Greenland is underlain by early Proterozoic orogenic belts (Fig. 3). Several of these consist largely of reworked Archaean rocks that underwent strong deformation and metamorphism during early Proterozoic ('Hudsonian') oro-

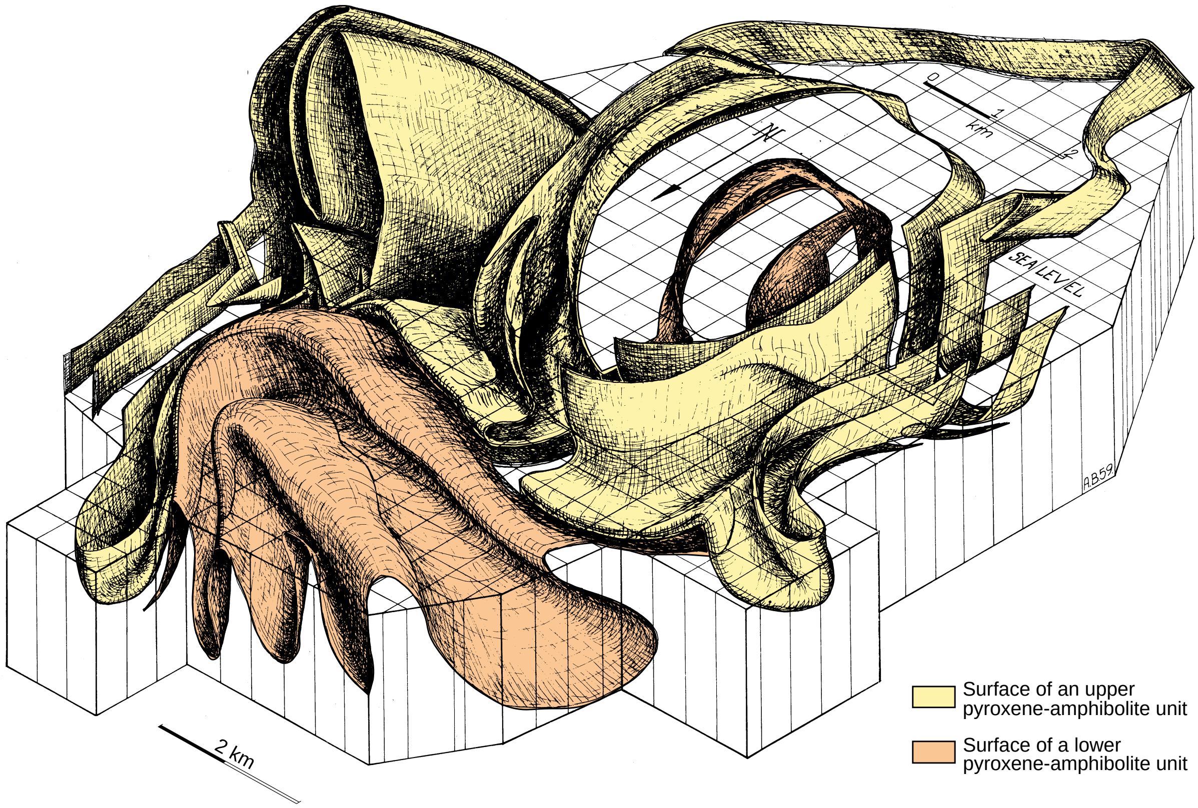

Fig. 8. Structural stereogram of the western Toqqusap Nunaa area north of Atammik (*c.* 65°N), southern West Greenland, showing complex fold structures in the late Archaean gneiss complex. Slightly modified from Berthelsen (1960).

genic events around 1850 Ma ago. Others are made up of juvenile early Proterozoic crust.

Nagssugtoqidian mobile belt

The Nagssugtoqidian mobile belt (Fig. 3; van Gool *et al.* 1996, 1999) extends from Søndre Strømfjord to Disko Bugt in West Greenland. It consists mainly of reworked Archaean gneisses [74, 75] but also includes early Proterozoic supracrustal and intrusive rocks [67, 78, 81]. Main structures trend ENE–WSW. The peak of Proterozoic tectonic and metamorphic activity was at *c.* 1850 Ma when large parts of the belt underwent granulite facies metamorphism. Early Proterozoic orogenic activity is believed to be related to collision of two Archaean continents, with a suture present within the Nagssugtoqidian mobile belt (Kalsbeek *et al.* 1987).

Reworking of Archaean gneisses in the Nagssugtoqidian mobile belt was first recognised by Ramberg (1949); a swarm of basic dykes, the Kangâmiut dykes (2040 Ma, Nutman *et al.* 1999), which are well preserved in the Archaean craton to the south, become increasingly deformed and metamorphosed on entering the Nagssugtoqidian mobile belt (see Fig. 18).

Supracrustal rocks

Early Proterozoic supracrustal rocks are prominent in the central part of the Nagssugtoqidian mobile belt [67], and are dominated by pelitic and semipelitic metasediments. Marble and calc-silicate rocks are common within these metasedimentary units, and pelitic rocks may be rich in graphite. While the metasediments are cut by sheets of 1920 Ma quartz diorite, age determinations on detrital zircons (Nutman *et al.* 1999) show that deposition must have taken place later than *c.* 2000 Ma. Within the Nagssugtoqidian mobile belt late Archaean metasediments [68] are also present, for example at the southern shore of Disko Bugt. They are not easily distinguished in the field from Proterozoic rocks, and since isotopic age determinations are few, it is not certain that all supracrustal sequences shown on the map have been assigned to the correct age category.

The involvement of early Proterozoic supracrustal rocks in complex fold structures and shear zones in the central part of the belt shows that the deformation was of Proterozoic age.

Felsic and intermediate intrusions

There are only a few granitic and quartz dioritic intrusive bodies in the Nagssugtoqidian mobile belt. Some are of Archaean origin [80], whereas others are of early Proterozoic age [78]. A large sheet of quartz diorite [81], dated at 1920 Ma, occurs close to the border of the Inland Ice at 68°N (Henderson 1969; Kalsbeek *et al.* 1987); it is folded and strongly deformed at its margins, but igneous textures and minerals are preserved in its centre. Strongly deformed Proterozoic quartz dioritic to tonalitic rocks (not shown on the map) also occur within reworked Archaean gneisses south of the main quartz diorite body, and have been interpreted as remnants of an early Proterozoic island arc tectonically interleaved with the Archaean rocks (Fig. 9; Kalsbeek *et al.* 1987; van Gool *et al.* 1999).

A large area (*c.* 30 × 50 km) east and north-east of Sisimiut/Holsteinsborg is made up of early Proterozoic hypersthene gneisses (Kalsbeek & Nutman 1996). In the field these cannot easily be distinguished from Archaean rocks that occur farther east, and on the map all rocks in this region are shown as Archaean, overprinted by Proterozoic granulite facies metamorphism [75].

Ammassalik mobile belt

The Ammassalik mobile belt extends from 64°30′N to 68°N in southern East and South-East Greenland (Fig. 3), and is probably an extension of the Nagssugtoqidian belt of West Greenland. The belt is dominated by reworked Archaean gneisses [74, 75] which were tec-

Fig. 9. Rock face at south side of inner Nordre Strømfjord/Nassuttooq, southern West Greenland, showing tectonic contact between pale Archaean tonalitic gneisses and overlying dark dioritic gneisses and supracrustal rocks of Proterozoic age. Thin slices of marble and calc-silicates occur at the contact and within the Archaean gneisses. The height of section is *c.* 350 m. Photo: J.A.M. van Gool.

Fig. 10. Ammassalik mobile belt. Archaean gneisses reworked during the early Proterozoic in granulite and retrograde granulite facies, with supracrustal layers consisting of amphibolites and paragneisses. East of northernmost Sermilik (*c.* 66°30′N), South-East Greenland. The prominent summit is 1750 m high; relief seen is *c.* 1500 m. Photo: J.C. Escher.

tonically interleaved with metasediments during the early Proterozoic (Fig. 10; Chadwick *et al.* 1989; Kalsbeek 1989). In the Ammassalik district early Proterozoic pelitic metasediments [67] are prominent, and locally contain abundant kyanite; thick marble units also occur. Archaean anorthositic rocks [85] are present in a few places.

Early Proterozoic plutonic rocks

A late tectonic suite (1885 Ma old) of leuconoritic and charnockitic intrusive rocks [81], the Ammassalik Intrusive Complex, occurs as a WNW–ESE-trending series of intrusions at 65°30′N (Friend & Nutman 1989). This suite was emplaced into gneisses and sediments, in which it caused widespread anatexis and produced a series of garnet-rich granitic gneisses [71].

Early Proterozoic quartz dioritic to tonalitic intrusions [81] occur locally; one is shown just north of latitude 66°N. Their age is not precisely known, but may be of the order of 2000 Ma. Early Proterozoic gneisses, formed locally by deformation of such intrusive rocks, are not distinguished on the map.

Scattered post-tectonic granite plutons [78] associated with diorites and local gabbro occur over the central part of the Ammassalik mobile belt. Their isotopic age is about 1680 Ma, much later than the peak of tectonic and metamorphic activity in the belt which was between 1900 and 1800 Ma ago (Kalsbeek *et al.* 1993a). Isotopic data show that the granites are largely of crustal origin.

Rinkian mobile belt

The Rinkian mobile belt (Henderson & Pulvertaft 1987; Grocott & Pulvertaft 1990) lies to the north of the Nagssugtoqidian mobile belt in West Greenland between latitudes 69°N and 75°N (Fig. 3). The mobile belt is characterised by the presence of a distinctive early Proterozoic sedimentary succession several kilometres thick, the Karrat Group [62], which overlies reworked Archaean gneisses [74]. It has not been possible to define a natural boundary between the Nagssugtoqidian and Rinkian belts. Nearly everywhere north of the Archaean craton effects of Proterozoic deformation and metamorphism can be found. However, in the area east and north-east of Disko Bugt the Archaean rocks appear to have been less strongly affected by Proterozoic reworking than in the areas to the north and south (Garde & Steenfelt 1999).

Gneisses and intrusions

Reworked Archaean gneisses [74] in the Rinkian mobile belt are similar to those of the Archaean craton. On Nuussuaq, and farther north, they contain anorthosite bodies [85] and several dioritic intrusions [82]. North of Nuussuaq sheets of Archaean augen gneisses occur locally (not distinguished on the map) and have been used as structural markers to unravel the complex thrust tectonics of that area (Pulvertaft 1986).

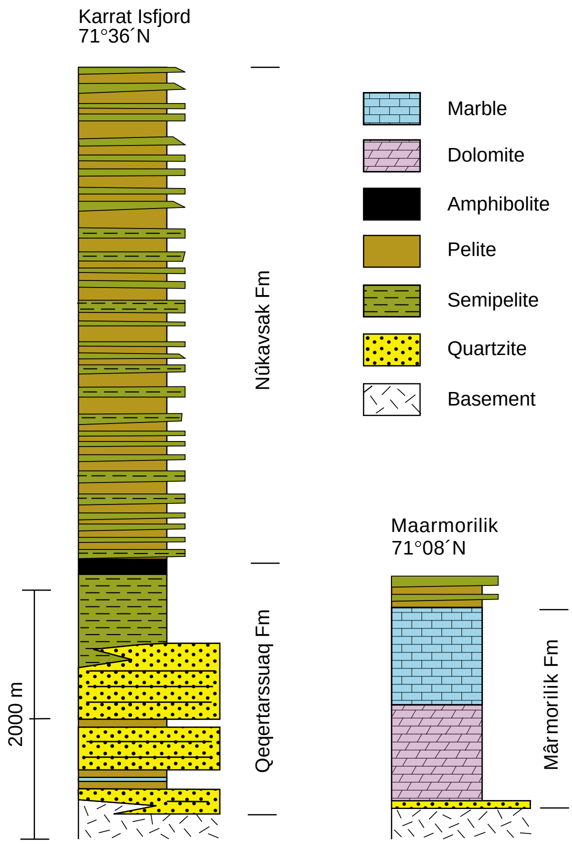

Fig. 11. Schematic lithostratigraphic sections of the lower Proterozoic Karrat Group in the Maarmorilik – Karrat Isfjord region. The Nûkavsak Formation consists of a flysch succession of interbedded greywacke and mudstone, now metamorphosed in amphibolite facies. Based on Garde (1978) and Henderson & Pulvertaft (1987).

North-east of Disko Bugt/Qeqertarsuup Tunua a well preserved 2800 Ma old tonalitic intrusive complex [80] shows few signs of Proterozoic deformation. It was emplaced into a late Archaean greenstone belt [68] and earlier gneisses (Kalsbeek & Skjernaa 1999).

The 1860 ± 25 Ma old Prøven charnockite [78] (Kalsbeek 1981) in the Upernavik area (*c.* 72°30′N) consists of charnockites and leucogranitic rocks. It was emplaced into Archaean gneisses and early Proterozoic metasediments (the Karrat Group), which are here of granulite facies metamorphic grade. There may be a connection between emplacement of the Prøven charnockite and the high-grade metamorphism.

Supracrustal rocks: Disko Bugt

North-east of Disko Bugt a well preserved *c.* 2800 Ma old Archaean greenstone belt consists of basic metavolcanic rocks [68] and acid [66] metavolcanic rocks. The basic rocks, which are mainly greenschists and meta-pillow lavas, contain a subvolcanic sill complex of gabbros and dolerites [82] (Marshall & Schønwandt 1999). The Archaean rocks are overlain discordantly by an early Proterozoic succession [62] consisting of a lower unit of marble and orthoquartzite overlain by thick shallow-water siltstones and sandstones. Early Proterozoic deformation and metamorphism are at a minimum in this area (Garde & Steenfelt 1999).

Supracrustal rocks: the Karrat Group

The Karrat Group [62] was deposited unconformably on the Archaean crystalline basement, and is widely exposed over a 400 km coastal stretch north of Uummannaq (Fig. 3). U-Pb age determinations on detrital zircons have shown that deposition of the Karrat Group took place later than *c.* 2000 Ma ago (Kalsbeek *et al.* 1998a), while it must have been deposited before the emplacement of the Prøven charnockite which has been dated at *c.* 1860 Ma.

The Karrat Group is divided into three formations (Henderson & Pulvertaft 1987). The two lowest formations, the Mârmorilik Formation (up to 1.6 km thick; Garde 1978) and Qeqertarssuaq Formation (more than 2 km thick; Fig. 11), comprise shelf and rift type sediments, dominated respectively by marbles and clastic sediments with minor volcanic rocks. However, these two formations appear to be correlatives, originally separated by a basement high. The upper formation, the Nûkavsak Formation, with a minimum structural thickness of 5 km, is a typical turbidite flysch succession. Extensive tight folding makes reliable estimates of the stratigraphic thickness of the Karrat Group uncertain. Proterozoic sedimentary successions similar to the Karrat Group occur in the Foxe fold belt on the west side of Baffin Bugt in north-eastern Canada (the Piling and Penhryn Groups; Henderson & Tippet 1980; Henderson 1983) suggesting correlation of the Rinkian mobile belt of Greenland and the Foxe fold belt of Canada.

The Karrat Group and its underlying crystalline basement are complexly interfolded into dome structures and gneiss-cored fold nappes (Fig. 12; Henderson & Pulvertaft 1987). Tectonic interleaving of cover rocks with basement gneisses has also taken place, and the south-

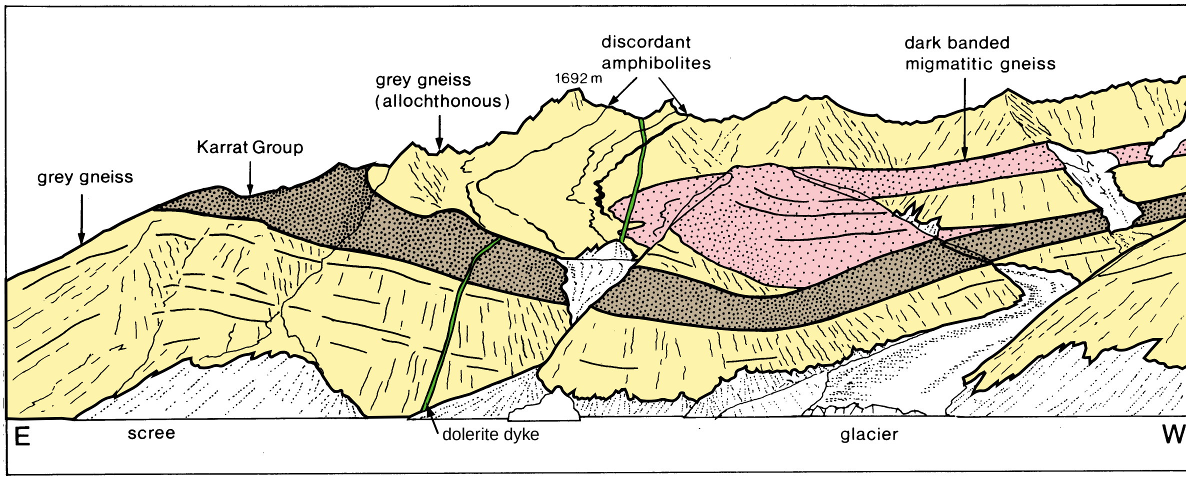

Fig. 12. Sketch of part of one of the characteristic nappes in the Rinkian mobile belt (Kigarsima nappe seen from the north). North side of Upernivik Ø (71°20′N), central West Greenland. Slightly modified from Henderson & Pulvertaft (1987).

ern part of the Rinkian belt is characterised by flat-lying thrust sheets (Pulvertaft 1986). High-grade metamorphism at relatively low pressure characterises parts of the Rinkian belt.

North-West Greenland and Inglefield mobile belt

North of 75°N the Karrat Group has not been recognised (Dawes & Frisch 1980). This region consists mainly of reworked Archaean gneisses with banded iron formation and supracrustral units [74]. The *c.* 2700 Ma old Kap York meta-igneous complex [82] at 76°N is composed of a suite of plutonic rocks ranging from gabbro to granite in composition (Dawes *et al.* 1988). A major anorthosite complex [85] is exposed at 77°30′N (Nutman 1984).

Inglefield Land (78°–79°N), is mainly composed of high-grade supracrustal and granitoid rocks belonging to the early Proterozoic Inglefield mobile belt (Dawes 1988). They are overlain by middle Proterozoic sediments with basaltic sills of the Thule Supergroup and Cambrian deposits of the Franklinian Basin.

The oldest rocks recognised in Inglefield Land are metasediments of the Etah Group [67], dominated by marbles, calc-silicate rocks and quartzofeldspathic paragneisses. These are intruded by a variety of metaplutonic rocks, mainly of intermediate to felsic composition, which form the Etah meta-igneous complex. Most rocks are strongly deformed, but less deformed syenitic and monzonitic rocks are also present, and post-tectonic granites occur locally (Dawes 1996; Thomassen & Dawes 1996). Reconnaissance SHRIMP U-Pb zircon analyses of samples of granitoid rocks have yielded ages of 1900–1960 Ma with indications of high-grade metamorphism at around 1750 Ma (Dawes 1999; F. Kalsbeek & A.P. Nutman, unpublished data). Archaean and Proterozoic basement provinces in North-West Greenland can be matched across Baffin Bugt with similar units on Devon Island and Ellesmere Island in Canada (Dawes *et al.* 1988; Frisch & Hunt 1988).

Ketilidian mobile belt

Gneisses at the southern margin of the Archaean craton are unconformably overlain by early Proterozoic sediments [64] and basalts [63]. Towards the south these supracrustal sequences are progressively affected by deformation and metamorphism as the Ketilidian belt is approached (Fig. 3). The centre of the Ketilidian mobile belt is largely built up of juvenile early Proterozoic granitic rocks (the Julianehåb batholith [70, 78]). Farther south high-grade metasedimentary gneisses [67] are prominent. Recent investigations of the Ketilidian belt have been reported by Chadwick & Garde (1996) and Garde *et al.* (1998, 1999).

Early Proterozoic supracrustal rocks

The best preserved Ketilidian supracrustal rocks occur in Grænseland north-east of Ivittuut where they are

Fig. 13. The basal part of the Ketilidian succession in central Grænseland, South-West Greenland, with the Archaean basement in the left background, viewed towards west-north-west. The unconformity forms the red-brown slope in the middle distance, with sporadic sub-Ketilidian regolith and Ketilidian carbonate deposits. Relief is about 500 m. Orange coloured tent in the right foreground indicates the scale. Photo: A.A. Garde.

locally almost unmetamorphosed and only superficially deformed (Fig. 13); the precise age of deposition is not known. They have been divided into a lower sedimentary part, the Vallen Group, with *c.* 1200 m of shales and greywackes with subordinate quartzite, conglomerate and carbonate rocks [64], and an upper volcanic part, the Sortis Group [63], which consists mainly of basic pillow lavas and contemporaneous basic sills (Bondesen 1970; Higgins 1970). Southwards these sequences become strongly deformed and intruded by Ketilidian granites.

High-grade (up to granulite facies) supracrustal units [67] are prominent in the southern part of the Ketilidian mobile belt. These are composed of pelitic and semipelitic gneisses with local marbles, quartzites, meta-arkoses, and basic metavolcanic rocks. The clastic sediments are composed mainly of erosion products of the Julianehåb batholith produced more or less contemporaneously with its emplacement (Chadwick *et al.* 1994b; Garde & Schønwandt 1995; Garde *et al.* 1998). Acid volcanic rocks [65] occur in the inner fjord area north-east of Qaqortoq/Julianehåb (61°30′N).

Early Proterozoic granitoids and basic–intermediate intrusions

The central part of the Ketilidian mobile belt is built up mainly of granites, granodiorites and tonalites, commonly with porphyritic textures, which are collectively known as the 'Julianehåb batholith' (Chadwick *et al.* 1994a; Garde & Schønwandt 1995; Chadwick & Garde 1996; Garde *et al.* 1998; 'Julianehåb granite' in older publications; Allaart 1976). Large parts of the batholith were emplaced between 1855 and 1800 Ma ago in a sinistral transpressive setting. Major shear zones were formed during emplacement of the batholith, giving rise to tectonic fabrics of variable intensity. Strongly deformed parts of the batholith are shown as gneisses [70] on the map, less deformed varieties as foliated and non-foliated granitic rocks [78]. Basic and intermediate intrusions [81] of various ages are also present. These were commonly emplaced simultaneously with felsic magmas, and may occur as mixed rocks in 'net-veined intrusions'. Many of the basic and intermediate plutonic rocks are 'appinites' (see Fig. 18), i.e. they contain hornblende

Fig. 14. Upper part of the 1740 Ma post-tectonic Graah Fjelde rapakivi granite intrusion, with large rafts of older Ketilidian country rocks (dark grey). Outer coastal area north of Danell Fjord (*c.* 61°N), South-East Greenland; the exposure is *c.* 600 m high. Photo: A.A. Garde.

as the main primary mafic mineral. Isotopic data show that the granites of the Julianehåb batholith are of juvenile Proterozoic origin and do not represent reworked Archaean rocks (van Breemen *et al.* 1974; Patchett & Bridgwater 1984; Kalsbeek & Taylor 1985; Garde *et al.* 1998).

Rapakivi 'granites' [77] are a prominent constituent of the southern part of the Ketilidian mobile belt (Fig. 14). The rapakivi suite rocks are characterised by mantled K-feldspar phenocrysts, high Fe/Mg ratios and high levels of incompatible elements. Apart from granites the suite includes norites, quartz monzonites and quartz syenites. Isotopic ages between 1720 and 1750 Ma have been obtained from these rocks (Gulson & Krogh 1975; Garde *et al.* 1998).

Archaean – early Proterozoic basement in the East Greenland Caledonian fold belt

The crystalline basement rocks within the East Greenland Caledonian fold belt consist of polyorogenic quartzo-feldspathic gneisses and granitoid rocks, which were overlain by Proterozoic and Palaeozoic sedimentary successions prior to involvement in the Caledonian orogeny (Higgins *et al.* 1981). In the Scoresby Sund region Archaean basement gneisses [74] are prominent. Farther north the crystalline basement consists mainly of early Proterozoic gneisses [70] (up to *c.* 2000 Ma old) of tonalitic to granitic composition; some deformed granite sheets have given ages of *c.* 1750 Ma.

The late Archaean basement gneiss complex (Fig. 15) [74], which outcrops in the inner Scoresby Sund region and areas immediately north (70°–73°N), consists of a variety of migmatitic gneisses with scattered foliated granitoid plutonic rocks [80]. Archaean ages of *c.* 3000–2600 Ma have been recorded (e.g. Rex & Gledhill 1974, 1981; Steiger *et al.* 1979; see Fig. 31), but interpretation is uncertain due to the complex geological history and repeated disturbance of the isotope systems.

In the Charcot Land tectonic window in the north-western part of the Scoresby Sund region (72°N) the Archaean gneissic basement of the foreland is overlain by an early Proterozoic supracrustal succession [67] of low-grade metasediments and metavolcanics (Steck 1971); these are cut by two major post-kinematic granodioritic–granitic intrusions [78] emplaced *c.* 1840 Ma ago (Hansen *et al.* 1980).

The basement gneisses in the central and northern parts of the fold belt (north of 74°N), comprise rock units predominantly related to an early Proterozoic event of crust formation (Kalsbeek *et al.* 1993b). Amphibolite facies orthogneisses [70] are widespread, with occasional areas of granulite facies [71]; supracrustal rocks [67] occur locally. The gneisses comprise both older migmatitic rocks and younger more homogeneous foliated granites. The protolith ages indicate that crust formation took place *c.* 2000 Ma ago. Late granite emplacement is dated at *c.* 1750 Ma. Comparable granitoid rocks at *c.* 73°15′N also give early Proterozoic ages (1700–2000 Ma, Rex & Gledhill 1981). A few isolated intermediate and mafic intrusions [81] occur in the Dove Bugt region (76°–78°N; Hull