DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2011/57

Geology and mineral resources of the Archaean craton (66°- 63°30'N), southern West Greenland

Mineral resource assessment of the Archaean Craton (66° to 63°30'N) SW Greenland Contribution no. 11

Henrik Stendal, Bo Møller Stensgaard, Peter W. U. Appel, Ali Polat & Karsten Secher

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF CLIMATE AND ENERGY

G E U S

D A N M A R K S O G G R Ø N L A N D S G E O L O G I S K E U N D E R S Ø G E L S E R A P P O R T 2 0 1 1 / 5 7

Geology and mineral resources of the Archaean craton (66°- 63°30'N), southern West Greenland

Mineral resource assessment of the Archaean Craton (66° to 63°30'N) SW Greenland Contribution no. 11

Henrik Stendal, Bo Møller Stensgaard, Peter W. U. Appel,
Ali Polat & Karsten Secher

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF CLIMATE AND ENERGY

G E U S

Contents

The mineral occurrences in Appendix B are in ascending order according to their mineral occurrence identification number. Page numbers in Appendix B refers to the individual mineral occurrences (and is not a continuation of the rest of the report).

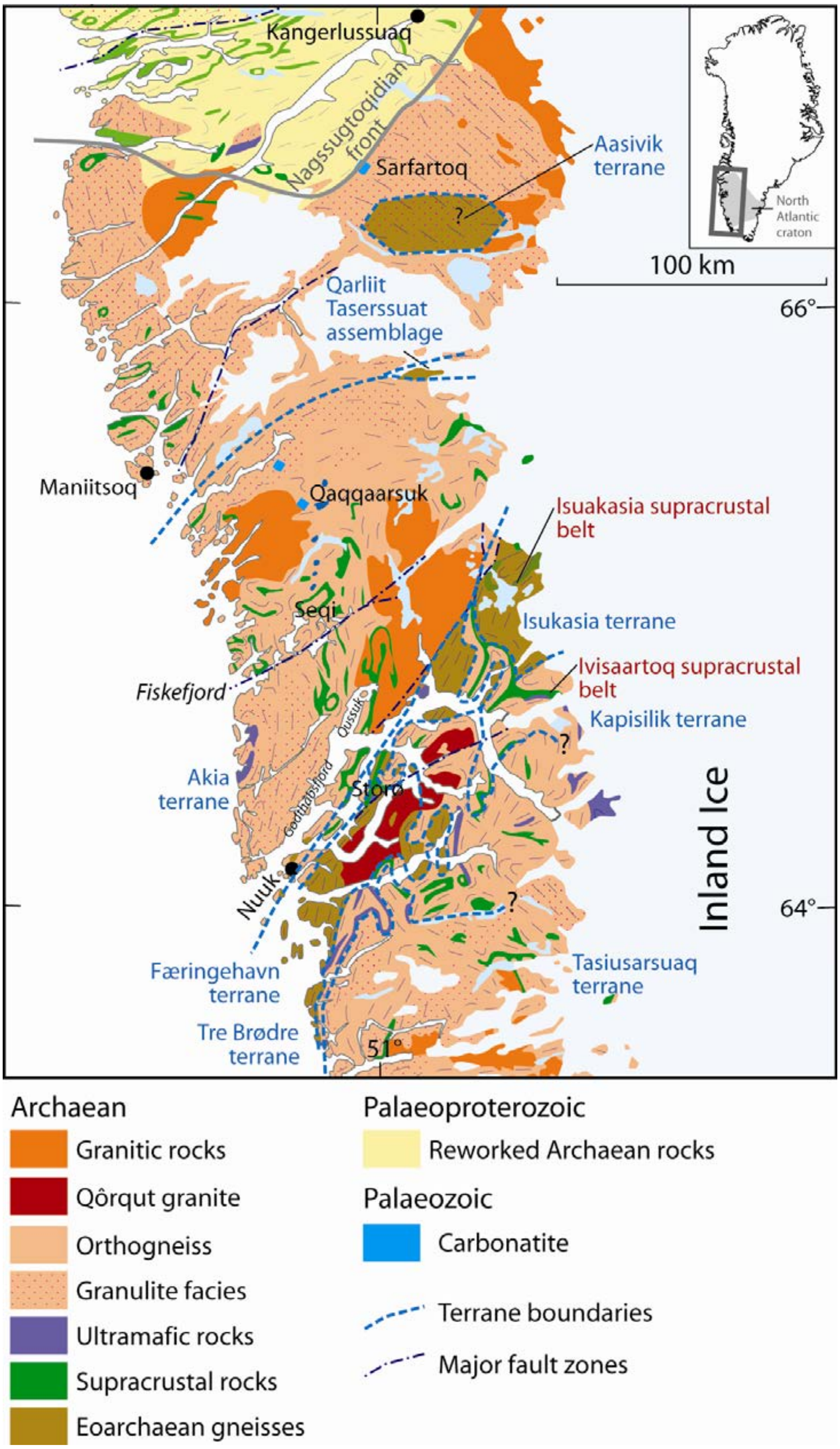

Figure 1. *Simplified geological map showing the main components and regional setting of the Nuuk–Maniitsoq region, southern West Greenland.*

Introduction

As part of the part of the general assessing of the mineral resource potential in Greenland, which is carried out for various parts of Greenland by the Geological Survey of Denmark and Greenland in cooperation with the Bureau of Mineral and Petroleum, the Nuuk region (from 63°30'N to 66°N) was evaluated in the period from 2004 to 2008. The assessment involved compilation of existing and new data, new geological mapping, detailed investigations on mineral occurrences and the geotectonic evolution, new geochemistry and geochronology and an overall evaluation of the geological model and mineral potential of the region.

The present report provides a general overview of the mineralisation pattern and potential within different settings and terranes in the Nuuk region. This overview is followed by individual mineral occurrence sheets for all the 222 mineral occurrences (from showings to mines) that have been identified within the region from exploration and research by commercial companies and government institutions. All scientific literature and archived released company reports have been reviewed. This, together with the new investigations and revisits on various mineral occurrences during the assessment of the Nuuk region provide the basis for the identifications and descriptions of the individual mineral occurrences.

The mineral occurrence sheets describe each mineral occurrence by a type locality in a standard form. The type locality is the site that has been chosen as the representative mineral occurrence of a group of occurrences, to which also this occurrence belongs. The information in the sheets is extracted from the Greenland Mineral Occurrence Map (GMOM) database, which is used by GEUS to store and record information on mineral occurrences in Greenland. The principles for the GMOM database together with descriptions of the applied classifications and terms can be found in Stendal et al. (2004) and Thorning et al. (2004).

For updates on the mineral occurrences included in this report check the online version of the Greenland Mineral Occurrence Map (www.geus.dk/gmom).

Geological introduction

The Nuuk region (66°– 63°30’N) comprises the Akia terrane to the north and the southern part of the Tasiusarsuaq terrane. Between these two terranes, the central part of the Nuuk region comprises more complex geology with several terranes of different evolution and age. The most important lithologies for the mineral potential of the region are the supracrustal belts, including greenstone belts. A second important rock sequence is the magmatic intrusive complexes, such as several magmatic layered ultramafic-mafic complexes within the Akia terrane (Figs 1 and 2). If no magmatic primary textures exist it is in many cases not possible to distinguish whether occurrences of mafic and/or ultramafic rocks should be classified as separated magmatic complexes or as part of a supracrustal rock sequence.

Isua, Ivisaartoq - Ujarassuit, Sermitsiaq – Bjørneøen - Qussuk, Storø and Tasiusarsuaq greenstone belts, SW Greenland (Fig. 1), are interesting from a mineral potential point of view. They are located within the recognized Eoarchaean Isukasia (3.8–3.6 Ga), Mesoarchaean (~3.07–2.95 Ga) Kapisilik, Færingehavn and the Meso–Neoarchean Tre Brødre and Tasiusarsuaq tectonic terranes (e.g. Friend & Nutman 2005; Fig. 2). Field relationships indicate that the Isukasia terrane is structurally overlain by the Kapisilik terrane to the south; and the Kapisilik terrane is in turn structurally overlain by the Faeringehavn and Tre Brødre terranes to the south-southwest. The Kapisilik and Isukasia terranes were juxtaposed by 2.95 Ga. It appears that the collision between the Tre Brødre and the Kapisilik terranes occurred shortly after 2.8 Ga. All these three belts contain both metasedimentary and metavolcanic supracrustal rocks and are characterized by poly-phase deformation and metamorphism. Geodynamic settings of these belts are interpreted on the basis of recently obtained extensive trace element geochemical data (Garde 2007a, b; Polat 2005; Polat & Hofmann 2003; Polat *et al.* 2002; Polat *et al.* 2008; Polat *et al.* 2007; Stendal & Scherstén 2007a, b).

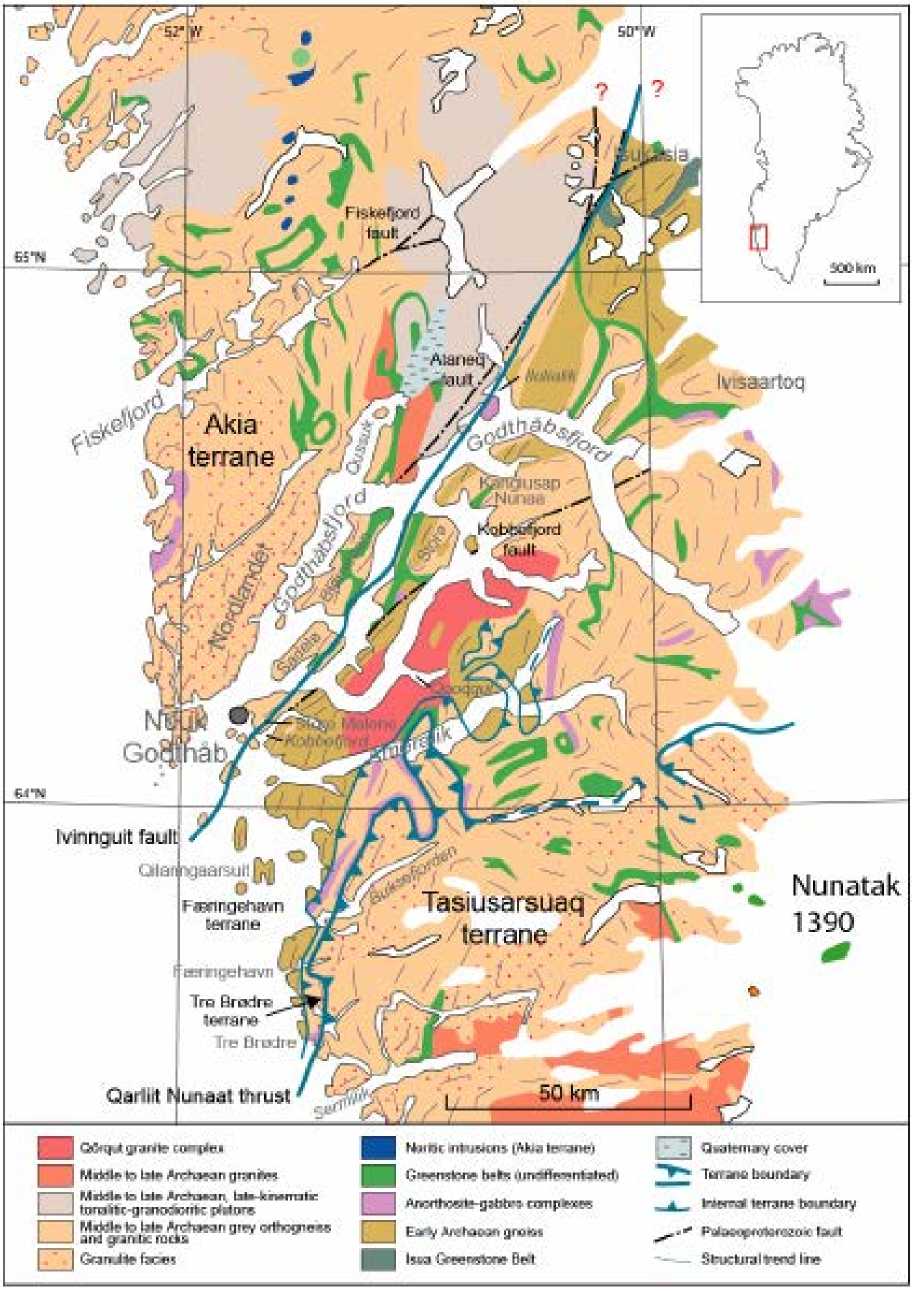

Figure 2. *Simplified geological map of central Nuuk region with indications of terrane boundaries.*

Eoarchaean

Isua greenstone belt

The Eoarchaean Isua greenstone belt of the Isukasia terrane (3.8–3.7 Ga) is about 30 km long and up to 4 km wide and occurs in a terrain of quartzo-feldspathic orthogneisses (Fig. 3; (Appel *et al.* 1998; Nutman *et al.* 2002). The Isua greenstone belt contains the oldest rocks deposited on the surface of Earth, comprising volcanic, volcaniclastic, clastic and chemical sedimentary rocks (Myers 2001; Polat & Hofmann 2003, and references therein). These supracrustal rocks have been repeatedly metamorphosed up to amphibolite facies and folded during several phases of deformation. Despite the poly-phase deformation and metamorphism, some low-strain zones display a wealth of well-preserved primary volcanic structures such as pillow lavas, minor debris flows, and pillow breccia. Conglomerates and pelites, mainly staurolite-mica schists can be traced for some kilometres along strike. Banded iron formations (BIF) and cherts are interbedded with volcanic rocks. In the low-strain domains, the variably deformed pillow basalts are intercalated with ultramafic units. The original stratigraphic relationship between mafic (pillow lavas) and ultramafic units (serpentinites) have been disrupted and complicated throughout the belt. Although the ultramafic rocks are closely associated with pillow lavas, it is not clear whether they were originally emplaced as extrusive flows or intrusive sills, due to intense deformation and metamorphic recrystallisation.

The Isua greenstone belt can be broadly divided into an eastern and a western part (Fig. 3). On the basis of recent mapping, the eastern part of the belt has been divided into three lithotectonic domains: northwestern, central, and southeastern domain (Appel *et al.* 1998; Myers 2001). Each domain is characterized by different lithological associations and intensities of deformation. Similar lithotectonic domains also exist in the western part of the belt. The western part of the belt has been informally divided into three arc-shaped lithotectonic units: the outer, central, and inner arc units. According to Nutman *et al.* (2002), the outer arc unit is composed of *c.* 3.8 Ga volcano-sedimentary rocks, whereas the central arc unit is characterized by *c.* 3700 Ma volcano-sedimentary rocks. No age has been assigned to the inner arc unit. Volcanic rocks in the central arc unit appear to be the most extensive lithological rock type and are exposed continuously both in the eastern and western parts of the belt. The central arc unit of the western part of the belt appears to be the continuation of the central lithotectonic domain of the eastern part of the belt. However, it is not clear whether the inner and outer arc units of the western part of the belt are the continuation of the northwestern and southeastern domains, respectively, of the eastern part of the belt.

On the basis of extensive geochemical data coverage obtained from the least altered volcanic rocks in the western part of the belt, Polat and Hofmann (2003) have recognized the presence of two geochemically distinct volcanic associations in the Isua greenstone belt: (1) low-HFSE, and (2) high-HFSE associations. Geochemical differences between the two suites cannot be attributed to post-deposition alteration, fractional crystallization, the degree of partial melting, or crustal contamination processes but could be explained by two geochemically-distinct sources in the early Achaean mantle. The geochemical trends suggest that the Isua greenstone belt was formed by similar geodynamic processes that produced Phanerozoic supra-subduction ophiolites (Polat *et al.* 2002).

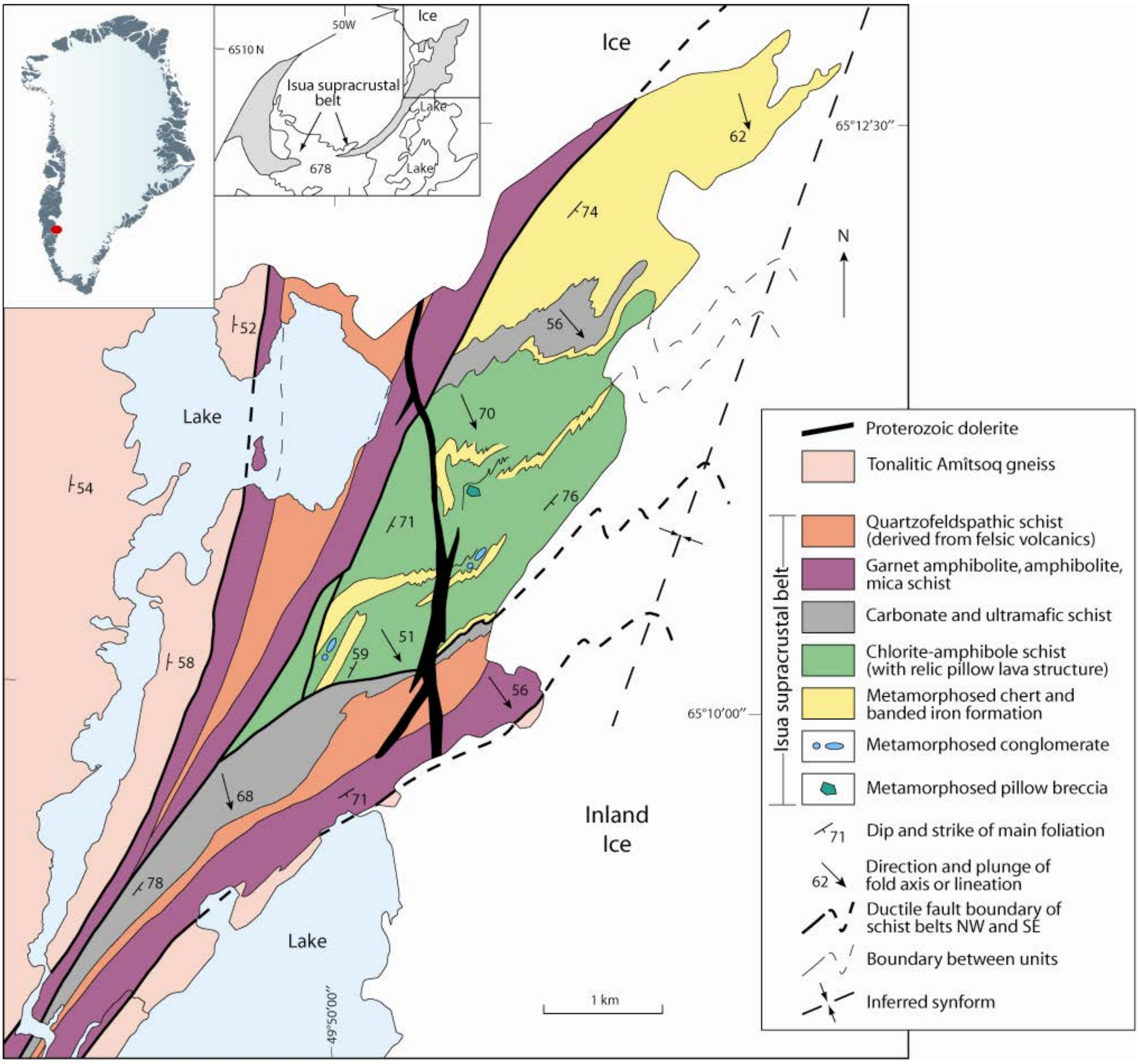

Figure 3. *Map of the Isua greenstone belt, Isukasia, southern West Greenland.*

Mineral occurrences

Precious metals

Gold is found in two settings. 1) Gold occurs in narrow sheeted dolomite veins in ultramafic to mafic intrusive rocks and in fuchsite stained shear zones, cutting intrusive ultramafic rocks (Appendix A). 2) Gold is also found in a peculiar assemblage of galena – sphalerite mineralisation in tonalitic rocks intruded into the greenstone belt (Appel *et al.* 2000); Appendix A). The gold mineralisation has been explored in some detail by NunaOil A/S, and later, Nunaminerals A/S.

Base metals

Copper sulphides are found at several localities in the Isua greenstone belt, mainly as stratabound occurrences in banded tuffaceous amphibolites, but locally also as discordant quartz veins with semi massive chalcopyrite, galena and sulphides of nickel, antimony and maximum up to 10.4 g/t gold (Appel 1979, 1980b, 1982b, 1990a; Appel *et al.* 2000; Appendix A). Chalcopyrite is sometimes associated with cubanite and pyrrhotite. Locally the chalcopyrite occurs in veins as massive chalcopyrite with minor quartz. Sheeted quartz vein system up to more than one m wide is sometimes seen in pillow structured amphibolites. These sheeted quartz veins rarely contain more than a few percent of chalcopyrite. Field relationships, rare-earth elements and isotopic data indicate that the sulphides are partly of submarine exhalative origin, and partly derived through leaching of basaltic rocks (Appel 1982b).

Iron and ferroalloys

The most prominent mineral occurrence found in the Isua greenstone belt is the large Algoma type oxide facies iron formation. With an estimated tonnage of more than 2000 Mt of ore it is a World class iron resource. Diamond drilling has indicated an average grade of 34% Fe (Appendix A). It has over time been explored by several companies. It is mainly magnetite-quartz banded ore (Appel 1978, 1980a, 1982a, 1983, 1990b, 1991), but a large part of the ore is hematite-quartz banded iron ore. The genesis of the hematite ore is controversial, but a likely explanation is that it is an oxidized part of the magnetite ore. The present outcrop of the Isua iron ore is very close to the pre-Quaternary surface, which at this place was dominated by warm and arid conditions witnessed by the abundance of silicate. Smaller occurrences of iron formation are found throughout the Isua greenstone belt.

Chromite bands up to a metre wide are found in a small layered intrusion about 20 km south of Isua. The intrusion, which probably is older than the Isua greenstone belt itself, display magmatic evolution from dunite, harzburgite and gabbro anorthosite to anorthosite. The chromite bands occur in the dunites whereas harzburgites contain scattered chromite grains (Chadwick & Crewe, 1986, Appel *et al.*, 2002, Rollinson *et al.*, 2002).

Meso–Neoarchaean

Akia terrane

The Akia terrane has undergone a complex history of volcanic and plutonic igneous activity, deformation and metamorphism (e.g. (Garde 1997, 2007b, 2008; Garde *et al.* 2007; McGregor *et al.* 1991; Riciputi *et al.* 1990 and references therein). To the north, the Akia terrane borders the Eoarchaean orthogneisses of the Aasivik terrane (3.78–3.55 Ga; Rosing *et al.* 2001; Fig. 1). The southern of the Akia terrane is defined by the Ivinnguit fault (Friend *et al.* 1988). The Akia terrane comprises two continental crustal complexes: a dioritic core dated at *c.* 3220 Ma that forms most of the Akia peninsula, and a larger block dated at 3.05–2.97 Ga, mainly tonalitic orthogneiss with enclaves of supracrustal rocks between (Garde 2007a, b). The bulk of the orthogneisses consist of tonalite that was intruded into, or was tectonically intercalated with supracrustal rocks and associated mafic intrusive complexes (Fig. 1). The supracrustal rocks are older than *c.* 3.05 Ga (the age of the oldest orthogneisses that intrude them). The supracrustal rocks are interpreted as remnants of oceanic crust, into which the precursors of the orthogneisses were intruded, presumably in a convergent plate-tectonic setting (Garde 1990, 1997; Garde *et al.* 2000). Most of the Akia terrane underwent granulite-facies metamorphism during a thermal peak at 2.98 Ga except for the most eastern part, which was exposed to high amphibolite facies conditions. Immediately thereafter, part of the terrane underwent retrogression and contemporaneous emplacement of granitic rocks derived from mobilisation of TTG gneisses (Garde 2007a, b). The Qussuk peninsula itself is underlain by relatively young components of orthogneiss and granite including the 2982±7 Ma Taserssuaq tonalite complex and the 2975±5 Ma Qugssuk granite, and experienced a simpler structural history than the remainder of the terrane (Garde *et al.* 1986; Garde *et al.* 2000).

The norite belt east of Maniitsoq forms a 15 x 75 km belt of isolated bodies of predominantly gabbro-norite to leucogabbro, with minor true norites and leuconorites (Fig. 4). These mafic bodies are intruded into the regional gneiss complex. The age of the norite belt is uncertain, but likely around 3.0 Ga (Secher 2001) and references therein). In the same area an Archaean carbonatite, Tupertalik, West Greenland is located 50 km east of the town of Maniitsoq as a narrow comformable sheet of carbonatite emplaced in the basement gneiss. It has been dated to 3.0 Ga (Bizzarro *et al.* 2002; Larsen & Pedersen 1982). The limited size makes the intrusion of no economic interest for accumulations fo commodities such as REE, Nb, Ta and phospure, although finds of blue lazurite locally has been used for lapidary purposes.

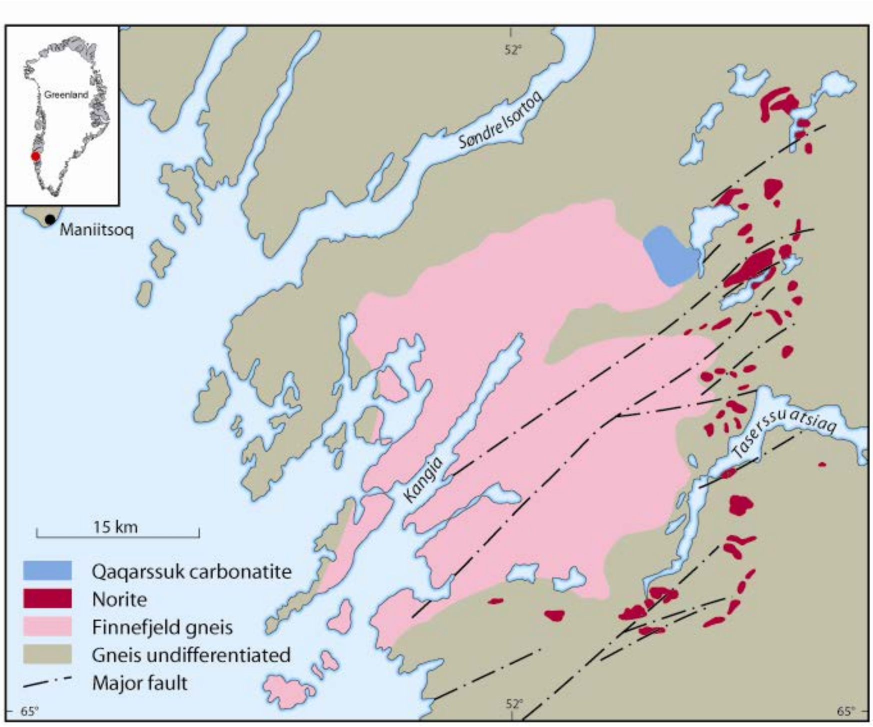

Figure 4. *Simplified map showing the distribution of the norite bodies within the Norite Belt of southern West Greenland and the distribution of the Qaqqaarsuk carbonatite complex and the Finnefjeld gneiss.*

The Qussuk area forms a relict arc comprising volcaniclastic meta-andesite with major and trace element island arc signatures, intercalated with volcano-sedimentary schist, tholeiitic amphibolite and orthopyroxene-rich cumulate rocks (Garde 2007a, b; Fig. 5). A zircon U–Pb age of 3071±1 Ma is obtained from volcano-sedimentary schist. This island arc complex is embedded within *c.* 3000 Ma TTG gneisses and granites, implying plate-tectonic processes for continental crustal accretion (Garde 2007a, b). The supracrustal rocks at Qussuk roughly form a N–S trending belt, which continues southwards through Bjørneøen, Sermitsiaq and St. Malene close to Nuuk (Garde 2007a, b; Hollis *et al.* 2004); Fig. 5a, b, c).

Younger intrusive bodies in the Akia terrane are alkaline ultramafic dykes described as kimberlites and lamproites (Jensen & Secher 2004; Jensen *et al.* 2004; Jensen *et al.* 2003; Larsen 1991a, b). The dykes in the Maniitsoq area are around 560 Ma in age (Secher *et al.* 2008). The 165 Ma (Secher *et al.* 2008) old Qaqqaarsuk carbonatite complex is emplaced into Archaean basement (Akia) in at least two stages, with concomitant metasomatic alteration of the wall-rock. The main-stage carbonatite consists of olivine søvite and dolomite carbonatite ring-dykes, whereas the late stage carbonatites comprise fine-grained dolomite carbonatite, ferrocarbonatite, late stage søvite and REE carbonatite (Knudsen 1991; Secher *et al.* 2008).

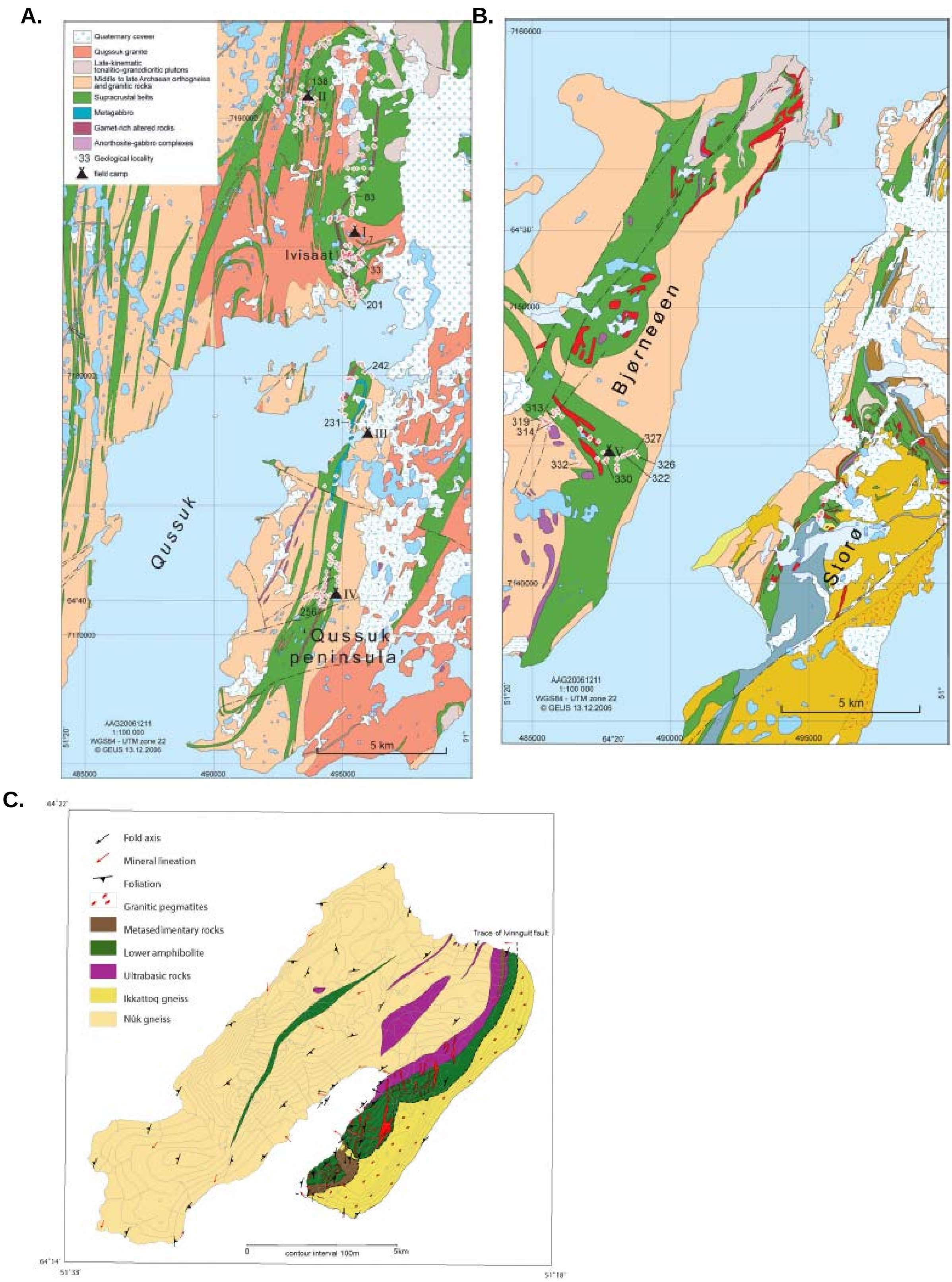

Figure 5. *Geological maps of the A: Qussuk area, B: the Bjørneøen area (maps from Garde* 2007a; B: legend as in figure A besides the units in: greyblue – anorthosite, yellow – layered amphibolite, brownish-yellow – Amitsoq gneiss complex, brown – biotite-rich tonalitic gneiss, red - pegmatites) *and C: the Sermitsiaq area in the Nuuk region, southern West Greenland. From Hollis et al. 2004.*

Mineral occurrences

Precious metals

Gold: Gold was first discovered at Qussuk by GEUS in 2004 (see Hollis 2005). Later, the commercial exploration and mining company NunaMinerals A/S was granted a license covering the Qussuk area and subsequently undertook further exploration. Systematically sampling of surface samples and a 400-linekilometer airborne geophysical program were undertaken in 2006 and 2007. Identified drill targets were drilled in 2008 and 2009 (Christiansen 2008, 2009).

The auriferous structures at Qussuk are located within an area stretching more than 20 km. Five mineralised zones in a 75 km2 large area have been identified for the above work. From north to south the zones were named by Nunaminerals A/S as: the Alma zone, the Swan North zone, the Swan zone, the Blue Fox zone, and the Plateau zone. The following descriptions of the zones are based on press released from NunaMinerals A/S.

Alma zone: The alteration zone is traceable for <1.5 km along strike. Surface work returned several samples in the 1.0-4.5 g/t Au range. One drill hole intersects a narrow gold mineralisation.

Swan North zone: A distinct 30-80 m wide zone of altered metavolcanic rocks, highly enriched in garnet, biotite, quartz and iron-copper sulphides, is traceable for minimum 4 km along strike. 17 holes were drilled along 1,100 m strike to test this zone. The best results was are reported from DDH-25 intersecting 23 m with an average grade of 1.24 g/t Au including intersections of: 2 m @ 8.46 g/t Au, 1m @ 3.59 g/t Au and 1 m @ 3.34 g/t Au.

Swan zone: A large south facing fold with pronounced staining on the surface. Quartz, sillimanite, fuchsite, garnet and cordierite-rocks with up to 15% pyrite dominate the sequence, but only low gold grades are reported so far. On the western flank of the fold structure, a 50 m wide tourmaline bearing unit yield moderate gold grades on surface. The best intersection from four drill holes on the Swan Zone were 0.8 g/t Au over 2 m.

Blue Fox zone: A coastal exposure on the south side of the Qussuk bay, fine grained amphibolite with quartz veins. Several surface samples in the 2-21 g/t Au range are reported, but target outcrop is limited due to close proximity to the sea.

Plateau zone: Several narrow zones with intense quartz veining and associated iron-copper sulphides in various amounts. 20 holes were drilled in this area along 3 km strike. In the central target area visible gold was identified in 7 drill holes along 600 m strike. Surface samples return up to 36 g/t Au. The best drill sections include: 0.6 m @ 19.1 g/t Au and 1.1 m @ 12.6 g/t Au.

Bjørneøen is underlain by Archaean gneiss with an N-S orientated belt of Archaean amphibolites, which host gold mineralisation. The supracrustal rocks at Bjørneøen represent the continuation of the supracrustal rocks at Qussuk. The area was explored in detail by NunaOil 1995-97. However, the area was never drill tested

The amphibolites at Bjørneøen host scattered gold occurrences (max. 4 ppm Au; highest gold values are found in garnet-pyrite micaschist) and minor lead-zinc (combined 0.1-0.2%) and up to 0.1% Cu occurrences in two siliceous and pyritic bands surrounded by an alteration zone. The two mineralised bands are mostly conformable with the foliation in the enclosing amphibolites, up to 8 m thick and consist of rusty weathered siliceous, garnitiferous and pyritic mica schist. The pyrite, together with pyrrhotite, minor chalcopyrite and traces of native copper occurs disseminated, typically with 5–10 vol. per cent. The mineralised bands stop abruptly to the north, although the amphibolite belt continues to the north-west. Traversing and prospecting 4–5 km further north and north-west did not reveal any mineralization other than scattered quartz veins with traces of sulphides. The lead-zinc occurrences probably represent a volcanic-associated massive sulphide occurrence.

The genesis of the gold formation at Bjørneøen and Qussuk has been debated. It seems that the gold content in general are elevated within the supracrustal rocks at Qussuk. Elevated auriferous rocks from the systematically sampling program of surface samples and sediment samples from the entire Qussuk area contain also enhanced levels of copper and copper correlates with gold (Andreasen 2007). However, recorded visible gold and rocks with gold content larger than 1 g/t are always found in quartz vein systems and their surround alteration halos.

From investigated field relationships and geochemistry Garde (e.g. 2007a) suggested that a metamorphosed and partly deformed widespread epithermal aluminous hydrothermal alteration system exists at Qussuk. This system predates deformation and metamorphism. The mineralogical composition of the altered rocks combined with their slightly elevated gold content is suggested to have been developed in an island arc subvolcanic setting (Garde 2007a, b; Garde et al. 2007; Garde et al. 2006; Hollis et al. 2006b).

However, later investigations by Schlatter & Rasmussen (2010a, b, c) on the gold-bearing quartz vein systems from Qussuk with visible gold and gold content values often above 1 g/t Au and their associated alteration halos, which contain the highest and economically interesting gold values, suggest that these gold mineralisations represents hydrothermal orogenic gold type. The authors suggest that the gold mineralisation formed as a epigenetic deposit under post-peak metamorphic conditions and at retrograde upper greenschist to lower amphibolite facies metamorphism conditions. The authors also discuss the possibility of two different sources of gold; one related to primary volcanogenic alteration (sea floor alteration; a volcanogenic epithermal alteration system that along strike in Bjørneøen have are more evolved and have formed volcanogenic massive sulphide occurrences with base metal accumulations) and one related to orogenic style gold.

It is plausible, as suggested by Schlatter and Christiansen (2010a, b, c), that both an early subvolcanic and epithermal hydrothermal alteration with associated slightly to moderate elevated gold and base-metal mineralisation system and a later, post-peak hydrothermal syngenetic orogenic hydrothermal gold system, occur at Qussuk. The early system have resulted in widespread alteration and more dispersed slightly to moderately increased gold and base-metal content, whereas the later system have resulted in more focused alteration with higher gold content.

Platinum Group Elements: The Amikoq intrusion is a 200–1000 m thick layered intrusion covering ~30 km^2 situated south of Fiskefjord. The mafic- to ultramafic rocks of the magmatic complex is enriched in Au, Pt, Pd, Cu and Ni (Kristensen 2006); Fig. 6). These increased values of PGE metals indicate the possibility of finding a reef-type PGE-mineralisation in the Amikoq complex or in other similar complexes in the region. Analytical data for selected rock samples from the Fiskefjord area show enhanced values of precious metals such as gold (Au), platinum (Pt) and palladium (Pd). The highest values are (FA-MS method) 326 ppb Au, 51 ppb Pt and 27 ppb Pd from a rusty band with disseminated sulphides (Appendix A). It seems that the weakly sulphide-bearing norite and amphibolite sequences have the highest concentrations of precious metals. The precious metal values clearly demonstrate that the magmatic mafic-ultramafic complex is a promising target for PGE exploration.

Chromite is present in rocks with high magnetite content with up to 1.4% Cr. The magnetite is often an alteration product from chromite, but primary magnetite also occurs. The content of both Cu and Ni vary with values up 0.17% for. There is no correlation between Cu and Ni, because Ni occurs in both sulphides and olivine, and Cu mainly in sulphides. The ultramafic rocks are characterised by high MgO content up to 40% (Appel *et al.* 2005; Kristensen 2006).

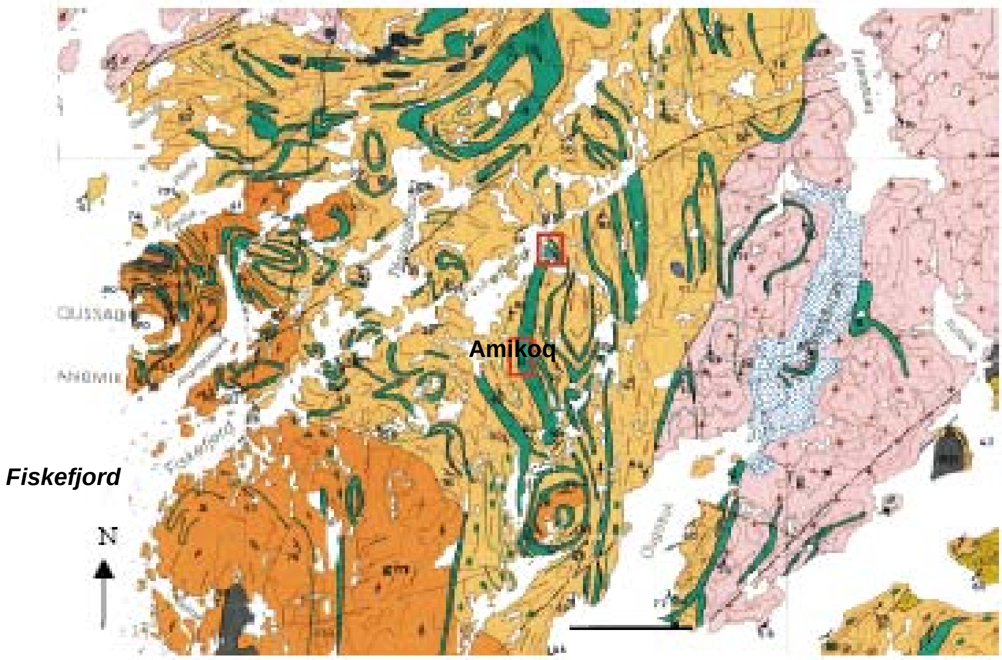

Figure 6. *Geological map showing the location of the Amikoq layered intrusion. Map from Hollis et al. 2006.*

Base metals and ferroalloys

The Norite Belt in the Maniitsoq area of southern West Greenland hosts a suite of noritic-gabbroic rocks (Secher 1983). The mafic bodies are situated in a 15 × 75 km tract in the Maniitsoq norite belt around Sillisissanguit Nunaat. The size of the individual norite bodies varies from 2 × 4 km to only a few metres across (Secher 2001). The dominating rocks are leucogabbro-norite, locally with massive sulphide segregations. The orthomagmatic sulphide occurrences within the norites are scattered throughout the belt (Appendix A). The sulphides include pyrrhotite, chalcopyrite, pyrite and pentlandite, which in the superficial environment are creating impressive gossans and rust zones (Secher & Stendal 1989). The Ni-content of the mineralised rocks is up to two volume percent. The norite and associated rocks have relatively high Pd and Pt contents, up to 0.6 and 2.2 g/t respectively and Au yields up to 2.1 g/t (Secher 2001).

The semi-massive pyrhotite occurrences on Sermitsiaq are hosted by fine-grained laminated amphibolites (+ tourmalinites). The sulphide-bearing parts of the amphibolite have carbonate alteration, which is seen as calc-silicate rocks and in parts as quartz stringer zones. The dominating pyrrhotite occurrences also carry chalcopyrite. The sulphide lenses are 0.5 – 1 m thick and 20 – 30 m long where the semi-massive parts are 10 – 20 cm thick (Appendix A). Apart from sulphides, the supracrustal rocks are reported to contain tungsten (scheelite; Olsen 1986).

Speciality metals

The 165 Ma Qaqqaarsuk carbonatite complex consists of carbonatites intruded into Archaean basement in at least two stages (Knudsen 1991; Kunzendorf & Secher, 1987). The emplacement events were associated with extensive alteration of the wall rock. There is an increase in REE, Sr, Ba, Nb and Th in the carbonatites during the evolution of the complex and a decrease in the HREE/ LREE ratio. Niobium mineralisation is generated as pychrochlore-rich cumulate in the late stage søvite as well as by pyrochlore precipitation associated with metasomatic alteration of basement adjacent to REE carbonatite veins. Pyrochlore occurrences have up to 15 wt% Nb2O5. The pyrochlore comprises locally up to 20 wt% Ta2O5. The carbonatite is also characterised by having enrichment of REE especially within carbonatite veins (Knudsen 1991¸ Appendix A).

Gemstones

Diamonds: Kimberlites are numerous in the Maniitsoq area (Appendix A). The region hosts several clusters of kimberlitic dykes and sills, which appear to be controlled by pre-existing joint systems or concordant with the enclosing gneiss. The Maniitsoq region has a large concentration of dykes and boulder occurrences of a calcite-kimberlite affinity within the West Greenland alkaline province (Jensen & Secher 2004; Jensen *et al.* 2004; Nielsen & Jensen 2005; Nielsen *et al.* 2006). Calcite-kimberlites appear constrained to a 560 Ma event in the Maniitsoq region (Secher *et al.* 2008). The first diamonds from in situ kimberlite were found at the locality Timitta Tasersua East in 1997 by Platinova A/S (Chartier 1998). The same year a 792 kg sample of the large Majuagaa dyke yielded 25 microdiamonds (<0.5 mm) and 16 macrodiamonds. In 2003, GEUS sampled Majuagaa kimberlite dyke that were subsequently tested for diamond content, where 125 microdiamonds were recovered (Jensen *et al.* 2004). In 2006 Crew reported that 20 small (50 kg) samples from five kimberlite localities returned at total of 67 diamonds. Of these, two stones are categorized as ‘macrodiamonds’, and six diamonds measure between 0.5 and 1mm along at least one edge.

Other gemstones within the Maniitsoq area apart from diamond are lazurite and corundum (pink) well known from the area (Appendix A).

Industrial minerals

Olivine: Ultramafic-mafic complexes in the Fiskefjord region are numerous and some of them consist of pure olivine rocks from which one olivine mine where in production from 2005 to 2008 – the Seqi Olivine Mine (Appendix A). The deposit is hosted within a 600 × 1200 m lens-shaped peridotite–dunite complex and is fully exposed. The complex has tectonic contact to the surrounding rocks and is easily identified in the field because of its pronounced orange colouring due to weathering. Combined geological and geophysical studies have outlined a mineable resource of 46 Mt and an indicated resource potential in excess of 100 million tonnes.

Apatite: Apatite enrichment is also found in silico-søvite at Qaqqaarsuk, where the apatite content in the silico-søvite is 3.5 to 6 wt% P2O5 (Appendix A). At one locality, a 12 m thick layer with an average of 3.9% P2O5 can be followed 100 m along strike, indicating a probable reserve of about 0.8 Mt ore. Apatite-rich dolomitic carbonatite dikes can in one case be followed over 200 m averaging 3.4 wt% P2O5 over 13 m of thickness indicating about 1.5 Mt ore (Knudsen 1991).

Soapstone: The Ataneq area also comprises soapstone deposits (Appendix A). In the area between the Ataneq fault and the Ivinnguit fault soapstone are formed in a tectonic lineament parallel to the fault zones. In this lineament ultramafic rocks are hydrothermal altered to soapstone (talc). The zone strikes 55° and the soapstone can be followed for at least one kilometre with varying thickness from 0.5 – 4 metres in thickness. The deposit is exposed from the elevation of 600 – 700 m. The possibility to extent the soapstone zone is present both towards NE and SW (Hollis *et al.* 2006b; Thøgersen 2006; Thøgersen *et al.* 2006)

Quartz: Ataneq is a highly complex fault system. The main NE-SW fault is approximately 50 to 75 m wide. Conjugating faults to the main fault are very common. These strike almost north-south and vary from 5 to 40 m across and can be followed for at least one kilometre. The Ataneq fault in eastern Qussuk peninsula is characterised by extensive silica impregnation of the host rocks in a ~1 km wide zone. Most rocks within this zone of intense alteration are pale, massive and thoroughly silicified, with a fine-grained sugary texture dominated by milky quartz (Appendix A). The silica impregnation has in some places happened during shearing contemporaneously with the quartz formation (Hollis *et al.* 2006b; Thøgersen 2006; Thøgersen *et al.* 2006). Late brittle crushing in these already silicified rocks occurs together with formation of K-feldspar. The extensive amounts of quartz have never been investigated for its purity.

Ivisaartoq greenstone belt

The Ivisaartoq greenstone belt (~3075 Ma) contains the largest Mesoarchaean supracrustal assemblage in SW Greenland (Fig. 7; Chadwick 1990; Friend & Nutman 2005; Polat *et al.* 2008; Polat *et al.* 2007) and references therein). The belt occurs within the recently recognized Mesoarchaean (~3.07–2.95 Ga) Kapisilik tectonic terrane (Friend and Nutman 2005), which is tectonically bounded by the Eoarchaean Isukasia terrane to the north, and the Eoarchean Færingehavn and the Meso–Neoarchaean Tre Brødre terranes to the south and west, respectively. The precise age of the volcanic and intrusive (gabbro, diorite) rocks in the Ivisaartoq greenstone belt is unknown. Siliceous volcanoclastic sedimentary rocks have yielded an average U-Pb zircon age of 3075 ± 15 Ma (Friend & Nutman 2005; Polat *et al.* 2008; Polat *et al.* 2007), constraining the maximum age of the belt. The Ivisaartoq greenstone belt is intruded by weakly deformed 2961 ± 12 Ma granites to the north, constraining the minimum age of the belt (Chadwick 1990; Friend and Nutman 2005).

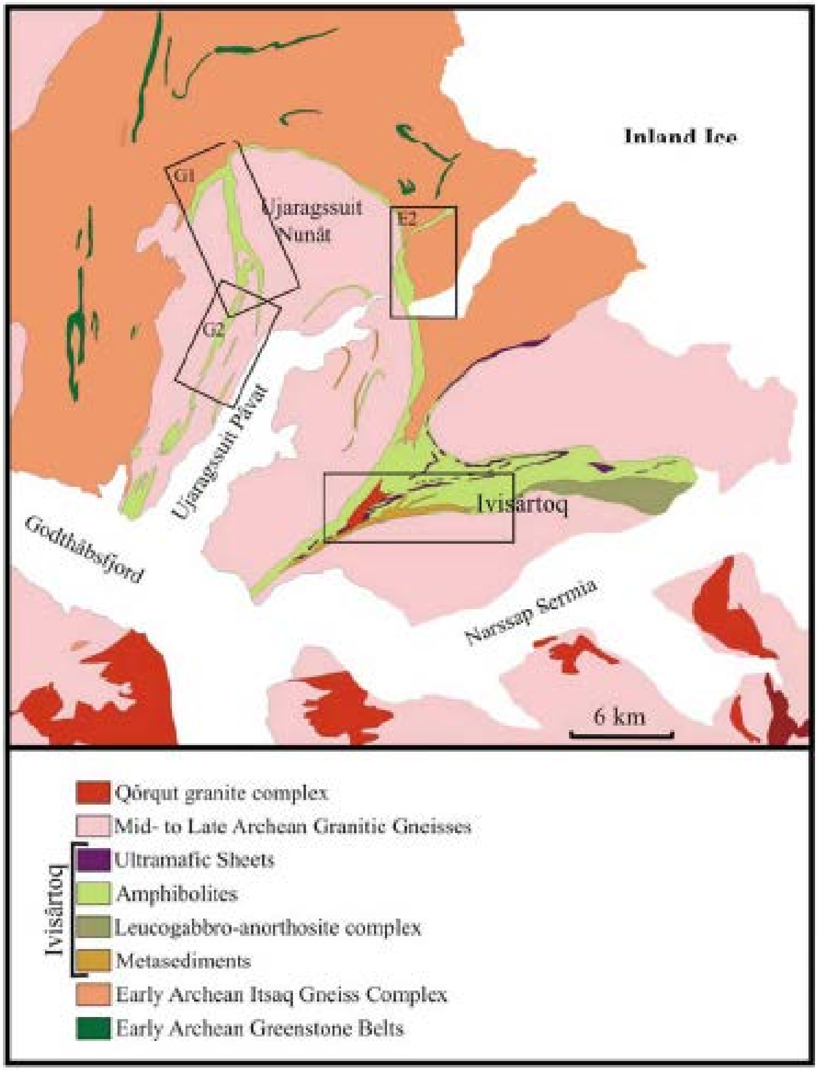

Figure 7. *Simplified geological map of Ujarassuit and Ivisaartoq region, southern West Greenland. Map from Hollis et al. 2006.*

Despite the isoclinal folding and amphibolite-facies metamorphism, the Ivisaartoq greenstone belt contains well-preserved primary magmatic structures, such as pillow lavas, volcanic breccias, and clinopyroxene cumulate layers (picrites) (Chadwick 1990; Polat *et al.* 2007). The belt also includes variably deformed gabbroic to dioritic dykes, actinolite schists, and serpentinites. Gabbros and minor diorites occur as one to several tens of metre-thick sills and dykes in pillow basalts. They also occur sporadically between pillow basalts and ultramafic flows. Chilled margins between pillow basalts and gabbroic dykes are preserved in a few locations. Primary igneous textures and minerals are locally preserved in low-strain domains. Sedimentary rocks constitute a volumetrically minor component of the belt. Chadwick (1990) has subdivided the belt into a lower and an upper amphibolite unit. These units are separated by a thin layer (up to 50 m-thick) of magnetite-rich ultramafic schists, called the ‘magnetic marker’. Hydrothermal alteration of the ‘magnetic marker’ and volcanic rocks in its vicinity resulted in the formation of calc-silicate rocks hosting strata-bound scheelite mineralization (Appel 1994, 1997). The intensity of deformation appears to increase towards the boundary between the two amphibolite units, suggesting that they are tectonically juxtaposed. Trace element patterns of gabbros and diorites are similar to those of pillow basalts.

The Ivisaartoq rocks underwent at least two stages of post-magmatic metamorphic alteration, including seafloor hydrothermal alteration and syn- to post-tectonic calc-silicate metasomatism, between 3.07 and 2.96 Ga. The trace element characteristics of the least altered rocks are consistent with a supra-subduction zone geodynamic origin and shallow mantle sources. On the basis of geological similarities between the Ivisaartoq greenstone belt and Phanerozoic forearc ophiolites, and intra-oceanic island arcs, Polat *et al.* (2007) suggested that the Ivisaartoq greenstone belt represents a relic of dismembered Mesoarchean supra-subduction zone (either forearc or back-arc) oceanic crust. This crust might originally have been composed of a lower layer of leucogabbro and anorthosite, and an upper layer of pillow lavas, picritic flows, gabbroic to dioritic dykes, and dunitic to wehrlitic sills.

Supracrustal rocks in the Ujarassuit region are thought to be associated with the Mesoarchaean Ivisaartoq supracrustal belt (Fig. 7), based on extrapolation of regional structural trends, and field-based study by GEUS (Hollis *et al.* 2006b). The supracrustal belt at Ujarassuit lies in a region between the Eo- to Palaeoarchaean Isukasia and Færingehavn terranes, and possibly has genetic links to the Mesoarchaean Akia terrane to the west (Friend and Nutman 2005). The Akia terrane in this area is thought to be bound to the east by the extension of the Ivinnguit fault, which is sub-parallel with the Proterozoic Ataneq fault here. However, no detailed mapping has been undertaken in this particular area to test that interpretation or to investigate in detail the timing and degree of reworking of some of these important structures.

Mineral occurrences

Precious metals

Gold: The Ivisaartoq greenstone belt is dominated by a several kilometres long and several tens of metres wide rust zone of massive to semi massive pyrite. This sulphide zone has been prospected in some detail by Nunaminerals and by GEUS. Scattered minor gold showings have been found in sulphide patches in mafic pillow lavas (Appendix A).

Ferroalloys

Tungsten: The most significant commodity occurrence within Ivisaartoq greenstone belt is occurrence of tungsten. It occurs as stratabound mineralisation in altered ultramafic rocks and in discordant, metre wide and tens of metres long veins consisting of garnet, feldspar, diopside, vesuvianite and scheelite. The best tungsten mineralisation is found in the so-called magnetic marker. This is an altered ultramafic unit separating a lower and upper sequence of mafic and ultramafic pillow lavas and intrusive gabbroic rocks. The scheelite-bearing magnetic marker is 3.5 km long. The maximum grade is 0.35% W over a width of 2.5 m (Appel 1994). These tungsten occurrences appear to be part of a regional tungsten province, which can be traced in greenstone enclaves for more than 100 km (Appendix A).

Storø greenstone belt

The Storø description given here has largely been adopted from Østergaard & van Gool (2007). The supracrustal rocks on Storø (Fig. 8) comprise a tectonically dismembered sequence of mafic to intermediate amphibolite, ultrabasic rocks, garnet-mica-sillimanite schist and fuchsite-bearing quartzite (Appel *et al.* 2000; Appel *et al.* 2003; Hollis *et al.* 2004).

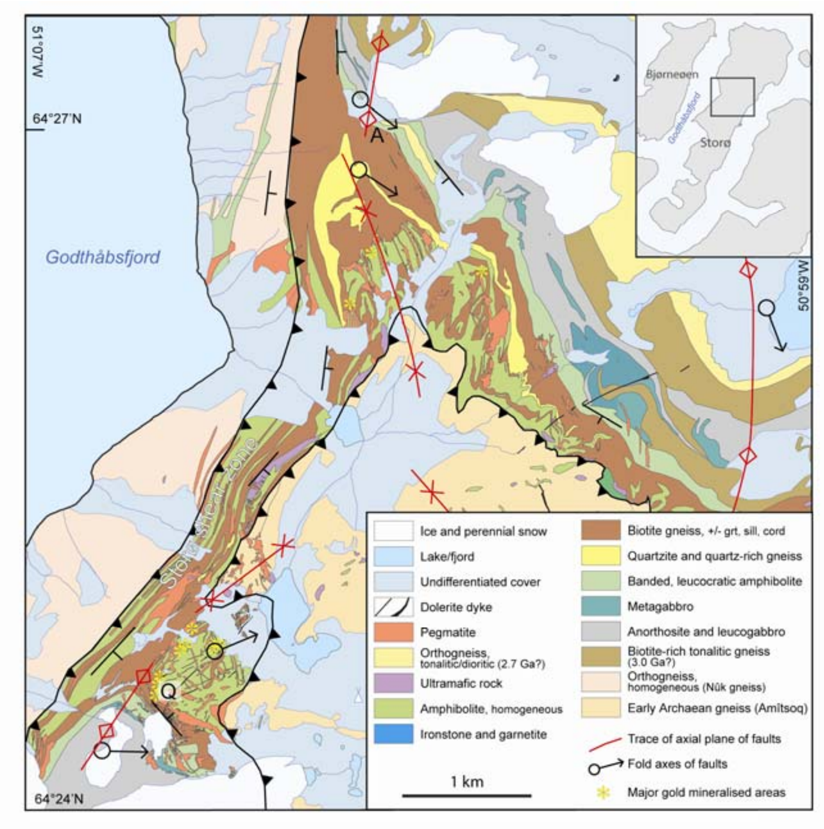

Figure 8. *Geological map of the eastern part of central Storø with location of the Qingaaq (Q) and Aapparlaartoq (A) gold prospects. Map from Østergaard & van Gool (2007).*

The sequence is coherent on the central and northern part of Storø especially around the two mountains Qingaaq (1616 m) and Aapparlaartoq (1440 m). The supracrustal belt overlies anorthosite and metagabbros, and consists of 150 m banded grey heterogeneous amphibolites, which are laminated on mm–cm scale. The banded amphibolite is overlain by 100–200 m of heterogeneous brown metasedimentary and metavolcanic rocks, which include quartzo-feldspathic garnet-sillimanite-biotite gneisses, quartzitic gneisses and massive garnet-rich units with variable amounts of muscovite, graphite and minor staurolite. The uppermost part of this succession consists of a 10–20 m wide poorly-foliated unit of highly aluminous rocks consisting of garnet, sillimanite, mica and feldspar. Based on their geochemistry, these rocks are unlikely to be metasediments, but may rather be the result of pre-metamorphic alteration (sericitisation?) of a basaltic or more felsic volcanic precursor. Knudsen *et al.* (2007) argues that the high alumina rocks are metasediments. The uppermost tectono-stratigraphic unit in the sequence comprises homogeneous, fine to medium-grained black amphibolites, which can be up to 250 m wide. It contains several thin sheets of rusty garnet-biotite schist, garnetiferous, amphibole-, diopside-, and pyrrhotite-bearing gneiss and zones of calc-silicate veining. The majority of gold mineralised zones occur in alteration zones within this upper amphibolite unit.

Detrital zircons from garnet-mica-sillimanite gneisses and quartzites on Storø indicate two distinct populations. The zircons in the garnet-biotite-sillimanite gneisses show ages of *c.* 2.82–2.92 Ga (Hollis 2005; Hollis *et al.* 2006a; *et al.* 2006b) probably derived from an immature sedimentary precursor formed in a volcanic arc. The quartzites have significant proportions of older zircons showing ages of *c.* 2.9–3.1 Ga, with a peak around 3.07 Ga, as well as few detrital zircons of >3.6 Ga (Hollis *et al.* 2006a; Hollis *et al.* 2006b; Knudsen *et al.* 2007; Rink-Jørgensen 2006); van Gool and Scherstén, unpublished data), which may represent a more mature sediment formed as an erosional product of an older continent. These ages correspond well to zircon populations from Mesoarchaean and Neoarchaean supracrustal belts other places in the Godthåbsfjord region. Several metavolcanic rocks of the Storø belt yield U-Pb zircon ages between 2.80–2.85 Ga, which are interpreted as volcanic protolith ages (Hollis 2005; van Gool and Scherstén unpublished data). Many samples yield a metamorphic age of *c.* 2.63 Ga (Hollis 2005), while some samples contain metamorphic zircons of 2.55–260 Ga (Nutman *et al.* 2007; van Gool and Scherstén, preliminary, unpublished data). The metamorphism around 2.63 Ga coincides with thrusting on the Storø shear zone, representing a phase of crustal thickening. The younger metamorphic ages overlap with intrusion of the Qôrqut granite south of Storø. Numerous pegmatite intrusions occur widespread in the Nuuk region, southern West Greenland (Steenfelt *et al.* 2007a); especially along the Ivinnguit fault zone e.g. Storø and Sermitsiaq and in relation to the Qorqut granite or to similar phases of granitic intrusions around 2600 Ma (McGregor 1973). The emplacement of pegmatites on Storø occurred during crustal-scale thrusting in the Storø shear zone around 2630 Ma (Hollis 2005; Hollis *et al.* 2006a).

Mineral occurrences

Precious metals

Gold: The structural setting of the gold prospect on central Storø is dominated by kilometre-scale folds in the hanging wall of the Storø shear zone. The latter is a 300–400 m wide ductile shear zone with oblique reverse movement, which traces the north-western slopes of the island. The shear zone and the folds overprint earlier structures (Østergaard & van Gool 2007; Appendix A). Calc-silicate alteration is common within the amphibolite, and probably represents syn-volcanic, pre-metamorphic spilitic alteration characterised by abundant diopside and epidote, locally also garnet or calcite (Eilu *et al.* 2006). More important with respect to gold mineralisation is the presence of younger biotite-garnet alteration domains, which may be up to *c.* 50 m wide and enclose all of the auriferous quartz veins. These domains involve a progressive increase in the modal concentrations of biotite, garnet, quartz, diopside and sulphides (pyrrhotite and arsenopyrite) towards the gold enriched zones (Eilu *et al.* 2006).

Gold mineralisation at Storø occurs at several tectono-stratigraphic levels within the upper part of the supracrustal belt and comprise high-grade zones of quartz veins and disseminated sulphides and sulpharsenides (5–30 g/t Au), which extend for several hundred metres and are up to 10–12 metres wide. Gold also occurs locally within sulphide-rich garnetite units primarily consisting of almandine garnet (>60%), biotite and pyrrhotite (0.5–3 g/t Au), which are associated with the high-grade zones. The most promising gold targets occur in the Qingaaq area (Fig. 9), whereas mineralisation on Aapparlaartoq is poorly constrained. The highest gold grades occur in both areas in similar pairs of fold hinges in the hanging wall of the Storø shear zone.

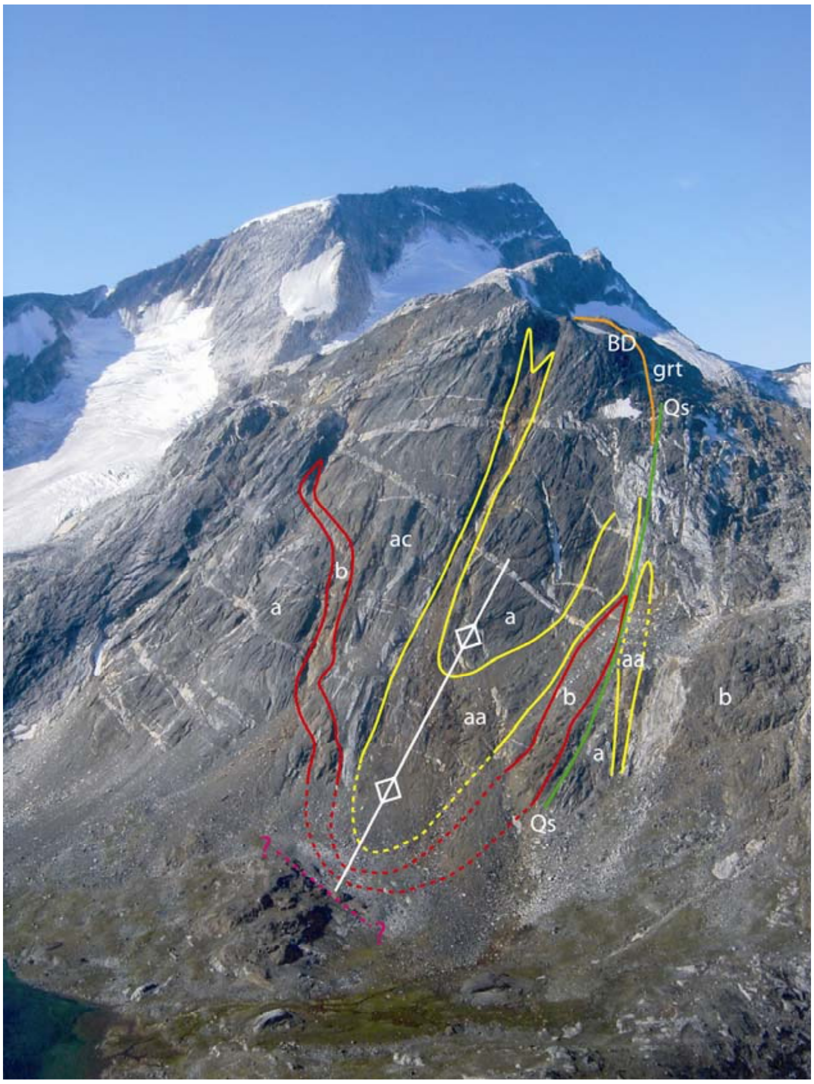

Figure 9. *Photo taken towards southwest of the 600 m high cliff-face hosting the Qingaaq gold occurrence at Storø, southern West Greenland. The predominant antiform (indicated by white line) and the course of the Qingaaq shear zone are outlined (indicated by green line and labelled Qs at the ends). Folded and straight pegmatites are seen as light coloured dykes in the cliff-face. Red outlined area (labelled b) indicates the garnet-sillimanite biotite gneiss ("upper gneiss") within the upper amphibolite unit. Yellow outlined area (labelled aa) southeast of the Qingaaq shear zone in yellow (left-side of the photo) indicates altered amphibolite, including amphibole-bearing feldspathic gneiss, garnet (-biotite) amphibolite, calc-silicate altered amphibolite, quartz-veined amphibolite and general rusty weathering amphibolite. This area includes the highest gold values of the Main Zone. The area northwest (right side of the photo) of the shear zone outlined in yellow (aa) indicates the gold mineralised New Main Zone. This zone constitutes altered amphibolite within a pegmatite-rich zone, separated from Main Zone by the Qingaaq shear zone. Gold mineralisation occurs in an antiform fold hinge in both the Main Zone and the New Main Zone. The orange line at the top of little Qingaaq indicates the BD Zone. This zone is associated with the contact between garnet-rich gneisses and amphibolites, and is also gold mineralised. The purple line in front of the cliff-face indicates a potential thrust contact with the overlying Eoarchaean orthogneiss. Abbreviations: a, main upper amphibolite; ac, main upper amphibolite with calc-silicate veining/alteration; b, upper biotite gneiss. The lake in the lower*

left corner is 470 m a.s.l. The top in the background is the mountain Qingaaq (1616 m.a.s.l.), and the top in the foreground is Little Qingaaq (1070 m.a.s.l.). Figure slightly modified from Østergaard & van Gool 2007.

The Qingaaq and Aapparlaartoq gold prospects can be described in some details:

Qingaaq gold prospects: Three significant targets crop out on the north face of the mountain Qingaaq located at two separate stratigraphic levels, the BD zone and the Main zone (Østergaard & van Gool 2007; Fig. 9).

- BD Zone: Mineralisation developed along the contact between the upper amphibolite and the underlying sillimanite-garnet gneiss and gold occurs within both rock types up to 20 m away from the contact. Gold grades in drill core samples range up to 30 g/t over 2 m and preliminary evaluation of more than 40 mineralised sections indicate a mean gold grade of 8.3 g/t Au at a 3.0 g/t Au cut-off and 5.1 g/t Au at a 1.0 g/t Au cut-off (Østergaard & van Gool 2007).
- Main zone: The Main Zone is located at the foot of the Qingaaq north slope, structurally above the BD Zone within altered amphibolites. Gold grades in drill samples range up to 10 g/t over 10 m and preliminary evaluation of more than 130 gold bearing intersection indicate a mean gold grade of 9.7 g/t Au at a 3.0 g/t cut-off and 5.1 g/t Au at a 1.0 g/t cut-off (Østergaard & van Gool 2007).The New main zone is a narrow quartz veined domain (2–10 m wide) within altered amphibolite, which can be traced uphill for *c.* 100 m. Gold is generally associated with swarms of quartz veins, often rich in arsenopyrite. Channel samples return up to 7.6 g/t Au over 3.27 m (across-strike) (Østergaard & van Gool 2007).

Aapparlaartoq gold prospect: The SE-face of the mountain Aapparlaartoq hosts the Aapparlaartoq BD zone. In this zone several high-grade boulder and surface samples have been collected (up to 50 g/t Au), whereas a systematic channel sampling program so far has been inhibited by steep topography and lack of detailed maps. The best grades occur in sheeted quartz-veins with disseminated arsenopyrite (Østergaard & van Gool 2007). At the Aapparlaartoq East ridge gold mineralisation occurs within altered amphibolite and rusty beds at 700–900 m a.s.l. on the ridge east of Aapparlaartoq mountain. The dominating sulphide is arsenopyrite within discontinuous quartz lenses (1–6 g/t Au). The extent of mineralisation has not been defined (Østergaard & van Gool 2007).

Timing of gold mineralisation on Storø: An age obtained on arsenopyrite by Pb-Pb methods yielded an age of 2863±24 Ma and a garnet age of 2748±62 Ma (Juul-Pedersen *et al.* 2007). This arsenopyrite date looks rather old compared to new data. It could reflect arsenopyrite formed during primary sea floor and/or volcanogenic alteration. Ages of two arsenopyrite samples associated with gold mineralisation from the BD zone and Main zone have been determined by Re-Os method. The ages show that the BD zone has a poorly constrained age of 2714 ± 53 Ma, while the Main zone has a well constrained age of 2636 ± 23 Ma (van Gool et al. 2007). The latter date is in agreement with a 2635 Ma U-Pb age of a zircon associated with arsenopyrite from Main zone (Nutman *et al.* 2007). The 2635 Ma is interpreted as the age of a epigenetic orogenic gold mineralisation event. The Re-Os data may suggest that the mineralisation in the BD zone is older (pre-metamorphic) than that in Main zone (syn-metamorphic), although the large error in the analysis from the BD zone precludes a final conclusion.

Genetic model of gold mineralisation on Storø: The gold mineralised intermediate and basic volcanic rocks of the Storø supracrustal belt probably formed in a volcanic back-arc or intra-arc environment as indicated by the presence of several distinct detrital zircon populations within adjacent garnet-mica-sillimanite gneisses and quartzites (Hollis *et al.* 2006a; Knudsen *et al.* 2007). The gold occurrences occur within zones of intense alteration, most of which are pre-metamorphic and intensely deformed. These alteration zones, and perhaps also the earliest mineralisation event, could be syn-volcanic, in an arc environment, or associated with an early shearing event at low metamorphic grades. The gold may provenance from a nearby volcanic source, potentially the volcanic protolith to the upper amphibolite sequence. The earliest gold could probably by pre-metamorphic, and part of the mineralisation is bound to the lower contact of the upper amphibolites (BD zone). The highest gold concentration occurs in and near the antiformal hinge of the Main zone, at a hanging wall thrust ramp in the Storø shear zone, associated with folds in massive anorthosite rocks. The mineralisation in the quartz vein system of the Main zone represents a post-peak, amphibolite facies hydrothermal orogenic gold system.

Base metals

In the Meso-Neoarchaean supracrustals of the Nuuk region several base metal occurrences are reported for copper and zinc (Appel 1990a). Examples can be seen in Appendices A, and one example from Sermitsiaq is described here as a key example. The semi-massive pyrrhotite occurrences are hosted by fine-grained laminated amphibolites (+ tourmalinites) on Sermitsiaq. The sulphide-bearing parts of the amphibolite have carbonate alteration, which is seen as calc-silicate rocks and in parts as quartz stringer zones. The dominating pyrrhotite occurrences also carry chalcopyrite. The sulphide lenses are 0.5 – 1 m thick and 20 – 30 m long, where the semi-massive parts are 10 – 20 cm thick. The metal contents are low with gold content not exceeding 100 ppb, copper yields up to 600 ppm, zinc up to 0.1% and Pb up to 100 ppm.

Pegmatites

Numerous pegmatite intrusions occur widespread in the Nuuk region, especially along the Ivinnguit fault zone, e.g. Storø and Sermitsiaq, and in relation to the Qorqut granite or to similar phases of granitic intrusions around 2600 Ma (McGregor 1973). The emplacement of the pegmatite on Storø occurred during crustal-scale thrusting in the Storø shear zone around 2630 Ma (Hollis 2005; Hollis *et al.* 2006a). A number of minerals of possible economic significance have been located within the pegmatites in the Nuuk region (Appendix A). Around and inside the Qorqut granite, the biotite rich parts of pegmatites often are associated with magnetite, garnet, pyrite and occasional molybdenite. At a couple of localities, e.g. at Storø and Sermitsiaq, are also found uraninite, frequently altered to yellow β-uranophane (Secher 1980). Pegmatites in the Ivisaartoq area are known for their local accumulation of blue-green beryl (var. aquamarine, which at one locality has delivered large well shaped crystals of up to 4 × 17 cm). Tourmaline (var. dravite) is another typical pegmatite mineral, which is well known form the western part (Sermitsiaq) and southern part of the Nuuk region (Ameralik). A typical feature of the Greenland tourmaline is the black colour, the well-developed crystal faces with shiny surfaces and the large sizes. Crystals of up to nearly 2 kg a piece are recorded (Petersen & Secher 1993). The economic potential of these pegmatites has not been evaluated in detail (Steenfelt *et al.* 2007).

Northern Tasiusarsuaq greenstone belt

The Tasiuarsuaq terrane (e.g. Escher & Myers 1975; Friend & Nutman 2001; Friend & Nutman 2005; Hollis *et al.* 2006b; Kolb & Stendal 2007; Stendal 2007; Stendal & Stensgaard 2007; Stendal & Scherstén 2007a; Stendal *et al.* 2007) southeast of Kangerdluarssenguup taserssua is dominated by mafic rocks (amphibolite), tonalitic to granodioritic gneisses (Fig. 1). The mafic rocks comprise pillowed amphibolite (calc-silicate alteration), massive amphibolite (gabbroic), and ultramafic pods and dykes. The mafic rocks comprise pillowed amphibolite (calc-silicate alteration), massive amphibolite (meta-gabbro), and ultramafic pods associated with magnetite-bearing, black amphibolite. Dimensions of these mafic complexes ranges from 50 up to more than 1000 m, and they are intruded by the country rock granitoid gneisses and cross-cut by brown-weathered dolerite dykes (up to 30 m wide) with well developed chilled margins and generally strike E-W. Alterations are common within the amphibolites such as calc-silicate formation within pillowed lava sequences. The pillowed mafic sequences have intercalations of 1–2 m wide rusty, sulphide-bearing layers (exhalites). Occurrences of garnet-sillimanite-biotite-sulphide rocks represent a prominent alteration type in the area, post-dating the granitoid formation.

The age of the Tasiusarsuaq terrane is assumed to be within the range of 2.92–2.86 Ga. Investigated mafic complexes are dominated by amphibolite to upper amphibolite facies metamorphic rocks, although greenschist facies rocks are present at Nunatak 1390. Gradations between rocks that more or less preserve primary textures enable correlation of spatially separated mafic-ultramafic units. This led to the belief that greenstones in the region were derived in a similar geo-tectonic environment.

The Kangiata Nuna 1:100.000 geological map sheet (Escher 1981) comprises a large greenstone granite belt with 20 – 30% of greenstones and at least two generations of tonalite and granodiorite (Tasiusarsuaq terrane). The greenstone granite belt is estimated to make up more than 1200 km^2 and with a possible extension towards the south. Mafic sequences and exhalites (greenstones) in the Tasiusarsuaq terrane south and southeast of Kangerdluarsunnguup Tasersua may become economically interesting judged from elevated gold and arsenic contents.

Garnet-sillimanite-biotite ±sulphide rocks seem to record a regional phenomenon. The alterations are pervasive and independent of rock types or geological terrane boundaries. The alteration must have occurred after or during the amalgamation of micro continents in the Nuuk region, if it can be assumed to represent one event.

Mineral occurrences

Precious metals

Gold: The area was visited in 2005 (Hollis *et al.* 2006b) and revisited in 2006 (Stendal & Scherstén 2007a, b) because of the indications of gold and arsenic in the region (Appendix A). The area contains amphibolite deduced to have originated as a pillowed mafic volcanic sequence. The amphibolites have plenty calc-silicate minerals (diopside, epidote and ±garnet) and intercalations of 1 – 2 m wide, rusty, sulphide-bearing layers (exhalites).

The sulphides are pyrite, pyrrhotite, chalcopyrite and arsenopyrite. It is worth noting that this area is the only place outside Storø, which carries arsenic in considerable amounts. The arsenopyrite-bearing rusty amphibolite is either an exhalite or an altered amphibolite layer with some garnet formation. It was not possible to follow the mineralised layer over long distances due to coverage with mainly talus material.

Analytical results from 2005 (Hollis *et al.* 2006b) yielded gold in one sample with 456 ppb Au and 1.48% As. The mafic rocks have some Cu up to 0.16%. In general, the gold content is low except for one sample, which yielded 456 ppb Au and 1.48% As. The mafic rocks have some Cu concentrations up to 0.16% and average contents of Ni and Cr. Samples from 2006 confirmed the enhanced Au (up to 495 ppb) and up to 0.47% As.

In the northern area of Qarliit Nunaat elongated rusty zones mineralised with a sulphide assemblage are common. These mineralised zones are associated with quartz veins and sinistral oblique-slip shear zones. The quartz veins represent shear veins parallel to the foliation or, locally, make up an en echelon array of extension veins in competent wall rocks. The mineralised zones are up to 6 m wide and can continuously be followed over several km along strike. Several, up to 4, parallel zones are developed at the amphibolite-gneiss contact. In general, the mineralisation appears to be continuous along the entire strike extent of the amphibolite lenses.

The sheared amphibolite and gneiss in the Qarliit Nunaat area comprises a distinct alteration assemblage with disseminated sulphides of up to 20 vol. %. In the grey banded migmatitic gneiss, a garnet-muscovite-pyrite-chalcopyrite-pyrrhotite alteration paragenesis is developed. The altered amphibolite is locally weakly enriched in gold < 10 ppb Au. The strongly sheared nature of the host rocks and the close association with quartz veins point to a syn-tectonic hydrothermal origin of the mineralisation and alteration with D1 deformation. The alteration paragenesis developed in the different wall rocks point to syn-metamorphic hypozonal hydrothermal event typical hypozonal orogenic gold systems (Kolb & Stendal 2007; Appendix A).

Concluding remarks

Some of the important results of the resource assessment of the mineral potential within the Nuuk project carried out by GEUS are:

- Discovery of remanents of a deformed island arc complex with andesistic volcaniclastic rocks. Gold-copper (probably stratabound type) and gold only (orogenic gold type) mineralisation were discovered within this arc system during fieldwork carried out by GEUS as part of the Nuuk project (Andreasen 2007; Garde 2007a, b, 2008; Garde *et al.* 2007; Hollis *et al.* 2006b; Schlatter & Christensen, 2010a, b).
- Determination of a magmatic layered ultramafic-mafic complex in the Fiskefjord area (the Amikoq complex) with the potential for PGE occurrences (Kristensen 2006; Appel *et al.* 2005; Hollis *et al.* 2006b).
- The Storø gold deposit has been studied in co-operation with Nunaminerals A/S and has been debated a lot concerning geological setting and age constraints (Eilu *et al.* 2006; Juul-Pedersen *et al.* 2007; Knudsen *et al.* 2007; Nutman *et al.* 2007). The gold deposit is probably an orogenic gold type.
- The discovery of a new carbonatite (158 Ma±2), the Tikiusaq deposit (Steenfelt *et al.* 2006; Steenfelt *et al.* 2007b).
- The discovery of ultramafic lamprophyre boulders at Nunatak 1390 and in inner Fiskefjord (Sand *et al.* 2007; Stendal & Scherstén 2007a, Stensgaard 2007).
- The diamond potential of Maniitsoq region has been confirmed and the potential is promising with a suggested analogy to South Africa (Nielsen *et al.* 2006).
- Discovery of localities with enhanced gold content in rock or/and sediments samples in the inner Fiskefjord area and southwest of the western most part of the Isukasia supracrustal belt (Stensgaard 2007).

The potential for mineral resources in the studied region is good and the commodity groups are briefly commented below:

- The precious metals such as gold, platinum and palladium are promising targets in the region. The geological settings are believed to be prospective for the above metals and several interesting precious metal occurrences and more advanced prospects are known. The gold potential on Storø is the most advanced gold prospect in the region. Considerable work has also been carried out on Qussuk. The gold occurrences in the Isua greenstone belt have also received considerable amount of attention. With regard to PGE, the Fiskefjord platinum-palladium project (the Amikoq project) is the most recent advanced project. However, also the PGE's within the Norite Belt have received considerable amount of attention.
- The base metals are not the most obvious target in the region. Copper are known by several occurrences but only as smaller occurrences. The best base metal potential is probably at Bjørneøen.

- The iron and ferroalloy group is represented by the world class BIF deposit, the Isua BIF deposit. The deposit has seen several detailed campaigns from various companies and is very advanced. The latest and ongoing project on the deposit, by London Mining Plc., is preparing a feasibility study of the deposit. Ferroalloy such as nickel and tungsten are present but need more exploration. The best targets are found within the nickel-bearing Norite Belt and within tungsten occurrences in the Godthåbsfjord area; with the best potential in the Ivisaartoq Supracrustal Belt.
- The speciality metals such as rare earth elements, niobium and tantalum are known from the Qaqqaarsuk carbonatite, but more exploration is needed to judge the potential for these elements.
- The fissionable metals such as uranium and thorium are known from pegmatites in the Godhåbsfjord tract and in relation to the Qorqut granite but with the present knowledge they are not of any economic interest. Similarly, the Qaqqaarsuk carbonatite hosts a potential for uranium within pyrochlore minerals.
- Gemstones are especially known from the Maniitsoq area with diamond, lazurite and coloured corundum. Rubies are also known from the Nuuk region. Beryl is known from Ivisaartoq and at other localities within pegmatites.
- Industrial minerals are well represented in the region by the former olivine mine, Seqi Olivine Mine, which produced nearly pure forsterite. The mine operated from 2005 to 2008 but where closed due to strategy decisions by its owner Minelco A/S. Another industrial mineral, which could become of economic interest, is the apatite content of the Qaqqaarsuk carbonatite.

References

Andreasen, B. 2007: Mineralogical and geochemical investigations of gold-bearing Mesoarchaean supracrustal rocks from the Qussuk area, southern West Greenland. Characterisation of selected geological environments. Mineral resource assessment of the Archaean Craton (66o to 63o30') SW Greenland. Contribution no. 6. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2007/79**, 77 pp.

Appel, P.W.U. 1978: On a banded iron-formation in the Early Precambrian Isua supracrustal belt, West Greenland. In: Smith, I.E.M. & Williams, J.G. (eds): Proceedings of the 1978 Archean Geochemistry Conference, 326–328. University Toronto Press.

Appel, P.W.U. 1979: Stratabound copper sulfides in a banded iron-formation and in basaltic tuffs in the early Precambrian Isua supracrustal belt, West Greenland. Economic Geology **74**, 45–52.

Appel, P.W.U. 1980a: On the Early Archaean Isua iron-formation, west Greenland. Precambrian Research **11**, 73–87.

Appel, P.W.U. 1980b: Stratabound galena and sulphides of Ni-Sb-Cd-Ag in the early Precambrian Isua supracrustal belt, West Greenland. 11th Int. Mineral Ass, Novosibirsk 1980b, 140–148.

Appel, P.W.U. 1982a: On the genesis of the Early Archaean Isua iron-formation, West Greenland. In: Sidorenko, A.V. (ed.): Sedimentary geology of highly metamorphosed Pre-cambrian complexes, 221–232. Moskva

Appel, P.W.U. 1982b: Strata-bound sulphides in the Early Archaean Isua supracrustal belt, West Greenland. In: Amstutz, G.C., El Goresy, A., Frenzel, G., Kluth, C., Moh, G., Waushkuhn, A. & Zimmermann, R.A. (eds): Ore genesis: The state of the art, 405–412. Berlin, Heidelberg: Springer-Verlag.

Appel, P.W.U. 1983: Rare earth elements in the early Archaean Isua iron-formation, West Greenland. Precambrian Research **20**, 243–258.

Appel, P.W.U. 1990a: Copper, zinc and nickel occurrences in the Nuuk region, West Greenland. Open File Series Grønlands Geologiske Undersøgelse **90/9**, 28 pp.

Appel, P.W.U. 1990b: Mineral occurrences in the 3.6 Ga old Isua supracrustal belt, West Greenland. In: Naqvi, S.M. (ed.): Precambrian continental crust and its economic resources **8**, 593–603.

Appel, P.W.U. 1991: The Isua iron ore deposit at Isukasia, West Greenland. Open File Series Grønlands Geologiske Undersøgelse **91/3**, 31 pp.

Appel, P.W.U. 1994: Stratabound scheelite in altered Archaean komatiites, West Greenland. Mineralium Deposita **29**, 341–352.

Appel, P.W.U. 1997: High bromine contents and low Cl/Br ratios in hydrothermally altered Archaean komatiitic rocks, West Greenland. Precambrian Research **82**, 177–189.

Appel, P.W.U., Fedo, C.M., Moorbath, S. & Myers, J.S. 1998: Recognizable primary volcanic and sedimentary features in a low-strain domain of the highly deformed, oldest known (~3.7-3.8 Gyr) Greenstone Belt, Isua, West Greenland. Terra Nova **10**, 57–62.

Appel, P.W.U., Bliss, I.C., Coller, D.W., Grahl-Madsen, L. & Petersen, J.S. 2000: Recent gold discoveries in Archaean rocks of central West Greenland. Transactions Institution of Minig and Metallurgy (Section B: Applied earth science) **109**, B34–B41.

Appel, C.C., Appel, P.W.U. & Rollinson, H.R. 2002: Complex chromite textures reveal the history of an early Archaean layered ultramafic body in West Greenland. Mineralogical Magazine **66**, 1029–1041.

Appel, P.W.U., Coller, D., Coller, V., Heijlen, W., Moberg, E.D., Polat, A., Raith, J., Schjødt, F., Stendal, H. & Thomassen, B. 2005: Is there a gold province in the Nuuk region? Report from field work carried out in 2004. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2005/27**, 79 pp.

Bizzarro, M., Simonetti, A., Stevenson, R.K. & David, J. 2002: Hf isotope evidence for a hidden mantle reservoir. Geology **30/9**, 771-774.

Chadwick, B. 1990: The stratigraphy of a sheet of supracrustal rocks within high-grade orthogneisses and its bearing on Late Archaean structure in southern West Greenland. Journal of the Geological Society London **147**, 639–652.

Chartier, T. 1998: A report on the 1997 West Greenland diamond project, southern West Greenland, exploration licence # 4/95, Maniitsoq, Southwest Greenland, 30 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 21570).

Chadwick, B. & Crewe, M.A. 1986: Chromite in the early Archean Akilia Association (ca 3,800 my), Ivisârtoq region, inner Godthåbsfjord, southern West Greenland. Economic Geology and Bulletin of the Society of Economic Geologists **81**, 184–191.

Christensen R (2007) Prospecting in the Qussuk area. 2006. Unpublished report for Nunaminerals 15 pages and 4 appendices.

Christensen R (2008) Prospecting in the Qussuk area. 2007. Unpublished report for Nunaminerals 22 pages and 4 appendices.

Eilu, P., Garofalo, P., Appel, P.W.U. & Heijlen, W. 2006: Alteration patterns in Au-mineralised zones of Storø, Nuuk region - West Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2006/30**, 73 pp.

Escher, A. & Myers, J.S. 1975: New evidence concerning the original relationships of early Precambrian volcanics and anorthosites in the Fiskenæsset region, southern West Greenland. Rapport Grønlands Geologiske Undersøgelse **80**, 84–87.

Escher, J.C. 1981: Geologisk kort over Grønland, 1:100 000, Kangiata nuna 63 V2 Nord. Copenhagen: Grønlands Geologiske Undersøgelse.

Friend, C.R.L. & Nutman, A.P. 2001: U-Pb zircon study of tectonically bounded blocks of 2940-2840 Ma crust with different metamorphic histories, Paamiut region, South-West Greenland: implications for the tectonic assembly of the North Atlantic craton. Precambrian Research **105**, 143–164.

Friend, C.R.L. & Nutman, A.P. 2005: New pieces to the Archaean terrane jigsaw puzzle in the Nuuk region, southern West Greenland: steps in transforming a simple insight into a complex regional tectonothermal model. Journal of the Geological Society London **162**, 147–162.

Friend, C.R.L., Nutman, A.P. & McGregor, V.R. 1988: Significance of the late Archaean granulite facies terrain boundaries, southern West Greenland. In: The Deep Continental Crust of South India **31**, 22–24.

Garde, A.A. 1990: Thermal granulite-facies metamorphism with diffuse retrogression in Archaean orthogneisses, Fiskefjord, southern West Greenland. Journal of Metamorphic Geology **8**, 663–682.

Garde, A.A. 1997: Accretion and evolution of an Archaean high-grade grey gneiss-amphibolite complex: the Fiskefjord area, southern West Greenland. Geology of Greenland Survey Bulletin **177**, 114 pp.

Garde, A.A. 2007a: A relict island arc complex with synvolcanic epithermal alteration in western Godthåbsfjord, southern West Greenland: field work in 2006 at Qussuk and Bjørneøen. In: Stendal, H. (ed.): Characterisation of selected geological environments Mineral resource assessment of the Archaean Craton SW Greenland Contribution no. 1. Danmarks og Grønlands Geologiske Undersøgelse Rapport, **2007/20**, 13–40.

Garde, A.A. 2007b: A mid-Archaean island arc complex in the eastern Akia terrane, Godthåbsfjord, southern West Greenland. Journal of Geological Society London **164**, 565–579.

Garde, A.A. 2008: Geochemistry of Mesoarchaean andesitic rocks with epithermal gold mineralisation at Qussuk and Bjørneøen, southern West Greenland. Mineral resource assessment of the Archaean Craton (66o to 63o30') SW Greenland. Contribution no 8. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2008/4**, 52 pp.

Garde, A.A., Larsen, O. & Nutman, A.P. 1986: Dating of late Archaean crustal mobilisation north of Qugssuk, Godthåbsfjord, southern West Greenland. Rapport Grønlands Geologiske Undersøgelse **128**, 23–36.

Garde, A.A., Stendal, H. & Stensgaard, B.M. 2007: Pre-metamorphic hydrothermal alteration with gold in a mid-Archaean island arc, Godthåbsfjord, West Greenland. Geological Survey of Denmark and Greenland Bulletin **13**, 37–40.

Garde, A.A., Friend, C.R.L., Nutman, A.P. & Marker, M. 2000: Rapid maturation and stabilisation of middle Archaean continental crust: the Akia terrane, southern West Greenland. Bulletin of the Geological Society of Denmark **47**, 1–27.

Garde, A.A., Hollis, J.A., Kelly, N., Steenfelt, A., Stendal, H. & vanGool, J.A.M. 2006: Archaean island arc - hosted gold mineralisation at western Godthåbsfjord, southern West Greenland. In: The 27th Nordic Geological Winter Meeting Abstract Volume Oulu Special issue I, 39. Bulletin of the Geological Society of Finland.

Hollis, J.A. 2005: Greenstone belts in the central Godthåbsfjord region, southern West Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2005/42**, 215 pp.

Hollis, J.A., van Gool, J.A.M., Steenfelt, A. & Garde, A.A. 2004: Greenstone belts in the central Godthåbsfjord region, southern West Greenland Preliminary results from field work in 2004. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2004/110**, 109 pp.

Hollis, J.A., Frei, D., van Gool, J.A.M., Garde, A.A. & Persson, M. 2006a: Using zircon geochronology to resolve the Archaean geology of southern West Greenland. Geological Survey of Denmark and Greenland Bulletin **10**, 49–52.

Hollis, J.A., Schmied, S., Stendal, H., van Gool, J.A.M. & Weng, W.L. 2006b: Supracrustal belts in Godthåbsfjord region, southern West Greenland Progress report on 2005 field work: geological mapping, regional hydrothermal alteration and tectonic sections. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2006/7**, 171 pp.

Jensen, S.M. & Secher, K. 2004: Investigating the diamond potential of southern West Greenland. Geological Survey of Denmark and Greenland Bulletin **4**, 69-72.

Jensen, S.M., Secher, K., Rasmussen, T.M. & Schjødt, F. 2004: Diamond exploration data from West Greenland: 2004 update and revision. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2004/117**, 90 pp.

Jensen, S.M., Lind, M., Rasmussen, T.M., Schjødt, F. & Secher, K. 2003: Diamond exploration data from West Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2003/21**, 50 pp.

Juul-Pedersen, A., Frei, R., Appel, P.W.U., Persson, M.F. & Konnerup-Madsen, J. 2007: A shear zone related greenstone belt hosted gold mineralization in the Archean of West Greenland A petrographic and combined Pb-Pb and Rb-Sr geochronological study. Ore Geology Reviews **32**, 20–36 pp.

Knudsen, C. 1991: Petrology, geochemistry and economic geology of the Qaqarssuk carbonatite complex, southern West Greenland. Monograph Series on Mineral Deposits **29**, 110 pp.

Knudsen, C., van Gool, J.A.M., Østergaard, C., Hollis, J.A., Rink-Jørgensen, M., Persson, M. & Szilas, K. 2007: Gold-hosting supracrustal rocks on Storø, southern West Greenland: lithologies and geological environment. Geological Survey of Denmark and Greenland Bulletin **13**, 41–44.

Kunzendorf, K. & Secher, K 1987: Dispersion of niobium and phosphorus in soil overlying the Qaqqaarsuk Carbonatite Complex, southern West Greenland. Journal of geochemical exploration, **28**, 285–296.

Kolb, J. & Stendal, H. 2007: Geological environments and hydrothermal mineralisation in Nunataarsuk, Qarliit Nunaat and Ameralik, Nuuk region, SW Greenland - a field report 2007. Mineral resource assessment of the Archaean Craton SW Greenland Contribution no 2. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2007/58**, 44 pp.

Kristensen, T. 2006: En geologisk og geokemisk tolkning af mafiske og ultramafiske bjergarter og deres økonomiske mineralpotentiale, Fiskefjordsregionen, sydlige Vestgrønland, 166 pp. Unpublished M.Sc. thesis, Aarhus Universitet.

Larsen, L.M. 1991a: Registration of kimberlites and other potentially diamond-bearing rocks in Greenland. Rapport Grønlands Geologiske Undersøgelse, **152**, 61–65.

Larsen, L.M. 1991b: Occurrences of kimberlite, lamproite and ultramafic lamprophyre in Greenland. Open File Series Grønlands Geologiske Undersøgelse, **91/2**, 36 pp.

Larsen, L.M. & Pedersen, A.K. 1982: A minor carbonatite occurrence in southern West Greenland: the Tupertalik intrusion. Rapport Grønlands Geologiske Undersøgelse **110**, 38–43.

McGregor, V.R. 1973: The early Precambrian gneisses of the Godthåb district, West Greenland. Philosophical Transactions of the Royal Society London **273**, 343–358.

McGregor, V.R., Friend, C.R.L. & Nutman, A.P. 1991: The late Archaean mobile belt through Godthåbsfjord, southern West Greenland: a continent-continent collision zone? Bulletin of the Geological Society of Denmark **39**, 179–197.

Myers, J.S. 2001: Protoliths of the 3.8-3.7 Ga Isua greenstone belt, West Greenland. Precambrian Research **105**, 129–141.

Nielsen, T.F.D. & Jensen, S.M. 2005: The Majuagaa calcite-kimberlite dyke, maniitsoq, southern West Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2005/43**, 59 pp.

Nielsen, T.F.D., Jebens, M., Jensen, S.M. & Secher, K. 2006: Archetypical kimberlite from Manntsoq region, southern West Greenland and analogy to South Africa. Geological Survey of Denmark and Greenland Bulletin **10**, 45-48.

Nutman, A.P., Friend, C.R.L. & Bennett, V.C. 2002: Evidence for 3650-3600 Ma assembly of the northern end of the itsaq Gneiss Complex, Greenland: Implication for early Archaean tectonics. Tectonics **21**, 5-1–5-28.

Nutman, A.P., Christiansen, O. & Friend, C.R.L. 2007: 2635 Ma amphibolite facies gold mineralisation near a terrane boundary (suture?) on Storo, Nuuk region, southern West Greenland. Precambrian Research **159**, 19–32.

Olsen, H.K. 1986: Tungsten mineralisation in Archaean supracrustal rocks at Sermitsiaq, southern West Greenland. Rapport Grønlands Geologiske Undersøgelse **130**, 60-63.

Østergaard, C. & van Gool, J.A.M. 2007: Assessment of the gold mineralisation on Storø, Godthåbsfjord, southern West Greenland. Characterisation of selected geological environments. Mineral resource assessment of the Archaean Craton (66o to 63o30') SW Greenland. Contribution no. 5. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2007/78**, 20 pp.

Petersen, O.V. & Secher, K. 1993: The minerals of Greenland. Mineralogical Record, **24**, 1–65.

Polat, A. 2005: Geochemical and petrographic characteristics of the Ivisaartoq and Storø greenstone belts, southern West Greenland. In: Hollis, J.A. (ed.): Greenstone belts in the central Godthåbsfjord region, southern West Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2005/42**, 80–112.

Polat, A. & Hofmann, A.W. 2003: Alteration and geochemical patterns in the 3.7-3.8 Ga Isua greenstone belt, West Greenland Precambrian Research **126**, 197–218.

Polat, A., Hofmann, A.W. & Rosing, M.T. 2002: Boninite-like volcanic rocks in the 3.7–3.8 Ga Isua greenstone belt, West Greenland: geochemical evidence for intra-oceanic subduction zone processes in the early Earth. Chemical geology **184**, 231–254.

Polat, A., Frei, R., Appel, P.W.U., Dilek, Y., Fryer, B., Ordonez-Calderon, J.C. & Yang, Z. 2008: The origin and compositions of Mesoarchean oceanic crust: Evidence from the 3075 Ma Ivisaartoq greenstone belt, SW Greenland. Lithos **100**, 293–321.

Polat, A., Appel, P.W.U., Frei, R., Pan, Y., Dilek, Y., Ordonez-Calderon, J.C., Fryer, B., Hollis, J.A. & Raith, J.G. 2007: Field and geochemical characteristics of the Mesoarchean (~ 3075 Ma) Ivisaartoq greenstone belt, southern West Greenland: Evidence for seafloor hydrothermal alteration in supra-subduction oceanic crust. Gondwana Research **11**, 69–91.

Riciputi, L.R., Valley, J.W. & McGregor, V.R. 1990: Conditions of Archean granulite metamorphism in the Godthab-Fiskenaesset region, southern West Greenland. Journal of Metamorphic Geology **8**, 171–190.

Rink-Jørgensen, M. 2006: In situ U-PB datering af zirkoner i teori og praksis til bestemmelse af alder og populationer af detritale zirkoner, med anvendelse på en prøve fra Nuuk regionen i det sydlige Vestgrønland., Unpublished B.Sc. project thesis, University of Copenhagen.

Rollinson, H.R., Appel, P.W.U. & Frei, R. 2002: A metamorphosed, Early Archaean chromitite from West Greenland: Implications for the genesis of Archaean anorthositic chromitites. Journal of Petrology **43**, 2143–2170.

Rosing, M.T., Nutman, A.P. & Løfqvist, L. 2001: A new fragment of the earliest Earth crust: the Aasivik terrain of West Greenland. Precambrian Research **105**, 115–128.

Schlatter, D.M. & Christensen, R. 2010a: Characterisation of host rocks and hydrothermal alteration of the Qussuk gold occurrence, southern West Greenland. Geological Survey of Denmark and Greenland Bulletin **20**, 63–66.

Schlatter, D.M. & Christensen, R. 2010b: Geological, petrographical and lithogeochemical investigations on the Qussuk gold mineralisation, southern West Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport 2010/10, 53 pp.

Schlatter, D.M. & Christensen R. 2010c: Geological, petrographical and geochemical investigations on the Qussuk gold mineralization, southern West Greenland. In: Nakrem H.A., Harstad A.O., Haukdal G. (eds) 29th Nordic Geological Winter Meeting, Geological Society of Norway, p 173.

Secher, K. 1980: Distribution of radioactive mineralisation in central West Greenland. Rapport Grønlands Geologiske Undersøgelse **100**, 61–65.

Secher, K. 2001: The Pd+Pt dispersion in noritic and undifferentiated mafic rocks of the Archaean craton east of Maniitsoq, southern West Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2001/123**, 22 pp.

Secher, K. & Stendal, H. 1989: Weathering products of sulphides in the arctic - with a case history on a Cu-Ni-sulphide occurrence in West Greenland. In: Balasubramaniam, K.S. (ed.): Weathering; its products and deposits 2 Products - deposits - geotechnics, 499–522. Athens: Theophrastus Publications.

Secher, K., Nielsen, T.F.D., Heaman, L., Jensen, S.M. & Schjødt, F. 2008: Emplacement of kimberlites and UMLs in an alkaline province located 64º–67ºN in southern West Greenland – Evidence from 40 new robust age analyse: 9th International Kimberlite Conference (9IKC), Frankfurt, Extended Abstract No. 9IKC-A-00173, 3 pp.

Steenfelt, A., Hollis, J.A. & Secher, K. 2006: The Tikiusaaq carbonatite: a new Mesozoic intrusive complex in southern West Greenland. Geological Survey of Denmark and Greenland Bulletin **10**, 41–44.

Steenfelt, A., Secher, K. & Garde, A.A. 2007a: An overview of pegmatite occurrences in Greenland and their economic potential. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2007/2**, 46 pp.

Steenfelt, A., Schjødt, F., Sand, K.K., Secher, K., Tappe, S., Moberg, E.D. & Tukiainen, T. 2007b: Initial assessment of the geology and economic potential of the Tikiusaaq carbonatite complex and ultramafic lamprophyre dykes. Mineral resource assessment of the Archaean Craton (66o to 63o30') SW Greenland. Contribution no 3. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2007/64**, 53 pp.

Stendal, H. 2007: Characterisation of selected geological environments. Mineral resource assessment of the Archaean Craton SW Greenland Contribution no 1. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2007/20**, 88 pp.

Stendal, H., Nielsen, B.M., Secher, K. & Steenfelt, A. 2004: Mineral resources of the Precambrian shield of central West Greenland (66º to 70º 15' N). Part 2. Mineral occurrences. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2004/20**, 212 pp.

Stendal, H. & Stensgaard, B.M. 2007: Geological environments, mineral deposits and metallogenetic modelling, Greenland. GAC-MAC 2007 - For a change of climate. 23-25 May, 2007, Yellowknife, Canada 2007, 79 only.

Stendal, H. & Scherstén, A. 2007a: Geological Environments: Oceanic crust and hydrothermal alterations - Field report 2006. In: Stendal, H. (ed.): Characterisation of selected geological environments Mineral resource assessment of the Archaean Craton SW Greenland Contribution no. 1. Danmarks og Grønlands Geologiske Undersøgelse Rapport, **2007/20**, 59–88.

Stendal, H. & Scherstén, A. 2007b: A well-preserved bimodal Archaean volcanic succession in the Tasiusarsuaq terrane, South-West Greenland. Geological Survey of Denmark and Greenland Bulletin 13, 53–56.

Stendal, H., Secher, K. & Stensgaard, B.M. 2007: Greenstone belts in Greenland and related occurrences - possible counterparts in North America and Fennoscandia. Proceedings of the Ninth Biennial Meeting of the Society for Geology Applied to Mineral Deposits Dublin 2007, Dublin 2007, 939–942.

Stensgaard, B.M. 2008: Gold favourability in the Nuuk region, southern West Greenland: results from fieldwork follow-up on multivariate statistical analysis. Mineral resource assessment of the Archaean Craton SW Greenland Contribution no 9. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2008/8**, 74 pp.

Thorning, L., Christensen, L., Schjøth, F. & Stendal, H., 2004: Greenland mineral occurrence map. Status report for the development of a proto type for the Internet, January 2004. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2004/28** , 52 pp.

Thøgersen, G.J.-P. 2006: Karakterisering af det hydrothermale system langs Ataneq forkastningen på Vestgrønland, 177 pp. Unpublished M.Sc. thesis, Aarhus Universitet.

Thøgersen, G.J.-P., Stendal, H. & Zimmermann, H.D. 2006: Hydrothermal alteration along the Ataneq fault in the Nuuk region, Westgreenland. In: The 27th Nordic Geological

Winter Meeting Abstract Volume Oulu Speciel issue I, 161. Bulletin of the Geological Society of Finland.

Appendix A – Table and maps of mineral occurrences of the Archaean craton (66°N to 63°30’N)

Table 1. *Mineral occurrences from southern West Greenland. A description of all occurrences are given in Appendix A. The id. no. refers to an internal number used by GEUS for the archiving of information on mineral occurrences in Greenland. The id. no. refers to the "representative" locality within a group of similar occurrences.*

Id no.	Locality name	Commodity	Comments
161	Sillisisanguit Nunaat	Nickel-copper-PGE	Maniitsoq norite belt
163	Seqi	Olivine	Closed mine
164	Isua	Iron	BIF
169	Ivisaartoq	Tungsten	Skarn
170	Storø	Gold	Lode gold
528	Qussuk-1	Gold-copper	Epethermal or sta-taabound gold
531	Qaqqaarsuk	Niobium-REE-phosphor	Carbonatite
533	Maniitsoq	Diamond	Kimberlites
540	Sermilik	Tungsten-molybdenum	Skarn
542	Sermilik	Gold	Sulphide gold
544	Store Malene	Tungsten	Skarn
547	Molybdenum	Molybdenum	Skarn
548	Lille Narssaq	Gold	Sulphide gold
554	Ivisaartoq	Tungsten	Skarn
566	Ivisartoq	Tungsten	Skarn
568	Ujaragssuit	Chromite	Layered intrusion
569	Sulugutaussaq	Zinc-tin-iron	Massive sulphides
570	Simiutat	Molybdenum	Skarn

571	Isua	Gold-silver-copper	Sulphide gold
572	Isua	Gold-silver-zinc	Sulphide gold
573	Isua	Iron	BIF
574	Isua	Iron	BIF
575	Isua	Copper	Massive sulphide
592	Sermitsiaq	Tungsten	Skarn
595	Storø-2	Gold	Lode gold
596	Ivisaartoq	Molybdenum	Stockwork
597	Sagdlerssua	Gold, cerium	Clastic-hosted
598	Ivisaartoq	Gold	Sulphide gold
599	Ivisaartoq	Tungsten	Skarn
600	Isua	Gold	Sulphide gold
601	Isua	Silver-copper	Vein
602	Isua	Gold-siver-copper	Sulphide gold
603	Bjørneøen	Tungsten	Skarn
604	Storø	Tungsten	Skarn
606	Qilangarssuit	Tungsten	Skarn
607	Simiutat	Molybdenum-copper-tin-zinc	BIF
610	Ilulialik	Molybdenum-nickel-copper	Vein
611	Qilangarssuit	Copper	Stratabound
621	Qeqertaussaq	Gold	Lode gold
622	Sermitsiaq	Uranium	Pegmatite

627	Eastern Nunataarsuk	Gold-copper	Sulphide gold
628	Qarliit Nunaat	Copper-zinc	Massive sulphides
629	Nunatak 1390	Zinc-copper	Massive sulphides
630	Fiskefjord-1 (Amikoq)	PGE	Layered intrusion
631	Fiskefjord-2 (Amikoq)	PGE	Layered intrusion
632	Kangerluarssenguup taserssua	Gold	Lode gold
633	Qooqqut Lake-1	Copper-zinc-nickel	Massive sulphides
634	Qooqqut Lake-2	Zinc-copper-nickel	Massive sulphides
635	Bjørneøen	Gold-copper-zinc	Lode gold
636	Sermitsiaq	Copper-zinc	Massive sulphides
637	Ataneq-1	Quartz	Hydrothermal
638	Ataneq-2	Soapstone	Hydrothermal
640	Ivisaartoq, lake 430	Beryllium	Pegmatite, gemstone
648	Qingap ilua, Storø	Uranium	Pegmatite
656	Sermitsiaq	Tourmaline	Pegmatite, gemstone
719	Qaamasoq	Nickel-copper-PGE	Mafic association
735	Iliverlup Qaarsua	Diamond	Kimberlite dike
736	Inner Fiskefjord	Gold	Lode gold, sulphide gold
752	Kangerluarsuk	Corundum	Metamorphic
753	Tupertalik	Lapis lazuli (lazurite)	Metamorphic

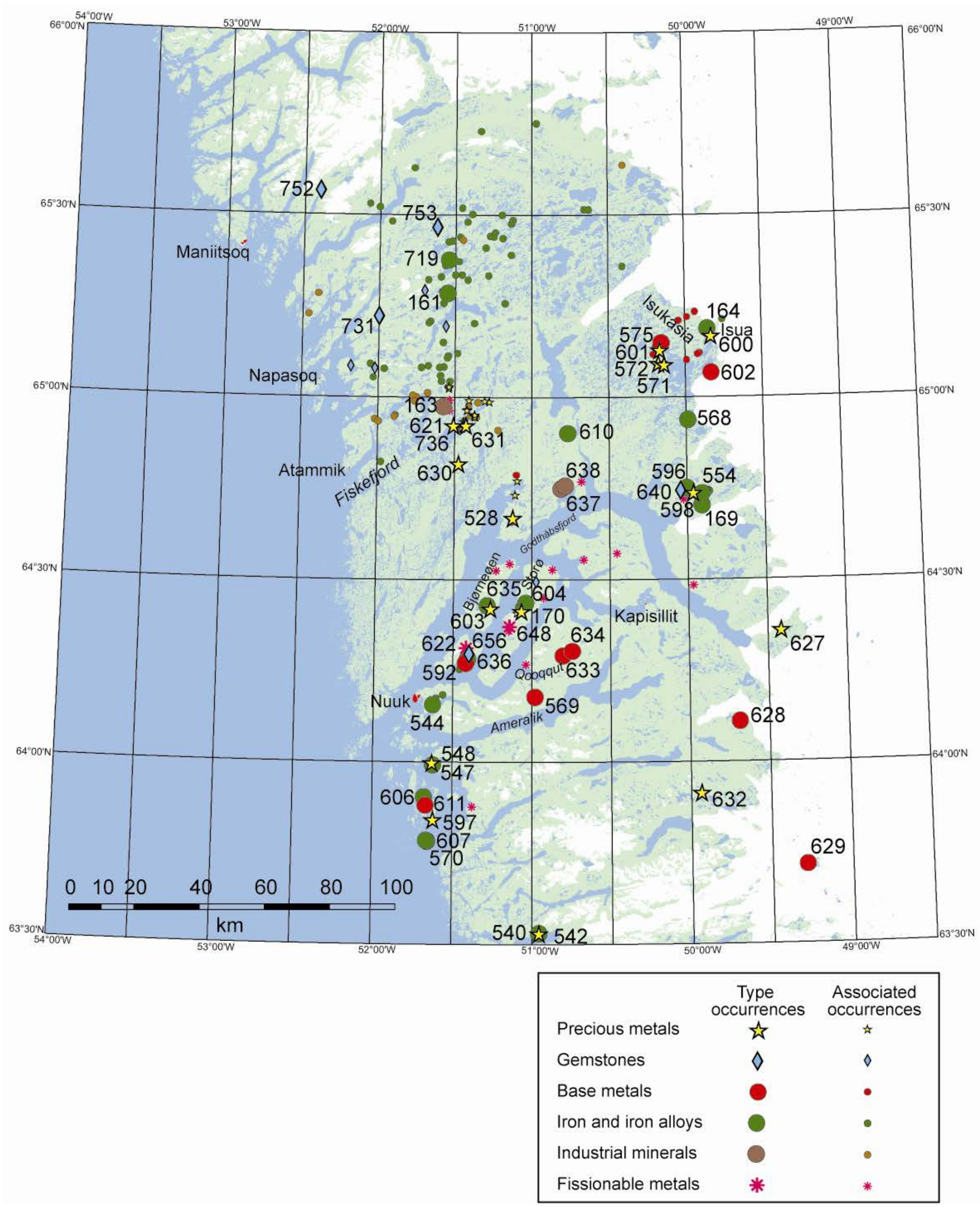

Figure 10. *Map showing the distribution of Mineral Occurrences in southern West Greenland which have been addressed by this work. Different coloured symbols refer to different commodity groups. The "representative" mineral occurrence localities within a group of similar occurrences are numbered.*

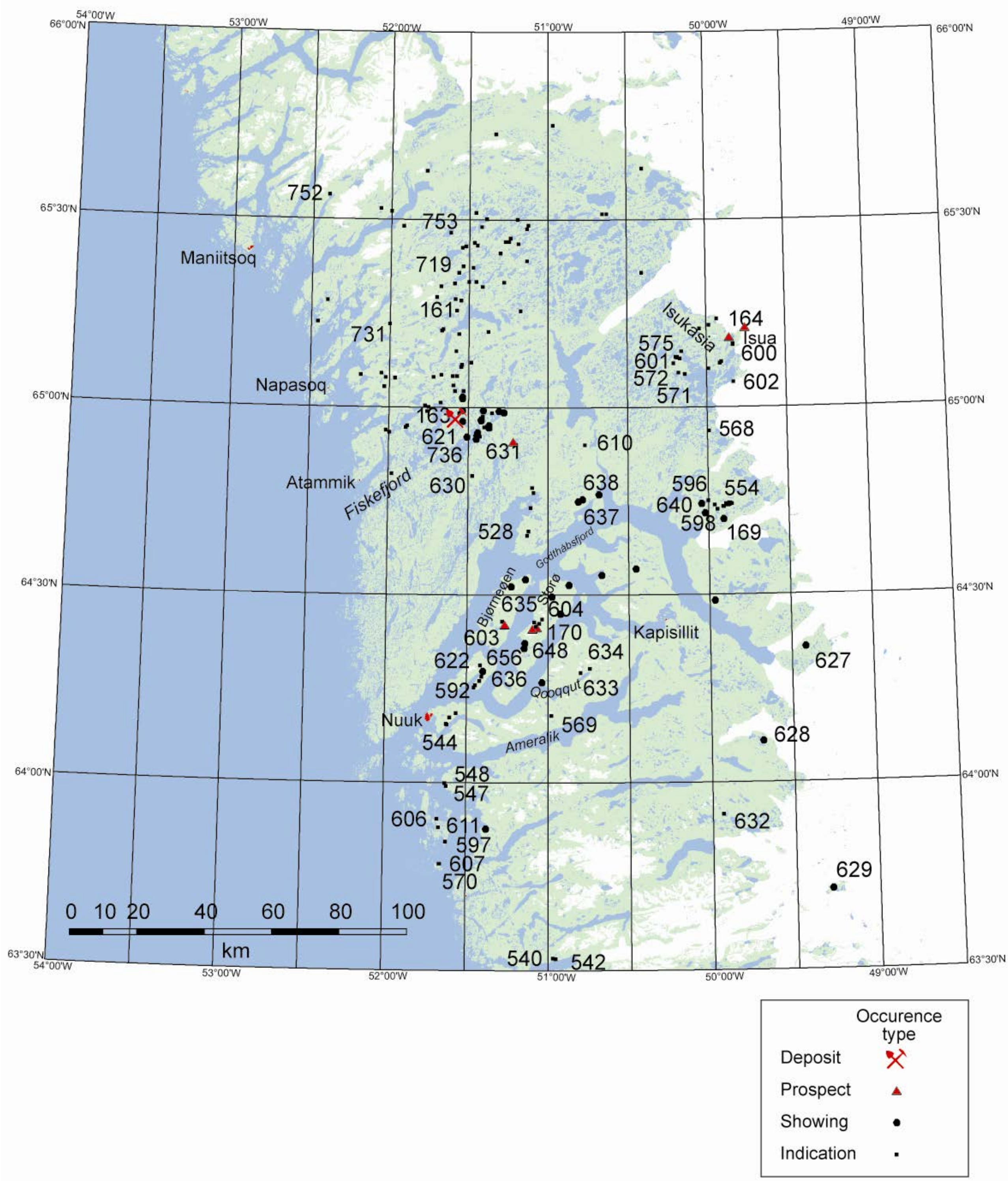

Figure 11. *Map showing the distribution of Mineral Occurrences in southern West Greenland which have been addressed by this work. Different symbols refer to different economic significance; from indication, showing, prospect to deposit.*

Appendix B – Mineral occurrence sheets for the Archaean craton (66°N to 63°30'N)

The mineral occurrences in Appendix B are in ascending order according to their mineral occurrence identification number. Page numbers in Appendix B refers to the individual mineral occurrences (and is not a continuation of the rest of the report).