DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2005/27

Is there a gold province in the Nuuk region?

Report from field work carried out in 2004

Peter W. Uitterdijk Appel, Dave Coller, Vincent Coller, Wouter Heijlen,
Else D. Moberg, Ali Polat, Johann Raith, Frands Schjøth,
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(1 CD-Rom included)

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GEUS

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GEUS

Aappalaartoq mountain on Storø to the left with rusty metasediments minor amphibolites. On top are light grey anorthosites.

Contents

Abstract

In 2003 GEUS in Copenhagen and Bureau of Minerals and Petroleum (BMP) in Nuuk decided to carry out a survey of the Nuuk region in order to assess the economic potential of the region immediately around the capital of Greenland. The area has several generations of greenstone belts and several regional structural features. A compilation of known data was compiled in 2003 and in 2004 field work was initiated. Several projects were carried out some financed by GEUS and some by BMP. The present report is a status report on results from the field work in 2004 financed by GEUS only aimed at unravelling the genesis of the known gold occurrences in the region.

Detailed field work and some laboratory work on the greenstone belt on Aappalaartoq and Qingaaq mountains on central Storø where gold showings were discovered in the 1990's revealed that the gold is epigenetic, but has been metamorphosed and deformed. It has also been shown that the 2.55 Ga Qoorqut granite post date the gold forming events and is thus not genetically associated with the mineralisation. It has not yet been established how the gold was emplaced and from which source the gold was derived.

Fluid inclusion studies in the Isua Greenstone Belt and the Storø deposit, although preliminary, indicate similar types of fluids and similar fluid evolution, which is compatible with gold mineralising fluids in Archaean greenstone belts worldwide. The origin of the fluids is probably metamorphic or might be linked with widespread magmatic activity in the central Nuuk region. Furthermore, in the northeastern IGB, fluid flow reconstruction indicates important pressure fluctuations during the retrograde evolution of the area, linked with changes in fluid pressure that could be due to disjunctive tectonic processes or due to magmatic activity. All these aspects are favourable for the formation of gold mineralization in the area.

Limited work on the Ivisaartoq area has shown that the extensive tungsten occurrences are not related to any intrusive granitic rocks. Further work in the next field season will hopefully cast new light on the genesis of these occurrences. Detailed work on a number of shear and fault zones in the area North of Storø has shown that they host extensive hydrothermal alteration features, but so far have none of these features proved to be auriferous. Work on the Qussuk peninsular on the North side of Godthåbsfjorden revealed interesting gold showings in alteration zones in a greenstone enclave.

Introduction

The Nuuk region centred around Godthåbsfjord (Fig. I-1) and stretching from the coastal areas West and South of Nuuk to the Inland Ice at Isua and further South has attracted fairly little attention from an exploration point of view until quite recently. The Kryolite Company A/S carried out a regional survey in the 1970's during which they discovered a World class iron deposit in the Isua greenstone belt at the edge of the Inland Ice (Keto, 1970). Unfortunately, about two thirds of the ore body is covered by the Inland Ice and the average grade is a mere 34 % Fe. Kidd Creek carried out tungsten exploration, but ceased the activities after one year (Downes & Gardinev, 1986). A small molybdenum showing about 30 km South of Nuuk attracted attention of a junior exploration company (Gustafson & Karup-Møller, 1977). In the 1990's Nuna Oil A/S now NunaMinerals A/S carried out grass root exploration in several of the greenstone belts in the Nuuk region. As a result of this work the company discovered minor gold showings in the Isua greenstone belt and prominent gold showings in a greenstone belt on Storø in Godthåbsfjorden. NunaMinerals explored and diamond drilled the Storø gold showings until mid 1990's whereafter they pulled out and released the concession. For further details and references, see Appel et al. (2000) and Appel et al. (2003). In 2004 NunaMinerals took up the concession on Storø again.

Early 2003 no exploration activities were planned in the Nuuk region and no geologic mapping were planned either. The geology of the Nuuk region was not known in much detail. Small areas of greenstone belts had been mapped by GEUS geologists and other teams. Detailed age work was carried out throughout the Godthåbsfjord area by Nutman and others (Nutman et al., 2004). The Isua greenstone belt has been studied in great detail by different international research teams. However, from a metallogenetic point of view not much has been done. Neither is there any comprehensive understanding of the depositional and tectonic setting of the different mid-Archaean greenstone belts in the Nuuk region.

Early 2003 a project was initiated with the title: *Preliminary evaluation of the economic potential of the greenstone belts in the Nuuk region.* (Appel et al., 2003). The project was financed jointly by GEUS and Bureau of Minerals and Petroleum (BMP). The study indicated that there is a potential for a gold province in the Nuuk region. It also indicated that there are possibilities for other types of mineral occurrences, e.g. tungsten, which may prove to be of economic importance. The report also presented an account on the general geology and an evaluation of compiled geophysical, geochemical and ore geological data together with an extensive reference list.

Late 2003 it was decided by GEUS and BMP to initiate a project in the Nuuk region. The overall aim of the study was to establish whether or not there is a gold province in the Nuuk region. There is no officially recognised definition of a gold province. In this project a gold province is defined as follows: *A gold province is a region with widespread gold anomalies and gold occurrences. The gold occurrences were formed at approximately the same time and by the same processes.*

The two main purposes of the ongoing activities in the Nuuk region are:

1. To determine if there is a gold province in the Nuuk region
2. To define the depositional and tectonic setting of the greenstone belts of the Nuuk region.

The field work financed exclusively by GEUS concerning the first purpose is presented in the present report, whereas the activities aimed at achieving a better understanding of the numerous greenstone belts in the region, their depositional and tectonic setting financed jointly by GEUS and BMP, the preliminary results have been described in a report entitled: *Greenstone belts in the central Godthåbsfjord region, southern West Greenland*. (Hollis et al., 2004).

The present report is a preliminary account on the fieldwork carried out to achieve the first purpose, namely answering the question whether there is a gold province in the Nuuk region or not. The project was carried out by geoscientists from GEUS in co-operation with Ali Polat from Windsor University (Canada), Johann Raith from Montangeologisches Universität in Leoben (Austria), Dave Coller, consultant from Era-Maptech, Dublin (Ireland) and Astrid Juul-Pedersen and Mac Persson, masters students from Geological Institute, University of Copenhagen (Denmark). This project was financed exclusively by GEUS.

Fieldwork was carried out on Central Storø in the mountains of Aappalaartoq and Qingaaq, where the most significant gold showings appear (Fig. I-1). Further work was carried out in the Ivisaartoq area and in several areas north of Godthåbsfjord in an area Northeast of Storø and on the south shore of Ameralik fjord. The limited work carried out on Bjørneøen West of Storø essentially confirmed previous work carried out by NunaMinerals. No work was carried out in the Isua area, but a short description of the gold showings in this area is presented in the report. All the above mentioned areas are outlined on Fig. I-1. The present report includes field reports from several of the participants, presented in appendices.

The present report is not meant as a full comprensive report, but merely a presentation of data collected during the field work and limited laboratory work mainly focussed at ore geologic investigations of the mineral paragenesis at Storø in order to determine the sequence of events which led to formation of the gold occurrences. The most detailed work presented in this report is the structural study on Storø by Dave Coller. It is believed that his studies will greately benefit the exploratory work to be carried out by mining companies in their search for economic gold deposits on Storø.

Enclosed with this report is a CD-ROM containing:

1. The full report as a pdf-file
2. An ArcView© project file with the structural data from Storø, geo-referenced sample locations and analytical results.
3. Digital photos from the 2004 fieldwork.
4. Scanned reports as PDF files of non-confidential company reports from Kryolitselskabet Øresund A/S, Kidd Creek Ltd., Greenland Mineral Exploration syndicate and NunaMinerals A/S (formerly NunaOil A/S) activities.

Instructions for accessing the CD-ROM are given at the end of this report.

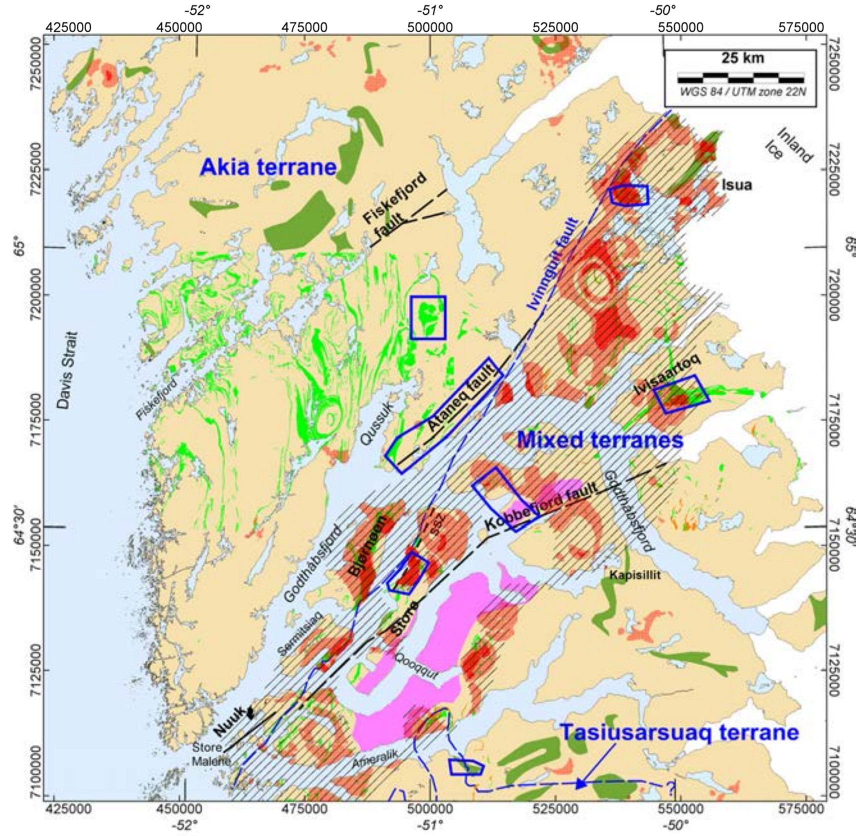

Fig. I-1. *Simplified outline of the Nuuk gold tract (hatched area). The red areas are defined as the 10% most favourable areas for gold (Nielsen et al., 2004). Areas where field work was carried out during 2004 are outlined by blue boxes except Isua where only laboratory work was carried out on gold-bearing samples. Green colour indicate greenstone belts. Purple is the Qooqqut granite.*

Storø greenstone belt

Introduction

The present chapter deals with the auriferous greenstone belt on central part of Storø. The greenstone belt enclaves on the remaining part of Storø have been described by Hollis et al. (2004). Central Storø is covered by an exploration licence and BMP could not support work in that part of Storø, whereas there were no problems for BMP to support work on the remaining part of Storø.

The greenstone belt outcropping on the mountains Qingaaq and Aappalaartoq (Fig. St-1) on central Storø host several gold occurrences (Appel et al., 2003). The area is covered by an exploration licence owned by NunaMinerals A/S. NunaMinerals A/S (formerly NunaOil) carried out exploration work and diamond drilling with intervals since the early 1990's. In 2004 the company diamond drilled a site on top of Qingaaq. Fieldwork on Storø in 2004 was carried out by GEUS geoscientists together with Dave and Vincent Coller (consultants Era Maptech, Ireland) and two master's students Astrid Juul-Pedersen and Mac Persson also participated in the fieldwork.

Main part of the work at central Storø was carried out by Dave Coller and is reported in his report entitled: *Field Report on Structural Mapping of the Auriferous Greenstones on Central Storø, Nuuk Fjord, West Greenland*. The report is seen in Appendix A. The report and all figures can be viewed on the enclosed CD-ROM. Peter Appel and Astrid Juul-Pedersen carried out the preliminary work on the genesis of the gold mineralization on Storø.

Ore geology

The auriferous greenstone belt on central Storø consist of highly deformed and amphibolite facies metamorphosed banded to massive amphibolites with rare pillow structures and metasediments comprising garnet micaschists, sillimanite schists and fuchsite-stained quartzites. Intercalated in the metasediments are frequent bands of iron-formation (Fig. St-2). The bands are up to 50 cm thick and can be traced along strike for tens of metres pinching and swelling. The origin of these magnetite-rich bands is debated.

Drill cores from previous NunaMinerals drilling campaigns and samples collected during the 2004 field season have been investigated in thin and polished thin sections. The investigations were carried out in reflected and transmitted light under the microscope as well as in scanning electron microscope. A number of samples have been analysed at Actlabs and the results are shown in a Table on the CD-ROM.

Gold occurs in several settings such as sheeted quartz veins, where it is seen as discrete grains. Visible gold is also seen in banded amphibolites and in garnet-mica schists. Fig. St-3 shows one of the mineralised zones recently discovered by NunaMinerals. On the left is a massive to banded amphibolite and on the right rusty garnet-mica schist. In the amphibolite and in the metasediments trains of thin quartz veins, often with visible gold, are seen traversing the contact between the amphibolite and the metasediments at a small angle. This indicates that the gold mineralization is discordant to the stratigraphy. Further down the hill Dave Coller found that the gold mineralization was deformed by late movements in the regional shearzone (see Collers report in Appendix A).

The ore minerals in order of decreasing abundance are:

Pyrrhotite	FeS
Ilmenite	FeTiO3
Arsenopyrite	FeAsS
Loellingite	FeAs2
Chalcopyrite	FeCuS2
Sphalerite	ZnS
Gold	Au
Wehrlite	BiTe
Mejonite	NiTe
Molybdenite	MoS2
Hessite	Ag2Te
Bravoite	(Fe,Ni,Co)S2
Gersdorfite	(Ni,Co,Fe)AsS
Bismuth	BiTe
Scheelite	CaWO4

The ore minerals display an interesting sequence of events in the gold mineralization:

1. First event. Gold was introduced in the greenstone belt and was trapped in the lattice of arsenopyrite.
2. Second event. During increasing metamorphism arsenopyrite became unstable and formed pyrrhotite and loellingite (Fig. St-4). Gold could not be incorporated in the loellingite lattice, but formed discrete grains (Fig. St-4).
3. Third event. During decreasing metamorphic conditions loellingite reacted with pyrrhotite and formed arsenopyrite, but most of the gold still occurred as discrete grains, often at the border between loellingite and arsenopyrite.
4. Fourth event. During a later metamorphic event garnet formed and replaced loellingite, arsenopyrite and pyrrhotite, but left discrete gold grains intact (Fig. St-5).

This sequence of events shows that the gold was introduced prior to at least one phase of metamorphism, but was later metamorphosed again.

Preliminary conclusions

The work carried out so far shows that the gold is closely associated with the regional structure along Godthåbsfjord. The gold was introduced after at least one phase of deformation and was deposited in a system of discordant quartz veinlets in amphibolites and rusty metasediments. The mineralization is discordant to the lithological contact. The gold mineralization was formed prior to one phase of metamorphism. The gold is clearly shear-zone related and was introduced at around 2.8 Ga. The Qoorqut granite with an age of ~2.5 Ga has thus no genetic relationship to the gold mineralization. Lead isotopes at Isua gold mineralization indicate a 3.8 Ga source, which probably are the greenstones. The gold at Storø is probably derived from the mid-Archaean greenstone belt in which the gold mineralisation is situated.

Fig. St-1. *Aappalaartoq mountain to the left. Rusty metasediments and amphibolites and light grey anorthosite on top.*

Fig. St-2. *Qingaaq mountain. Package with garnet mica schists with intercalated magnetite-rich bands*

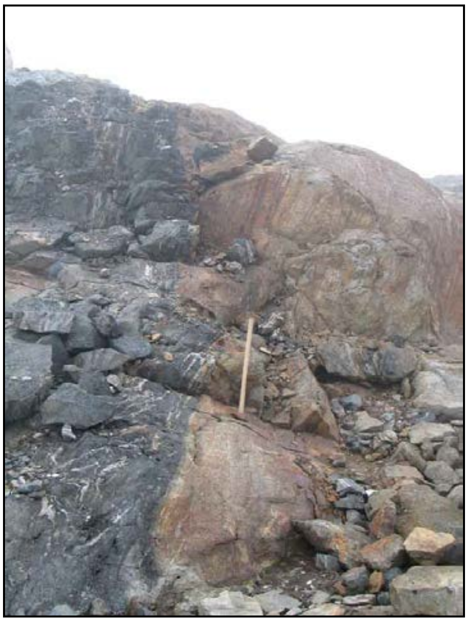

Fig. St-3. *Qingaaq mountain. Gold mineralised zone with auriferous quartz veins slightly discordant to the amphibolite-metasediment contact. Hammer for scale*

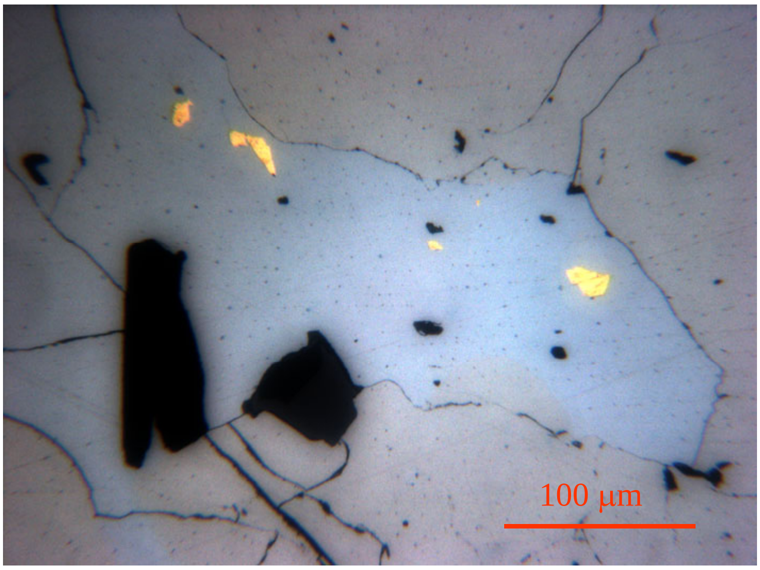

Fig. St-4. *Bluish loellingite grain with visible gold enclosed in arsenopyrite. Photomicrograph in reflected light*

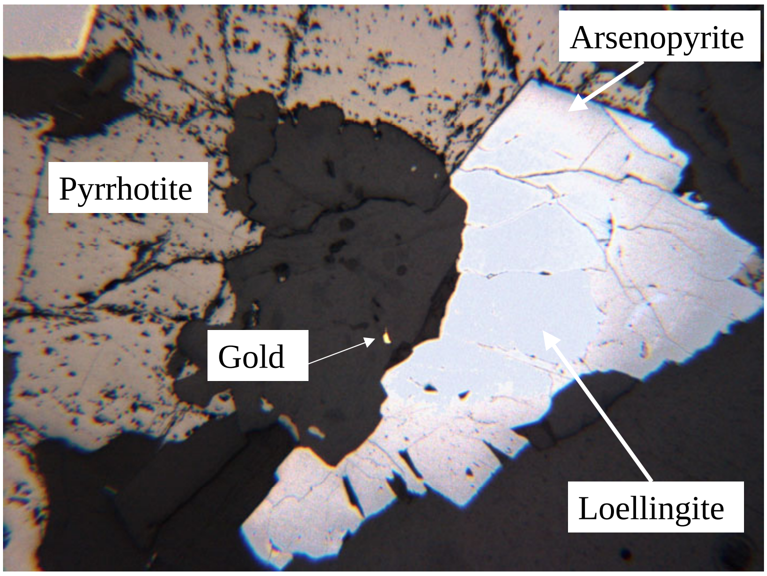

Fig. St-5. *Mineral paregenesis in garnet amphibolite. Garnet replace loellingite and arsenopyrite and leave free gold. Photomicrograph in reflected light*

Ivisaartoq greenstone belt

Introduction

Peter Appel, Ali Polat and Johann Raith carried out fieldwork in the Ivisaartoq greenstone belt. Weather conditions were not at all favourable. The base for the fieldwork was an excellent geological map made by Brian Chadwick (Chadwick, 1986; Chadwick & Coe, 1988). The participants had copies of Brian's field maps available for their fieldwork. Scanned copies of Brian Chadwicks field maps can be viewed on the enclosed CD-ROM. NunaMinerals A/S (formerly NunaOil A/S) has carried out some exploration work in the Ivisaartoq area. The non-confidential company reports can be viewed on the enclosed CD-ROM. Johann Raiths and Ali Polats field reports are shown in Appendices B and C and on the enclosed CD-ROM.

The greenstone belt at Ivisaartoq comprises mafic and ultramafic pillow lavas with intercalated metasedimentary rocks. Brian Chadwick divided the greenstone belt into several units separated by the so-called magnetic marker and by peridotite markers (Fig. Ivisaartoq-1). The pillow lavas are exceptionally well preserved and represent the best-preserved volcanic structures in the Nuuk region that we have observed so far. The pillows come in all sizes up to a couple of metres long. They are deformed but still display very well preserved cooling rims and ocelli (Fig. Ivisaartoq-2).

Significant features of the greenstone belt at Ivisaartoq are the multiple events of calc-silicate alteration most spectacularly displayed in the pillow lavas. The earliest event probably took place at or immediately below the sea floor. By this event the centres of the pillows were partly replaced by calc-silicates now represented by diopside and epidote (Fig. Ivisaartoq-3).

After at least one phase of deformation, calc-silicate alteration took place where diopside + garnet ± epidote ± vesuvianite ± scheelite veins anastomose through piles of deformed pillow lavas (Fig. Ivisaartoq-4). The veins may be metre wide and show no signs of deformation. However, they can be traced along strike into more and more deformed stages and may eventually be equivalent to the strongly boudinaged calc-silicate bands seen in metasediments and pillow lavas (Fig. Ivisaartoq-5). Garnets in these calc-silicate veins and bands may appear as up to 10-cm big euhedral crystals. Often garnets display a very pronounced zonarity (Fig. Ivisaartoq-6 and 6a). The zoned garnets have been investigated at the Scanning electron microscope. The garnets have a grossular core rimmed by a garnet with composition intermediate between grossular and andradite. There is an abundance of titanite in the rock as well as zircons. Most zircons are about 30 micron in size. If feasible they will be dated and their REE contents will be analysed and compared to the REE profile of the garnets in an attempt to establish the timing of the hydrothermal event, which formed the garnets and possibly also the associated tungsten mineralization. The latest calc-silicate alteration event followed a brittle deformation where the fragments of country rock are embedded in fine-grained epidote.

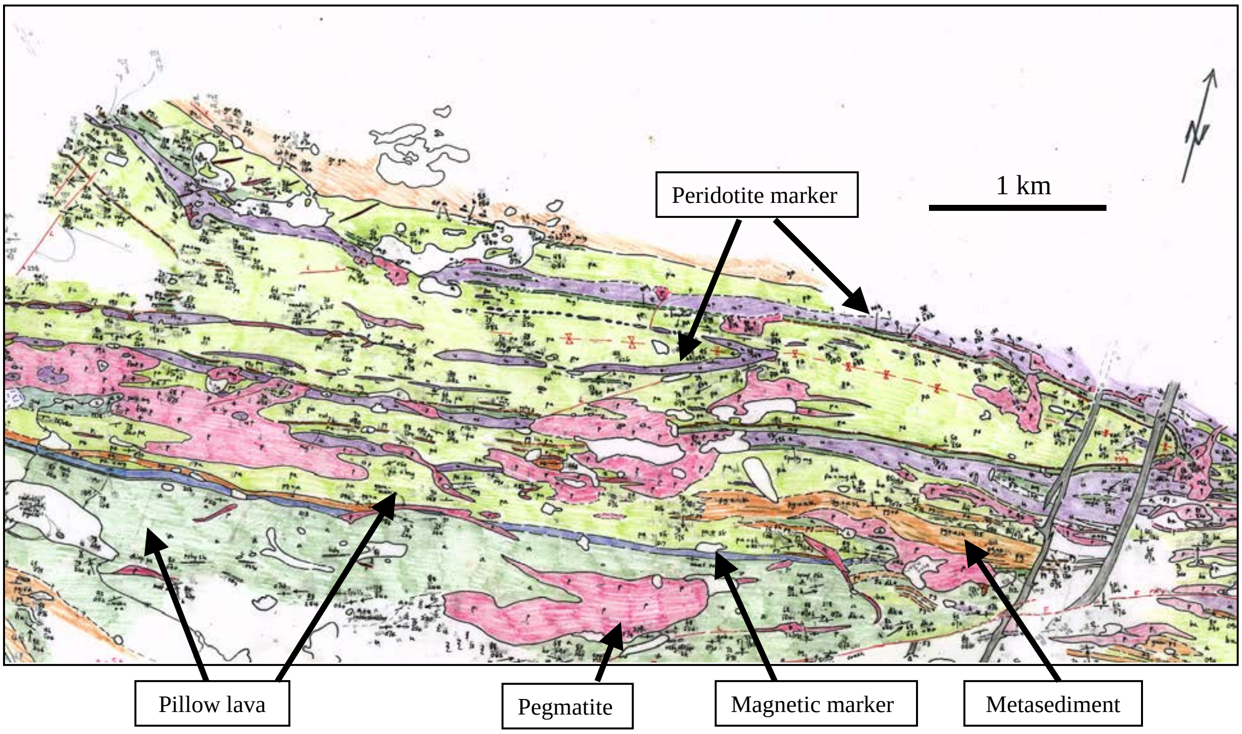

Fig. Ivisaartoq-1. *Field map of central Ivisaartoq greenstone belt. Mapped by Brian Chadwick.*

Fig. Ivisaartoq-2. *Pillow lava with well preserved cooling rim and ocelli. Coin for scale*

Fig. Ivisaartoq-3. *Pillow lava with well preserved cooling rim and centers partly replaced by diopside and epidote. Hammer for scale*

Fig. Ivisaartoq-4. *Anastomosing calc-silicate vein in banded amphibolite. Hammer for scale*

Fig. Ivisaartoq-5. *Boudinaged calc-silicate vein in pillow lavas. Hammer for scale*

Fig. Ivisaartoq-6. *Well zoned garnets in calc-cilicate vein consisting of diop-side, garnet an dlocally vesuvianite. Zoned garnets are ~3 cm across*

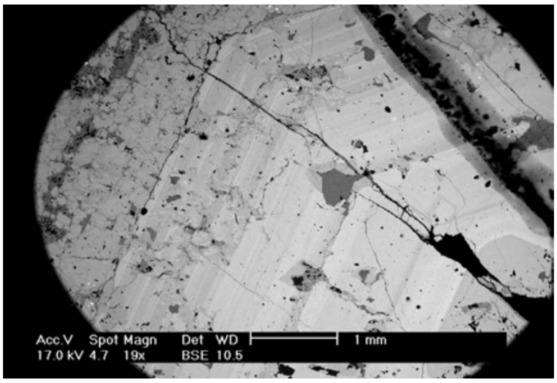

Fig. Ivisaartoq-6a. *Back scatter image from scanning electron micro-scope of the well zoned garnet*

Fig. Ivisaartoq-7. *Rusty patch in pillow lavas and intrusive gabbros. Hammer for scale.*

Rustzones are abundant in the Ivisaartoq area. The name of the area is actually derived from the reddish colour of Sea Trout, when it goes up the streams from the sea. Along the southern margin of the Ivisaartoq greenstone belt, a several tens of metres wide and kilometres long rustzone is displaying a distinct red iron oxide cap. The zone consists of massive to semimassive to disseminated pyrite in a quartz-rich rock often carrying small amounts of fuchsite. Numerous analyses have been made over the years on many samples but none of them returned any significant gold values. Other rustzones in the Ivisaartoq area are all much smaller. They rarely exceed a couple of metres in width and can mostly be traced for a few hundreds of metres along strike. Most of the rustzones are patches of rust in between pillows (Fig. Ivisaartoq-7), whereas others occur in the gabbro intrusions. A few rust-stained narrow shearzones have been found. Only one sample from 2004 of a rusty sheared metasediment returned gold (sample 493029 with 479 ppb Au).

Ivisaartoq greenstone belt hosts the most extensive tungsten occurrence in the Nuuk region (Appel, 1988, 1990). Appel (1988) suggested that the tungsten was of submarine exhalative origin and precipitated at or immediately below the sea floor and thus appears stratabound. This explanation was challenged by Johann Raith who, however, based on his limited field work in 2004 agree that granites or pegmatites did not play a significant role in the formation of the tungsten occurrences at Ivisaartoq (see Johann Raiths report in Appendix B). Further work in 2005 by Johann Raith will hopefully shed more light on the metallogenesis of the tungsten in the Nuuk region.

Another peculiar feature in the Ivisaartoq greenstone belt is the bromine enrichment in the magnetic marker and the peridotite markers. Bromine contents in Archaean rocks of that region are generally below detection limit of 5 to 10 ppm. However, at Ivisaartoq bromine contents over 400 ppm has been encountered. Chlorine contents in the contrary are very low so Cl/Br ratios are very low compared to most other greenstone belts in the World (Appel, 1997). No convincing explanation for the high bromine and low Cl/Br ratios has so far been offered. Interestingly enough is it that NunaMinerals studies (Arndt pers. comm.) and the present study has revealed high bromine contents and low Cl/Br ratios in one of the gold-bearing zones on Qingaaq on Storø.

Geochemical investigations

Ali Polat is presently investigating the altered and unaltered volcanic rocks in the Ivisaartoq greenstone belt. He collected and is in the process of analysing 88 samples for major elements and trace elements (LILE, REE, HFSE, Cr, Co, Ni, Sc, and V). See Ali Polats field report in Appendix C.

Conclusion and recommendation

The limited work carried out at Ivisaartoq during the field season has not brought much new information. Gold may very well be present in economic quantities in this greenstone belt, but it will need much more work before we know. It is also necessary during the 2005 field season to make a thorough study of the calc-silicate alteration and relate the different episodes to the deformation and metamorphic events. A structural survey for shearzones on aerial photographs with follow up in the field is also high on the priority list. The Cryolite Company prospected a molybdenite showing presumably related to a granite intrusion in an area close to the Inland Ice (Keto, 1960). A brief survey of this showing should be made. In order to improve the understanding of the tungsten mineralization event(s) some UV-lamping should be carried out. This can not be done until after 20 August, when it gets dark enough during night for the fluorescence of the tungsten mineral scheelite to be clearly visible.

Isua greenstone belt

No fieldwork was carried out in the ~3.8 Ga Isua greenstone belt (IGB) in 2004, neither was any research directly related to the gold showings at IBG carried out. However, since the IGB gold showings may be part of a Nuuk gold province it is appropriate to include a brief description of them in this report. Furthermore, a very detailed fluid inclusion study carried out on samples of a pillow breccia from IGB by Wouter Heijlen (GEUS) in 2004 and 2005 for other purposes proved to have significance for how the history of the gold showings at IGB can be interpreted. These results will be described in a section below.

Gold showings at IGB were discovered during an early phase of exploration by NunaMinerals A/S (Olsen & Grahl-Madsen, 1994; Bliss, 1996). The company did detailed mapping, ground and airborne geophysics and chip sampling in the IGB. They found several small gold showings mostly in fuchsite-bearing metacherts cut by minor shearzones. They also found a gold showing in an intrusive tonalite sheet and a gold showing in a shearzone hosted sheeted dolomite vein. NunaMinerals has given up their concession in the Isua area. GEUS carried out work in that area in the late 1990's.

In the western part of the IGB (Marked 1 on Fig. IGB-1) a small but fairly high-grade gold showing was found in an intrusive tonalite sheet. There are a couple of mineralised zones each less than one metre wide and traceable for a few tens of metres only. The zones are not betrayed by any rust staining, so there are good chances that more showings of this type can be found. Apart from silicates, the mineral assemblage comprise galena, sphalerite and gahnite. The ore minerals display a complex history. The first ore mineral was galena, which was replaced by sphalerite, which again was replaced by the Zn-spinel gahnite. At a later stage gahnite was replaced by muscovite (Appel, 2000). Grab samples yield up to 4.7% Pb, 9.6% Zn, 5.8 ppm Au and 180 ppm Ag. There is no visible gold. A peculiar feature is that the showing contains up to 51 ppm mercury, which probably is the highest mercury content registered in any rock in Greenland.

In a pile of pillow lavas and intrusive mafic and ultramafic rocks a shearzone hosted sheeted dolomite vein with visible gold was discovered by NunaMinerals (marked 2 on Fig. IGB-1). The sheeted dolomite vein has thin folded bands of fine-grained tourmaline. This gold showing occurs about one kilometre from the regional shearzone, which touches the Storø gold showings. In between the gold showing and the shearzone there is virtually no exposures only endless boulderfields. The auriferous dolomite vein is up to 2 metres wide and can be traced for about 100 metres along strike. It is boudinaged. The vein displays a complex mineral assemblage with dolomite, tourmaline, galena, arsenopyrite, visible gold, magnetite, Zn-rich chromite, pentlandite, pyrrhotite and gersdorffite. Grab samples yield values up to: 106 ppm Au, 115 ppm Ag, 178 ppm Bi and 3.8% Pb. The area has been prospected in fairly good detail by NunaMinerals so the chance of finding further outcrops of this type of gold showing is slim. However, the area is generally very poorly exposed especially towards the regional shearzone so more gold showings could probably be found.

Preliminary lead isotope work has been carried out by Robert Frei, Geological Institute, University of Copenhagen. His results show that the lead is very unradiogenic. It was extracted from ~3.8 Ga old rocks and emplaced at about 2.8 Ga (Frei, pers. comm.).

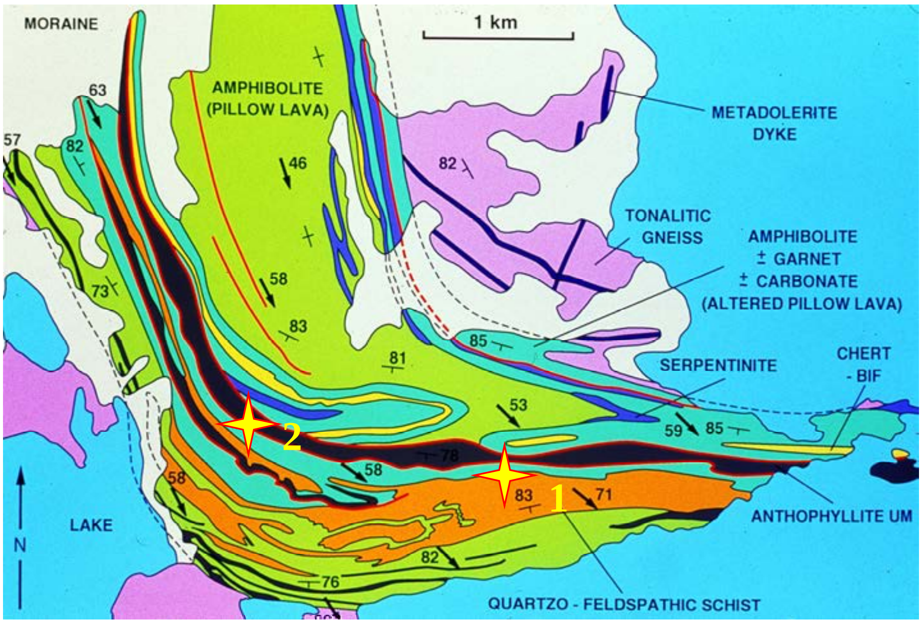

Fig. IGB-1. *Geological map of the south west part of the Isua greenstone belt with the two most prominent gold showings marked. Mapped by John Myers.*

Bjørneøen

Several years ago NunaMinerals A/S discovered small galena showings with small amounts of gold. The sulphides are found intercalated in banded amphibolites. GEUS work carried out by Bjørn Thomasen in 2004 did not reveal additional showings; see Thomasen's report in appendix E.

Shear and faultzones

This study was carried out by Henrik Stendal and focussed on shear- and faultzones in the areas: Fiskefjord region, Qussuk peninsula, Sermitsiaq, the inner part of Godthåbsfjord and Ameralik. For further details consult the full field report in Appendix D.

The results obtained so far outlined that the Qussuk peninsula is interesting regarding the gold potential. It looks as if the gold is connected to garnet-bearing supracrustal rocks. Some of the amphibolites of the Fiskefjord area have a geochemical signature indicating komatiitic origin. These rocks are high in Ni, Cr and Mg. The platinum group elements are detected but with values up to 22 ppb Pt and Pd. The Ameralik area looks interesting but much more work is needed for outlining more about the gold potential.

The gold potential of the shear-zones in the inner Godthåbsfjord north of Storø is regarded as low. No significant gold contents for this region have been detected. The hydrothermal system of the Ataneq fault in the eastern part of the Qussuk peninsula is barren with respect to gold. Copper and barium is recorded from the fault in connection with the huge hydrothermal activity (silicification) in the fault zone.

Fluid flow and gold mineralization in the Nuuk region, West Greenland: first insights from fluid inclusions in the Isua Greenstone Belt

This survey was carried out by Wouter Heijlen, former Post Doc at GEUS, on samples collected by Peter Appel in Isua and on Storø.

Gold mineralization has been discovered at various places in supracrustal rocks of the central Nuuk region, notably in the Ivisaartoq area and the Isua greenstone belt (Appel et al., 2000). Mineralization is epigenetic and vein-bound, yet little is known about the gold-bearing fluids and precipitation mechanisms. Detailed fluid inclusion investigation in an area of low-deformation in the northeastern IGB sheds some light on fluid flow during metamorphism and retrogression of that area, which might have a bearing on gold mineralization.

Fluid inclusions in the Isua greenstone belt

In the northeastern IGB, a pillow lava breccia occurs in a zone low deformation (Appel et al., 1998, 2001). Following early hydrothermal alteration, upper greenschist to lower amphibolite metamorphism resulted in a biotite-muskovite schist, but the primary breccia structure is well-preserved. Angular breccia fragments are cemented by granular quartz veins having some minor carbonates. A detailed petrographic study of the quartz microstructure and the fluid inclusions in veins and in quartz globules in the breccia fragments revealed the presence of five compositional types of inclusions (Heijlen, 2005):

- CO_2-rich inclusions ("G_1")
- CH_4 + H_2 inclusions ("G_2")
- halite-saturated brine + CO_2 (± solid carbonate) ("W_1")
- metastable high-salinity brine without halite daughter minerals (± solid carbonate) ("W_2")
- and low-salinity, aqueous fluid inclusions ("W_3")

Moreover, fluid inclusion populations show different relations with the quartz microstructure, which enabled reconstruction of a relative paragenesis of fluid flow. The oldest fluid inclusion populations are found in strained, remnant quartz crystals that survived full recrystallisation during retrograde static and dynamic recovery. These populations consist of immiscible assemblages of highly saline (~30 wt% salts) and CO_2-dominated fluids (W_1 and G_1). Their density, composition and spatial occurrence in the quartz indicates that they represent end-members of an unmixing process involving an initially homogeneous H_2O-CO_2-NaCl (+other salts) fluid. The presence of trapped, highly ordered graphite in CO_2-dominated inclusions, and of carbonate solids in the aqueous-dominated inclusions, further suggests that unmixing induced cogenetic carbonate and graphite formation from the physically separated end-member fluids. Modelling this immiscibility process shows that it likely occurred at 420 to 460°C and 3.2 to 4.4 kbar, i.e. very close to peak metamorphic conditions determined from mineral assemblages and from garnet-biotite geothermometry (460-480°C and 3.6 to 4.4 kbar; Appel et al., 2001). Consequently, the oldest fluid still present in these crystals had probably a metamorphic and/or magmatic origin (Fig. F-1).

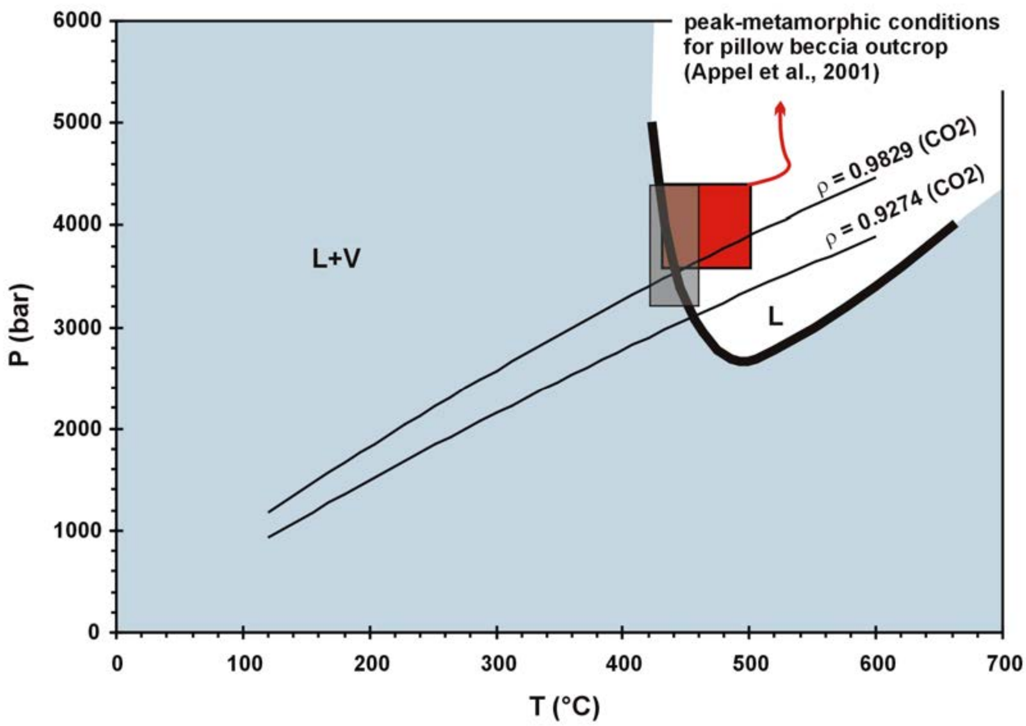

Fig. F-1. *Fluid inclusion constraints on trapping conditions of immiscible CO_2 and brine inclusions in remnant vein crystals at the breccia outcrop (northeastern IGB). Thick curve is the immiscibility boundary for a fluid having X_{H2O} = 0.6813, X_{NaCl} = 0.1119, X_{CO2} = 0.2068, derived to be the approximate composition of the aqueous end-member fluid (Heijlen, 2005). Blue field represents region of immiscibility (L+V). Thin lines are isochores for highest and lowest density CO_2 end-member fluids. These lines slightly underestimate pressure, since a fraction of H_2O is present in the inclusions. Grey box gives preferred estimate of trapping conditions.*

Subsequent further recrystallisation of quartz during the retrograde evolution caused redistribution, remixing and obliteration of the peak-metamorphic fluid inclusion assemblages. Most inclusions have been wiped out the recovered crystals and those remaining suffered significant post-entrapment changes. However, free fluids present in the rock were trapped along microfractures in recrystallising grains at different stages of this evolution. Again, such fluids present an immiscible brine and gaseous phase. Furthermore, gaseous carbonic fluids become CH_4-dominated in fluid inclusion assemblages formed successively later in the evolution. Raman analyses showed that these later fluids have X_{H2} of ~0.03 which increases up to ~0.3 during the retrograde evolution of the rocks. However, CO_2 inclusions trapped earlier were not affected by hydrogen diffusion through the quartz host, which suggest that CH_4 + H_2 fluids were present in the rock when quartz was chemically closed for hydrogen mobility (T < ~250°C).

Based on the fluid inclusion paragenesis, the volumetric properties of successive carbonic-dominated fluid inclusions in the samples suggest that the retrograde evolution closely followed a mean geothermal gradient of 30°C/km. However, large variabilities in density of progressively trapped CO_2- and CH_4-dominated fluid inclusion assemblages in recrystallised grains, indicate pressure fluctuations from this P-T path between ~0.5 and 2.5 kbar at temperatures of 200 to 300°C (Fig. F-2). Given the tectonometamorphic evolution of the area it is unlikely that such pressure fluctuations are due to complex (tectonically induced) burial stages of the rocks. Therefore, pressure fluctuations are probably due to differences in fluid pressure.

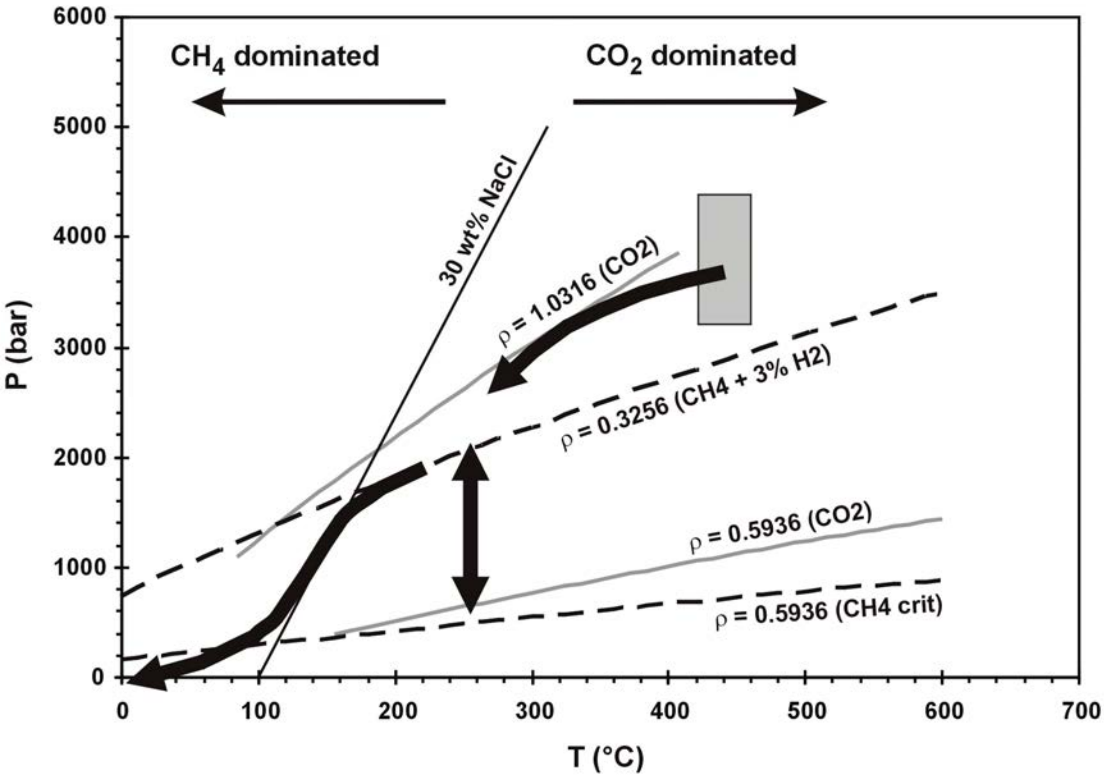

Fig. F-2. *Boundary conditions on retrograde evolution of the pillow breccia outcrop as deduced from fluid inclusions (Heijlen, 2005), showing the preferred retrograde path. This path is close to a mean geothermal gradient of 30°C/km.*

Preliminary study of fluid inclusions in minerals associated with gold mineralization in the IGB and at Storø.

An attempt was made to investigate the fluids that formed a Fe-rich dolomite-galena-arsenopyrite vein with associated gold mineralization in the IGB. Dolomite crystals have an equidimensional, planar-s texture, are variably deformed (e.g. twinning) and have many clustered and trail-bound fluid inclusions. Inclusions are generally small (up to 10 µm) and are monophase gaseous, although some mixed gas-aqueous inclusions were found. They are all CO_2-dominated (Tm_{CO2} ~ -57°C, i.e. close to -56.6°C, the triple point of pure CO_2) and show a very large range in density/molar volume, as indicated by the homogenisation temperatures which can be to liquid, or to vapour (i.e. molar volume lower and higher then 93.1 cm^3/mol). Lowest molar volume found (highest density inclusion) was 51.8 cm^3/mol. However, the physico-chemical properties of the inclusions are difficult to interpret since post-trapping changes (e.g. leakage) clearly played an important role in these dolomite samples.

Quartz gangue samples from gold mineralization at Storø were also checked for their fluid inclusion content. The quartz is associated with pyrrhotite, chalcopyrite, loellingite, titanite and carbonate. Blocky quartz crystals show some indications for static recovery, and have many secondary fluid inclusion trails. However, small (1-5 µm) monophase gas inclusions can be found in clusters together with various small (~1 to 20µm), rounded to botryoidal opaque solid inclusions (dirty zones in crystals). Based on their occurrence, the solids are likely to be graphite. Associated fluid inclusions are the oldest ones found in the quartz, and contain CO_2. Their melting temperature is only slightly depressed, indicating the presence of a very minor component of another gas (Tm_{CO2} = -58.4 to -57.8°C), while molar volume ranges between 44.6 and 51.9cm^3/mol (Th_{CO2} between -10.4 and +11.8°C; n = 7).

Younger, intra- and intergranular trails of fluid inclusions contain either low-density CH_4 (molar volume > 98.6 cm^3/mol), low- to high-salinity biphase aqueous inclusions, or a mixture of both. Although some low-salinity aqueous inclusions have been found, most inclusions do not freeze on cooling to -180°C (Fig. F-3). Those that did showed first melting at temperatures as low as -80°C and complete melting at T< -30°C, indicating a high salinity. In general, their cryogenic behaviour is similar as the high-salinity W2 inclusions in different quartz segregations of the pillow breccia occurrence in Isua, described above. Also, their association (sometimes in the same fluid inclusion trail) with low-density CH_4 inclusions is comparable to that found in Isua.

Although these observations are preliminary, they indicate a similar succession of the nature of the carbonic fluid (CO_2 towards CH_4) and occurrence of gaseous carbonic fluids associated with highly saline aqueous ones. This might suggest that similar fluids as found in the northeastern part of the IGB played a role in gold mineralization in Storø. The change of CO_2- to CH_4-dominated fluids in both localities might indicate similar buffering by (changing) host-rock mineralogy.

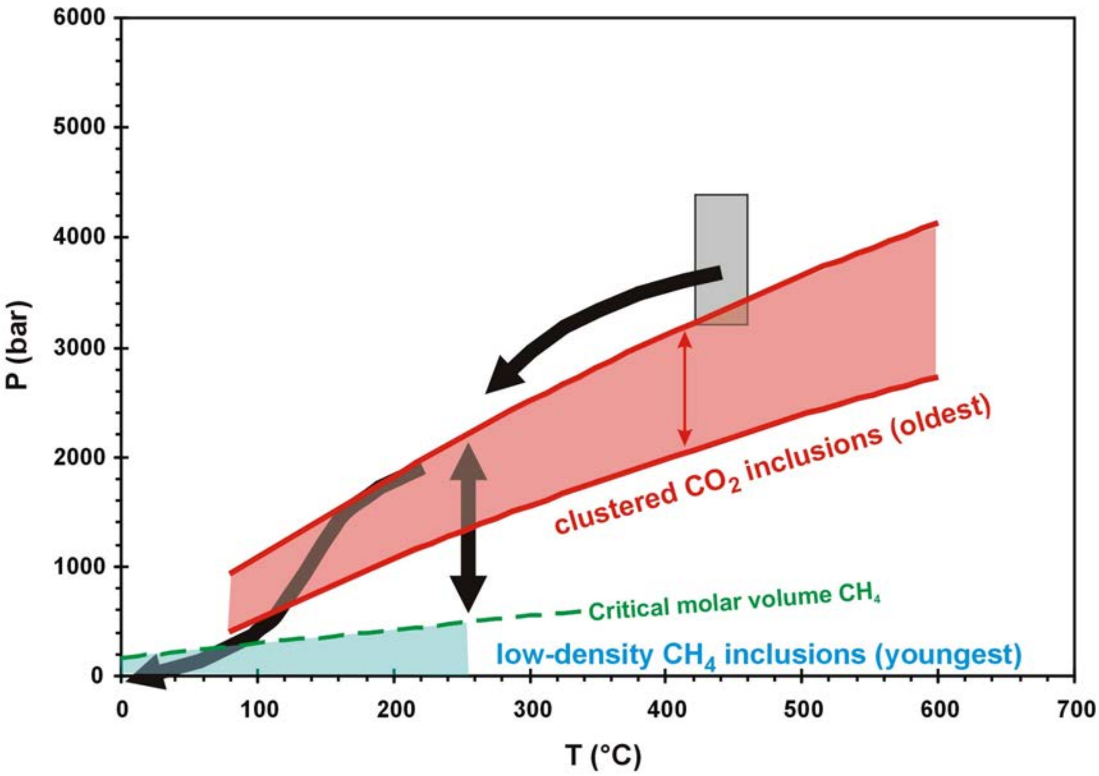

Fig. F-3. *Properties of fluid inclusions associated with mineralization at Storø (preliminary results), compared with P-T path derived for the northeastern IGB.*

Comparison with Archaean lode gold mineralization worldwide

Extensive studies of epigenetic gold mineralization in Archaean supracrustal rocks worldwide have shown that such mineralization occurred at various crustal levels (e.g. Hagemann & Brown, 1996; Groves et al., 2003), although the majority seems to have been formed at temperatures of 250 to 350°C and pressures between 1.5 and 3 kbar. In many cases, large pressure fluctuations during ore formation are recorded by fluid inclusions. Typically, mineralising fluids were moderately to low-salinity, H_2O-CO_2-CH_4 fluids, although high-salinity of the aqueous member have been reported (e.g. Archaean greenstone belts in Finland; Poutiainen & Partamies, 2003). Interestingly, the Nanulaq gold deposit in southern Greenland (hosted in Palaeoproterozoic metabasic rocks of the Nanortalik Nappe) also seems to have formed from highly saline fluids (Kaltoft et al., 2000). The nature of the carbonic fluid (CO_2 vs. CH_4) component shows often variability, indicating changing redox conditions at the depositional sites, which could on their turn reflect fluid rock interaction (e.g. Mikucki, 1998). Fluid immiscibility was ubiquitous and seems to have triggered mineralization in some cases (Bowers, 1991).

Fluid inclusion studies in the IGB and associated with the Storø deposit, although preliminary, indicate similar types of fluids and similar fluid evolution, which is compatible with gold mineralising fluids in Archaean greenstone belts worldwide. The origin of the fluids is probably metamorphic or might be linked with widespread magmatic activity in the central Nuuk region. Furthermore, in the northeastern IGB, fluid flow reconstruction indicates important pressure fluctuations during the retrograde evolution of the area, linked with changes in fluid pressure that could be due to disjunctive tectonic processes or due to magmatic activity. All these aspects are favourable for the formation of gold mineralization in the area.

Explanatory notes to the CD-ROM

The CD accompanying this report contains field data from the Nuuk Region collected by the Geological Survey of Denmark and Greenland (GEUS) in 2004. In agreement with the stated strategy of the Greenland Home Rule Government, the CD has been compiled with the basic philosophy in mind that quality controlled digital data should be released for general use in order to promote their use in mineral exploration.

There are three ways to browse and manipulate the compiled data: as ArcView GIS 3.3 views, as ArcMap 9.x and as ArcReader dataframes. ArcReader is a freeware and available for download from www.esri.com.

Figures numbered in this chapter is prefixed with 'Ex-'.

This chapter describes:

General information
Directory structure of the CD
Compiled ArcView GIS 3.3 views

General information

The area of interest on this CD is within longitudes 49°00' – 52°30' W and latitudes 63°30' – 65°15' N.

The Nuuk Field Report 2004 project file has been constructed using ArcView GIS version 3.3 and it makes full use of many of the facilities in this version of the program. The project has been designed and tested in Windows 2000 and XP. The screen layout of views has been optimised for a 17" screen size.

The ArcView GIS 3.3 project file has been used to produce the ArcMap 9.x and ArcReader dataframes. It is anticipated that the user has basic knowledge of GIS software (ArcView GIS 3.3, ArcMap 9.x or ArcReader) and its use.

Directory structure of the CD

The directory structure of the CD is visualised in Figure Ex-1 and Ex-2. Figure Ex-1 shows the top level and Figure Ex-2 shows the sub levels.

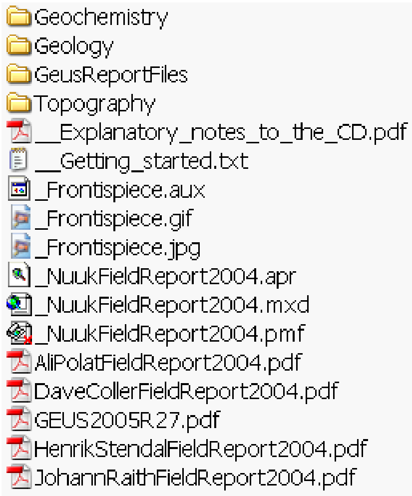

Figure Ex-1. *Top level directory of the CD. The '_NuukFieldReport2004.apr' file is the ArcView GIS 3.3 Project File, the '_NuukFieldReport2004.mxd' file is the ArcView 9.x users and the '_NuukFieldReport2004.pmf' file is for ArcReader users. The 'Geus2005R27.pdf' file is the GEUS report as a PDF-file. The PDF-file '__Explanatory_notes_to_the_CD.pdf' describes more detailed the data sets on the CD. The '__Getting_started.txt' file describes briefly how to get started with this data set.*

The subdirectory 'GeusReportFiles' contains selected company report as PDF-files from mineral exploration in the Nuuk region. The PDF-files each have a unique number and a cross-reference to the references is given here:

20036.pdf	Downes & Gardinev 1986
20044.pdf	Gustafson & Karup-Møller 1977
20062.pdf	Keto 1960
20167.pdf	Keto 1970
21329.pdf	Olsen & Grahl-Madsen 1994
21453.pdf	Bliss 1996
21648.pdf	Skyseth 1998
21649.pdf	Smith 1998

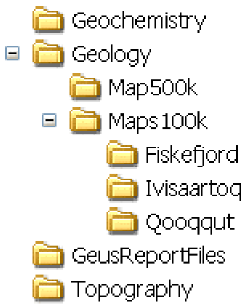

Figure Ex-2. *Directory structures showing the sublevels of the CD. The top level is shown in Figure Ex-1.*

Added functionality in ArcView GIS 3.3 project file

The three blue tool buttons marked ‘1024’, ‘1280’ and ‘1600’ serve two purposes:

1. In the Project window, press one of the buttons to resize the project window to fit a screen with 1024 × 768, 1280 × 1024 or 1600 x 1200 pixels, respectively

2. In any View, press one of the buttons to select and make active one from a list of Views. Selecting a View also resizes it to a screen with 1024 × 768, 1280 × 1024 or 1600 x 1200 pixels, respectively

Compiled ArcView 3.3 Views

The compiled views are only from ArcView GIS 3.3. The ArcMap and ArcReader versions the dataframes of the GIS compilation are almost identical with the views in ArcView GIS 3.3.

The different types of digital data sets are arranged into six views in the ArcView GIS project file ‘_NuukFieldReport2004.apr’:

01. Frontispiece

02. Location of the Nuuk region

03. Digital topographic map 1:100 000

04. Geological map 1:500 000

05. Digital geological map 1:100 000

06. Rocks and geochemistry

01. Frontispiece

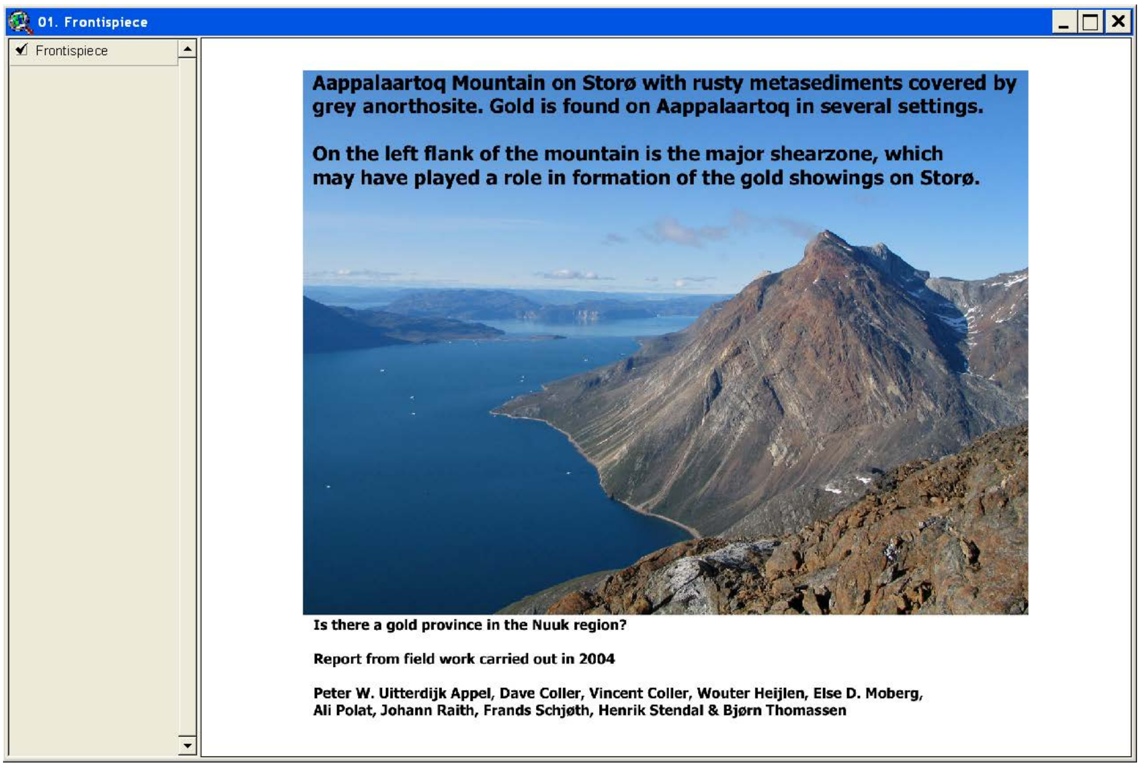

Figure Ex-3. *Screenshot of '01. Frontispiece'. Photo showing: Aappalaartoq Mountain on Storø with rusty metasediments covered by grey anorthosite. Gold is found on Aappalaartoq in several settings. On the left flank of the mountain is the major shearzone, which may have played a role in formation of the gold showings on Storø.*

02. Location of Nuuk region

The location of the Nuuk region shown on the digital topographic data at the scale of 1:2 500 000 only as polygons. The copyright of digital topographic data at scale 1:2 500 000 is as follow:

Topographic base: G/2.5 M Vector, Copyright KMS/GEUS 1997

The projection parameter is:

UTM-zone:	24 (*i.e.* the central meridian is 39° West)
False Easting:	500 000 metres
Geodetic reference:	WGS84

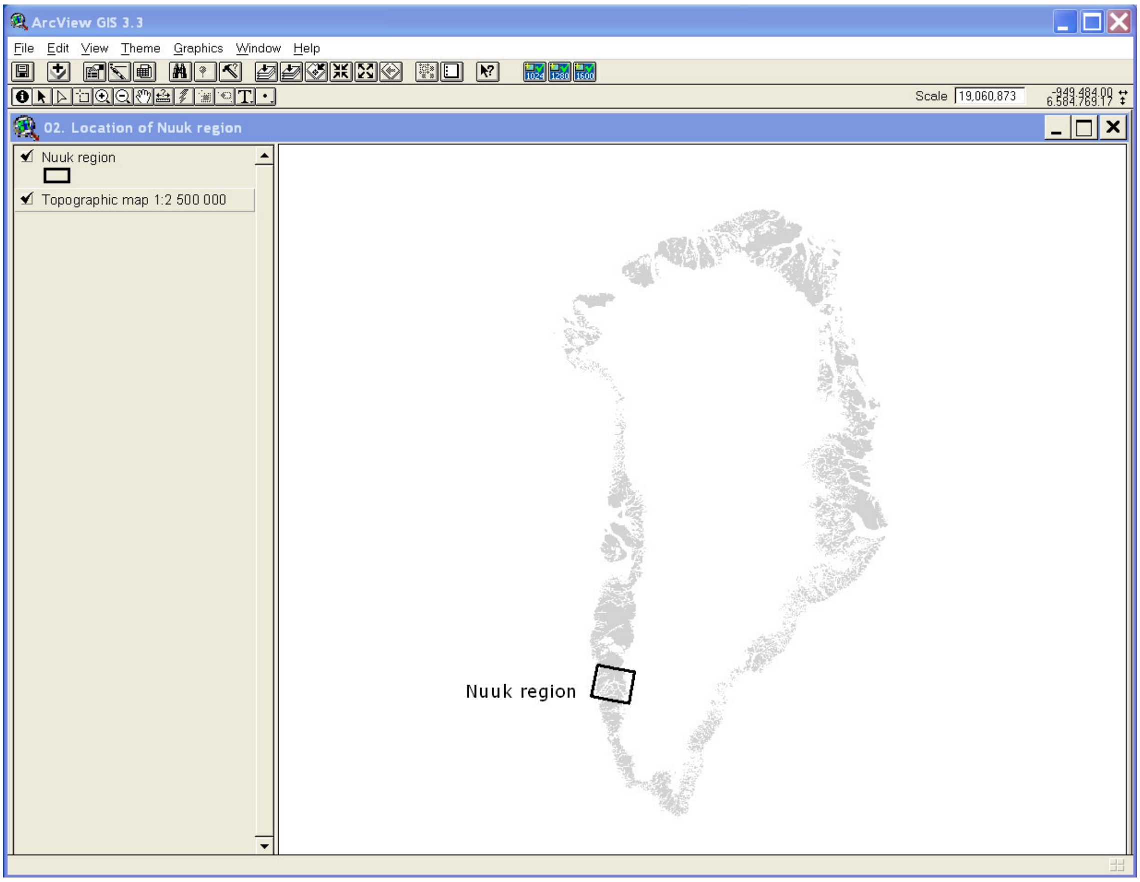

Figure Ex-4. *Screenshot of '02. Location of the Nuuk region'.*

03. Digital topographic map 1:100 000

The digital topographic data set, prepared digitally from aerial photographs at the scale of 1:100 000 in UTM zone 22 with the geodetic reference WGS84, at the Photogeological Laboratory at GEUS. Point control by Kort & Matrikelstyrelsen, Copenhagen, with permission A.200/87. The copyright of digital topographic data set is as follow:

Topographic base map: Copyright GEUS, 2003, 2004

The projection parameter is:

UTM-zone:	22 (*i.e.* the central meridian is 51° West)
False Easting:	500 000 metres
Geodetic reference:	WGS84

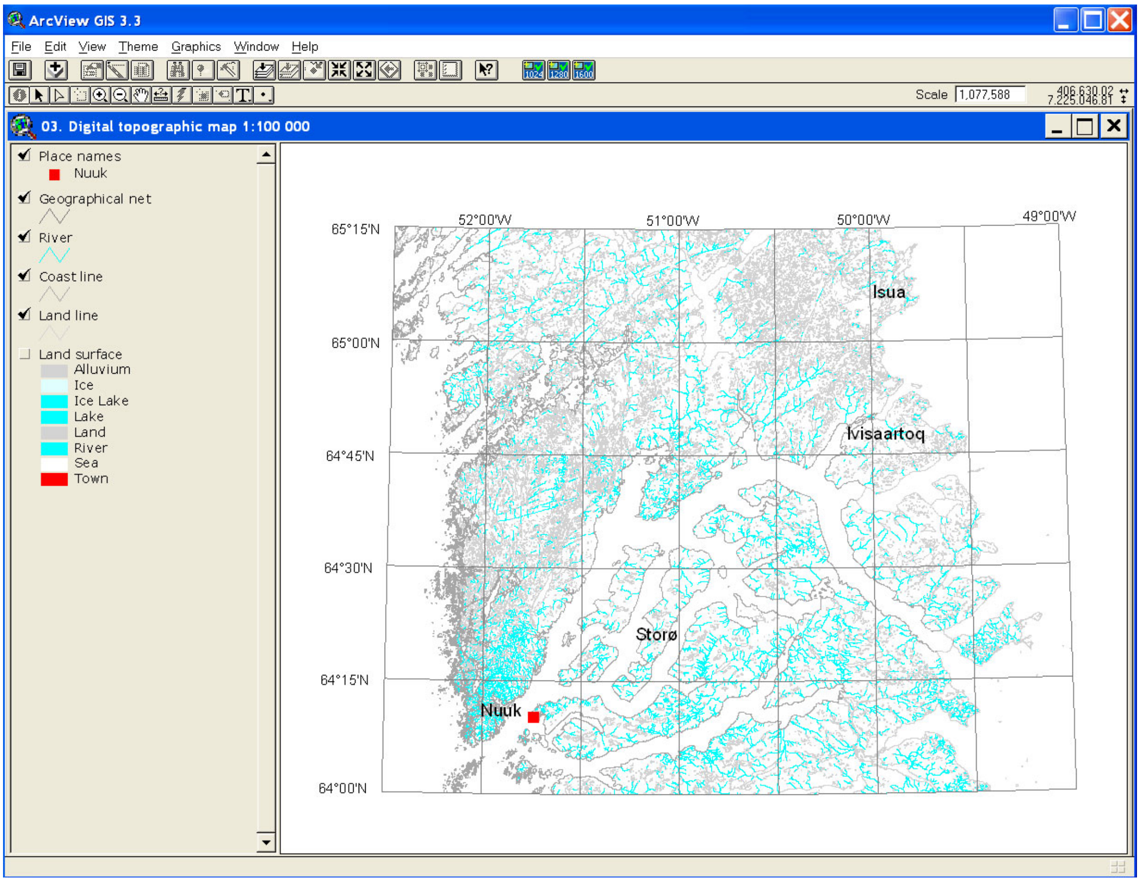

Figure Ex-5. *Screenshot of '03. Digital topographic map 1:100 000'.*

04. Geological map 1:500 000

The geological map for the Nuuk Region has been clipped from the scanned digital version of the Geological Map 1:500 000 (Allaart 1982). The published map is in projection Lambert conformal conic, the scanning, georeferencing and the digital topographic data ('03. Digital topographic map 1:100 000') therefore does not fit perfectly in the ArcView GIS version.

The projection parameter is:

UTM-zone:	22 (*i.e.* the central meridian is 51° West)
False Easting:	500 000 metres
Geodetic reference:	WGS84

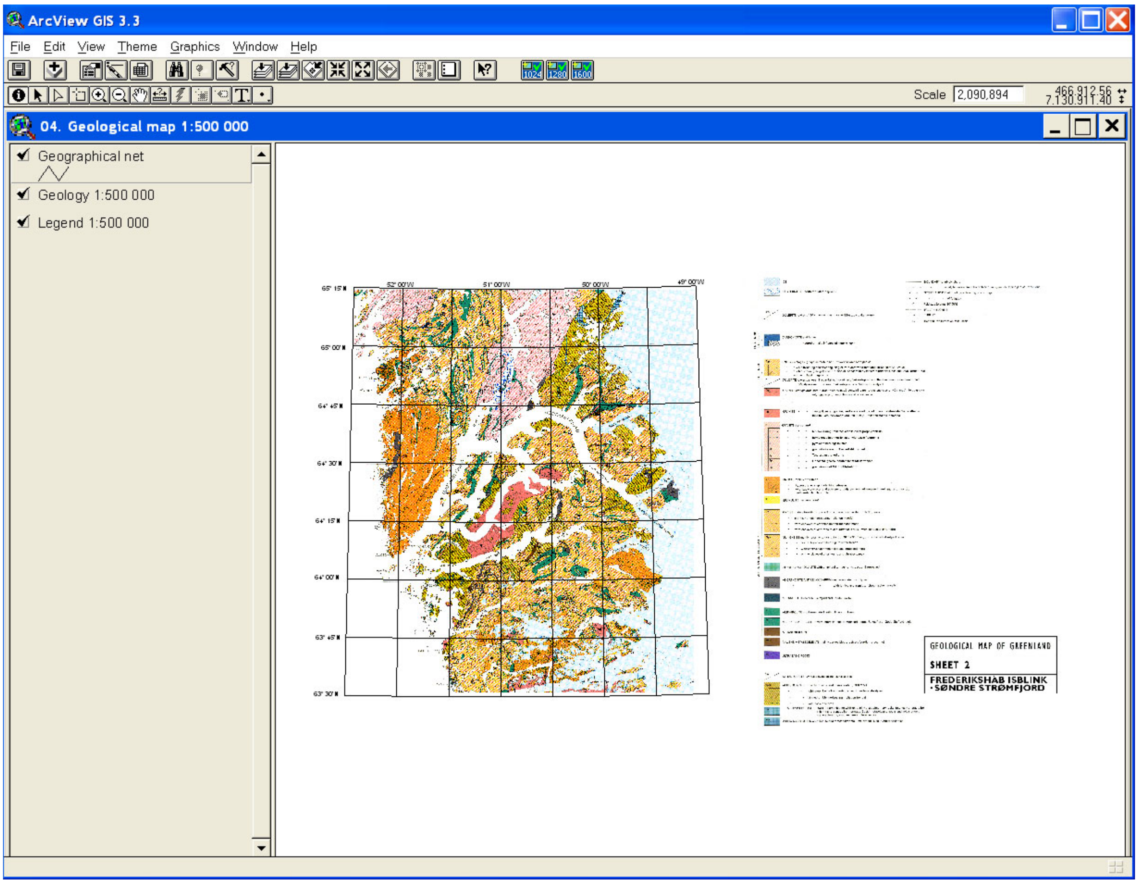

Figure Ex-6. *The screenshot of '04. Geological map 1:500 000'.*

05. Digital geological map 1:100 000

This view contains the digital version of the three published 1:100 000 scale maps that cover the region (data copied from Hollis *et al.* 2004). These maps are:

Fiskefjord 64 V.1 Nord (Garde 1989) in the north-west
Ivisârtoq 64 V.2 Nord (Chadwick & Coe 1988) in the north-east
Qôrqut 64 V.1 Syd (McGregor 1983) in the south-west

These maps were based on older versions of the topographic data, and the latter two are based on a Lambert conformal conic projection with standard parallel 60°30'N. These maps do not have a perfect fit with each other, or with the newest topographic data presented in '03. Digital topographic map 1:100 000'. The lithologies are shown as polygons, with legends for each of the three maps presented separately.

The projection parameter is:

UTM-zone:	22 (*i.e.* the central meridian is 51° West)
False Easting:	500 000 metres
Geodetic reference:	WGS84

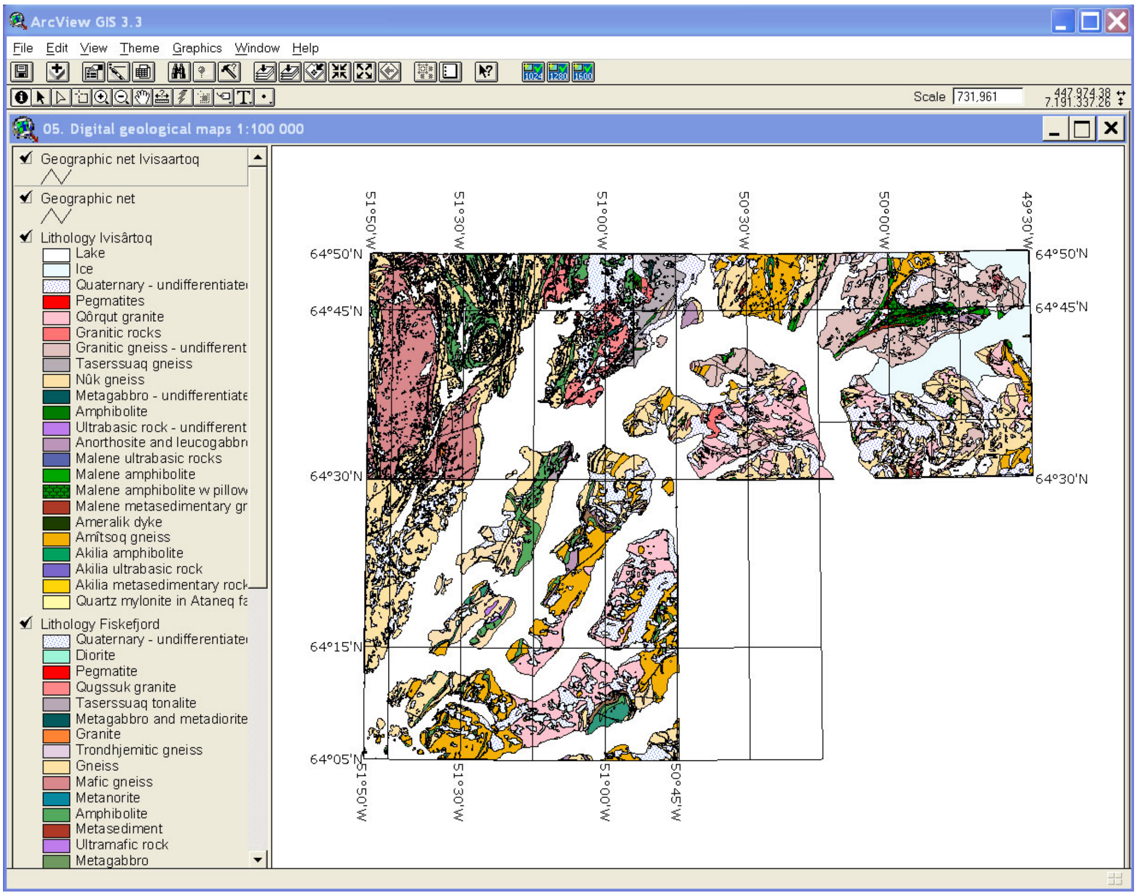

Figure Ex-7. *Screenshot of '05. Digital geological maps 1:100 000'.*

06. Rocks and geochemistry

This view contains rock sample locality and chemical analyses. ‘Localities’ with rock samples collected during the season 2004 and ’Rock geochemistry’ with all analyses. The analytical methods can be seen in a table named 'rock_lab_method'.

The projection parameter is:

UTM-zone:	22 (*i.e.* the central meridian is 51° West)
False Easting:	500 000 metres
Geodetic reference:	WGS84

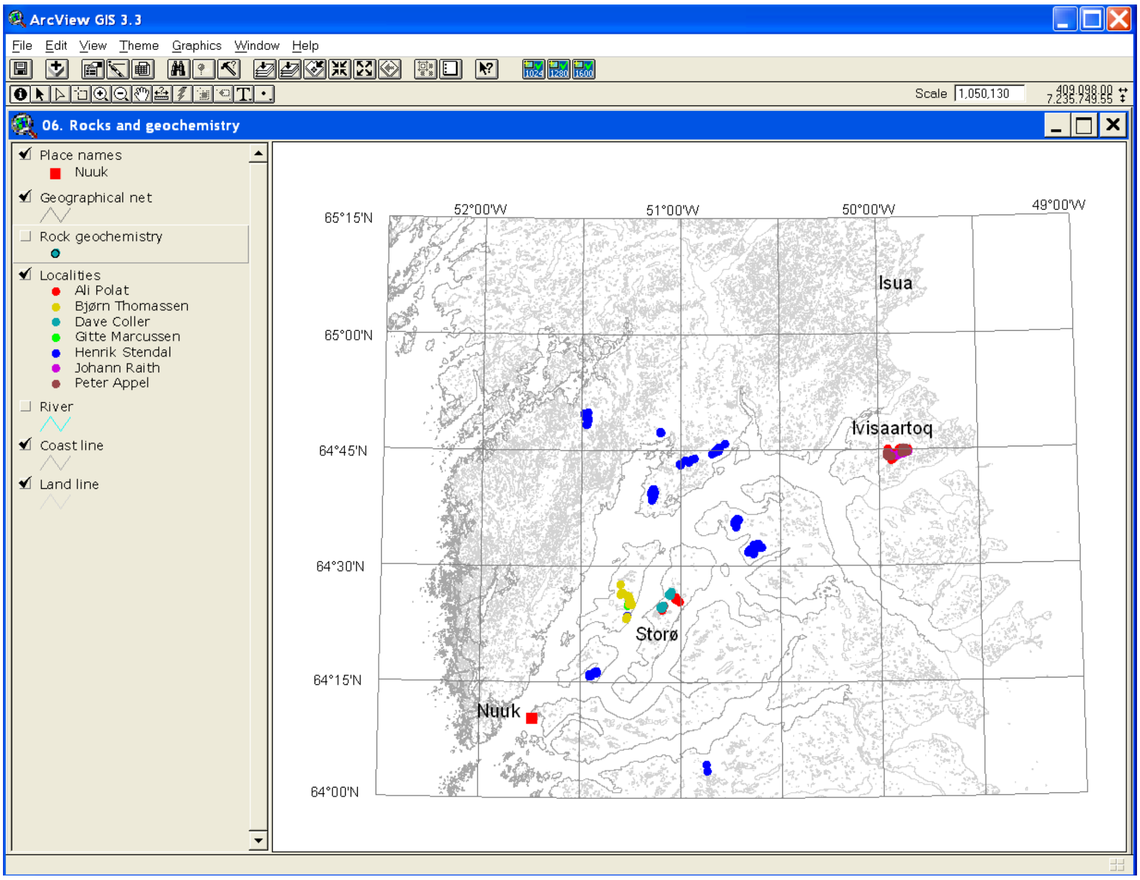

Figure Ex-8. *Screenshot of ’06. Rocks and geochemistry’.*

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Appendix A. Dave Coller and Vincent Collers's report

Introduction

Structural mapping of the central Storø gold area was carried out under contract to GEUS as part of their review of the mineral potential for the Nuuk region during 12 July –2 August 2004. The mapping focused on the areas of known gold on Qingaaq and Aappalaartoq, which is currently under licence to Nuna Minerals A/S. More regional stratigraphic and structural mapping of the majority of the greenstone areas on Storø was also being undertaken by the GEUS mapping team during the same period.

Objectives

To generate an improved structural framework for the gold mineralization
To review the previous mapping of this central area
To establish a structural chronology and timing for the gold mineralization
To produce a new map and sections for the main gold areas.

Previous work

Nuna Minerals A/S formerly NunaOil A/S have been exploring the Storø area for gold since the early 1990's with several drilling programs in 1995 and 1996 and during this present summer. The history of exploration is reviewed (Appel et al., 2003) and notes that there were some problems with the registration of the mapping and sampling grids.

Of particular value is the former mapping of Aappalaartoq Mountain at 1:5,000 (Pedersen, 1994), of Qingaaq north slope by D Coller 1995 and a report on the drilling in 1996 (Smith in Appel et al., 2003). Scanned maps from the first two reports have now been corrected to the new ortho air photo base in the new ArcView project (*this report*) and form part of the GIS database.

Regional geological and geophysical compilation including aeromagnetic survey, stream sediment and rock sampling has already been carried out by GEUS and is reported in the recent publication (Appel et al., 2003).

Mapping program and follow-up analysis

Mapping was carried out with the aid of a Garmin Summit GPS system and the new aerial photos made available by GEUS. Corrected ortho-photos were generated after the field program and these have been used to register all data and mapping of large pegmatites and to extrapolate mapping units from ground control.

The mapping program focused on the main gold prospect on Qingaaq Mountain and to a lesser extent on Aappalaartoq Mountain. Mapping on Aappalaartoq was restricted to two sections due to terrain difficulties and the map was compiled using the new data, the former mapping by JS Petersen and the new ortho-rectified air photos.

Results of the structural mapping and preliminary models for the control the gold mineralization were presented at a one day GEUS workshop 'Nuuk Gold Meeting' 24 November 2004 (*Storo Power Point Presentation CD, November 2004*).

Deliverables

Deliverable	Notes
Excel Database of all the field data (GEUS guidelines) and field notebooks	Excel Data emailed and on CD in report
Samples and sample record book	Samples for assay, dating and analysis
ArcView project of data integration and maps	Delivered onto the GEUS computer network
Construction of 4 geological cross-sections of central Storø	True scale cross-sections, templates generated from DTM
PowerPoint presentation	CD delivered to GEUS
Report	CD and hard copy

Excel Database

A database has been completed of the field data using the template and guidelines proposed by GEUS.

ArcView project

The field data, maps and other data have been compiled into a GIS project for the gold area using ArcView 3.2 (project file = storo.apr). This project is an accurate base map, which can be integrated into the regional mapping of Storø being undertaken by the GEUS team.

The following are points of information regarding the GIS project:

- The structural data has been converted into separate tables for each type and shape files for map display of the strike/dip and plunge/plunge direction. A 'geo-symbol' library has been included.
- The detailed lithological description is retained for each location but these have been grouped into broader mapping and digitised (file = unit.shp).

- The JSP Pedersen map of Aappalaartoq has been corrected using the lakes and rivers on the ortho air photos. The map now largely fits with the field data but is still incorrect in detail. An earlier map of the north slope of Qingaaq by NunaOil A/S (D.Coller) has also been corrected to the new base.

Generation of DTM

A digital terrain model was generated from spot heights that were derived from the air photos. This data became available from GEUS after the field season. The DTM model is in an ArcView project 'dtm.apr' and was used to generate four true scale cross-sections for geological interpretation - see next section.

Construction of 4 Geological cross-sections of central Storø

Geological sections were constructed from field data and the DTM for the central Storø area to illustrate the structural geometry and influence of topography on the geological maps. The sections are shown in the PowerPoint slide prints and as enclosures. The main points regarding the sections are summarized in the structure section.

PowerPoint presentation

A PowerPoint presentation of the results of the field mapping was presented in November at GEUS. These results do not include any new dating or micro-structural studies, which will refine the structural chronology and timing of the mineralization period. The slides of the diagrams and field photographs are shown in the CD-ROM.

Results of the mapping

Stratigraphic sequence hosting the gold mineralization

The known gold mineralization is hosted predominantly in a thick amphibolite package within a mixed supracrustal sequence with greenstone affinities. On Qingaaq and Aappalaartoq the structural base of the supracrustal package is intruded by large anorthosite, although this intrusive relationship can only be see on the eastern part of Aappalaartoq (J,van Gool, GEUS). The structural top of the sequence is truncated by thrusted Amitsoq gneiss.

To date two significant semi-continuous gold zones have been identified on Qingaak– Main Zone and New Main Zone which both occur within the amphibolite sequence. This same horizon hosts gold on Aappalaartoq. Gold also occurs within the mica schist and garnetite rocks immediately underlying the amphibolites on Qingaaq but its extent and grade has not been assessed.

Supracrustal package and estimated deformed thicknesses

Qingaaq Mountain	**Meters- deformed section**
Upper schist and amphibolite with ultramafic lenses	150-200m minimum (top is truncated by upper thrust plate of Amitsoq Gneiss
Main amphibolite- main gold host	150m
Schist Group including thin quartzite and garnet-magnetite bands	200m
Lower amphibolite and leuco-gabbro gneisses	120m
Total package	**620-670m**
Aappalaartoq Mountain	
Upper schist and amphibolite with ultramafic lenses	150m minimum
Main amphibolite	250-300m
Quartzitic schist with garnet magnetite bands	150m
Quartzite (fuchsitic)	0-50m
Lower amphibolite and leuco-gabbro gneisses	120m
Total package	**670-770m**

The supracrustal sequence best outcrops on Qingaaq and Aappalaartoq where it is openly folded. The sequence is dominated by amphibolites and high alumina silliminite and quartzitic schists with leuco-amphibolites and gabbroic gneisses at the base. (see table below). The schist group comprises quarto-felspathic schists which may contain biotite, garnet, silliminite with some fuchsitic quartzite units. A distinctive garnetite-magnetite marker unit occurs on both Qingaaq and Aappalaartoq.

Intrafolial folds and tectonic contacts within the package results in variations in thickness and truncation of units. For example the thick fuchsitic quartzites on Aappalaartoq are very thin or absent on Qingaaq (see Section 4).

Where the supracrustal package becomes highly deformed in Storø Shear Zone it is intruded by or interleaved with sheets of grey gneiss of unknown age.

Structure

One of the key objectives of the structural mapping was to investigate the relationship between the development of the gold structures and the tectonic events on Storø- in particular the Storø Shear Zone. At least two major structural events can be established in the supracrustal rocks of central Storø.

- Early Ductile Thrusting
- Development of the Storø Shear Zone

On the mesoscopic level a peak metamorphic phase of garnet porphyroblast growth appears to separate these two tectonic events but detailed metamorphic textural studies and dating are required. These two events may correspond to the two SHRIMP dates within the Ivinguit Fault reported by Alan Nutman.

Early Ductile Thrusting (D1)

Near the top of Qingaaq the NW-SE striking, north-dipping sequence of supracrustals represents a ductile thrust zone with decreasing strain from the basal anorthosite to the main amphibolite (see slide on CD-ROM). This is an area of relatively low strain and only weakly overprinted by the later Storo Shear Zone (D3). This early ductile thrust event affects both the intrusive anorthosite and greenstones.

The internal deformation of the thrust zone is characterised by strong planar fabrics, tight shear generated folds (see slides on the CD-ROM) and shear surfaces which truncate layers (see slides on the CD-ROM). In the upper part of the thrust the main amphibolite has relatively low internal strain. Several schist horizons have syn-tectonic quartzo-felspathic melt lenses associated with this early deformation. Shear folds indicate a top to west thrust component.

On a larger scale stratigraphic units appear to be truncated on the Aappalaartoq Mountain, most notably the quartzite unit (see sections).

Refolded folds in the interleaved mica schists and the upper part of the main amphibolite suggest that this zone has a higher thrust strain towards the Amitsoq gneisses.

The style of the gold vein structures in the relatively lower strain amphibolite suggest that they also formed by thrusting and are most likely associated with this early thrust event.

Some of the quartz-felspar pegmatites appear to be emplaced as syntectonic sheets within the higher strain zone near the top of Qingaaq and become folded in the Storo Shear Zone. These pegmatites have not been dated. Notably though in the lower strain amphibolites in the upper parts of the thrust sheet on the north slope of Qingaaq and Aappalaartoq undeformed pegmatite dykes cross-cut the main ductile fabric and they too become deformed in the Storo Shear Zone.

As mentioned above, the main coarse garnet porphyroblastic texture overgrows the early planar ductile fabrics associated with the thrusting.

Storø Shear Zone (D2-D3)

At Qingaaq all of the structures within the D1 ductile thrust zone, including the gold zones become folded and sheared in the NNE trending Storø Shear Zone.

The new planar fabric associated with the D2-D3 folds, shears and flattening deformation deform the garnet porphyroblasts which overgrow the D1 fabric. A more detailed study of the garnet growth and overall metamorphic history is being undertaken by Mac Persson.

Features of the Storo Shear Zone

- A wide zone of high strain ductile deformation > 1000m wide on east side of Storo
- The strain is dominantly a planar shape fabric expressing a largely flattening deformation. Areas of linear fabrics appear to be related to F3 fold hinges.
- Several narrower zones of shear and open folds on the eastern margin of the zone.
- Units within the greenstone stratigraphy are attenuated and truncated within the main shear zone. Some of the truncations may however be related to the earlier thrust deformation.
- Grey gneiss occurs as discontinuous lenses within the shear zone. Ultramafic units also occur as discontinuous irregular lenses.
- Gold zones are folded by folds associated with the shear zone deformation.
- There is a large volume of syn-tectonic pinch &swell and folded pegmatites within the Storo Shear Zone. Some pegmatites may pre-date the shear zone whilst others are quite late in the shear deformation.

The Ivinguit Fault is not definable in the area of the gold mineralization although it may be interpreted as part of the Storo Shear Zone structure.

Lineations

There is a systematic plunge variation of the lineation between Qingaaq and Aappalaartoq. This parallels the plunge of the minor F3 fold axes. The opposing northerly fold plunges and lineations on Qingaaq and southerly plunges on Aappalaartoq are associated with the refolding (D3) of the regional dip of the D1 thrust sheet as illustrated on Section 2.

The finite linear shape fabric and mineral fabrics appear to be the product of superimposed strain and not a constrictional strain. The lineation does not indicate the movement vector on the Storo Shear Zone.

It is predicted that fold hinges may have secondary thickening and concentration of gold structures that will plunge broadly parallel to the minor folds at surface.

Pegmatites

The numerous pegmatite intrusions in the gold district provide some excellent timing markers for the tectonic evolution of the region. Samples have been collected of the different relative age pegmatites for dating.

Pegmatites which cross-cut D3 marginal folds to the shear zone become folded within the high strain part of the shear zone will provide a key date for the deformation.

Sections

Critical to any interpretation of the structure of a region is the construction of cross-sections, particularly in high relief areas. Four cross-sections have been constructed.

Section 1	NW-SE section across the Qingaaq Gold Zone and margin of the Storo Shear Zone.
Section 2	NE-SW along strike section from Aappalaartoq to Qingaaq
Section 3	NE-SW along strike section of Qingaaq Gold Zone (part of Section 2)
Section 4	W-E section across Aappalaartoq

Nb. The NW-SE section on Qingaaq illustrates the structure cross-section of the eastern part of the Storø Shear Zone.

Samples

Samples of rocks were collected for analysis. The sample numbers and their location are detailed in the database. These samples fall into the following groups:

- Dating of pegmatites and sulphides
- Chemical analysis and gold assay for sulphide zones
- Structure and metamorphism

Gold Structures and Mineralization

Key features of the gold structures:

1. The highest grade gold zones are associated with sub-planar zones of flat-lying sheeted quartz veins (& sulphides) which are sub-parallel to the amphibolite layering and main planar fabric. On the northern slopes of Qingaaq the ‘Main Zone’ clearly transects the layering in the amphibolite.
2. The high-grade gold zone ‘New Main Zone’ near the base of the amphibolite is folded and displaced by folds and shears associated with the Storo Shear Zone.

3. Some zones of disseminated gold and arsenopyrite within garnet- rich altered amphibolites and schists have few quartz veins (type A ore of NH Pedersen) and are very difficult to define in the field but are significant zones of gold in core.
4. The main host for the gold zones is the upper and lower contacts of the main amphibolite unit. Gold also occurs within the garnet-mica schists underlying the main amphibolite.
5. Many of the gold zones are clearly associated with visible arsenopyrite and other sulphides.
6. The structural metamorphic relationships in the field suggest that the gold mineralization predates the main garnet grade metamorphism (post D1) which supports the micro-textural

Tectonic Models - Discussion

The interpretation of the results of the field mapping of the Central Storo area suggest that there are at least two distinct tectonic events albeit protracted events. These events are summarized in the 'Table of Events'. This table is updated from that presented at the GEUS meeting in November 2004 (PowerPoint). At present, the age of events are not well constrained but the current geochronology program will provide new data.

The early D1 Phase of deformation is a west directed ductile thrusting of the Greenstone package following or at the time of the intrusion of the anorthosite complex which locally forms the footwall. The regional extent, order of displacement and large scale geometry of this thrust is unknown. The thrust at Storo could represent the shallow up dip segment of a steep crustal reverse fault (not uncommon). We have not yet definitively defined the crustal structures (or terrain boundaries) along the Nuuk Fjord or if the Storo Shear Zone and Ivinguit Fault represent collisional or reactivated crustal boundaries.

The gneisses structurally overlying the Greenstones are in tectonic contact with the Greenstones and appear to represent a thrust sheet ' Amitsoq Gneiss Thrust Sheet'. However, it is not certain if this is a true thrust in the sense of older gneisses thrust onto younger Greenstones.

The structural relationships suggest that the gold mineralization is part of this early thrust event and predate the Storo Shear Zone sensu-strictu. The isotopic date on arsenopyrite presented by Robert Fry at the November 2004 GEUS meeting (2853+/- 91Ma) also suggests a relatively old age for the gold related hydrothermal system.

The gold zones are clearly laterally extensive sheets whose down-dip extent (to the east) is not known, although the 'Amitsoq Gneiss Thrust Sheet' most likely truncates the complete main amphibolite host. One interpretation of the northerly plunges of later structures on Qingaaq and the contrasting southerly plunges on Aappalaartoq is that they were controlled by the original dip variations on the thrust sheet. This geometry could be interpreted in terms of side-wall thrust ramp areas (see Power Point Presentation).

The Storo Shear Zone is a protracted compressional event that has a complex set of structural relationships of multiphase syntectonic pegmatites and progressive fold development. The marginal strains suggest the shear zone is flattening structure rather than a strike-slip or reverse crustal fault but strain studies within the most intense part of the shear zone and along different sections along strike may indicate a different pattern. The width and length of the zone strongly suggests that it is a crustal scale fault (>30km depth) and the project should endevour to track the Storo Shear Zone, the D1 thrust sheet and the Ivinguit Fault on a regional basis.

New dating of the various pegmatites phases should constrain the sequential evolution of the Storo Shear Zone and clarify what are reactivation events and what may be primary collisional events

Tectonic evaluation of Gold Mineralization in the Nuuk Fjord Region - suggestions for the way forward

The following is an outline of recommendations arising from the preliminary results of the 2004 mapping program. These have recently been presented to GEUS as a separate discussion document.

Preamble

One of the main economic objectives of the Nuuk Fjord program is to establish whether or not the occurrences of gold mineralization are related to crustal scale tectonic processes similar to those proposed for some of the major Archean gold provinces. This requires us to define the tectonic framework, structural and metamorphic history, mineralizing processes and age relationships. The 2004 field program has significantly progressed the geology of the region and has gathered valuable information on some of the key components and criteria required to construct a robust crustal scale gold model for Nuuk Fjord.

On the district and deposit scale at Storø we are now forming a more detailed picture of the setting and key criteria for the gold mineralization, which is a crucial part of the overall interpretation and gold model. There is emerging a more confident set of events with relative timing of the gold phase although there are many aspects of the system that are still in the process of being interpreted, awaiting age dating, metamorphic, isotopic, chemical, alteration and micro-structural interpretation. The linkage of the shear and fault system for the gold occurrences, which may characterize the outflow zone of a crustal scale hydrothermal system, is still to be established but this should be possible by integrating all of the data with the structural framework.

There are two tasks that are important in the development of the tectonic evolution of the gold mineralization, which I am highlighting for discussion. Firstly, the construction and restoration of geotectonic sections and secondly, the district and deposit scale interpretations of the other gold occurrences within the Nuuk Fjord region.

Construction of Geotectonic Sections

A principal objective of the first phase regional mapping has been to produce a new map for the Nuuk Fjord region, which begins to define the main tectonic units in terms of age, assemblage, structural, igneous and metamorphic patterns and histories, and most importantly the nature, geometry and age of their boundaries. More precisely for a gold model it is important to define, which boundaries are crustal scale faults, which ones were potentially active (or reactive) at the time of mineralization, and what is their crustal geometry and displacement? It is also critical for reconstructing crustal models to try to interpret the surface data in three dimensions. This can be achieved by the following two procedures:

- Construction of several geotectonic cross-sections which cover areas of new mapping information (see Figure 1 for suggestions).
- Sequential restoration of one section (or sections) that includes the gold mineralization. This is essentially back-stripping of the tectonics to window the pre-, syn- and post-gold mineralization crustal cross-sections.

Recommended components of the geotectonic cross-section:

1. Set up a topographic profile template, which can accommodate crustal scale faults i.e. faults which exceed crustal thickness >30km. Note that the length of a fault is a general indication of its likely depth.
2. Produce a surface section with the metamorphic state and histories of the tectonic units. Of particular importance may be tectonic juxtaposition of metamorphic facies/grade and modified gradient patterns, which may indicate crustal fluid circulation. Metamorphic gradients and structural data may allow for projecting the units onto the vertical section, particularly the regional dips and mega- folds.
3. Define the crustal scale faults (or shear zones) on the map with their movement histories. Draw the faults on section from the structural and metamorphic histories of the juxtaposed tectonic units (or terrains- however they are defined). Precise dips are not important and surface dips may be misleading, but it is important to represent the general dip direction i.e. reverse fault, thrust, extensional fault or strike slip. Strain gradients and width of effect of some of the crustal faults would be useful to represent.
4. Profile the results of the regional geochemistry along the section lines.
5. Indicate on the sections all mineralizations and other related information such as ‘alteration’ fluid chemistry?, age etc. As yet we do not have precise age dating of specific faults (Alan Nutman type SHRIMP dates) but we can use what published data is available.
6. Include large intra-terrain faults that may be connected to the crustal scale faults. Fault connectivity and reticulation patterns are important in fluid focusing in crustal convection systems.
7. Integrated magnetics and gravity where data is available can provide some pseudo 3D images that can be used as constraints. Local geophysics may also be useful.

Important results arising from the constructing these sections

1. Sections will highlight the critical areas, where we need more information, and moreover what type of data is required to better constrain the sections e.g. metamorphic history, age of an intrusion, deconstruct the polyphase structural history, age data, chemical information.
2. Multiple sections will allow a comparison of the tectonics along the Nuuk Fjord corridor. This will allow more confident correlation of crustal scale structures along the corridor, highlight multiple movement phases along single structures, and provide a more complete approach to the terrain history.
3. Constructing the sections focuses attention on map relationships and may solve certain map interpretation problems.
4. Sections will provide another layer of information to the regional statistical analysis.

A note on the section restoration

The primary aim will be restore a tectonic section back to the gold event ‘ the gold window’ to allow us to describe the metamorphic environment, the structural position and structural level of the different tectonic blocks and to evaluate emplacement criteria for the gold in terms of structural level, crustal structures and associated faults and connectivity. This process will obviously rely on an integrated understanding of the post-gold tectonic evolution that should be a major product of the mapping program. The whole outcome of this process will be a foundation for any gold model that we consider possible for the Nuuk Fjord.

Detailed mapping of the other gold occurrences and major fault structures that may be connected to the gold mineralization event

Whilst there is now emerging a detailed local structural and geological interpretation for the gold on Storo, where almost all of the previous work has been focused, there is a necessity to have a detailed context for the other gold occurrences within the Nuuk Fjord region. This is necessary to avoid what may be a unique setting at Storo, i.e. representing only one particular manifestation of a crustal scale hydrothermal system, and also to gather valuable, more diverse information on the gold setting regionally to allow an accurate representative set of criteria for the gold controls to be established.

The deposits in most major gold camps are individually different but will share a number of similarities that enable them to be linked into a single gold system; at the moment we are not able to define the set of key criteria that link the different gold occurrences together to allow us to define a gold and exploration model.

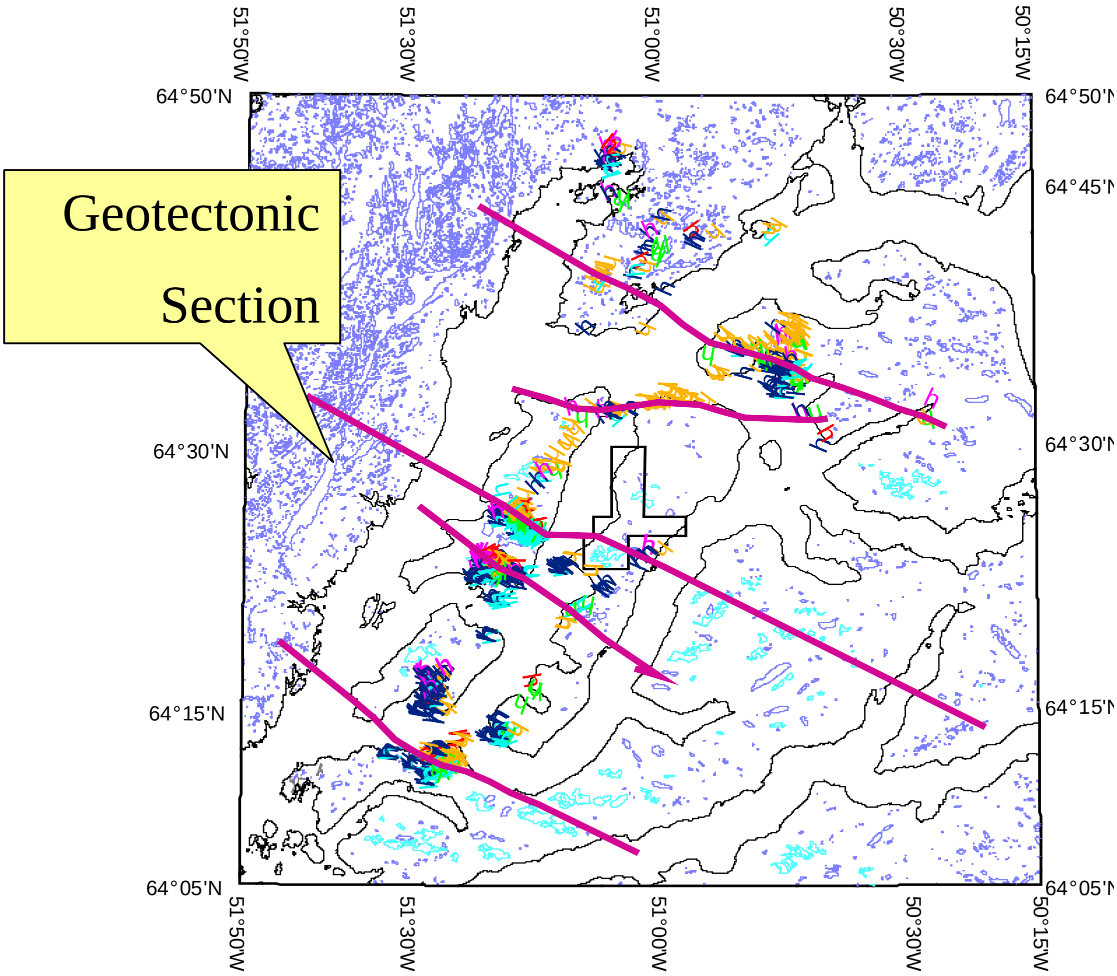
2005 Program

1. Geotectonic sections. Construction from 2004 and earlier field/map data and results of 2004 analyses and detailed studies.
2. Field studies in key areas along the geotectonic sections highlighted by their construction in order to constrain the model interpretation.
3. Field mapping around all the other gold prospects and significant geochemical signatures and possibly statistically targeted gold areas. This is critical as we are so far only have detailed data and context the Storo prospects which is insufficient to construct a robust model.

Suggested work program for discussion

2-4 weeks constructing tectonic sections
1 week to restore one section (manually)
3-4 weeks field program on other gold occurrences
Open field program to complete details of the geotectonic sections.

Suggested Regional Geotectonic Cross-sections based on 2004 Field Results



Coloured readings are 2004 regional field data from GEUS report on 2004 Field Program

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Appendix B. Johann Raith's report

Scheelite mineralization in the Ivisaartoq greenstone belt, southern West Greenland

Report of fieldwork from July 22 - August 1, 2004

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Introduction

The main aim of field work in the Ivisaartoq greenstone belt, SW Greenland, in 2004 was to collect field data and samples of strata-bound tungsten mineralization previously interpreted as of sedimentary exhalative origin (Appel, 1994). The author was introduced to the area by P. Appel (GEUS) and was based in camp with A. Polat.

The base camp was located at 64° 44.05 N and 049° 55.72 W at an altitude of about 780 m above sea level. Field work focussed on the zone above the magnetic marker (Chadwick, 1990) as this is showing the best tungsten mineralization. This zone was followed from the base camp towards ENE along strike for about 5 km. The detailed observations reported below were mainly made in an area of about 5 x 1 km.

This report documents field relationships among the different lithologies of this greenstone belt, the deformation events and observations on scheelite mineralization in this area. It will focus on those observations, which are relevant for constraining the relative timing of ore formation and understanding the genesis of tungsten mineralization.

Host rocks

Scheelite mineralization occurs in an about 50 m thick sequence associated with the so-called magnetic marker, which separates the lower from the and upper volcanic sequence of this greenstone belt (Chadwick, 1990). Scheelite was mainly reported at its top in massive to banded calc-silicate rocks (Appel, 1994). Rocks within this sequence are amphibolite facies supracrustals (metamorphosed pillow basalts, ultramafics, clastic to calcareous sediments (?)) and igneous rocks (metagabbros, metaperidotites). Pegmatites of m to km size are widespread throughout the whole belt. Recently published U-Pb ages of detrital zircons from the Ivisaartoq belt indicate that this greenstone belt is of Mid-Archaean (<3.1 Ga) age (Nutman et al., 2004).

Amphibolites, mostly representing metamorphosed pillow basalts are the dominant lithology. They are characterised by amphibolite facies assemblages (hornblende + plagioclase ± epidote etc.) and are commonly altered (see below).

Several horizons of metamorphosed ultramafic rocks have been used to subdivide the Ivisaartoq greenstone belt (i.e., peridotite markers; Chadwick, 1990). The most prominent horizon is the magnetic marker, a distinctive seam (10-50 m thick) of metaultramafic rocks containing magnetite, olivine, spinel, carbonate, chlorite, tremolite, serpentine, tourmaline, and sulphides.

The supracrustal rocks overlying the magnetic marker and the scheelite-bearing calc-silicate rocks include several petrographic varieties of fine-grained gneisses (e.g. quartzitic biotite gneiss, muscovite-biotite gneiss, garnetiferous muscovite-biotite-sillimanite gneiss). Sedimentary protoliths are envisaged, at least for the garnet- and sillimanite-bearing varieties. Other rocks in this supracrustal package are banded metabasites characterised by interlayering of dark and light bands from the dm to cm scale (outcrop 17, Plate a a). They contain boudinaged, up to 10 cm thick layers of coarse-grained pyroxene.

The supracrustal rocks were intruded by igneous rocks, now present as metagabbro, orthogneiss and pegmatites. Preserved intrusive contacts of gabbro and felsic gneisses are to be seen at outcrop 36 (Plate 2 a). There, the gabbro crosscuts an older planar fabric (S_0, S_1?) in the gneiss. This gneiss (JR04IV35A) has been sampled for dating.

Intercalated in the banded metabasites medium-grained leucocratic orthogneiss is to be found. It is aligned in the main planar fabric and shows evidence of early deformation (i.e. isoclinal folding). It is therefore interpreted as a felsic intrusive rock unrelated to the widespread younger pegmatites (outcrop 17, Plate 2 b). This orthogneiss (JR04IV17B) has also been sampled for dating.

The most dominant intrusives are pegmatites. Normally they are very coarse-grained (quartz-feldspar-muscovite) rocks; rarely a finer-grained aplitic margin has been observed (Plates 1 b, 2 c). It is clear from field relations that they were emplaced after the main D_1 deformation event as S_1, and F_1 (?) folds are crosscut by pegmatite dykes (Plate 2 d). However, the pegmatites have been affected by a later deformation event (D_2) that produced open folds (outcrop 23, Plate 1 c). From the same outcrop it is clearly documented that epidote-rich alteration (type 1 see below) in the metabasite is crosscut by pegmatite dykes.

Types of alteration

Type 1: Altered pillow basalts

Locally, pillow structures are perfectly preserved in the upper volcanic sequence of the Ivisaartoq greenstone belt (see also Appel 1994). The least deformed pillows are documented from outcrop 12 (Plate 1 d) where several compositional zones within the pillows can be distinguished. Commonly the cores of these pillows show alteration to fine-grained epidote-rich assemblages. The pillows show variable degrees of deformation (Plates 1 e, f).

Higher strain resulted in development of schlieren-like, and banded textures in the metabasites; in the latter case it is practically impossible to recognise the primary features. Only in the field the original nature of the protolith can be reconstructed by following the gradational textural changes along outcrops from high strain to low strain zones.

It is to be noted that garnet + cpx is not stable in this type of alteration. Garnet is only developed in the cores of some pillows (Plate 1 d); but there it coexists with epidote, quartz, and calcite. In addition scapolite (determined in thin section) may occur in the altered core. From field relationships type 1 calc-silicate rocks are interpreted as *early-stage alteration* predating scheelite-bearing calc-silicate rocks of type 2.

It would need to be confirmed by more fieldwork, petrography and geochemistry if type 1 calc-silicates are scheelite-/tungsten-free and by which processes they formed (e.g., ocean floor metamorphism?). Ali Polat's project will focus on these aspects.

Type 2: Banded to massive, scheelite-bearing calc-silicate rocks

This type of calc-silicate rock is the host rock of scheelite mineralization and was the major exploration target in the Ivisaartoq area. The main calc-silicate horizon is developed on top of the magnetic marker and was trench-sampled during previous exploration. It is up to about 10 m thick and forms a discontinuous horizon that was traced for about 4 km. Individual lenses of these calc-silicate rocks can be tens to even hundreds of meters long. Towards the hanging wall supracrustal rocks (biotite ± sillimanite gneiss, banded amphibolite, marble etc.) are overlying this horizon

The layering (defined by variation in modal grt-cpx-ep-qtz ± calcite) and the coarse-grained fabric is characteristic for these rocks, as well as their high content of garnet that coexists with clinopyroxene.

The contact of this type of calc-silicate rock to the gneissose host rocks in the hanging wall is clearly discordant because the calc-silicates replace an older planar fabric (S_0, S_1) and folds. Form relicts of rafts of the host rock may be preserved in the calc-silicate rock. Excellent examples of this replacement of an older fabric can be studied at outcrop 20 (Plates 3 a, b). Locally, white-green hornblende gneiss (hornblende-plagioclase) separates the greenish calc-silicate rock from the adjacent biotite gneiss (Fig. 4/8).

The upper contact of the calc-silicate rocks to these felsic gneisses is best studied at outcrop 5. There, a several dm-thick contact zone is developed between the greenish calc-silicate rock and the gneiss. From field observations and hand specimens (Plate 3 e) it is again clearly documented that these sulphide-bearing (chalcopyrite-bornite) hornblende-gneiss is discordant to the planar fabric of the gneiss. The green hornblende-rich nodules in the hornblende gneiss are elongate ellipsoid-shaped although this rock lacks the penetrative deformation typical of the host biotite gneiss.

It is therefore argued that type 2 calc-silicate rocks formed after or late during the main deformation event (D_1, see below) and coeval metamorphic crystallisation producing the planar fabric in the felsic biotite gneiss.

Scheelite-bearing red-brownish to greenish calc-silicate rocks were also observed at outcrops 21. There, several up to c. 1 m-thick boudinaged layers of banded (s 160 /70) calc-silicate rock occur in fine-grained metabasites (deformed pillow basalts?, Plate 4 a). In the boudin necks and at the margins of the grt-cpx-rich calc-silicate rocks a very coarse-grained (up to 5 cm crystals!) amphibole-plagioclase rock containing minor scheelite is developed (Plates 4 a, b). Centimetre-thick quartz veins are developed about sub-vertically to the foliation of calc-silicate rocks; they are interpreted as local extensional veins formed during boudinage of the more competent calc-silicate bodies. In some of some of these veins molybdenite is present (outcrop 10; Plates 4 c, 3 d). At outcrop 21 scheelite was also observed in foliation-parallel calc-silicate veins (grt-qtz) within altered pillow basalts (Plate 4 d).

Scheelite-bearing and scheelite-free calc-silicate rocks containing garnet-cpx-ep-qtz-scheelite have also been found in veins clearly crosscutting the planar fabric of the metabasites (outcrop 3, Plates 4 e, f). These veins show zoning, the central part of the vein being richer garnet, the rim richer in clinopyroxene.

Type 3: Alteration of metagabbros

In the more massive metagabbros alteration is preferably developed along a network of fractures and veins (outcrop 31, Plate 5 a). In the metagabbro a 10-20 cm thick irregular vein containing coarse epidote and quartz is surrounded by a symmetrical green epidote-rich alteration halo (Plate 5 b). Where this vein extends into felsic biotite gneiss no such characteristic alteration halo is developed but the vein mineralogy changes and the vein contains quartz and tourmaline (Plate 5 c). Garnet is lacking in this type of alteration.

Type 4: Alteration of pegmatites

Based on field observations it is concluded that alteration of type 1-3 predate emplacement of the pegmatites. However, rarely alteration of the pegmatites has been observed which must therefore be unrelated to the main alteration phases. The best example is seen at outcrop 23 (Plate 5 e). Epidote-rich alteration products are developed along fractures of brecciated pegmatite. Due to alteration the pegmatite is of red-pinkish and not as usual of white colour. Petrographically this type of alteration is characterised by epidote and quartz.

Sequence of events

The tentative sequence of events in the Ivisaartoq greenstone belt is summarised in Table 1. The earliest fabric preserved in the rocks, referred to as D_0, is the sedimentary layering (S_0) defined by alternating supracrustal lithologies. The earliest igneous activity is formation of extrusive basalts with formation of in part excellently preserved pillow textures (Plate 1 d).

Metagabbros are clearly intrusive into the basalts (Plate 2 a) and sediments but it is unclear if they precede the first stage of alteration. The intrusive vs. extrusive origin of the ultramafic units (metaperidotites) can only be speculated at present. The close spatial association of the supracrustal rocks with the magnetic marker suggests an extrusive origin at least for the latter. Alteration of the pillow basalts (calc-silicate rocks type 1, Plates 1 d-f) preceded a first stage of quartz veins and emplacement of an orthogneiss precursor intercalated in the supracrustal rocks. The main penetrative D_1 fabrics affected all these rocks and formed at amphibolite facies conditions within the sillimanite stability field. D_1 resulted in formation of the dominant planar fabric in the rocks. S_1 poles have maxima at NNW and at S to SW and S_1 planes are mostly steeply S dipping. The axes of coeval isoclinal to tight F_1 folds plunge flat to steep to the SW.

It is important to note that formation of calc-silicate rocks containing scheelite postdates the early D_{1a} fabrics (Plates 3a-c, e). Because the calc-silicate horizons are, however, boudinaged the D_1 event is split into an early (D_{1a}) and a late (D_{1b}) stage. Boudinage of calc-silicate layers and formation of local quartz-filled extension veins (Plates 3 d, 4 a-c) within the boudins are correlated with D_{2b}. Formation of ENE-WSW oriented quartz veins and quartz-epidote veins plus their epidote-rich alteration (type 3) could also correspond to late D_{1b}.

Emplacement of pegmatites post-dates D_1. However, the pegmatites together with the older rocks of the greenstone belt were deformed by a second deformation event (D_2). In the study area F_2 axes are E-W to WNW-ESE oriented and flat plunging. A late stage of epidotisation (alteration type 4, Plate 5 d) locally affected the pegmatites.

Due to the restricted area where structural observations were collected, it is not yet clear how the two main deformation events reported in this study correlate with the two major deformation events distinguished by Chadwick (1990) and the structural and metamorphic within the larger regional context.

Scheelite mineralization

Finding scheelite was strongly hampered by the restrictions to do UV lamping in July. Hence, outcrops were checked with the UV lamp using a black cloth. However, with this method only very small spots/areas can be checked.

Scheelite was only found in the garnet-bearing banded to massive calc-silicate rocks (type 2; garnet-cpx-epidote-quartz ± calcite). The best samples are from blocks at outcrop 5 where scheelite is found in discordant quartz veins (up to 2 cm thick) within coarse-grained garnet-rich calc-silicate rocks (Plate 3 f). Up to several cm large Mo-bearing scheelite porphyroblasts showing yellowish fluorescence were found in this sample; minor Mo-poor bluish fluorescent scheelite forms rims around these porphyroblasts. Hence, at least two stages of scheelite are present in this sample. Traces of scheelite were also found in-situ at outcrops 5 and 21. At the later locality scheelite is present in the very coarse-grained hbl-plg (?) envelope around banded calc-silicate boudins and in garnet-quartz-rich calc-silicate layers intercalalated in altered pillow basalts (Plate 4 d). At outcrop 3 traces of scheelite were observed in a dm thick calc-silicate vein crosscutting metagabbro (Plate 4 e).

The limited observations indicate "late" epigenetic formation of scheelite; it occurs in discordant veins and is mostly associated with garnet-rich calc-silicate rocks of type 2. At present it is unclear if these scheelite porphyroblasts are local mobilisation product of an earlier (e.g. syngenetic) stage of mineralization.

Field observations do *not* support any genetic relationship of tungsten mineralization with felsic intrusive rocks. Scheelite-bearing calc-silicate rocks of type 2 are predating emplacement of the pegmatites. Within the supracrustal sequence only one dm-thick layer of orthogneiss of older age than the pegmatites was observed (outcrop 17; Plate 2 b). But this orthogneiss does not show any evidence of alteration or spatial relation to the calc-silicate rocks and scheelite mineralization.

The mineral assemblages of type 2 calc-silicate rocks (garnet-cpx-epidote-qartz-titanite ± calcite) are indicative of higher temperatures. In combination with the textural observations (e.g. calc-silicate formation postdating S_1) I therefore interpret these skarn-like calc-silicate rocks as reaction products (reaction skarns); i.e. they rather formed by interaction of higher-T fluids with suitable host rocks than by isochemical metamorphism of protoliths of unusual chemical composition (e.g., exhalites, pre-metamorphic alteration zones). As an alternative to the syngenetic origin of tungsten mineralization it needs therefore to be tested if the strata-bound appearance of tungsten mineralization at Ivisaartoq is not the result of channelised metamorphic fluid flow (e.g. fluid flow and focussing along the tectonic (shear ?) zone that separates the lower from the upper group of amphibolites).

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Figure captions for plates which can be viewed on the enclosed CD-ROM

Plate 1

a. Outcrop outcrop 17, 64° 44.32N, 49° 52.97W. Banded amhibolite interlayered with felsic gneiss; part of supracrustal sequence above the magnetic marker. To the right (arrow) orthogneiss. Photo 4/30.
b. Outcrop 23, 64° 44.32N, 49° 52.55W. Contact of pegmatite dyke with metabasite. Note the finer-grained aplitic rim (grey; not visible: minor biotite and garnet). Photo 3/32.
c. Outcrop 23, 64° 44.32N, 49° 52.55W. Metre-scale open fold (F_2) with parasitic folds. A thin pegmatitic dyke (white) is folded by F_2. The pegmatite crosscuts the S_1 fabric in the metabasite and its epidote-rich alteration (light green bands; alteration type 1). Photo 3/35.
d. Outcrop12, 64° 44.83N, 49° 51.93W. Excellently preserved pillow basalts. The pillows show various zones of alteration: Calc-silicate assemblages of type 1 are developed in the core of the pillow on the left side of photo. Photo 2/28.
e. Outcrop 11, 64° 44.68N, 49° 51.33W. Deformed pillow basalts with still visible black rims and lighter, calc-silicate-bearing cores. Photo 2/24.
f. Outcrop 35, 64° 44.40N, 49° 52.18W. Deformed pillow basalts with, elongate ellipsoid-shaped calc-silicate-rich cores. Photo 5/20.

Plate 2

a. Outcrop 35, 64° 44.40N, 49° 52.18W. Intrusive contact of metagabbro and felsic gneiss. An older (S_0?, S_1?) fabric in the gneiss is clearly crosscut by the gabbro. Sample JR04IV35A for dating was taken from this gneiss. Lens cap is c.5 cm. Photo 5/18.
b. Outcrop 17, 64° 44.32N, 49° 52.97W. Orthogneiss aligned in S_1 fabric in metabasites; see Plate 1 a for overview. Sample JR04IV17B was taken from this gneiss for dating purposes. Photo 4/32.
c. Outcrop 23, 64° 44.32N, 49° 52.55W. Pegmatite dyke with finer-grained aplitic offset dyke (left) partly intruding along the main S_1 (?) fabric of amphibolite. Photo 3/34.
d. Near outcrop 10, 64° 44.58N, 49° 51.43W. Intrusive contact of pegmatite to banded gneiss of the supracrustal sequence. A F_1 (?) fold is crosscut by the pegmatite. Photo 4/15.

Plate 3

a, b. Outcrop 20, 64° 44.30N, 49° 53.07W. Calc-silicate rocks of type 2 (garnet-epidote-cpx) replacing felsic gneiss. The green calc-silicate rocks clearly crosscut an older fabric (S_0, S_1?) in the gneiss. Photos 3/13 & 3/14.
c. Outcrop 28, 64° 44.50N, 49° 51.40W. Clearly discordant contact of banded gneiss (upper right) and massive to weakly banded calc-silicate rock of type 2 (lower left). Along the contact a cm-thick white (feldspar-rich?) reaction zone is developed. Photo 4/8.

d. Outcrop 10, 64° 44.58N, 49° 51.43W. Boudinaged calc-silicate layer (light green) in banded gneiss of the supracrustal sequence. Irregular white quartz vein within the calc-silicate rock contains molybdenite. Photo 4/17.
e. Hand specimen JR04IV5B from outcrop 5 (marked with blue stick in the field), 64° 44.03N, 49° 54.60W. Contact zone between calc-silicate rocks and biotite gneiss of the supracrustal sequence. Between the coarse-grained scheelite-bearing calc-silicate rocks (see f) and the gneiss a few dm thick reaction zone containing large amphibole poikiloblasts in a palgioclase - quartz - biotite - sulphide matrix are developed. The amphibole-rich rock crosscuts the gneiss fabric although the amphibole poikiloblasts show syn-kinematic elongation. The dominant sulphides (not visible in photo) were identified as chalcopyrite and bornite in polished sections.
f. Hand specimen JR04IV5/4 from outcrop 5 (marked with blue stick in the field), 64° 44.03N, 49° 54.60W. Calc-silicate rock (type 2) containing garnet + cpx + epidote + quartz + calcite + scheelite. Scheelite (only visible in UV light) occurs as cm-large porphyroblasts mainly in the central quartz vein.

Plate 4

a. Outcrop 21, 64° 44.35N, 49° 52.74W. Boudinaged calc-silicate layer in amphibolite. Note development of coarse-grained calc-silicate rock in boudin neck (bottom part of photo; see detail in b) and development of extension veins (about normal to the main foliation planes) filled with quartz. Photo 3/24.
b. Outcrop 21, 64° 44.35N, 49° 52.74W. Detail of margin of calc-silicate boudin containing cm-sized amphibole and plagioclase; minor scheelite (only visible in UV light) has been observed in this calc-silicate seam. Photo 3/23.
c. Outcrop 10, 64° 44.58N, 49° 51.43W.Extensional quartz veins containing molybdenite (arrow) at margin of calc-silicate boudin in contact with amphibolite. Photo 4/19.
d. Outcrop 21, 64° 44.35N, 49° 52.74W. About 10 cm-thick calc-silicate vein in altered pillow basalt. The vein contains garnet and quartz and scheelite (black marker pen).
e. Outcrop 3, 64° 44.05N, 49° 54.61W. About 10 cm-thick calc-silicate vein showing zoning (garnet-rich central part, cpx-rich outer parts). Minor scheelite (only visible in UV light) has been detected in this vein. Photo 2/1.
f. Outcrop not exactly located. Discontinuous zoned calc-silicate veins (garnet, cpx) in amphibolite (former pillow basalt?). Photo 3/1.

Plate 5

a. Outcrop 31, 64° 44.4N, 49° 52.21W. Calc-silicate veins (alteration type 3) in metagabbro. Photo 4/12.
b. Outcrop 31, 64° 44.4N, 49° 52.21W. Epidote-quartz vein in metagabbro surrounded by epidote-rich alteration halos. Alteration type 3. Photo 4/13.
c. as b. showing extension of the same vein (160/84) into banded felsic gneiss of the supracrustal sequence. The black mineral is tourmaline. Photo 4/14.
d. Outcrop 23, 64° 44.32N, 49° 52.55W. Epidote-rich alteration (type 4) in brecciated pegmatite. Large alkalifeldspars show reddish colour. Photo 3/29.

Appendix C. Ali Polat's Report

Sample collection during the field season of 2004 was undertaken in the mid to late Archean greenstone belts in the Nuuk region, southern West Greenland. Sampling included the mid Archean Ivisârtoq greenstone belt and the late Archean Storø supracrustal rocks. Fieldwork for the Ivisârtoq greenstone belts was mainly focused on mafic to ultramafic volcanic rocks and gabbros in order to determine their tectonic settings and to understand their petrogenesis. In addition, altered pillow basalts and calc-silicate formations were sampled to understand sea-floor hydrothermal alteration and post-magmatic metamorphic alteration. A total of 88 samples were collected from the Ivisârtoq greenstone belt. Samples will be analysed for major and trace (LILE, REE, HFSE, Cr, Co, Ni, Sc, and V) elements. In addition to the above elements, a sub-set samples from the Storø belt will be analysed for Au. These samples have been crushed and powdered, and will be analysed by May 2005. Thin sections of these samples are currently in preparation.

Ivisaartoq belt

The following rock types have been sampled from the Ivisârtoq belt:

1. Pillow cores with minor to absent calc-silicate alteration
2. Pillow rims
3. Pillow cores, with occelli (spherulite) textures
4. Pillow core, with significant epidotization
5. Pillow basalts with significant silicification
6. Pillow basalts with significant carbonitization
7. Ultramafic pillow basalts
8. Ultramafic flows with cumulate texture
9. Actinolite schist
10. Serpentinite
11. Amphibolite
12. Gabbro
13. Calc-silicate (epidote + garnet + carbonate)
14. Calc-silicate (garnet + vesuvianite + diopside + amphibole + quartz)
15. Calc-silicate (epidotite)

During field work at least two different types, or stages, of calc-silicate hydrothermal alteration were recognised. The first stage of calc-silicate alteration is associated with pillow basalts. Both pillow rims and cores show the effects of alteration. Rims are composed of 1-3-cm-thick fine-grained amphibole + biotite + chlorite ± epidote. Cores display mineralogical zonation. Most cores have occelli (spherulite) texture. Calc-silicate minerals appear to replace the occelli texture. The inner part of the cores is composed of quartz + carbonate + epidote. The outer part of the core is composed dominantly of amphibole + albite + epidote. The second type of calc-silicate alteration is associated with shear zones. It ranges from several-cm to several tens of meters. This calc-silicate alteration is composed of epidote + garnet + diopside + vesuvianite + amphibole ± sulphides.

Storø belt

Approximately 40 metavolcanic and metasedimentary rock samples were collected from the island of Storø. The purpose of the sampling in the Storø area is: (1) to assess their trace element characteristics, (2) to clarify the relationship between different supracrustal units; (3) to establish criteria for gold prospectivity in the area; and (4) to determine the geodynamic evolution of the area. The following rock types were collected from the belt during 2004 field season:

1. Amphibolite
2. Garnet-amphibolite
3. Garnet-mica schist
4. Calc-silicate (quartz + diopside + hornblende)
5. Garnet-plagioclase-hornblende-qtz schist
6. Quartz-biotite-garnet schist
7. Quartz-feldspar-garnet schist
8. Quartz-feldspar-mica schist
9. Garnet-mica-magnetite schist
10. Garnet-quartz-mica schist
11. Muscovite-quartz-feldspar schist
12. Amphibole-quartz-feldspar schist

Appendix D. Henrik Stendal's report

Fieldwork Nuuk region, July and August 2004

The aim of the fieldwork was to investigate the geological setting and evolution of important greenstone belts with respect to their mineral potential, especially for precious metals. The study and sampling was focussed on areas around known gold-bearing mineral occurrences (Storø and Bjørnøen) and unknown areas with respect to gold occurrences such as Fiskefjord region, Qussuk peninsula, Sermitsiaq, the inner part of Godthåbsfjord and Ameralik Fig. 1).

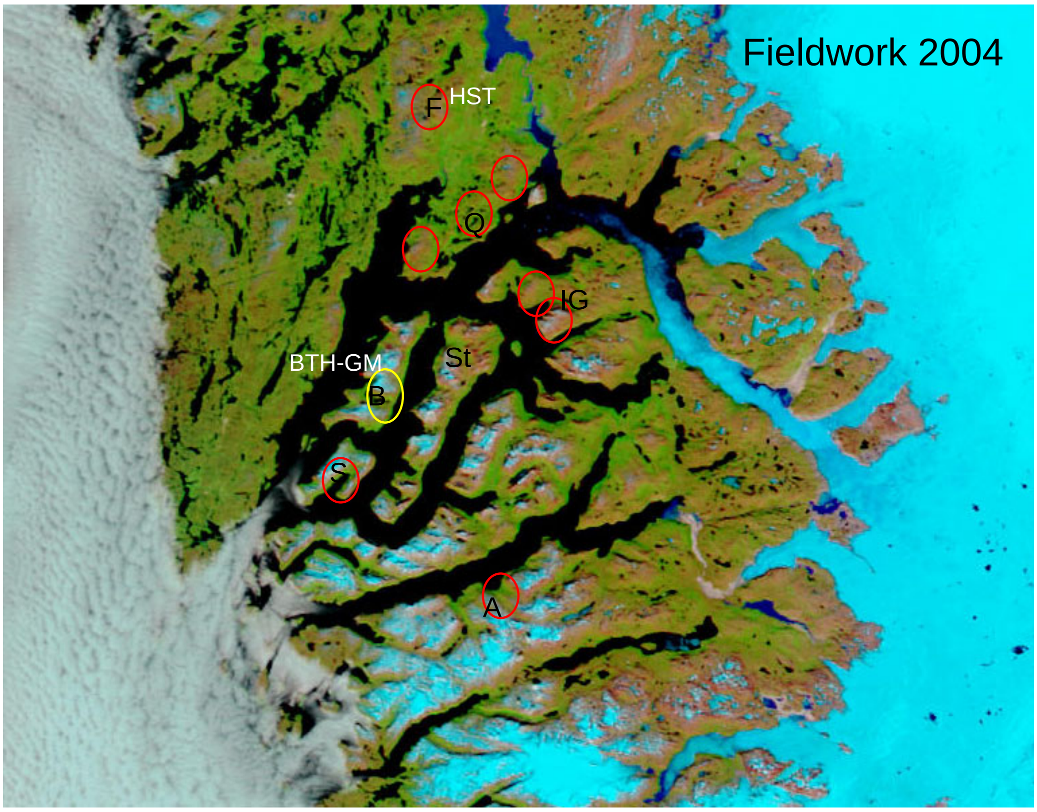

Figure hst-1. *Fieldwork areas for Henrik Stendal (HST) and Bjørn Thomassen – Gitte Marcussen (BTH-GM). A: Ameralik; B: Bjørnøen; F: Fiskefjord area; IG: Inner Godhåbsfjord; Q: Qussuk peninsula; S: Sermitsiaq; St: Storø.*

The data in this report comprise field observations, some geochemical data analysed by Instrumental Neutron Activation Analysis (INAA), and Induced Coupled Plasma (ICP). Sampling positions and the sample record is shown on the enclosed CD-ROM. The distribution of Au, Cr, Cu, Mg and Ni for all samples of the study region is shown in histograms (Fig. 2).

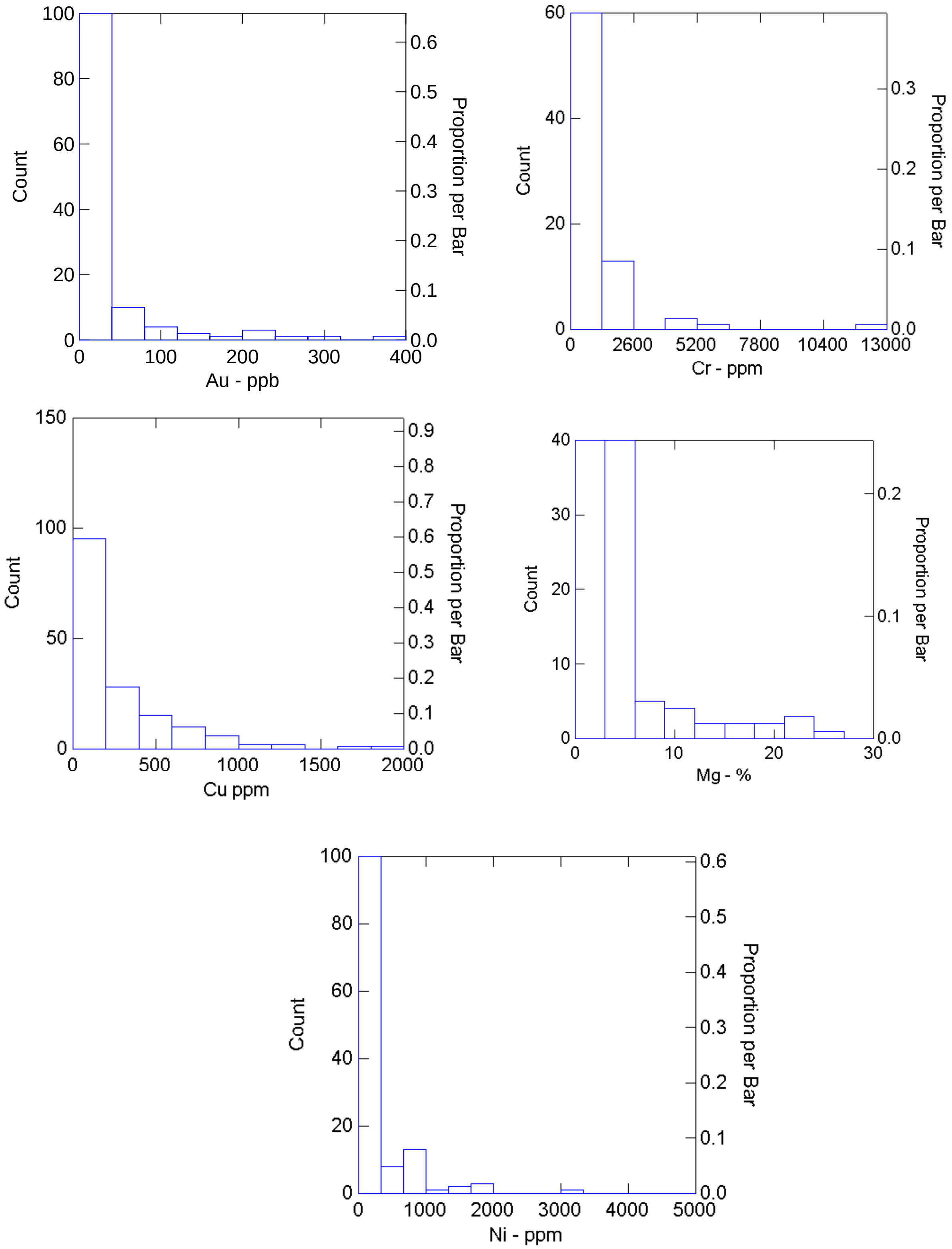

Figure hst-2. *Histograms of Au, Cr, Cu, Mg and Ni for all samples collected by HST.*

Fiskefjord region

The study area in the Fiskefjord region was carried out around N 64^o 49.054' and W 051^o 28.356' at ~300 m elevation. Geologically, the camp was located in the Akia tectono-stratigraphic terrane of southern West Greenland. The focus was a mafic- to ultramafic sequence including dunite, norite and amphibolites hosted in tonalitic and trondhjemitic gneiss (Fig. 3). The general structural trend strikes more or less in N-S directions (Garde 1997). The Fiskefjord area is located in the c. 3.2-2.97 Ga Akia terrane, covered by the published geological map sheet Fiskefjord (scale 1:100 000; (Garde 1989)).

Figure hst-3. *The mafic sequence of the Fiskefjord area with dunitic rocks (rusty rocks in the middle), light grey norite (foreground) and amphibolite (black rocks to the right).*

Analytical results - Fiskefjord area

The mafic and ultramafic signatures are mirrored in the high contents of Cr, Mg and Ni (Fig. 2; Data can be seen on the enclosed CD-ROM). The chromium content varies in the in the ultramafic rocks from 0.24 – 1.27% and the amphibolites the Cr value peaks at 0.15%. The Mg content show the same variation with up to 26% in the dunites but some of the amphibolites have remarkable high contents e.g. 12 – 17% in fine-grained amphibolites (490820-822; Data can be seen on the enclosed CD-ROM). The Ni content correlates with the values for Cr and Mg with up to 0.31% in the ultramafic suite and in the Mg-bearing amphibolites Ni reaches up to 0.12%. The copper content is in average rather high for the amphibolite often ranging from 0.1 – 0.2%. The precious metal contents vary with gold values up to ~250 ppb gold in amphibolites and 22 ppb Pt in an ultramafic rock. The sulphur content is very low and only a few samples exceed 1% S.

The relatively high Mg, Ni, Cr and low Ti contents indicate that the amphibolite might be of the komatiitic type, which are typical for old Archaean terranes.

Qussuk peninsula

The geological investigation at the Qussuk peninsula in northern Godthåbsfjord, southern West Greenland (Fig. 1), had the objective to locate areas of hydrothermal alteration and determine the types of mineral occurrences within them. The focus areas were the southern part of Qussuk peninsula with greenstone sequences and the eastern part with the Ataneq fault.

Figure hst-4. *Alterations along a vein of magnetite-bearing black amphibolite – alteration products are diopside and epidote.*

The Qussuk area is located in the eastern part of the c. 3.2 – 2.97 Ga Akia terrane, covered by the published geological map sheet Fiskefjord (scale 1:100 000; Garde 1989). This area has escaped the 2975 Ma granulite facies event elsewhere in the terrane, and is hence considered to have a larger gold potential (Hollis *et al.* 2004). Massive silica impregnation along the Palaeoproterozoic Ataneq fault in the eastern part of the Qussuk peninsula, similar to that previously described from the adjacent western part of the Ivisaartoq map sheet area (Park 1986).

Detailed descriptions of the lithologies and the geological setting can be found in Hollis *et al.* (2004), thus in this report these matters will only briefly be mentioned. Large parts of the supracrustal belts in the Qussuk area consist of leucocratic 'grey amphibolite', which generally contains biotite in addition to hornblende and plagioclase. This lithology corresponds to the 'leuco-amphibolite' or 'grey amphibolite' of andesitic. The grey amphibolites contain primary fragmental textures and are probably of volcaniclastic origin (Hollis *et al.* 2004). Large and very prominent, rusty weathering exposures of sillimanite-garnet-biotite-rich metasedimentary rocks occur on the south-facing hills north of the head of Qussuk the rust stain is in part derived from local iron sulphides.

Hydrothermal alteration

Hydrothermal alteration by fluids that appear to have been rich in CO_2 was observed in several places within dark amphibolites. The most prominent zone of hydrothermal alteration occurs in several generations both as an early alteration and as a later vein related alteration (Fig. 4). The amphibolite in the alteration zone shows fragmental texture, which in most places are interpreted as alteration phenomena. The alteration products mainly consist of diopside besides epidote, titanite and sometimes garnet.

Figure hst-5. *Red coloration (hematite) of gneiss in a fracture zone parallel to the Ataneq fault.*

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. The silica impregnation has in some places happened during shearing contemporaneously with the quartz formation. Late brittle crushing in these already silicified rocks occurs together with formation of K-feldspar. The latest event is red colouring (oxidation of iron; hematitization) along fractures fracture zones up to one-m wide alteration (Fig. 5). The host rocks (tonalites) are often disseminated with mm-big euhedral crystals of pyrite.

Sulphide mineralisation

The grey amphibolite contains several thin layers or zones of disseminated iron sulphides, which appear to follow certain stratigraphic levels, although the latter are now difficult to discern (Fig. 6). The sulphide-mineralised zones (1-2 m thick) always seem to be associated with, or identical to, layers of medium-grained, quartz-biotite-hornblende-iron-sulphide-bearing rocks. The sulphide-mineralised zones are related to prominent escarpments in the terrain but the mineralization is probably of syn-sedimentary origin.

Figure hst-6. *Rusty (sulphide-bearing) metasediments at the eastern part of Qussuk.*

At the head of Qussuk Bay a prominent rust mountain consisting of an amphibolite sequence intercalated with quartz-bearing gneisses and biotite-schist (Fig. 7). This sequence has typically 1-5 vol% iron sulphides (pyrrhotite and pyrite). At least three rusty sequences occur, which are from a few m to 10 m wide. Granites and pegmatites intrude the supracrustal rocks. Some minor lenses are semi massive consisting of quartz and pyrrhotite.

Figure hst-7. *Sulphide-bearing rusty supracrustal rocks on the rusty mountain at the head of Qussuk Bay.*

Analytical results - Qussuk

The supracrustal rocks such as amphibolites and quartz-mica±garnet gneiss carry a little bit of gold (Data can be seen on the enclosed CD-ROM) with numbers up to 233 ppb gold. The highest values are often connected with garnet-bearing mica schists. The sulphide-bearing quartz mica schist all contain gold but the content is low, raging from 20-150 ppb with the most anomalous samples from the head of Qussuk. The mafic components of the amphibolites are easily observed by high Cr contents (up to 0.2%), elevated Ni (often 500-1000 ppm) and rather high Fe, Mg and Ca contents. The copper values are in general high with up to nearly 1000 ppm, except for one sample which has 0.37% Cu. Two samples are outstanding concerning the contents of Pb and Zn (samples 490891 and 491620; Data can be seen on the enclosed CD-ROM) with max 0.8% Zn and 0.12% Pb from sulphide-bearing mica schist/gneiss. The amount of sulphides in the rock samples are mirrored in the sulphur content of the samples (Data can be seen on the enclosed CD-ROM), it yields up to 11 % sulphur. In Hollis *et al.* (2004) it is reported that most of the gold-bearing samples outside Storø have been collected in the Qussuk area, where both rock and soil samples indicate the occurrence of a new gold occurrence that deserves further investigation. The anomalous samples are found within the greenstone sequence in the southern part of the Qussuk peninsula and at the head of the Qussuk Bay. This is the same areas as in this investigation but the values reported in Hollis *et al.* (2004) are higher than in this study.

The hydrothermally altered Ataneq fault zone has a completely different geochemically distribution than the supracrustal rocks. The hydrothermal zone is not gold bearing. The only anomalous elements in the zone are Ba and Cu (Data can be seen on the enclosed CD-ROM).

Inner Godthåbsfjord

This area comprises the Kangaarsuk peninsula and the peninsula towards southeast (see detailed maps in Hollis *et al.* (2004)). The areas have the same rock types as the Storø greenstone belt and gneisses belonging to the Færingehavn terrane. The region includes large areas of Ikkattoq orthogneisses, supracrustal rocks and intrusive rocks of Qoorqut granite (2.53 Ma) and pegmatites.

The analytical results (not given in a table) tell that the rocks collected in this region have no gold. The only metal of interest is varying copper values of amphibolites up to 0.65%.

Sermitsiaq

The geology of Sermitsiaq is described in Hollis *et al.* (2004). The purpose of the study reported here was to have a look at the sulphide-bearing greenstones because the Ivinnguit fault cuts through the sequence. The semimassive pyrrhotite occurrences are hosted by fine-grained laminated amphibolites (± tourmalinites). Large pegmatite bodies intrude the sequence. Apart from sulphides, the supracrustal rocks are reported to contain tungsten (scheelite) (Olsen 1986). The sulphide-bearing parts of the amphibolite have carbonate alteration, which is seen as calc-silicate rocks. The pyrrhotite occurrences also carry chalcopyrite.

The analytical results can be seen on the enclosed CD-ROM. The gold content do not exceed 100 ppb, the chromium is low compared to Fiskefjord and Qussuk areas, copper yields up to 600 ppm, zinc up to 0.1% and Pb up to 100 ppm. The calcium content varies due to the amount of calc-silicates of the amphibolites.

Ameralik

This locality has only been investigated during one-day reconnaissance. The area lies in the transition of Færingehavn and Tre Brødre terranes. The geology looks complicated but some alteration patterns look interesting with respect to mineralization. One big loose block (1 m^3) was albitised and disseminated with sulphides (pyrite and chalcopyrite). The analyses gave nearly 2% copper and 200 ppb gold. Much further work has to be done in this area.

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Appendix E. Bjørn Thomassen's report

Introduction

The fieldwork was part of GEUS' project 14131: *Is there a gold province in Nuuk region?* With the specific task to localise and investigate gold and lead-zinc mineralization previously reported from Bjørneøen by Nunaoil A/S, and if possible, reveal new mineralization on the island. The work was carried out 9–23 July 2004 from two fly camps on south-eastern Bjørneøen. The author was accompanied by Gitte Marcussen (GMa) the whole period and by Bo Møller Nielsen (BMN) 9–14 July. The weather was unstable with four days lost due to rain and fog.

Bjørneøen is a *c.* 250 km² island situated 25–50 km NNE of Nuuk, South-West Greenland. The investigated part of the island is covered by Nunaminerals' exploration licence 2002/07 and has a moderate relief with a relatively dense cover of arctic vegetation in the valleys. The island was explored by Nunaoil 1995–97. This work included detailed mapping, sampling and VLF/magnetic geophysics in two grid nets, and the collecting of a total of 94 stream sediment samples and 433 rock samples, of which 64 were channel samples and 173 chip samples (Skyseth 1998, Smith 1998).

Bjørneøen is underlain by Archaean gneiss with an N-S orientated belt of Archaean "Malene" amphibolites, which host the mineralization. This appears as scattered gold (max. 4 ppm Au) and minor lead-zinc in two siliceous and pyritic bands surrounded by an alteration zone and is believed by Nunaoil to represent sedimentary exhalative deposits.

Accomplishments

Nunaoil´s 1997 grids nets, marked by bamboo sticks, were localised. With the help of Skyseth's 1998 report, it was possible to find the mineralised localities. Channel sample sites, appearing as saw cuts with spray painted numbers, were precisely identified, and chip sample sites and blast holes were also easy to identify in the field although some of the flagging had vanished.

The main effort was made on the investigation and sampling of the best mineralised parts of the known mineralization. Furthermore, the area to the north-west was visually inspected for signs of mineralization during foot traverses.

South Grid
A half-day was spent in the southern grid (BLS) together with BMN. Nunaoil's two main Pb-Zn-mineralised localities were visited and resampled. They are up to 0.5 m thick conformable lenses of quartz-garnet rock with semi-massive sphalerite, galena and magnetite.

North Grid
The northern grid (BSS) comprises a western (BLW) and an eastern (BLE) base line. The main part of the time was spent, together with GM, on the western base line, which covers the best mineralization. The work here comprised the sampling of all Nunaoil localities with > 1 ppm Au (B.Th.), and measuring and sampling of profiles across the mineralised unit (GM).

The two mineralised bands are mostly conformable with the foliation in the enclosing amphibolites, up to 8 m thick and consist of rusty weathering 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. A *c.* 1 m thick quartz vein with blebs of sulphides (but no gold, according to Nunaoil) occurs near the western mineralised band.

Area to the NW
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.

A total of 45 rock samples (482201–45) were collected by the undersigned. Sample lists with GPS co-ordinates and brief descriptions are enclosed. Additional sampling was conducted by GM and BMN.

Suggestions for further work

To establish the range of metal concentrations and to control the Nunaoil results, it is recommended to analyse all the collected samples for gold and base metals (Au+48 package).

Mineralogical and petrographic studies should be carried out to determine the gold-bearing mineral(s) and the nature of their host rocks. It should also be established weather the hanging wall and footwall amphibolites are different, as suggested by Nunaoil.

In order to explain the original setting of the mineralised bands (Originally one or two bands? Why do the bands stop towards the north? Influence of the Ivinnguit Fault? etc.) a structural analysis should be performed.

Nunamineral director Ole Christiansen has given us access to the company’s raw data from Bjørneøen. This data should be used when necessary.

References

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