DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2009/94

Annual workshop on the geology of southern West Greenland related to field work: abstract volume 1

Compiled and edited by Jochen Kolb & Thomas Kokfelt

2. edition

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF CLIMATE AND ENERGY

GEUS

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Foreword

It is a long tradition that GEUS organises a workshop related to its field activities in Greenland, bringing together geologists from GEUS and all the external collaborators. The basic idea of these workshops is to present and discuss data collected during field work and later laboratory work at home. The focus is aimed to be on the discussions. At the same time, field activities for the upcoming field season are discussed and organised.

In this volume, abstracts are collected that cover topics on field work in 2008 and topics that cover areas of future interest related to the field work plans in southern West Greenland. The abstracts reflect the work that has been done since 2008 in various projects co-financed by the Bureau of Minerals and Petroleum (BMP) and the Geological Survey of Denmark and Greenland (GEUS), namely (1) Homogenisation and conceptual modernisation of geological maps of the region at scale 1:100,000; (2) Integrative data analysis for characterisation and favourability of economic metals, southern West Greenland, 61°30'–64°; (3) Structurally controlled hydrothermal alteration and mineralisation on a regional scale and detailed studies of selected greenstone belts, southern West Greenland, 61°30'–64°; and (4) Economic potential of gabbro-anorthosites in the Fiskenæsset region. These projects run from 2008–2010 and cover the area between 61°30'–64° in southern West Greenland. This is the first abstract volume and the first workshop in this 3-year project.

The workshop is divided into four different topics: (1) Regional geology; (2) Hydrothermal mineralisation and alteration; (3) Fiskenæsset complex and regional geology; and (4) Open session. The program is given on the following pages and the abstracts in this volume occur in the program-order. This abstract volume is aimed at giving basic information about the presentations and as a reminder back home. It is the first time (at least for a long time) that we do this and we hope that the volume is appreciated. We believe it is a good idea and that the volume will help in remembering better what has been presented and discussed during the workshop.

We wish you all a pleasant and informative workshop at GEUS.

God fornøjelse,

Jochen and Thomas

Thursday, 23rd April room: Ole Winter

Time	Session	Authors	Title	Chairman
09:00 - 09:30	Regional Geology		Welcome	Kokfelt
09:30 - 09:50		Scherstén, Næraa, Kemp	Zircon U-Pb-Hf constraints on crustal growth of the Tasiusarsuaq terrane	
09:50 - 10:10		Dziggel	Petrology of amphibolite to granulite facies supracrustal rocks in the Buksefjord region, southern West Greenland	
10:10 - 10:30		Coffee break		
10:30 - 10:50		Keulen, Schumacher, Kokfelt, Scherstén	Structural overview of the area North of Buksefjorden	
10:50 - 12:00		Kokfelt, Scherstén, Keulen	Presentation of the map legend	
Poster		Kokfelt, Scherstén, Næraa, Keulen	Overview of geochronological data in the area between Ameralik and Frederikshåb Isblink	
12:00 - 13:00		Lunch break		
13:00 - 13:20	Hydrothermal Mineralization & Alteration	Kolb	Structurally controlled hydrothermal mineralisation in the Buksefjord-Kangiata Nuna region	Kolb
13:20 - 13:40		Steensgard	Hydrothermal mineralisations and geochemical results from 2008 fieldwork in the Buksefjord area, southern West Greenland: what did we find ?	
13:40 - 14:00		Schlatter	Petrographic and lithogeochemical surface data from the new gold occurrence on Qilanngarssuit island, southern West Greenland	
14:00 - 14:20		Coffee break		
14:20 - 14:40		Schjøth	GanFeld: Reporting of collected field data	
14:40 - 15:00		Schlatter & Larsen	GanFeld: introduction and news	
15:00 - 17:00		Schlatter & Larsen	GanFeld: field experiment	
17:00 - END		all	Restaurant (Bredgade 76)	

Friday, 24th April room: Ole Winter

Time	Session	Authors	Title	Chairman
09:00 - 09:50	Fiskenæsset complex & regional geology	Myers	The Fiskenaesset Anorthosite complex	Kalvig
09:50 - 10:10		coffee break		
10:10 - 10:30		Kalvig, Appel, Polat, Rudashevsky N., Rudashevsky V., Stepanov	Interim results of the PGE investigation on the Fiskenæsset anorthosite complex	
10:30 - 11:00		Windley	Shear zones and suture on tectonic boundaries in the Græde-fjord region	
11:00 - 11:20		Schumacher, Keulen, Probst, Piazolo	Metamorphism and host rock interaction with pegmatites	
11:20 - 12:00		all	discussions in working groups	
12:00 - 13:00		Lunch break		
13:00 - 13:20	Open session	Steenfelt	Major crustal features of the southern part of the North Atlantic Craton reflected in geochemical and aeromagnetic data	Steensgard
13:20 - 13:40		van Hinsberg, Schumacher, Franz	Tourmaline as a comprehensive petrogenetic indicator mineral	
13:40 - 14:30		all	Final discussion and farewell	
14:30 - open		all	discussions in working groups	

Zircon U-Pb-Hf constraints on crustal growth of the Tasiusarsuaq terrane

Anders Scherstén, Tomas Næraa & Tony Kemp

In situ zircon U-Pb-Hf-O isotope data provides a powerful tool for the unfolding of crustal evolution and growth. Zircon has relatively high (up to %-level) concentrations of Hf and low Lu/Hf, which enable spot measurements of Hf-isotope compositions with only minor age corrections. Hf- and O-isotope data has proven to be a powerful tool in deciphering continental crust evolution as zircon spot data (Kemp *et al.* 2005).

2.7 to 3.25 Ga TTG gneisses within the Tasiusarsuaq terrane have Mesoarchaean and Paleoarchaean depleted mantle (DM) model ages (DM values from Chauvel & Blichert-Toft 2001). It seems from the data that there were two episodes of crust formation, and that rocks that crystallised during the second stage mixed with the existing crust. For each growth stage, the most depleted rocks have εHf_t ~2.5; with the lowest values ranging down to -9.5 in a time versus εHf diagram (using reference values from Söderlund *et al.* 2004 and Bouvier *et al.* 2008). Depleted εHf_t are associate with mantle like $\delta^{18}O$ ~5.5, while higher $\delta^{18}O \leq 8$ are noted in the rocks with the lowest εHf_t. Each crustal reservoir evolves along trends that correspond to $^{176}Lu/^{177}Hf$ ~0.01, i.e. Bulk to Upper Continental Crust ratios (Rudnick & Gao 2002).

Pb-loss occurs in a number of samples. In some cases this caused U-Pb-Hf-O decoupling, which is indicated by an apparent diversion from the host-rock εHf_t-evolution, and, at least in one case, through heavier $\delta^{18}O$. This implies that while Pb was lost, there appears to have been little Hf-isotope re-equilibration with the host rock. The heavier $\delta^{18}O$ indicates re-equilibration with a meteoric component, possibly from metamorphic fluids.

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Chauvel, C. & Blichert-Toft, J. 2001: A hafnium isotope and trace element perspective on melting of the depleted mantle. Earth and Planetary Science Letters **190**, 137–151.

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Rudnick, R.L. & Gao, S. 2002: Composition of the Continental Crust. Treatise on Geochemistry **3**. In: Rudnick, R.L. (ed.): The Crust, 1–64. Elsevier, Amsterdam.

Söderlund, U., Patchett, P.J., Vervoort, J.D. & Isachsen, C.E. 2004: The ^{176}Lu decay constant determined by Lu–Hf and U–Pb isotope systematics of Precambrian mafic intrusions. Earth and Planetary Science Letters **219**, 311–324.

Petrology of amphibolite to granulite facies supracrustal rocks in the Buksefjord region, southern West Greenland

Annika Dziggel

The geology of the Buksefjord region is characterized by a complex zone of several juxtaposed tectonic units, including the Færingehavn, Tre Brødre, and Tasiusarsuaq terranes. Each of the terranes preserves a characteristic polyphase metamorphic evolution that culminated in extensive high-grade metamorphism and partial melting between ca. 2720-2700 Ma (Nutman & Friend 2007). The high-grade metamorphism and clockwise P-T evolution of the terranes are interpreted as a response of crustal thickening and accretion of the terranes during the Neoarchaean.

The mostly amphibolite facies Færingehavn terrane contains rare, higher grade metamorphic enclaves that record two episodes of granulite facies metamorphism. Early (Palaeoarchaean) orthopyroxene-bearing mafic and dioritic granulites record rather ordinary (medium-P) granulite facies metamorphism that has been dated at ca. 3400-3650 Ma (Nutman & Friend 2007). These early granulites are locally overprinted by ca. 2700 Ma high-pressure assemblages that have recently been discovered on the island Quilanngarsuit (Nutman & Friend 2007). The high-P granulites are characterized by Grt-Cpx-Pl-Qtz-(Hbl) assemblages in metabasites, suggesting PT-conditions of up to 750°C and 12 kbar (Nutman & Friend 2007). The predominance of amphibolite facies mineral assemblages and abundant decompression textures suggest that the clockwise PT-evolution involved near isothermal decompression at relatively high temperatures.

The ca. 2825 Ma Tre Brødre terrane appears to be restricted to a ca. 5 km wide crust sheet that separates the Færingehavn terrane in the northwest from the Tasiusarsuaq terrane in the southeast. It has been argued that the metamorphism in this terrane never exceeded amphibolite facies conditions. Typical mineral assemblages include Hbl+Pl+Qtz±Grt in mafic rock types, and Grt+Bt+Crd+Sill+Oam+Qtz in metapelites. However, rare hornblendite enclaves, consisting of Hbl, Pl, Cpx and Grt contain prograde Grt coronas separating (igneous?) Pl from the mafic domains. We interpret these textures to document a granulite facies overprint of the rock, possibly outside the Opx stability field. The existence of such higher grade metamorphic enclaves points to a more complex PT record of the Tre Brødre terrane. Abundant decompression textures in the more common mineral assemblages again indicate that near-isothermal decompression followed the amphibolite facies metamorphism.

The Tasiusarsuaq terrane occupies the largest portion of the Buksefjord region. Petrological and geochronological data indicate that it underwent medium-P granulite facies metamorphism at ca. 2800 Ma, some 100 million years before the final collisional event (e.g. Nutman *et al.* 1989). Typical mineral assemblages in the mafic granulites include Opx-Cpx-Pl-Qtz±Grt±Hbl. In contrast to the more common medium-P mineral assemblages, some of the mafic granulites contain abundant garnet coronas and Grt-Qtz symplectites separating (both metamorphic and igneous) Pl from Cpx, Hbl, and, locally Opx. We interpret these textures to document a second (higher pressure?) metamorphic episode that possibly correlates with crustal thickening and terrane accretion during the Neoarchaean. Retrogression under amphibolite facies conditions was associated with the final exhumation of the terrrane, again pointing to decompression at relatively high temperature conditions.

Taken in conjunction, we suggest that the data document the response of the different terranes to crustal thickening and final exhumation during, or shortly following, terrane accretion in the Neoarchaean. The metamorphic record reflects 1) the relative position of the terranes within the overall tectonic framework, and 2) the presence or absence of a reaction-triggering fluid phase to allow for the replacement of the earlier formed metamorphic assemblages.

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Nutman, A.P. & Friend, C.R.L. 2007: Adjacent terranes with ca. 2715 and 2650 Ma high-pressure metamorphic assemblages in the Nuuk region of the North Atlantic Craton, southern West Greenland: Complexities of Neoarchaean collisional orogeny. Precambrian Research **155**, 159-203.

Nutman, A.P., Friend, C.R.L., Baadsgaard, H. & McGregor, V.R. 1989: Evolution and assembly of Archean gneiss terranes in the Godthåbsfjord region, southern West Greenland: structural, metamorphic, and isotopic evidence. Tectonics **8**, 573–589.

Structural overview of the area North of Buksefjorden

Nynke Keulen, John C. Schumacher, Thomas F. Kokfelt & Anders Scherstén

One of the aims of the field campaign in 2008 was to investigate the proposed (e.g. Friend *et al.,* 1996, Nutman & Friend, 2007) folded terrane boundary between the Tre Brødre Terrane (outer part of fold on the Buksefjorden map sheet) and the Tasiusarsuaq Terrane (inner part of fold) in the area north of the Buksefjorden. This terrane boundary is mainly based on geochronological work; although a terrane by definition (Sengör & Dewey, 1990) is based on a structural and metamorphic discontinuity. We tried to find metamorphic petrologic (different PTt-history) and structural (significant tectonic structure in between the two areas) evidence for the proposed terrane boundary.

In the terrane model of Friend, Nutman and co-workers the Qarliit Nunaat thrust forms the boundary between the Tre Brødre and Tasiusarsuaq terranes. South of the Buksefjorden we observed intensive shearing between the Færingehavn and the Tasiusarsuaq Terranes (cf. Crowley, 2002). The Tre Brødre Terrane is here only a few kilometres wide. The tectonometamorphic styles are different at either side of the Buksefjorden. The large-scale structure in the area North of the Buksefjorden is formed by a relatively open fold-structure with a steep dipping axial plane and a shallow SSE-SSW dipping fold axis. Syntectonic pegmatites cutting through the axial plane of this fold structure are dated to c. 2.72 Ga. The fold has a wavelength of several kilometres and consists of grey biotite gneiss intruded by leucogabbroic rock (mapped as anorthosites). Overlying amphibolites and mica-schists are included in the fold zone. Some shearing was observed between the gneiss on the outside of the fold zone, with both dextral and sinistral directions. Shearing occurs at the contact between different lithological units (mica-schist - leucogabbro; leucogabbro - gneiss), but also within specific rock units (e.g. in the leucogabbro). As noted by Friend *et al.* (1996), these shear zones are no wider than 100 m and often only tens of meters or less. The orientation of these small-scale shear zones fits with flexural slip during folding, rather than shearing before folding. Thus, no structural discontinuity was observed between the Tasiusarsuaq and the Tre Brødre Terrane.

Few rocks in the area yield firm constraints on metamorphic grade, but amphibolites suggest mid- to upper amphibolite-facies peak metamorphism with no evidence for earlier higher-grade assemblages (see Schumacher et al., this volume for details). We find no evidence for a metamorphic discontinuity across the proposed Tasiusarsuaq - Tre Brøde terrane boundary.

A tonalitic gneiss from within the Tasiusarsuaq Terrane north of the Buksefjorden yield an unconstrained age of c. 2.83 Ga, or possibly two age components at 2.85 and 2.82 Ga. Further work is required to resolve these ambiguities. Nevertheless, the current data is suggestive of either an age overlap between the Tasiusarsuaq Terrane and the Tre Brødre Terrane, or that there are rocks of broadly the same age as those in the Tre Brødre Terrane within the Tasiusarsuaq Terrane.

Within the area, no significant (i.e. wide and high strained) shear zones were observed, except on the peninsula at the mouth of the Buksefjorden. This shear zone is at least 400 m wide, and nearly completely mylonitic. Pegmatites within the shear zone are partially sheared and saussuritised. This steep-dipping sinistral shear zone strikes roughly SSE-NNW, with a dominant lineation dipping 30-60° SE and locally down-dip. It is likely that this shear zone is the northward continuity of the large shear zone south of the Buksefjorden. Zircons from one mylonitic pegmatite were dated to 2.82 Ga and represent either an early deformation along this shear zone, or zircons from the gneiss in the wall rock.

Late deformation features include 1) two conjugate sets of quartz veins, locally filled with sulfide minerals, indicating a roughly NS directed extension. 2) A cataclastic fault zone and a pseudotachylyte/ultracataclasites both indicating top to N movement direction, were observed within the area N of the Buksefjorden. 3) Epidote veins and open fractures striking EW. 4) Dolerite dykes striking EW. These four features are not necessarily all related/contemporaneously, but indicate a change in the orientation of the major stresses in the earth's crust.

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Sengör, A.M.C. & Dewey, J.F. (1990) Trans. R. Soc. London Ser. A (**331**)1620, 457–477p

Presentation of the map legend

Thomas Kokfelt, Anders Scherstén & Nynke Keulen

GEUS is currently producing a seamless digital web-based 1:100 000 scale geological map in southern West Greenland and South-West Greenland between N61°30' – 64°. The geological data concerning locality descriptions, photos, structural geology, metamorphic petrology, geochemistry and geochronology will become available on the web, together with the interpretations concerning the geological environments. The currently available geological observations are conceptually modernised and updated with field work in selected areas.

The area has been mapped in the 1960s and 1970s on 9 individual map sheets. To integrate these map sheets into a seamless map, first of all an integrated legend that is valid for the whole area is required. Ideally, this integrated legend should be used for ongoing projects in the Gothåbsfjord region and on the Kapisillit map-sheet, just north of the project area as well.

Here we propose a compiled and revised legend for the northern half of the project area (N62°30' – 64°). This legend incorporates an earlier integrated legend for three map sheet in the Gothåbsfjord area (Garde & van Gool, unpl. data) as well as the legends from the current map sheets between N62°30' – 65°. As far as possible, we apply the classification recommendations of Le Maitre (1989) and Gillespie & Styles (1999) for igneous rocks, Roberson (1999) for metamorphic rocks and Hallsworth & Knox (1999) for sedimentary rocks.

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Overview of geochronological data in the area between Ameralik and Frederikshåb Isblink

Thomas Kokfelt, Anders Scherstén, Tomas Næraa & Nynke Keulen

Geological mapping and geological interpretation of complex tectonometamorphic terranes largely profit from the accessibility of precise and accurate geochronological data. The current mapping project in Southern West – South West Greenland has the aim of generating an improved digital seamless geological map of the area between N64.0' and 61.30' (see also previous abstract by Kokfelt et al.), and providing an updated interpretation of the geology of the area. To this end we present radiometric age dates on zircons from c. 30 rock samples of TTG gneisses, granite/pegmatites, amphibolites, metagabbros, mica-schists and anorthosites from the area between Ameralik and Frederikshåb Isblink collected during the 2007 and 2008 field seasons.

The new age dates are obtained at the laser ablation facility hosted at the GEUS mapping department (Hollis et al., 2006; Frei & Gerdes, 2009). This facility includes a New Wave UP 213 laser coupled to a ThermoFinnigan Element2 magnetic sector field - inductively coupled plasma - mass spectrometer (SF-ICPMS). The applied setup involves a low-volume sample chamber and Helium as flushing gas, which together secure fast washout times and smooth, spike-free signals. The obtained age dates are highly accurate and precise as validated by within runs of widely used zircon standards (i.e. 91500, Plesovice; see also Frei & Gerdes, 2009). Compared to conventional SIMS and TIMS techniques, laser ablation offers much faster sample throughput (at least by a factor 3–4). Meanwhile the spot size of 30 µm still allows for real in situ measurements with frequent cases of cores and rims of zircon minerals being dated.

The presentation form is a poster showing the simplified geological map and localities for dated rocks. Literature zircon age data are compiled for comparison. We provide a preliminary geological interpretation of the obtained ages and distinguish visually and conceptually between magmatic, metamorphic or sedimentary ages. Overall, the distribution of obtained ages indicates that 1) magmatic intrusions of TTG assemblages occurred in a broad interval from c. 3.22–2.83 Ga, 2) granulite facies metamorphism associated with intrusion of the Ilivertalik Augen Granite occurred at c. 2.8 Ga, 3) an extensive 2.72–2.70 Ga tectonothermal event, in some areas associated with granite intrusions, occur throughout the area and 4) late, generally undeformed, granite and pegmatite, associated with the c. 2.55 Ga Qôrqut Granite Complex, intrudes the northern parts of the area.

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Hollis, J.A., Frei, D., Gerdes, A. Garde' A.A., van Gool, J. A.M. (2006). High precision LA-SF-ICP-MS U-Pb zircon dating of Archaean gneisses, southern West Greenland, *Geochimica et Cosmochimica Acta*, **70,** A260.

Structurally controlled hydrothermal mineralisation in the Buksefjord-Kangiata Nuna region

Jochen Kolb

The localities studied in 2008 in the Buksefjord and Kangiata Nuna map sheet areas were chosen with the aim to locate and interpret hydrothermal mineralisation and alteration in the area. Two hydrothermal alteration and mineralisation types were identified in the field: (1) Quartz veins with associated Bt-Qtz-Po-Ccp±Grt±Hbl±Di±Py alteration and (2) massive sulphide lenses comprising mainly Po and minor amounts of Py, Ccp, Mo and Sp. These lenses a surrounded by rocks containing Oam-Grt±Crd±Sil±Mag±Gru±Gah(gahnite), which is interpreted as a metamorphosed hydrothermal alteration zone.

Numerous quartz veins were observed in the area as tracers of hydrothermal mineralisation. They are 1–20 cm wide and are continuous along strike and down dip over several meters to up to 200 m. Besides Qtz they contain minor Po, Py and Ccp. In general, most of the veins are parallel to S_2 on the limbs of F_3 folds or they are parallel to S_3 in the D_3 shear zones. They often form at the gneiss-amphibolite contact. Locally, a striation on the quartz vein surface of S_3 parallel veins is observed to be parallel to the L_3 mineral stretching lineation. The quartz veins are surrounded by a 5 cm to 1 m wide alteration halo of variable composition, depending on the wall rock type. In the TTG-gneiss, the hydrothermal alteration comprises Ms, Qtz, Ccp and Po. In the amphibolite a Bt, Qtz, Act, Po and Ccp alteration formed, locally with Ms and Ep. The mafic granulites in the central part of the map sheet have a slightly different alteration containing Bt, Di, Tm, Qtz, Po, Py and Ccp, whereas the alteration assemblage in nearby gneiss is the same to that described above. Composite systems of several parallel quartz veins together with alteration zones can be 50–200 m wide and can be followed along strike and down dip to up to 250 m if the outcrop situation allows that. The quartz veins are generally only weakly enriched in Au with values to up to 20 ppb. Only on the island of Qilanngaarsuit, the quartz veins and the alteration zones record Au grades of up to 800 ppb. The quartz veins are structurally controlled by the F_3 folds that are obvious from the map pattern. The veins are most abundant in the steep limbs of the folds and in limbs sheared off by D_3 strike-slip deformation in the amphibolite facies.

The massive sulphide lenses are 2–7 m in diameter and 5–30 m long. Although several lenses may occur along strike, the total size of the mineral occurrences is regarded as being too small to be of economic significance. They are enriched in Fe, Co, Ni, Cu, Bi, Mo, Zn and Sn. These massive sulphides are interpreted as a syngenetic hydrothermal mineralisation, possibly related to hydrothermal activity on a palaeo-seafloor. The rocks were later metamorphosed, possibly up to granulite facies, and deformed into boudins, representing the massive sulphide lenses.

The two types of hydrothermal mineralisation (orogenic gold type and VMS type) shown here are either structurally controlled or deformed. A detailed structural description is, therefore, a prerequisite for their interpretation and prediction in the field.

Mineralisation and alteration in the Ameralik–Sermilik corridor: what did we find in 2008?

Bo Møller Stensgaard, Annika Dziggel, Jochen Kolb & Denis Martin Schlatter

The northwest-southeast oriented corridor from outer Ameralik to inner Sermilik (from Little Narsaq to Alangordlia on the map in Figure 1), within the North Atlantic craton of southern West Greenland, intersect a complex geological region of several juxtaposed Archaean terranes (the Færingehavn, the Tre Brødre and the Tasiusarsuaq terannes) separated by more or less distinct structural features. The terranes are dominated by gneiss but enclaves, slivers, and restricted belts of supracrustal rocks are found throughout. Each terrane preserves a poly-metamorphic evolution and complex deformation. The structures and complex geological evolution of the corridor provide settings for hydrothermal mineralisation and associated alteration.

Prior to the field season, volcanogenic massive sulphide (Po, Ccp) occurrences within the Færingehavn terrane were known at several localities from the islands and mainland southeast of the outer Buksefjord area. Beside an Ujarassiorit rock sample (the public mineral hunt program in Greenland) with highly anomalous gold, which not have been reproducible in subsequent studies, no known mineralisation have been reported within the Tre Brødre terrane. Only massive iron-sulphide occurrences (possible granulite facies volcanogenic sulphide occurrences) and altered ultramafic rocks, which now appear as calc-silicate-magnetite rocks, are described from the area just north of central Sermilik.

Based on a review of geophysical, geochemical, structural, metamorphic and lithological data combined with empirical models for hydrothermal mineralisation and alteration (e.g. models for the development of orogenic gold and associated alteration) four areas and several reconnaissance stops were selected for further investigations.

The first area is the area of Qarajat kuat north of outer Buksefjord within the Tre Brødre terrane (Fig. 1). The area is dominated by amphibolite, paragneiss, schist, anorthosite and pegmatite. Only few localities with hydrothermal alteration and mineralisation were found. Disseminated iron-sulphides are hosted by silificied and Bt-rich schist and amphibolite at two localities. Geochemical analyses of rock samples from this setting have not yielded any notable values for base metals or gold.

A pervasive alteration zone was encountered at another locality in the Qarajat kuat area. The zone is 20–30 m wide and exposed for 150–200 m. The host rocks comprise amphibolite, meta-ultramafic rock, paragneiss and coarse-grained orthogneiss. Besides a probably late, cross-cutting milky-white, 1 m wide quartz vein, all other rocks have a moderate to strong rusty appearance. A probably early boudinaged and reddish 1–1.5 m wide quartz vein is also observed. Composite rock samples from rusty rocks yield elevated Zn (~3000 ppm) and As (77 ppm). Two scree sediment samples from the gossan yield highly anomalous values for Ag, Cu, Cd, Mo, Pb, Zn, and REE.

The second area is located at the southern coast of the outlet of the Buksefjord at the western boundary of the Færingehavn straight belt (Fig. 1). The highly anomalous gold sample (ca. 100 g/t Au) submitted to the Ujarassiorit program originates from this area. The amphibolite facies TTG gneiss and associated supracrustal rocks are part of the Færingehavn straight belt, and are characterized by a N–S trending, sub-vertical and often mylonitic foliation. The mineralisation is associated with up to 0.5 m thick quartz-veins oriented along discrete, S3-parallel shear zones. The veins contain abundant enclaves of greenschist facies mafic rocks, which are mainly composed of Act, Ep, Qtz, Pl and locally Chl. They can be followed along strike for at least 25 m, and are often developed as sheeted quartz veins. The quartz veins are locally very coarse-grained, and contain up to several cm large crystals of Act, Py, Po and Ccp. The mylonitic wall rocks contain a several cm-wide alteration halo that is composed of an inner Qtz-fuchsite and an outer Bt alteration. The presence of greenschist facies minerals in these S3-parallel shear zones indicates that they postdate D3 shearing in the Færingehavn straight belt. However, the lineation in the quartz veins and associated alteration zones is parallel to those in the amphibolite facies mylonites and plunges moderately to the SW. This may indicate a progressive exhumation during shearing. Shear sense indicators point to an E block up sense of movement with a sinistral strike slip component. No elevated gold values were obtained from the quartz veins. Similar to the conclusions from previous non-Survey follow up, it is concluded, that the anomalous gold content in the Ujarassiorit sample from this area not is reproducible.

The third area selected for detailed investigations is located within the northern part of the Tasiusarsuaq terrane in the area south of Qaaqatsiaq (Fig. 1). The area is dominated by a large enclave of mafic granulite and meta-leucogabbroic rocks. The area is characterised by a fold interference pattern typical of the Tasiusarsuaq terrane. In general, the mineralisation occurs in different structural settings that are closely related to the D3 structures. The D3 structures in the area are characterized by open to tight upright folds with axial traces trending NW–SE to W–E. Sinistral strike-slip shear zones are commonly developed along the sub-vertical north-eastern limb of these folds, or as conjugate sets of steep shear zones that crosscut the S2 foliation. Mineral assemblages of Hbl, Pl, Qtz and, locally, Grt, indicate that shearing occurred under amphibolite facies conditions. Mineralisation occurs (i) as a pervasive hydrothermal overprint in dilational sites at the intersection of the conjugate shear zones; (ii) as bedding-parallel, subhorizontal, highly silicified bodies along the shallowly dipping south-eastern limbs of the F3 folds; or (iii) in association with foliation-parallel and sigmoidal quartz veins within the NW–SE trending shear zones. The ore assemblage in all these settings is similar, and comprises Po, Py, Ccp. The highest gold values obtained from the mineralised samples are 37 and 26 ppb Au. The latter sample also contain 22 ppm As. Elevated Au concentrations (58 ppb) together with elevated Cu and Zn were also found in scree sediment sample from gossan associated with the silicified iron-sulphide mineralised mafic granulite.

The fourth area is located north of central Alangordlia, north of Sermilik, within the Tasiusarsuaq terrane (Fig. 1). This area is dominated by fine- to medium-grained mafic granulite which is intercalated with TTG gneiss and intruded by younger, but also foliated granitoids. Even though D3 shear zones are common, the area is less mineralised than those further to the north. The D3 shear zones crosscut the regional S2 foliation, which dips at moderate angles to the SE. The D3 shear zones strike NW–SE and NE–SW, and dip at moderate to steep angles to the NE and NW. The mineralisation was investigated in one location, where it is situated in a dilational jog at the intersection between two cross cutting, up to 0.5 m wide mylonitic shear zones. The mineralised zone is strongly silicified and also contains hydrothermal Hbl. The ore mineral assemblage comprises Py and Ccp. No elevated values for gold or other metals were detected.

Reconnaissance stops were carried out in the Færingehavn straight belt, the area north of central Buksefjord, the area south of the central Ameralik and along the northern coastline of the fjord Sermilik.

Most notable mineralizations and alterations from these stops are:

i. A large hydrothermal stockwork-type mineralisation east of Qinguussaq, south of central Ameralik (Fig. 1). The host rock to the mineralisation is a white, medium-grained orthogneiss mainly made up of Qtz and Fsp. Mafic minerals are generally absent due to hydrothermal alteration with only some Bt preserved. Locally, small specks of Py and Ccp are recognised. Stockwork-type, mm-scale quartz-feldspar veinlets crosscut the gneiss. Nearby grab samples from fieldwork in 2005 by GEUS have yielded up to 200 ppb gold and 2 % Cu. However, these values were not reproduced.

ii. Further to the south, south of Qaarajugtoq (Fig. 1), north of the central Buksefjord, an area was visited during a short reconnaissance stop to investigate rusty gneiss. Two scree sediment samples yield 107 and 378 ppb Au together with elevated Ag (0.7 and 1.5 ppm), Cu (331 and 539 ppm), Zn (94 and 208 ppm) and S (0.14 and 0.21 %) concentrations. These numbers are supported by a composite rock sample with elevated gold values (47 Au ppb) and elevated base metal content.

Also reconnaissance stops at Simiutat and at Little Narsaq and a camp at Qilanngaarsuit (Fig. 1) provides important observations on the general mineralisation pattern for the Ameralik–Sermilik corridor. Observations and results from Qilanngaarsuit will be given in other presentations.

Though no economic mineralisations have been encountered in the Ameralik–Sermilik corridor during the 2008 field season, the data document mineralisation types not previously described from the corridor and that processes and settings favourable for the formation of hydrothermal veins systems are present. Especially the Færingehavn straight belt and secondary structures in neighbouring areas would be of interest for further investigations.

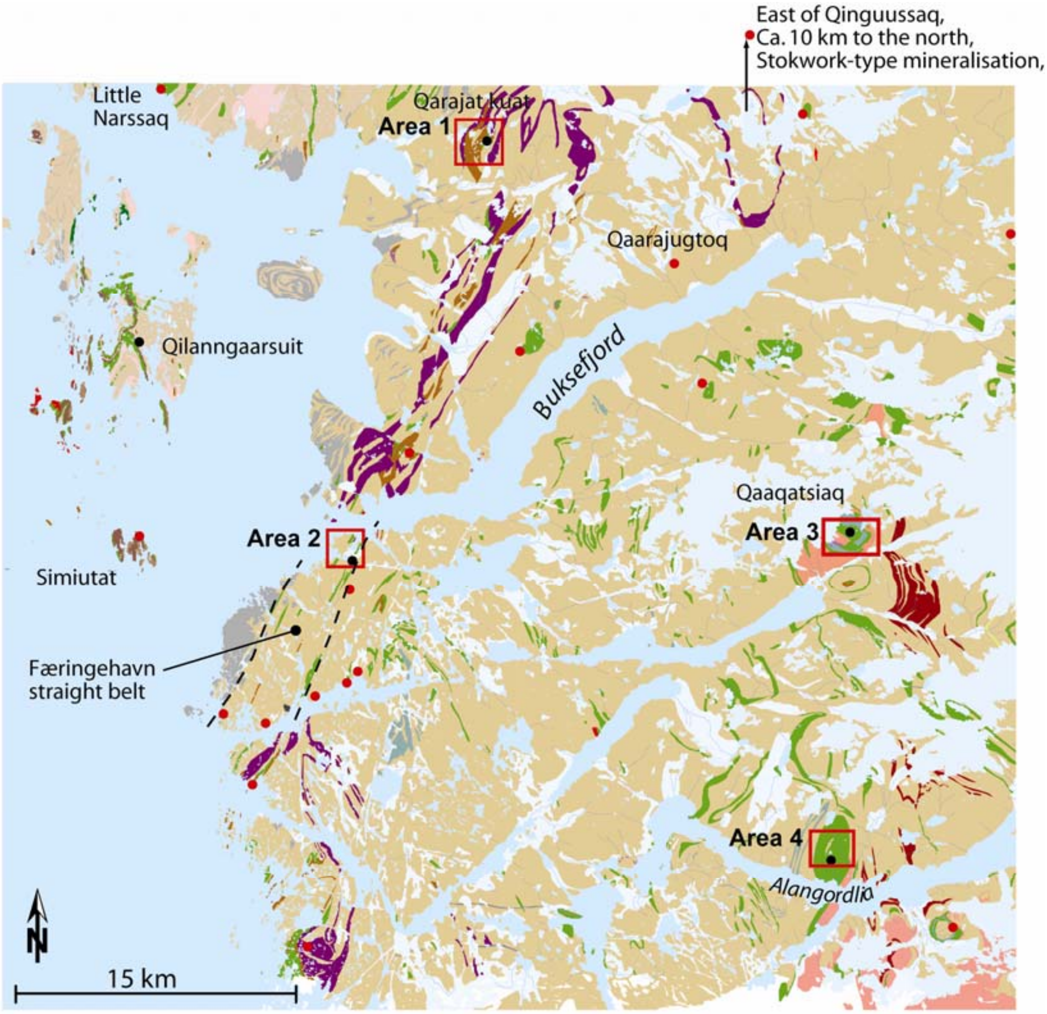
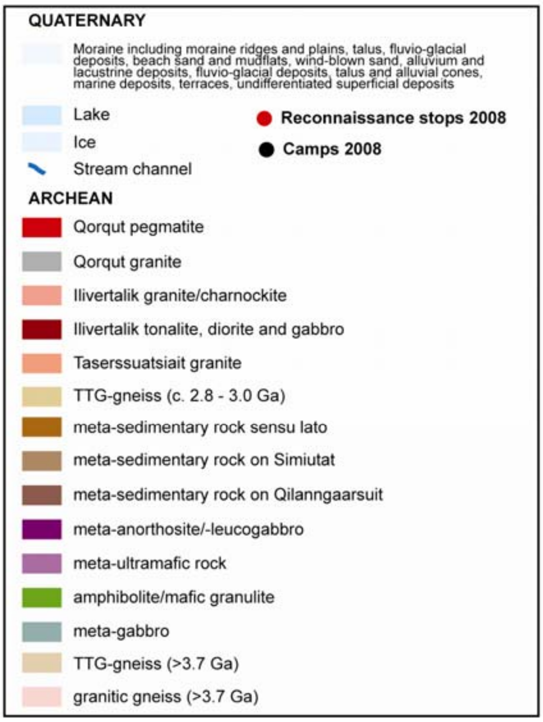


Figure 1. *Geological overview of the Ameralik–Sermilik corridor (from Little Narsaq to Alangordlia) with indications of the reconnaissance stops and camps. The outline of the Færingehavn straight belt is only indicated at the Færingehavn peninsula.*



Petrographic and lithogeochemical surface data from the new gold occurrence on Qilanngaarsuit Island, southern West Greenland

Denis Martin Schlatter

The about 6 x 5 km large Qilanngaarsuit island is located in southern West Greenland about 35 km south of Nuuk and 13 km south of Narsaq (Fig. 1), in the Færingehavn terrane of the North Atlantic craton. In this paper we present petrographic and lithogeochemical data from a new gold occurrence which was discovered during field work carried out in 2008.

The Palaeo- to Mesoarchaean rocks on Qilanngaarsuit are mainly quartzo-feldspatic gneiss, metamorphic mafic to ultramafic rocks, paragneiss and metamorphosed mafic dykes (Fig. 1). Similar meta-ultramafic rocks, amphibolites, and paragneiss occur in the Godthaabsfjord area and are known as the “Malene supracrustals”. However rocks grouped in the Malene supracrustals under this name occur in different terranes and are also of various ages.

Grey quartzo-feldspatic TTG gneiss of >3.7 Ga (Amitsoq gneiss) is the most represented rock (Fig. 1). The gneiss is medium-grained with variable fabric ranging from banded, nebulitic to agmatitic. It comprises mainly Qtz, Pl, Bt and, locally, Hbl. Leucosomes are composed of Qtz, Fsp and Grt. The gneiss base is overlain by amphibolite which is medium- to coarse-grained comprising mainly Hbl, Pl, Qtz, Cpx and Grt. Two types of amphibolites are distinguished: (1) banded amphibolite shows a cm-scale lamination of dark Hbl-Pl-Qtz layers and pale Cpx-Hbl-Pl-Qtz layers together with abundant leucosomes; and (2) homogeneous, dark green amphibolite comprising Hbl, Pl, Qtz and Grt with local leucosomes. Rocks which occur less abundant include brownish paragneiss containing Grt, Sil, Ky, Mag, Qtz, Pl, Bt and Oam and locally small lenses of marble within the paragneiss. This lithology was intruded by various generations of pegmatite dykes and, later, by Palaeoproterozoic dolerite dykes. The contact between the supracrustal rocks and the ancient gneiss is always tectonic. The rocks are metamorphosed in amphibolite- to granulite- facies and show in detail a complex and polyphase metamorphic history. Although the tectonic history is complex involving several deformation phases (D_1-D_4) which are not discussed here, the structure is dominated by synform-antiform pairs, which is apparent from the large-scale F_3 folded amphibolites seen on the map (Fig. 1).

The geology and the potential for hydrothermal mineralisation were investigated by two detailed geological profiles located in the amphibolites in the central part of the island (Figs. 1 & 2).

The lithology studied from the two profiles (Fig. 2) consists of weakly altered Hbl-Pl-rich amphibolite of type 2 in the structural footwall and type 1 in the structural hanging wall, Bt-, Sil- and Grt-rich schists, quartz veins and pegmatites. A hydrothermal alteration zone elevated in gold (up to 672 ppb) is located in an about 8 m wide zone, which contains numerous quartz veins and sulphides in Bt- Grt-and Sil-rich schist (Fig. 2; profile A). This zone is easily identified by its characteristic rusty and stained surface. In detail, several horizons, each about one meter wide, occur in this zone. Each of these horizons consists of a distinct hydrothermal alteration assemblage, comprising Bt, Qtz, Grt, Po, Py, Ccp and, locally, Sil and Tur (Fig. 2). The quartz veins are 10-20 cm wide and locally several parallel veins form a laminated texture. The veins are parallel to the main foliation and can be followed along strike over several hundred meters, whereas, locally, sigmoidal extension veins crosscut the foliation. In places, they are sheared off or boudinaged due to flexural slip folding of the regional syncline structure. Quartz veins of about 10 cm width lacking hydrothermal alteration halos occur in the structural hanging wall (Fig. 2, profile B). Samples from these veins are only slightly elevated in gold. It appears that quartz veins characterised by a pronounced hydrothermal alteration halo are more favourable to contain gold. At station 08bms110 about 180 m north of profile B (Fig. 2), about one meter wide Bt- and sulphide-rich schist contains several quartz veins with 769 ppb gold. The rocks analysed (Fig. 2) are beside the elevated Au contents, not elevated in any other elements, except of some samples being slightly elevated in As and Ba.

Quartz veins elevated in gold also occur in an about 10 m wide zone in the northernmost part of Qilanngaarsuit island (station 08bms104; Fig. 2). In detail, this zone consists of marble and paragneiss at the contact with amphibolite of type 2. The quartz veins have been chipped over the entire zone and returned 52 ppb gold. Other quartz veins containing green, fuchsitic Ms are widespread and occur structurally controlled at various tectono-stratigraphic levels. However, these quartz veins lack a characteristic alteration halo and are, notably, also barren of gold.

Interestingly, stream sediment samples taken in the northernmost and southernmost part of the greenstone belt on Qilanngaarsuit island (stations 08bms113 and 08bms96; Fig. 1) also yield elevated gold above 25 ppb, which underlines the gold potential of the area and suggest that the Au-zone can be traced on surface for several kilometres.

Because the narrow quartz vein systems with elevated gold (Fig. 2) are only enveloped by relatively narrow proximal and distal alteration envelopes and a regional scale alteration system is absent, it is suggested that new gold showings at Qilanngaarsuit island represent an epigenetic rather than a syngenetic mineralisation. Furthermore, rocks of the proximal alteration zone have a relatively high Na and Ca content and are enriched in K, which suggests that potassium was added during hydrothermal alteration, which is documented from epigenetic gold deposits elsewhere.

The Godthaabsfjord is now recognized as a gold province and the recently found anomalous gold zone on Qilanngaarsuit island is situated along the south-western strike extent of the known Godthaabsfjord occurrences (i.e.; Storø, Qussuk). Although gold detected in this work is below one ppm, it is conceivable that additional systematic work such as channel sampling of surface profiles and drilling may identify zones with higher gold than what is known to date and the results also suggest that there is a good potential for finding additional gold anomalous zones in the other Archaean supracrustal between Nuuk and Qilanngaarsuit island.

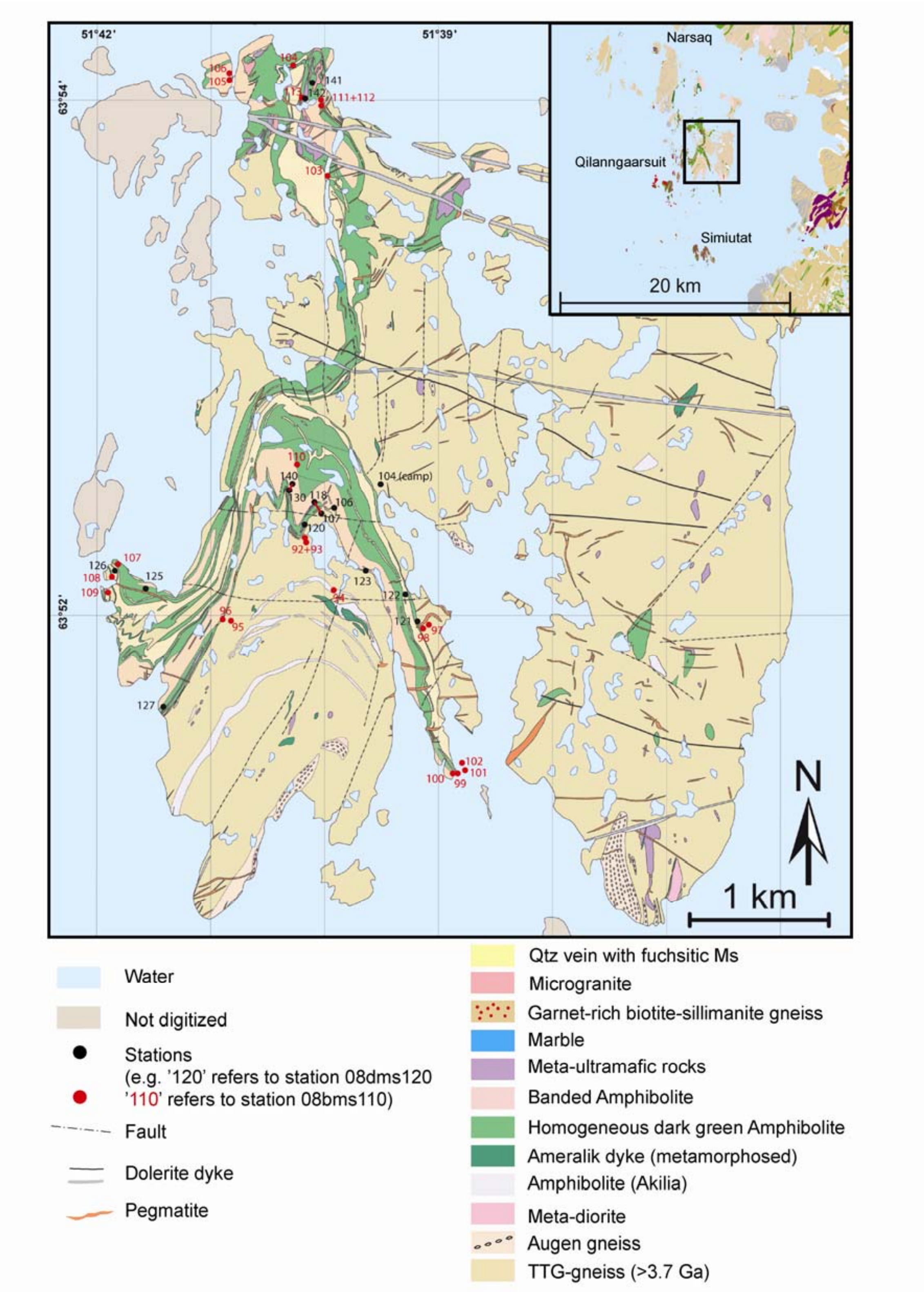


Figure 1. *Schematic geological map showing the studied locations on Qilanngaarsuit island (redrawn after a field map from Chadwick 1974, GEUS archive). The rocks of the Malene supracrustal assemblage form large-scale F_3 synform-antiform pairs. Two profiles in the central part of the island have been studied in detail and are indicated by red lines. One sample from profile A (station 107 to 118) returned 672 ppb gold.*

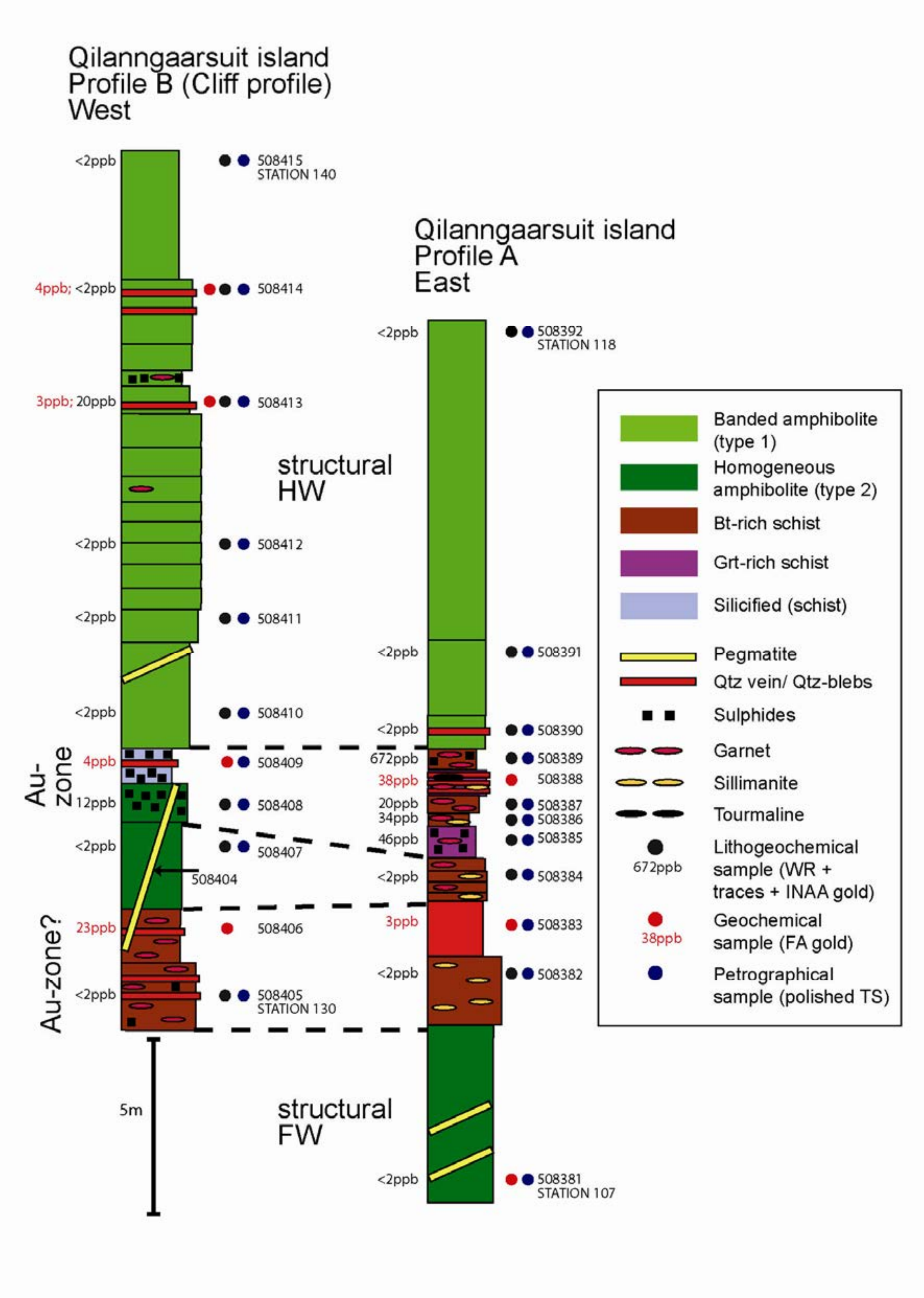


Figure 2. *The two profiles from the central part of the Qilanngaarsuit island are located about 250 m apart, between stations 08dms107 to 118 and stations 08dms130 to 140, respectively. The Au-zone is located in Bt-rich schist and can be correlated between the two profiles.*

GanFeld: introduction and news

Denis Martin Schlatter & Uffe Larsen

GEUS is carrying out geological expeditions in Greenland during the short arctic summers. In the past, field books together with sample tag books were used to register the field data and observations. As GIS and GPS technologies have improved drastically over the last few years and powerful PDAs are now available, GEUS has decided to use a mobile solution to capture field data, which is also a better and easier way to store afterwards the data into the GEUS databases.

It has quickly materialised that GanFeld developed and applied by the Geological Survey of Canada (GSC) was the most advantageous solution with respect to digitally captured field data in Greenland.

GanFeld allows to systematically capturing data in an organised manner and allows compulsory data to be collected. This is of particular interest as GEUS typically carries out expeditions together with external collaborators. Furthermore, GanFeld uses ArcPad which is an ESRI product that GEUS is already familiar with and has acquired the license.

GanFeld furthermore allows flexibility with respect to modifications and changes which are specific for geological field work in Greenland. During the spring of 2008, the GSC has helped to implement the digital field data capturing at GEUS and, during the summer 2008, the first pilot project was carried out in Southern West Greenland (Buksefjorden area).

All field geologists were equipped with HP iPAQ PDA’s and with wireless GPS receivers (tomtom), and the system has been extensively tested. Power supply in the field was provided by either generators or by sun cell systems. Suitable geo-referenced base maps such as geological and geophysical maps were used as layers directly on the PDA.

The pilot project has shown that the PDAs are robust against humidity, rain and snow; that they are relatively modest with respect to energy consumption and that the PDAs work fine in strong sun light. Although a tablet PC is more powerful than a PDA, the latter fits into a vest or a pocket and is thus more suitable for field work in remote arctic alpine terrain.

Typically a remote base camp is centrally located and provides services to small flight camps. The field base camp was responsible for collecting and storing the field data, which were exchanged with the flight camps via SD (Secure Digital) Memory Card on a weekly basis. The base camp also produced overview maps, showing the field activities of each field team. This allowed monitoring the progress of the expedition and also permitted briefing of the management about the status of the field work.

The use of GanFeld in Greenland during the summer 2008 resulted in a comprehensive data-set, which in turn allowed to evaluate the data by the GEUS data centre and to build a data model. Based on the past experience with GanFeld, GEUS is now implementing certain changes and modifications to the software.

In detail, we plan to modify code lists, we will add new fields and we will change the interface slightly. The data model in the Oracle database has been altered so that it can handle the data from GanFeld. A module with the purpose to transfer data from GanFeld to the Oracle database has been programmed. This module also checks data and generates lists with errors, which have to be corrected. In detail a routine is being built where the field data are stored in the Oracle database. It is the purpose to make the data accessible via an internet platform in order to allow editing of the field data by external collaborators.

These changes will allow using the digital data capturing system optimally in future Greenland expeditions. Although for the moment only the Economic Geology and the Mapping department used GanFeld, it is conceivable that in the future other departments at GEUS will use this technology.

International dialogue with colleagues from other surveys in Europe and elsewhere with respect to the use of digital data capturing is ongoing.

GanFeld: Reporting of collected field data

Frands Schjøth

Denis Martin Schlatter, GEUS and Uffe Larsen, GEUS are working with the software and hardware for capturing data in the field using GanFeld and getting the data stored in GEUS's central database (see "GanFeld: introduction and news" by Denis Martin Schlatter & Uffe Larsen).

I am working on how to easily get the GanFeld data out in a report style for use in e.g. a field report. The GanFeld software creates 5 dBaseIV files **Station**, **Earthmat**, **Sample**, **Structure** & **Photo** (has the extension ".dbf" and can read by Excel spreadsheet) and it is the GanFeld software on the PDA which controls the links between the data files. When the 5 DBaseIV files are copied to a laptop it is also possible to work with them using the GanFeld software if the ArcPad software also is installed on the laptop, but still you do not have all data visual at one time on one page.

I have used Crystal Report for ESRI (provided at no cost on ArcGIS version 9.3, by ArcGIS higher version you have to buy a license) as a generator to a report. The unique id for linking the 5 DBaseIV files together is the "station-id" in the file **Station** and through the file **Earthmat** using the "earthmat-id" it can be linked to **Sample** & **Structure**. The file **Photo** can be linked directly by "station-id". I only provide data from fields that have content, so for empty fields the heading of the field and the empty content are dynamically omitted in the report.

An example of a report I have used Bo Møller Stengaard's data from field season 2008 and only page 2 of 140 pages.

Station

08BMS002

Latitude=	63,96987	Entry type=	GPS
Longitude=	-51,28098	Pdop=	5
Easting=	486242	Sat used=	6
Northing=	7093687	Visit date=	27-06-2008
Elevation=	614 Elevation method= bluetooth-GPS	Visit time=	09:23:53
Altimeter=	0	Partner=	Annika Dziggel
Obs type= outcrop		Plotval=	S002
Trav no=	2 Air photo=		

Station note: Since last station note:

gneiss - marked as biotite schist on the map¬

Earthmat

08BMS002

08BMS002A

Earthmat letter= A

Material: metamorphic

schist (schist< 1cm)

Colour: black

Map unit:

Mineral assemblage: Pl | Qtz | Hbl | Grt

Mineral fabric: mafic amphibolite, banded, with lots of white leucosomes.

60 pct mafic minerals, 15-20 pct garnets, rest is leucosomes

Metamorphic grade: amphibolite

Texture: agmatitic

Notes: Mafic pod with leucosomes that are garnet bearing. The mafic pods are boudinage in relative mafic biot rich plag-amphibole schist¬ /gneiss. The leucosome melts cotain garnets - between 0.2-1 cm in size. The leucosomes are generally ll to the foliation

Sample

08BMS002

08BMS002A

08BMS002A-01

GGUno = 515113

Sample number: 1

Sample type: rock hand RS

Sample orientation:

Sample dep: 0

Purpose: metamorphism | geochem general

Notes: Sample of the mafic amphibolite pod with garnet-bearing (rich) leucosomes.

Sample

08BMS002

08BMS002A

08BMS002A-02

GGUno = 515114

Sample number: 2

Sample type: rock hand RS

Sample orientation:

Sample dep: 0

Purpose: metamorphism | geochem general | petro thin section

Notes: Sample of the biot rich schist¬ /gneiss. check for other minerals.

Structure

08BMS002

08BMS002A

08BMS002A-01

Structure number: 1

Class: planar

Structure type: foliation

Detail: inclined, first generation

Method & readings: Trend-Strike / Plunge-Dip

210 / 26

Sym ang: 210

Relative age: 0

Notes: 2nd meas. 200/27

Lineation 220/25

s-c' fabric (see AD picture)

normal s-c fabric also obs. = top to the north

Symbol: 18

Photo

08BMS002

08BMS002P01

Photo number: 1

Category: minor lith.

File number: 1

File name: 08BMS0001.jpg

Direction: 0

Caption: picture of outcrop. pict no 1541-1545 - the mafic pod with leucosomes and the biot rich scist¬ /gneiss

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Figure 1. Example of report using Crystal Report for ESRI on Bo Møller Stengaard's Gan-Feld data form field season 2008 page 2 of 140 pages.

The Fiskenæsset Anorthosite Complex

John S. Myers

Thin, stratiform layered anorthosite complexes are a distinct feature of the Archaean Earth. They are characterised by megacrysts of equidimensional calcic plagioclase (~ An 80-85) commonly up to 5 cm in diameter. All known examples of these Archaean anorthosite complexes have been repeatedly fragmented by igneous intrusions and tectonic processes, strongly deformed, and extensively recrystallised. The Fiskenæsset complex is one of the best exposed Archaean anorthosites, with the best known igneous stratigraphy and tectonic history. In addition, it contains well preserved igneous structures and, to a lesser extent, igneous minerals. The stratigraphy and structure of the complex were mapped by GGU during the 1970's, accompanied by investigations of petrography, mineral chemistry, whole rock geochemistry and mineral potential.

The Fiskenæsset complex comprises seven major lithostratigraphic units which are, in ascending order: lower gabbro (50 m), ultramafic (40 m) lower leucogabbro (50 m) middle gabbro (40 m), upper leucogabro (60 m), anorthosite (250 m) and upper gabbro (50 m) (Myers 1985). Within these units several sub-units are recognized based on composition, texture and structure. Igneous structures include mineral-graded layers, size-graded layers, trough-layers, snowflake structures and slump structures. A few small portions of roof contact with basaltic metavolcanic rocks, now amphibolite, can be seen but the original basal contact of the layered intrusion has not been observed and so the original thickness of the Fiskenæssset complex is unknown. Small pipe-like bodies of mafic pegmatite cut across igneous layering in the lower leucogabbro, middle gabbro and upper leucogabbro units and were emplaced by magmatic drilling associated with pulsating turbulent flow of magma and rock fragments.

A detailed study of the whole rock geochemistry of the Fiskenæsset anorthosite complex and spatially associated metavolcanic amphibolite by Bailey, Gwodz and Myers indicated that the anorthosite complex and associated metavolcanic rocks were derived from similar tholeiitic magmas. The study included whole rock XRF and neutron activation analyses of up to 50 elements in each of ~ 200 samples, including ~ 150 stratigraphically controlled samples located on the measured sections in Myers (1985). Another study of major elements and 14 trace elements in 100 samples from a small part of the Fiskenæsset complex and associated amphibolite reached a similar conclusion (Weaver *et al.* 1981).

The magmas that formed the Fiskenæsset complex were emplaced in multiple pulses during at least three major intrusive episodes (1. lower leucogabbro + ultramafic + lower leucogabbro units; 2. middle gabbro unit; 3. upper leucogabbro + anorthosite + upper gabbro units) based on composition and igneous structures. The complex does not represent the crystallisation of a single magma chamber but formed from numerous sheet-like intrusions of magma emplaced into both solidified and unconsolidated previous injections of magma. Subsequently, the whole stratiform complex was fragmented by the intrusion of sub-concordant sheets of tonalite associated with thrusting between ~ 2.9 - 2.8 Ga. This tectono-magmatic stratigraphy was folded into large recumbent nappe-like structures, and then refolded into dome-and-basin fold interference structures by two sets of folds with steep axial surfaces at high angles to each other.

Economic exploitation of the Fiskenæsset complex has been restricted to the extraction of rubies, however, the economic potential of several other rocks and minerals have been investigated. Thin, discontinuous layers of chromite are widespread in the ultramafic, upper leucogabbro and anorthosite units and have been studied in most detail by Ghisler (1976).

The PGE content of the Fiskenæsset complex was found to be low but there is a gradual increase in Pd/Pt upwards related to overall igneous differentiation (Page *et al.* 1980). However, there are significant variations related to different episodes of intrusion, and PGE's are concentrated in some individual small batches of magma. Where the latter were associated with magmatic currents and formed ultramafic channel deposits, these currents influenced both the concentration and location of the PGE's.

The primary thin, discontinuous nature of chromite and PGE-bearing rocks, their disruption and dispersion by thrusting and intrusions of tonalite and the complex tectonic structure, make their economic exploitation unlikely, unless in conjunction with quarrying of anorthosite and leucogabbro for alumina.

Molybdenite, typically platy crystals 2-3 mm across and other smaller sulphide minerals are disseminated throughout the Fiskenæsset complex (Myers 1974). They are best seen where the rocks are least deformed and recrystallized but also occur in veins of anorthosite that cut across previously deformed anorthosite. The economic potential and significance of these sulphide minerals has not yet been investigated. Likewise, the economic potential of sulphide-bearing mafic pegmatite pipes that cut across the layering in the lower part of the Fiskenæsset complex and the economic potential for Fe and V in the magnetite-layered upper gabbro unit.

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Interim results of the PGE investigation in the Fiskenæsset anorthosite complex

Peter W.U. Appel, Per Kalvig, Ali Polat, Nikolay Rudashevsky, Vladimir Rudashevsky & Nikolay Stepanov

The first traces of PGE in the Fiskenaesset complex were found more than thirty years ago in a chromitite banded bronzitite on central Qeqertarsuatsiaat during GGU activities in the area. In the early seventies the first exploration for PGE was carried out in the anorthosite complex. However, no continuation of the bronzitite or other PGE-bearing rock units was found. In the early nineties limited sampling for PGE was carried out by GGU.

The strategy of the present project was to test whether a geochemical survey at two selected sites could reveal geochemical tracers revealing the presence of PGE-mineralisation. One 730 m long traverse was made across the complex on central Qeqertarssuatsiaq hosting the known PGE-bearing bronzitite; another traverse – 1775 m - was made across a suit of anorthosite, ultramafics, ‘amphibolites’ and gneisses at Sinarsuk, in the eastern part of the complex.

A total of two-hundred fifty-four samples from the two profiles have been run for Pt, Pd and Au (Fire Assay- ICP-MS), revealing elevated PGE values in ultramafics and amphibolites only, peaking 21 ppb Pt and 57 ppb Pd in the ultramafics.

In addition to the field work and the subsequent geochemical program laboratory investigations were carried out on a number of chip- and channel samples collected from an ultramafic unit on northern Qeqertarssuatsiaq by GGU in 1991; one sample running 6 ppb Os. The laboratory work carried out in Russia revealed the presence of a number of PGE minerals together with pyrrhotite, troilite, chalcopyrite, pentlandite, bornite, cubanite, covelite and violarite. Chemical analyses of the channel samples revealed grades up to 750 ppb Pd and 160 ppb Pt.

Shear zones and suture on tectonic boundaries in the Grædefjord region

Brian Windley

According to the model of Windley & Garde (2009) the craton of West Greenland contains six Neoarchaean crustal blocks, each of which has an upper zone of prograde amphibolite facies rocks on its southern side, and a lower zone of prograde granulite facies rocks partly retrogressed to amphibolite facies on its northern side. The tectonic boundary between the bottom of the Bjørnesund block and the top of the Sermilik block should occur just to the south of Grædefjord. If the crustal block model is correct, there should be major shear zone on this boundary, which in principle represents a suture between the two crustal blocks. Where the boundary comes down to the western coast a few kilometres south of Grædefjord, there is in fact a major, 400 m-wide, semi-vertical shear zone that consists of augen, mylonitic, cataclastic and banded gneisses. A prominent mineral and rodding lineation plunges moderately to the west. On the southern side of the shear zone amphibolite facies gneisses contain amphibolite lenses, some melt veins in which contain orthopyroxene demonstrating the former presence of granulite facies metamorphism. On the northern side of the shear zone there are prograde amphibolite facies gneisses with muscovite and epidote porphyroblasts, as pointed out by Kalsbeek (1976).

The upper zone of the Bjørnesund block is at least 50 kilometres wide, but the upper zone of the Sermilik block is only 4-10 kilometres wide. To answer the question of why this zone is so unusually narrow, the boundary between the lower and upper zones of the Sermilik block was examined on the northern side of Grædefjord. Here, a wrongly mapped mica schist is clearly a 250 m-wide, north-dipping shear zone containing banded, cataclastic, augen mylonitic gneisses with a prominent down-to-north rodding and mineral lineation and thrust-motion kinematic indicators. The lower zone of the Sermilik block has clearly been thrust to the south over the upper zone, which in consequence appears foreshortened.

The occurrence of these two major shear zones on predictable tectonic boundaries provides confirmation of the viability of the crustal block model.

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Metamorphism and host rock interaction with pegmatites

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Peak metamorphism in the Akulleq and Tasiusaruag has long been recognized as ranging from amphibolite facies to granulite facies, and ages of the peak metamorphism are ~2.7 Ga. The granulite facies is defined as the P-T condition at which hornblende in rock with basaltic bulk compositions breaks down to clinopyroxene and orthopyroxene, and the facies boundary is approximately isothermal (ca. 660-700°C) over a pressure range of about 2-14 kbar. Field observation in 2007 and 2008 are in accord with most of the mapped amphibolite-/granulite-facies boundaries except in the area approximately bounded by 63.5-64°N and 51-52°W; here the facies boundary may lie further to the southeast.

Scattered across the region are numerous small ultramafic bodies. Many of these ultramafic bodies have interacted with pegmatites. In most localities, the ultramafic rocks and the pegmatites form only coarse biotite and calcic amphibole; however, based observations made in the Summer of the 2008, we suggest that the spectacular sapphirine-, kornerupine- and corundum-bearing rocks from the Fiskenaesset region may also result from the interaction of fluid-rich granitic pegmatites. For the rocks with the aluminous assemblages, the scenario appears to be that granitic pegmatites intruded near, but probably after the peak metamorphism. Judging by the extent of the metasomatism, these pegmatites were fluid-rich, and this fluid drove reactions and exchange of material among ultramafic, country and pegmatitic rocks. Some of these kinds of aluminous reaction zones extend for tens to hundreds of meters. Some of the material for the reactions may be transported over distances that exceed outcrop scale. The general effect of the metasomatism suggests that (1) quartz, plagioclase and K-feldspar from the pegmatites and the anorthosites or quartzofeldspathic gneisses enclosing the ultramafic bodies all seem to have reacted extensively with the ultramafic rocks and (2) the fluids associated with the pegmatites have facilitated the reactions. Complete characterization of the metasomatism requires more study, but the metasomatic reactions have several basic types:

(1a) forsterite/serpentine + plagioclase => Ca-amphibole + Al2O3 (for aluminous minerals) ± albite
(1b) forsterite/serpentine + plagioclase + diopside => Ca-amphibole ± albite
(2) forsterite/serpentine + SiO2 => anthophyllite
(3) forsterite/serpentine + K-feldspar => biotite + anthophyllite
(4) diopside + K-feldspar => biotite + Ca-amphibole

For production of the aluminous assemblages of the Fiskenaesset region, an essential bulk compositional requirement is that enough reactive forsterite/serpentine is available to convert all the anorthite component of the plagioclase to hornblende + "Al2O3" and to eliminate free quartz from the environment (reactions 1a, 2, 3). These effects result in Al-rich silicates like cordierite, sapphirine and kornerupine and corundum, which would be incompatible with free quartz, set in assemblages with abundant phlogopite, calcic amphibole and orthoamphibole. The most likely sources of the fluids that enhance the metasomatism are the pegmatites. The pegmatite veins have been observed in close proximity to both sapphirine- and corundum-bearing rocks and the common occurrence of kornerupine, which is commonly boron-bearing, further suggests fluids derived from a pegmatite source.

In the majority of cases, ultramafic rock and the pegmatites form only coarse biotite and calcic amphibole and lack the aluminous assemblages. The assemblage that is produced may be due to many factors, but the bulk composition of the ultramafic may be the key. Detailed work on a reaction at locality 07JCS045 (63°59'39.78"N, 51°22'47.79"W) shows a marked decrease in modal clinopyroxene from the ultramafic rock as the coarse hornblende develops. Hornblende and new apatite from these metasomatic reaction zones adjacent the pegmatite veins are enriched in fluorine and chlorine confirming the contribution of the pegmatite fluid. In this example, quartz and plagioclase (An30-35) is still present in the pegmatite vein, but K-feldspar has been almost completely lost. This suggests reactions 1b and 4 dominated in this reaction zone.

Study of the ultramafic rock and the pegmatite reaction zones many provide a better understanding of the post-peak metamorphism and the factors that control mineralization associated with the ultramafic rocks.

Major crustal features of the southern part of the North Atlantic Craton reflected in geochemical, aeromagnetic and aeroradiometric data

Agnete Steenfelt

The southern part of the North Atlantic Craton (NAC) extending from 61° to 64° N in West Greenland (Fig. 1) has been the target of a number of geochemical and geophysical surveys with regional coverage that have been acquired by GEUS and commercial companies (see references). Geochemical data are based on systematically collected samples of stream sediment (fine fraction and heavy mineral fraction) and till (heavy mineral fraction), and geophysical data are based on airborne magnetic and radiometric recordings. The geochemical and geophysical maps based on the data exhibit regional variation patterns that are variably related to known lithological units and enhance characteristics that have not been recognised during geological mapping. Rock chemical data obtained by GEUS are not systematic in nature and are not suitable for illustrating regional variation, but they can be used to ascertain the lithochemical control of the surface or airborne data.

The variation in lithophile and rare earth elements reveals interesting changes in the chemistry of orthogneiss complexes, the main component of the exposed crust of the NAC. A conspicuous zone of elevated magnetic response is correlated with high Sr and high La/Yb ratio in stream sediments and rocks. The zone comprises both granulite and amphibolite facies domains, and it is interpreted to reflect magmas derived from metasomatised mantle. The remaining orthogneisses have signatures compatible with slab-derived magmas. The variation in exposed crustal level is particularly shown by the variation pattern for U in stream sediment.

Two major granitic plutons, the Ilivertalik and Neria granites, have diverse chemical characteristics, which have implications for their origin and mineral potential. The Neria granite, being a high-heat-producing (radioactive) granite intruding into supracrustal sequences at a high crustal level, has a high mineral potential, while the Ilivertalik granite representing remelted orthogneisses at low crustal level has a low mineral potential.

The Fiskenæsset complex is reflected in stream sediment Cr and Co distribution, and the major supracrustal belts, Bjørnesund, Ravns storø, Kvanefjord, Isorsua, Târtoq are distinctly reflected in the surface and airborne data. The Târtoq belt is the only Archaean supracrustal sequence with strong As enrichment. The gold potential appears better in the southernmost belts.

Major shear or fault zones are outlined by the aeromagnetic data, and some elevated U and Au values in stream sediment suggest hydrothermal mineralisation within these zones.

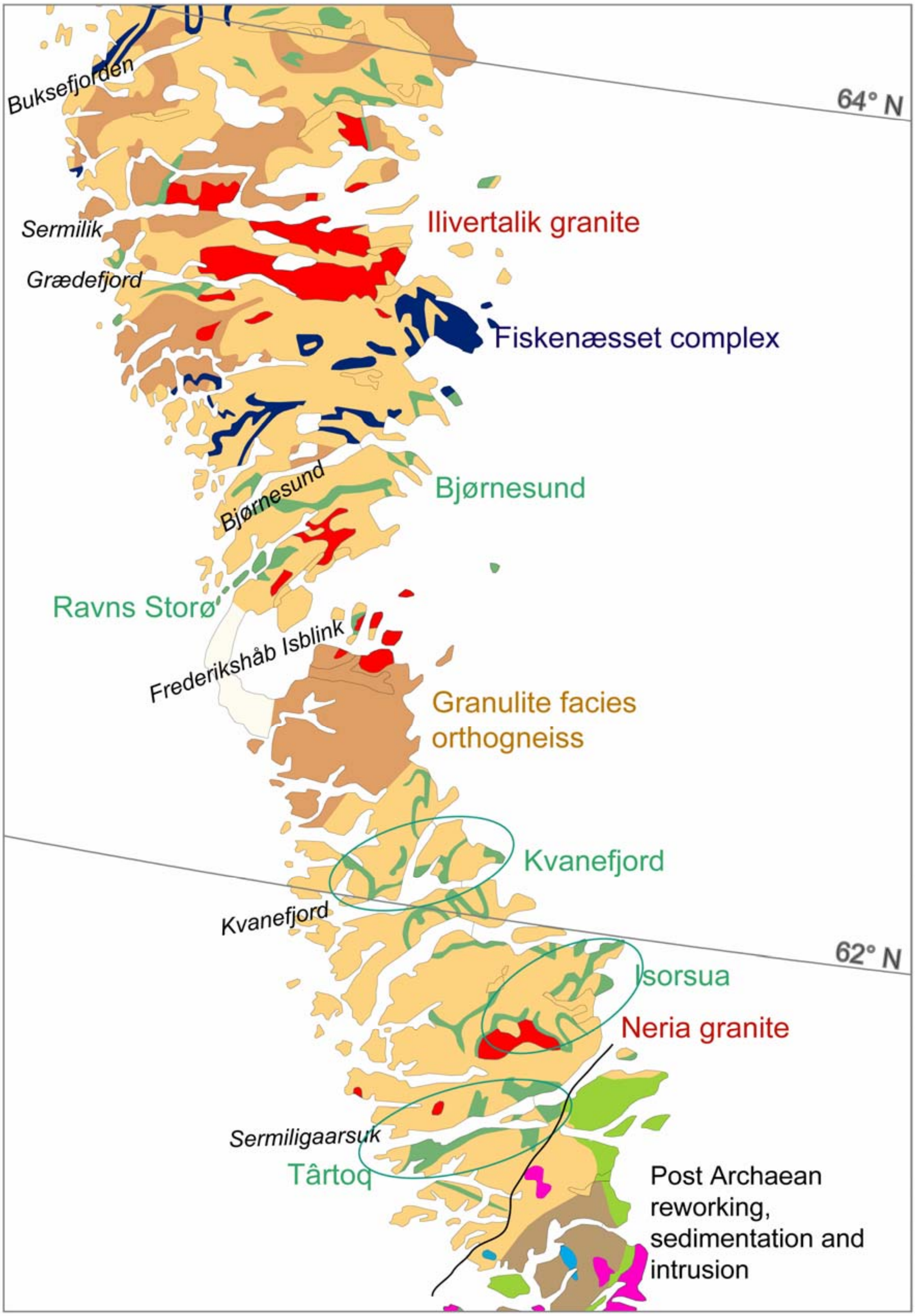

Figure 1. *Major lithological units and place names within the southern North Atlantic Craton in southern West and South-West Greenland. Light beige colour is amphibolite facies orthogneiss. Based on 1:2500000 scale map by Escher & Pulvertaft (1995).*

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Tourmaline as a comprehensive petrogenetic indicator mineral

Vincent van Hinsberg, John Schumacher & Gerhard Franz

Minerals are our best source of information on conditions and processes in the Earth's interior. The presence or absence of a mineral as well as its chemical and isotopic composition can act as precise indicators of the pressure, temperature and chemical conditions at depth. Tourmaline is especially suited as a petrogenetic indicator mineral, due to its singularly large stability range in pressure and temperature (early diagenesis up to 950°C and 70 kbar), and bulk rock composition (altered MORB to granite, pelite and impure limestone). It is further characterised by highly variable trace element chemistry, which, in combination with negligible diffusion rates, allows it to capture and preserve a chemical signature of its environment.

Recent work on tourmaline is providing the tools to read this record. Element partitioning between tourmaline and fluid has been shown to be systematic and predictable (von Goerne & Franz 2000; von Goerne *et al.* 2001), allowing tourmaline composition to be used to reconstruct the chemistry of associated fluids. Furthermore, compositional variations due to sector zoning, which is a ubiquitous property of metamorphic tourmaline, has been shown to be a sensitive indicator of temperature, allowing complete temperature histories to be reconstructed from individual, growth zoned tourmaline grains (van Hinsberg & Schumacher 2007). Relative pressure information can further be derived from the K-content of tourmaline in well-constrained host rocks. Isotopes complement this and can provide information on element sources (e.g. B and Pb-isotopes) as well as allow for dating of individual tourmaline growth zones (e.g. Ar-Ar dating).

Combined, this makes tourmaline a truly powerful monitor of its environment. Furthermore, tourmaline is a highly refractory phase, with negligible diffusion of elements even at elevated temperature. It is largely unaffected by deformation or reworking events, preserving its information into the sedimentary record (van Hinsberg & Schumacher 2007). When its composition is modified, this is directly evident in disturbed sector zoning textures. This robustness makes tourmaline an especially attractive source of information on the conditions in the Archaean. Aside form reconstructing the conditions for Archaean rocks, this information can also be used in comparative studies to probe the principle of uniformitarianism.

In this presentation these various issues will be addressed as well as their applications to the field area.

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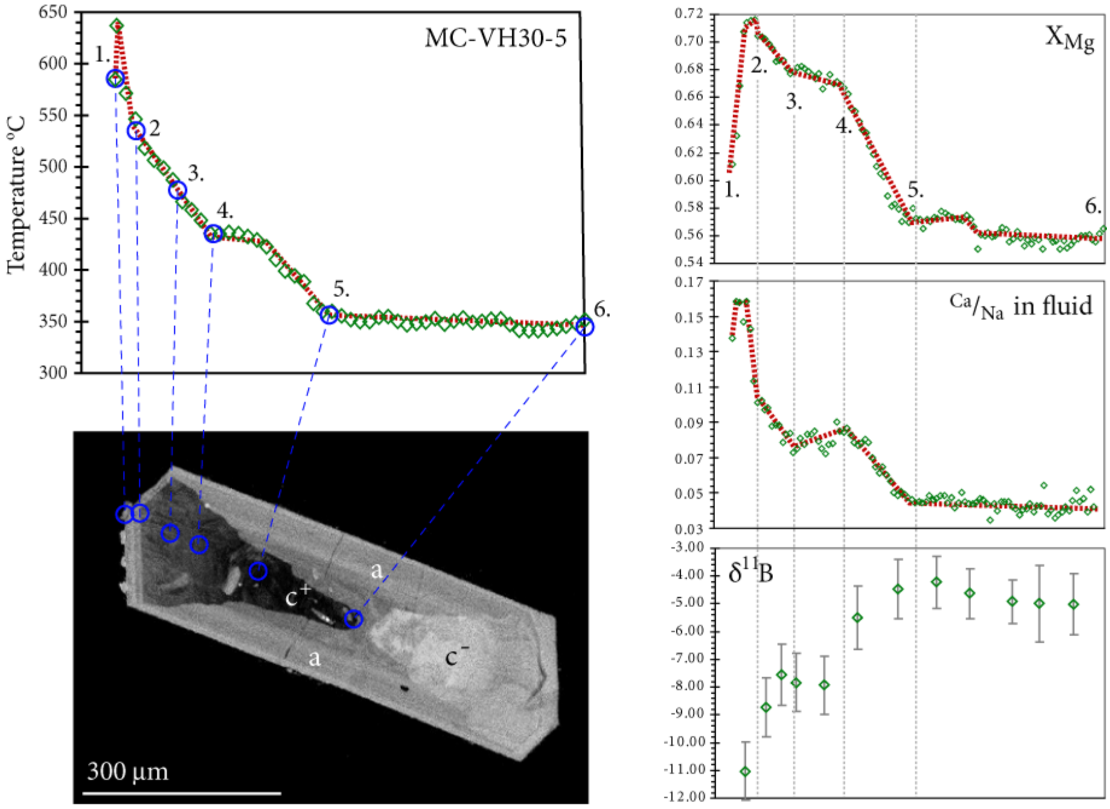

Figure 1. *Example of the use of tourmaline as a petrogenetic indicator mineral for a growth, and sector zoned tourmaline grain from the Desges Valley metapelites of the French Massif Central. Inter-sector thermometry reveals nucleation at 350°C, followed by a progressive temperature increase towards peak metamorphism (independently estimated to be 650°C at 7kbar) The outermost zone represents a thin retrograde growth. Combining this temperature information with mineral-fluid partitioning data allows the Ca-Na ratio of the fluid to be reconstructed. This shows a smooth overall increase towards peak metamorphism, except for a kink at position 4, which we have been able to link to Ca-release in the garnet + chlorite = biotite + staurolite reaction. B-isotopic signature shows a consistent decrease, in agreement with closed-system fractional incorporation of B.*