DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2002/9

Workshop on Nagssugtoqidian and Rinkian geology, West Greenland

Abstract volume

Edited by Bo M. Nielsen and Kristine Thrane

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Contents

Introduction

This report present the programme and the abstracts for the:

Workshop on Nagssugtoqidian and Rinkian geology in West Greenland

held at GEUS, Copenhagen, February 22-23, 2002.

The workshop is organised as part of the performance contract with the Ministry (activity 4.1 and 4.2). The aims of these activities are a regional geological investigation of the region between Nordre Strømfjord and Ilulissat leading to compilation of a 1:500 000 geological map sheet, and a mineral resource assessment of an area from Maniitsoq (Sukkertoppen) to Nuusuaq. The workshop deals with aspects of the Nagssugtoqidian and Rinkian geology in West Greenland, both on regional and more local scale. Presentations report results from fieldwork in 2001 and follow-up laboratory work, as well as some aspects of associated projects in the area, both recent and older. The work was carried out jointly by the GEUS departments of Economic Geology and Geological Mapping together with collaborators from other institutions.

Participants at the workshop are from the following institutions:

British Geological Survey
Danish Lithosphere Centre
Geological Survey of Denmark and Greenland
University of Aarhus
University of Copenhagen
Université Henri Poincaré Nancy
University of St. Andrews
University of Texas at Austin
University of Wroclaw

The organisers of the meeting are:
Jeroen van Gool, Kristine Thrane and Bo Møller Nielsen (all GEUS).

Workshop programme

Official programme Friday 22nd February:

9.00 – 9.15	Welcome. Leif Thorning & Christian Knudsen (GEUS)
9.15 – 9.45	General introduction to the Nagssugtoqidian orogen – what do we know? Jeroen van Gool (GEUS)
9.45 – 10.05	The Nagssugtoqidian-Rinkian orogens in a North Atlantic context current models and challenges. Jim Connelly (The University of Texas at Austin) & Jeroen van Gool (GEUS)
10.05 – 10.25	Dating the Nagssugtoqidian: a historical review. Feiko Kalsbeek (GEUS)
10.25 – 10.45	Mineral resource potential of Precambrian rocks (66°N - 70°15'N), West Greenland: current ideas and problems. Henrik Stendal (GEUS)
10.45 – 11.00	*Coffee break*
11.00 – 11.20	A laser ablation approach to common Pb studies of Archean gneisses, Nagssugtoqidian orogen. Eirik Krogstad (Danish Lithosphere Center)
11.20 – 11.40	Geochemical variation from Nagssugtoqidian to Rinkian. Agnete Steenfelt (GEUS)
11.40 – 12.00	Crust thicknesses in Greenland, what do we know today? Trine Dahl-Jensen (GEUS)
12.00 – 12.20	Ongoing interpretation of geophysical data from the Nagssugtoqidian and Rinkian orogen, West Greenland. Bo M. Nielsen & Thorkild M. Rasmussen (GEUS)
12.20 – 13.20	*Lunch break*
13.20 – 13.40	Studies of kimberlitic rocks in the Kangerlussuaq region, southern West Greenland. Sven M. Jensen *et al.* (GEUS)
13.40 – 14.00	Mantle xenoliths in West Greenland kimberlites. Henriette Hansen (GEUS)
14.00 – 14.20	Plans on M.Sc. study, based on field work 2001. Uni Àrting (University of Copenhagen)

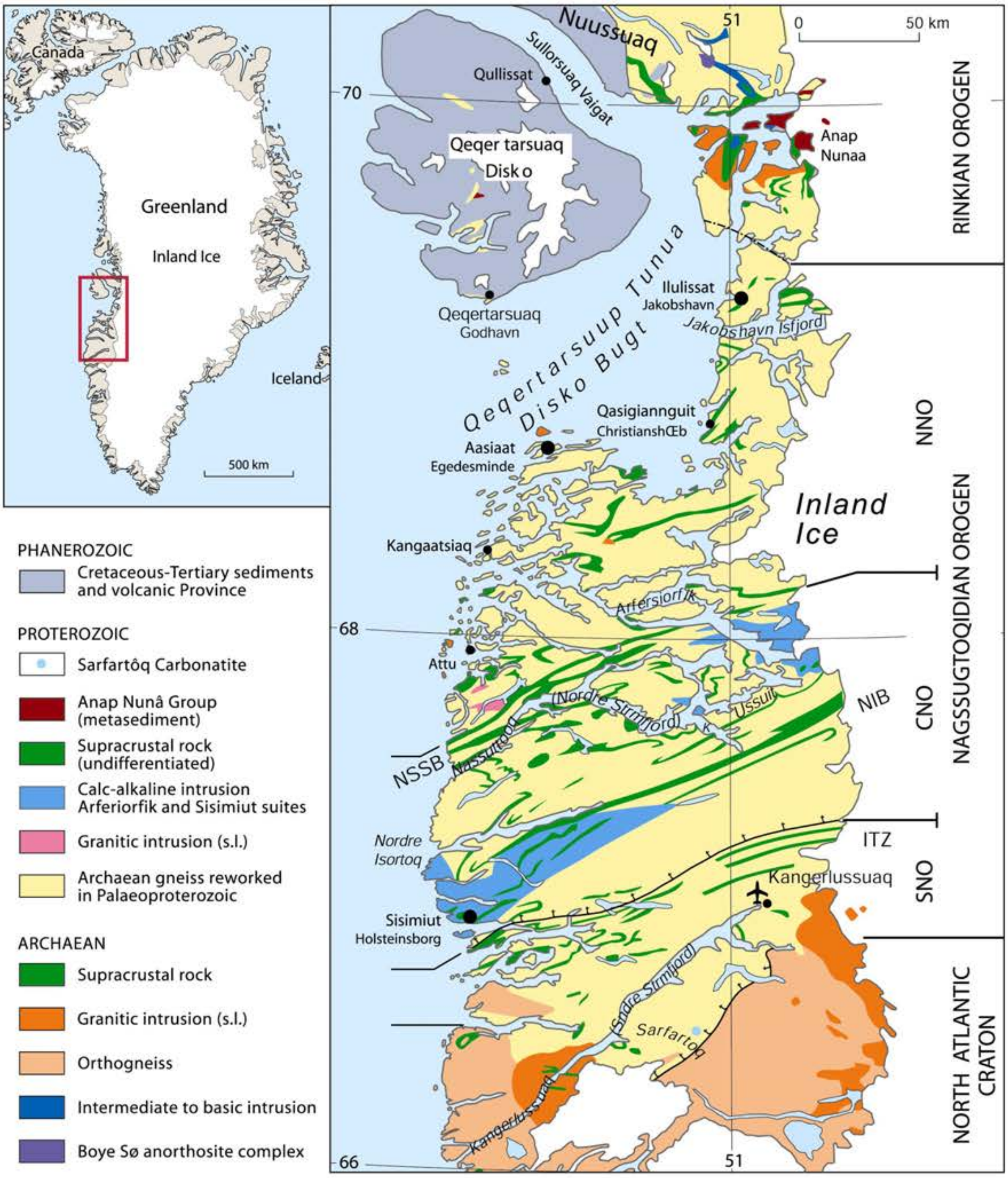
14.20 – 14.40	What will Robert do in West Greenland the next 5 years? Robert Frei (University of Copenhagen)
14.40 – 15.00	*Coffee break*
15.00 – 15.20	A re-evaluation by boat of the Precambrian region east of Disko Bugt. Adam Garde (GEUS)
15.20 – 15.40	Preliminary U-Pb ages from the Disko Bugt region. Kristine Thrane (GEUS) & Jim Connelly (The University of Texas at Austin)
15.40 – 16.00	First impression on structural evolution of the northern Nagssugtoqidian foreland. Stanislaw Mazur (University of Wroclaw)
16.00 – 16.20	Patterns of regional deformation associated with pegmatite emplacement geometries, Kangaatsiaq, West Greenland. Ian Alsop (University of St. Andrews)
16.20 – 16.40	First insights in the metamorphic evolution of metasedimentary sequences from the Kangaatsiaq and Lersletten area: Differences and similarities to rocks from the Ussuit Area, inner Nordre Strømfjord. Sandra Piazolo (GEUS)
16.40 – 17.00	Conclusion and questions revealed under the first workshop day. Jeroen van Gool (GEUS).

Official programme Saturday 23rd February:

10.00 – 10.05	Welcome.
10.05 – 10.25	The geology of the Ikamiut Peninsula, Sydostbugt. Chris Thomas (British Geological Survey)
10.25 – 10.45	Was the Kangaatsiaq-Lersletten area affected by the Nagssugtoqidian orogen, and if so, to what extent? Adam Garde (GEUS)
10.45– 11.05	The Precambrian supracrustal rocks in the Lersletten region and preliminary conclusions on associated massive sulphide mineralisation. Claus Østergaard (GEUS)
11.05 – 11.25	*Coffee break*
11.25 – 11.45	Review of the work in the Liverpool Precambrian Boundary Programme in the Sisimiut - Itilleq area of the southwestern Nagssugtoqidian Orogen. John Korstgård (University of Aarhus)

11.45 – 12.05	Old and new perspectives of the Nordre Strømfjord shear zone. Kai Sørensen (GEUS)
12.05 – 12.25	Pyrrhotite occurrences SSE of Simiutannguaq, Nordre Strømfjord, West Greenland. Heine Buus Madsen (University of Aarhus)
12.25 – 13.30	*Lunch break*
13.30 – 14.00	Granite petrology and geochemistry in the South Indian Dharwar Craton: geodynamical implications. Jean-Francois Moyen (Université Henri Poincaré Nancy)
14.00 – 14.30	Introduction to data available in the ArcView Interface: What is there? What has been done? What will be done? What should be done? Sandra Piazolo & Jeroen van Gool (GEUS)
14.30– 17.00	Discussion

Map of West Greenland (66ºN to 70º30’N)



Abstracts

Patterns of regional deformation associated with pegmatite emplacement geometries, Kangaatsiaq, West Greenland

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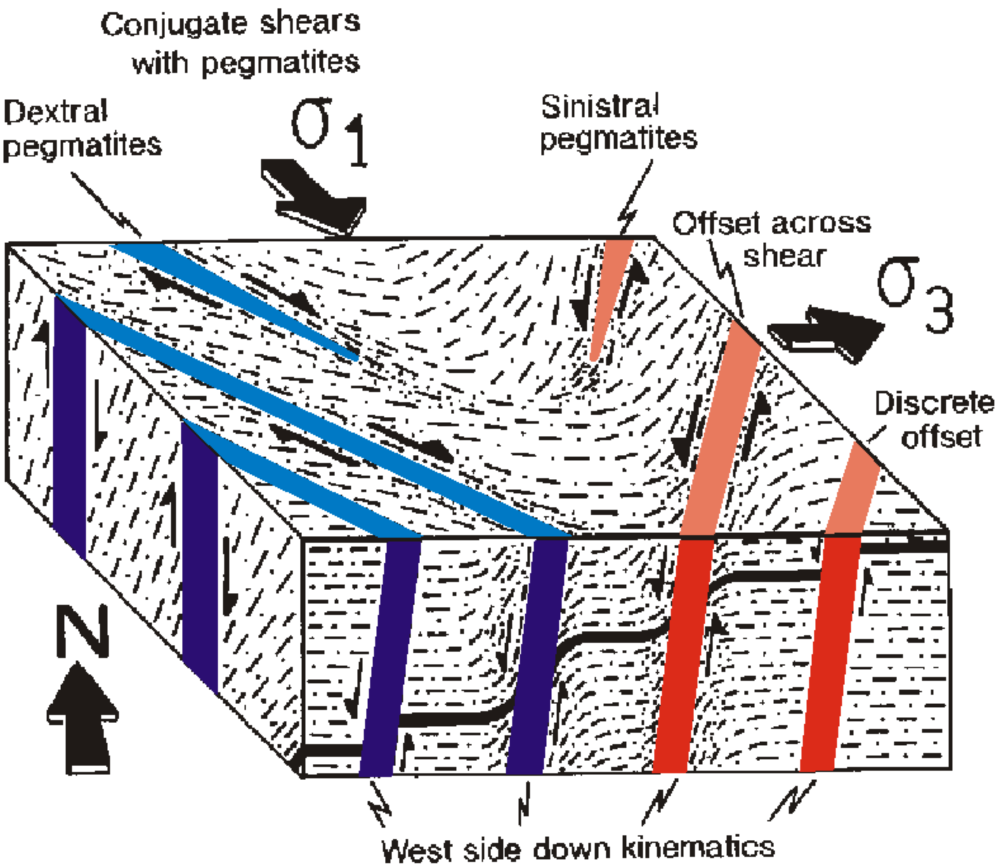
The Precambrian gneiss terrane of western Greenland comprises upper amphibolite to granulite facies gneisses which were intensly deformed during Archaean and ? Proterozoic orogenesis. The typically banded ortho and para gneisses contain foliation -parallel pegmatitic melts which are cut by E-W trending moderately South dipping shears associated with consistent South-side down kinematics. These extensional shears typically contain pegmatitic material and are most common in the northern parts of the mapped area South of Disko Bugt.

Extensional shears are subsequently overprinted by a consistent, conjugate pattern of late-stage regional shear zones associated with granitic pegmatite emplacement covering some ~4,000 km^2 south of Disko Bugt. NE-trending sub-vertical pegmatites are typically < 1m thick, and associated with decametric scale sinistral shear zones, whilst SE-trending pegmatites contain strike-slip lineations and relate to dextral shear. Both sets of shears interact with one another, thus demonstrating contemporaneous development which may have been further facilitated by the input of melt and fluids. Although pegmatites display intimate sheared margins, they do not contain a pervasive shear zone fabric indicating that they did not concentrate and localise later deformation. Increasing displacement gradients along individual shears are marked by a thickening of the associated pegmatite, thus highlighting the syn-tectonic nature of the intrusions. Co-planar systems of brittle-ductile shears associated with en-echelon fracture tips and also containing pegmatitic melts are observed. Discrete sinistral and dextral offsets occur across these pegmatites suggesting that the conjugate emplacement system continues into the brittle-ductile environment. The overall difference in trend between the sinistral and dextral pegmatite sets is >60˚ and in some cases approaches ~90˚. Pegmatites are considered to mark the shear failure planes with the increase in the acute angle suggesting that the deformation transfers from the Coulomb (brittle) fracture criterion to the von Mises (ductile) failure criterion. Shear-related pegmatites also display systematic relationships with respect to the trend of regional foliation, which itself contains early pegmatitic melts.

The overall conjugate pegmatite/shear system possibly reflects palaeovertical with N-S directed shortening and W-E extension. This extension is associated with a component of trans-tensional West-side down kinematics. As the strike-slip dominated conjugate pegmatite system coincides with planes of shear failure within the gneisses, it is thus considered to reflect quasi-Andersonian emplacement tectonics. As such the pegmatites may provide a reliable record of regional stress systems operating within the crust at that time.

Conjugate pegmatite systems are subsequently cross-cut by megacrystic K-feldspar rich pegmatitic sheets. These relatively late sheets, which may be up to 10's of meters thick, display razor sharp cross-cutting contacts with the host ortho and paragneisses and may be associated with an intense flow fabric defined by an alignment of mafic (biotite-rich) clots during emplacement. As these pegmatites clearly overprint the ductile fabrics within the host gneisses and post-date the conjugate pegmatite shear system, they may represent a reliable marker by which to bracket the upper age limit of earlier regional deformation.



Block diagram illustrating the geometry and kinematics of pegmatite emplacement patterns in the Kangaatsiaq region. Note the distinctive overall conjugate system associated with West-side down kinematics. Inferred regional stress system at time of emplacement is also shown.

Plans on M.Sc. study, based on fieldwork in NNO, summer 2001

Uni. Egholm Árting, Copenhagen University

As the title indicates there is no final description of this thesis. So this talk will revolve around three main subjects; a mafic dyke, meta-dolerites and magmatic intrusive complexes, represented as a slideshow.

A mafic dyke, described as ”Globule Dyke” by Ellitsgaard-Rasmussen, 1952, was followed throughout the mapping area from the entrance to the Arfersiorfik fjord northwards along its N-S strike. It consist of a homogeneous, often columnar fractured, 5-10m central dyke. On both sides of the central part, a zone of multiple dykes is found. These dykes are from decimetres to meter scale, and all have chilled margins on both sides, often preserved as a 1-3cm thick glass. These dykes also are columnar fractured and in rare cases a glassy mantle seems to enclose the individual coulombs. This indicates a rapid coolinghistory of this dyke, and probably with presence of water-filled fractures in host rock.

Meta-dolerites are also found throughout the entire mapsheet, but with marked increase southwards. These are discordant, and to a varying degree tectonised, but in the larger ones (20m) the igneous fabric is clearly preserved. They are in most cases not as strongly deformed as the hostrock. At the sides a foliation is developed parallel to contact, but in central parts the igneous texture are preserved. These dykes are often garnitiferous, and the pyroxens and plagioclase are relatively altered. Orientations seem to be dominated by a E-W trend in the southern area, but vary randomly elsewhere.

Remnants of mafic to ultramafic intrusive complexes are seen in the southern part of the Kangatsiaq area. These vary in size from meter to kilometre-scale bodies. Magmatic layering is preserved in some cases. Layers vary from gabroic/noritic to more ultramafic compositions. Anorthositic horizons are also observed in the large bodies, they are also found in smaller scale, as enclaves/lenses in the regional ortogneiss. These large complexes are in some cases intruded by sheets of the regional tonalitic ortogneiss, indicating that these predate the gneiss. Dating and a geochemical analysis could reveal some of these questions.

Tectonic evolution of the North Atlantic region – an overview from a West Greenland perspective

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Archaean cratons were amalgamated in the North Atlantic region along a complex array of orogenic belts during the Paleoproterozoic. Despite significant advances in data quality and models in most of these belts over the past decade, an accurate, fully-integrated regional tectonic model does not exist for the entire North Atlantic region, in part, due to: 1) a lack of geochronological data from the Rinkian belt, 2) a lack of general data, including geochronology, from the Foxe belt of northeastern Canada, and 3) an insufficient effort yet to fully synthesize available data from those orogens with adequate data. While this last point may be arguable, the fact remains that no large-scale model exists that reflects and honours well-established first-order observations from these different belts. In fact, given the latitude permitted by the lack of data in some regions, it is even more surprising that no model has been successfully presented.

It has long been thought that the Nagssutoqidian Orogen correlates directly with the Torngat orogen of Labrador. But recent studies have complicated this picture with the suggestion that the suture in the Torngat orogen may strike northwards onto Baffin Island. This boundary would have to turn dramatically south to align with the proposed suture of the central domain of the Nagssutoqidian Orogen. Three alternatives seem possible: 1) the Torngat suture does not pass northwards onto Baffin Island, but links instead directly with the Nagssugtoqidian Orogen as previously proposed, 2) the suture passes through Baffin Island but links further north in West Greenland, perhaps as far north as the Rinkian belt (and, while tectonically related, the Nagssugtoqidian orogen does not contain a suture), 3) the Nagssugtoqidian-Rinkian system is an intracratonic belt and the Torngat orogen turns west to link with the main Trans Hudson belt of Canada

Evidence supports a model in which the Nagssugtoqidian-Rinkian belt is intercratonic and contains a suture that links with that of the Torngat Orogen (whether it passes through Baffin Island is still debated by some workers). The exact position of this suture within West Greenland will help define its link with the Torngat Orogen. An irregular trace for this boundary might be expected given the transition from the strike-slip system of the Torngat orogen to the initially thrust-dominated (and therefore, relatively flatter) Nagssutoqidian-Rinkian system.

A northern and southern continent apparently collided across the Nagssugtoqidian-Rinkian system by 1860 Ma, thereby placing this region into an intracratonic position by this time. Accepting the West Greenland - Torngat Orogen link, the western margin of the North Atlantic Craton may have remained as an open margin after this time, along the strike-slip Abloviak-Komaktorvik shear zones. Alternatively, the “core zone” may have already collided with the Nain Province by this time. After closure across the Nagssugtoqidian-Rinkian system, magmatism stepped sequentially to the Cumberland Batholith and then to the Narsajuaq - De Pas magmatic arc system (above NE-dipping subduction zones). This would have been related to overall convergence between the Superior Province and the newly amalgamated eastern craton. Rocks from these magmatic systems were eventually thrust southwestward over the Superior Province in the New Quebec - Ungava - Baffin orogens, as the amalgamated North Atlantic/northern cratons collided with the Superior Province. An important outstanding problem remains in the nature and affinity of the “core zone” between the Torngat and New Quebec orogens.

Eight questions related to the apparent Palaeoproterozoic age of the Naternaq (Lersletten) supracrustal sequence, central West Greenland

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New evidence reported at this workshop by J.N. Connelly and K. Thrane, coupled with previous reconnaissance SHRIMP U-Pb zircon data by the Danish Lithosphere Centre, strongly suggests that the Naternaq supracrustal sequence is of Proterozoic age. The Naternaq supracrustal sequence was not differentiated in the field from other supracrustal sequences of presumed or established Archaean age. This raises serious magmatic, structural, metamorphic and geodynamic issues related to the interpretation of the Kangaatsiaq map area and the boundary region between the Nagssugtoqidian and Rinkian orogens. The following few points are among the numerous questions we need to address:

1) Are contact relationships between the supracrustal sequence, tonalitic-granodioritic orthogneisses, and granitic-pegmatitic rocks well established and unequivocal?

2) Is marble in supracrustal sequences a reliable West Greenlandic Proterozoic marker?

3) Is the metamorphic grade in the Naternaq supracrustal sequence lower than in adjacent supracrustal sequences, some of which have previously been reported to be Archaean in age?

4) Folds in the hinge zone of the major overturned fold in the Naternaq supracrustal sequence plunge steeply SE, whereas most regional fold axes in orthogneisses have very persistent, shallow westerly plunges. What is the relationship between these structures?

5) Are the previously reported Palaeoproterozoic Ar-Ar hornblende ages from the Kangaatsiaq map area sufficient evidence to presume major Nagssugtoqidian reworking including penetrative deformation and partial melting?

6) The shallow W-plunging regional fold systems e.g. in the north-eastern and southern parts of the map area are associated with emplacement of syn- to late-kinematic, pink granitic to pegmatitic sheets in orthogneisses. Are these granites contemporaneous with the granites in the Naternaq supracrustal sequence, or are they Archaean like other pink granites in the central Nagssugtoqidian orogen?

7) In the SW corner of the map sheet area, and in the Attu area, there are discordant, E-W trending metadolerite dykes. Are these dykes early Nagssugtoqidian and affected by mild regional Nagssugtoqidian reworking, or were they emplaced during the waning stage of major Palaeoproterozoic reworking in the Kangaatsiaq map area?

8) A few flat-lying brittle-ductile high-strain zones have been observed near the metadolerite dykes. Are these the *only* Nagssugtoqidian structures in this subarea, or just the *latest* ones?

Surveying the southern Rinkian fold belt, central West Greenland

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In late Palaeoproterozoic time the Archaean continental terrains in the North Atlantic region were gradually amalgamated during a series of major orogenic events to form one of the earliest large continents on Earth. The boundary zone between the Nagssugtoqidian and Rinkian orogenic belts east of Disko Bugt is one of the least known members of this immense orogenic collage. From 9–17 August, 2001 the authors addressed critical Archaean and Proterozoic relationships in this region and collected sample material to date the main Rinkian tectonic and metamorphic events as precisely as possible and compare them with the evolution of the Nagssugtoqidian orogen.

It was established already in 1987–1991 that Palaeoproterozoic structural reworking was strong in eastern Nuussuaq and between southern Arveprinsen Ejland and Jakobshavn Isfjord, whereas the intervening Ataa domain was only mildly affected by reworking. It was also shown that the Ataa domain preserves low-grade Palaeoproterozoic sedimentary rocks deposited unconformably on Archaean supracrustal rocks, although the entire succession was previously considered to be Archaean; a similar discovery is seemingly on its way also for the northern Nagssugtoqidian Naternaq (Lersletten) supracrustal sequence.

In 2001 we studied both supracrustal rocks and tectonics at the Nuussuaq-Ataa domain boundary, where two major Proterozoic shear zones were previously proposed: (1) the NW-trending *Puiattup Qaqqaa shear zone* in southern Nuussuaq, and (2) the *Torsukattak shear zone*, a largely unexposed younger extensional shear zone along the fjord Torsukattak with oblique downthrow to the south-east. The extension was mainly inferred from intense SE-plunging extension lineations on southern Nuussuaq and an apparent tectonic reworking of the Puiattup Qaqqaa shear zone towards Torsukattak, besides an abrupt decrease in the metamorphic grade from north to south across the fjord. We confirmed the presence of previously suggested acid metavolcanic rocks with abundant pale, fine-grained fist-sized and larger volcanic clasts at the southernmost exposures of Nuussuaq. Asymmetric volcanic clasts and porphyroclasts within the intense, SE-plunging LS fabric clearly indicate downthrow of the southern hanging wall, proving that the Torsukattak structure is indeed a major extensional shear zone. We hope that U-Pb dating of magmatic zircons from the metavolcanic rock will reveal its volcanic age and minimum age of the gneissic basement of Nuussuaq, allowing us to compare the timing of volcanism at the continental margin of southern Nuussuaq with the arc-type volcanism in the Ataa domain. The latter was previously dated at c. 2800 Ma. A discordia age for the Torsukattak shear zone may also be obtained. Besides, we hope to distinguish between Archaean and Palaeoproterozoic metamorphism and determine the P-T-t path.

A second target was the major low-angle ductile imbrication of Archaean orthogniesses, previously reported from south of the Ataa domain. It is critical for the correlation between the Rinkian and Nagssugtoqidian belts that the timing of this supposed Proterozoic thrusting can be compared with the main crustal shortening event in the central Nagssugtoqidian orogen at c. 1830 Ma. The early thrusting was followed by open to tight folding, emplacement of a suite of up to c. 100 m thick mafic sills, and reworking of the sills by continued thrusting.

We studied and sampled the thrusts and confirmed the predominant westward movement direction was westwards. The thrust package consists of subhorizontal, upper greenschist - lower amphibolite facies, high-strain zones few metres thick and commonly ultramylonitic, separated by <100 m thick zones of much less deformed rocks. In the high-strain zones there are abundant well-developed δ- and σ-shaped K-feldspar and plagioclase porphyroclasts within an intense LS fabric dominated by a shallowly E-plunging extension lineation.
The geochronological, structural and metamorphic study north-east of Disko Bugt initiated in 2001will help to update understanding of the Rinkian orogen and its position in the contemporaneous framework of Palaeoproterozoic orogens in Greenland and Eastern Canada. In 2002, with support from the Carlsberg Foundation, the survey will be extended into the central part of the Rinkian fold belt.

Mantle xenoliths in West Greenland kimberlites

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Mantle-xenolith bearing kimberlite dykes are abundant in the Kangerlussuaq area of West Greenland. The mantle xenoliths carry information about the composition and thermal state of the deep, unexposed levels of the lithosphere and their compositions can be used to interpret how geodynamic processes affected the region at large depths and to assess the diamond potential of the kimberlites. The southern deformation front of the proterozoic nagssugtoqidian orogen passes through the area and south of it is an archaean craton unaffected by proterozoic deformation. Kimberlites with mantle xenoliths occur in the nagssugtoqidian as well as the undeformed region, and at present xenoliths from dykes intruded into each of the regions are investigated.

In the archaean region, at least 90 % of the xenoliths encountered in the field at the 5 to 10 m wide, partially exposed kimberlite Locality A dyke had peridotitic or pyroxenitic compositions ranging in size from < 1 cm to a maximum at about 15 cm. The Locality A dyke is exposed over a distance of at least 500 m. The 'Tuttu' dyke in the proterozoically deformed area north of Kangerlussuaq is a distinct 5 to 10 m wide, approximately 500 m long train of kimberlite blocks and exposures hosted in banded grey gneiss. 1 to 10 cm large dunitic, harzburgitic and lherzolitic (ol+opx+cpx+/-gt) xenoliths were identified in the 'Tuttu' dyke.

Xenoliths from the kimberlite dykes have been analysed for major element mineral chemistry by the JEOL Superprobes at the Geological Institute, University of Copenhagen, and the Geological Institute, University of Aarhus. A few of the Locality A dyke xenoliths have been subjected to reconnaissance laser ablation analyses by the LSX-200 Nd:YAG CETAC laser attached to the Perkin Elmer ICP-MS at GEUS. Generally, major element compositions of minerals within individual xenoliths is homogeneous. Average olivine compositions range between approximately Fo87 and Fo92 where each xenolith display a Fo variation of less than 1 %. Garnet wehrlites contain the olivines with the lowest Fo, garnet harzburgites and garnet lherzolites the most Fo-rich olivines.

In Locality A dyke xenoliths, average Ni-contents in olivine vary between 2305 and 2982 ppm which is within the range of 2900 +/- 360 reported by Ryan et al. (1996) for garnet peridotites. Orthopyroxene contains less than 1.6 wt. % CaO and $Mg/(Mg+Fe^{2+})$ is between 0.893 and 0.953. Al_2O_3 is highest in the orthopyroxene contained in an ilmenite-bearing garnet lherzolite, intermediate in the garnet harzburgites, and lowest in ilmenite-free garnet lherzolites. Clinopyroxene $Mg/(Mg+Fe^{2+})$ is between 0.930 and 0.966 and correlate positively with Cr_2O_3 in clinopyroxene. Garnet $Mg/(Mg+Fe^{2+})$ range from 0.788 to 0.897 and tend to correlate positively with Fo contents of olivine. CaO and Cr_2O_3 contents of the garnets show a limited variation for individual xenoliths, and two Locality A dyke xenoliths plot clearly within the G10 field of Gurney (1984) and Gurney and Zweistra (1995).

Low-Ca garnets in a garnet harzburgite xenolith have very low Zr (c. 10 ppm) and Y (< 1ppm) contents suggesting that this xenolith represents original lherzolite mantle depleted by partial melting (Griffin et al., 1992). The REE pattern for these garnets is more depleted except for La, Nd and Sm than REE patterns of garnets in lherzolites, and the sinuous pattern resemble that of low-Ca garnet in a harzburgite xenolith from the Sarfartoq area (Garrit, 2000). The low REE contents supports that the garnet is hosted in a rock depleted by partial melting, whereas the sinuous shape may indicate post-depletion metasomatic enrichment processes (Hoal et al., 1994) or disequilibrium garnet growth (Shimizu & Sobolev, 1995). Garnet lherzolites have much higher Zr and Y concentrations in the garnets (Zr: 20-120 ppm, Y: 10-20 ppm), and their chondrite-normalised REE patterns are more like those of typical LREE-depleted and M- to HREE enriched garnets of primitive mantle (e.g., Haggerty, 1995). Zr-Y-Ti relations in garnet from the lherzolites also suggest that they experienced phlogopite and melt metasomatism (Griffin & Ryan, 1995; Griffin et al., 1999). The Locality A dyke garnets were not investigated for zoning in Zr and Y but Ti contents, which follow Zr in some metasomatic processes (Griffin et al., 1999b), are essentially the same in core and rim regions. This may indicate that if metasomatic processes affected garnet compositions, then there was sufficient time for equilibration to take place between the metasomatic agents and whole garnet grains up to 3 mm large.

The different xenolith types and their distinct mineral compositions clearly demonstrate the heterogeneous character of the West Greenland lithospheric mantle, even on a small width scale. Calculation of equilibration pressures for the clinopyroxene-bearing xenoliths in the Locality A dyke using the Nimis & Taylor (2000) single clinopyroxene thermobarometry equations suggests that these xenoliths were derived from a depth interval of 49 to 69 kbar. This corresponds approximately to 150-215 km, and implies vertical zonation with depleted and metasomatised zones in the mantle lithosphere beneath the archaean craton as also reported by Garrit (2000) for regional collections of xenoliths from Sarfartoq and Maniitsoq. Calculated temperatures are between 1030 and 1190°C, and the P-T relations of the xenoliths suggest they were all derived from within the diamond stability field (Kennedy & Kennedy, 1976).

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Studies of kimberlitic rocks in the Sisimiut–Kangerlussuaq region, southern West Greenland

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The alkaline province of southern West Greenland is known to encompass 2500 Ma of alkaline activity (Larsen & Rex 1992) and includes swarms of dykes described as lamproites and kimberlites (Larsen 1991). The alkaline ultramafic dykes within the Sisimiut–Kangerlussuaq and Sarfartoq regions intrude the border zone between the Archaean craton and the Palaeoproterozoic Nagssugtoqidian orogen (Fig. 1, van Gool et al. 2002). Lamproite dykes in the Sisimiut area are 1.2 Ga old, whereas the Sarfartôq and a swarm of associated kimberlitic dykes have ages of around 0.6 Ga (Larsen & Rex 1992). A precise spatial relationship between to two intrusive events has not been established. Since the description of the Sarfartôq carbonatite complex and the kimberlitic dykes related to this complex (Larsen 1980; Secher & Larsen 1980) the Sisimiut–Kangerlussuaq region has seen several campaigns of commercial diamond exploration. Numerous reports of diamond-favourable indicator minerals from till sampling, finds of kimberlitic dykes, and recovery of actual diamonds from kimberlitic rocks have emerged since 1995 (Olsen et al. 1999). A drilling programme in late 2001 confirmed the unusually great length and width of a magnetic kimberlitic dyke (Ferguson 2001), but the results of testing for its diamond content were still pending as of 1 February, 2002.

A project concerned with general scientific aspects of kimberlitic and related rocks in the Sisimiut–Kangerlussuaq region was established in 2000. A major task has been to compile all occurrences registered by Survey staff (Larsen 1991) and companies in a GIS environment. In addition, company analyses of kimberlite indicator minerals from numerous till samples are entered into GEUS databases and GIS. At present, approximately 7800 point localities (till sample locations, in situ kimberlites and boulders) and approximately 90.000 mineral analyses of 3000 till samples are stored. Fieldwork in 2000 consisted of one week's reconnaissance. New dyke occurrences discovered by exploration companies were visited and sampled. A number of further localities in the vicinity of these occurrences were visited for comparative study. The 2001 fieldwork focused on the spatial distribution of dyke rocks and detailed studies on mantle xenoliths from the kimberlitic dykes. The regional part of the work was concentrated in areas with little or no previous information on kimberlitic rocks. Studies and sampling of mantle xenolith-bearing rocks are described by Hansen (this volume).

Bedrock exposure is poor in the region intruded by the swarms of alkaline ultramafic and carbonatitic dykes and sills, and dykes are difficult to trace because they are thin, easily eroded and often covered by overburden and vegetation. Therefore, both stream geochemical data and aeromagnetic data are investigated with the aim of identifying geochemical and geophysical signatures reflecting occurrences of kimberlitic and related dykes.

The broad term ‘kimberlitic’ is used here in acknowledgement of the fact that the classification of the ultramafic dyke rocks of West Greenland is not resolved with unanimity. Many of the dyke rocks resemble kimberlites and have previously been described as such (Larsen 1980; Scott 1981; Larsen 1991; Larsen & Rex 1992). Mitchell et al. (1999) however take the view that the dyke rocks have no affinity with ‘archetypal’ kimberlites, but are ultramafic lamprophyres and should be termed melnoites or aillikites. In light of the actual occurrence of diamonds in the West Greenland dyke rocks, Mitchell et al. (1999) consider them to represent one of the few bona fide examples of diamond-bearing ultramafic lamprophyres. One of the aims of the project is to work towards a generally accepted classification of the West Greenland kimberlitic and related rocks.

The kimberlitic and related rocks are typically observed as scattered boulders, trains of boulders or occasionally as dykes or sheet-like bodies with dips ranging from near horizontal to vertical. Fieldwork in 2000 and 2001 in areas with little previous coverage has added approximately 50 samples of kimberlitic dykes and more than 300 kimberlitic boulders to the existing data bank.

Niobium (Nb) in the fine fraction (<0.1 mm) of stream sediments has proved to be a convincing ‘pathfinder’ element for kimberlites and lamproites in the Sisimiut-Kangerlussuaq region. Kimberlitic and lamproitic rocks in the region are clearly enriched in Nb relative to the Archaean country rocks and there appears to be a strong spatial relationship between the ultramafic alkaline dykes and stream sediment anomalies of Nb. Nb anomalies and the presence of high-pressure chromite in the stream sediment samples in the eastern and south-eastern part of the study area warrant follow-up.

Although magnetic data have been used with some success in the search for kimberlitic dykes in the Kangerlussuaq region (Ferguson 2001), there is a need for establishing a database with petrophysical properties of both kimberlitic dykes and host rocks in order to fully utilise the geophysical data available. The petrophysical properties of 22 representative kimberlitic samples collected in 2001 have been measured by the Geological Survey of Finland, and these data will be used in modelling the geophysical response obtained in the airborne surveys. It is planned to collect further samples for petrophysical measurements. Magnetic profiling at ground level should be conducted at selected kimberlitic dyke occurrences in future fieldwork.

Compilation and publication of all non-confidential company data submitted in assessment reports to the Bureau of Minerals and Petroleum in Nuuk is planned for 2002. A compilation of this type covering the North Slave Craton in Nunavut, Canada (Armstrong 2002) has received very positive response from industry.

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Deformation of the Kangamiut dykes across the Ikertoq Complex, the Nagssugtoqidian Mobile Belt

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Field work in the Ikertoq Complex (Ramberg 1949), started in 1972 in a project initiated by Juan Watterson, Liverpool (Bridgwater et al. 1973). The present author participated in 1974 and 1975 and was given the task of doing a traverse across the complex in the inner parts of the fjords. The objective was to record changes in deformation and metamorphism of the Kangamiut dykes and their host gneisses as they entered the Nagssugtoqidian Mobile Belt from the Archaean terrain to the south (Korstgård, 1979, 80). Detailed studies in smaller areas were carried out by Davidson (1978,79), Grocott (1977, 79), Jack (1978) and Nash (1979, a,b).

The Ikertoq complex is situated at the southern boundary of the Proterozoic Nagssugtoqidian mobile belt in West Greenland. The Archaean block south of the Ikertoq complex and the Ikertoq complex were intruded by a NNE-trending swarm of basic dykes - the Kangamiut dykes - around 1850 Ma ago. In the southern part of the Ikertoq complex the dykes intruded along late Archaean (Nag. 1) shear zones. Deformation (Nag. 2) following dyke emplacement created in the northern part of the Ikertoq complex a zone of ductile overthrusting which caused metamorphism of the dykes and their host gneisses to granulite facies in the northern and amphibolite facies in the southern part of the complex.

The Nag. 1 shearing along Itivdleq caused retrogression of the granulite- and amphibolite facies Archaean gneisses to low-amphibolite facies. The shearing produced a new steep fabric in the gneisses developed through recrystallisation of plagioclase and quartz and crystallization of new mafic phases. Continued activity in the Nag. 1 shear zones following dyke intrusion caused local syn- to post-emplacement deformation of the dykes. The dykes intruded along the Nag. 1 shear zones also developed primary pinch & swell structures in the ductile shear zone host gneisses.

Post-dyke Nag. 2 deformation north of Itivdleq transformed the dykes into schistose amphibolites through recrystallisation of plagioclase and crystallization of hornblende, garnet and pyroxenes at the expense of augite. The country rocks are mainly quartzo-feldspathic gneisses with thin (2-300 m) supracrustal units consisting of amphibolite, garnet-biotite-sillimanite gneiss and mica schist. The quartzo-feldspathic gneisses are tonalitic to granodioritic in composition and correspond chemically to igneous calc-alkaline granitoids. The amphibolites correspond chemically to tholeiites and show affinities to ocean-floor basalts and their field occurrence suggests that they were originally basaltic lavas or tuffs. The garnet-biotite-sillimanite gneisses are clearly of sedimentary (pelitic) origin whereas the chemical character of the mica-schists indicate that acid to intermediate volcanics may have been the precursors of these rocks. The Kangamiut dykes are quartz tholeiites with strong chemical affinities to modern ocean-floor basalts. Nag. 2 deformation and metamorphism caused chemical changes in dykes and quartzo-feldspathic gneisses. Dykes metamorphosed to amphibolite facies show a decrease in CaO and an increase in mainly K2O, Rb and Sr. At the amphibolite-granulite facies transition both metadykes and quartzo-feldspathic gneisses show a decrease in mainly K20 and Rb and an increase in CaO and MgO. These changes in chemistry at the high grade facies transition are caused by the development of relatively dry pyroxene-bearing mineral assemblages unable to accommodate K and Rb. The H20 liberated by the dehydration reactions acted as a transporting agent and moved the expelled material to higher crustal levels.

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Pyrrhotite occurrences SSE of Simiutannguaq, Nordre Strømfjord, West Greenland

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Simiutannguaq is situated between Giesckes Sø and Ataneq Fjord in the vicinity of Nordre Strømfjord steep belt (Agto map 67V1). Semi-massive pyrrhotite have been sampled along strike over a distance of about 22 km. The area was mapped by putting out a grid and then made observations along the lines. The rocks in the area have an overall strike of approx. 265° and a slope of 60°N, which is coincident with Nordre Strømfjord steep belt, and occasional folds and flexures appear. The semi-massive pyrrhotite-mineralisations were found in a supracrustal sequence, which comprises of foliated amphibolite, biotite garnet ± graphite ± sillimanite gneiss and skarn ± sulphide minerals.

The semi-massive pyrrhotite is easily found in the field because of it's yellow to redish rusty colors. Two parallel layers of pyrrhotite lenses were found, a northern layer with greater lenses than the southern where the pyrrhotite only were found as sporadic pods. The lenses varied a lot in thickness (0,2-1m), lenght (up to 100m in the northern layer) and width (6m or more).

The most common host rocks to the pyrrhotite lenses were skarn, amphibolite, biotite garnet gneiss and some altered siliceous rocks which occasionally contained graphite.
The semi-massive pyrrhotite in the southern zone was found in amphibolites, which seemed to be part of boudinage structures. The pyrrhotite had clearly been ductile deformed, so movement had occurred after precipitation of the pyrrhotite.
The semi-massive pyrrhotite contains quartz-, feldspar-, biotite- and graphite-clasts with varying grain sizes. The quartz and feldspar have been intensely brecciated in which the pyrrhotite precipitated. The graphite might have precipitated during the granulite facies metamorphism, which has taken place in the area.

Chip samples of the mineralised pyrrhotite beds yield up to 0.3 % Cu, 4 % Mn, 40 ppb Au, 600 ppm Ni, and 400 ppm Zn. Chip samples of the amphibolites yield up to 97 ppm Ni, 79 ppm Cu and 550 ppm Zn. Kryolitselskabet Øresund has taken some powder samples of varius lithologies where they only found one with notable copper (1500 ppm).

Future plans: Constructing isochondiagram of the amphibolite data, petrographic descriptions of the ore, genetic interpretation of the deposits and possible mineral analyses by microprobe and/or scanning electron microscope.

First impressions on structural evolution of the northern Nagssugtoqidian foreland

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Preliminary results of structural investigations carried out in western Greenland during the field season of 2001 are presented. The structural work was an integral part of the GEUS's mapping project. The study area was situated in the northern segment of the Nagssugtoqidian orogen between vicinities of Kangaatsiaq in the south and the southern coast of Sydostbugten in the north. This part of the orogen is mainly composed of amphibolite-grade Archean orthogneisses accompanied by relatively thin metasedimentary belts.

The main S_1 foliation resulted from penetrative ductile deformation under upper amphibolite facies conditions. It is developed parallel to the axial planes of isoclinal folds F_1, cross-cutting basite dykes and lithological boundaries. The later were rotated on the fold limbs into parallelism with the foliation. The S_1 planes were later folded due to a progressive strain into isoclinal folds, most probably in the same deformation event. The origin of the foliation and its subsequent folding during the D_1 event were accompanied by a long-lasting pervasive migmatization.

On stereoplots poles to the S_1 foliation are scattered along a regular girdle with an axis gently plunging to the WSW. Two main maxima represent foliation planes steeply dipping to the NNW and gently inclined to the SSW. The former orientation predominates in the area south and west of Kangaatsiaq, whereas the latter attitude prevails on the southern coast of Sydostbugten. The mineral stretching lineation generally trends WSW-ENE, i.e. approximately parallel to the axis of the foliation girdle. It is subhorizonal or shallow plunging to the WSW. The main lineation probably comprises several generations of linear structures, successively overprinted during structural evolution of the study area.

Several folds F_2 responsible for the scatter of S_1 foliation planes on the stereoplot were found in the area at outcrop- and map-scale. Despite of their size, the tight to open folds show variable, often complex geometry. Only locally their axial planes correspond to a subtle cleavage, cross-cutting the main foliation S_1. The folds axes are roughly parallel to the lineation and plunge gently to the WSW or ENE. Only in the hinge zones of map-scale F_2 folds, axes of parasitic minor folds of the same generation become relatively steeply inclined. The parastitic folds are responsible for the apparent scatter of lineation projection points along a small circle centered around an axis steeply plunging to the NNE. This scatter seems to indicate the origin of the lineation earlier than the F_2 folding.

The numerous F_2 mesofolds are usually asymmetric with fairly uniform SSE vergence in the area south and west of Kangaatsiaq. This geometry suggests an occurrence of a large-scale antiform hinge to the south of the study area. In contrast, only few F_2 mesofolds were found on the coast of Sydostbugten and, unlike those in the vicinity of Kangaatsiaq, they are symmetric or show the NNW asymmetry.

Scarce kinematic indicators are usually associated with the main stretching lineation L_1. At microscale, they are mostly destroyed by recrystallization due to static annealing. On the other hand, mesoscopic indicators are often flattened and reoriented on the fold limbs or obliterated by subsequent migmatization. The majority of documented D_1 shear sense indicators are approximately symmetric and must have resulted from coaxial strain and/or a total strain combining effects of successive superimpositions of several strain increments. Asymmetric fabric has been found only in zones of steeply dipping foliation and it usually indicates a sinistral rotational shear component (in the present-day coordinates). Subtraction of the effects of the steep foliation attitude, would result in the same indicators implying a top-the W or NW sense of shear.

The southern coast of Sydostbugten exposes several D_2 high strain zones of shallow inclination, overprinted on the pre-existing fabric. They usually dip to the SSW at a low angle and, thus, show orientation similar to that of most of the S_1 foliation planes in that area. The S_1 foliaton is gradually deflected towards the high strain zones, from steep NNW- or SSE-inclinations, through moderate dips, up to the shallow dips to the SSE. The axes of these mutually opposite deflections on both sides of the high strain zones are parallel to the stretching lineation.

The gneisses in the D_2 high strain zones show strong linear fabric probably developed due to mostly coaxial constriction. They are well recrystallized in high temperature conditions. In rheologically weak metasediments, progressive deformation lead to the development of localized zones of rotational shear and to mylonite formation. The resulting D_2 strain extensively modified the older fabric. The foliation S_1 was often transposed into the new mylonitic foliation due to passive rotation into parallelism with non-coaxial shear planes. In places, however, the S_1 foliation was cross-cut and partly obliterated by the S_2 structures. The deformation took place in the syllimanite and biotite stability field and was not followed by any extensive recrystallization. The L_2 stretching lineation developed on the S_2 foliation of the mylonitized metasediments, uniformly plunges to the SW and is parallel to the L_1 structures in the nearby rocks. At the same time, asymmetric kinematic indicators apparently document a top-to the SW sense of shear within the D_2 zones of rotational strain.

In summary, it seems that the development of the main D_1 fabric of rocks in the study area took place under conditions of a pervasive high-temperature deformation and can be tentatively attributed to a hypothetical thrusting event. The still hot rocks, already containing penetrative deformational structures, were subsequently folded and subjected to the D_2 strain localized in shallow dipping zones. The latter probably developed due to extensional regime induced by a gravitational instability of the orogen. This deformation was mostly coaxial on a regional scale and became completed by the growth of a top-to the SW shear zones in rheologically weakest horizons. The latest increments of this deformation seem to be temporarily related to the cessation of the high temperature metamorphic conditions.

Ongoing interpretation of geophysical data from the Nagssugtoqidian and Rinkian orogen, West Greenland

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Qualitative approaches through filtration and processing of magnetic data from the Nagssugtoqidian and Rinkian orogen provide a wealth of new structural information on the orogen.

Magnetic responses from deep-seated geological features can be emphasised through different approaches. One approach is the stripping filtering, which emphasise features from selected crustal levels by applying upward continuations to different heights (Jacobsen 1987). The stripping technique provides an estimate of the magnetic field below a specified depth when the response from the overburden. Different stripping techniques exist but the method of Jacobsen makes use of the simplicity of the upward continuation to make a stable and physically comprehensible filtering. An estimate of the magnetic responses from depth intervals in the subsurface, denoted “sounding filtering”, can be achieved from the upward continuations of the fields by subtracting responses from different depth levels.

The results of the stripping filtering reveals that the tectonic boundaries of the Nagssugtoqidian orogen can be followed down to a nominal stripping depth of minimum 15 kilometres. Especially the Ikertôq thrust zone has a very pronounced response with a large horizontal gradient. The southern Nagssugtoqidian front can also be followed to a stripping depth of minimum 15 km, but the boundary is not so sharply defined. On the normal total magnetic intensity anomaly map, the Nordre Isortoq steep belt is defined as a low magnetic feature. At a stripping depth of 3 kilometres this feature begins to diminish from the east to the west and at a stripping depth of 15 kilometres, only the western part of the feature can be observed. The responses for Nordre Strømfjord steep belt show behaviour opposite to this. In the magnetic total field intensity anomaly map the Nordre Strømfjord appears as an irregular discontinuous feature, but at a stripping depth of 6 kilometres it is continuous and sharply defined with a more southern location than mapped on the surface. With a stripping depth of 3 km or more the magnetic field in the area at Sydostbugt, at Christianshaab, north of Grønne Ejland and at Ilulissat and eastward to the Inland ice is dominated by a number of relatively strong positive anomalies. The anomaly in Sydostbugt has formerly been interpreted to be a deep-seated intrusion. Similar responses observed in this part of the region could also originate from deep-seated intrusions. At a stripping depth of 6 kilometres a large anomaly is seen.

Another approach is to construct a magnetic potential map denoted pseudogravity through filtering in the Fourier domain of magnetic total field. In this way short-wavelengths magnetic anomalies from shallow sources are suppressed. The pseudogravity transformation converts the magnetic data to the analogous gravity field that would be observed if density varied proportional with the magnetic moment of the rocks. The magnetic data transformed through the pseudogravity method are similar to gravity data, which means that maximum horizontal gradient of the pseudogravity data on a regional scale is directly above vertical contacts An offset of the peak is expected for a dipping contact. If sources of gravity and magnetic anomalies are the same, the constructed pseudogravity anomalies generated by the magnetic field will be identical to the gravity field observed.

A comparison between the pseudogravity and the observed gravity reveals a significance difference. This implies that the gravity and magnetic field reflects different causative sources or their magnetisation and densities are not uniform. However, it should be noted that the sampling distance of the gravity field is large and can contribute to insufficient description of the field

Several techniques can be applied to address the depth and geometry of the sources. One approach will be to model selected anomalies or profiles. A relatively more objective and automatic approach will be used in this presentation, where analyses of the analytical signal of the magnetic total field will be used. The analytical signal is a function related to magnetic fields by the derivatives. It is a non-measurable parameter, which is completely independent of the direction of the Earth's field. Peaks of the sources will occur directly over the edges of wide bodies and over the centre of narrow bodies.

The ratio between the real and imaginary parts of the analytic function has a simple relation to the dip of a source and the direction of magnetisation. Unfortunately, it is not possible to determine both the dip and the direction of magnetisation independent of each other. In order to obtain an estimate of one of these quantities, a priori information about the other has to be supplied. Anomaly variations around the peaks in the analytical signal are used to estimate the source geometry and depth. The results from this analysis of the analytic signal will be presented together with a study of lineaments in the magnetic field data.

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Formation of an unusual mineral assemblage including a possibly new mineral (S endmember of Ba-Scapolite?) as well as Ba-feldspar and F-rich chondrodite at a contact between a marble and pegmatite

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A possibly new mineral ”X” has been found in a reaction zone between a sedimentary marble and a pegmatite on the island of Akugdlit (E 404131, N 7589125). The mineral could be a S endmember of the Ba scapolite series, but further detailed work has to be performed to verify this preliminary description. Representative analyses and the distribution of elements per formula unit (based on the general scapolite formula) is given in the Tab.1. The framework of the general scapolite structure consists of two types of four-member rings made of SiO_4 and AlO_4 tetrahedra. Type 1 rings consist solely of tetrahedra (T1) the vertices of which point in the same direction whereas type 2 rings (T2) consist of tetrahedra that point alternately towards opposite ends of the z axis. The rings are arranged such as to outline continuous channels parallel to the z axis that normally contain Na^+ and Ca^{2+}, and the larger cages that contain Cl^-, CO_3^{2-} or SO_4^- anions. The general scapolite formula for the Marialite – Meionite series is $W_4Z_{12}O_{24}.R$, where W = Ca, Na, K; Z = Si, Al; R = Cl, CO_3, SO_4. In the case of the described mineral Ba seems to replace Na and Ca and the larger cages contain predominately SO_4 and also some minor amounts of Cl. In thinsection, the mineral has a low relief (Fig. 1).

The described S and Ba rich mineral is found at the contact between a marble and a intruding late, undeformed Grt-Musc-Plag bearing pegmatite. It is associated with diopside, celsian (Ba endmember of the feldspar group) (Fig.1, Tab.2), pyrite, baryt and large amounts of apatite. Additionally, several other minerals form in the marble at the contact, which point to the influx of not only Ba, S but also F rich fluids. Such indicators are F rich chondrodite (humite group mineral) (Tab.3), phlogopite and tremolite. The latter assemblage was stable at host rock temperatures of about 550 °C and fluid composition of X_{CO2} < 0.5 assuming pressures around 4 to 5 kbar.

Table 1: Mineral X - microprobe analyses

weight percent

No.	SiO2	Al2O3	TiO2	Cr2O3	BaO	MgO	FeO	MnO	CaO	Na2O	K2O	SO3	Cl	F	Total
X1	31.190	20.960	0.000	0.000	27.890	0.000	0.000	0.000	8.630	0.468	0.121	6.010	0.754	0.000	96.023
X2	29.590	20.240	0.031	0.000	26.990	0.000	0.000	0.000	9.970	0.922	0.027	9.070	0.532	0.000	97.373
X3	29.890	19.860	0.010	0.000	26.350	0.126	0.086	0.016	10.320	0.627	0.080	8.530	0.561	0.000	96.457

ferrous form with ideal cations = 16, ideal oxygen = 25

No.	Si	Al	Ti	Cr	Ba	Mg	Fe	Mn	Ca	Na	K	SO3	Cl	F	Sum
X1	5,857	4,638	0,000	0,000	2,052	0,000	0,000	0,000	1,736	0,000	0,000	0,847	0,000	0,000	14,284
X2	5,414	4,364	0,000	0,000	1,935	0,000	0,000	0,000	1,954	0,000	0,000	1,245	0,000	0,000	13,668
X3	5,516	4,319	0,000	0,000	1,906	0,000	0,000	0,000	2,040	0,000	0,000	1,181	0,000	0,000	13,781

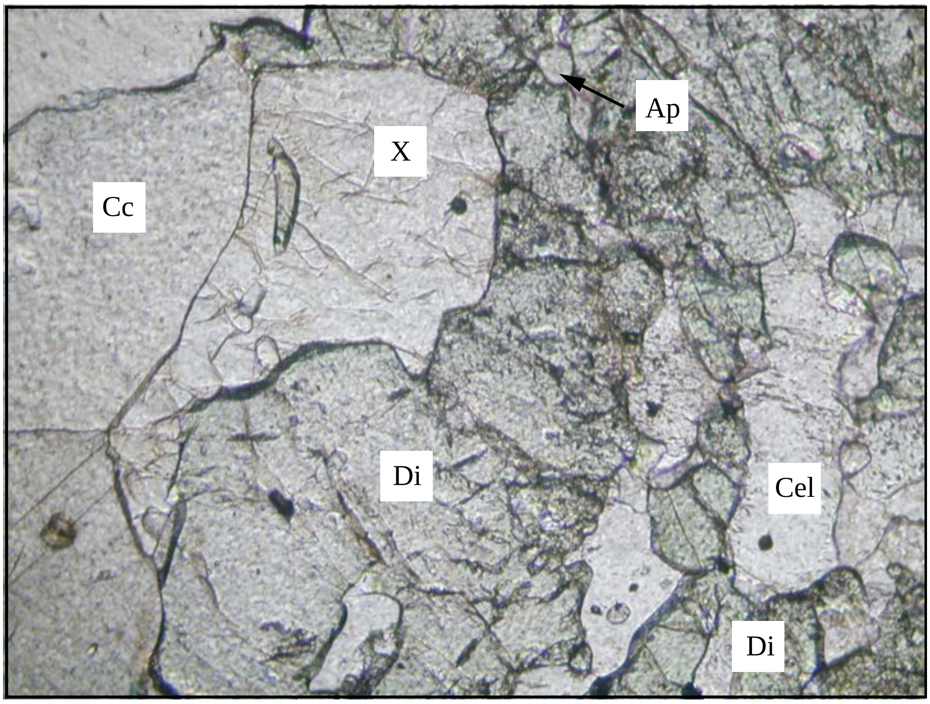

Figure 1: Mineral assemblage at contact zone between marble and pegmatite. X = mineral X, Cel = Celsian, Ba-feldspar, Di = diopside, Cc = calcite, Ap = apatite. Width of view = 5 mm.

Table 2: Celsian (Ba – feldspar) - microprobe analyses

weight percent

No.	SiO2	Al2O3	TiO2	Cr2O3	BaO	MgO	FeO	MnO	CaO	Na2O	K2O	SO3	Cl	F	Total
Cel1	34,630	26,600	0,000	0,000	36,940	0,000	0,090	0,000	0,032	0,175	1,033	0,000	0,000	0,016	99,516
Cel2	34,610	26,420	0,000	0,000	37,020	0,021	0,126	0,000	0,056	0,159	0,938	0,000	0,000	0,000	99,350
Cel3	35,220	26,290	0,000	0,000	36,790	0,000	0,091	0,000	0,050	0,157	1,123	0,000	0,000	0,000	99,721

ferrous form with ideal cations = 5, ideal oxygen = 8

No.	Si	Al	Ti	Cr	Ba	Mg	Fe	Mn	Ca	Na	K	SO3	Cl	F	Sum
Cel1	2,104	1,904	0,000	0,000	0,879	0,000	0,005	0,000	0,002	0,021	0,080	0,000	0,000	0,003	4,995
Cel2	2,107	1,896	0,000	0,000	0,883	0,002	0,006	0,000	0,004	0,019	0,073	0,000	0,000	0,000	4,990
Cel3	2,129	1,873	0,000	0,000	0,872	0,000	0,005	0,000	0,003	0,018	0,087	0,000	0,000	0,000	4,987

Table 3: Chondrodite - microprobe analyses

weight percent

No.	SiO2	Al2O3	TiO2	Cr2O3	BaO	MgO	FeO	MnO	CaO	Na2O	K2O	SO3	Cl	F	Total
chn1	34,120	0,000	0,712	0,021	0,000	55,850	3,050	0,217	0,020	0,013	0,000	0,000	0,000	7,990	101,994
chn2	33,650	0,000	0,533	0,000	0,000	56,420	3,140	0,243	0,000	0,000	0,000	0,000	0,000	7,700	101,686
chn3	33,440	0,012	0,616	0,012	0,040	56,260	3,180	0,192	0,023	0,000	0,000	0,000	0,015	8,000	101,790

ferrous form with ideal cations = 7, ideal oxygen = 10

No.	Si	Al	Ti	Cr	Ba	Mg	Fe	Mn	Ca	Na	K	SO3	Cl	F	Sum
chn1	2,196	0,000	0,034	0,001	0,000	5,359	0,164	0,012	0,001	0,002	0,000	0,000	0,000	1,626	7,770
chn2	2,170	0,000	0,026	0,000	0,000	5,425	0,169	0,013	0,000	0,000	0,000	0,000	0,000	1,571	7,804
chn3	2,163	0,001	0,030	0,001	0,001	5,426	0,172	0,011	0,002	0,000	0,000	0,000	0,002	1,637	7,806

Overview of the metamorphic evolution of tonalitic gneisses and metasedimentary sequences from the Kangaatsiaq, Lersletten and Sydostbugten area – first comparison to adjacent areas

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Two main metamorphic facies are observed in the area of the Kangaatsiaq map sheet. In the southern part of the area, largely unretrogressed granulite facies rocks are present. First results from microprobe analyses show that the granulite facies assemblage with Opx, Ti- and F- Amph and Bt was stable at 800 ± 20 °C at medium pressures. Such a high grade is supported by Opx bearing melt batches that are abundant in the area. In rock units exposed along the Ataneq fjord retrogression from granulite facies to amphibolite facies of approximately 640 °C at 4 to 5 kbar is well documented. In the partly retrogressed rocks, two types of Bt are present. The relict granulite facies Bt is Ti- and F-rich, whereas the new amphibolite facies Bt is virtually devoid of F and Ti. With retrogression, feldspars become richer in Na and poorer in Ca. Very similar estimates for both peak temperature metamorphism and retrogression are recorded in a layered, garnetiferous amphibolite at one of the islands in the W of the mapping area (E 390719, N 7575329). Here, recorded peak temperatures are 780 °C and retrograde conditions are at 620 - 640 °C. Metapelitic rocks of the area on the west side of the Qornussa fjord (E 402601, N 7582847) show relicts of kyanite and retrogression to the assemblage Sill-Grt-Bt-Fsp-Qtz which points to PT conditions of around 650 °C at 3 to 5 kbar. Cord has also been seen in the field but at this point it is not clear with which other minerals it formed an assemblage. The presence of kyanite can be attributed to medium pressures at temperatures above 700 °C. Element maps of garnets of the area show generally only minor variations in Ca, Mg, Fe, Cr and Mn from core to rim. Fe increases slightly at the rim while Mg and Ca decrease. The lack of a profound chemical zonation is at this point interpreted as a indicator that the area remained at temperatures above 500 - 550 °C for a very long time.

In the Lersletten area the observed, but rare, high grade metamorphic assemblage is Fo - Cc in marbles and Grt - Amph - Plag in mafic rocks. These assemblages point to temperatures above 700 °C. In most of the calcsilicate rocks the highest grade assemblage observed is Di - Cal - Phlog ± Dol and in metapelitic rocks Sill and Grt are present. These assemblages were stable at temperatures of approximately 620 ± 50 °C at 4.5 ± 0.5 kbar. During retrogression Tre forms which points to a decrease in temperature. Later reaction of Tre + Cal -> Dol + Qtz and formation of talc can be attributed to temperatures below 500 °C and influx of H_2O rich fluids. In general, most of the rocks of the Lersletten area are strongly or completely retrogressed to lower amphibolite to greenschist facies. Nevertheless, it cannot be excluded that some of the rock units in this area never reached metamorphic grades above lower amphibolite facies conditions.

To put the data obtained from rocks found in the Kangaatsiaq map sheet area into a regional perspective, several localities north of the Kangaatsiaq area were visited and studied. Composition of two generation of amphiboles in a Grt bearing amphibolite from the Sydostbugten area point to two metamorphic events. One at roughly 730 °C and one at 650 °C. Further to the north, at the peninsula of Nunatarsuaq (E of Isfjord), first microprobe analyses of a Grt amphibolite point to temperatures of 730 °C. In this rock Grt is rimmed by Plag which can be interpreted as a result of near-isothermal decompression. Another 100 km to the north (northern coast of the Torssukatak fjord), peak metamorphic conditions (Stau-Musc-Bt-Qtz-Fsp) at around 660 °C and retrogression at 550 to 610 °C are recorded. These rocks are thought to have been strongly affected by the Rinkian orogeny.

Although, this data is only preliminary, it seems that high temperature metamorphism extended from the southern part of the map sheet to at least the area around the town of Kangaatsiaq. Later retrogression took place under medium pressure amphibolite facies conditions. After this retrogression, the whole area remained at temperatures of at least 500 °C for an extended period of time. At least parts of the Lersletten area were subject to upper amphibolite facies to granulite facies metamorphism, but in this area strong retrogression due to high fluid influx retrogressed most of the rocks to greenschist facies assemblages. Such variation in metamorphic grade can not only be explained by a complete retrogression of former high grade assemblages but also juxtaposition of two different sets of tectonic slices with different metamorphic grades.

The metamorphic history established so far for the rocks of the Kangaatsiaq map sheet area, shows distinct differences to rocks further to the north. In the latter, no high temperature assemblage was observed so far. Further investigations supplemented with deformation texture studies and geochronological work are needed to refine the presented preliminary data and clarify the differences and similarities of rocks from different parts of the studied area.

Introduction to data available in the ArcView Interface: What is there? What has been done? What can be done? What should be done? and what does it possibly mean???

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We present a database which can easily be accessed through the GIS based ArcView program. In this database, topographic maps which cover the area visited in the 2001 field season, including the Disko Bugt area and the Ussuit area, are available. In addition to topographic maps, preliminary geological maps of Ussuit and Kangaatsiaq, and the published map sheets of Disko Bugt and Agto as well as the geological map of Henderson are provided.

Field data collected during the summer 2001 by the members of the Department for Geological Mapping and international co-workers has been put into the database. In the course of the project, the existing data will continuously be checked and updated to provide the user with the most up-to-date information. To access the data the program ArcView is used. This GIS based program allows to select specific attributes such as rock type, lineations, strike and dip of foliation, bedding or faults, sample locations etc. and represent them as symbols on a topographic or geological map. Within the ArcView environment it is also possible to search for specific combinations of features using SQL search facilities, for example the combined attributes of tonalitic gneiss and S-L fabric or samples for which thin-sections, chemical analyses etc. are already available. We hope that this database helps to visualize the different datasets and any combination of these and to provide the user with a good overview of the data currently available. Especially, the representation of structural data and direct link to a stereoplot program should be helpful and a good basis for discussions. In addition, overlays of geophysical data, rock type and areas of mineralisation are also possible and potentially of both scientific and commercial interest.

We show one example of the spatial distribution of the type of fabric in terms of S, S>L, S-L, L>S, L as seen in the field, which shows an interesting pattern. On the basis of a plot of this distribution five mostly WSW – ENE trending areas which are dominated by a specific type or combination of fabrics can be distinguished in the mapping area (Kangaatsiaq map sheet) (Fig.1). One area is seen in the S (area 1), here the fabric is dominated by the development of a strong S fabric without or only with low intensity lineations. This feature coincides with the area of dominantly granulite facies rocks. A bit further north, a second area (area 2) shows predominately S>L fabrics. Interestingly this area does not extent over the whole map sheet. Nevertheless, it may continue to the W (area 2b), but this area is defined by only a few data points. Further north, a belt (area 3) of dominantly S-L fabric is developed in the W, and towards the E an area which is dominated by an S fabric is seen (area 4). This area is not well defined as there are relatively few locations recorded. North of the Tunorssuaq fjord, no fabric type dominates (area 5).

Looking at this pattern, several questions can be raised which would need to be adressed in future work and discussions. Possible questions are:

1) Is the lack of linations in the southern part of the mapping area due to a) the higher grade which hinders lineation formation (result of annealing?) or b) a different type of deformation in this area? or c) different geologists recording different data in a different way?

2) Is a specific pattern associated with a) a specific rock type or b) fold pattern?

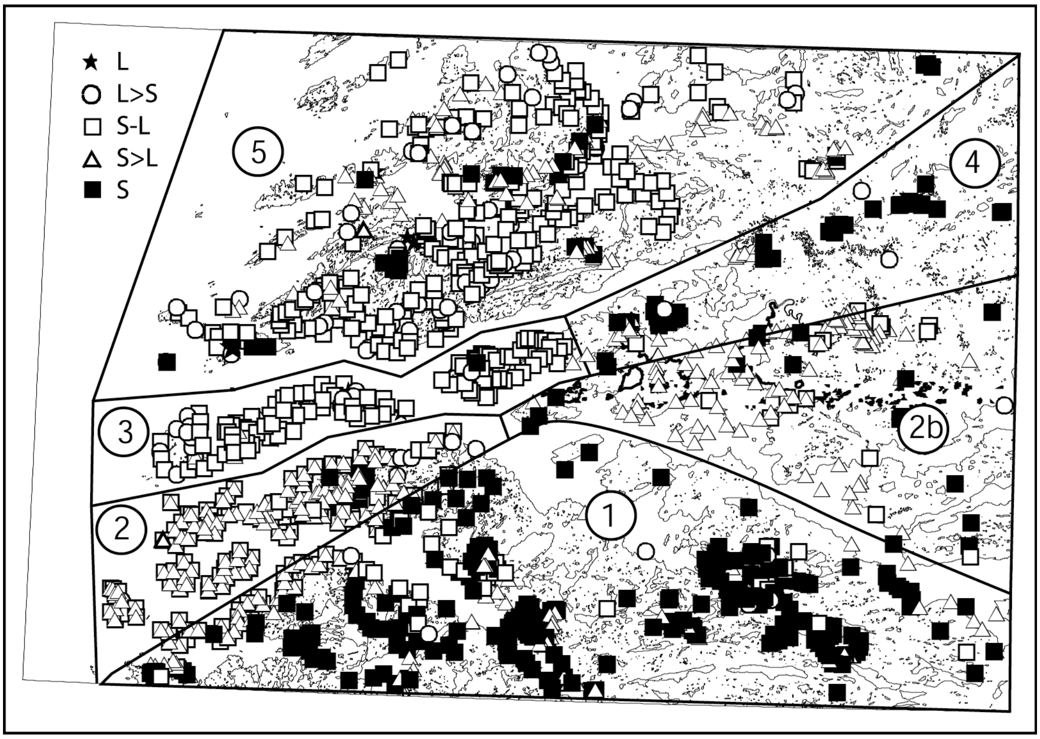

Figure 1: Illustration of the types of fabric using the program ArcView. Numbers correspond to areas described in text.

The above example shows that visualization of field data can help to distinguish areas, characterized by similar features and that such representation can be a good basis for further investigations. We hope that the presented database that is still UNDER CONSTRUCTION will be used extensively. We welcome any suggestions for improvement and any new set of data, which supplements the existing datasets.

Geochemical variation from Nagssugtoqidian to Rinkian

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A geochemical atlas of West and South Greenland, published last year (Steenfelt 2001), is based on chemical analyses of the <0.1 mm fraction of systematically collected stream sediments and contains distribution maps for 43 major and trace elements. The data set behind the atlas has been compiled using data selected from 18 individual sampling campaigns over a 20-year period. The analytical data have been quality controlled and calibrated by means of standards and re-analysis of sets of samples from batches collected in different campaigns (Steenfelt 1999, 2001).

The geochemical distribution patterns displayed by grid images of single elements or groups of elements reflect lithological variation and outline geochemical boundaries between tectonomagmatic and tectonostratigraphical domains within the Precambrian of West and South Greenland (Steenfelt 1994).

In the region from 66 N, i.e. from the Nagssugtoqidian southern foreland, to 74 N at the presumed northern limit of the Rinkian orogen geochemical data are presented at this workshop to provide information on

1. Nature of Palaeoproterozoic supracrustal sequences
2. Geochemical differences between Palaeoproterozoic intrusions (Sisimiut charnockite, Prøven charnockite)
3. Distribution of alkaline rocks
4. Crustal level, metamorphic grade and geochemical boundaries within the Archaean basement

Ad1. Rinkian supracrustals (sc) have higher concentrations of As, Sb, Au, Zn, HFSE, LILE and LREE than Nagssugtoqidian sc. HFSE, LILE and LREE are assumed to reflect the involvement of Archaean basement.

Ad2. Prøven charnockite (ProC) has higher K, lower Ca and Mg than Sisimiut charnockite (SiC). In trace elements ProC has higher HFSE, LILE and REE than SiC.

Ad3. Nb outlines kimberlite distribution. The Disko Bugt lamprophyres are not recognised in the geochemical maps. There is an alkaline rock in the Karrat area of the Rinkian.

Ad4. Very low LILEs in the Nag. provide evidence for low/mid crustal level in accordance with prevalence of granulite facies rocks. A geochemical boundary is outlined by Si and Ca maps and multi-trace-element factor score map through the CNO. This is the strongest geochemical boundary in the Archaean basement of West Greenland and must indicate a major change in crustal level. Another, minor, change is observed over Jakobshavn Isfjord, particularly in the Sr distribution. The Rinkian basement is rich in LILEs and the Cs pattern suggests high level granitic magmatism in the Rinkian orogen.

Mineral resource potential of Precambrian rocks (66°N – 70°15'N), West Greenland: current ideas and problems

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Evaluation of the mineral resource potential of the region from Maniitsoq (Sukkertoppen) to the southern part of Nuussuaq, West Greenland (66°N to 70°15'N) is part of the GEUS 'Contract with the Ministry (Resultatkontrakt – indsatsområde # 4.2)' running from 2000 to 2003 (GEUS 2000). Several exploration companies and the Geological Survey have been active in the study area from 1960 to 2000, investigating several mineral occurrences and significant amounts of data of various types already exist. The mineral resources can tentatively be divided into the following groups:

1. Base metals in volcanic massive sulphides (VMS)
2. Banded Iron Formation (BIF)
3. Gold
4. Diamonds
5. Special metals
6. Industrial minerals

Larger known mineral occurrences are:

1. Massive– semi-massive sulphide occurrences of the VMS type are found at Eqi, on Arveprinsen Ejland (Anderson showing), Naternaq (Lersletten) and in the Nordre Strømfjord steep belt (Ataneq).
2. Archaean iron formations form extensive layers of both banded iron formation (BIF) and mixed oxide and sulphide horizons within the greenstone-dominated successions. The biggest deposit is Itilliarsuk.
3. Mesothermal gold mineralisation is hosted in (a) the c. 2800 Ma old basic-acid succession at Eqi. (b) Syngenetic gold (e.g. Saqqaq) within chemical sediments as stratiform quartz/chert and massive-sulphide layers. These beds can be followed over 15-20 km in length. (c) As widespread epigenetic gold occurrences in shear- and breccia-zones e.g. Itilliarsuk and Attu.
4. Diamondiferous kimberlites are known especially from the southern part of the study area (Kangerlussuaq) and both macro- and microdiamonds are recorded.
5. Special metals like Nb-Ta in pyrochlore are found in connection with the 600 Ma Sarfartoq carbonatite. Monazite and allanite are common in pegmatites.
6. The industrial mineral is graphite, has been explored by several companies at the Akuliaruseq deposit. Recently, interests are focussed on garnets in heavy mineral sand from the Nordre Isortoq area.

During the fieldwork 2001 a number of minor mineral occurrences are registered and given in Table 1.

Mineralising events are presently not known in detail but some major episodes can be distinguished. (a) The oldest known mineralising event is the formation of syngenetic massive sulphides in the greenstone succession (~2800 Ma) at Eqi. (b) A second episode is contemporaneously with the regional peak metamorphism in the Disko Bay region (1900-1850 Ma). (c) A pronounced regional albitization post-dates the regional Palaeoproterozoic deformation. Fine-grained rutile-bearing albite-rich rocks replace Archaean granodioritic orthogneisses and Palaeoproterozoic metasediments. This episode might be more or less contemporaneously with (not genetically related) lamprophyre and lamproitic rocks with an age of c. 1750 Ma including a spectacular ultramafic flow with magnetite. (d) The fourth major mineralising event is the formation of a carbonatite (600 Ma) and related kimberlite dykes.

The current knowledge of the ages of the supracrustal rocks and mineral occurrences poses some problems:

- Are the supracrustal units and their associated VMS occurrences related to one unique time? If several stages of VMS genesis exist, which one is the most favourable? Is the fluid regime and metal composition variable over time?
- Are the numerous iron formations (both BIF and IF) an exploration guide for VMS and gold deposits?
- Are the gold occurrences structurally controlled, or can we suspect that some occurrences may have a primary host rock control? Or both? What is the significance of the NE–NNE major fault- and shear zones for the distribution of gold deposits?
- Are diamonds only related to the 600 Ma kimberlite/lamproite suite?

The above questions will be addressed in the talk and although some questions are too early to answer, the geological evolution of the study area is the key factor to understand the overall potential for new discoveries of both base and precious deposits in the region.

Genetic relation	Geological relation	Lithology	Ore minerals	Region/site
Syngenetic	Volcanic Massive Sulphide (VMS)	Amphibolite /exhalite/carbonate/ Calc-silicate rocks	Pyrrhotite-chalcopyrite	Naternaq, Nordre Strrømfjord
	Iron Formation (IF)	Amphibolite/gabbro	Magnetite /pyrrhotie /pyrite	Inuarullikkat Fjord
	Stratiform graphite schist	Mica schist	Pyrrhotite /graphite	Nordre Strømfjord, Aku-liaruseq
	Mafic/Ultramafic rocks	Gabbro/dunite /peridotite	Magnetite /pentlandite	Ataneq, Qasigiannguit, Ussuit
	Pegmatites	Qu-fsp pegmatite in gneiss/amph. K-fsp pegmatite in gneiss/amph.	Monazite Allanite	Distributed over the whole region
Epigenetic	Shear zones	Amphibolite/gneiss	Magnet-ite/pyrite/gold	South of Attu
	Fault zones	Amphibolite/gneiss	Pyrrhotite /pyrite /chalcopyrite	Kuup Akua, Ataneq, Ogaatsut, Laksebugt
	Quartz - carbonate veins	Amphibolite/gneiss	Magnetite /pyrite /pyrrhotite /gold	Attu, Kangilinaaq
	Lithological contacts and other lithologies	Mafic to ultramafic /gneiss Marbles and calc-silicates	Pyrrhotite /pyrite Fluorite	Ataneq, Kangilinaaq Kuup Akua

Table 1.

Old and new perspectives of The Nordre Strømfjord shear zone

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Mapping of the Agto map sheet was started in 1966 as a university project by Erling Bondesen and continued under his leadership till 1969. During this first period half of the map sheet area was mapped: the westernmost part of the shear zone and the area to the northwest of the zone. During compilation of these initial results the structure now known as the NS shear zone was recognized as a large scale, transcurrent and sinistral zone of ductile shear. In its western end the zone was shown to be distinctly wedge shaped, widening downwards with an opening angle of app. 40 deg. The geometry and inferred kinematics was published in Bak et al., 1975. At that time shear zones was a ”hot” topic within structural geology (see preceding review by Korstgaard) and mapping of the remaining part of the Agto map sheet was carried out as a second university project from 1975 to 1978, under the guidance of the author together with colleagues John Korstgaard and N.Ø.Olesen of Århus University.

On the final, resulting map (Olesen, 1984) the shear zone appears as a wide band of highly parallellized lithologies crossing the map sheet from its southwestern corner to its northeastern corner. Microstructural studies confirmed the kinematic model. In plagioclase feldspars studied by Olsen and Kohlstedt (1984, 1985) predominance of just one slip system ((010)[001]) was demonstrated leading to a relatively simple fabric pattern. This inference was confirmed by the TEM study by the same authors, in which the intracrystalline processes was investigated.

After completion of the mapping Sørensen (1983) made a renewed structural analysis of the shear zone focusing on two aspects: the apparent flat topped strain profile and the marginal zones of strain increase. If true, this profile suggests a process of weakening followed by hardening. It was suggested that the weakening process was of a chemical nature. Data in support of this suggestion was collected at Tiggait in 1980 by the author and John Winter, who made detailed sampling of a gneiss unit rotating into the shear zone and demonstrated (Sørensen and Winter, 1989) that deformation was accompanied by significant chemical changes. This paper happens to be the last published by participants in the aforementioned mapping projects. In it, the question of the relationship between chemical mobility and deformation is discussed. Suffice it to say our work ended on a note of significant uncertainty.

In Sørensen, 1983, it was concluded, that the model developed for the shear zone at Tiggait ”can only be considered representative for the westernmost, highest-grade, and most deeply eroded part of the NS zone. Between this part of the zone and its easternmost extension a transition in mechanics must take place”. ”Must”, retrospectively, seems a fairly strong word. The coming summer, John Korstgaard, Bill Glassley and the author will visit the easternmost part of the shear zone between Arfersiorfik and the Inland Ice in order to map and collect samples with a view to gain new insight in the Nordre Strømfjord shear zone at a level supposed to be different in mechanics to its high grade western part.

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The supracrustal rocks of the Ikamiut district

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Supracrustal rocks crop out extensively in the ground south and west of Ikamiut, the small settlement that lies on the peninsula between the bays of Nivập Pậ and Sydostbugt in the southeast corner of Disko Bugt. Mapping at 1:25 000 scale, undertaken during August 2001, refined and simplified the original mapping by Henderson, resolving some of the peculiarities of outcrop pattern that arose from his reconnaissance mapping of 1969.

The supracrustal rocks are interlayered with orthogneisses of dominantly granodioritic to more tonalitic composition. Contacts between supracrustal rocks and orthogneisses are generally marked by high strain and mylonites are extensively developed. In the south, some contacts appear less strained and there is some evidence to suggest discordance between the contact and the fabrics in the rocks on either side. In addition, the orthogneisses appear to contain an extra phase of deformation in addition to the phases of deformation that are seen to affect all the rocks across the area as a whole. No cross-cutting or intrusive relationships have been observed between the orthogneisses and the supracrustal rocks.

The rocks are disposed about kilometre-scale open to tight upright folds that deform the penetrative fabrics and the mylonitic contacts. A strong, penetrative stretching lineation is consistently orientated to the WSW down the plunge of the major folds.
The dominant supracrustal lithologies are psammites and micaceous psammites and schistose to gneissose pelites and semipelites. In general, the siliciclastic supracrustal rocks are readily distinguished from the granodioritic and tonalitic gneisses. Amphibolites form a subordinate, but important component of the supracrustal units.
The semipelitic and pelitic lithologies are migmatitic with ubiquitous, thin quartz-feldspar leucosomes. Garnet is commonly abundant and is wrapped by the penetrative schistose to gneissose fabric. Sillimanite is present locally and appears, locally, to pseudomorph ?kyanite and replace biotite.

Coarse quartz-plagioclase pegmatite is locally abundant, forming metre-thick, lenticular bodies within the micaceous host rock. Garnet, muscovite and sillimanite are locally present in these pegmatitic bodies, indicating derivation from a metasedimentary source. Other ‘pegmatitic’ bodies of pale rock in this area are layered internally and may be deformed quartzose psammites lying within the more pelitic rocks.
More siliceous rocks vary from dark micaceous psammites to quartzites. The psammitic rocks are locally garnet bearing and, where amphibolites occur in adjacent outcrops, may also contain amphibolite, suggesting a volcanic input. It is thought that all the siliceous rocks are likely to be sedimentary in origin, but it is possible that some of them may have been acid volcanic rocks. The more micaceous psammitic rocks are commonly migmatitic, with a quartz-feldspar leucosome.

Subordinate, but locally significant lenticular units of amphibolite commonly contain abundant and large garnet porphyroblasts with very fine quartz-plagioclase pressure shadows. The amphibolites are massive to layered and heterogeneous with thin, marginal calc-silicate bearing units. The amphibolites and associated rocks are thought most likely to be metavolcanic in origin. Sulphide mineralisation occurs locally in the margins or amphibolites where calc-silicate bearing units are developed.

The Ikamiut supracrustal rocks are, in general, very similar to those described from Lersletten, although no carbonate rocks, marbles, banded iron formation or layered cherts have been recorded in the Ikamiut area. At this stage, it seems sensible to correlate the Ikamiut rocks with those from Lersletten, and those on the Christianshåb peninsula to the northeast, the latter being along strike from Ikamiut.

Linking the Nagssugtoqidian orogen and Rinkian belt: Preliminary ages from the Disko Bugt region.

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Samples were collected across a transect in the Disko Bugt region during the 1997 and 2001 field seasons to determine ages of basement gneisses and supracrustal rocks and to constrain the age of deformation in the area. This information will test proposed temporal links between the Nagssugtoqidian orogen and Rinkian belt, and permit more regional correlations with segments of the Trans-Hudson Orogen in northeast Canada. We report preliminary data from seven samples analysed by TIMS and four by LAM-ICP-MS at the University of Texas at Austin.

Five samples of presumed Archean metaigneous rocks have been analysed from this transect. They are discussed from north to south. Two samples collected in the southeastern part of north of Nuussuaq represent a metavolcanic rock and the Itilli diorite. The metavolcanic rock, containing abundant fine-grained volcanic clasts, yielded euhedral to subhedral zircons that are interpreted to be of igneous origin. Two fractions from this sample fall on a line with intercept ages of ~2872 Ma and ~1850 Ma. The upper intercept is interpreted to represent the timing of volcanism and a minimum age for the underlying basement. The lower intercept represents high temperature Pb-loss and thus dates metamorphism at this locality.

The second sample from this region represents the Itilli diorite, which is described by Garde and Steenfelt (1999) as demonstrably intruding into the surrounding basement rocks. The rock yields a preliminary crystallization age of ~3030 Ma, to our knowledge, the oldest age obtained from the Nagssugtoqidian and Rinkian orogens. This requires the host basement rocks in this area to be older than 3000 Ma.

Two samples of foliated, but homogeneous, layers of tonalite within the typical orthogneisses were collected in the southern part of Disko Bugt in 1997, one just south of Pakkitsoq fjord and the other on the east shore of Sikuiutsoq fjord. The more northern sample yields preliminary data that suggests an age of 2785 Ma whereas the more southerly sample yields a preliminary age of 2792 Ma.

The ca. 2.80-2.75 Ga ages of these new samples and those of Nutman & Kalsbeek (1999) are similar to ages of orthogneisses and foliated granites in the northern Nagssugtoqidian orogen. In contrast, the two ages from north of Torsukattak fjord are significantly older. While very preliminary, we wonder whether existing data hint at the existence of two crustal blocks in this transect: a younger southern block that is an extension of the northern Nagssugtoqidian orogen and a northern, older block. The boundary is marked by the Torsukattak shear zone and an abrupt metamorphic break. Further analyses on more samples are required to test this hypothesis.

The second objective was to establish the timing of metamorphism and deformation across this transect. To date, we have analysed zircons from three samples from a belt of mixed metasediments and orthogneisses between Sikuiutsoq fjord and the ice cap in the northern part of Nunatarsuaq. These specifically constrain the timing of gneissic layering, folding and amphibolite facies metamorphism.

A deformed pegmatite dyke along the east shore of Sikuiutsoq fjord cuts across gneissic layering. Three fractions yield a preliminary age of 1842 Ma, thus requiring the high temperature fabrics to predate this age. An amphibolitic gneiss and a syn-folding granite dyke were collected from a single outcrop east of this locality. Two concordant fractions of small round zircons from the amphibolitic gneiss yield an age of ~1814 Ma, which we interpret to represent the timing of amphibolite facies metamorphism. The granite contained large, elongate zircons with distinct cloudy cores and large, brown rims. We interpret the cores as inherited, while the rims represent the age of the intrusion of the granite. Two fractions of zircon tips yield a preliminary age of ~1817 Ma.

This age constraint for the gneissic banding is consistent with the age of peak metamorphism in the Nagssugtoqidian orogen (ca. 1860 Ma). Similarly, the amphibolite-facies folding of this layering overlaps with the ca. 1820 Ma age for F2 folding established for the central Nagssugtoqidian orogen (Connelly et al. 2000).

In addition, we report preliminary results of detrital zircons from 4 metasedimentary sequences collected during the 2001 field season and analyzed, as part of a pilot study, using quardropole LA-ICPMS at The University of Texas at Austin. Two metasediments from the northern part of the Disko Bugt (the northern and the southern part of Anap Nuna) are thought to represent the same sequence. The northern sequence contains both Archaean and Palaeoproterozoic zircons. The sediment is of such low metamorphic grade that it is unlikely to contain any metamorphic zircons - accordingly, we interpret the Proterozoic zircons to be detrital and, thus, the sediment to be Proterozoic (which is also supported by the structural pattern (Garde & Steenfelt, 1999)).

The metasediment from the southern side has a very different detrital zircon age distribution. The sediment is dominated by Archean zircons around 2500-2700 Ma. In this case it is difficult to say whether the zircons are pre-2800 Ma old grains which have suffered Pb-loss or if they are concordant age, and it is therefore not possible to say if the deformation of the sediment is Archaean or Palaeoproterozoic.

The two last metasedimentary rocks are from the central map area of 2001. In the southern part of the area, a wide spread metasedimentary sequence occurs that is different from other metasediments in the area. It is a fine-grained, quartz-rich sediment with abundant small garnets. A similar type is seen in the central Nagssugtoqidian orogen. The rock is dominated by Archaean zircons, making it impossible to say whether it is an Archaean or a Proterozoic metasediment.

The other metasediment analysed from the 2001 map area is from the large metasedimentary band at Lersletten that has been folded. It contains only Palaeoproterozoic zircons. It is not possible at this moment to say if the zircons are detrital or metamorphic. Either way, the large structures at Lersletten must be Paleoproterozoic.

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Review of Nagssugtoqidian geology with emphasis on the transition to the Rinkian Orogen

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The present project of GEUS in West Greenland was devised to link the work by the DLC in the central and southern segments of the Nagssugtoqidian Orogen (CNO and SNO, see map on page 8) and the work by GGU in the southern Rinkian Orogen of the Disko Bugt area. The area of interest was named the Northern Nagssugtoqidian Orogen (NNO) and forms the transition from typical Nagssugtoqidian geology, dominated by ENE-trending structures, to the Rinkian belt, dominated by large fold structures and typically subdivided in domains with distinctly different geological evolutions.

The most recent model for the tectonic evolution of the Nagssugtoqidian Orogen shows it as a collisional orogenic belt. A complexely deformed suture zone in the CNO separates a northern and southern Archaean block of very similar character. They comprise predominantly late Archaean (2870-2810 Ma) orthogneisses with remains of older, dioritic crustal segments and mafic supracrustal rocks, intruded by less-deformed granitic bodies (*c.* 2700 Ma). In the southern foreland and the SNO, the Archaean gneisses are intruded by dykes of the NNE-trending Kangamiut dyke swarm (2040 Ma). Observations from the CNO are interpreted to show the following elements in the evolution:

- Deposition of metasediments both in continental margins and in basins distal to the Archaean plates between 2000 and 1950 Ma
- Subduction of an oceanic plate indicated by calc-alkaline plutonism of the Arfersiorfik and Sisimiut intrusive suites between 1940 and 1870 Ma
- Collision resulting in northwest-directed thrusting and development of a main gneissic fabric under progressively increasing metamorphic grade, resulting in peak metamorphism between 1860 and 1840 Ma
- Isoclinal folding, of which the age and kinematics are poorly constrained
- Kilometre-scale upright folding in ENE-trending folds was under way by 1925 Ma and was accompanied by currogated, low-angle (possibly extensional) top-to-east shear zones
- The latest penetrative deformation was sinistral shearing in a series of steep belts, dated in the Nordre Strømfjord area at ca 1775 Ma.
- Very slow and consistent cooling histories of the whole orogen indicates that uplift occurred statically as the result of erosion

The northern segment of the Nagssugtoqidian orogen is the least known within the region. Reconnaissance mapping by the GGU and short visits by the DLC led to the suggestion that the evolution of the NNO was transitional between the CNO and the Rinkian belt. The NNO is, like the remainder of the Nagssugtoqidian Orogen, dominated by Archaean orthogneisses. The majority of the supracrustal rocks here are intruded by these igneous rocks and must also be of Archaean age. The only known candidate for Palaeoproterozoic supracrustal rocks is the Naternaq-Ikamiut-Christianshåb supracrustal belt. No equivalents of the Palaeoproterozoic calc-alkaline intrusives have been identified nor have the phases of north-directed thrusting or east-directed shearing been recognised. Minor shear zones have been recognised, but none at the scale of the ones in the CNO. On the other hand, the metamorphic grade appears to be progressively decreasing from the granulite/upper amphibolite facies in the CNO and of the same age as in the remainder of the orogen. The dominant ENE trend of the main fabric persists in the NNO and also the late ENE-trending upright folds appear to continue from CNO into the NNO.

The southern Rinkian Orogen is characterised by a phase of west to north-west-directed nappe emplacement and kilometre-scale upright folds, very similar to the CNO, but it lacks the consistent ENE trending fabric of the Nagssugtoqidian Orogen. Metamorphic grade is variable at lower amphibolite to greenschist facies, but the age of peak metamorphism is not known. Cooling ages from the southern Rinkian Orogen are not consistent, suggesting that smaller tectonic units were uplifted separately and syn-tectonically.

In general there are consistent elements and progressive variations from the CNO, through the NNO to the southern Rinkian that could suggest that this whole area has undergone a common tectonic evolution. However, there is still a significant gap in the knowledge of the area, specifically lack of age data, and these matters are still under debate. Hopefully, the present project can resolve some of the outstanding problems.

The Precambrian supracrustal rocks in the Lersletten region and preliminary conclusions on associated massive sulphide mineralisation

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The Precambrian supracrustal rocks in the Lersletten region, West Greenland, outlines a major fold structure at least 25 km long and up to c. 3 km wide embedded in Archaean orthogneisses and granitic rocks belonging to the Northern Nagssugtoqidian Orogen (NNO). The belt forms a negative signature on the regional aeromagnetic map, which further indicates that the belt may be extented to the supracrustal rocks in the Christianshaab area.

The Lersletten supracrustal belt is dominated by amphibolite, siliceous quartzo-feldspathic rocks and garnet-mica schists. Marble and calc-silicate rocks, quartzitic rocks, carbonate and oxide facies iron formation, and sulphide mineralised chert-rich layers of presumed exhalitic origin are minor constituents. In spite of strong internal folding and possibly thrusting the belt possesses a crude lithological stratigraphy dominated by amphibolite along the outer margin of the major fold, succeeded by siliceous quartzo-feldspathic schist alternating with garnet mica-schist, in which other horizons of amphibolite are found. Where marble is present, usually intercalated with calc-silicate rocks, it immediately succeeds the marginal amphibolite.

Sporadic findings of strongly deformed pillow-like structures and sheared plagioclase aggregates (original phenocrysts?) suggests that the marginal amphibolite origins as basic pillow flows and pillow breccias. The origin of the siliceous quartzo-feldspathic schist is unclear based on field appearance, it might be a clastic sedimentary rock or perhaps an acid volcanic rock, or a mixture of clastic and variable reworked volcanic material.

Sulphide mineralisation occurs at the transition between the marginal amphibolite and an irregular sequence of chemical sediments dominated by dolomite marble and minor carbonate and oxide facies banded iron formation hosted by cherty rocks of supposed exhalative origin. The mineralisation is dominated by pyrrhotite besides minor chalcopyrite and sphalerite (Fe and Cu locally up to c. 3 vol.%, respectively) and subordinate pyrite, arsenopyrite, magnetite and graphite. Semi-massive to massive sulphide mineralisation is especially found near Round Lake and Finger Lake and may form up to 2*10m long lenses. Thinner, conformable horizons containing disseminated to semi-massive sulphides may be followed for up to a few hundreds metres outside these areas. Metre-sized and larger, tight, overturned angular folds are common within the mineralised zones and the massive sulphide lenses commonly occur in the hinge zones of such folds.

Sulphide mineralisation occurs locally in up to three separate sequences of marble and chert-rich rocks. The field work carried out this summer suggests that this is most likely due to repetition of a single original sequence by folding; thus massive sulphide mineralisation was probably only developed at one stratigraphic level. The possible volcanic origin of the supracrustal rocks and the exhalative nature of the host rocks (i.e. laminated chert intercalated with fine-grained ”black ore” sulphide mud) suggests that the sulphide mineralisation resembles a VMS deposit developed in a volcanic-arc setting. It is suggested that secondary hydrothermal remobilisation during folding and deformation of the supracrustal rocks caused the disseminated sulphides to migrate into distinct semi-massive and massive ore horizons.

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