# Nordic Mineralogical Network

## 4th Annual Meeting
## September 28 – October 2 2009

## Department of Geology
## University of Helsinki

# 4th Annual Meeting
# Nordic Mineralogical Network

## Participants:

| | Presentation |
|---|---|
| **Maarten Aerts**<br>Natural History Museum, Geology<br>University of Oslo<br>Box 1172, Blindern, N-0318 Oslo, Norway | oral |
| **Tonçi Balic-Zunic**<br>Institute for Geography & Geology<br>Dept. Mineralogy<br>University of Copenhagen<br>Øster Voldgade 10, DK-1350 Copenhagen K, Denmark | |
| **David Cornell,**<br>University of Gothenburg, Box 460, SE-40530, Sweden | poster |
| **Henrik Friis**<br>Institute for Geography & Geology<br>Dept. Mineralogy<br>University of Copenhagen<br>Øster Voldgade 10, DK-1350 Copenhagen K, Denmark | oral |
| **Snorri Guðbrandsson**<br>Institute of Earth Sciences, University of Iceland | poster |
| **Pasi Heikkilä**<br>Department of Geology<br>P.O. Box 64, FI-00014 University of Helsinki, Finland | |
| Dr.geol, docent **Vija Hodireva**<br>Faculty of Geographycal and Earth Sciences<br>University of Latvia<br>Alberta str. 10, Riga, LV-1010, Latvia | poster |
| **Hanna Junttila**<br>Assistentti/tohtorikoulutettava (geologia ja mineralogia)<br>University of Oulu | oral |
| **Milda Kairyte**<br>Vilnius, Lithuania | - |
| **Anna Katerinopoulou**<br>Institute for Geography & Geology<br>Dept. Mineralogy, University of Copenhagen<br>Øster Voldgade 10, DK-1350 Copenhagen C, Denmark | - |

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| **Afsoon Moatari Kazerouni**<br>Geologisk Institut -Aarhus University,<br>C.F. Moellers Alle 1120, DK-8000 Aarhus, Danmark | poster |
| **Tomas Kohout**<br>Department of Physics<br>P.O. Box 64, FI-00014 University of Helsinki, Finland | oral |
| **Kirsi Larjamo**<br>Department of geology<br>P.O. Box 64, FI-00014 University of Helsinki, Finland | - |
| **Seppo Lahti**<br>GTK, Geological Survey of Finland<br>Betonimiehenkuja 4, FI-02150 Espoo, Finland | oral |
| **Sari Lukkari**<br>PhD, researcher<br>Department of Geology, FIN-00014 University of Helsinki, Finland | - |
| **Ilze Lūse,**<br>Department of Applied Geology, Faculty of Geography and Earth Sciences,<br>University of Latvia,<br>Alberta Street 10, Riga,<br>LV-1010, Latvia, | poster |
| **Luca Menegon**<br>Institutt for geologi<br>Universitetet i Tromsø<br>Dramsveien 201, N-9037 Tromsø, Norway | poster |
| **Jüri Nemliher,**<br>Institute of Geology at Tallinn<br>University of Technology,<br>Ehitajate tee 5, 19086, Tallinn, Estonia | - |
| **Lars Arnskov Olsen**<br>Department of Geography and Geology<br>University of Copenhagen<br>Private address:<br>Rued Langgards Vej 21, 3. th, DK-2300 Copenhagen S, Denmark | **-** |
| **Benedetta Periotto** (Phd student)<br>Department of Geography and Geology, University of Copenhagen<br>Öster Voldgade 10, DK-1350 Copenhagen K | poster |
| **Matti Poutiainen**<br>Department of geology<br>P.O. Box 64, FI-00014 University of Helsinki, Finland | - |
| **Timo Ridaskoski**<br>Department of geology<br>P.O. Box 64, FI-00014 University of Helsinki, Finland | - |

**Ilona Romu** oral
Department of geology
P.O. Box 64, FI-00014 University of Helsinki, Finland

**Tapani Rämö** oral
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**Valby van Schijndel**, PhD Student poster
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**Jarkko Stenman** -
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**Sigurjón Bödvar Thórarinsson** poster
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**Akseli Torppa** oral
M.Sc., Researcher
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**Reidar G. Trønnes** oral
Natural History Museum, Geology
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**Pekka Tuisku** -
University of Oulu

**Ragnar Törnroos** -
Department of geology,
P.O. Box 64, FI-00014 University of Helsinki, Finland

**Mira Valkama** oral
University of Turku

# 4th Annual Meeting - Nordic Mineralogical Network

## Program:

### Monday 28.9

18.00 Ice breaking party, Department of Geology, Campus Kumpula

### Tuesday 29.9

Session I *Chairman Ragnar Törnroos*
09.00 Welcome words
09.15 Tonçi Balic-Zunic *Introduction*
09.30 Maarten Aerts *Silicate melt – fluid miscibility upon cooling in the Earth's crust: the transition from granite to pegmatite*
10.00 Ilona Romu *On the crystallization of the ultrapotassic dykes of Vestfjella, Antarctica*

10.30 Coffee

Session II *Chairman Pasi Heikkilä*
11.00 Reidar G. Trønnes *Chemical provinces and melting of the NE Atlantic mantle*
11.30 Hanna Junttila *Adsorption of Ni and Cu onto natural iron precipitates, in Vihanti bog iron ore deposit*
12.00 Henrik Friis *Advances in neutron instrumentation with potential for mineralogy*

12.30 Lunch

Session III *Chairman Pasi Heikkilä*
13.30 Tapani Rämö *On the isotopes of some minerals in the Luumäki granite pegmatite*
14.00 Akseli Torppa *REE and LILE minerals in the Panjavaara Carbonatite, Finland*

14.30 Coffee

15.00 Seppo Lahti *Viitaniemi pegmatite*
+++ Briefing for excursion

### Wednesday 30.9

Excursion to the Viitaniemi pegmatite in Eräjärvi
Guide Seppo Lahti
08.15 Busses start at Kumpula
Lunch in field
18.00 Back to Helsinki

### Thursday 1.10

09.00 Mineralogical Museum, Arto Luttinen

12.00 Lunch

Session IV *Chairman NN*
13.00 Luca Menegon The *Bed Rock Geology Group at the University of Tromsø*
13.20 Tomas Kohout *Daubreeltie and troilite as a source of low-temperature cometary and minor body magnetism*

13.50 Poster session
14.30 Posters + coffee + NMN meeting
15.15 Meeting closure

17.00 Meeting dinner

## Friday 2.10 (optional)

09.00 Ferry to Sveaborg
…. back in your own time

## POSTER SESSION

David Cornell, Åsa Pettersson, Joanna Wojtyla, Linn Karlsson, Valby van Schijndel
*Finding a Lost Continent Under the Kalahari Using Zircon Dating*

Snorri Guðbrandsson, Wolff-Boenisch, D., Gislason, S.R., Oelkers, E.H.
*Dissolution rates of crystalline basalt as a function of pH and temperature*

Vija Hodireva, Denis Korpechkov
*Heavy mineral assemblages in the Devonian and Quaternary deposits as kimberlite trace in Western part of the East-European platform*

Afsoon Moatari Kazerouni, Henrik Friis, Johan B. Svendsen
*Generation of Quartz in Claystone Diagenesis- Examples from the Siri Canyon, Danish North Sea*

Ilze Lūse, Valdis Segliņš, Agnese Stunda
*Illite polytype diagnostics between primary and secondary mineral phases*

Luca Menegon, Holger Stunitz, Erling Ravna, Kåre Kullerud, Steffen Bergh
*The Bed Rock Geology Group at the University of Tromsø*

Benedetta Periotto, Nestola F., Balic-Zunic T., Ohashi H.
*High-pressure systematic of* $NaMe_3+Si_2O_6$ *pyroxenes: volume compression vs* $M^{3+}$ *cation radius*

Valby van Schijndel David H Cornell Linn Karlsson Johan R. Olsson
*The 300 Ma Dwyka diamictite Southern Africa*

Sigurjón Bödvar Thórarinsson P.M. Holm, S. Tappe, L.M. Heaman, C. Tegner,
*U-Pb zircon ages from the Kap Washington Volcanic Province, North Greenland -implications for the evolution of the Arctic Basin*

Mira Valkama *An ore petrological and geochemical study of the polymetallic skarn ores at Pitkäranta*

# Silicate melt – fluid miscibility upon cooling in the Earth's crust: the transition from granite to pegmatite.

Maarten Aerts[1,2], Alistair C. Hack[2], Peter Ulmer[2] and Alan B. Thompson[2]

[1]*Natural History Museum, Geology, University of Oslo, Norway*

[2]*Institute for Mineralogy and Petrology, ETH Zürich, Switzerland*

Silicate-bearing aqueous fluids are important mass transfer agents in the Earth's interior. In-situ observations of high-pressure, high-temperature fluid-rock interactions revealed how increasing solute contents can drive such aqueous fluids to melt-like behaviour at great depths in the Earth. For granitic systems, a continuous transition from hydrous magma to low-temperature hydrothermal solution has been postulated, but has not been reconciled by available data. Here we show experimental evidence for the stable coexistence of fully miscible peralkaline solutions with a model-granite at upper-crustal depths and temperatures down to 350°C. In strong contrast to subduction-zone environments, complete miscibility in a granite-$H_2O$ system was found to occur during cooling as opposed to heating. Such low-temperature fluids and their phase relations are dramatically different from those of mantle and subduction zone fluids, and suggest that vastly enhanced mass transport related to supercriticality occurs along completely different thermal pathways in the crust compared to mantle. The fluids we have identified tend to dissolve wall rocks during cooling and are likely most important at the cooling margins of large intrusive complexes and at the late dying stages of granite fractionation and pegmatite petrogenesis. These experimental results indicate that the occurrence of supercritical silicate-bearing fluids is not restricted to the deep Earth and provide a possible explanation for the frequently observed causal relation between aqueous vapor saturation of granitic melt and the formation of giant crystals in granitic pegmatites.

# Advances in neutron instrumentation with potential for mineralogy

Henrik Friis[1+2], Emil Makovicky[1] and Mark T. Weller[2]

[1] Institute for Geography & Geology, University of Copenhagen, Dept. Mineralogy, Øster Voldgade 10, 1350 Copenhagen K, Denmark
[2] School of Chemistry, University of Southampton, Highfield, Southampton, Hampshire, SO17 1BJ, UK

This presentation deals with recent developments in instrumentation at Institut Laue-Langevin (ILL) in Grenoble, France, and how these are of interest to the mineralogy community. In classical X-ray diffraction studies of minerals one relies on the scattering power of electrons for a specific site. As a consequence the accuracy in atom position is influenced by the number of electrons and hence the atomic number of the elements present in the mineral. This dependence on electrons result in often poor accuracy for the position of the light elements like H and Be, but these have high scattering powers in neutron studies. Normally, single-crystal neutron diffraction requires significantly larger sample material than what is necessary for X-ray diffraction analyses. However, we will here present instruments that enable us to do single-crystal neutron diffraction on 1 $mm^3$ crystals or even powder analyses down to 5-10 mg. With such sample sizes neutron diffraction becomes relevant to study many mineralogical problems and also study rare minerals, which are by definition only found in small quantities.

# Adsorption of Ni and Cu onto natural iron precipitates, in Vihanti bog iron ore deposit

**Hanna Junttila, Seppo Gehör and Erkki Eijärvi**

University of Oulu

The mires in Vihanti area, central Finland contain exceptionally high amounts of natural iron precipitates having goethite (GÖT) and siderite (SID) as the main Fe-phases. This study concentrates into properties of goethite and siderite as adsorbents for Ni and Cu. A scanning electron microscope (SEM-EDS) study was carried out in aiming to recognize the characteristics of adsorption process.

The adsorption efficiency of the iron minerals on Ni and Cu was studied by using the batch technique. A known amount of adsorbent and 200 ml of solution was added to 250 ml plastic bottle. After shaking the adsorbent was filtered and dried and there was made a polished section of the material.

Eight polished thin sections were prepared for the SEM-EDS study. A SID bulk sample and a GÖT bulk sample were taken into study to represent the unhandled natural Fe-precipitates. Two GÖT samples and four SID samples were chosen to represent the Fe-precipitates adsorbed by Ni or Cu in different conditions (dosage, pH and amount of Ni or Cu).

The SEM-EDS study on eight SID and 11 GÖT grains proved that the natural Fe-precipitates do not contain copper or nickel in measurable amounts.

The efficiency of siderite as adsorbent has been verified in the laboratory tests. The adsorption capacities of the samples that were analyzed have been over 90% for initial solutions with 10ppm Ni and about 50% for initial solution with 100ppm Cu. Anyway, only few of analyzed siderite grains contained remarkably Ni or Cu. The highest concentrations were measured in small grains that had grain size of 20µm at the maximum. There cannot be seen a particular trend of adsorbing to certain types of grains. The elevated metal concentrations were measured either in the boundary of the grain or in the middle of the grain or both.

For goethite the adsorption capacities have been similar to siderite. Analyzed goethite grains had elevated Ni or Cu concentrations at least at the boundary of the grain. Also bigger grains (over 50µm) had adsorbed these metals. On the case of goethite, there can be seen a clear trend of metals adsorbing to grains that have irregular surface texture. This means, that porous-looking grains had better Ni and Cu concentrations than smooth or regular shaped grains.

# Daubreeltie and troilite as a source of low-temperature cometary and minor body magnetism

**Tomas Kohout[1, 2], Radek Zbořil[3], Patricie Týcová[4], Jakub Haloda[4], Andrei Kosterov[5], Michael Jackson6[4], Martti. Lehtinen[7],**

1. Department of Physics, University of Helsinki, Finland, tomas.kohout@helsinki.fi
2. Institute of Geology, Academy of Sciences of the Czech Republic, Prague, Czech Republic
3. Centre for Nanomaterial Research, Palacky University, Olomouc, Czech Republic
4. Czech Geological Survey, Prague, Czech Republic
5. Earth Physics Department, Institute of Physics, St. Petersburg University, St. Petersburg, Russia
6. Institute for Rock Magnetism, University of Minnesota, Minneapolis, MN, USA
7. Geological Museum, University of Helsinki, Finland

Various FeNi phases are dominant magnetic phases in most chondritic meteorites. In addition, iron-bearing sulphides are present in meteorites and in cometary dust. The low-temperature magnetic properties of the alabandite (Fe,MnS) daubreelite ($FeCr_2S_4$) and troilite (FeS) were investigated.

Daubreelite is paramagnetic above its Curie temperature $T_c$=150 K and ferrimagnetic below $T_c$. On cooling through the $T_c$ saturation magnetization of daubreelite sharply increases at 80 K. Below $T_c$, magnetic susceptibility of daubreelite ranges between 0.5-3.5 $10^{-4}m^3/kg$ reaching maximum immediately below it. Further cooling through magnetic transition at $T_m$=60 K (accompanied by spin-glass-like features and cubic-to-triclinic symmetry reduction) reveals as a local maximum of FC (Field Cooled) induced magnetization and susceptibility at $T_m$.

Similarly to daubreelite, alabandite is paramagnetic above its Curie temperature $T_n$=148 K and anti-ferromagnetic below $T_n$.

At room temperature troilite is antiferromagnetic. At temperature $T_m$=60 K a magnetic transition of uncertain origin occurs (most likely transition to ferrimagnetic state). Below $T_m$ the saturation magnetization and coercivity of troilite significantly increases. The coercivity reaches ~300mT at 5 K. This value is underestimated as the powdery sample used do not saturate at 5 T. Susceptibility of troilite is low (~4 $10^{-7}m^3/kg$) with a local maximum at $T_m$ (~1.7 $10^{-6}m^3/kg$).

The magnetization and susceptibility of iron bearing sulphides, especially daubreelite, is significantly increased in low temperature range. Those minerals can contribute to or even control magnetic properties of bodies in the cold regions of our Solar System.

The thermal conditions of the objects in the main asteroid belt are probably above those temperatures. However the icy trans-Neptunian objects as well as comets containing “magnetic” iron sulphides within the dusty fraction are among candidate objects for recording low-temperature magnetic events. This can be also the case of the comet 67P/Churyumov-Gerasimenko which will be visited by the Rosetta space probe with the magnetometer on board as well as on the lander. The magnetic properties of iron bearing sulphides must be considered while interpreting the magnetic observations of such bodies.

# On the crystallization of the ultrapotassic dykes of Vestfjella, Antarctica

Ilona Romu (1), Arto Luttinen (2), and Hugh O´Brien (3)

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*3 Geological Survey of Finland, PO Box 96, FIN-02151, Espoo, Finland*

The Vestfjella ultrapotassic dyke swarm in western Dronning Maud Land, Antarctica is comprised of 16 dykes at nunataks Kjakebeinet (73°47´ S 014°51´ W) and Muren (73° 44´ S 015° 00´ W). The ultrapotassic swarm was first discovered during the FINNARP 1998 expedition and, subsequently, Luttinen et al. (2002) dated two of the dykes at 159 Ma, pointed out some affinities to spatially and temporally related orangeites (group II kimberlites) of southern Africa (Mitchell, 1995; Smith, 1983), and referred to them as lamproites on geochemical and mineralogical basis. During austral summer 2007, 11 previously un-documented ultrapotassic dykes were discovered. Products of volatile-rich lamproite and orangeite magmas are typified by notably variable mineral assemblages. Especially, the distribution of trace-element enriched accessory mineral phases may hamper geochemical interpretations. In our study, petrography and mineral chemistry are used to reconstruct the crystallization and cooling history of the dykes, specifically the relation of zoned phenocrystic phases to the groundmass mineral assemblage.

References

Luttinen, A.V., Zhang, X., Foland, K.A., 2002. 159Ma Kjakebeinet lamproites (Dronning Maud Land, Antarctica) and their implications for Gondwana breakup processes. Geological Magazine 139 (5), 525-539.

Mitchell, R.H., 1995. Kimberlites, orangeites, and related rocks. Plenum Press, New York, 410 p.

Smith, C.B., 1983. Pb-Sr and Nd isotopic evidence for sources of southern African Cretaceous kimberlites. Nature, 304, 51-54.

# REE and LILE minerals in the Panjavaara carbonatite, Finland

**Akseli Torppa**

University of Helsinki, Department of Geology

A small swarm of carbonatite dikes, characterized by a notably diverse mineral composition, has been discovered at Panjavaara, eastern central Finland. Particularly, the REE and LILE carbonate minerals in the studied rocks include a number of moderately-to-extremely rare mineral species, for instance, an uncommon member of the calcite-strontianite solid-solution series with ca. 1:1 Sr-Ca ratio. In total, over 20 different minerals that occur in more than trace amounts have been identified in the dikes; comprising carbonates, phosphates, silicates, sulphates, sulphides, and oxides.

The chemical composition of the Panjavaara carbonatite dike swarm is characterized by strong enrichment in light-REE (La-Sm) and LILE, especially Ba and Sr. Average concentrations of La, Sr, and Ba, in the studied samples (n=17) are 3.2, 3.8, and 4.8 %, respectively. A total of 50 dikes of this type, ranging from 1-60 cm in width and from meters to tens of meters in length, have been observed in an area of 70 km$^2$.

In the present work, a preview to the mineral composition of the Panjavaara carbonatite dike swarm is given. The structures and chemical compositions of the minerals have been examined by X-ray powder diffraction and electron microprobe. In addition, single crystal X-ray diffractometry was applied for the study of certain species.

# Chemical provinces and melting of the NE Atlantic mantle

**Reidar G. Trønnes, Natural History Museum, University of Oslo**

Our recent geochemical investigation of a suite of primitive off-rift basalts from Iceland and Jan Mayen (Debaille et al., GCA, 2009) has demonstrated an important source contribution of subcontinental lithospheric mantle (SCLM). A compilation of our data on the primitive off-rift basalts and pre-existing data on the tholeiitic basalts from Iceland and nearby oceanic ridges indicates the existence of three main composite mantle components, characterized by the following relative isotope ratios (H: high, I: intermediate and L: low ratio) for $^{87/86}$Sr, $^{143/144}$Nd, $^{206/204}$Pb, $^{187/188}$Os and $^{3/4}$He, respectively:

1. Iceland plume component: I, I, H, H, H (depleted lower mantle mixed with recycled oceanic crust)
2. Strongly depleted and later re-enriched SCLM: H, L, I, L, L
3. Depleted asthenosphere: L, H, L, I, L

At least the two first composite components contain enriched and depleted subcomponents with distinct isotope signatures. The isotope ratio variations between the fertile components are larger than between the refractory components. The $^{3/4}$He ratio, however, is much higher in the depleted plume component than in the depleted SCLM and asthenospheric components. The old SCLM material could in principle be recycled and embedded in the lower mantle and supplied to the melting zone by the Iceland plume. However, a regional isotopic variation pattern indicates that this material originated from the nearby continents and became partially delaminated and embedded in the upper mantle during the continental rifting and separation of especially Greenland and the Jan Mayen Ridge and Greenland and Spitsbergen. The influence of SCLM is most clearly recognized north of central Iceland, in the Northern Rift Zone, along the Kolbeinsey, Mohns, Knipovich and Gakkel Ridges, and especially at Jan Mayen and the westernmost Gakkel Ridge close to the Yermak Plateau. The SCLM-signal is weaker for the Snæfellsnes Peninsula, the Mid-Icelandic Belt and the Western and Eastern Rift Zones and weakest for Vestmannaeyjar, the Southern Volcanic Flank Zone, the Reykjanes Peninsula and the Reykjanes Ridge. The regional geochemical patterns have interesting implications for the interaction between lateral plume flow, ridge-focussed asthenospheric flow and the possible delaminated patches of SCLM.

# POSTER SESSION

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*Dissolution rates of crystalline basalt as a function of pH and temperature*

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U-*Pb zircon ages from the Kap Washington Volcanic Province, North Greenland - implications for the evolution of the Arctic Basin*

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# Heavy mineral assemblages in the Devonian and Quaternary deposits as kimberlite trace in Western part of the East-European platform

**Hodireva Vija, Korpechkov Denis.**

Sedimentation in the Devonian and Quaternary periods was very different, even though main provenances of clastic material during both periods were located at the same place in Baltic Shield, north from territory of Latvia.

Some stratigraphically well defined layers in the Upper Devonian sandstones with specific mineral assemblage genetically related to the supposed kimberlitic rocks of the East-European platform have been discovered in shallow sea sediments. Re-washing of a large amount of Quaternary glacial clastic material formed the modern beach placers. The primary composition of the Quaternary sediments in the Western Latvia zone was formed by the Baltic Ice Stream (main flow direction from NW). While composition of sediments in the zone of the Gulf of Riga, Central Latvia was formed by the Ice Stream of the Gulf of Riga (main flow direction from NNW). At present, four intermediate collectors of kimberlite mineral assemblages are identified in the territory of Latvia. Two types of kimberlite indicator-minerals transporting features – long distance and short distance transportation have been discussed.

The Devonian sandstones and Quaternary beach placers were found to contain garnet varieties, including pyrope, chrome spinels and other indicator-minerals. Specific mineral grain morphology is one of the most important evidences for two possible material transportation pathways leading from supposed kimberlitic magmatic complex areas: a very short transportation (30-40 km, in Latvia), and a longer transportation (from the Baltic Sea bottom, southern Finland and north-western Russia). The kimberlite mineral assemblages containing such kimberlite indicator-minerals as pyrops and chrome spinels, as well as chrome diopside and moissanite have been found in alluvial deposits from NE Latvia. High chromium variety of pyrope, Cr-pyrope, is typical for the supposed kimberlites in this area. Chemical composition of some mineral grains suggests that they belong to diamond assemblages. Diamond potential of the area was evaluated.

# Generation of Quartz in Claystone Diagenesis- Examples from the Siri Canyon, Danish North Sea

**Afsoon Moatari Kazerouni1, Henrik Friis1, Johan B. Svendsen2**
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2*DONG Energy, Exploration and Production, Agern Allé 24-26,2970 Høsholm, Denmark*

The Paleocene sequence of the Siri Canyon consists of hemipelagic and turbidite marl and claystones interbedded with massive and blocky glauconitic sandstones deposited from sandy mass-flows and sandy turbidites. The Palaeogene sediments in the Danish area are rich in siliceous microfossils as well as late Paleocene-early Eocene volcanic ash layers. The mineralogical composition of the Sele Formation has been examined in 49 core samples from five wells with depths ranging from 1700 to 2900 m. Previous studies has suggested that the diagenesis of the shales and the interbedded sandstones is closely related - and that the shales act as a significant source for diagenetic quartz in the sandstones. Furthermore, it has been shown that the sandstones were silica cemented in two major phases – an early opal/microquartz phase and a late massive macroquartz cementation phase.

The main diagenetic phases recorded are: Smectite, zeolite, opal-CT, microcrystalline quartz and chlorite. Pyrite is abundant in all samples. This study explores the potential sources of $SiO_2$ in the shale, and the timing of their active phases.

Altered volcanic ash-layers are almost pure smectite, zeolite and plagioclase, but most samples have a minor detrital component of illite. Altered biogenic silica is a major component of some samples.

The alteration with depth of the various components result in successive stages of silica-release. In shallow samples the alteration of volcanic ash has already been completed. Released silica was partly consumed for the precipitation of smectite and zeolite. Opal-CT is not systematically related to volcanic ash, and some silica may have been mobilized and migrated into interbeddded sandstones. Also a major part of the biogenic silica has been transformed into opal-CT and partly to microcrystalline quartz. The microcrystalline quartz is an internal sink for dissolved silica, but the shale may have been an active silica exporter during this transition.

With deeper depth of burial, opal-CT is fully transformed to microcrystalline quartz. During this phase, Silica has been partly mobile and depending on the rate of dissolution compared to the rate of precipitation, silica may have been lost to sandstone cementation. Zeolite was completely dissolved. The zeolite dissolution may also mobilized silica and activated the shale as silica exporter.

At deep burial, iron-rich chlorite has replaced a minor part of smectite. The release of silica in the smectite to chlorite transformation occurs at the expense of iron. Therefore, a third phase of silica mobility was active. Microcrystalline quartz may have been an internal sink, but the shale would also be a potential silica supplier at this stage.

Many studies have shown a significant transformation of smectite to illite with depth, which is considered a major silica source for quartz cement i sandstone. The Sele Formatione in the Siri Canyon has not been influence by illite formation, even at burial depth of approximately 3000 m. Potassium feldspar is not recorded, even at the shallowest depth, and it is suggested that the lack of dissolvable potassium sources has delayed the smectite transformation. The major silica mobilization in the Sele Formation shale occurs at shallow depths, related to the transformation of biogenic opal and volcanic ash, and at intermediate depths, related to the dissolution of opal-CT and zeolite. It is likely that the shales may have been an active silica exported during these processes. The early phase is related to major export of silica, documnted by sandstone ementation, preserving the initial porosity as well as protecting later overgrowth, and thereby ensure high permeability. During the intermediate phase, the shale itself was the major consumer of silica. Consequently, the Sele shale can in places be zeolite rich whereas other parts of the shale can be silica rich. This has significant impact on the mechanical tability of the shale, and hence the ability to drill (especially horizontal) in the shale. Late phase mobilization of silica (smectite to chlorite transformation) is at an initial stage and does not contribute significantly to the massive quartz cementation of the interbedded sandstones.

# Finding A Lost Continent Under the Kalahari Using Zircon Dating

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## ABSTRACT

We have found a new source of information about what lies beneath the Kalahari sands. The regions known as the Kheis and Rehoboth Provinces were thought to be underlain by either an ~1800 Ma orogenic belt, or a northern branch of the ~1200 Ma Namaqua-Natal Province, now largely covered by Cretaceous to Recent sand. Glacial diamictites of the Permian Dwyka Group exposed at Rietfontein west of the Kalahari carry cobbles plucked from the bedrock by the ice sheet which covered the Gondwana supercontinent about 300 Ma ago. Microbeam U-Pb zircon dating of the granitic cobbles shows that they contain no evidence of crustal growth or orogeny at either 1800 or 1200 Ma. Rather they testify to the presence of an 2500 to 2900 Ma Archean crustal block beneath the Kalahari, with a lesser ~2050 Ma component, coeval with the Bushveld complex of the Kaapvaal Craton to the east. The cobbles are most likely derived from the Rehoboth Province, with origins from the Kheis Province and Kaapvaal Craton considered less likely. This has important implications not only for the tectonic framework and assembly of Southern Africa, but also for exploration for diamonds and other ore deposits.

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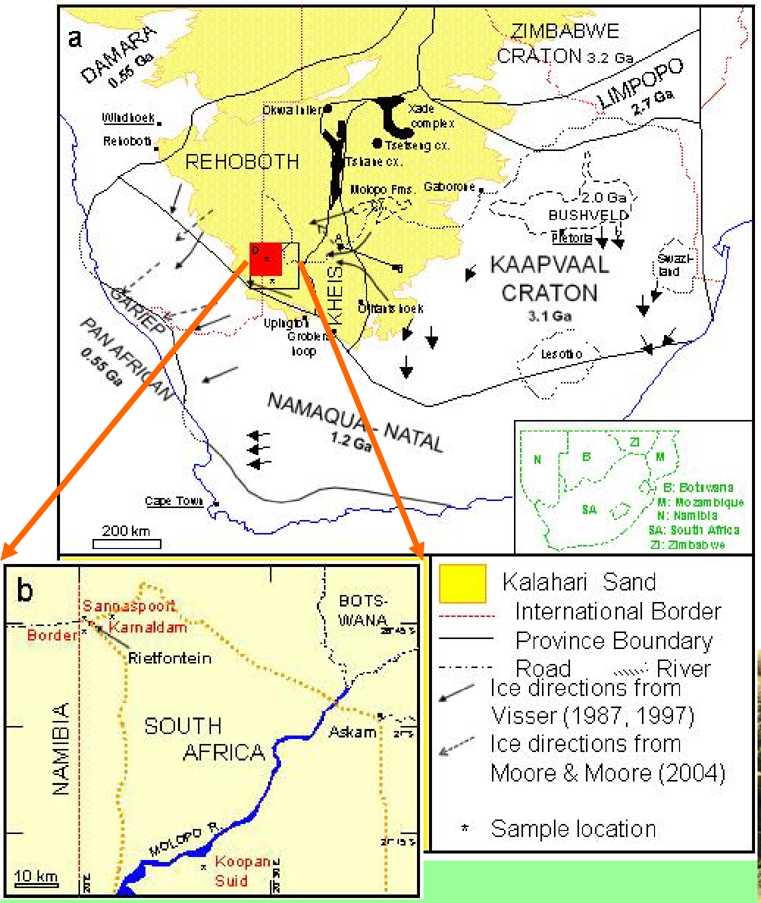
PRECAMBRIAN FRAMEWORK OF SOUTHERN AFRICA



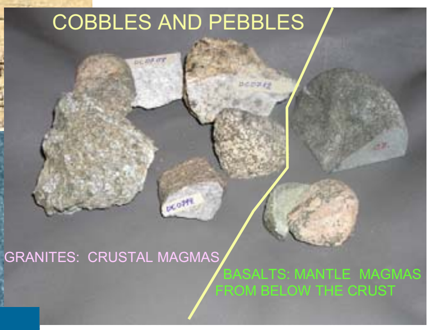
The age of each southern African crustal province is well known, except for the **Kheis and Rehoboth** Provinces, largely covered by Kalahari Desert sands.

Are they an ~1800 Ma orogenic belt (Cornell et al., 1998), or part of the ~1200 Ma Namaqua-Natal Province (Moen, 1999).

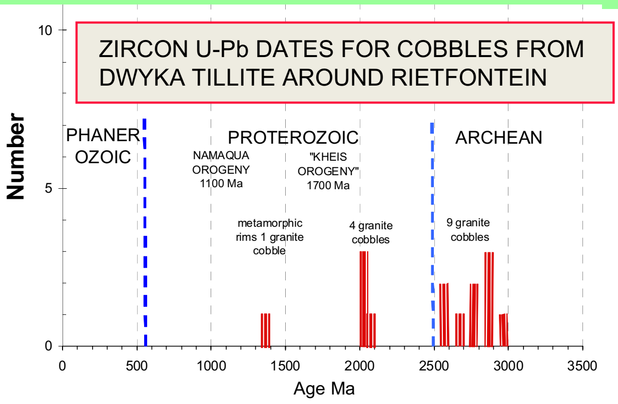
Carboniferous tillite at Rietfontein sampled the bedrock under the Kalahari **!!**

**RESULTS:** 13 GRANITE COBBLES DATED
9 are ARCHEAN: 2580 -2900 Ma
4 are 2020 - 2050 Ma
Nothing 1700 or 1100 Ma!

DID THEY COME FROM THE KAAPVAAL CRATON ?
Right Age, but NO BANDED IRON PEBBLES
NO JASPER, NO DOLOMITE, NOT LIKELY



ZIRCONS FROM GRANITE COBBLES WERE DATED BY ION PROBE AND LA--ICPMS



## CONCLUSIONS

1. An archean continental block lies under the kalahari
2. Prospects for diamonds, gold, nickel in the archean terrane
3. 2050 ma is the age of the bushveld complex, which has major platinum group elements, vanadium & chrome resources.
4. BOTH PREVIOUS MODELS ARE WRONG, NO KHEIS or NAMAQUA OROGENY

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# Dissolution rates of crystalline basalt as a function of pH and temperature

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Reducing CO2 emissions is one of most important environmental challenges of the 21st century. The Carb-Fix project in Hellisheiði, Iceland (www.carbfix.is) aims to find a permanent storage solution for captured CO2 in Iceland. Reykjavik Energy, University of Iceland, CNRS France and Columbia University participate in the Carb-Fix project where CO2 – rich water from the Hellisheiði geothermal power plant will be injected into basaltic rock formation. Hellisheiði is a basaltic formation, approx. 400.000 years old, with both hyaloclastite and crystalline basalt. Injecting CO2 charged waters into basaltic rock formations may be a viable solution given the high amount of Ca, Mg and Fe in basalt and the relatively fast dissolution of the host rock compared to silicic rocks (Wolff-Boenisch et al., 2004). The pH at the Carb-Fix injection site is 9.3 but CO2 injection water has a pH of 3.5. In order to model and predict the CO2 – rock interaction in the field, lab studies have to be undertaken.

Dissolution rates of crystalline basalt have not been determined as a function of temperature and solution composition in contrast to basaltic glass (Oelkers and Gislason, 2001). Far-from-equilibrium dissolution rates of crystalline basalt were measured in Ti mixed flow reactors at pH 2 - 11, and at temperatures from 5 to 75 °C. The material used was obtained from a dyke on Stapafell Mountain on Reykjanes Peninsula in Iceland because of its similar chemical composition (Gudbrandsson et al., 2008) to basaltic glass that was used for former dissolution experiments (Gislason and Oelkers, 2003).

Comparison between dissolution rates of basaltic glass from Gislason and Oelkers (Gislason and Oelkers, 2003) and crystalline basalt of similar chemical composition and size fraction (45-125 um) shows consistently lower rates for crystalline material under acidic as well as alkaline conditions. Evaluation of the non-stoichiometric release of the divalent cations into solution indicates preferential release of Mg and Fe from the crystalline basalt at pH 4. This suggests potential in-situ precipitation of rather magnesite and siderite than calcite at the injection site.

Gislason, S. R. and Oelkers, E. H. (2003) Mechanism, rates, and consequences of basaltic glass dissolution: II. An experimental study of the dissolution rates of basaltic glass as a function of pH and temperature. Geochim. Cosmochim. Acta 67, 3817-3832.

Gudbrandsson, S., Wolff-Boenisch, D., Gislason, S.R. and Oelkers, E.H. (2008) Dissolution rates of crystalline basalt at pH 4 and 10 and 25-75°C. Mineralogical Magazine 72, 155–158.

Oelkers, E. H. and Gislason, S. R. (2001) The mechanism, rates, and consequences of basaltic glass dissolution: I. An experimental study of the dissolution rates of basaltic glass as a function of aqueous Al, Si and oxalic acid concentration at 25 °C and pH = 3 and 11. Geochim. Cosmochim, Acta 65, 3671-3681.

Wolff-Boenisch, D., Gislason, S. R., Oelkers, E. H. and Putnis, C. V. (2004) The dissolution rates of natural glasses as a function of their composition at pH 4 and 10.6, and temperatures from 25 to 74 °C. Geochim. Cosmochim. Acta 68, 4843-4858.

# Illite polytype diagnostics between primary and secondary mineral phases

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For illite polytype diagnostic samples from glacial till were fractionated in 2; 1; 0.4 and 0.2 μm fractions without chemical treatment. Samples fractionation was performed by washing to avoid coagulation, flocculation processes and increase resolution of XRD patterns. XRD data obtained on X'PERT-PRO with CuK 2θ wavelength, 1/2° divergence slit, 10 mm horizontal mask, 2θ step size of 0.05° and counting time of 300 s per step. Characteristic reflexes of illite polytypes were carried out after XRD results quantitative analyze. XRD quantitative analyze and illite polytype diagnostic were realized on untextured samples. For mineral phases quantitative analyze were used QUANTO software based on the Rietveld method.

To determine illite polytype quantities there are several analytic methods applied, including XRD. Most of methods subdivide area of maximum or separate typical for $2M_1$ polypype high from characteristic maximum for all illite polytypes or screening typical only for 1M polytype maximum.

Because the XDR patterns unbasal reflexes are in very low intensity and cannot be surely distinguish from background, in the samples under examination there was not possible to determine quantities of separate illite polytypes.

The XRD patterns containing typical unbasal reflex 2θ in the area from 23° to 35.5°, and in between maximum of primary mineral phases (quartz, albite, orthoclase etc.) were determined weak illite unbasal reflexes corresponding to 1M*d* polytype.

Study demonstrates very high primary mineral phase domination in the size fraction under 2 μm. In these mineral phases prevail quartz, albite, orthoclase, calcite and the typical clay minerals e.g. illite, illite-smectite, kaolinite, chlorite, smectite.

Determination of illite unbasal reflexes is complicated because distinctive maximums are overlaid by mentioned above maximums of primary mineral phases. Therefore possible were to determine only three typical for illite polytypes maximums at -116 $2M_1$, -113 1M*cv* un -113 1M*tv*.

## The Bed Rock Geology Group at the University of Tromsø

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Holger Stunitz – Deformation processes
Erling Ravna – Metamorphic Petrology
Kåre Kullerud – Geochemistry
Steffen Bergh – Structural geology
Luca Menegon – Microstructures and deformation processes
Corine Davids – Fission track and Ar-dating
Pritam Nasipuri - Metamorphic petrology

Their main research activities focus on 3 major topics:

(1) Processes of deformation and metamorphism at elevated temperatures and pressures.
(2) Metamorphism and geochemistry of high pressure rocks in the Caledonides.
(3) Regional and tectonic synthesis of the Precambrian provinces of Northern Norway.

(1) The processes of deformation are studied in two ways. (a) by experiments using solid medium technology (Griggs rigs) in the rock deformation lab at Tromsø, and (b) by field work in the Proterozoic Lofoten and Seiland Igneous Province of the Northern Norwegian Caledonides. The work involves all members of the group, and the main purpose is to understand the rheological behaviour and strength of the lower crust better. The current debate comprises two opposing views: one of a weak lower crust and one of a strong lower crust. There is growing evidence (also from our studies) that a dry lower crust may be very strong, but initial brittle deformation may cause fluid infiltration and subsequent weakening of “wet” rocks. We are complementing the field observations with deformation experiments on single crystal feldspars during replacement reactions to investigate the chemical effects on deformation.

(2) The characterization of HP- metamorphic rocks is mainly undertaken by Erling Ravna and Kåre Kullerud, but all members of the group are involved in studies of the Caledonian Tromsø nappe and its tectonic framework. One occurrence of HP-overprinted carbonatites in the Tromsø Nappe Complex probably is the consequence of fluid-rock interaction of subducted material with the mantle wedge. The exhumation history of the Tromsø nappe may serve as a classical example of deep-seated, thrust-related thickening of the continental crust.

(3) The regional geology of the Archean to Paleoproterozoic West Troms basement complex (WTBC) is poorly understood and is the subject of structural and metamorphic/geochemical studies in conjunction with radiometric age dating performed by Fernando Corfu at the University of Oslo. The studies are mainly conducted by Steffen Bergh and Kåre Kullerud, together with Corine Davis (postdoc), who is studying the late low temperature history. The structure of the WTBC consists mainly of low-angle dipping gneiss regions bound by steep ductile shear zones and highly deformed supracrustal belts. Late stage retrograde shear zones are the target for extensive regional studies.

# *High-pressure systematic of NaMe3+Si2O6 pyroxenes: volume compression vs M3+ cation radius*

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Na-clinopyroxenes (Na-cpx) have recently attracted interest in the high-pressure world as it has been experimentally found that they can be stable throughout a wide range of temperatures and pressures. It is evident that determining their thermodynamic properties is crucial to better constrain the $P/T$ conditions for the geological processes in which they are involved. In this work we have determined the compressibility of a synthetic Na-cpx with composition NaInSi2O6 up to about 8 GPa in order to provide further information on the high-pressure systematic of NaMe3+Si2O6 cpx (with Me3+ = trivalent cation). A single crystal of NaInSi2O6 (space group $C2/c$) with size 150x80x50 $\mu m^3$ was selected for the HP single-crystal X-ray diffraction study and loaded in an ETH-type diamond anvil cell. The measurements were performed using a four-circles STOE STADI IV diffractometer on which the software SINGLE 08 has been recently installed allowing to perform the eight-position diffracted-beam centering and to fit the diffraction peak profiles. Such centering procedure ensures precise and accurate unit-cell parameters which provide values of room pressure bulk modulus with insignificant errors. The NaInSi2O6 cpx was investigated at 12 different pressures up to 7.83 GPa. No evidences of phase transformation were found from the change of lattice parameters. Using a third-order Birch-Murnaghan equation of state (BM3) to fit the pressure – unit-cell volume data we could refine simultaneously the unit-cell volume *V0*, the room pressure bulk modulus *KT0* and its first pressure derivative *K'*. Using EoSFIT5.2 software we obtained the following coefficients: $V0$ = 463.42(3) Å$^3$, *KT0* = 109.0(6) GPa, *K'* = 3.3(2). Following a recent work published on NaVSi2O6 cpx, we have calculated the relative compression $V/V0$ to 10 GPa using the published BM3 for NaVSi2O6, NaAlSi2O6, NaCrSi2O6, NaFe3+Si2O6 end-members, for our sample (all having C2/c space group) and for C2/c- NaTiSi2O6 end-member just to 4.34 GPa. Previous works on CaMe2+Si2O6 $C2/c$ cpx suggested that the empirical *KT0*x*V0* = constant relationship is followed in C2/c cpx only in the case of the same valence-electron character. The preliminary data presented in this work support this hypothesis for NaMe3+Si2O6 as well. In fact, while a perfect linear relation is showed for those cpx having a 3*d*-transition element at M1 site, the cpx with Al and In at M1 site lie completely out of this trend.

# The 300 Ma Dwyka diamictite Southern Africa

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The 300 Ma Dwyka diamictite is thought to have a source region from the East,as this is indicated by the ice directions. New evidence shows that the Dwyka source region from the Rietfontein area comes from the Kheis and Rehoboth Province and not the Kaapval Craton. The pebbles from the Dwyka diamictite thus show what is buried under the Kalahari sands. Mafic pebbles of the Dwyka diamictite, near Rietfontein in South-Africa, are dated with Baddelyeite dating. This gave an average age of 1.11 Ma which is similar to the Umkondo Large Igneous Province and one of the mafic pebbles gave a ~10 Ma older age of 1.25 Ga. No older ages where found which indicates that the pebbles didn’t came from the Bushveld-aged magmatism of the Molopo Farm Complex which lies East of the Kheis Province. The geochemistry of all the mafic pebbles is compared with data of the Umkondo LIP sills which are characteristic for the LIP occurrences in South-Africa and Zimbabwe, and with geochemical data of the Rouxville Formation, one of the upper units of the Koras Group. The bimodal Koras Group volcanic rocks near the Orange River are suggested by several auteurs that it is part of the Umkondo LIP. As are the Xade and Tshane intrusions that lie on the Kalahari Line but are mostly covered now by Kalahari sands. Geochemical data suggests that the mafic pebbles from the Dwyka diamictite near Rietfontein does indeed come from the same mantle source as the Umkondo LIP. Therefore, the pebbles can only come from as far east as the ‘Kalahari Line’ of the Kheis Province.

# U-Pb zircon ages from the Kap Washington Volcanic Province, North Greenland – implications for the evolution of the Arctic Basin

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The Kap Washington volcanic sequence at the north coast of Greenland is bimodal with alkaline basalts, trachytic to rhyolitic lavas, tuffs and ignimbrites predominating. Associated with the volcanics is a swarm of coast-normal alkaline basaltic dykes which intensifies towards the outer coast. The volcanics are believed to be linked to rifting in the Arctic Basin and have featured prominently in geotectonic reconstructions of the Arctic region (e.g. Batten et al. 1981).

Here we report U-Pb zircon ages from silicic lavas and intrusions of the Kap Washington sequence. A total of ten samples have been dated and the duration of magmatism is constrained at present to ca. 10 million years. - from 71 to 61 Ma (based on 206Pb/238U ages of concordant analyses).
Three age ‘groups’ have been identified: 71-69 Ma (n = 6); 68-65 Ma (n = 2); and 64-61 Ma (n = 2). The oldest group comprises trachytic and rhyolitic lava flows from Kap Kane and a rhyolitic sill from the Kap Washington peninsula.
The two younger groups comprise silicic lavas exposed on Lockwood Island. The exposed sequence on Lockwood Island is estimated to be 3-4 km thick and was previously thought to be the oldest part of the succession (Brown et al. 1987).

The new age data from the Kap Washington volcanics together with 40Ar/39Ar ages for the associated dyke swarm (Kontak et al. 2001) suggest that continental extension and magmatism occurred in the area between ca. 82 and 61 Ma. This age bracket seems to preclude any relation to initial spreading on the Nansen-Gakkel Ridge (52 Ma-present) and an association with spreading in the Labrador Sea-Baffin Bay-Makarov Basin system seems the most probable. We propose that the Kap Washington magmatism ceased with the onset of seafloor spreading in the Northeast Atlantic-Eurasia Basin system, which shifted the tectonic regime in North Greenland from extensional to compressional, culminating with the Eurekan deformation in early Eocene.

References:
Batten et al. (1981): Nature 294: 150-152.
Brown et al. (1987): J Geol. Soc. Lond. 144: 707-715.
Kontak et al. (2001): Can. Mineral. 39: 997-1020

# An ore petrological and geochemical study of the polymetallic skarn ores at Pitkäranta

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Pitkäranta is an ancient mining area along the north-eastern shore of Ladoga, where Fe, Cu, Zn, Pb, Sn and Ag were exploited in the 19th to 20th Centuries. Numerous geological, mineralogical, geochemical and technical have been made on Pitkäranta, including Törnebohm (1891), Trüstedt (1904, 1907, 1908), Erämetsä (1939), Palmunen (1939), Eskola (1951), Khazov (1973) and Sundblad (1991). Very few ore petrological studies have, however, been made of these deposits.

The Pitkäranta and Kovadjärvi regions are located in the southeastern part of the Fennoscandian Shield. The Pitkäranta region is dominated by the Palaeoproterozoic Ladoga schist formation which, together with slabs of gneissic Archaean dome structures, constitute an allochthonous terrane complex that amalgamated to the Archaean continent during the Svecokarelian orogeny at 1.9-1.8 Ga. The Pitkäranta ores are hosted by carbonate layers enclosing the gneiss-granite domes. The Kovadjärvi region is dominated by the Palaeoproterozoic Tulomozero greenstone belt, along the Archaean-Proterozoic boundary. All these rock units are cut by the 1.54 Ga anorogenic Salmi Batholith with the Pitkäranta region on the southwstern side and the Kovadjärvi region on the northeastern side of this batholith. The Kovadjärvi deposit is hosted by a carbonate layer within the the Tulomozero greenstone belt.

The Pitkäranta ores are widely accepted to have formed as a classical skarn deposit from hydrothermal solutions which emanated from the Salmi rapakivi batholith and reacted with the marble layers. The origin of the Kovadjärvi ores is less well understood. The ore deposits have complex structures and the paragenesis of individual parts of the Pitkäranta orefield is variable. The present study areas has included the Old mine field of Pitkäranta (Toivo and Klee deposits), the Herberz, Hopunvaara and Lupikko mine fields, as well as the Kelivaara (Kitilä) and Kovadjärvi deposits. The following ore types have been distinguished:

*Magnetite-sphalerite ore* occurs in most deposits in the Pitkäranta mining area, often with hematitized magnetite grains, sometimes with moderate amounts of cassiterite. Magnetite-sphalerite ores in the Kovadjärvi deposit have significantly less contents of Sn, Be and In compared to the Pitkäranta ores, and are also different from a textural viewpoint. *Epidote-bearing compact magnetite ore*, often with hematitized rims, and without significant amounts of sulphides has been recognized in the Kelivaara deposit. *Cu-rich ore* occurs in the Klee, Kelivaara, Hopunvaara and Lupikko deposits with chalcopyrite and sphalerite as dominant minerals and with unknown Cu3AgFeS4 and stannoidite (in Hopunvaara) and cubanite (in Lupikko). *Sphalerite-rich ore without magnetite* occurs in the Klee and Hopunvaara deposits with minor amounts of bismuth minerals.

Several of the ore types in Pitkäranta have high In contents (>70 ppm), locally up to 500 ppm. Be is also a characteristic element in the Pitkäranta ores, with grades commonly at 10-100 ppm Be. The high contents of these elements is in agreement with a rapakivi-related origin for the Pitkäranta ores. In contrast, the very low Be, In and Sn contents in the Kovadjärvi magnetite-sphalerite deposit indicates a different origin compared to the Pitkäranta ores.