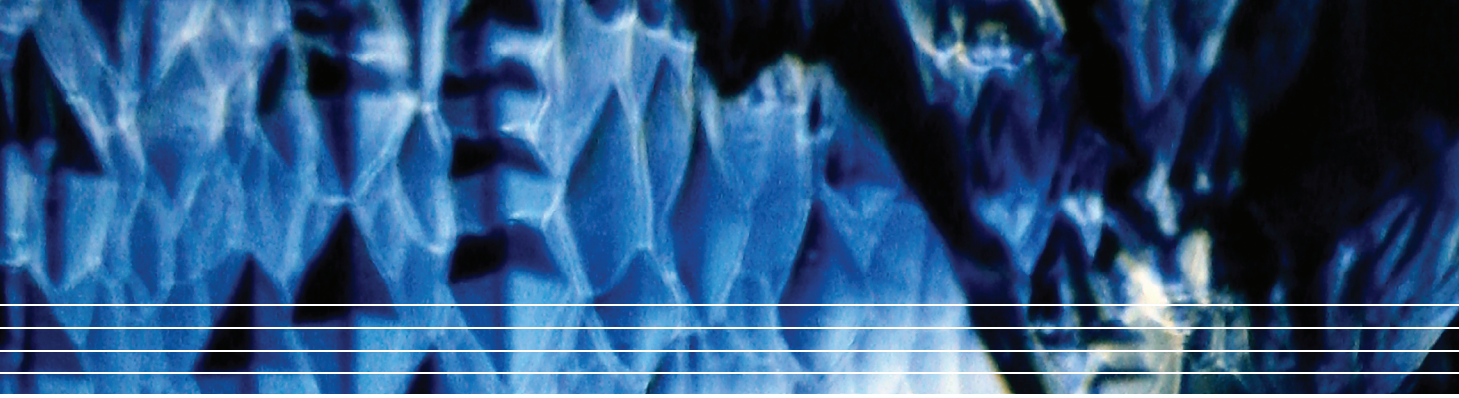

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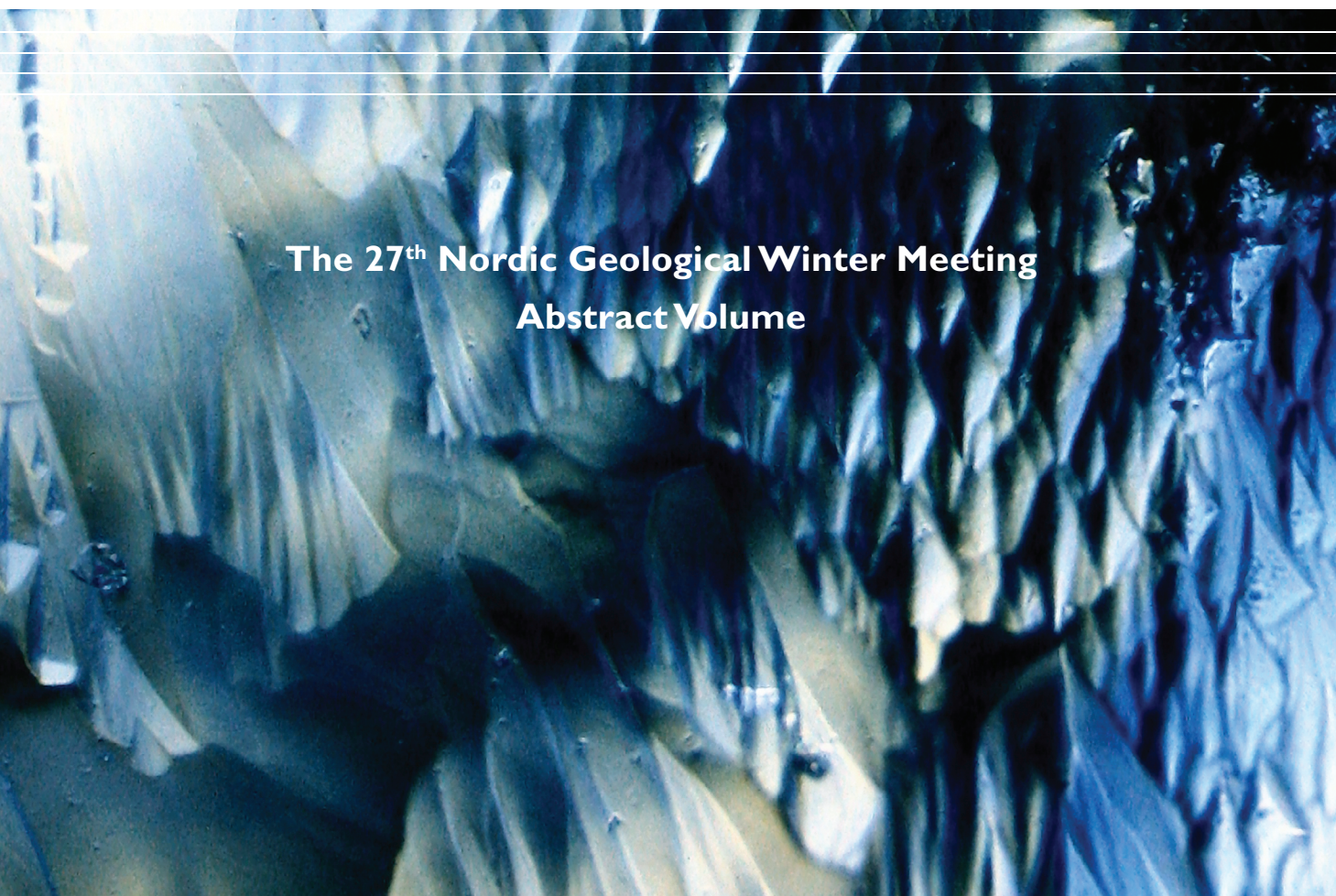

The 27th Nordic Geological Winter Meeting
Abstract Volume

The 27th Nordic Geological Winter Meeting

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Edited by

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27th Nordic Geological Wintermeeting
Abstract volume

This abstract volume contains the presentations given at the 27th Nordic Geological Wintermeeting in Oulu, January 9–12, 2006. The abstracts in this volume are multidisciplinary and have been grouped under 17 thematic sessions (see programme).

348 abstracts in this volume include key-note lectures, oral presentations and poster presentations as indicated in the programme. All abstracts are printed in an alphabetical order of the first author. Some of the abstracts have been reformatted and also the English have been slightly improved when necessary. We hope that the final result meets the expectations of the authors.

On behalf of the 27th Nordic Geological Wintermeeting I would like to thank convenors of the sessions for reviewing the abstracts. I would also like to thank all authors for their contribution to this abstract volume.

Antti Pasanen
Guest Editor

Foliation Study of Deep Drillholes at Olkiluoto, SW-Finland

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According to the Nuclear Energy Act, all nuclear waste generated in Finland must be handled, stored and permanently disposed of in Finland. The two nuclear power companies, Teollisuuden Voima Oy (TVO) and Fortum Power and Heat Oy, are responsible for the safe management of the waste and have established a joint company, Posiva Oy, to implement the disposal programme for spent fuel. As a part of the site investigations for the fuel disposal at Olkiluoto, SW-Finland, several deep drill holes has been drilled to the bedrock.

Great bulk of Olkiluto bedrock is composed of Svecofennian migmatitic metasediments and granitoids. Ductile deformation has affected every lithological unit at Olkiluoto except to young dolerites. For the Olkiluoto site, occurrence of S-tectonites with a relatively constant orientation of the foliation seems to be characteristic, and this has important implications for underground construction, repository design and layout, and long-term safety. Most important foliations created by different deformation phases are penetrative and slightly segregated foliation (S_1) mainly parallel to stratification (S_0) and strong metamorphic or segregation banding (S_2) associated with shear related foliations and created by phase D_2 of multistage deformation.

First systematic foliation study of several deep drillholes, together with general surface mapping of outcrops and trenches was done in years 2004 and 2005. Foliation was systematically logged along seven cored drillholes. The total length of these ten drillholes is 4521 meters. Logging was done using 1-meter resolution, for the characterisation of the type and degree of foliation. Orientation of foliation planes was mostly done by using OPTV drillhole images and WellCAD software. Based on direct observation of the rock cores, the parts of the drillholes which contained foliated rock were divided to three kinds of core segment. *Regularly foliated* – tight, equidimensional foliation pole cluster; *folded* – foliation poles fall on the arc of the great circle; *irregular* foliation – wide, irregular dispersion of poles.

Evaluating the potential of serpentine and serpentinite in CO_2 capture and sequestration.

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Concerns about global warming have already led to legislation penalizing excessive CO_2 emissions, which in turn has a cumulative impact on energy intensive industries. Unless there is a net decrease in global energy production based on fossil fuels or unprecedented technological advances in energy efficiency or compensating energy resources, alternative strategies are required for reducing the rate of anthropogenic CO_2 addition to the atmosphere.

One response is to directly capture CO_2 emissions, for example by chemical reactions producing carbonate minerals e.g. from ultramafic rocks and minerals (Goff and Lackner 1998, Kohlmann et al 2001). Another strategy is bedrock sequestration of CO_2 e.g. in oil fields, but in Finland sedimentary basin sequestration is not an option. In Finland 30–40 Mt/yr of mineral product would be required when converting e.g. serpentine to magnesite to achieve reduction in CO_2 emissions to 1990 level as required in the Kyoto protocol.

It is necessary to consider whether the process could be either technically or economically feasible, or applicable if implemented at local scales. As a first step to assessing the viability of this process we are producing a GIS-based inventory of potential sources of ultramafic rocks and minerals, e.g. serpentinite and serpentine, and principal sources of CO_2. The aim is to provide potential sources for emissions-related mineral carbonation processes, as well as to consider whether there is a potential economic and environmental synergy in combining CO_2 sequestration with novel metal extraction from ultramafic rocks.

Goff, F. & Lackner, K. S. (1998). Environmental Geosciences 5, 89–101.

*Kohlmann, J., Zevenhoven, R. Mukherjee, Arun B. & Koljonen, T. (2001). **Mineral carbonation for long-term storage of** CO_2 from flue gases. Final report for Finnish National Research Programme CLIMTECH (1999–2002). Helsinki University of Technology, Energy and Environmental Protection. Espoo, June 2002, 64 p.*

The chemistry of thermal discharges from Central Andes between 22ºS and 24º30'S

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Several thermal discharges from Central Andes (El Tatio Geothermal Field, Puritama, Pozo 3, Ojos de Tara and Ojos de Hécar in Chile; Incachule, Pompeya, Tocomar and La Mina in Argentina) were chemically analyzed for gas and water.

The temperatures vary among 23 and 90ºC. The principal inorganic gases present are CO_2 and H_2O, H_2S contents are very variable, absent in some cases (Hécar, Incachule and Geyser Blanco in El Tatio). Low N_2/Ar ratios are present in Incachule, Tara, Hécar and Geyser Blanco, while Pompeya shows high N_2/Ar ratio. A strong depletion of O_2 shows all samples, except in Hécar. CH_4 contents have two end members, a relative low CH_4 contents in El Tatio, Hécar and Pompeya, and high CH_4 in Tara and Incachule. The thermal discharges are characterized by the presence of different hydrocarbons being alkanes more abundant, alkenes, aromatics and heterocyclics are present in minor proportions. The discrimination diagrams indicate that all thermal discharges have affinity with hydrothermal systems, but the origin of component of gas is variable. Pompeya and El Tatio show mixing process between hydrothermal and magmatic source, but with a strong influence from magmatic source in Pompeya and some sites in El Tatio, supported principally, by a high N_2/Ar that indicate a no atmospheric source for N_2. The low N_2/Ar ratios, caused by a high contents of Ar, and high contents of Ne indicate that Incachule, Tara, Geyser Blanco and Hécar have a third source of origin of gas, an atmospheric source, having a strong influence in Geyser Blanco and Hécar. The contents of hydrocarbons indicate a probable origin from organic sedimentary rocks in subsurface. The waters classification show that neutral chloride waters are emitted in El Tatio, Pozo 3, Tara, Incachule, Pompeya, Tocomar and La Mina, acid sulfate waters in Hécar and, mixing between acid sulfate and neutral chloride waters in Puritama.

Hauser, A. (1997). SERNAGEOMIN, Chile, Bull. Nº 50.
Martínez, C. (2005). Graduate Thesis, Univ. Cat. Norte, Chile.
Tassi, F., Vaselli, O., Capaccioni, B., Viramonte, J., Martinez, C., Aguilera & F. Montegrossi, G. (2003). 4th FIST Congress, Italy.

Geological Reservoir Characterization of Heterolithic Sandstone Bodies, with reference to Northeast Greenland (Jameson Land) and the Mid-Norwegian Shelf (Halten Terrace)

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Detailed information about the spatial distribution of reservoir flow units and barriers is a key factor in successful management of heterolithic hydrocarbon reservoirs. Sedimentological and structural studies of outcrop analogues are therefore needed in addition to 3D seismic and well data. The present contribution presents preliminary results from ongoing reservoir analogue study in North-East Greenland performed by University of Oslo, Statoil ASA and partner companies in the assets on the Halten Terrace. The project aims at improving (1) basic knowledge of tidally influenced deposits and (2) the geological reservoir models for the Early to Middle Jurassic reservoirs on the Mid-Norway Continental Shelf. In this area large amounts of hydrocarbons are reservoired in paralic, often strongly tidally influenced and heterolithic sandstone succession (the Tilje-, Ile- and Garn formations).

The Jurassic Neill Klinter Group of Jameson Land, Northeast Greenland, offers a unique opportunity for comparisons with the time equivalent and rather similar Jurassic section as in the Halten Terrace. Furthermore, the two basins belong to the same North Atlantic rift system and share the same overall tectonic regime and climate.

Preliminary data from Northeast Greenland is suggested to have great input value in reservoir management of heterolithic reservoirs in the Halten Terrace. The main focus has been on heterogeneity characterization by measuring sandstone body dimensions and their relationships with shale content within succession. This improves particularly stratigraphic correlation, seismic interpretation and reservoir model building and therefore also recovery from existing oil and gas/condensate fields.

Kuovila wollastonite-calcite marble, a new potential GCC-deposit in SW Finland

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GTK explored the Kuovila calcite-wollastonite marble deposit in 1999–2002 and 2004 for its suitability as a raw material for paper coating pigment GCC. The deposit is located in southwestern Finland within the 1.9 Ga Uusimaa Belt, which is composed of high-grade metamorphic felsic and mafic volcanic rocks, mica gneisses and granites. Exploration included geological mapping, magnetic and gravimetric ground surveys and the drilling of 57 holes, altogether 6084 metres.

The Kuovila deposit occurs as a east-west trending fold. Host rocks are felsic and mafic volcanic rocks. Deposit is composed of two lense-like bodies, which are 20–150 m wide and about 1850 m long. The deposit is covered by 3–15m thick sandy till layer. The indicated resources of the Kuovila deposit estimated to the depth of 50 m to 125 m are 45 Mt calcite marble with 74% calcite. The resoursces include 20.2 Mt calcite marble containing 81.8% calcite, and 5.8 Mt wollastonite-calcite marble composed of 62.5% calcite and 13% wollastonite (8–60%). Based on drilling in 2004, the inferred calcite resources are ca 100 Mt.

The Kuovila deposit comprises alternating, 10–45 m thick layers of calcite and calcite-wollastonite rock, which are separated by 3–10 m thick felsic and mafic volcanic rock layers. Calcite marble layers continue at least to the depth of 150 meter. Calcite marble is typically coarse-grained, light gray or white in colour including thin silicate interlayers. Calcite content of the calcite marble ranges from 60 to 95% and calcite in the marble is low in magnesium, iron and manganese. Thin silicate interlayers are composed of quartz, feldspars, diopside and phlogopite. The wollastonite-calcite rock occurs in the border zone of the deposit and also as individual layers. It is composed of alternating beds of calcite, quartz, wollastonite, diopside and garnet. Laboratory scale benefication tests from the core samples were carried out at GTK and they produced concentrates containing over 99% calcite. After fine-grinding, the ISO-brightness of minus 30 microns fraction of the calcite concentrates is 90.4–95.7% and yellowness 0.3–1.8%, which correspond with the commercial GCC products.

Geology of Noachis Terra, Mars

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The studied area is located in the central part of the Noachis Terra on Mars (36-47°S, 20-30°E). The region is part of the southern highlands to West of the Hellas basin, and has been generally described as ancient terrain with large, eroded craters modified by e.g. fluvial and aeolian processes. We have studied the area using the freshest data sets available – THEMIS and MOC – in conjunction with Viking imagery, to find out what input they can give to the geological analysis of this highland region. The topography is determined from the MOLA 128 pixel/degree DTM. The first observation was that the tectonic features are clearly oriented. They appear to be more or less parallel to the Hellespontus Montes as well as to the large graben system, which is located 1900–2500 km to west and northwest from the Hellas basin center. This may indicate that the local tectonics is controlled by the Hellas impact event, which interpretation was concluded also from the study of polygonal craters in the Hellas area (Öhman et al., 2005). Furthermore, the area displays many features, which can be seen as an indicator of water/ice. For example, numbers of smaller channels are associated with craters with smooth floors as well as with depressions of the region. These depressions show also different characteristics than the highlands with layered deposits and smooth floors with smaller amount of impact craters. This suggests the existence of water reservoirs in some point of regional geological history. There are also few lake chains, which are quite common features in the Hellas region (Lahtela et al., 2005), and pingos which are described as cone-shaped mounds with cores of ice. According to this preliminary study, the Noachis Terra has been modified by several geological processes, which characterize unforeseeably versatile geological history of the region.

Öhman et al. (2005). In: Impact tectonics, Springer, Berlin-Heidelberg.
Lahtela et al. (2005). LPS 36, #1683.

Occurrence of halloysite in Virtasalmi kaolin deposits and its effect on rheological properties

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Mineralogical studies of processed Virtasalmi kaolin samples show that the clay fraction is mostly composed of kaolinite and considerable amount of metahalloysite or dehydrated halloysite. Halloysite tubes were observed using SEM and after formamide treatment identified by XRD. The halloysite content, measured by XRD, in kaolin from Kahdeksaisiensuo is 10–50% and from Litmanen 5–40%.

The effects of mineralogy on kaolin rheology were studied by comparing clay mineral compositions, particle morphologies and particle size distributions of kaolin with the viscosity values determined from kaolin suspensions both at low and high shear speeds. Typical kaolin sample from Litmanen (2 samples) has low viscosity, while kaolin samples from Kahdeksaisiensuo (8 samples) have both low and high viscosities. The presence of halloysite tubes and the monodispersed particle size distribution of kaolin is considered to be one reason for the high viscosity at Kahdeksaisiensuo. However, in some samples from Litmanen and Kahdeksaisiensuo, halloysite tubes are common but their influence on viscosity is not as clearly apparent. In this case, the broad particle size distribution of kaolin is thought to eliminate the effect of the halloysite tubes.

The morphology of halloysite may indicate either a weathering or hydrothermal origin for the Virtasalmi kaolin deposits. Halloysite most probably represents a weathering product derived from plagioclase in the parent rock, because there is no other evidence for hydrothermal activity. The typical Virtasalmi kaolin texture, namely well-crystallized platy kaolinite, usually as a combination of "books" and dehydrated halloysite tubes, indicates a primary origin for Virtasalmi kaolin.

NorNet – The New tool for promoting environmental co-operation

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Northern Environmental Research Network (NorNet) is a thematic network for environmental research and sustainable use of natural resources related to northern issues. Launching new cooperative research programs and large R&D projects, as well as promoting multidisciplinary problem-oriented research and education, are the main focuses of the network.

The following partners have joined the NorNet-network: University of Oulu, Geological Survey of Finland, Finnish Environment Institute, Finnish Game and Fisheries Research Institute, Finnish Forest Research Institute, MTT Agrifood Research Finland and Regional Environment Centres (Lapland, Kainuu and North Ostrobothnia).

Land use and Land cover is the main theme of the NorNet research program 2005–2011 implemented by multiple research projects. The subject responds to the lack of information about tools and ways to solve problems of different conflicts in Northern Finland relating to the multiple use of forests and other forms of land use. Another important basis for the programme is approaching of the management of land and water ecosystems in a more integrated and comprehensive manner including social and historical aspects. In addition, concerns about the depopulation of the northern countryside and the data management of geo- and biodiversity are focus areas of the program as well. The aim of the program actions is to enhance co-operation between disciplines, research teams and research institutes. The program is directly related to research training of environmental graduate school and co-operation with business life and regional development organisations is also encouraged.

Links between volcanism and the distribution and timing of massive sulphide (VMS) deposits

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The links between volcanism and massive sulphide deposits are being studied as part of the "Global Volcanic-hosted Massive Sulphide (VMS) Project", which is IGCP project 502. Different types and settings of VMS deposit show different degrees of influence from volcanic or magmatic processes, with the most distinct genetic connection shown by some felsic-hosted deposits. These influences include:

(1) Basin-wide volcano-tectonic events cause deposition of VMS on specific time-stratigraphic horizons.

(2) With the exception of mid-ocean ridge settings, major VMS deposits are mainly associated with felsic volcanic rocks, even where felsic rocks form a minor component of the region.

(3) Most VMS deposits form in proximal volcanic settings.

(4) Most VMS deposits form at a particular stage in the evolution of their host volcanoes, typically late in the magmatic-hydrothermal cycle following a significant felsic eruptive event. The specific relationship in time and place implied by these last two points indicate that either the magmatic-hydrothermal cycle creates an important part of the ore solution, or controls when and where a metal-bearing geothermal solution can be focused and expelled to the sea floor, or both.

(5) VMS deposits occur preferentially at times and places where both felsic and mafic magmas were erupted. In felsic-dominated regions, eruption of the mafic rocks commonly closely followed deposition of the ore-host felsic package.

(6) Volcanic host rocks influence the morphology and stratigraphic position of VMS. Volcaniclastic and especially pumiceous strata promote deposition of VMS below the sea floor via replacement, whereas coherent lava flows and intrusions promote deposition of VMS on the sea floor.

(7) Volcanic rocks and/or magmas are probably the source of metals in most VMS deposits.

Silurian to Early Devonian tectonic and hydrothermal activity along the margins of the Fennoscandian Shield

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A widely distributed system of Phanerozoic low-temperature fluorite-calcite-galena mineralization is known along the margins of the Fennoscandian Shield. It occurs as narrow veins in the Precambrian crystalline basement and as pore fillings in Vendian to Lower Cambrian sandstones. Lead isotopic compositions are highly radiogenic ($^{206}Pb/^{204}Pb$ ratios 17–35), with characteristic isotopic signatures for each Pb source.

Age estimates of the hydrothermal system were achieved using Sm-Nd isotopes in fluorite and calcite from the Götemar and Tindered veins in SE Sweden, the Lovisa veins in SE Finland, and the Laisvall sandstone-hosted mineralization in the Caledonian front. Although no isochrons were obtained, isotope data for certain geologically well-defined fluorite populations yielded linear trends, indicating Silurian to Devonian ages. Coprecipitated fluorite-calcite pairs gave the most reliable and precise age estimates.

Our Sm-Nd results for Laisvall are consistent with well-dated lead mobilization in the interior of the Caledonides (Stuckless et al., 1982) and Ar-Ar ages of K-feldspar overgrowths associated with lead mineralization at Laisvall (Sherlock et al., 2005), and suggest that the hydrothermal activity along the Caledonian front took place at 420–430 Ma (Wenlock/Ludlow). Our Sm-Nd results for the Baltic Sea region veins are consistent with precision ages of regional fracture systems in Latvia (Brangulis & Kanevs, 2002) and suggest that the low-temperature hydrothermal veins in the Baltic Sea region were formed in conjunction with faulting, uplift and the transition from marine to fluvial sedimentary conditions during the Lochkovian to Pragian, i.e. at c. 410–415 Ma. The time lag between the hydrothermal activity in these two environments is in accordance with sedimentological evidence for a southeastwards migrating Caledonian thrust front during the Late Silurian to Early Devonian.

Sherlock, S.C. (2005). EPSL (in press).
Brangulis, A.J. & Kanevs, V. (2002). Geol. Surv. Latvia, 70 p.
Stuckless et al. (1982). Sver. Geol. Unders. C 798, 49 p.

Detrital zircon geochronology: Potential and pitfalls

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Dating of single, detrital zircons by instrumental U-Pb methods (SIMS, LAM-ICPMS) has become an important tool in the interpretation of provenance of clastic (meta) sediments, stratigraphic correlation and crustal evolution studies. Most researchers active in this field seem to move in the direction of a "quantitative research strategy" in the sense of Fedo et al. (2003), sometimes without sufficient regard for the problems caused by inadequate sample sizes. It is easily shown by numeric simulations that datasets are unlikely to be even semiquantitatively representative of the sediment sampled unless unrealistically large numbers of grains are analysed (Andersen, 2005). Quantitative interpretation of non-representative datasets may lead to unjustified conclusions, and eventually bring the method into discredit.

Although a good illustration of the nature of the problem, the numerical experiments by Andersen (2005) may be less helpful in practical research, because they do not suggest a way out of the impasse caused by poor representativity.

There are, however, different ways to overcome this problem: (1): Combining the "qualitative" and "quantitative" strategies of Fedo et al. (2003). (2): Replacing histogram scores and accumulated probability plots with qualitative abundance scores as suggested by Andersen (2005). (3): Constructing robust confidence bands for random-sampling histograms. In approaches (1) and (2), much of the quantitative information contained in a zircon age distribution pattern is sacrificed. The confidence interval approach may therefore be most fruitful of the three.

There is no unique method to assign confidence intervals to histogram scores, but several algorithms have been proposed over the last four decades. Some of these seem to work well with the type of data of concern here. The benefit of this approach is that much of the quantitative information contained in an abundance histogram is preserved, and that it gives a largely model-independent estimate for the size of fractions that may have been missed in the random sampling process.

Fedo, C.M., Sircombe, K.N. & Rainbird, R.H. (2003). Reviews in Mineralogy and Geochemistry 53, 277–303

Andersen, T. (2005). Chem. Geol. 216, 249–270

Hf isotope variations in Transscandinavian Igenous Belt zircons

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Zircons from granitic rocks retain a memory of the $^{176}Hf/^{177}Hf$ in the magma from which they crystallised, and are therefore an important indicator of granite petrogenesis and a monitor of the evolution of the continental crust. A large Lu-Hf isotope dataset exists for Fennoscandian Shield rocks (Patchett et al. 1981, Andersen et al. 2002, Söderlund et al. 2005). However, Lu-Hf data have until now been unavailble from the Transscandinavian Igneous Belt (TIB), despite its importance in models of regional crustal evolution.

The U-Pb ages and Lu-Hf isotope ratios in 138 zircons from six strategically important TIB granitoids have been determined by laser ablation multicollector ICPMS at the Department of Geosciences, University of Oslo. Zircon ages range from ca. 1850 to 1670 Ma, consistent with and slightly younger than previous age data. At emplacement, the TIB zircons define a well-constrained $^{176}Hf/^{177}Hf$ range from 0.2815 to 0.2818 ($\varepsilon_{Hf}(t)$ = -6 to +5). The 1860 Ma Finspång granitic augen gneiss contains a significant fraction of inherited zircons with lower initial $^{176}Hf/^{177}Hf$ (< 0.2814; $\varepsilon_{Hf}(t)$ < -7), which must have been derived from sources with a signficant crustal prehistory (cf. Andersson et al., 2004).

The Hf isotopic compositions of the TIB zircons completely overlap the range of Paleoproterozoic detrital zircons in 1500 – 1100 Ma metasedimentary rocks from the Telemark block, supporting a significant TIB source component. On the other hand, zircons with $^{176}Hf/^{177}Hf_i$ < 0.2818 are less frequent in the late Proterozoic Brøttum and Rendalen Formations (Hedemark Group) suggesting a less significant TIB contribution to those sediments.

Andersen, T., Griffin, W.L. & Pearson, N.J. (2002). J. Petrol. 42, 1725–1747.

Andersson, U.B., Högdahl, K., Sjöström, H. & Bergman, S. (2004). GFF 126, 16–17.

Patchett, P.J., Kuovo, O., Hedge, C.E. & Tatsumoto, M. (1981). Contrib. Mineral. Petrol. 78, 279–297.

Söderlund, U, Isachsen, C.F., Bylund, G., Heaman, L.M., Patchett, P.J., Vervoort, J.D. & Andersson, U.B. (2005). Contrib. Mineral. Petrol. (in press).

T.I.B. affinity and a parautochthonous setting of high-grade orthogneisses in the southern Eastern Segment of the Sveconorwegian Province

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The southern Eastern Segment (SES) forms a polymetamorphic high-grade orthogneiss complex in the southeastern Sveconorwegian Province. Regional scale migmatisation took place at about 1.44 and 0.97 Ga. Reworking at 0.97 Ga also involved emplacement of eclogites and high-P granulite facies metamorp-hism.

New mapping combined with petrological, structural and geochemical data allows identification of widespread, medium- to coarse-grained, and in places K-feldspar porphyritic, syenitoid to granitoid gneiss protoliths in the SES. U-Pb analyses of igneous zircon (NORDSIM) from three key localities dates this magmatism at 1.68–1.67 Ga [weighted average $^{207}Pb/^{206}Pb$-ages, 2σ errors: (I) Vägaholm metasyenite, 1666±15 Ma (n=4, MSWD=0.6), (II) Fröllinge metagranite 1676±10 Ma, (n=10, MSWD=1.3), and (III) Hinneryd augen gneiss, 1684±10 Ma (n=9, MSWD=0.7)]. The analyses of the Hinneryd augen gneiss was carried out on the same zircon sample dated by Lindh (1996) at 1.55 Ga by conventional TIMS analysis. The TIMS data appears to reflect mixing between igneous 1.68 Ga zircon and secondary zircon formed at 1.45 and/or 0.97 Ga. The new age data contradicts that all heterogeneously veined augen gneisses in the SES are younger than the surrounding migmatite gneisses.

The new data on orthogneisses in the SES demonstrate close geochemical and textural similarities with coeval syenitoid and granitoid plutonism in the unmetamorphosed Trans-scandinavian Igneous Belt (TIB) east of the Sveco-norwegian Province. The 0.97 Ga age of high-pressure metamorphism and the structural character of the TIB-like orthogneisses in the SES suggest a Sveconorwegian parautochthonous setting for this high-grade orthogneiss complex.

Lindh, A. (1996). GFF 118, 163–168.

Magnetic fabric (AMS) and magnetomineralogy at basement-cover-interfaces of the Caledonian margin, Autochthon and Lower Allochthon, Central Sweden

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Sections from two drill cores across the erosional unconformity between Fennoscandian Granite (Revsund) and Cambrian Gärdsjön Fm. (Langviken SGU 73007 (Tasjön) and Hara 79002) were investigated by means of magnetic susceptibility analyses (AMS, field and temperature dependent susceptibility) to track changes of magnetomineralogy and corresponding magnetic fabrics. The aim of this exemplary study is to gather general constraints on the relationship of alteration (palaeoweathering) and fabric at basement-cover-interfaces. The drill cores are not oriented, so regional strain directions cannot be determined.

The "Hara" autochthonous granite is a paramagnetic type (kappa = 100-450*10^{-6} [SI]). Main magnetic carriers are Fe-bearing phyllosilicates. The "Tasjön" autochthonous granite is a ferromagnetic type (kappa < 20*10^{-3} [SI]), dominated by magnetite. Towards the unconformity a decrease of bulk kappa is observable in both profiles. The Tasjön high-kappa granite altered significantly towards unconformity, decreasing its bulk susceptibility down to < 100*10^{-6} (low-kappa granite), typical for saprolites in palaeoweathering profiles. Both basement granites show a vertical gneissic foliation, which is older than unconformity-related features. In both profiles a comparable unconformity-related fabric change is traceable by AMS, independent of the petrographic (and magnetomineralogic) type: towards the unconformity the magnetic lineation gradually decreases its inclination, whereas magnetic foliation stays stable. That indicates a composite AMS fabric resulting from superposition of primary gneissic and an overprinting flat-lying secondary fabric.

Whether this secondary fabric is due to burial compaction or additional simple shear deformation, has yet to be clarified. The unconformity-related alteration and flat-lying fabric development might have facilitated propagation of detachments subparallel with this fabric during orogenic deformation.

1.45 Ga metamorphic imprint on zircons from the Transscandinavian Igneous Belt and the Eastern Segment

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The relation between the Transscandinavian Igneous Belt (TIB) and the Eastern Segment (ES) of the Southwest Scandinavian Domain (SSD) is complex and not yet fully understood. The aim of this study has been to examine how the protolith ages vary between the two domains, and wether the ES and TIB have had a similar metamorphic history.

Zircons from 13 different locations across the boarder between the TIB and ES have been analysed using the ion-microprobe of the Swedish Museum of Natural History, Stockholm. The samples were collected along a transect in south-central Sweden, from Jönköping to Kölingared, 35 kilometres north-west of Jönköping.

Samples from both the TIB and ES fall into two different age groups; 1.68–1.70 and ~1.45 Ga.

All samples with 1.68–1.70 Ga ages were mainly from oscillatory zoned zircons. These zircons are interpreted to be magmatic in origin, and thus indicate the protolith ages of both the ES and TIB rocks.

The ~1.45 Ga ages were obtained from thin rims and recrystallized domains in zircons from seven granites, derived from both the TIB and ES.

As the samples have similar protolith and metamorphic ages, we suggest a common history for the ES and the TIB rocks of this study, from their origin until at least ~1.45 Ga.

The results also implies that the 1.46–1.42 Ga metamorphic event (Christoffel et al., 1999; Söderlund et al., 2002) of southwestern Sweden must have extended further north and east than previously reported.

Christoffel et al. (1999). Precambrian Research 98, 173–195.
Söderlund et al. (2002). Precambrian Research 113, 193–225.

Petrology, major and trace element geochemistry of the Kivakka layered intrusion, northern Karelia, Russia

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The Oulanka layered igneous complex is located in northwestern Russia. It is one of the Paleoproterozoic layered complexes, 2440–2500 Ma in age, scattered within the northern Fennoscandian (or Baltic) Shield in eastern and northern Finland and adjacent Russia and Sweden. These widespread mafic rocks have been interpreted as representing the initial stage of continental rifting at the turn of the eons. The Kivakka intrusion forms part of the Oulanka layered igneous complex together with the Lukkulaisvaara and Tsipringa layered intrusions. The Kivakka intrusion is hosted by migmatized Late Archean biotite and amphibole gneisses, granite-gneisses, and granodiorite-gneisses The internal structure of the intrusion (2000 m in thickness) can be divided into two principal units: marginal series and an overlying layered series, the latter being further subdivided into zones. The dominant rock types of the marginal series are gabbronorite cumulates. The layered series is composed of a succession of cumulates (listed in order from bottom to top): olivine, bronzite-plagioclase, bronzite-plagioclase-augite, and plagio-clase-augite-pigeonite. Based on cumulative mineral assemblages, the layered series was subdivided into five zones: dunite and peridotite, pyroxenite, norite, gabbronorite and gabbronorite with pigeonite as a low-Ca pyroxene. The layered series which forms the major part of the intrusion is characterized by cryptic and rhythmic layering with the rhythmic layers a few centimetres thick. The distribution of Ni and Co is controlled by the distribution of olivine and the distribution of Sr depends on the plagioclase distribution. The succession of cumulates and distribution of trace elements is fully consistent with regularities of fractional crystallization.

Early Weichselian interstadial lake deposits at Björkö Island, Kvarken Archipelago, Finland

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Two till-covered gyttja deposits were found at Björkö Island, Kvarken Archipelago, during Quaternary geological mapping and closer De Geer moraine ridge investigations year 2004–2005.

The conform succession of the two gyttja layers were interlayered by a massive silt. The succession is considered as one lithostratigraphic formation with three members (to be later defined). This succession of sediments was excavated by tractor excavator and will be studied for pollen, diatoms, insect rests and macrofossils. The lateral extent of the layers were studied with gamma-logger sond from groundwater tubes and with ground penetrating radar. AMS- radiocarbon and OSL analysis are used to estimate the age of the deposits.

The study is at its preliminary stage and only the uppermost gyttja layer has been studied for pollen and some macrofossils. The vegetation development begins with treeles tundra with NAP – Betula pollen assemplage zone (PAZ). Later the vegetation develops to Birch forest with high amount of Juniperus (Betula – Juniperus PAZ), indicating still rather open vegetation. This is replazed by a Betula – Picea PAZ with spruce up to 30 % of the total pollen spectra indicating that spruce colonisized the area. Climatic deteoriation is reflected by treeles vegetation (Betula – NAP PAZ) at the upper part of the gyttja.

It seems clear that this succession of deposits represent the most continuous record of interstadial deposits at the Ostrobothnian region. (Nenonen, 1995; Donner, 1996). The analysis of this record will give important regional paleovegetational information which will help the biostratigraphic and chronostratigraphic interpretation of the other Ostrobothnian Weichselian stratigraphic locations.

Nenonen, K. (1995). Pleistocene Stratigraphy and reference sections in southern and western Finland. Geological Survey of Finland, Regional Office for Mid-Finland.

Donner, J. (1996). Quaternary Science Reviews 15, 471–479.

White cement: mineralization and nodulisation effects caused by K_2O, SO_3, MgO and F

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The formation of alite (C_3S) and belite (C_2S) in white cement clinkers is influenced by the presence of minor components. In order to investigate the combined effects of potassium, magnesium, sulphur and fluor a series of 32 different cement starting materials was prepared. Each sample weighed 40 g and represents a specific combination of the following accessory concentrations: SO_3: 0.15 and 1 weight%, K_2O: 0.2 and 1 weight%, MgO: 0.6, 1.4, 2.2 and 3.0 weight%, F: 0.04 and 0.25 weight%. The cement paste was filled in cylindrical containers (approx. 20 cm^3), allowed to harden for one month at room temperature under atmospheric conditions, and finally cut into discs 1 cm thick and 2 cm across. These were burnt in a kiln at 1400°C for 20 minutes after heating at a rate of 20°C per minute. At the end of the run, the kiln was turned off, and cooled to room temperature. Specimens were then examined by XRF, XRD, microprobe and optical microscopy. In addition, the free lime content was analysed. The volume change of the specimens was determined in order to measure the effect that different properties of the partial melt (viscosity and surface tension) are likely to have on the size distribution of cement clinker which is important for stable kiln operation.

First results indicate that C_3S in our run products contains ≤1.32 weight% MgO and ≤0.15 weight% K_2O, whilst maximum weight percentages for SO_3 and F lie at 0.26 and 0.22, respectively. In C_2S, SO_3 concentrations (≤2.74 weight%) tend to clearly exceed those in C_3S; also K_2O contents (≤0.99 weight%) are higher. Lower maximum values however, are observed for MgO and F; they are 0.75 weight% and 0.10 weight%, respectively. Volume changes range from 23% to 35% and appear to correlate with low SO_3/K_2O for high shrinkage.

Kerton, P. (2003). International Cement Review, September Issue, p. 73–78

First paleoceanographic drilling of Cenozoic sediments in the central Arctic Ocean

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IODP Expedition 302, Arctic coring expedition (ACEX), was the first mission-specific expedition in the history of scientific deep-sea drilling. ACEX was a three-ship operation, using an icebreaker as drilling platform assissted by two support icebreakers, including a nuclear powered ship. The primary target was the recovery of the ca 410 m thick Cenozoic sediment sequence draping the Lomonosov Ridge sedimentary bedrock at near 88°N and at a water depth of about 1.2 km. Key paleoceanographic objectives included the determination of the history of ice rafting and sea ice, and Arctic's role in the development of global climate during post-Paleocene times. A secondary target was to sample the underlying sedimentary bedrock to decipher the tectonic history of the ridge and the formation of the Eurasian Basin.

ACEX penetrated 495.5 m at three sites with a recovery of 68 %. Maximum subbottom depth was 427.9 m, barely sampling the bedrock sediments.

Four lithologic units are defined. Age control is provided by dinocyst (throughout), diatom and silicoflagellate (middle Eocene) biostratigraphy, magnetostratigraphy (chiefly Neogene), and ^{10}Be concentrations (Neogene). A long hiatus occurs at 197 mbsf, encompassing the late middle Eocene through (most of) the early Miocene interval. Age/depth relationships in the ACEX cores clearly demonstrate sedimentation rates on the order of 1–2 cm in the middle Miocene through Pleistocene interval, which is a factor of 10 to 20 times higher than previous estimates based on short gravity and piston cores. The biosiliceous Eocene sediments show elevated C_{org} concentrations. Early Eocene laminations also witness of a largely isolated, poorly oxygenated basin at depth. A brief episode (<1 myr) characterised by near-fresh surface waters occurred near the early/late Eocene transition. The Paleocene Eocene Thermal Maximum interval was partly recovered, indicating surface water temperatures >20°C. The transition to the bedrock was not recovered, but the underlying 1,4 m muds of Campanian age were deposited under shallow-marine conditions.

Ni-containing sulfides in impactites of the Lappajärvi, Sääksjärvi, Suvasvesi South, and Paasselkä meteorite craters

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The craters are situated in the central part of Finland and were formed in crystalline rocks. Impact melt rocks and/or suevite of the all craters have relative high concentrations of Ni, Co, Gr, PGE and others that are well recognized geochemical signatures of meteoritic contaminations (e.g. Schmidt et al., 1997). The main carriers of Ni, Co, and other siderophile elements in impactites are sulphides and metal. The Lappajärvi melt rocks contain pyrrhotite droplets and oxide-silicate globules (d < 2 mm) rich in Ni rimmed by pyrrhotite and occasionally with pentlandite and chalcopyrite. Sääksjärvi impact melt rocks contain Fe-Ni-Co monosuphfide, millerite (Ni,FeS), pentlandite, chalcopyrite, and sphalerite. The sulphide minerals occur as either spherule-like or irregular inclusions. The Suvasvesi South suevite houses altered impact melt inclusions with euhedral grains of Ni-Co containing pyrite (bravoite). Bravoite is present also in strongly recrystallized impact melt rocks of the Paasselkä impact crater. According to morphologic and composition features, a fraction of sulphides and metal in Lappajärvi and Sääksjärvi impactites are a shock re-worked meteorite matter, that experienced shock-induced melting or, less likely, are condensates of impact generated vapour cloud (Badjukov et al., 2001). Other fraction of sulphides and metal with low Ni and Co contents has terrestrial origin and formed by shock melting of a target. The reduced from target rocks and Fe-sulphide metal suggests to be slightly enriched in Ni and Co due to presence of disseminated meteorite matter in an impact melt. The last fraction of pyrrhotite, pentlandite, chalcopyrite, and other sulphide grains was formed by post-impact hydrothermal activity by mobilization of meteorite and terrestrial Ni and Co. Bravoite in the impactites of Suvasvesi South and Paasselkä seems to have originated in similar processes. The Ni-Co-Cu-Zn mineralization observed in the Lappajärvi and Sääksjärvi craters can be characteristic feature of the post-shock hydrothermal activity in impactites enriched in a meteorite matter.

Schmidt G. et al. (1997). GCA 61, 2977–2987.
Badjukov et al. (2001). LPSC XXXII, abstr., CDROM, #1532

High pressure crystal chemistry of feldspars and the phase transitions in Sr-anorthite

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Due to their open framework feldspars belong to the low-pressure rock forming minerals and are considered unstable under the mantle conditions. Different large cations can be incorporated in the cavities of the aluminosilicate framework of feldspars and the stabilizing and destabilizing influence of elements other than K, Na and Ca is of particular interest. A systematic analysis of the cation coordination polyhedra in feldspars (Makovicky & Balic-Zunic, 1998) showed that the Eu and Sr introduce the smallest distortion in the framework at room pressure and temperature.

In the present investigation the crystal chemical changes in Sr-anorthite (80% Sr, 20% Ca) under high pressure are investigated in detail. Sr-anorthite shows a phase transition at 4.3 GPa from the I-1 to I2/c symmetry, and a second transition at 7.3 Gpa with an apparent preservation of the symmetry (Nestola et al., 2004). Both transitions are displacive in character and preserve the basic structure. The crystal structure parameters of both high-pressure polymorphs have been obtained from measurements of a single crystal in a diamond anvil cell on a four-circle diffractometer with the CCD detector. Use of a sensitive high-resolution area detector enabled fast collection of the full available reciprocal space which gives a large number of redundant observations necessary for a satisfactory refinement of low symmetry structures with a high number of parameters. In this way we were able to obtain accurate structural data. The crystal chemical characteristics are compared to pure anorthite and other feldspars for which the high-pressure data exist in order to better characterise the influence of the large cation on the crystal structure under a high pressure.

Makovicky, E. & Balic-Zunic, T. (1998). Acta Cryst., B54, 766–773.

Nestola, F., Boffa Balaran, T., Benna, P., Tribaudino, M. & Bruno, E. (2004). Am. Mineral. 89, 1474–1479.

Fluid chemistry of the hypozonal Fäboliden orogenic gold deposit, northern Sweden

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Southwest of the well-known Skellefte District in northern Sweden a new ore province is presently being explored, the so called Gold Line. Today the largest known gold deposit in the Gold Line is the Fäboliden orogenic gold deposit.

The gold mineralization is commonly hosted in quartz veins, which parallel the steep main foliation, within a shear zone in the metagreywacke host rocks. The fine-grained (2–40 µm) gold is closely associated with arsenopyrite in the quartz veins.

Two main groups of fluid inclusions are present in the Fäboliden quartz veins. 1) Primary inclusions with a CO_2-CH_4 or a H_2S ($\pm CH_4$) composition (the latter recognized for the first time in a Swedish ore deposit). 2) Secondary fluid inclusions composed of pure CH_4 and low-salinity aqueous fluids. The primary fluid inclusions are associated with arsenopyrite (+gold) and the CO_2-CH_4 fluid was also involved in precipitation of graphite. The graphite-forming reactions should generate a H_2O phase as well. However, the presence of a H_2O phase was not detected in any of the primary fluid inclusions and is suggested to have been consumed by wall rock reactions, generating hydrated alteration minerals such as Ca-amphibole, biotite, and minor tourmaline. Fluid inclusion data indicate arsenopyrite and graphite deposition at a pressure condition of ~4 kbars. Graphite is useful as an indicator of the metamorphic grade because the graphitization process is irreversible with no effects on the graphite structure during retrogression (Beyssac et al., 2002). Graphite in the mineralized quartz veins at Fäboliden indicates maximum temperatures of 520–560°C for the hydrothermal alteration system.

Pyrrhotite was deposited after a subsequent pressure decrease and a later input of pure CH_4 and low-salinity aqueous fluids, as suggested by the secondary fluid inclusions. These later fluids were trapped at a substantially lower pressure of ~0.3 kbars and a temperature of ~400°C.

Beyssac et al. (2002). J. Metamorphic Geol. 20, 859–871.

Mid-crustal magma mixing and forced garnet stability in Late Ordovician plutons, Norwegian Caledonides

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Several mafic plutons intruded high-grade metasedimentary rocks of the Helgeland Nappe Complex (north-central Norway) from 448–445 Ma. The magmas caused melting of metapelitic aureole rocks, which resulted in a range of peraluminous migmatites, related leucosomes, and porphyritic, garnet-bearing granites. Locally, mixing of dioritic magma with peraluminous granitic magma occurred. The scale of such mixing varied from meter-width composite, mingled dikes to the 5-km-long Svarthopen pluton. The hybrids are generally mildly peraluminous quartz diorite to tonalite, with biotite + garnet ± amphibole. Plagioclase cores reach An75 and rims adjacent to garnet are as low as An25. Al-rich hornblende is typically skeletal; it yields unreasonably high Al-in-hornblende pressures (≥1.0 GPa). In contrast, pressure estimates from garnet-hornblende barometry are in the 600 to 800 MPa range, which is consistent with other barometric studies. The garnets range from idiomorphic to ragged, many contain acicular apatite and zircon and most have higher grossular component (up to 20%) and lower almandine component (66 to 70%) than is seen in garnets from aureole migmatites. The hybrids have initial $^{87}Sr/^{86}Sr$ (448 Ma) and $\delta^{18}O$ of 0.7082–0.7101 and +8.3 – +9.3‰ (VSMOW), respectively. By comparison, non-hybridized diorites have $^{87}Sr/^{86}Sr$ as low as 0.7057 and $\delta^{18}O$ = +6‰.

Numerical modeling of hybrid compositions shows that at 700 Mpa, garnet + plagioclase + other ferromagnesian phases should be stable from >800°C to 700°C. This supports the idea that mid-crustal mixing of metaluminous mafic and peraluminous felsic magmas can yield magmatic garnet. If so, the "garnet signature" of rare earth element patterns may result from fractionation of mid-crustal hybrids, as well as deep-seated (lower crust, upper mantle) processes.

Kohtla oil shale mining museum, NE Estonia – towards the future GEOPARK

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In the Kohtla area, NE Estonia, in the centre of Estonian oil shale mining the Kohtla oil shale museum was established in 2001. The museum provides an opportunity to learn about the oil shale mining in Estonia and visit one of the old underground mine with its all peculiarities, including operational underground mining equipment.

An about 450 My old oil shale (kukersite) is probably the most organic matter enriched oil shale in world (organic matter content reaches 40–45 wt%, oil yield as high as to 500 l/t, an average calorific value in open-pit mines is about 2800 kcal/kg). The chocolate-like oil shale is mainly composed of vast accumulations of microscopic remains of fossil alga Gloecapsomorpha prisca, forming beds commonly 10-40 cm in thickness.

The Estonia oil shale deposit has been the largest commercially exploitable oil shale deposit in the World since World War II (mined since 1918 already). The annual production peaked with 31 million tons of oil shale in 1980. Most of oil shale is directly burnt as fossil fuel in power plants, however its unique chemical composition makes it a valuable resource for chemical industry as well.

At the present the Kohtla area represents a good example of actual relationship between oil shale mining and social and natural environmental impact, with all its negative and positive effects. There are large waist hills nowadays utilize by people for different attractions, large recultivated landscapes with a selection of orchids, nature trails showing different sides of this impact and many nice targets for Paleozoic fossil lovers. Local traditions in mining, good position within the NE Estonian oil shale mining area, a number of old closed open pit and underground mines which can be accessed by interested tourists, well developed Kohtla oil shale museum infrastructure and necessary human potential to provide high quality service for visitors make the Kohtla museum and adjacent areas a primary target in building up the Estonian oil shale GEOPARK.

The 1890 and 1964 end moraines at Brúarjökull, a surge-type glacier in Iceland.

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The objective of this study was to investigate end moraines associated with fast-flowing ice. The ice-marginal environment of the surge-type glacier Brúarjökull in eastern Iceland was explored with emphasis on end moraines formed by the last two surges of the glacier in 1890 and 1964. The morphology, sedimentology and structural geology of the end moraines was investigated and a sequential model of their formation erected.

There is a relationship between the topography in the glacier forefield and the end-moraine morphology. Low and narrow end moraines, consisting of blocks and coarse sediment, are found in front of elevated areas while high and broad end moraines, consisting of fine sediment, are found in low-lying areas. It is proposed that the low and narrow end moraines were formed when the advancing glacier both scraped together boulders that pre-existed in the elevated areas, and dumped freshly-plucked debris at the ice-margin. They are therefore termed *scrape-dump moraines*. The high and broad end moraines were formed when the glacier pushed into the soft foreland sediments. These end moraines can be defined as *push moraines* and are primarily the result of ductile deformation of the foreland sediments. However, brittle deformation becomes frequent at the later stages of the push-moraine formation. It is proposed that the high and broad push moraines formed without considerable permafrost in the sediments. However, patches of permafrost in front of the moraine are thought to have resisted the forward advance of the push moraine in some places, and increased the local compression. It is furthermore suggested that seasonal frost played a significant role in the rheology of the uppermost strata by increasing their shear strength, causing domination of ductile deformation.

This study adds to the literature on end moraines of surge-type glaciers and should help to understand the morphology and structural geology of end moraines associated with paleo-ice streams and fast flowing ice.

Low-grade sedimentary rocks on Vanna, Troms, North Norway: a new correlative of the Paleoproterozoic (2.2–2.4 Ga) cover suites in northern Fennoscandia

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The West Troms Basement Complex comprises Archean to Paleoproterozoic igneous, metamorphic and supracrustal rocks subdivided into: (i) a north province of Archean tonalitic gneisses, (ii) a central-south region comprising dominantly felsic and mafic intrusive rocks, and (iii) narrow NW-trending belts with high-strained, low- to medium grade volcanic and sedimentary rocks (Vanna sediments, Ringvassøya Greenstone Belt, Senja Shear Belt).

The low-grade, par-autochthonous Vanna sediments unconformably overly the 2885±20 Ma old tonalitic basement (U–Pb zircon) and are tilted, folded and locally thrusted. Previous workers considered them as Late Precambrian in age and forming part of the lower Caledonian sequences in north Norway. New U–Pb ages for magmatic zircon and titanite of an intrusive gabbro-diorite sill within the Vanna sediments, however, yield a crystallization age of 2221±2.6 Ma. Mafic dykes of the underlying tonalitic basement that do not truncate the basement-cover contact have been dated to 2400 Ma; which represents a maximum age for the sediments. Laser ICP-MS U–Pb analyses of detrital zircons from the Vanna sediments suggests that the 2885±20 Ma old tonalitic basement was the most important source for the sediments, however, several zircon populations in the range c. 2700 Ma – c. 3400 Ma can be identified. Noteworthy is the lack of evidence of 1.8–1.7 Ga metamorphic resetting and a weak to moderate Caledonian overprint (413±5 Ma).

These new U–Pb age datings in Vanna indicate the diorite must be part of other Paleoproterozoic intrusive suites and corresponding sedimentary cover units in northern Fennoscandia. Examples include the Ringvassøy and Kautokeino-Karasjok greenstone belts of Finnmark, the Kittilä and Kuusamo greenstone belts in northern Finland, and the Nipissing diabase (2219±4 Ma) of Canada. These suites formed by Proterozoic crustal extension prior (or synchronous?) to Svecokarelian crustal uplift, contraction and regional metamorphism.

Detrital zircons in late Svecofennian metasandstones in central Sweden and southern Finland

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Deformed and metamorphosed quartz-rich sandstones in southern Finland and east-central Sweden were presumed to be deposited in late Svecofennian time (< c. 1.88 Ga). On the basis of this assumption detrital zircons were selected from four localities (Luukkola, Pyhäntaka and Tiirismaa in Finland and Hamrånge in Sweden) for U-Pb SIMS determination.

The obtained ages define three age groups, 2.90–2.40 Ga, 2.15–1.96 Ga and 1.92–1.84 Ga, with no correlation between age and Th/U-ratio. The groups are similar in all four samples, which supports correlation, and they are comparable to previously reported detrital ages in this part of the Fennoscandian Shield. The oldest zircon analysed gave an age of 3.32 Ga (Tiirismaa).

The maximum ages of sedimentation (and of subsequent deformation and metamorphism), indicated by the youngest zircon, from the four localities are 1842±10 Ma (Luukkola), 1865±11 Ma (Pyhäntaka), 1848±13 Ma (Tiirismaa), and 1855±10 Ma (Hamrånge), respectively. Possible source rocks for these zircons are found in and in the vicinity of the vast Ljusdal Batholith in Sweden. Importantly, rocks with such ages are rare in Finland.

It is concluded that one or several sedimentary basins covered an area of at least 400x500 km at c. 1.85–1.82 Ga ago in the Fennoscandian Shield. Basin formation can be constrained between 1.86 and 1.83 Ga, the latter age by onset of regional metamorphism in southern Finland.

Stratigraphically below the metasandstone at Hamrånge is a metadacite with an U-Pb zircon TIMS age of 1888±6 Ma. This indicates affinity to the metavolcanic rocks in Bergslagen to the south, rather than to the younger equivalents at Loos to the northwest. It also suggests a significant time gap of >30 Ma between the volcanism and sand deposition in the Hamrånge area.

Lithology and geometry of the Upper Jurassic Sognefjord Formation (Troll West Gas province, Northern North Sea) and relation to seismic properties

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A strong link between geological parameters, processes and seismic attributes, will increase the ability to predict geological properties from analysis of seismic data. By combining geological information from wells with rock physics and seismic modelling it is possible to construct seismic attributes for different sedimentary facies and depositional environments. The study area is located on the Troll West field, and data coverage includes 3 wells with good core coverage and a high resolution 3D seismic cube. A geological model is constructed based on these data.

Different depositional systems will give different seismic signatures due to varying lithologies and depositional processes. With rock physics analysis the P to S velocity ratio versus acoustic impedance plots are used to interpret different trends in seismic response for various gas saturations. Based on rock physics analysis, an alteration in the response can be seen for various scenarios of the sand/shale ratio, lamination, lithification, porosity and pore structure. Seismic models are established based on the rock physics analysis and pre stack and post stack seismic modelling is performed. The results are compared to real seismic data. Various seismic attributes, and in particular Amplitude Versus Offset (AVO) analysis, are correlated to the various geological scenarios.

Our study shows the benefit of including geological data and geological processes in the construction of a seismic model. Conversely, it also points to the ability to use seismic in mapping, not only in conventional structure-mapping, but also to map the distribution of the various geological depositional systems forming the rock.

International Geological Congress, IGC-33, Nordic Countries, Oslo 2008.

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During IGC-32 in Firenze 2004, the Nordic countries were awarded the next congress, IGC-33 to be held in Oslo 2008. IGC has been held in the Nordic countries only twice, in Stockholm 1910 and in Copenhagen 1960. These meetings were of great benefit for the Nordic geoscience communities and we expect the effect of the upcoming event to be even greater.

The Congress will have a strong focus on the Arctic realm, and a separate Arctic Consortium has been put together to ensure the Arctic component. However, we plan to make the congress a geo-scientific congress at large, with a strong interdisciplinary approach. Committees are therefore composed with personnel from the various geo-disciplinmes, and also representing the broad range of societal functions in which geo-scientists are important.

IGC-33 will take place in the period 26 july to 21 August 2008, with the congress itself in the period 5-14 August. The congress will be held at the Norway Congress Centre, just north of Oslo. Sufficient hotel capacity is already reserved, and the planning process is well underway. A significant programme of pre –and post congress excursions is being planned. The excursions include all the Nordic countries, Svalbard, Greenland, and northwest Russia. Being located in Oslo, several excursions will of course also focus on the many aspects of the geology of the Oslo Graben. A number of general, topical and special symposia are planned, but we expect an active participation from the whole international geoscientific community in our further planning of the scientific programme.

Publication and distribution of the First Circular is planned before the end of 2005. Here, we invite organisations and individuals to propose and take responsibility for symposia and excursions. We aim at IGC-33 to become an important meeting place and a showcase for the state-of-the-art within all aspects of modern geosciences.

EUROBRIDGE: Origin and geodynamic significance of the high-velocity lower crust in the Fennoscandia-Sarmatia suture zone

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The presence at the bottom of the crust of a thick rock layer with high P-wave velocities of 7.2-7.4 km/s and densities of 3.0–3.1 g/cm^3 (thus a "HVLC"-layer) has been revealed by seismic-gravity modelling along the EUROBRIDGE seismic profile. That profile transects the Fennoscandia-Sarmatia boundary suture zone (FSSZ) in the SW part of the East European Craton.

This HVLC appears to be relatively young and underlies various Palaeoproterozoic terranes in the FSSZ, additionally extending for more than 250 km into NW Sarmatia, which contains the large Korosten gabbro-anorthosite-rapakivi pluton of 1.79–1.74 Ga age. The HVLC also participates in a conspicuous antiformal structure beneath the FSSZ that was apparently formed during the collision of Fennoscandia with Sarmatia and is made up of stacked, wedge-shaped, middle- and lower-velocity crustal layers with rocks of Sarmatian provenance. These boundaries between these layers are marked by major detachments and sharp seismic reflectors.

At the present Earth's surface, intense bimodal magmatism and associated HT/MP granulitic metamorphism with strong mylonitization along a system of listric faults occurred at ca. 1.8–1.79 Ga, thus creating what subsequently became a metamorphic core complex.

Altogether, we consider that the HVLC beneath the FSSZ was formed ca. 1.8 Ga ago by post-collisional melting of the lower crust. At higher crustal levels, that process produced the Korosten Pluton. The HVLC layer is thus most probably composed of restitic garnet granulites or eclogitic granulites.

Roughness anisotropy of Venus surface.

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Nowadays, the results of the *Magellan* orbital radar experiments (1990–1994) are the main source of information about Venus' surface. Doppler centroid shifts f_D derived from Magellan radar altimeter data characterize along-track (north – south) anisotropy of the backscattering function of the surface. We start involving these data in geological studies of Venus.

A globally horizontal surface with an isotropic backscattering function leads to $f_D = 0$; some areas on Venus exhibit consistently positive or negative f_D values. This means the dominance of northward or southward surface slopes over the radar footprint, respectively. 81.3% of the studied Venus surface has f_D between ±935 Hz. These values are equivalent to ±0.4° surface tilts in the periapsis regions, and up to ±0.8° in the polar regions. Steep large-scale slopes (≥ 0.4° at the baselines of tens of kilometers) related to topographic features are clearly seen in the f_D maps. Elongated bright/dark features in f_D map usually are caused by rifts, troughs, etc., while large tessera areas have extremely noisy, spotty f_D appearance due to ubiquity of steep large-scale slopes.

In plains that occupy the major part of the Venus surface, there are usually no large-scale slopes responsible for systematically non-zero f_D observed in many locations. In these cases the non-zero f_D is caused by the anisotropy of small-scale surface topography (surface roughness). There is a global hemispherical trend of roughness anisotropy: equator-facing topographic slopes are steeper than pole-facing. The trend is consistent with the global wind pattern distribution, if the observed anisotropy is due to the presence of microdunes.

Detailed comparison of f_D maps with Magellan SAR mosaics showed that several small lava flows with uniformly strong anisotropy are well distinguished from the surroundings in the f_D maps. The flow itself hardly causes the observed surface roughness anisotropy, however the rough flow surface may favor accumulation of wind-blown material and produce the anisotropy due to deposits in the wind shadows.

Elevated erosion surfaces in southern Norway and West Greenland: their significance in studies of uplift and tectonic events

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Large-scale landscapes near the passive continental margins around the northern North Atlantic are commonly erosion surfaces at high elevation. The early geomorphologists suggested that these quasi-planar surfaces had developed near former base levels (the sea) and had been uplifted in the late Cenozoic. But the shift towards process geomorphology in the 1960s, combined with denial of large-scale landforms as relevant for conclusions about uplift events, made studies of large-scale landforms out-of-fashion.

Recent developments in a number of disparate fields are beginning to change this paradigm. Today can large-scale landscapes be analysed more objectively than formerly using high resolution digital elevation models to identify erosion surfaces. These studies, combined with interpretations of fission track data and sequence stratigraphic interpretations based on offshore hydrocarbon industry well and seismic data, have led to new interpretations of the amount and timing of uplift tectonism of passive margins.

We present a model of uplift and erosion which combines landform analysis, geology and fission track thermochronology. We constrain the relative event chronology from the landform record with the geological record and with age control from thermo-chronology that gives insight into the cooling history of subsurface rocks. We conclude that this combined approach validates the interpretation of large-scale landforms as governed by different base levels in the past and that we can use the combined approach to estimate uplift and reconstruct tectonic events.

Bonow, J.M. (2004). Palaeosurfaces and palaeovalleys on North Atlantic previously glaciated passive margins- reference forms for conclusions on uplift and erosion. PhD-thesis. Dissertation No. 30, The Department of Physical Geography and Quaternary Geology, Stockholm University.

Japsen, P., Green, P.F. & Chalmers, J.A. (2005). J. Geol. Soc. Lond. 162, 299–314.

Analysis of $(M_2Cu_2O_3)_7(CuO_2)_{10}$, (M = Sr, Ca), spin-ladder composite compounds.

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As new more complicated solids are being synthesized, many new unusual structures are discovered. Spin-ladder $(M_2Cu_2O_3)_7(CuO_2)_{10}$, (M = Sr, Ca) crystals are modulated composite crystals originally discovered as a byproduct in the synthesis of the superconducting phase $Bi_2Sr_2CaCu_2O_8$. Themselves they are superconducting at high pressure. Their superconductivity is located in chains and not in layers as in the majority of the high temperature Cu – O superconductors.

In the present work the spin-ladder crystals were synthesized by a flux growth and with a travelling solvent floating zone (TSFZ) technique. The crystal structures were solved both in a super-cell and as four dimensional modulated composite structures with two incommensurate parts. All crystals were twinned, with the twin domains related by a two fold rotation around [011].

Magnetic susceptibility measurements were preformed on crystals grown with the TSFZ technique. Apart from a Curie-Weiss interaction of a free copper spin, the measurements revealed an existence of a next-nearest neighbour dimer interaction of the copper spins in the chains. The dimers were separated by two Zhang – Rice singles, resulting from electron vacancies situated on oxygen atoms.

Geonat 2003–2005 – Geological Information and Nature Values for the Sustainable development of the Northern Kvarken area – Results

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Geology and Geological Nature values of the Northern Kvarken area in the Gulf of Bothnia, the Baltic Sea, has been mapped and surveyed in co-operation project between Geological Survey of Finland (GTK) and Geological Survey of Sweden (SGU) in years 2003–2005. The project was funded by European Union (Interreg IIIA Kvarken MittSkandia), SGU, Regional council of the Ostrobothnia, Vaasa town, municipality of Mustasaari, Forsstyrelsen Natural Heritage Services and K.H. Renlund foundation. Total expenses of the project were 11.5 milj.SEK.

Geological mapping of the Quaternary deposits, bedrock and seabed with the mapping of the geological nature values were the main tasks of the project. To present 16 GeoSites of Geological Nature values were selected. Special interest was given to the Nomination of the Nature World Heritage area in the Kvarken Archipelago with geological criteria (Breilin et al 2004).

In the Northern Kvarken area Quaternary deposits show a great variations of different moraine formations and glacial striations. A new till covered gyttja deposit was found in the Björkö island by the Turku University team. Geological bedrock information is more detailed than before.

The results will be introduced in written report and in two geological map sheets 1) Quaternary deposits and marine geology and 2) bedrock in scale 1:200 000. In same map sheets several thematical maps are also included. Results will be published also in GTK's and SGU's own map series. For the Finnish funding partners detailed soil mapping for land use planning purposes and interpretation of the fracture zones for the grounwater investigations has been done. In Sweden special interest was given to study the sulphide bearing sediments and to map aggregate quarries.

Breilin, O. et al. (2004). Geology of the Kvarken Archipelago. Geological Survey of Finland, 47 p.

Formation of saw-tooth moraines in Bødalen, western Norway

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The Bødalen valley, an outlet valley of the Jostedalsbreen Ice Cap, contains a set of frontal- and lateral moraines whit both peculiar morphology and sediment assembly. These marginal moraines were deposited during the Little Ice Age (a.d. ~1750; Matthews et al, 1979) by the renewed Jostedalsbreen ice cap that was formed subsequent to the Holocene climatic optimum. After the Little Ice Age maximum, the retreat of the glacier in Bødalen was interrupted by several small readvances forming five main moraine ridge systems. These terminal moraines are relatively large, up to 9 m high, with steep distal and gentle proximal slopes. Four of these display a characteristic saw-tooth pattern in plan view. From an oblique angle the overall shape of these ridges are arcuate, but at a smaller scale they show a "zig-zag" pattern, where the most ice-distal part ("tooth") is highest. All the terminal moraines consist of matrix supported sandy diamicton. At the ice-proximal ("bay") part sediment structures are virtually absent, which contrast with the "tooth"-part, where weak shear bands and alignments of boulders are visible. Between "bay"– and "tooth"– parts weak shear bands are still recognisable.

We conclude that the material of the terminal moraines likely represents reworked proglacial lake sediments. All the aforementioned structures are derived during the formation of the terminal moraines. In the ice-distal position sediments were probably sheared, whereas the more ice-proximal sediments were bulldozed to final position.

Matthews J.A., Cornish R. & Shakesby R.A. (1979). Journal of Glaciology 22 (88), 535–546.

Gravity model of the Lockne Impact Crater

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The Ordovician marine Lockne impact structure is partly hidden under Caledonian thrusted units and partly eroded outside the erosional Caledonian front. Measurements of the impact generated fracturing indicate strongly increased fracturing in the crystalline Tandsbyn breccia within (the ring part of) the structure, compared to the southern external terrains. To the north, at Nordanbergsberget, the limit of the impact generated fracturing is not reached. The hill Nordanbergsberget was therefore suspected to be the central uplift feature of a larger impact structure.

Subsequent measurements with VES technique in the ring synform where it is eroded, where it is suspected to occur under thrusted rock units, and beyond the northern limit of the larger crater, indicated that significant amounts of low resistivity rocks occur under the thrusted units. To the north outside the crater normal, crystalline rock resistivities were again obtained under the thrusted rocks cover.

These new constraints were introduced to gravity models together with measured densities of the involved rock types. Additional gravity measurements were made on lakes and in a wider surrounding of the crater to increase the accuracy of the model. The gravity models account for the regional variation, the Caledonian cover rocks, the roots of the present mountain belt, and the effects from a large, ca 18 km diameter crater centred at Nordanbergsberget. This is in agreement with the considerable size, ca 2 km, of the intensily fractured central uplift feature.

The crater is complete in the NNW-SSE direction. In the SW-NE direction it is seen that 90 % of the eastern part of the structure is missing. This missing part was displaced along NNE-SSW oriented shear zones just east of the central uplift and eroded prior to the Caledonian thrusting. The resulting half circular feature is also reflected in the present topography as evident in digital elevation data of the region.

ESIR at Ilumetsa – an example of international student cooperation in impact crater research

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In October 2004, European Student Impact Researchers group (ESIR), currently with 15 members from 7 countries (www.geophysics.helsinki.fi/esir/), was founded in Helsinki. It was created to re-establish personal and professional connections between graduate students and young researchers in the field of impact studies. As the NorFA and ESF-IMPACT programs were terminated by 2004 and new proposals for European impact research collaboration were at standstill, an initiative for student cooperation was taken. The different scientific backgrounds of the members strengthen the interdisciplinary approach required in such a complex subject as impact research. Furthermore, the collaboration ensures the possibility of gaining first-hand experience in methods and material otherwise unavailable for individual students.

The first major activity was a short course/field campaign at the Quaternary Ilumetsa impact crater field, SE Estonia, mainly organized by the impact researchers at the University of Tartu and financed by the Finnish Wihuri foundation. By combining different geophysical methods (magnetic, electric, seismic and georadar) with each other, and peat drilling, we were able to obtain a multidimensional view of two Ilumetsa structures, Põrguhaud (Hell's grave) and Sügavhaud (Deep Grave), and the target. The status of the Ilumetsa craters, geologically studied in the sixties and seventies, has been somewhat questionable as no meteorite fragments nor shock metamorphic features have been recorded. The studies gave an insight into the geophysical aspects of young and small meteorite impact structures in theory and practise. Plado et al. (this issue) report the preliminary scientific results of the course.

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Ca. 1.45 Ga tectono-magmatic event in SW of the East European Craton: indications of convergent tectonics

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The increasing body of geochronological data show that ca. 1.45 Ga magmatic-tectonic event affected the SW margin of the East European Craton (EEC) to a greater scale then previously thought. Ubiquitous and rather voluminous granitoid magmatism is now known in southern Sweden (Scania, Blekinge and Småland), on the Danish Island of Bornholm and western Lithuania. Felsic dyking, anatexis and high-grade metamorphism of this age are identified in the Sveconorwegian crust segment between the Mylonite Zone and the Protogine Zone, SW Sweden. Further north, in Dalarna region of Sweden, dolerite and porphyry dykes were also intruded at this time.

Most of these granitoids form rather well defined compositional trend from quartz monzodiorites to monzogranites. They are predominantly metaluminous, ferroan, ultrahigh-K (shoshonitic) sub-alkaline to marginally alkaline rocks. The rocks are enriched in Th, U and REE. They show similarities to A-type granites, however, they are not typical ones.

Structural data obtained from granitoid plutons in Blekinge and Scania show that these rock bodies were intruded during SW-NE compression and associated with shear zones. The general structural pattern on Bornholm also indicates similarly directed contractional stress during the emplacement of ca. 1.45 Ga granitoids. Although in Lithuania the Precambrian rocks are covered by the Phanerozoic sedimentary cover and structural studies are hindered, the rocks there show both magmatic and HT solid-state deformations.

Regional compression (with local extension), granitoid magmatism and shearing at ca. 1.45 Ga suggest that the SW margin of EEC collided with a foreign continent. The position of the orogen's core is still open question.

Greenland Icesheet variability and its IRD contribution to the northern Labrador Sea and David Strait.

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Little is known about the contribution of Ice Rafted Debris (IRD) from the Greenland Icesheet to the North Atlantic during the last glacial. Earlier studies suggest that during the Heinrich events the flux of icebergs from Greenland was minor compared to the Laurentide Icesheet centred over Hudson Bay. Here we present preliminary results from a paleoceanographic study with focus on ice-ocean-climate interactions in the Davis Strait and northern Labrador Sea. Our study is based on multiproxy evidence (IRD, faunal isotopes, sediment geochemistry) from late Quaternary marine records.

A 1.6 m long core from the Davids Strait corresponds entirely to the Younger Dryas cooling, with very high sedimentation rates between 70–400 cm/ka. Most of the sediment represents IRD although some horizons contain shell fauna that was picked for AMS dating. The IRD abundance curve (>500µm) suggests one, or possibly two, large pulses of terrigenous sediment fluxes. The IRD petrology consists of relatively large amounts of basalt and detrital carbonate. The main source of basalt in the region is Disko Bay in West Greenland and we therefore expect a significant amount of the IRD contribution in the area to originate from icebergs calved from the Greenland Icesheet. Alternatively, basalt could have derived from local submarine outcrops in the Davis Strait, where widespread iceberg scouring has been documented by side scan sonar.

A second, 8.6 m long core from the northern Labrador Sea displays a hemipelagic sequence that appears to represent the last 30-40.000 years. The Holocene section is rather condensed while glacial sedimentation rates are estimated to ~50 cm/ka. Continuous XRF scanning has been performed resulting in high-resolution bulk-chemistry profiles reflecting main element concentrations. Interestingly, the Fe counts display a clear negative correlation with the Greenland ice core isotope signal while distinct Ca peaks are related to detrital carbonate peaks that define Heinrich events 1 and 2. Further analyses are planned that can generate a more quantitative picture of iceberg sources in the Davis Strait.

Composition of melt inclusions and age of zircon from plagiogneisses of the Archean complex penetrated by the Kola Superdeep Borehole (Baltic Shield)

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Presented are the first results of the definition of the time of capture of the primary melt and fluid inclusions in zircons from metavolcanic plagiogneisses of the Archean complex of the Kola Superdeep Borehole from a depth of 10601–11411m. The time of capture of inclusions is established by defining the isotope age of the host zircon with the help of the SHRIMP-II equipment. The prismatic zircons (with an age of 2813 to 2887 Ma) have a magmatic origin, whereas complicate grain crystals of zircon (with an age of about 2675 Ma) were formed from the Late Archean metamorphic protoliths. The zircons with melt inclusions of plagiorhyodacite and plagiorhyolite composition (+syngenetic fluid inclusions of liquid CO_2) relate to the primary magmatic zircons of early generation (with an age of 2842 to 2887 Ma), which were formed from deep melts during partial crystallization of CO_2 saturated magma. More younger zircons (with an age of 2829 to 2813 Ma) also crystallized from deep melts of plagiorhyodacite composition. Upon eruption on the surface their fast nonequilibrum crystallization took place with the formation of intergranular melts of rhyolite composition, which as inclusions were trapped at a final stage of the zircon crystallization.

Long time-series monitoring of hydrogeochemistry in the Tjörnes Fracture Zone, Iceland.

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Monitoring of groundwater chemistry can further our understanding of chemical reactions between minerals and aqueous solutions in water-rock systems. Further, in seismically active areas, hydrogeochemical monitoring may detect anomalies which are precursory to – or caused by – earthquake activity (King et al., 1981; Toutain et al., 1997; Federico et al., 2004). Water samples from a 1500 meter deep well in the Tjörnes Fracture Zone, Iceland, have been collected on a weekly basis from July 2002 to the present for isotopic and elemental analysis, with the aim of identifying changes related to seismic activity. All water samples have been analysed for a range of cations and anions, as well as oxygen, hydrogen and strontium isotopes. Metal concentrations in the water show an apparent correlation with seismic activity, where Cu, Zn, Mn, Fe and Cr increase significantly prior to an M 5.8 earthquake. Claesson et al. (2004) proposed that these hydrogeochemical anomalies were due to influx of groundwater which had interacted with their host rocks in response to stress-induced modification of the rock permeability. Concentrations of more soluble elements (e.g. B, Ca, Cl, Li, Mo, Na, Rb, S, Si, Sr) increased rapidly shortly after this earthquake. The extremely low δD of the water, indicates an ice age origin. Recovery of Ca-concentrations to pre-earthquake values over a time-period of 2 years may constrain the timescale and mechanisms of fault unsealing and resealing. Differing enrichments of soluble elements imply differing source aquifers characteristics.

King et al. (1981). Geophys. Res. Let. 8, 425–428.
Toutain et al. (1997). EPSL. 149, 113–119.
Federico et al. (2004). J. Volc. Geoth. Res. 133, 81–104.
Claesson et al. (2004). Geology 32, 641–644.

U–Pb constraints on the Late Paleoproterozoic evolution of the West Troms Basement Complex, northern Norway

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The West Troms Basement Complex was build during the Archean and variously reworked and expanded in the late Paleoproterozoic before being caught in the Caledonian collisional events.

In common with the Archean crust to the east of the Caledonides, the basement in West Troms underwent extension and dyking at various stages in the Paleoproterozoic. The latest of these extensional events is represented by 1988 Ma gabbro, which occurs in a sequence of metasedimentary rocks of in the Mjelde-Skorelvatn zone, one of several NW-trending shear systems in the region. The 1988 Ma age suggests an affinity of this succession with ophiolitic units in Finland. The main Svecofennian activity in the region was the intrusion of mafic and felsic plutons at around 1800 Ma. The 1801 Ma Hamn gabbro in Senja and the 1792 Ma granitic Ersfjord granite in Kvaløya (Corfu et al., 2003) are major representatives of this period of magmatism, which also coincides with the emplacement of the bulk of the AMCG suite in Lofoten-Vesterålen further south. Deformation along NW striking shear zone was accompanied by some magmatic activity and was in the waning stages by about 1770 Ma. However, there is evidence for some more protracted metamorphic or hydrothermal activity forming titanite down to 1750 Ma. A significantly younger timing for D3 shearing in these zones seems to be indicated by 1570–1580 Ma zircon in felsic dykes associated with this episode of tectonism. More work is in progress to confirm these data, which would imply a considerably extension of the timing of deformation in the region, or reactivation during a subsequent 'anorogenic' event.

Corfu, F., Armitage, P.E.B., Kullerud, K. and Bergh, S.G. (2003). NGU-Bull 441, 61–72.

The Skardfoss formation, its age and bearing on the lithostratigraphy of the Telemark supracrustals, South Norway

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The Telemark supracrustals form a thick metavolcanic-metasedimentary sequence in Telemark, South Norway. Its oldest part is the c. 1510–1500 Ma old (Bingen et al. 2005 and references therein) Tuddal formation (TF) dominated by felsic vulcanites and overlain by the Vemork formation (VF) basalts with sedimentary interbeds. Dons et al. (2004) place the upper boundary of the TF upon a thin, flow-banded rhyolite, named here informally the Skardfoss formation (SF). The SF is overlain by polymictic conglomerate (MC), VF-type basalts and thin quartzite beds followed by the main TF body. Its lower contact is slightly erosional whereas the upper contact is marked by felsic volcanoclastic breccia followed by a VF metabasalt.

The SF rhyolite yields a U-Pb zircon age of 1495.6 ± 1.4 Ma, which overlaps the age of the TF indicating that the SF represents the last event of the Tuddal felsic volcanism, but the SF could also be included into the lower part of the VF as it is underlain by basalts. The transition from TF to VF is thus interbedded, which supports Dons' (1960) original inclusion into his Rjukan group (cf. Dahlgren et al. 1990). This is supported by new observations in the Homvatnet area, c. 30 km SW from Skardfoss, where a VF-type basalt is in direct contact with the bulk TF, but is overlain by a SF-type flow banded rhyolite, which again is overlain by MC-type conglomerates and the bulk VF basalts. The abrupt switch from felsic volcanism to basaltic and the MC-type conglomerates, indicate that although no greater unconformity can be seen between the TF and the VF they represent two different evolutionary stages of the Rjukan rift. It would be reasonable to change their ranks to groups.

Bingen, B. et al. (2005). ***Nor. J. Geol. 85, 87–116.***
Dahlgren, S. et al. (1990). Geonytt 17, 38–39.
Dons, J.A. et al. (2004). Berggrunnskart Fröynstaul 1514I, 1:50 000.
Dons, J.A. (1960). ***Nor. Geol. Unders. 208, 49–58.***

A seismic trial for CO_2 geological storage

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Capture and geological storage of CO2 has the potential to reduce emissions of greenhouse gasses to the atmosphere. CO2SINK is the first European R&D project to test in situ the geological storage of CO_2 into an onshore aquifer. The project is carried out by 15 partners from academia, government and industry of eight European countries. The site is located at Ketzin, near Berlin – Germany. Main objectives of the seismic imaging aspect of the project are to provide an understanding of structural geometry of possible flow pathways within the planned reservoir and to evaluate the evolution with the time of the reservoir during and following the injection of CO_2. A seismic pilot study was performed in 2004 in order to test different seismic sources, to define their optimal acquisition parameters and to test different geophone setups. Two perpendicular lines were measured. 120 geophones per line were set with a spacing of 20 m. The sources used included a weight drop, a small vibrator and a medium size Vibsist. The Vibsist is a recently developed multi-impact, time-distributed source that uses a tractor/excavator-mounted hydraulic rock breaker, powered through a computer controlled flow regulator. One short-term goal of the pilot test was to gather argument of the source selection for the main project. The analysis was therefore focused on the general question about the quality of seismic profiling with the considered sources. The conclusion of the source comparison has been that whilst all three sources image the upper 500 ms with approximate the same clarity, the Vibsist source provided the deepest penetration and gave a better image at deeper levels.

Recent developments in electrical imaging

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The development of DC resistivity electrical imaging techniques has been rapid in the last decade. This applies to data acquisition as well as inverse modelling techniques, and has lead to a greatly expanded practical applicability of the method. A trend today is to move from traditionally used electrode array types such as Wenner towards arrays that are more efficient for multi-electrode equipment with multi-channel measuring capability, e.g. multiple gradient array measurements (e.g. Dahlin & Zhou, 2004). On the data processing and analysis side robust (L_1-norm) inversion (Loke et al., 2001) and time-lapse inversion can be mentioned as valuable tools.

The improved data acquisition speed, in combination with development of interpretation software and low cost powerful computer capacity, paves the way for 3D imaging. A logistically simple way to carry out 3D surveys is to measure a number of parallel lines in the field, that are merged before inverting with 3D software.

Resistivity imaging is now becoming widely used in environmental and engineering applications where increased knowledge about the subsurface is sought. Important applications include of groundwater resources mapping and vulnerability studies, contaminant mapping and monitoring, geotechnical pre-investigation, natural resources prospecting, geothermal prospecting, permafrost mapping, leakage detection etc..

Good quality induced polarisation imaging, using data acquisition equipment that is primarily designed for resistivity imaging, has proved to be feasible on a time and cost efficient basis in some environments. In other environments data quality problems will occur with such equipment in standard configuration. A prime application for IP imaging appears to be mapping and characterisation of buried waste (e.g. Carlson and Zonge 2003), which is expected to become increasingly important for rehabilitation and re-use of areas used as landfills.

Dahlin, T. & Zhou, B. (2004). Geophysical Prospecting, 52, 379–398.

Loke, M.H., Acworth, I. & Dahlin, T. (2003). Exploration Geophysics, 34(3), 182-187.

Carlson, N.R. & Zonge, K.L. (2003). Exploration Geophysics, 34(1/2), 114–119.

Manhaul tectomict: the patchy deforming bed of a cold-based Antarctic glacier

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It is the perceived wisdom that cold-based glaciers are frozen to their bed and have little or no effect on that bed. They certainly are not expected to produce till. Work in the Allan Hills, Transantarctic Mountains, Antarctica has provided good evidence that perceived wisdom got it wrong on both accounts.

Here we want to show the field and laboratory evidence for patches of subglacial til deposited by an advance of the cold-based Manhaul Glacier. Patches range from mere dm^2 to several m^2 and are often found on steeply inclined or vertical bedrock or boulder (stoss-)faces.

Microscopic studies revealed that linear (shears, faults, grain lineaments) microstructures dominate over circular (turbate) ones. Apart from linear microstructures there is widespread evidence for brecciation, as well as for some grain crushing. As the Manhaul tectomict preserves a record of glaciotectonic rather than of sedimentary processes it is the result of subglacial deformation. A low water and clay content appear to be fundamental in underpinning the planar brittle deformation style of cold-based glaciers.

The preservation potential of this tectomict is extremely low.

Hydrothermal red-staining adjacent to fractures in granodioritic to dioritic rock, Simpevarp, south-east Sweden

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Red-staining of the wall rock adjacent to fractures, caused by hydrothermal alteration and oxidation, is a common phenomenon in crystalline rocks. The mineralogical changes and the extent of the oxidation that have taken place during the formation of the red-stained wall rock have been studied in drill core samples of dioritic to granodioritic rocks belonging to the Transscandinavian Igneous Belt. Altered rock samples are compared with adjacent reference rock samples. SEM-EDS studies show that the red-staining is caused by minute inclusions of Fe-rich minerals, mainly hematite, hosted in pores in K-feldspar and albite replacing primary plagioclase. Accompanying this alteration is hematitization of magnetite, chloritization of biotite, formation of sericite, prehnite, titanite and epidote, and increased micro-porosity and micro-fracturing. Temperatures of c. 280–400°C for the red-staining event are suggested based on the secondary mineralogy. Primary quartz, K-feldspar and titanite remained rather fresh during alteration. The reference rock is often hydrothermally altered as well, showing that the hydrothermal alteration reached further into the wall rock than the red-staining. Whole rock chemistry shows highly enriched values of K, Na, Rb and H_2O in the red-stained rock associated to formation of secondary K-feldspar, albite and water-bearing minerals like chlorite, prehnite and sericite. In contrast, Ca, Sr, Cs, Be, Cr and Ga and partly also Al, Th, and S are depleted in the red-stained samples. This depletion is probably associated to break down of primary plagioclase, alteration of biotite, hornblende and augite and oxidation of magnetite and subordinately pyrite. Si, Fe_{tot}, Mg, Ti and REE:s remained fairly constant. Mössbauer spectrometry analyses reveal that Fe^{3+}/Fe_{tot}-contents are elevated by about 3–10 % in the red-stained rock, caused by oxidation of magnetite to hematite and an increased amount of Fe^{3+}-bearing minerals like chlorite and epidote. In conclusion; 1) the intense red-staining is produced by relatively moderate oxidation 2) The mineralogy has changed considerably whilst the change in whole rock chemistry is less pronounced.

Crystal structure of bøgvadite

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Bøgvadite, $Na_2SrBa_2Al_4F_{20}$, is an aluminofluoride which until now has only been found in the cryolite deposit at Ivittuut, Southwest Greenland. It is found in the central part of columnar aggregates of thomsenolite, fluorite, topaz, barite and jarlite, and was originally called mineral X (Bøgvad 1933). Bøgvadite occurs as rectangular, uniformly orientated crystals 0.1-0.2 mm in diameter arranged as an irregular pavement covering a few square centimeters (Pauly and Petersen, 1988).

The crystal structure has been solved using single-crystal data (Mo$K\alpha$ X-ray diffraction, CCD area detector). The crystal lattice of bøgvadite is rectangular pseudo-orthorhombic with a = 7.134(2), b = 20.011(5) and c = 5.344(1) Å, V= 763.0(3) Å^3, Z= 2 and D_x= 3.901 g/cm^3. The true symmetry is monoclinic, space group $P2_1/n$. Crystals are twinned with (001) as a twin plane.

Bøgvadite is a rare example of a fluoride with three different large cations (Ba, Sr, and Na) playing distinct roles in the structure. As ususal for fluorides, Al is coordinated octahedrally with six F. The octahedra form chains parallel to [001]. Ba and Sr are coordinated by ten, and Na by nine F atoms. Sr atoms occupy centers of symmetry in pentagonal antiprisms formed by F atoms. The structure of bøgvadite is related to that of the two isotypic fluorides jarlite ($Na_2(Sr,Na)_{14}Mg_2Al_{12}F_{64}(OH,H_2O)_4$) and jørgensenite ($Na_2(Sr,Ba)_{14}Na_2Al_{12}F_{64}(OH,F)_4$). The latter two contain fragments of octahedral chains of the same type as those found in bøgvadite.

Bøgvad, R. (1933). Meddr Grønland, 92(8), 1–11.

Pauly, H. & Petersen, O.V. (1988). Bull. geol. Soc. Denmark 37, 21–30.

The search for impact structures in Norway

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The search for impact structures in Norway is still in its infancy and compared to Sweden and Finland the number of discovered structures (3 possible) is very low. The geological composition and area dimensions of the three countries would indicate rather similar amounts of impact structures.

A systematic search for topographic impact structures in Norway is therefore started, in a first stage based on an automatic scan of digital elevation models (DEM) with spatial resolution between 25 m and 100 m. In this stage we defined topographic krater structures with diameters between 2 and 5 km, and correlated this kernel with the DEM ("matching"). The first screening picked out about 4500 circular structures, matching the topographic pre-described structure. Thereafter the different cases we briefly analysed manually (geological and geomophological setting), and the number were reduced to 1201. These circular structures may be of several different origins, a few of them might have an impact origin. The goal is now to visit and look up these structures in the field, but for our small project group this task is immense. Based on a website presentation (www.geo.uio.no/groper) and intensive national publicity of the project, we hope to engage students in the search. The fall 2005 and spring 2006 students (age 10 to 14) and their classes will participate in this hunt for impact structures in a national school project launched in co-operation with The Research Council of Norway.

The final results of this approach will be seen in early September 2006, when the different presentations have been submitted and awards handed out.

This project will continue with comparative analyses of available geophysical and geochemical information. This program is planned in cooperation with Geological Survey of Norway and with the University of Helsinki, Geological Survey of Finland and European Space Agency/ESTEC.

Did the Mjølnir asteroid impact ignite Barents Sea hydrocarbon source rocks?

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The organic rich shales of Late Jurassic age make up the main source rock for oil and gas in large parts of the Arctic. These sediments, presently on the average 100 m in thickness, may locally contain more than 15 % total organic carbon (TOC) and covered the target area of the Mjølnir impact. In late Jurassic an about 2km in diameter bolide hit this 400 m deep, wide epicontinental sea.

We suggest that the extreme richness of organic matter and highly volatile components in the target sediments resulted in colossal and intense fires in the impact area, both in the air and on the seafloor.

This theory is supported by numerical simulations and explains the large quantities of soot that have been found in samples associated with the Mjølnir impact.

Isostatic considerations of structural differences within the Scandinavian mountain chain and links to offshore tectonics

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Topographically, the Scandes mountain range can be divided in the Northern and Southern Scandes. Comparisons between the present topographic expression and the gravity field and the geoid show that the axis of highest elevation in the Northern Scandes is shifted eastwards compared to the minimum of the Bouguer anomaly, while the two coincide perfectly in the Southern Scandes.

Flexural, isostatic calculations yield a small component of regional isostatic compensation for the lithosphere of the Southern Scandes. This and comparison with regional seismic experiments show that additional support of the isostatic system is required from the lithospheric mantle. On the other side, for the topographic load of the Northern Scandes no regional isostatic support can be resolved. Local subsurface loading and horizontal tectonic forces overprint the isostatic compensations and increase the tectonic complexity. These distinctive features of the Scandes cannot be convincingly explained by currently existing models of the present and Neogene uplift and the isostatic mechanism of the Scandes.

Future concepts should integrate the geophysical and structural onshore-offshore observations, and incorporate overprint effects by local tectonics. Notably, the offshore prolongations of the major onshore detachments stemming from the Late Caledonian orogenic collapse control the crustal geometry in the deep Møre and Vøring basin, offshore Norway.

Geological sites for nature tourism in Kvarken and Western Finland

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UNESCO will next summer decide whether the Kvarken Archipelago area in the Bothnian Bay, Baltic Sea can be included in the World Natural Heritage List on geological grounds as a transboundary serial nomination to the High Coast World Heritage site in Sweden. Large swarms of De Geer- and other moraine formations and rapid land uplift (80cm/100 years) are the most significant features of Kvarken.

During the application process the Geological Surveys of Finland (GTK) and Sweden (SGU) have investigated the area in the extensive GEONAT – project funded mainly by the EU (Interreg IIIA Kvarken MittSkandia). One aim of the project was to use geological information from the bedrock, Quaternary and marine surveys for purposes of tourism, education and local economic development.

Sixteen sites – 8 in both countries – were selected as "Top Sites", and in addition about 40 other sites were chosen to introduce geological values to the public. A general poster about the geology and evolution of the whole area will be placed in strategic places in co-operation with the Gröna Bro – project. Thematic posters were planned for sites, formations and processes of special interest.

In a project called Geobotnia the Åbo Akademi University/Unit of Ostrobothnia, GTK and the Vaasa Region Development Company, VASEK, are making plans for "Geopark Ostrobothnia" to be included in the "European Geoparks Network" within a couple of years. In addition to the Kvarken Archipelago, the Terranova exhibition in Vaasa, the Söderfjärden meteorite crater, a mining museum in Korsnäs, the Kauhaneva and Lauhanvuori National Parks and the Wolf Cave (were the Neanderthal man lived possibly during the last Ice Age) will be included. The Geopark area also includes raised beaches, weathered rocks, paleosols, caves, large erratic boulders and dwelling sites from the Stone and Iron Ages. Not only geology, but also archaeology, history, culture, ecology and local economic development are important issues in a Geopark.

Plans for a European Geopark in Western Finland

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Geotourism has played only a minor role in Finland, and only recently has its potential been realized. From 2003, the University of Åbo Akademi/Unit of Ostrobothnia and the Geological Survey of Finland have run two development projects in western Finland to increase common knowledge of geology, to organize education for sustainable development, and to improve local economies through geotourism.

Three regional geological exhibitions and two site exhibitions were planned. Also, routes, boards and a public guide maps of the geological sites were prepared, and suggestions for further actions were made. A working group was formed to develop a geopark in western Finland, Geopark Ostrobothnia. It will cover an area of 160x80 km and will later be proposed to the European Geoparks Network and Global UNESCO Network of Geoparks. In a Geopark archaeological, historical, cultural and ecological aspects are important, too.

Two National Parks are located in planned Geopark: Kauhaneva-Pohjankangas, including internationally significant peatland areas and esker formations, and Lauhanvuori with the highest hill in W Finland and an exceptional geology. The Geopark would also include the archipelago of Kvarken, which is a candidate for inclusion in the World Heritage List. Swarms of De Geer- and other moraine formations and rapid land uplift (80cm/100 years and 100 hectares new land area /year) are the most significant features.

The well-preserved Cambrian meteorite impact crater at Söderfjärden and the pregalcial Wolf Cave in Kristinestad-Karijoki are also included. The Cave is the largest known cave in Finland, the oldest known possible dwelling site in the Nordic countries, and the only place in the world where signs of human life (probably Neanderthal man) is preserved in an area that has been covered by a continental ice sheet. The human activity is dated back to the Eem-interglacial >120 000 years ago. The Geopark area also includes raised beaches, weathered rocks, paleosols, caves, large erratic boulders and dwelling sites from the Stone and Iron Ages.

Apatite chemistry – a potential tool for IOCG exploration

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Northern Norrbotten is an important mining region of Sweden and is regarded as an iron-oxide copper-gold (IOCG) district hosting several apatite-iron oxide and copper-gold sulphide ores (e.g. Hitzman et. al., 1992). The IOCG group of deposits is diverse with respect to age, host rock, ore and alteration mineralogy as well as ore-forming processes and there is still an ongoing debate regarding a possible genetic link between "classical" Kiruna type ores and copper dominated end-members within this class of deposits.

Apatites from Kiruna-type apatite-iron deposits (Kiirunavaara, Rektorn, Nukutus, Ekströmsberg, Tjårrojåkka-Fe), IOCG copper occurrences (Tjårrojåkka-Cu and Nautanen), a 1.89 Ga andesite and a Perthite-monzonite group intrusion were collected and analysed for their mineral chemistry and rare earth elements using electron microprobe and LA-ICPMS analysis. The apatite chemistry can subsequently be used as an indicator of the composition of fluids involved in the formation of the deposits (Korzhinskiy, 1982). Different trends with regard to F-Cl content as well as REE pattern in the apatites were observed for apatite-iron ores with no spatial relation to copper mineralisation compared to the apatite-iron ore spatially related to a copper occurrence. The apatites from the former were almost pure F-apatites with steep REE patterns, while the apatites from the latter and the copper mineralisations themselves contained a large Cl-component and showed depletion in LREE.

It can be concluded that apatite chemistry could be a potential tool for distinguishing copper mineralising apatite-iron systems from barren ones. However, so far only one apatite-iron deposit spatially related to a copper occurrence has been studied and more studies are needed to confirm the results.

Hitzman, M.W., Oreskes, N. & Einaudi, M.T. (1992). Precamb. Res. 58, 241–287.
Korzhinskiy, M.A. (1982). Geochem. Int. 3, 45–60.

Metal associations in genetic types of gold deposits

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Elements potentially enriched in ores are commonly used in geochemical exploration. This method can be very useful enhancing the discovery rate. But how useful the metal association is in ore-genetic investigations, does it stand alone for such purposes? Review of data published on composition of different genetic types of gold deposits (orogenic, IOCG, skarn, porphyry and other intrusion-related, epithermal, Au-VMS, Carlin, placer) and their immediate alteration haloes indicates that:

1. A large number of elements is typically enriched in a deposit of any genetic type, except in placers which commonly only show enrichment in gold.

2. Independent of genetic type, most deposits are enriched in, at least, As, Au, S, Sb and Te. The sole systematic exception here are the placers.

3. Systematic variation in metal association between different genetic types can only be seen when an extensive set of elements (≥30) is analysed and all enriched elements are inspected together as potentially diagnostic groups. This seems to work well for, at least, the Carlin type. However, even analysing an extenve set of elements does not guarantee a correct identification of the genetic type.

4. There is not an element association which is diagnostic for magmatic-hydrothermal genesis for a gold deposit.

5. Most commonly, gold is the sole commodity in a deposit, and never can a genetic type of a gold deposit be indicated by the commodity association.

6. All genetic types or classes also contain exceptions regarding metal association. For example, despite what is stated in point 2 above, not all gold deposits, in any genetic group, are enriched in As, Sb or Te.

7. However, the metal associations can be useful, even alone, in defining the genetic type of a gold deposit in a geologically restricted area, for example, within an individual greenstone or schist belt.

Cooke & Simmons (2000). SEG Reviews13, 221–244.
Foster (1991). Gold Metallogeny and Exploration. Blackie, Glasgow.
Goldfarb et al. (2001). Ore Geol. Rev. 18, 1–75.
Hofstra & Cline (2000). SEG Reviews13, 163–220.
Meinert (1989). Econ. Geol. Monogr. 6, 537–552.
Nurmi et al.. (1991). Geol. Surv. Finland, Bull 351, 101 p.
Vanhanen (2001). Geol. Surv. Finland, Bull 399, 229 p.

Geotourism in northern Estonia and southern Finland – a new EU project

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The geology of northern Estonia and southern Finland has been the subject for scientific research for more than 100 years. However, not very much has been done to popularise the geology in the field for a more extensive public. A project called "Geoturismin edistäminen Virossa ja Suomessa – oppien tuntemaan maan menneisyyttä" or "Promotion of geotourism in Estonia and Finland – get acquaintance with the Earth´s history" was established in July 2005. The purpose with the project is to create popular information about the geology in both countries. The idea is to enlight people about the extensive time span of Earth history that covers the two areas. Paleo- to mid-Proterozoic formations in S Finland (1900–1275 Ma) and early Paleozoic formations in N Estonia (700–300 Ma). Both areas can geologically be tied by the Quarternary formations. The geological targets on focus in Finland in the beginning of the project are selected around the popular archipelago ring road in SW Finland. To get the needed local information and logistics, the project established cooperation with the community cluster Region Åboland – Turunmaan seutu and lokal history associations. Besides EU-foundation, the Finnish side the project is supported by State Provincial Office of Western Finland and K.H. Renlund foundation

Main geological targets in Estonia include Cambrian, Ordovician, Silurian and Devonian sedimentary rock, Palaezoic fossils, Estonian fameous oil shale, limestones and dolomites, karst processes and others. Several subprojects are planned to cross the border between Finland and Estonia, such as erratic boulders, meteorite craters, bogs and glacial landscape forms in Estonia and Finland. In total 16 booklets and 13 videofilms (DVD) and paths in the nature will be prepared during 2005–2007. From the Estonian side the project is also supported by the Ministry of Internal Affairs, NGO GeoGuide of Baltoscandia and the Institute of Geology at Tallinn University of Technology. A number of leading geologists from both countries are involved as experts.

Continental Deep Drilling – new challenges for geophysics

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Deep drilling of continents has become a powerful tool to study earth's crust and to test the validity of the geological and geophysical models. The ICDP (International Continental Scientific Drilling Program) program has given new challenges for Finnish geosciences. The Solid Earth Geophysics group of the Division of Geophysics, University of Helsinki is working on four ICDP-projects that aim to drill through large meteorite impact structures: (i) Chicxulub in Mexico – 65 Ma (Elbra, et al., 2005); (ii) Bosumtwi in Ghana – 1.07 Ma (Pesonen et al., 2003); (iii) Chesapeake in Virginia – 35 Ma (Pesonen, et al., 2004); and economically valuable areas: (iv) Outokumpu formation in Finland – 1.97 Ga (Kukkonen, 2004).

The objective of the project of the Solid Earth Geophysics group is to investigate physical properties (such as density, porosity, magnetic susceptibility, etc.) of the samples from deep drillings. These properties have importance in (i) understanding the formation of these structures, (ii) improving the geophysical modellings, (iii) estimating the environmental effects of the impacts, and (iv) dating the impact events. Measurements of petrophysics and paleomagnetism, coupled with rock magnetic studies, have been already carried out in Chicxulub drill holes and are currently ongoing in case of Bosumtwi and Outokumpu samples. Chesapeake Bay drilling is under way.

Results of Chicxulub reveal good correlation between petrophysics, paleomagnetism and rock magnetic data giving an useful tool to identify the impact layer (lower densities, stronger remanence magnetization, higher magnetic susceptibilities, etc.) and to verify that the event took place within the magnetic chron 29 R (~65Ma). We will highlight some of the results obtained so far.

Elbra, T. & Pesonen, L.J., (2005). ***Meteoritics & Planetary*** *Science 40 supplement, A44.*

Kukkonen, I.T. (2004). GSF Report Q10.2/2004/1, 9–10.

Pesonen, L.J, Koeberl, K. & Hautaniemi, H., (2003). Jb. Geol. B.-A., 581–604.

Pesonen, L.J, Elbra, T., Lehtinen, M., Donadini, F. & Salminen, J. (2004). ***U.S.G.S. Open-File Report 2004-1016,*** *71–72.*

Extensional brittle structures and their relations to the bimodal 1.6 Ga magmatism in the Helsinki region, southern Finland

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Brittle faults were studied in the Paleoproterozoic Svecofennian domain in the Helsinki region, southern Finland. Understanding the brittle deformation is important for rock mechanical applications. A distinctive set of WNW-ESE to NW-SE trending faults crosscuts the regional ductile deformation pattern and 1640 Ma rapakivi granites, and they occur parallel to the rapakivi-related diabase dykes. The fault rocks consist of cohesive and incohesive cataclasites, and slickensides indicate normal sense of shear. According to kinematic analyses of fault slip data the faults were formed in a transtensional regime with minimum stress in a NNE-SSW to N-S direction. The joint pattern subparallel to the normal faults also shows extensional features and seems to be associated to the faulting and also to late rapakivi-related fluidization. The same stress field fits also to reactivation of previous steep late-Svecofennian NNE-oriented transtensional faults in the area. Their original reverse east side-up movement is overprinted by lower grade mineralogy and dextral strike-slip slickenside striation.

The transtensional regime, expressed as these brittle structures, applies to the time after the cooling of the rapakivi granites but probably it existed already during the onset of bimodal rapakivi magmatism.

Kelvin inversion revisited in PEC/PMC sphere problems

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Geoelectric imaging utilizes stationary electric current for the geophysical characterization of geological medium. Current is fed by point-like transmitter electrodes (T) and electric potential is measured by receiver electrodes (R). Different bore-hole or on-surface T-R configurations can be used. Some natural geological inhomogeneities or man-made structures (like metallic objects or excavated cavities) within geologic medium on different geometric scales can be treated as spherical perfect electric conductors (PEC) or as perfect magnetic conductors (PMC). Perfect magnetic conductors are analogous (dual) to electric conductors with zero electric conductivity or infinite magnetic permeability.

Many elementary textbooks on electromagnetics present the classical Kelvin inversion problem for a PEC sphere in the field of a point charge. The sphere can be replaced by two point image charges, one situated at a specific (Kelvin) point and of specific intensity, and the other at the center of the sphere controlling the equipotential value of the sphere. However, it is not generally widely known that such a Kelvin inversion solution exists also for a PMC sphere (Hänninen, 2004). In this situation the sphere can be replaced by an image point charge at the same Kelvin point as in PEC solution but with opposite sign. The other image source is a homogeneous line source with specific intensity between the center of the sphere and the Kelvin point. The boundary condition on the surface of PMC sphere is a homogeneous Neumann condition with the normal derivative of the potential being zero. Making use of the duality we can directly convert the electrostatic problem to an analogous stationary electric current problem. The responses of these spherical geometries for geoelectric imaging can straightforwardly be yielded by superposing the potential fields of image sources and the original transmitter source field.

Hänninen, J.J. (2004). Solving Electromagnetic Boundary Problems with Equivalence Methods. TKK, Electromagnetics Laboratory, Report 434 (Dissertation).

Strong and stable NRM components in granulites in the Gödestad-Obbhult anomaly, SW Sweden

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The Eastern Segment, between the Mylonite and Protogine Zones in southern Sweden, is characterised by numerous occurences of granulite facies rocks. The regional magnetic anomaly pattern is complex with several distinctly low magnetic anomalies. One of them is the Gödestad – Obbhult anomaly. McEnroe et al. (1991) studied mafic granulites from Gödestad and reported extremely stable remanent magnetism due to ilmenite-hematite nano-scale exsolution. We have studied another locality (Obbhult) within the same regional anomaly. The Obbhult rocks show a greater variation in composition compared to Gödestad. Six 3–5 m wide granulite facies layers (OBB 1-6) were sampled. OBB 1 (opx, qz, plag, bi, hematite host with exsolved ilmenite), OBB 2 (opx, gt, plag, bi, hem/ilm xsl), OBB 5 (kfsp, sill, gt, cor, bi, hem/ilm xsl) and OBB 6 (opx, cpx, hbl, plag, bi, gt, mt, hem/ilm xsl) are all characterized by a steep NRM component with negative inclination, anomalously high coercivities and laboratory unblocking temperatures in between 560 and 650°C. The results from Gödestad were similar. Two other sites, OBB 3 (pl, cpx, hbl, bi, mt, hem) and 4 (kfsp, plag, gt, cor, bi, mt, hem) are strikingly different with coercivities lower than 20 mT, Q values below unity and a NRM component in the direction 360/58 close to the present geomagnetic field. Only few hematite grains in site 3 and 4 show exsolution textures. The continued study of the Obbhult rocks will focus on details of their magnetic mineralogy. The aim of this SGU supported project is to study the magnetic properties of metamorphic rocks at localities in SW Sweden.

*McEnroe et al. (2001). **Journal of Geophysical Research B: Solid-Earth 106 (12)***

Deformation structures and strain intensity characteristic of an Ocean-Continent transition.

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The transition from continental thinning of the lithosphere to the formation of oceanic crust in non-volcanic rifted margins involves exhumation of subcontinental mantle associated with large-scale detachment faults. During ocean drilling, low-temperature structures are commonly destroyed as evidenced by a very low recovery of all drill cores of upper basement serpentinized peridotite rocks and consequently, studies of deformation on this material are biased. This study is based on several detailed profiles of deformation (strain) across a well documented land-analogue to the Newfoundland-Iberia margin, the Tasna OCT, exposing a great variety of low-T deformation structures. The aim of the study is to describe the general deformation characteristic of mantle exhumation of a detachment fault system in magma-poor margins. Although the extending lithosphere shows a bulk brittle behaviour, deformation along the detachment faults is localized within "ductile" weak core zones formed by foliated cataclasites or gouges and surounded by wide "cataclastic" damage zones forming under greenschist facies to seafloor conditions. Although there is a progressively more intensified brittle overprint towards the top of the mantle, meaning that the strain decreases away from the core zones, local high-strain zones may be found within the damage zones at any depth. This leads to the conclusion that strain may be localized simultaneously at several weak zones or horizons in the serpentinized fault zones perhaps due to the reworking of pre-existing structures or local inhomogeneities of the peridotite mantle such as varied composition and degree of pre-exhumation serpentinization. The width of the damage zone suggests that multiple-deformation has occurred and this is also evidenced by the fact that structures are overprinted by successive brittle deformation during their exhumation at the seafloor. Thus exhumation needs to be treated as a complex and poly-phase process.

The Newfoundland-Iberia conjugate margin. New results from Site 1277.

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In this study we interpret the fluid-flow history of ODP Site 1277, which is located on the Newfoundland-Iberia margin. Site 1277 is the only drill hole on the Newfoundland side, which penetrated serpentinized peridotite basement rocks. We present a profile of oxygen isotope data from this Site, which preserves an isotopic gradient with progressively heavier $\delta^{18}O$ towards its base. On top of this gradient there are four enriched/ or depleted regions. The elements MnO, Sr and possibly CaO increase towards the top of the mantle. This chemical gradient may be attributed to the addition of calcite and chemical transfer towards the top of the profile. This gradient suggest that a CO_2-bearing fluid infiltrated from above. However this was probably not a pervasive event since there is no corresponding shift in $\delta^{18}O$. The isotopic and geochemical record may at this point be interpreted as follows: 1) pervasive serpentinization by a relatively cool fluid increased $\delta^{18}O$ to >8‰ at T~100°C, or alternatively, a warmer fluid ~5‰ T~160°C was channelized above the basement. This latter fluid flow event might post-date exhumation and could be caused by magmatic activity. This is evidenced by several heat sources in the area including basalt sills found at nearby ODP Site 1276 and meta-basalt or magmatic veins at Site 1277. 2) Depleted zones record either a late channeled (permeable) or the preservation of an earlier (impermeable) high-T fluid flow event. 3) ^{18}O-enriched zones are probably due to exchange with sea-water at low-T and correlate spatially with ophicalcite breccias. We conclude that after the mantle was exhumed at Site 1277 the exchange between sea-water and exhumed mantle rocks is restricted to zones of high permeability. Erosion must have been only minor at Site 1277, which is surprising considering this is an ocean-high of serpeninized peridotite which is considered very easily eroded.

Permafrost and periglaciation in the Nordic region

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Permafrost is defined as ground that remains at or below 0°C for at least two consecutive years. In the Nordic region permafrost is widespread, mainly occurring in the mountains. On a global scale the Circum-Arctic Map of Permafrost and Ground-Ice Conditions (Brown et al., 1997) covers the entire Nordic region. However, new investigations indicate ice-rich permafrost being frequently present at lower altitudes than previously anticipated. Permafrost is an important climate change indicator, but permafrost distribution now gets attention also as an important factor in rock slope stability, especially in western and northern Norway. The Norwegian Geological Survey, as a partner in the International Centre of Geohazards, in cooperation with the Norwegian Meteorological Institute and the Department of Geosciences, University of Oslo, now systematically investigates this relationship.

Only in Svalbard and large parts of Greenland does permafrost occur continuously in the landscape, with typical permafrost landforms such as ice-wedges and rock glaciers. In the rest of the Nordic area, due to the relative warming effect of the thermohaline circulation, the permafrost is discontinuous and controlled mainly by altitude and slope aspect. Therefore the permafrost has a highly heterogeneous pattern, where cold and relatively thick permafrost can be close spatially, in the same slope system, to shallow permafrost. This spatial relationship makes such mountain slopes highly active with respect to periglacial gravitational processes, and thus very sensitive to climatic variability. Palsas grow in lowlands with discontinuous or sporadic permafrost, while rock glaciers occur in highlands with discontinuous permafrost. This unique range of different permafrost types and periglacial landforms display the high geomorphological sensitivity of the region. Even small changes in temperature, precipitation or wind activity in the Nordic region can lead to changes in the distribution of permafrost, and the activity of permafrost landforms.

Extremely fresh early Paleoproterozoic boninite-like volcanics, Vetreny Belt, SE Fennoscandian Shield, Russia

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We presented data on composition and texture of the early Paleoproterozoic (2.41–2.45 Ga: Puchtel et al., 1997) mafic-ultramafic volcanic rocks in the riftogenic Vetreny Belt, SE Karelain craton. Initially, these volcanics were determined as olivine basalts and picrites and then, owing to the works of V.S. Kulikov (1988), as komatiites and komatiite basalts. They contain high-Mg olivine and pyroxenes, high-Cr spinel and remarkably fresh volcanic glass of andesite and andesite-dacite composition. The rocks have low TiO2 and Nb, high LILE (Sr, Zr, Ba, and others) and LREE.

Judging on petrographical and geochemical data, the studied volcanic rocks are similar to the Phanerozoic subduction-related boninite series. However, the volcanics of the Vetreny Belt formed in within-plate settings: this belt is a member of the early Paleoproterozoic Baltic large igneous province of the siliceous high-magnesian (boninite-like) series (Sharkov et al., 1997). It is shown that spinifex textures are typical not only of komatiites, but also for the boninite-like volcanics.

Kulikov, V.S. (1988). In: Komatiites and high-magnesian volcanics of the Early Precambrian of the Baltic Shield. Leningrad, Nauka, 20–88 (in Russian).

Puchtel, I.S. et al. (1997). Geochim. Cosmochim. Acta, 61, 1205–1222.

Sharkov, E.V. et al. (1997). Petrology, 5, 448–465.

Palaeolandscapes and glaciations on the Varanger Peninsula, Northern Norway

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The Varanger Peninsula with its well preserved paleic surface, extensive block fields, special geological setting and position by the shallow Barents Sea has caught the interest of geoscientists for almost a century. In this presentation some aspects concerning the paleic surface and the late Cenozoic development, including the impact of Pleistocene ice sheets, will be discussed. The peninsula is largely a plateau bordered by coastal or near coastal escarpements. Lithostructurally controlled inselbergs rise above extensive gentle palaeo plains. Large systems of V-shaped valleys are deeply incised in the plains. This indicates different modes of geomorphic processes probably connected both to the climatic and the tectonic history. The inselbergs are covered by blockfields and host zones of preglacial weathering. They are interpreted to have emerged by differential etching. Erratics up to the highest summits show that thick ice sheets have covered the peninsula. However, features like circular ablation morains, crossing meltwater channels, and meltwater channels cutting into blockfields and down into the V-shaped valleys indicate that several of the Pleistocene ice sheets to a very limited degree have remoulded the previous landscape. Cosmogenic datings support the survival of surfaces during several ice sheets.

The effect of volcanic eruption on metal mobility in surface waters

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The overall objectives of this study is to measure the effect of volcanic eruptions on the chemistry of surface waters in the vicinity of the Hekla volcano (Iceland), during and after the January 1991 and February 2000 eruptions. The Hekla volcano is one of the most active volcanic systems in Iceland. The last two eruptions took place in 1991 and 2000. The volume of tephra was 0.02 km^3 for the 1991 eruption (Gudmundsson et al. 1991) and 0.01 km^3 for the 2000 eruption (Lacasse et al. 2003). Experiments have shown that metal salts were adsorbed on the surface of the tephra and that they dissolved rapidly when exposed to de-ionized water and seawater (Frogner et al., 2001).

Snow samples, for this study, contained volcanic ash and were sampled during the initial subpilinian phases of the eruptions. Water samples from the river Ytri Ranga, in the vicinity of Hekla, were taken during and after the eruptions.

Dissolved metal and anion concentrations were very high in the melted snow samples (F: 66.2, Fe: 4.4, Al: 6.0 mmol/kg, Pb: 0.28 and Cd: 1.0 µmol/kg). The pH was as low as 2.6.

During the 1991 eruption, the concentration of metals and anions in the river water was stable until the first rain hit the pristine volcanic ash on day 4. The rain caused an increase in concentration of several elements. F and Cl concentrations were elevated just for one day where concentration of metals like Fe, Al, and Ti rose for up to 10 days before returning to initial concentrations.

In 2000, ash from the initial sub-plinian phase of the eruption fell directly into the river and quickly resulted in high F concentration (0.15 mmol/kg). The concentration went down to preeruption concentration (0.04 mol/kg) 25 hours after the beginning of the eruption. Si, Ca, Mg, Al, Fe, Mn, Cd, Co, Ni, Cu, Zn and Pb, increased in concentration in the river water, while Na, S, As and Mo decreased following the first rain on the ash during the 7^{th} day of the eruption.

Gudmundsson et al. (1991). Bull. Volcanol. 54, 238–246.
Lacasse et al. (2003). Bull. Volcanol. 66, 457–473.
Frogner et al. (2001). Geology, 29-6, 487–490.

Glacier temperature profiles and relation to landforms, exemplified by ice flow draining patterns in Northern Central East Norway

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Glacier temperature profiles and their relation to landforms are described on the basis of ice flow drainage pattern deduced from streamlining features, e.g., drumlinoid forms and glacial striations. In the northern central parts of East-Norway these patterns indicate the passage of a marked northeasterly-directed ice-stream across the area. This ice- flow had its origin in an ice-dome/ice-shed in the high plateaus of west central Norway.

In the mountains of Trollheimen, Skrymtheimen and Rondane, the ice flow drainage pattern seem to have moved independently of the landforms during an early phase of this glaciation/deglaciation. A combined effect of a polythermal glacier (ice sheet) and the landscape, however, seems to play an important roll as the ice sheet got thinner and an upper glacier zone of cold ice touched the highest mountains. In this situation the pre-existing landscape and landforms became more and more important for the flow pattern , and the ice-flow divided into a western and an eastern branch, moving on both sides of the Skrymtheimen mountains towards the northeast. As the surface of the inland ice got thinner over the Hjerkinn area, the thickness of the inland ice south of the Rondane mountain was still some 7-800 meters in the plateau areas south and east of these mountains. This thickness of the inland ice with related movements are though to explain the later ice flow from south and east that came into the Hjerkinn – Stororkelsjøen areas. These movements are tentatively correlated with the streamlining features with a westerly trend. This most probably developed at a late phase of the YD Chronozone.

Cretaceous Gross and Klein Spitzkoppe stocks in Namibia: topaz-bearing A-type granites related to continental rifting

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Anorogenic Damara igneous province in Namibia comprises mafic, silicic and alkalic volcanic and plutonic rocks that were emplaced at 124–137 Ma into the Neoproterozoic Damara orogenic belt between the Congo and Kalahari cratons. The magmatism was related to to the Tristan mantle plume and continental rifting that led to separation of South America and Africa. Silicic plutonic rocks include hornblende biotite granites and minor peralkalic granites (Brandberg), peraluminous granodiorite and tourmaline-bearing biotite granite (Erongo) and topaz granites (Gross Spitzkoppe, GS; Klein Spitzkoppe, KS). Associated with the plutons are mafic and silicic dikes and some lamprophyre dikes.

The GS and KS stocks consist of texturally different types of topaz-bearing biotite (annite-siderophyllite) granites. Columbite, magnetite, zircon, and monazite are typical accessory heavy minerals. Bimodal association is indicated by synplutonic mafic dikes and magmatic mafic inclusions. Against country rocks the stocks have stockscheiders consisting of pegmatite and layered aplite. Miarolitic cavities and pegmatite pockets contain precious topaz and beryl, and hydrothermal activity has locally produced wolframite-bearing greisen. The Spitzkoppe granites are evolved granites with high SiO_2 (73.5–77.8 wt.%), F (0.12–0.81 wt.%), Rb (446–957 ppm), Ga (24–54 ppm), Nb (56–258 ppm), and Ta (3-20 ppm), low TiO_2 (0.00–0.13 wt.%), MgO (<0.01–0.09 wt.%), P_2O_5 (<0.01–0.08 wt.%), Ba (0–164 ppm), and Sr (5–48 ppm), and show a negative $(Eu/Eu^*)_N$ anomaly (0.0–0.23). The granites are marginally peraluminous, ferroan alkali-calcic rocks, and they show chemical and mineralogical characteristics of A-type and within plate granites. Isotope studies (Nd, Sr) suggest dominant crustal origin with significant mantle component. The preferred genetic model is mafic underplating.

Frindt, S.& Haapala, I. (2004). ***Am. Mineral. 89, 841–856.***
Frindt, S., Haapala, I. & Pakkanen, L. (2004). ***Am. Mineral. 89, 841–856.***
Frindt, S., Trumbull, R.B. & Romer, R.L. (2004). Chem. Geol. 206, 43–71.

The aftermath of marine impacts: Faunal recovery and sedimentation in the Ordovician Tvären crater, Sweden

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The aftermath of marine impacts, in particular the patterns of faunal recovery in and around marine craters are poorly understood. In the Ordovician Baltoscandian epicontinental sea an bolide impact resulted in the approximately 2 km wide Tvären crater. The impacted sedimentary sequence at Tvären consisted of Ordovician carbonates resting on non-lithified sands of Early to earliest Middle Cambrian age. After the impact event and the settling of the impact ejecta and resurge material, deposition of carbonates continued (Dalby Limestone). The lithology and thickness of the post-impact Dalby Limestone vary depending on the depositional environment relative to the cratered seascape. The crater itself acted like a sheltering rim for the deposition of sediments, also causing a fairly rapid sedimentation rate compared to the normal sedimentation of the Dalby limestone. Drillings in the Tvären crater, situated in the Stockholm archipelago, Sweden, were conducted in 1991 resulting in an almost complete drill core through the sedimentary succession in the crater.

Detailed biostratigraphical studies of the invertebrate fauna show that the post-impact succession in the crater had a depth controlled palaeoecology for a significant time. The crater offered new habitats characterized by the crater morphology and sheltering rims. Environments from shallow and reef-like to deep can be found within the crater and can be correlated to the faunal characteristics. The first faunal members to be established after the impact are graptolites and chitinozoans and they are present during the complete post-impact succession. One of the most frequent faunal members are Asaphids, mostly *Neoasaphus ludibundus,* occurring abundantly already in an early stage. Small strophomenids and remopleuridiids enter at a later stage, after the crater become less restricted through filling of sediments and a reduction of depth. The rim wall, acting as a reef-like environment, was occupied by a diverse fauna of echinoderms, brachiopods, bryozoans, ostracods and trilobites.

Early onset of The Gulf Stream System in the Eemian – evidence from northern Russia

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Eemian marine sediments, exposed along rivers in the Mezen River drainage in the White Sea region of northern Russia, have been analysed for dinocysts, foraminifera, and molluscs. These assemblages allow for a detailed analysis of hydrography and distinction between local and large scale regional factors. The sediments are correlated with the NW European pollen and sea level records, and together represent the period from Late Saalian deglaciation and until the final stage of the Eemian (c. 134.5 – c. 120 ka).

The assemblages show that warm, saline water from the Murman Coastal Current began to enter the region a few centuries after the beginning of the Eemian, and increased significantly c. 700 years into the interglacial (c. 131.8 ka). The inflow culminated in the early Eemian. After this, isostatic uplift raised basin thresholds and narrowed entranceways, and the oceanic influence decreased.

The Murman Coastal Current is an offspring of the Gulf Stream System, and its early appearance in the Northeast Atlantic is in agreement with the succession of events in relation to vegetation development and eustatic sea level history in the Holocene. However, it places the onset – and the Eemian climatic optimum – several millennia before the 65°N summer insolation maximum at c. 127.5 ka. It is also in conflict with evidence from marine cores on the Iberian margin and in the North Atlantic, which suggest a late onset of the north-eastern branch of The Gulf Stream System. Some of the conflict owes to different usage of the term "Eemian", but even an adjustment of stratigraphic usage cannot solve the controversy.

Isøre Ting and the transformation of the Danish coastal landscape

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In early Medieval times many important decisions concerning the State of Denmark were made at "Isøre Ting" at the gathering of the "leding" – the conscripted naval fleet that gathered every spring from all parts of the country. Contemporary chroniclers tell us that kings were elected, the decision to convert to Christianism was made here, and important negotiations with emissaries from foreign nations were carried out.

The chroniclers also tell us that the "ting" was located in Odsherred at Isefjord, at the center of the kingdom – but where? Over the years several locations have been proposed. The problem is that the coastal landscape has been transformed by erosion and accumulation.

A site to the north of Rørvig has often been mentioned as a candidate for the location of Isøre Ting. As an experiment, we use a multidisciplinary approach to evaluate the rate of change in the coastal landscape, using luminescence dating and georadar analysis of coastal sediments and their structures, DEM landscape modelling, and AMS 14C-dating of organic remains to get an impression of how the landscape looked in early Medieval times. Preliminary results indicate that the embayment, which was thought to harbour the hundreds of ships, was dry land at the time.

Insight into granite petrogenesis from trace element, Sr and Pb isotopic zoning of K-feldspar megacrysts from the Monte Capanne monzogranite

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The well-exposed 7 Ma Monte Capanne monzo-granite on Elba, Italy, is a superb natural laboratory for granite petrogenesis, displaying spectacular field evidence for magma mixing (Gagnevin et al., 2004) and a wide variety of magma products containing abundant K-feldspar megacrysts, preserving both petrographic and cryptic records of open system behaviour.

Zoned K-feldspar megacrysts display indented resorption surfaces, caused by dissolution and regrowth following magma mixing. Ion microprobe profiles reveal that the megacryst rims and outer cores generally have higher Ba, lower P and lower Rb/Sr ratios compared with the inner cores, although the zoning can be more complex, especially in megacrysts with several resorption surfaces. Trace element patterns correlate with Sr isotopic zoning (Gagnevin et al. 2005a). Though variable, $^{87}Sr/^{86}Sr$ initial ratios generally decrease from core to rim, while *in situ* Pb isotopic analyses by Laser Ablation MC-ICPMS (Gagnevin et al. 2005b) reveal that core regions display a rimward decrease in $^{208}Pb/^{206}Pb$ and $^{207}Pb/^{206}Pb$, while the rims have higher $^{208}Pb/^{206}Pb$ and $^{207}Pb/^{206}Pb$. Concentration-weighted isotopic diffusion modelling shows that the isotopic and trace element profiles are caused by growth-zoning, rather than secondary diffusion. Early megacryst growth occurred in magmas contaminated by or derived from crust (high $^{87}Sr/^{86}Sr$ and $^{208}Pb/^{206}Pb$) and refreshed by influx of silicic melts (intermediate $^{87}Sr/^{86}Sr$ and low $^{208}Pb/^{206}Pb$), while later stages (rims and outer core) record recharge with mantle-derived magmas (low $^{87}Sr/^{86}Sr$, high $^{208}Pb/^{206}Pb$), and the effects of crystal fractionation and possibly hydrothermal fluids. This model reconciles all geochemical and isotopic data, as well as the extensive field occurrence of mafic enclaves and metasedimentary xenoliths.

Gagnevin et al. (2004). Lithos 78, 157–195.
Gagnevin et al. (2005a). J. Pet. 46, 1689–1724.
Gagnevin et al. (2005b). Geochim. et Cosmochim. Acta 69, 1899–1915.

Archaean island arc -hosted gold mineralisation at western Godthåbsfjord, southern West Greenland

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Newly discovered remnants of a 3070 Ma, strongly deformed island arc complex with andesitic volcaniclastic rocks at western Godthåbsfjord host low-grade (0.1–2 ppm) gold mineralisation at Qussuk and Bjørneøen. The complex hosts two different types of pre-metamorphic alteration at Qussuk: (1) spatially constrained lenses of meta-epidosite up to 200 x 400 m, interpreted as relicts of a hydrothermal feeder system, and (2) a garnet-rich alteration system of presumed volcanic-exhalative origin with gold mineralisation, which may form a mid-Archaean time stratigraphic marker in western Godthåbsfjord. It comprises tectonically disrupted lenses of massive garnetite and garnet-quartz-biotite rocks (± sillimanite- plagioclase-tourmaline) and irregular compositional layering, located along amphibolite horizons with finely disseminated Fe-sulphides, and with pockets of less altered volcanic and sedimentary rocks within them. The gold occurs both in the altered lithologies and in closely adjacent hosts. The Qussuk area was deformed and metamorphosed at c. 2980 Ma.

Another Archaean gold occurrence in sheared supracrustal rocks at Storø SE of Qussuk was found around 1990 by NunaMinerals A/S and has to date been interpreted as epigenetic and shearzone-related. This belt comprises both mid- and late Archaean components, and besides mafic amphibolite and metasediment also contains andesite and garnetite. The Storø area has seen late Archaean thermal reworking not known from Qussuk. Besides, complex thrusting and folding and insufficient age data have hindered correlation of the supracrustal parts of the tectono-stratigraphic terranes in western Godthåbsfjord. Ongoing tectonic studies and geochronology (to be reported elsewhere) aim at understanding the geological environment(s) and depositional ages of the supracrustal, as well as the processes that formed the gold mineralisation rocks in the Storø area.

Detrital zircon studies of the Vendian to Devonian successions of the Severnaya Zemlya Archipelago, North Kara Terrane: tectonic implications.

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Although the islands and archipelagos along the edge of the northern Eurasian continental shelf are few and far apart, the exposed sedimentary successions provide key evidence for understanding the tectonic evolution of this vast and little explored part of the high Arctic. On-going programmes seek to unravel this Phanerozoic and Neoproterozoic tectonic history, aided by the analysis of sediment provenance ages for the Kara and Barents shelves.

The present study is concerned with the Vendian to Devonian successions from the northern Kara Shelf. They crop out in the Severnaya Zemlya Archipelago, which, together with northern Taimyr, constitutes the major land areas of the North Kara Terrane (NKT). Several lines of evidence suggest that the NKT has been a part of Baltica at least since the Late Neoproterozoic. New isotope-ages support this interpretation and the possibility that the Caledonide Orogen was a sediment source in the Mid Palaeozoic.

So far six samples have been analysed. Most samples, including "Vendian" turbidites of Bolshevik Island, yield clear, in some cases dominating, populations of Vendian (540–650 Ma) zircons, indicating Timanian affinities (Gee and Pease 2004) of the source areas. Devonian Old Red Sandstones, sourced from the west to northwest, in addition yield Early to Mid Ordovician (460 – 490 Ma) populations characteristic of the igneous activity (rift-related volcanics) of October Revolution Island (Lorenz et al., 2004); a few younger Ordovician and Silurian zircons indicate other (?Caledonian) sources. Ordovician sandstones also yield evidence of this penecontemporaneous igneous activity. Archaen provenance ages are largely lacking, and younger Precambrian zircons are dominated by Mesoproterozoic to early Neoproterozoic ages, with indications of provenance from Grenvillian terrains. All in all, the zircon data provide strong evidence for the Baltica affinities of the NKT.

Gee, D.G. & Pease, V. (2004). Geol. Soc. London Memoirs 30.
Lorenz, H., Gee, D.G. & Whithouse, M.J. (in press). Geol. Mag.

Planet Earth – 2008

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The International Year of Planet Earth (IYPE) is the most important IUGS initiative within the field of Earth Science (sensu lato) for many decades. It is in harmony with the United Nations "Millennium Goals" with their focus on Sustainability. And it brings together all the UNESCO science programmes --- International Geosciences (IGCP), Man & Biosphere (MAB), International Hydrological Programme (IHP), Intergovernmental Oceanographic Commission (IOC) and Management of Social Transformations (MOST). The outreach potential of this Year is vast; let's grasp it!

The Year has been approved by UNESCOs Executive Board and General Assembly. It will be presented by Tanzania, with the support of many other countries, to the United Nations General Assembly in November 2005 for official proclamation. Earth Science related unions, eg. IUGG, IGU, INQUA, IUSS, and many organizations like the national Geological Societies, AGI, AAPG & ISRIC are participating.

Ten major themes have been identified for the Year: Groundwater, Climate, Health, Deep Earth, Megacities, Resources, Hazards, Ocean, Soils, and Life. Preliminary information (research priorities and outreach) about most of the themes is available in the form of brochures and on the web (www.yearofplanetearth.org).

The timetable for the Planet Earth Year is envisaged as follows – 2006 is dedicated to establishing working groups (committees), identifying priorities (bottom-up) and seeking sponsorship. 2007 (the first year of what is envisaged as a triennium) will get the research and outreach moving. 2008 will be THE year, with many activities and wide media exposure, culminating in Oslo at the World Geo-Congress (IGC) in August; 2009, is planned as a continuation, and an opportunity for the strongest initiatives to grow in the next decade.

The Nordic countries have been slow to respond to the IPYE initiative. We need to gather momentum fast, establish national working groups and work for Nordic (including the Baltic States) integration; maybe with individual countries leading our contributions to the different themes. Let the Oulu 2006 Nordic Wintermeeting be the big leap forward!

The concept of Baltica and relationships to the Timanide and the Caledonide Orogens

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The name Baltica has been given to an independent continent that was inferred to have existed in the Early – Mid Palaeozoic. It apparently achieved its independence in the late Neoproterozoic with the break-up of a larger continent. The relationships between this break-up and approximately contemporaneous Vendian orogenesis (Pan-African, Timanide, Cadomian, Baikalian, etc.) is not well defined, but by the Cambrian, Baltica is thought to have been surrounded by rifted (rifting) passive margins; it existed as an old continental core to an ephemeral plate. Baltica's life-span was from c. 540 to 440 Ma, when collision with Avalonia is thought to have started, but the plate remained a fairly well defined unit until the culmination of Scandian Orogeny (c. 420 Ma) along what is now its northwestern margin, and subsequent Uralian collision (c. 300 Ma) along its eastern margin.

The southern margin of Baltica, as it existed in the Early-Mid Palaeozoic, is obscure and there is little evidence to help define the passive margin and shelf edge. In the north, new work along the Eurasian margin testifies against a termination of Baltica along or near the present-day Eurasian shelf-edge, as shown in most reconstructions. However, recently acquired data suggest quite the opposite – that the Timanides and the Caledonides continue northwards from Eurasia's northwestern margin (Svalbard to Severnaya Zemlya), across Lomonosova (the Lomonosov Ridge in the Mesozoic, prior to opening of the Eurasia Basin) and probably into the continental shelves of Canada, Alaska and eastern Russia. Defining the configuration of Baltica is thus dependent on reconstructing the fragmentary evidence of Neoproterozoic and Palaeozoic Orogeny around the Arctic shelves and, perhaps, within the Arctic Basin itself – an exercise that is dependent on an understanding of the Mesozoic history of the Amerasia Basin. What we can be sure about, is that the more or less equidimensional shape of Baltica, as shown on most palinspastic reconstructions today, is highly unlikely!

Baltica's independence has been established on the basis of faunal evidence (Cocks & Fortey, 1998) and supported by palaeomagnetic data (Torsvik, 1998). The magnitude of its separation from other continents in the Early Palaeozoic is not uncontroversial. And, since it didn't exist in the pre-Palaeozoic, it should be called proto-Baltica (or something else) on Precambrian reconstructions!

Finnmarkian foreland basins and related lithospheric flexure in the Scandinavian Caledonides

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Early Ordovician greywackes in the (Baltica continent-related) Lower Allochthon document early Caledonian, Finnmarkian tectonic activity. Such rocks occur from the Jämtland area northwards along the eastern Caledonian margin, and imply a wide regional extent of a foreland basin in early Ordovician times. Turbidite sedimentation (Föllinge Formation) started already in early Arenig times in western (internal) areas with a main phase from Llanvirn to late Caradoc. Towards W, in the SW Jämtland area, the Föllinge Formation rests with an erosional unconformity on older beds. Towards east, however, it overlies successively younger beds related with a carbonate platform.

To the west of the Föllinge turbidite basin, obducted ophiolite fragments have been observed at the base of the Trondheim Nappes. The footwall of the ophiolites is built up of continental crystalline rocks, which, at this time, were probably still contiguous with the Baltica continent. Therefore, the ophiolites are assumed here to represent (the tip of) an orogenic load on top of the Baltica lithosphere. This load caused a flexure of the continental lithosphere, which resulted in the Finnmarkian foreland basin. Whilst the location of the tip marked the deepest part of the basin, the area of a sub-turbidite erosional unconformity may represent the location of the related flexural forebulge.

The available data are used to calculate the geometry and timing of the lithospheric flexure. Since the foreland basin was subsequently incorporated into the Scandian fold-and-thrust belt, a restoration of this deformation is done as a first step, based on published cross section data. The restored foreland-basin geometry is used as a base for numerical modelling in order to derive some characteristics of the flexure of the foreland lithosphere. In addition, lithospheric constraints allow to test the viability of the restoration.

Section balancing of the Lower Allochthon and restoration of the Neoproterozoic to Cambrian Baltica passive margin, north central Scandinavian Caledonides

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Modern maps provide detailed information on a major area of the Scandinavian Caledonide marginal fold- and thrust belt in north-central Sweden (Västerbotten). These maps cover the northern termination of the Jämtland Nappes, which represent the lower nappes (Lower Allochthon) of the Caledonides. New cross sections presented here are constructed in a direction subparallel with the nappe transport direction. They show a number of duplex structures and antiformal stacks, which are separated by synformal areas where higher nappe units are preserved. Sections were restored using 2D-Move software.

Lithologically, the thrust units are built up of passive margin sedimentary sequences. Modern biostratigraphic and sedimentological information shows an evolution from late Neoproterozoic rifts to a Cambrian age passive margin. Early stages of tectonic subsidence in spatially restricted (rift) basins are followed by wider-spread thermal subsidence and progressive onlap of early Cambrian clastic-sedimentary sequences onto the continent Baltica, with local basement highs persisting until mid-Cambrian times. Black shale deposition in mid- and late Cambrian times has been interpreted as a result of further subsidence, perhaps related to the onset of subduction of oceanic lithosphere which was attached to the Baltica continent. Early Ordovician sequences show a lateral transition from a shallow water carbonate platform on the continent in the E to relatively deeper water shales and greywackes in the W. The latter were deposited during early Caledonian convergence and collision (Finnmarkian phase). After a relatively quiet period in late Ordovician – earliest Silurian times continental collision of Baltica and Laurentia led to the major Caledonian deformation (Scandian phase) with the incorporation of the Baltica passive margin into the orogenic wedge and the formation of a fold-and-thrust-belt. The restoration of Neoproterozoic-Cambrian rift basins indicates NNW-trending basin margins oblique to the NNE-strike of the orogen.

Open source 3D visualization environment for geophysical seismic sounding data analysis

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OpenDX is an open source visualization software package. It provides most of the commonly used visualization techniques, which include color and opacity mapping, contours and isosurfaces, histograms, two-dimensional and tree-dimensional plotting, surface deformation, etc. for scalar data. For vector data, arrow plots, streamlines, streaklines, etc. are provided. Visualizations may be annotated with ribbons, tubes, axes, glyphs, text and display of data locations, meshes and boundaries. Data probing, picking, arbitrary surface and volume sampling, and arbitrary cutting/mapping planes are supported.

The implementation of virtual reality version of OpenDX opens new ways to study and analyze voluminous and multisource 3D data. The VR version has been implemented both on Linux IA32 and SGI Onyx platforms. The software architecture of VR version is implemented in an OpenDX network module containing interaction and user interfaces. This compact design allows OpenDX users to create VR visualizations in most of the cases simply by adding VR module into their existing networks.

In this case study, 3D tomographic seismic velocity models, 2D velocity models from refraction profiles and seismic reflection data have been imported to the OpenDX. In addition, topographic data and bedrock map of Finland have been imported. These data sets include modelled and measured data. In the future, different geophysical or geological 2D or 3D data sets can be imported using several different data formats. Virtual reality environment gives new insights into the comparison and understanding of different complicated data sets and models. The first results indicate great potential for studies with multisource modelled and measured data.

The Jokisivu gold deposit, southwest Finland

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The Jokisivu gold deposit is located within the Vammala Migmatite Zone of the Paleoproterozoic Svecofennian Domain of the Fennoscandian Shield; 170 km northwest of Helsinki and close to Huittinen town. Since November 2003, the deposit has been owned by Australian-based Dragon Mining NL. In 2005, a resource estimate is 1.47 Mt at 6.8 g/t Au for 322 500 oz (1), and feasibility study is going on.

The Jokisivu deposit is composed of two occurrences, named as Kujankallio and Arpola, locating 400 metres apart and mineralised zones have been intersected by diamond drilling along a strike of 400 metres and 200 metres, respectively. The deepest intercept is locating at the depth of 500 metres vertically below surface. Both mineralised zones remain open at depth and in the easterly strike direction.

Hypabyssal mafic intrusion – from quartzdiorite to diorite and gabbro – hosts the occurrences which consist of quartz veins in altered shear zones. High-grade zones are typically a couple of metres wide and they are characterised by laminated, pinching and swelling quartz veins showing crack and seal textures in strongly sheared and altered host rock with a strong, moderately ENE plunging lineation. Quartz veins are typically deformed and boudinaged indicating deposition in an actively deforming shear zone typical to orogenic gold deposits. Barren granitic pegmatite veins are following the strike of ore zone, usually cut the ore zone and having both post- and synkinematic structures with quartz veins.

Visible alteration is restricted only to the intensively sheared zones. The most common alteration types are silification, biotitisation, chloritisation and sulphidation, occurring in high-grade places with a specific Ca-rich mineral assemblage – garnet, diopside, amphiboles and labradorite (iridescent plagioclase). Typical ore minerals are gold, pyrrhotite, pyrite, arsenopyrite, loellingite, scheelite, chalcopyrite, sphalerite and Bi-tellurides. Gold is free, occurs both in shear zones and quartz veins and its grain size ranges from a few micrometres to a couple of millimetres.

(1) Dragon Mining NL, Press release, 24 February 2005. Website: www.dragon-mining.com.au

Erosional landforms and rock material in Noctis Labyrinthus (Valles Marineris, Mars)

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The system of Noctis Labyrinthus intersecting grabens is situated in the western end of the Valles Marineris canyon and extends for 976 km along the Martian equator. Stratigraphic, structural and geomorphologic relations indicate that the Valles Marineris troughs formed as the result of stretching and fracturing the planet crust, in response to Tharsis-centered stress (Tanaka, 1997). Poorly consolidated material was easily eroded and numerous erosional landforms are present on the surface (Komatsu et al., 1993).

Mars Orbiter Camera (MOC) data from Mars Global Surveyor and Planetary Fourier Spectrometer (PFS) data from the Mars Express mission have been used to analyse and describe the diversification of erosional landforms and rock material of Noctis Labyrinthus. On most MOC images the floor of the canyons is covered by a large quantity of bright eolian material accumulated around dark massive extended ridges, several kilometers long. Mesas, either single, large (few kilometers wide) or numerous, but relatively small (tens to hundreds meters), eolian wrinkles and ripplemarks often appear on the surface. Large accumulation of layered deposits overlay the floor in the eastern part of Noctis Labyrinthus. On most MOC images the canyon walls are covered by eolian material. The massive rock material sporadically appears as ridges. The walls are often fault surfaces. The floor of the Noctis Labyrinthus canyons is structurally more diversified than the canyon walls.

The diversification of material tones on MOC images, from light, through intermediate, to dark, indicates a differing mineral composition of the rocks. The analysis of PFS spectra gives e. g. in the wavelength range 900–1000 cm^{-1} an indication for the presence of pyroxene (presumably augite), but to allow for determining minerals unequivocally PFS spectra should be corrected for the contribution of atmospheric components. It will be done in a similar way as correction for OMEGA spectra (Mustard et al., 2005).

Komatsu, G. et al. (1993). J. Geophys. Res. 98, 11105–11121.

Mustard, J. F. et al. (2005). Science 307, 1594–1597.

Tanaka, K. L. (1997). Lunar Planet. Sci. XXVIII, abstract 1169.

Neoarchean sanukitoid series (high-Mg) granodiorites of the Koitere Complex in eastern Finland

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Sanukitoid series (high-Mg) granodiorites cover large areas in the Koitere Complex in the westernmost part of the Karelian craton. The Koitere sanukitoids mostly consist of porphyritic K-feldspar megacrystic granodiorites, which produce positive anomalies on the aeromagnetic maps. The occasional occurrence of orthopyroxene indicates high- temperature conditions for their crystallization or metamorphism.

Lobach-Zhuchenko et al. (2005) divided sanukitoids of the Karelian craton into the western sanukitoid zone (WSZ) in the West Karelian domain and the eastern sanukitoid zone (ESZ) in the Central Karelian domain. The sanukitoids of the Koitere Complex show geochemical characteristics similar to sanukitoids from the WSZ of Karelia and the Superior Province: low SiO_2 contents, high K_2O contents, high Mg numbers, fractionated REE patterns, high HREE contents compared with TTGs, negative Eu anomaly, relatively high Mg, Cr, and Ni contents (suggesting a peridotitic mantle-wedge source) and high Ba, Sr, and P contents (pointing to an enriched mantle source).

A SHRIMP U–Pb dating of zircons from one sample from the Koitere sanukitoid shows two zircon populations; the older group is ca. 2.82–2.84 Ga and the younger ca. 2.70–2.73 Ga. The older ages are mostly from cores of grains that have overgrowth rims belonging to the younger group.

The Koitere sanukitoids show strong long-term depletion in U and they have high μ values for the source indicating a significantly older crustal lead source, but positive ε_{Nd} (2.7 Ga) values of +0.3 to +1.4 that overlap those of West and Central Karelian Domain and suggest a lack of prolonged crustal prehistory. The isotopic and geochemical features of sanukitoids can be explained by partial melting of a metasomatized mantle-wedge source, either by significant amounts of slab-derived melts or by fluid-mobile elements during slab dehydration processes.

Lobach-Zhuchenko, S.B. Rollinson, H.R., Chekulaev, V.P., Sergeev, S.A., Matukov, D.I. & Jarvis, K.E. (2005). Lithos 79, 107–128.

Correlation of Archean cratons on the basis of Pb isotope systematics of Neoarchean granitoid rocks

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Preliminary time-fixed Pb isotope models for Neoarchean granitoids generated in different convergent plate tectonic settings (oceanic island arcs, young continental margins, and old continental margins) are presented and tested with ca. 700 Pb isotope analyses compiled from several publications on different Archean cratons. The models are based on the postulation that the mobility of Pb, U, and Th in magmatic and metamorphic processes, with time, gives rise to distinct patterns in Pb–Pb diagrams. The most important of these are the mixing arrays between crustal and mantle end-members and high Th/U trends caused by a loss of U relative to Th.

Pb isotopes are especially suitable in studying Archean rocks because of the strong fractionation of U and Pb between crust and mantle reservoirs and the shorter half life of the ^{235}U isotope, parent to ^{207}Pb, in the Archean. The rapidly increasing $^{207}Pb/^{204}Pb$ ratios are a sensitive indicator of involvement of crustal Pb.

The models, which are based on the idea of plumbotectonics of Zartman and Doe (1981), suggest that rapid recycling of crustal Pb through subduction-related processes gives rise to more radiogenic Pb isotope compositions in the mantle wedge. An increasingly radiogenic mantle source is created as the accretion of island arcs proceeds leading to the formation of a young continental margin. Interactions with significantly older continental nuclei with long-lived U-enriched upper crust and U-depleted (high-grade) lower crust Pb sources created different Pb isotopic signatures for the Neoarchean granitoids. In general, the Pb isotope models indicate increasing crust-mantle interactions during the formation of Neoarchean supercontinents.

The preliminary models are roughly consistent with the earlier results and interpretations, thus it is suggested that Pb isotope signatures of Neoarchean granitoids may be used in discriminating between tectonic settings, testing accretion models for Archean terrains, and as a tool for Archean craton correlation.

Zartman, R.E. & Doe, B.R. (1981). Tectonophysics 75, 135–162.

Paleoproterozoic deformation of Neoarchean K-feldspar megacrysts –microstructural and Pb isotopic constraints on temperature and timing from the Karelian Domain, eastern Finland

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Microstructural and lead isotopic studies on variably deformed K-feldspar megacrystic Neoarchean granodiorites from the westernmost part of the Karelian Craton, eastern Finland, place constraints on the temperature and timing of deformation in the vicinity of the Proterozoic-Archean boundary zone. The microstructures of K-feldspars show that they have recrystallized by grain boundary migration in the low temperature regime of recrystallization-accommodated dislocation creep (Regime 1 of Hirth and Tullis, 1992), indicating a deformation temperature of 400–500 C. The lead isotopic evidence suggests that at ca. 1.9 Ga, ^{208}Pb-rich lead evolved in the high Th/U sites (probably grain boundaries and fractures) of the rock entered the feldspar by grain boundary migration recrystallization of the original magmatic K-feldspar grains during retrograde metamorphism related to the Paleoproterozoic Svecofennian orogeny.

Hirth, G. & Tullis, J. (1992). Journal of Structural Geology 14, 145–160.

The Grängesberg apatite-iron deposit – biggest in Bergslagen, Sweden

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The Grängesberg apatite-iron deposit was mined for at least 300 years, but it was not until the late 19th century that modern, large-scale mining commenced. Mining at Grängesberg ended in 1989, well before of todays renewed interest for large iron deposits. When Hitzmans (1992) proposed that apatite-iron deposits are genetically linked to, and make up a sub-group of so called Iron oxide Copper-Gold deposits (IOCG) the mine had been closed for 3 years.

With the purpose to produce an up-to-date documentation of the Grängesberg Mining District, available to a broader audience, the Ore Documentation Project at SGU has recovered some of the scattered documentation from the mine archive, summarised older publication on the deposit, and digitized available maps and data.

This review shows that the Grängesberg apatite-iron deposit consists of several iron-ore bodies or layers hosted by metavolcanic rocks of dacitic to andesitic composition. Ore and host-rocks have been intruded by mafic and felsic dykes, pegmatites, and dolerites. Most host rocks have been strongly deformed, resulting in an intense, slightly undulating NE-striking foliation, dipping to the SE. Lineation plunge 50-80° to the SE. Strain has mainly been localized around the ore body. Late pegmatite dykes and dolerites are unaffected by deformation.

The largest and easternmost of the iron-ore bodies, the Export Field, consists of massive apatite-magnetite ore towards the hangingwall and apatite-hematite ore towards the footwall. To the west, in the Risberg Field, a similar style of iron-oxide mineralisation is found while mineralisation in the westernmost part of the district is dominated by disseminated low-apatite hematite ores.

Three styles of alteration are recognized, sodic-, potassic-, and iron-skarn alteration, the latter a significant iron accumulation in itself.

This review shows that mineralisation and alteration at Grängesberg is highly assymetrical and is not readily compatible with current genetic models.

*Hitzman, M. W. et al. (1992). **Precambrian Research 58, 241–287***

The Hamarøya Fault, North Nordland; an onshore equivalent to the eastern boundary fault of the Vestfjorden Basin.

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The Hamarøya Fault has previously been interpreted as a major, NW-dipping offshore basement fault representing the eastern boundary of the Vestfjorden Basin, a prominent Mesozoic half graben off the NW coast of Nordland. The fault is observable on seismic data and potential field data (grav./mag.) southwards to the Nordland Ridge, where it represents a transitional zone between the positive magnetic anomaly of outcropping basement and negative anomaly of the Vestfjorden Basin.

A closer inspection of the aeromagnetic data in conjunction with 3D image of the seafloor bathymetry indicates that the Hamarøya Fault is exposed on land on the northwestern most part of Hamarøya. Reconnaissance field work in this area reveals that the outermost parts of Bremneset in fact contains localized and left-stepping, NNE to NE-striking and WNW-dipping brittle extensional faults and fractures which at some localities splay into NNW to NW-striking faults and fractures, in addition to subordinate, steep ENE to WNW-striking sinistral and dextral wrench faults respectively.

Preliminary kinematic analysis and timing constraints of these fault-fracture systems indicates that the NNE-striking dominant fault sets originated by WNW-ESE orthogonal extension, tentatively in the Permo-Jurassic, in a dominantly left-stepping system, accompanying the development of NNW trending transfer or breach faults. Subsequent dextral strike- or oblique-slip reactivation along this NNE striking system, likely in the Early-Mid Cretaceous, produced oblique Riedel shears (ENE and NNE striking) in addition to strike-slip duplexes at the fault steps. A final tectonic event, possibly in the late Cretaceous-Paleogene, may have involved NE-SW oblique extension and given rise to the WNW to E-W, apparently dextral, wrench faults.

The complex interactions of multiple overlapping, fault-fracture sets observed along the Hamarøya Fault onshore may explain the overall asymmetry and stepwise attitude of the Vestfjorden Basin.

Re-Os isotopic and melt inclusion study of the Paleoproterozoic komatiites, Finnish Lapland

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The ca. 2.0 Ga ultramafic volcanic rocks from the Kitilä area are classified as Ti-enriched komatiites to picrites (Hanski et al., 2001). These rocks contain well-preserved chromite crystals which allow us to 1) study the compositional variation of trace elements in the magmas utilizing crystallized melt inclusions trapped in chromite grains and 2) determine precisely the initial Os isotopic composition of the magmas using chromite separates. Spinels are divided into the low-Ti and high-Ti types reflecting crystallization from komatiitic and picritic parental magmas, respectively. Interestingly, crystals of both spinel types may be found in a single sample which suggests mixing of two different, contemporaneous primitive magma types. Trace element data on melt inclusions acquired using the LA-ICPMS and SIMS techniques also reveal two contrasting magma compositions: they are either (ultra)depleted or highly enriched in incompatible elements with hump-shaped or LREE-enriched $(REE)_{CN}$ patterns, respectively. In addition, melt inclusions provide information on the original mobile trace element contents (Li, K, Be, Sr, Ba) and LILE/HFSE ratios of the magmas, indicating a non-contaminated nature of the komatiites and picrites.

The Re-Os isotopic compositions of chromite separates determined using NTIMS yield an average initial $^{187}Os/^{188}Os$ of 0.1131 ± 0.0006 (2σ; γ_{Os} = 0.1 ± 0.5) consistent with the evolution of the mantle source for these rocks with a long-term chondritic Re/Os ratio. These results coupled with an initial ε_{Nd} of ca. +4 (Hanski et al., 2001) are consistent with an asthenospheric or mantle plume origin and insignificant or no lithospheric interaction of the magmas. In this respect they share the source characteristics with typical Archean komatiites like those occurring in Munro Township, Canada.

Hanski, E. et al. (2001). J. Petrol. 45, 855–876.

SIMS and ID-TIMS chronology and chemistry of zircon in the ca. 2.2 Ga mafic intrusions in northern and eastern Finland: evidence for a multiepisodic history

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One distinct phase of the Paleoproterozoic mafic magmatism in Finland is represented by the ca. 2.2 Ga layered sills assigned to the gabbro-wehrlite association (GWA). These gravity-differentiated mafic-ultramafic bodies are widely spread in eastern and northern Finland and reach more than 100 km in length and several hundred meters in thickness. Most often they occur close to the base of the Karelian supracrustal successions, intruded into Jatulian quartzitic metasediments, but similar intrusions have also been found within the Archean Kuhmo Greenstone Belt.

Using SIMS, ID-TIMS and EPMA, we have studied zircons from several GWA intrusions from four Paleoproterozoic schist belts and the Kuhmo Greenstone Belt. Back-scattered electron images and electron microprobe analyses revealed that zircon crystals vary from well-preserved to porous and highly altered with individual grains often displaying irregular, hydrated, CaO-bearing domains. In the most pristine domains, suitable for establishing the crystallization ages, SIMS $^{207}Pb/^{206}Pb$ ages fall in the range of 2210–2220 Ma, which are consistent with the most concordant ID-TIMS U-Pb ages. One of the studied intrusions that had previously yielded a conventional U-Pb date of less than 2.0 Ga, could be shown by spot analysis to belong to the 2.2 Ga family. In contrast to the well-preserved domains, altered domains exhibit a variable and often strong U-Pb discordance up to 70% and have distinctly lower $^{207}Pb/^{206}Pb$ ages. Some zircon grains record isotopic resetting at the time of the Svecofennian orogeny (ca. 1.8–1.9 Ga), while the most discordant ones project in the concordia diagram to late Paleozoic lower intercept ages indicating a relative recent Pb loss. The mineral chemistry of zircon suggests that the leakage of radiogenic Pb can be ascribed to an open-system behavior related to hydrothermal alteration via action of $CaCl_2$-bearing fluids.

Epithermal Au and Ag-Au vein deposits: Old styles, new targets

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Epithermal deposits form ≤1 km below the surface, largely in volcanic belts, and have a variety of forms, depending on the permeability of their host rocks and structures. America's bonanza gold veins, and the huge silver vein systems in Mexico are well known; polymetallic veins also contain other valuable commodities such as indium.

Bonanza gold veins, with 10–50 g/t Au, Ag/Au <10, and very low base-metal and As content, form in extensional settings. Silicic volcanism is commonly accompanied by evidence for basaltic magmatism. Ore intervals range between 100 and 300 m vertical; ore is hosted by quartz veins with banded and colloform textures that indicate deposition as an amorphous silica gel, reflecting extreme disequilibrium. The top of the ore zone, typically flat, may be located ~10s to 250 m below the paleosurface. Alteration halos are narrow, <10s m, and characterized by clays, from smectite to illite with increasing depth. Such veins are commonly capped by a blanket of friable kaolinite-alunite alteration where there has been little erosion, formed by vapor condensation in the vadose zone.

By contrast to the gold-rich epithermal veins, the silver- and/or base metal-rich variety (Ag/Au from 10s to 100s) form in volcanic arcs and commonly show evidence of being intrusion centered. The coarsely laminated quartz veins plus common Mn carbonates with sulfides locally up to 10%, including silver sulfosalts may have halos of hypogene advanced argillic alteration near the causative intrusion, including pyrophyllite, dickite, zunyite, topaz, etc., and are zoned outward to muscovite. The tops of ore zones are typically 100s m below the paleosurface, with vertical intervals to 800 m. These veins may be overlain by kaolinite-alunite blankets, as well as advanced argillic or clay caps up to 100 m+ thick over the veins.

The potential for a relatively short lead time from discovery to mining, and the small footprint and low impact of a high-grade underground mine, has led to a new appreciation of the potential benefits of epithermal vein deposits. Mapping the lithology, alteration, and structure are the most effective exploration methods, coupled with the paleorelief reconstruction, conventional geochemistry and geophysics.

Petrography and geochemistry of the Kaapinsalmi 2.719 Ga sanukitoid intrusion, eastern Finland

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In 1984 Shirey and Hanson introduced the term sanukitoid to describe a distinct series of high-Mg granitoids that differ chemically from Archean TTG rocks. The geochemical signature of sanukitoids suggest a modified mantle wedge source. Sanukitoids have recently been identified at a number of locations in Finland, including Nilsiä, Lieksa, Kuittila, Arola, and Kuusamo. A further group of intrusions one of which shows a geochemical signature typical for sanukitoids, occurs near to the western margin of the Suomussalmi greenstone belt. This intrusion, referred to as Kaapinsalmi sanukitoid, is the topic of this study.

The main minerals of the Kaapinsalmi intrusion are oligoclase, quartz, biotite, and hornblende, and accessory minerals include epidote, microcline, sphene, apatite, zircon, allanite, sericite, carbonate, and chlorite.

Geochemically the Kaapinsalmi intrusion differs considerably from other intrusives in the area, being characterized by high Mg numbers (51.8–63.9) and low SiO_2 content (56.0–65.2%). Of the trace elements, Ba (407–1366 ppm), Sr (369–561 ppm), Cr (57–407 ppm), and Ni (38–207 ppm) display enriched concentrations compared to typical TTG series granitoids in the area. The chondrite normalized rare earth element pattern of the intrusion shows enrichment in LREE compared to HREE ((La\Lu)n=5.2–26.8). The U–Pb age of the Kaapinsalmi intrusion is 2719.8±4.5 Ma.

Sanukitoid intrusions ranging in age from 2705–2745 Ma are found throughout the Karelian Craton and have been subdivided into eastern and western zones (Lobach-Zhuchenko et al., 2005). The Kaapinsalmi sanukitoid intrusion shows similarities in composition and age to the western sanukitoid zone.

Lobach-Zhuchenko, S.B., Rollinson, H.R., Chekulaev, V.P., Sergeev, S.A., Matukov, D.I., Jarvis, K.E. (2005). Lithos 79, 107–128.

Shirey, S.B., Hanson, G.N. (1984). Nature 310, 222–224.

Validation of the REVEALS-model for southern Sweden

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The first step in the LRA (Landscape Reconstruction Algorithm) approach for quantitative reconstruction of past vegetation cover (Sugita & Walker, 2000; Sugita in prep a) is presented. It implies the validation of the REVEALS (Regional Estimates of VEgetation Abundance from Large Sites) model (Sugita in prep b) to estimate regional vegetation abundance (Hellman, 2005). The REVEALS model will be applied to fossil pollen data from southern Sweden for quantitative reconstructions of past regional vegetation abundance (RVA). RVA is needed to apply LRA for reconstruction of past land-cover from fossil pollen data at the local spatial scale (Sugita, in prep a, b). Large lakes in the two southern provinces of Sweden –(Skåne and Småland) were sampled for modern pollen assemblages used to estimate the modern vegetation cover with REVEALS. For validation, the model estimates were compared to modern vegetation compiled from satellite images, aerial photographs, forest inventory data, and crop statistics. The REVEALS estimates are shown to be in good agreement with the vegetation data for most taxa. Vegetation abundance is best estimated by REVEALS for *Acer, Pinus, Betula, Salix, Tilia, Secale,* and Cerealia in both areas, for *Fagus, Juniperus, Calluna* and Poaceae in Skåne, and for *Carpinus, Fraxinus, Ulmus*, Cyperaceae, *Filipendula*, and *Plantago* in Småland. Disagreement between the estimates and compiled vegetation for a few taxa is probably associated with difficulties in quantifying their cover from the vegetation data sources,.

Hellman, S. E. V. (2005). ESS bulletin, vol. 3 (1), 45–82

Sugita, S. & Walker, K. (2000). AGU 2000 Fall Meeting San Francisco, Carlifornia, Abstract. Eos Transaction, American Geophysical Union, 81, F268.

*Sugita in prep a. Theory of quantitative reconstruction of vegetation. **II. All you need is LOVE.***

Sugita in prep b. Theory of quantitative reconstruction of vegetation. I. Pollen from large lakes reveals regional vegetation.

Hydrogeological aspects of the Weichselian glaciation in the Polish lowland area

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The main advance of the Weichselian ice sheet in the Polish lowland begun ca. 32 ka ago and reached a maximum ca. 20 ka ago. This rapid environmental change had a great impact on the groundwater, mainly affecting its flow direction, velocity, and fluxes.

We have numerically reconstructed the subglacial groundwater flow in two and three spatial dimensions using finite differences and finite element methods for both steady-state and transient conditions.

Ice sheet advance caused large-scale changes in the position of the piezometric surface of groundwater both underneath the ice and some distance in front of it. All models show subglacial water discharge at the ice forefield driven by the down-ice decreasing pressure head. A transient 3D model shows significant changes in groundwater flow directions in the 4th, regionally extensive hydrogeological layer approximately 90 m below the ice-bed interface and up to 40 km in front of the glacier. Depending on the location of the ice margin, shifts in groundwater flow directions could have been in the range of 90º and in extreme cases reversals of flow occurred. Drainage through and eventually discharge from the deepest layer likely fed the Notec–Warta ice marginal spillway. Assuming 36 mm/a of basal ice melting (Piotrowski, 1997), the models show that on average about 15% of the meltwater formed at the ice sole could have drained through the bed as groundwater. The rest was evacuated to the ice margin in rapid discharge episodes through tunnel valleys or as a thin layer along the ice-bed interface. This study emphasizes dramatic changes in groundwater flow organisation in the Quaternary glacial/interglacial cycles.

*Piotrowski, J.A. (1997). **Subglacial hydrology in northwestern** Germany during the last glaciation: groundwater flow, tunnel valleys, and hydrological cycles. Quaternary Science Reviews 16, 169–185.*

Timing of ductile deformation and cooling history in the Svecokarelian orogen, south-central Sweden

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The Forsmark area, south-central Sweden, shows a complex history of ductile and brittle deformation. An elongate tectonic lens, c. 25x4 km in size and with a WNW orientation, is characterised by tubular folding of a tectonic foliation and high strain segments. Furthermore, high strain zones that strike WNW and NW bound the lens. The occurrence of tectonic banding, formed under amphibolite facies conditions, lower temperature mylonites, and several generations of brittle structures highlight the complexity of the deformation history along at least one of these zones (Stephens and Simeonov, this meeting).

Field relationships indicate that penetrative ductile deformation affected two suites of calc-alkaline intrusive rocks. U-Pb zircon dates show that the granites in the older suite and the tonalites-granodiorites in the younger suite are similar in age (1865±3 and 1864±3 Ma, respectively). Deformation started to affect the older suite after 1868 Ma and continued to affect both suites possibly after 1861 Ma. However, penetrative ductile deformation was completed prior to the intrusion of younger granite dykes at 1851±5 Ma. A U-Pb titanite age of 1844±4 Ma in one of these dykes supports this interpretation. Discrete ductile deformation continued after crystallisation of the dykes, i.e. after 1851±5 Ma.

$^{40}Ar/^{39}Ar$ hornblende data from amphibolites and a metagabbro, sampled both inside and outside the tectonic lens, suggest that the area cooled through c. 500°C between 1831±3 and 1796±3 Ma. The results indicate that the discrete ductile deformation in the high strain zones around the lens can possibly be correlated with the c. 1.82–1.80 Ga shear zone activity in central Sweden (Högdahl et al., 2001).

$^{40}Ar/^{39}Ar$ biotite data from surface samples show that cooling below c. 300°C occurred between 1700±4 and 1671±5 Ma. It is inferred that the bedrock started to behave in a brittle manner prior to c. 1700 Ma, i.e. during the later stages of or soon after the Svecokarelian orogeny (1960–1750 Ma).

Högdahl, K., Sjöström, H. & Gromet, P. (2001). Prec. Res. 105, 37–56.

Refinements of pollen-based palaeoenvironmental reconstructions using pollen accumulation rates rather than pollen percentages.

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Reconstructions of past vegetation based on pollen assemblages have always been hampered by the the fact that, since individual taxa are clasically expressed in terms of their percentage presence, it is difficult to compare the abundance of one specific taxon between a spatial range of sites for which the species composition of the pollen assemblage is distinctly different. At present the only way of following the abundance of a single species over space and through time is by using pollen accumulation. rates (PARs). The accuracy of PAR calculations, however, is highly dependant on the accuracy of the age-depth chronology. Recent developments in modelling pollen dispersal and pollen source area, coupled with the results of monitoring contemporary pollen deposition at the present day, indicate that the numerical value of PARs is to a very large extent dependant on basin size or, more precisely, the extent of the treeless area relative to the nearby forest.

Results are presented for northernmost Fennoscandia to demonstrate the advantages and restrictions of using PARs to reconstruct tree-lines, forest density and the abundance of individual tree species and the comparability of PARs from peat and lake sediment profiles is assessed. The question of 'when no pollen does not mean no trees' is also presented.

A new discovery of calcite-quartz-sulphide veins in the Kumpu Group conglomerate, Lake Immeljärvi, Kittilä (Part 1: Macroscopic studies)

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The beautiful lake Immeljärvi near the village of Sirkka (Levi) ~16.5 km NNW from Kittilä is formed in a steep ravine between the Levi and Kätkätunturi fells. The fells bounding the lake belong to the metasedimentary Kumpu Group and thus represent the topmost part of the preserved Palaeoproterozoic strata in the district. This ravine is controlled by the NNE striking Immeljärvi fault that intersects the gold mineralised E-striking Sirkka Shear Zone about 2 km north from the lake Immeljärvi. Our new discovery is a fresh road cut situating ~600 m north from the northernmost point of the lake Immeljärvi in an area where the ground is relatively flat and was previously unexposed (N = 7524800, Y = 2533370). Interestingly, this new outcrop is located in an area where the Immeljärvi fault should approximately run.

The studied dark grey road cut exposes a conglomerate, a rock type typical to the lower part of the Kumpu Group. In contrast to the other conglomerate outcrops of the adjacent area, at least those we are aware of, this particular outcrop is the first to contain abundant hydrothermal veins. Most of the veins have an appearance of fibrous veins (Passchier & Trouw, 1996). They are mostly composed of reddish fibrous calcite, but they may also contain minor amounts of quartz, bornite, chalcocite, chalcopyrite and some unidentified sulphosalts. On average, the veins are 5–15 mm wide, they have an elongated shape, they are thinning to both ends, and they are disconnected from other veins. Individual calcite fibres are ~1 mm wide and at most ~15 mm long. Some veins contain the median line typically related to fibre growth of fibrous veins. All vein boundaries are sharp.

To summarise, the studied outcrop demonstrates that in places where the Kumpu Group conglomerate is in close association with a distinct deformation structure, it may not only contain considerable amount of hydrothermal veins, but also some interesting ore minerals.

Passchier, C.W. & Trouw, R.A.J. (1996). Springer-Verlag, 289 p.

A new discovery of calcite-quartz-sulphide veins in the Kumpu Group conglomerate, Lake Immeljärvi, Kittilä (Part 2: Microscopic studies)

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The calcite-quartz-sulphide veins occur ~600 m north from the scenic Lake Immeljärvi in a conglomerate outcrop of the Kumpu Group that has been exposed lately by a new road cut. In this second part of the work the mineralogical contents of the veins are discussed. The results are based on a study of four thin sections with conventional polarising microscope and an electron probe microanalyser (EPMA). All studies were conducted in the Univ. of Oulu.

The matrix of the conglomerate immediately adjacent to the veins is mineralogically composed of the following main components: albite-twinned plagioclase, carbonate, chlorite and sericite. In many cases the contacts between the vein minerals and their wall rocks are rimmed by dark green bands about 1 mm wide. They consist of chlorite with minor biotite, the crystals of which occur as elongated blades perpendicular to the margins of the veins. The vein themselves are mainly composed of reddish calcite and minor quartz. Hydrothermal alteration that can be directly related to the veins is, if present at all, weak.

The main ore minerals in the veins are (listed with decreasing abundance): bornite (Cu_5FeS_4), chalcocite (Cu_2S) and chalcopyrite ($CuFeS_2$). Chalcocite is a supergene alteration product of bornite. All the three Cu-sulphides are found to be rich in accessory minerals, which include clausthalite (PbSe), naumannite (Ag_2Se) and hessite (Ag_2Te). According to the very preliminary EPMA-results, the bornite grains also contain complex sulphosalt minerals in the form of exsolution lamellae and bleb-like inclusions. However, the reliable identification of the latter mineral species is yet to be done.

Although Au-bearing mineral phases are still to be found, the existence of Ag-, Se- and Te-bearing minerals within the Cu-sulphides is anyway an interesting feature. This stems from the well-known fact that some elements, like silver, selenium and tellurium, are often fingerprints of the auriferous hydrothermal systems.

The similarity and continuation of gold mineralisation in and between the Levijärvi-Loukinen gold occurrence and old Sirkka test mine, northern Finland

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Mineralogically, there are three types of orogenic gold occurrences in the Kittilä greenstone area: 1) pyrite-dominated (e.g., Hirvilavanmaa, Soretialehto, Soretiavuoma N and Kettukuusikko), 2) pyrite-arsenopyrite-dominated (e.g., Suurikuusikko), and 3) more complex, pyrrhotite – chalcopyrite – pyrite – gersdorffite – arsenopyrite ± cobaltite-dominated (e.g., Levijärvi-Loukinen (L-L) and Sirkka test mine (Sirkka kaivos, SK)). Consequently, the local gold occurrences can be subdivided, if their metal associations are used as a basis for classification, into normal (merely Au) and atypical, polymetallic (Cu, Fe, Ni, Au ± Ag, Co) subtypes.

The polymetallic occurrences of L-L and SK are located about 17 km north from Kittilä in the >150 km long W to WNW striking Sirkka Shear Zone (SSZ) ~4.5 km apart. In both localities: 1) the host lithologies, deformation and alteration styles, and vein and breccia types are comparable; 2) the mineralogical contents and macroscopic vein textures of gold-related veins are similar; 3) gold is dominantly native and occurs mainly as inclusions in gersdorffite (NiAsS), arsenopyrite (FeAsS) and, less frequently, cobaltite (CoAsS). Both occurrences are hosted by a >2.05 Ga old volcano-sedimentary sequence of the Savukoski Group containing graphitic phyllite, phyllite and tuffite in close contact with mafic and ultramafic metavolcanic rocks. The metamorphic grade is mid- to upper-greenschist.

Mineralisations at L-L and SK are at least 5 km and 1.5 km wide, respectively. However, our recent field observations suggest that there is another mineralised site between these two localities. The new finding is a fresh civil engineering excavation about 100 m long (N = 7525800, E = 2533100). After sampling and a few geochemical analyses, it has become clear that this unnamed mineralised site is likely to be "the missing link" (although quite possibly of much lower grade) between the very similar gold-rich vein occurrences of L-L and SK. If this assumption holds true, then the atypical polymetallic gold mineralisation type the three sites represent is continuous to semi-continuous along the SSZ at least 10 kms.

Characteristics of the sulphide-facies iron formation near the Sirkka kaivos gold occurrence, northern Finland

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Gold mineralisation at Sirkka kaivos (SK) consists of six small subvertical gold-rich polymetallic lodes, which are enriched in Cu, Fe, Ni, Au ± Ag and/or Co. This is similar to the nearby-located Levijärvi-Loukinen gold occurrence (Holma et al., 2003). In both locations, the ore is typically in the form of mesothermal quartz-carbonate veins, containing variable amounts of pyrite, pyrrhotite, chalcopyrite, arsenopyrite, gersdorffite and cobaltite. However, the rocks of the SK occurrence have distinctly higher content of sulphides than the host rocks of other SSZ-related gold occurrences. The mineralised brittle-ductile deformation structures occur in a lithological association of graphitic phyllite, phyllite, tuffite and mafic and ultramafic volcanogenic rocks. The mineralogical and lithological assemblage is analogical with sulphide-facies iron formation, which represents a rock type not described before from the SK area.

The sulphide-facies iron formation is located several tens of meters N to NW from the site of the old test mine's shaft. The rocks are highly brecciated. The size of the breccia clasts vary greatly (from 1 mm to several tens of cms), but otherwise they are all similar. The clasts are composed of numerous minuscule (<5 µm, all almost equal in size) granules of Phase I pyrrhotite cemented by microcrystalline quartz and graphite. In some of the thin sections, the rock is weakly but observably banded (another feature referring to syngenetic origin?). The breccia clasts are enclosed in a massive sulphide matrix mainly composed of Phase II pyrrhotite. The hydrothermal origin of these rocks is supported by the mineralogical assemblage, which is composed of pyrrhotite I and II, quartz, carbonate with few grains of pyrite, arsenopyrite and chalcopyrite. Thus, the relatively high degree of sulphides at SK is the outcome of two separate mineralisation events, the first of which was syngenetic (forming the Fe-rich sulphide formation), and the second epigenetic (gold mineralisation of which mineralising fluids were atypical in their metallic content). The study also supports a model in which an earlier mineralisation has been partly remobilised during latter events.

Holma et al. (2003). Millpress, Rotterdam, 1073–1076.

Mineralogical composition of polymetallic gold vein ore and its adjacent wall rocks at Levijärvi-Loukinen, northern Finland

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The Levijärvi-Loukinen gold occurrence is situated 17 km north from Kittilä in a tectonised contact area between the dominantly volcanogenic rocks at north and metasedimentary rocks at south. The veins forming gold mineralisation and cutting the lithological association of graphitic phyllites–tuffites and komatiitic–Fe-tholeiitic metavolcanic rocks metamorphosed and hydrothermally altered in mid- to upper-greenschist facies are located within prevailingly brittle deformation structures. Alteration surrounding the veins varies from the proximal assemblage of quartz-carbonate-sericite-albite-rutile-graphite ± pyrrhotite (in graphitic phyllite) to that of quartz-carbonate-sericite/fuchsite ± pyrite (metakomatiite). Compositionally the veins vary from barren quartz-carbonate veins to carbonate-dominated sulphide-rich veins, the latter of which are critical for gold.

The main gangue vein minerals are ankerite, Fe-dolomite and siderite. In addition to these, the veins contain variable amounts of quartz and magnesite. The ore mineralogy of the veins is complicated, as besides pyrrhotite, chalcopyrite and pyrite, the three main opaques, they typically contain also different amounts of Fe-Co-Ni sulpharsenides, diarsenides and an extensive range of accessory ore minerals. However, the primary origin for pyrite is, at least in some cases, controversial. Volumetrically most important As-bearing mineral phases are, in the order of abundance, gersdorffite (NiAsS), arsenopyrite, cobaltian gersdorffite, cobaltian arsenopyrite and glaucodot ((Co,Fe)AsS). These five minerals are the main carriers of gold, the main form of which is native. Gold and most of the other accessory ore minerals occur in them as inclusions and/or fracture fillings. Accessory ore minerals include the following: pentlandite, argentopentlandite, violarite, sphalerite, millerite, galena, ullmannite, bismuthinite, safflorite, löllingite, hessite, native gold, native bismuth, and maldonite.

To summarise, the mineralogical content of the gold-related veins is such that the ore type they represent can be described as a polymetallic epigenetic gold mineralisation with atypical metal association.

The usage of short-wave ultraviolet light to evaluate the abundance of UV-sensitive minerals in rock samples: a case study from the gold mineralised Sirkka Shear Zone, northern Finland

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More than 200 rock samples have been studied under short-wave (S-W) (254 nm) ultraviolet light (UV) in an attempt to get mineralogical information of the following gold occurrences from northern Finland: Levijärvi-Loukinen, Sirkka kaivos, Päivänenä (Kettukusikko), Soretialehto, Soretiavuoma N, and Naakenavaara. It was known from the earlier studies that at least the quartz-carbonate-pyrite veins at Soretiapulju near Soretiavuoma N contain scheelite, an UV-sensitive mineral. Except Naakenavaara, all the studied occurrences are hosted by the Sirkka Shear Zone (SSZ), a major tectonic discontinuity hosting two subtypes of orogenic-style gold mineralisation: gold-only and polymetallic, atypical metal association (Cu, Fe, Ni, Au ± Ag, Co). Although these two occurrence types share many common features, e.g. mesothermal environment and similar host lithologies, mineralogically the vein contents of their occurrences are notably different. Studied samples represent both types.

The studied drill core samples were exposed in a dark room to the UV-light of the hand-held S-W ultraviolet lamp (Model UVS-54, Ultraviolet Productions Inc., San Gabriel, CA). The main results were as follows: 1) In all cases, calcite was the most abundant UV-sensitive mineral; 2) If calcite is excluded, there were generally no major differences in the UV-sensitive mineral abundances, or their species, between the different occurrences and their different vein types. However, it is possible the UV-sensitive mineral grains were just too small in diameter to be correctly identified or even noticed without more sophisticated techniques; 3) Samples from the two studied mineralisation types cannot be distinguished from each other with certainty by means of short-wave UV-light. However, the applied method (Robbins, 1994) was found to be usable whenever there is a need to discover anomalous samples rich in UV-sensitive minerals quickly, cheaply and easily from a larger set of geological samples.

Robbins, M. (1994). Geosci. Press Inc, Phoenix, Ariz., 374 p.

The Holocene-Anthropocene transition expressed in Spitsbergen lakes, Svalbard

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Gravity cores from lakes in western Spitsbergen show pronounced stratigraphical changes in the 20th century. Diatom valve and chrysophyte stomatocyst concentrations increased dramatically since ~AD 1920 and the diversity of diatom communities increased synchronously. The amount of diatom species compositional turnover since 1850 is about twice that of undisturbed temperate lakes over the same period, and is comparable in magnitude to changes observed in acidified lakes. However, the Svalbard diatom record do not indicate recent changes in water chemistry, but rather enhanced diatom production as the result of longer growing seasons, increased nutrient availability, or some combination of these factors. In several lakes, the nitrogen isotopic composition ($\delta^{15}N$) of sediment organic matter became increasingly depleted in the second half of the 20th century (by ~2‰), which is consistent with greater N supply from long-distance atmospheric sources. Comparisons with published precipitation nitrate-$\delta^{15}N$ values suggest that as much as 10-15% of the nitrogen in these lakes may originate from atmospheric subsidies of anthropogenic origin. Such changes in nutrient status are compatible with recent increases of algal production. Finally, we have observed dramatic dilutions of sediment ^{210}Pb activities in the unsupported inventories from each lake, suggesting episodes of accelerated sedimentation. At Skardtjørna, a lake for which mid- to late Holocene sediments are also available and well-dated, it appears that post-1960 sediment accumulation rates are several fold greater than the long-term average. The accelerated catchment erosion is perhaps a consequence of increased summer precipitation regionally. Taken together, these data suggest that lakes of western Spitsbergen have entered new limnological and geomorphic states for which no adequate Holocene analogues exist. Thus, the paleolimnological data provide distinctive stratigraphic signatures for the Holocene-Anthropocene transition on Svalbard, implying that human influences may be readily detected in lake sediments from Europe's most northern landmass.

Tracking ore-forming fluids in Bastnäs-type REE deposits

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The mineralogy and geochemistry of the epigenetic Bastnäs-type Fe-LREE skarn deposits in the Bergslagen mining district, south-central Sweden, have recently been studied in some detail (Holtstam, 2004, and refs. therein). Complementary trace element and isotopic analyses, and fluid-inclusions studies, of minerals have been carried out to constrain the origin of the ore-forming fluids.

Laser-ablation ICP-MS analyses of common skarn amphibole (tremolite-actinolite) indicate low total REE contents, with flat chondrite-normalized patterns and a slight enrichment of the middle REE except Eu. This suggests limited exchange with the REE-bearing fluids during mineralization.

Two distinct types of fluid inclusions (f.i.) were observed: A. Primary aqueous-carbonic f.i. in bastnäsite and dolomite. B. Aqueous f.i., with a primary appearance in fluorite and tremolite, and secondary in dolomite. Bastnäsite formation involved CO_2-bearing aqueous fluids with salinities in the range 6–29 eq. wt.% $CaCl_2$ at 300–400°C, and probably occurred at a stage of fluid immiscibility. Fluorite precipitated from a non-boiling aqueous fluid of low to medium salinities (0–16 eq.wt.% NaCl) during cooling from ca 150°C to 100°C.

REE minerals (ferriallanite, cerite, bastnäsite, percleveite, törnebohmite) separated from three samples from the Bastnäs deposit have been subjected to Sm-Nd isotopic analysis. Measured $^{143}Nd/^{144}Nd$ values are in the range 0.5107–0.5117, and the $^{147}Sm/^{144}Nd$ ratios 0.0363–0.1198. One of the samples yields a three-point isochron 1745±66 Ma (MSWD=0.02). Assuming an approximate age of ca 1.8 Ga, initial εNd-values in the range -1 to +1 are indicated, suggesting Svecofennian sources for the mineralization.

Holtstam, D. (2004). SGU Rapp. med. 119, 13–22.

Ore reserve estimation of the Anomaly No.3 of the Gol-e-Gohar iron mine (SW Sirjan, Iran) using ordinary kriging (OK) geostatistics

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Gol–e–Gohar, one of the largest known iron mines in Iran, is located in Kerman province. The host metamorphic complex consists of marble and metamorphosed mafic to ultramafic rocks. Anomaly No. 3 contains three ore zones: The Upper Magnetite, Hematite-Oxidation and Lower Magnetite zones, which are formed during regional metamorphism. The objective of this paper is to evaluate the suitability of ordinary kriging (OK) geostatistics and the polygonal method for resource estimation of Anomaly No.3 and introduce the technique which has a better accuracy in reserve estimation of the other five anomalies in the area. Since most of the linear kriging methods, especially OK, rely on the assumption of a Gaussian distribution, the total number of Fe analysis of magnetite and hematite (659 samples from 81 drillcores) are first normalized, and then the iron grade is kriged using the Geoease software. Variography studies reveal that among different examined trends, 0º and 90º show the best fit with a 15º tolerance. The best model, i.e. a spherical model with a range of influence of 1088.8 & 1520 meters, a nugget effect of 5.40 & 1.51, and a sill of 57.6 & 59.7, was fitted respectively to trends 0º and 90º (with a 15º tolerance). These variograms show that iron has a geometric anisotropy with the ellipse corresponding to the 0º and 90º trends, so that the highest range is in the E-W and the lowest in the N-S direction.

Using Ordinary Block Kriging (100×100m), total tonnage calculated 483,805,175 tonnes at a 95% confidence level with total error of 53,044,504 tonnes. Obviously Anomaly No. 3 would be classified as proved deposits, because more than 98% of its tonnage estimate has less than 20% of error.

Using the polygonal method, the tonnage of Anomaly No. 3 has been estimated at 4672,791,414 tonnes, with a 90% probability level and a 30% upper error limit, that on the basis of the geostatistical Verbal category is defined as possible reserves, and therefore the OK method is considered more reliability.

Sm-Nd isotopes in Paleoproterozoic mafic rocks in Finland – range of ages, mantle sources and crust-mantle interaction.

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Isotopic studies on mafic dikes, intrusions and volcanic rocks in Finland have revealed that rifting of the Archean lithosphere took place at several stages including ca. 2.44 Ga, 2.3 Ga, 2.22 Ga, 2.15 Ga, 2.1 Ga, 2.05 Ga, 2.0 Ga, and 1.8 Ga. These are well exemplified in the special volume containing U-Pb data from Finnish Lapland (Vaasjoki, 2001, editor, Geological Survey of Finland, Special Paper 33, 279 p). Mafic rock associations in the Karelian domain provide samples from the mantle below the Archean craton, and may be regarded as examples of ancient Large Igneous Provinces.

Sm-Nd mineral and whole-rock data made at GTK since the early 1980's include analyses on ca. 70 Paleoproterozoic mafic rock units in the Karelian domain. Generally the Sm-Nd mineral ages on well-preserved samples are consistent with the available U-Pb zircon ages. As many of the initial εNd values are based on the Sm-Nd mineral isochrons, they should give reliable estimates for the initial isotopic composition of the rocks in question. These data together with geochemical and other geological information provide tools for constraining the age and origin of mafic magmas and the evolution of the lithosphere.

The initial εNd values range from very positive to strongly negative and suggest that some rocks were derived from a depleted mantle source whereas others have a large contribution from old enriched lithosphere. Deep-crustal contamination of ultramafic magma may explain many features observed in mafic-ultramafic rocks (e.g., 2.44 Ga mafic intrusions with εNd of –2), but the isotopic results also show that various mantle sources with distinct isotopic compositions have existed during the Paleoproterozoic. Examples are provided by high-REE mantle-derived rocks showing a range of initial εNd values from nearly chondritic (e.g., the 2.6 Ga Siilinjärvi carbonatite, 2.0 Ga Jormua OIB, 1.8 Ga lamprophyres) to highly positive (e.g., the ca. 2.0 Ga Laivajoki and Kortejärvi carbonatites).

Definition of allo- and lithostratigraphic units in the Quaternary deposits of the Kvarken archipelago, western Finland.

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In connection to ordinary Quaternary geological mapping 13 research excavations by tractor excavator were done in the Björkö island in the Kvarken archipelago during summers 2004 and 2005. The area belongs to one of the most representative examples of De Geer moraine fields in Scandinavia (Zilliaccus, 1987; Breilin et al., 2004). Most of the excavations were crosscuttings into the DeGeer ridges.

In the preliminary stage of the research project an attempt was done to desciptively classify the deposits into allo- and lithostratigraphic units. In this procedure the surficial dominating till layer, into which the De Geer ridges are formed, is defined as the Björkö Alloformation. In the procedure this alloformation is divided into several lithostratigraphic formations and allostratigraphic members. These are the Gyttjesund Formation, the Furuäng Formation and the Uddskatan Allomember.

The basal Gyttjesund Formation comprice most of the Björkö Alloformation and covers the whole study area. It is a matrix supported blueish-grey massive silty till with silty to sandy lenses. Variation of clast petrology is low. The Furuäng Formation is light brown sandy till in which varying size sorted lenses are common. The upper part of formation is mostly well sorted and the particle size vary from fine sand to coarse gravel. The contact between these two formations is undulating and it varies from sharp to gradational. The Uddskatan Allomember lies on top of the Björkö Alloformation between the De Geer ridges. In southwestern and western parts of Björkö island it covers some De Geer moraine ridges. It is composed of well sorted brownish fine sand to gravel.

Breilin, O., Kotilainen, A., Nenonen, K., Virransalo, P., Ojalainen, J. ja Sten, C-G. (2004). ***Geology of Kvarken*** *Archipelago. Geological Survey of Finland.*

Zilliacus, H. (1987). Geographical Society of Finland.

Site suitability studies for Scots pine using airborne and terrestrial gamma-ray measurements in Finnish Lapland

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Low altitude airborne gamma-ray (AGR) data, obtained with the aircraft mounted 25 l NaJ(Tl) gamma spectrometer and interpolated into 50 by 50 m pixel size, over 1200 km^2 of glaciated terrain in Finnish Lapland were applied to classify and interpret site suitability for Scots pine (*Pinus silvestris* L.). The selection of the training and validation sets for the classification of AGR data was based on the forest management history and soil moisture content (θ_v) determined by dielectric (ε) measurements. The ground calibration measurements showed a significant negative correlation between the soil ε (i.e. θ_v) and terrestrial gamma-ray flux (TGR-γ) from potassium (γ_K) and thorium decay series (γ_{Th}), suggesting that the attenuation of gamma flux is due to soil θ_v. Both ground and airborne surveys indicated, that γ_K was significantly higher in drift of Scots pine stands than in drift of Norway spruce (*Picea abies* L Karst.) stands. Out of four tested combinations of the AGR channels, i.e. K, K and Th/K, K and Th and Th/K as well as K and Th, potassium alone resulted in the best overall accuracy of 80.44 % (Kappa coefficient, κ=0.609) to classify drift materials suitable for Scots pine. The present study demonstrates, that the TGR-γ_K and AGR-γ_K measurements provide basis to delineate soil θ_v patterns within the site and landscape level, thus having significant implication for the forest management planning to assess sites suitable for Scots pine.

Regional exploration projects for natural stone in Finland

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At the Geological Survey of Finland (GTK) regional exploration of natural stone have been in progress since 1988. The aim is to explore bedrock outcrops on a certain region to locate prospects suitable for natural stone production. Furthermore, environmental aspects are observed. The work is carried out jointly with the regional authorities and generally financed by European regional development funding. Until now, the regional exploration of natural stone cover a total of approx. 12 000 bedrock outcrops, covering roughly 30% of Finland's land area.

The regional natural stone exploration is based on a conventional geological mapping. The colour and texture of rock type is very carefully observed during the exploration. The spacing of fractures are measured or estimated. Different kind of samples are taken, also GPR (ground penetrating radar) is used in selected areas. The exploration has shown that less than 4 % of the bedrock outcrops studied could be suitable for natural stone production. The amount and type of these prospect areas varies in different regions and depends on the bedrock geology of the region. Different kind of new granite prospects, and especially from southeastern Finland many rapakivi granite prospects have been defined. Furthermore, several soapstone prospects have been identified in eastern Finland. In these areas detailed exploration and more intensive sampling should be done in prospect scale.

There are some challenges in regional exploration. Especially, in rapakivi granite areas sampling is challenged by intensive weathering. The samples taken from surfaces of outcrops do not always represent the colour of rapakivi granite in deeper parts of outcrops. The frequency of vertical and horizontal fractures is not always easy to identify due to soil cover and compact fractures. Occasionally, topography is so flat-lying that horizontal fractures cannot be seen. Hence, development is needed in regional exploration of natural stone.

Results of rock aggregate inventories in Finland 1989–2004

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At the Geological Survey of Finland inventories of rock aggregate outcrops have been in progress since 1989. The aim is to explore the outcrops and quality of the bedrock suitable for aggregates, bearing in mind the environmental aspects. The work has been carried out jointly with the environmental authorities, area planners, and producers of aggregates.

The inventories of rock aggregates cover currently a total number of 10278 bedrock outcrops (http://www.gtk.fi). We have performed 839 mechanical-physical tests on rock samples (50 kg rock /sample) in order to evaluate the quality of aggregates. Los Angeles, abrasion, Swedish impact, point load index, and Nordic ball-mill tests were used as testing methods.

The inventory has shown that less than 1.0 % of the bedrock outcrops studied met the highest quality requirements, yielding aggregates suitable for motorway surfaces. Best rock types are fine-grained felsic and intermediate metavolcanic rocks in which mineral grains are tightly interlocked as well as strongly deformed plutonic rocks that have tonalitic and granodioritic composition. Lower quality aggregates can be produced from medium- and coarse-grained granitic rocks and gneisses containing abundant mica minerals. However, these aggregates are suitable for most common end-use applications. Sulphide- and carbonate-bearing gneisses as well as strongly schistose rocks are unsuitable for the production of rock aggregates.

High-quality rocks are located mainly in the schist belts. Regions with shortage of high-quality rock aggregates are the rapakivi granite areas in SE and SW Finland. Local occurrences of high-quality rocks have also been found within low-quality rock areas. The regional inventories have played a significant role in identifying these occurrences.

High quality aggregates should be used only for applications where they are essential, because demand for high quality aggregates will increase and reserves decrease. Therefore, it is necessary to know the distribution and quality variations of rock aggregates.

http://www.gtk.fi/palvelut/kartoituspalvelut/maa-ainekset/kiviaines-kalliokiviainekset.htm.

The Ljusdal Batholith and related rocks, central Svecofennian Domain, Sweden

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The 1.86–1.84 Ga Ljusdal Batholith (LjB), south-central Sweden is sandwiched between the Bergslagen arc in the south and the Bothnian Basin in the north. It extends from the coast of the Baltic Sea NW-wards and it is enveloped between two major shear zones; the Hassela Shear Zone to the north and the Storsjön-Edsbyn Deformation Zone in the west. The southern boundary roughly coincides with the Gävle - Rättvik shear zone system.

K-feldspar megacryst-bearing granitoids dominates LjB, with smaller amounts of even-grained types, and minor mafic intrusions. In most cases LjB appears as augengneisses. In the NW the LjB passes over into K-feldspar megacryst-bearing granites (KFM granites) of the Transition Belt (TrB) in south Jämtland. The KFM granites were previously thought to belong to the c. 1.80 Ga Revsund granitoid suite. However, dated KFM granites yield ages between 1.89–1.85 Ga, i.e. older than or coeval with the LjB rocks, in spite of their lack of metamorphic overprint.

The granitoids of both LjB and the TrB are clearly dominated by high-K calc-alkaline compositions, with a slightly more alkaline trend for LjB, and aluminous trend for TrB. εNd(1.85Ga)-values of LjB granitoids range between +1.2 and –0.3, while two mafic plutonics yielded +2.7 and +2.5. KFM granites of the TrB yielded εNd(1.85Ga)-values in the range -0.8 to -1.7, while one 1.80 Ga granite had an intitial value of +0.4. Initial Sr values generally confirm the Nd data.

Though the LjB granitoids are significantly more juvenile than the KFM-granites, both fall within the εNd-evolution of the early Svecofennian crust. The TrB granites appear to contain a larger proportion of sedimentary material (with an Archaean component), while the LjB derives mainly from mantle and juvenile Svecofennian components. Also the 1.80 Ga granite has mainly juvenile protoliths. The mafic LjB rocks belong to the more strongly depleted mantle-derived rocks among both early Svecofennain and TIB episode rocks.

The Hassela Shear Zone – a link between migmatites and the contemporaneous Ljusdal Batholith?

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The central Svecofennian domain in Sweden is dominated by the c. 1.85–1.86 Ga Ljusdal Batholith (LjB), which is separated from the metasedimentary rocks of the Bothnian Basin to the north by the Hassela Shear Zone (HSZ).

During the Svecokarelian orogeny the rocks were folded (F_1-F_3) and generally metamorphosed under amphibolite or granulite facies condition. Partial melting resulting in different types of migmatites: 1) Stromatic migmatites, most common in metasedimentary rocks. 2) Heterogeneous diatexites (schollen migmatites), veined gneisses and schlieren-rich granites. 3) Leucocratic, more homogeneous peraluminous granites.

The U-Pb SIMS results on zircon rims from a veined migmatite and an intruding granite close to Hudiksvall, are overlapping and yield a combined age of 1859±3 Ma. Similar ages are obtained from a leucocratic garnet-bearing granite nearby (1858±6 Ma) and a schlieric granodiorite at Nedansjö (1861±2 Ma), located to the north of HSZ. Also north of HSZ is another but younger garnet-bearing, leucocratic granite (Algarsberget, 1845±12 Ma).

In the LjB a folded leucosome from a metasedimentary rock gave an age of 1820±7 Ma, similar to the known age of the Härnö granite located to the north of HSZ. A pegmatite cutting the fabric gave an age of 1805±5 Ma.

New geophysical data indicate that HSZ is folded in its eastern part suggesting that the c. 1.86 Ga leucosomes, prior to the folding, were all located to the north of the zone.

An augengneiss in the LjB gave an U-Pb TIMS age of 1858±7 Ma, coeval with the oldest generation of migmatites to the north of the HSZ. This may indicate a causal relationship between these rocks and that the HSZ was established already at this time. The process generating the LjB could also have been the heat source enhancing melting of the surrounding rocks, and the transpressive regime of the HSZ the necessary channel that attracted and expelled the melt. Later, both regions appear to have been subjected to melt episodes at 1.82 and 1.80 Ga.

The evolution of the Vestmannaeyjar volcanic system, southern Iceland.

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Vestmannaeyjar archipelago, off the south coast of Iceland, marks the southernmost tip of the Eastern Volcanic Zone (EVZ), which runs north-south across Iceland and marks the plate boundary between the American and Eurasian plates. It is believed that the plate boundary was relocated some 3 MA ago and since then has been propagating towards the south. Volcanism in the area of Vestmannaeyjar has been active during the Holocene with two major eruptive episodes, the former starting some 7–6 Ka ago and the second starting 1963 AD. The last eruption was some 30 years ago on the island of Heimaey, the largest island within the archipelago. In July-August 2003 we conducted brief surveys of the Vestmannaeyjar area, south of Iceland, to try to determine whether or not the recent volcanic eruptions here result from nascent plate boundary processes. We used the SIO SUBSCAN chirp seismic system to collect seismic profiles & sidescan sonar swaths from the R/V Bjarni Saemundsson, & the EM300 system on the R/V Arni Fridriksson to collect swath bathymetry & backscatter data. The aim of this survey is to get a comprehensive look at the evolution of the volcanic history of the area. An area named "Stora Hraun" or Big Lava located just southeast of Surtsey Island revealed three major volcanic tuff cones at a depth of some 75 metres below sea level. The largest of these tuff cones has a diameter of 1 km while the other two range in diameter from 400 to 500 meters. Based on the low erosion rates we estimate that palagonitisation took place before these craters were subject to erosion. Compared to the erosion state of the two parasitic cones formed in the Surtsey eruption (1963–1967) it can be suggested that the craters at Stora Hraun were fully palagonised at subaerial conditions prior to being submerged. This suggests a substantially lower sea level during the Pleistocene.

The Hekla eruption 2000, Iceland

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The 18th eruption of Hekla started on February the 26th in the year 2000. It was a short lived but intense event, emitting basaltic andesitic pyroclastics and lava. During the course of the eruption it was monitored by instruments and direct observations, thus giving a unique insight into the current activity of Hekla. The eruption started in a highly explosive manner giving rise to a sub-plinian eruptive column and consequent pyroclastic flows fed by column collapses. Once the explosive phase was over, the eruption went through three phases, namely fire-fountaining, strombolian and lava oozing. All phases can be accounted for in the eruption tremor. In this paper we shall describe the eruption of Hekla, the origin of its magma and show that the eruption tremor can be linked with an effusion rate during the explosive phase in the first hours of the eruption. Further we show that the eruption phases observed in Hekla can be linked with magma chamber overpressure prior to the eruption.

Constraints on the dynamics of subglacial basalt eruptions from geological and geochemical observations at Kverkfjöll, NE-Iceland.

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The Kverkfjöll area, NE Iceland is characterised by subglacial basalt pillow lavas erupted under thick ice during the last major glaciation in Iceland. The water contents of slightly vesiculated glassy rims of pillows in six localities range from 0.85±0.03 to 1.04±0.03 wt%. The water content measurements allow the ice thickness to be estimated at between 1.2 to 1.6 km, with the range reflecting the uncertainty in the CO2 and water contents of the melt. The upper estimates agree with other observations and models that the ice thickness in the centre of Iceland was 1.5–2.0 km at the time of the last glacial maximum. Many of the pillows in the Kverkfjöll area are characterised by vesiculated cores (40 to 60% vesicles) surrounded by a thick outer zone of moderately vesicular basalt (15–20% vesicles). The core contains ~1 mm diameter spherical vesicles distributed uniformly. This observation suggests a sudden decompression and vesiculation of the still molten core followed by rapid cooling. The cores are attributed to a jökulhlaup in which melt water created by the eruption is suddenly released reducing the environmental pressure. Mass balance and solubility relationships for water allow a pressure decrease to be calculated from the observed change of vesicularity of between 4.4 MPa and 4.7 MPa depressurization equivalent to a drop in the water level in the range 440–470 m. Consideration of the thickness of solid crust around the molten cores at the time of the jökulhlaup indicates an interval of 1–3 days between pillow emplacement and the jökulhlaup. Upper limits for ice melting rates of order 10–3 m/s are indicated. This interpretation suggests that jökulhlaups can reactivate eruptions.

Development of Gardnos Impact Crater to a Visitorcentre both for tourists and educational purposes

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Gardnos Impact Crater is a 5km diameter structure situated 7km north of Nesbyen in Hallingdal, eastern Norway. It is one of the most accessible impact craters in Europe. One of the main tourist routes between Oslo and Bergen runs along the outer limits of the structure. The last three years over 17000 people have visited the information centre in June, July and August.

Since 1994 there has been a political wish to develop the area to an information centre for geology both for tourism and educational purposes. For the last four years the Municipality of Nes has employed a geologist as a leader for the project. The main aim of the project has been to make geology available to the public.

Together with the regional geologist in Buskerud Telemark Vestfold we are working to gather interesting geological localities in the northern parts of the region. With joint marketing each locality will attract the attention of an increased number of potential visitors. The main challenge with developing these kinds of attractions is how to do it economically safe. It is not common that a municipal community gives this kind of project such backing. From April 2006 the project will be reorganized. Since 2002 we have proved that there is a potential to develop geological attractions, but a continuous development of the locality is necessary. What will happen after 2006? Is it important to develop these attractions and why is this kind of geological attractions interesting for the public?

Municipality of Nes, the county of Buskerud and the region collaboration Buskerud, Telemark Vestfold have been contributors to the project. Will they support Gardnos in the future or do we have to find other contributors?

West Greenland's mountains are surprisingly young

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The preserved Mesozoic–Cenozoic sedimentary and volcanic record of West Greenland makes this a key area for studying the uplift of passive continental margins. North Atlantic margins were uplifted and eroded during the Neogene, but the timing and extent of the uplift movements have been difficult to determine, leading to debate about whether the uplift was isostatic or tectonic. We have combined apatite fission-track analysis data with landform analysis to investigate the development of West Greenland landscapes across areas with substantially different geology.

We show that the mountains of West Greenland (65–71 N) are the end result of three Cenozoic phases of uplift and erosion. The first phase created a **planation** surface during the Oligocene–Miocene. This surface was offset by reactivated faults, resulting in megablocks that were tilted and uplifted to present-day altitudes of up to 2 km in two late Neogene phases.

These late Neogene uplift phases postdate rifting by c. 40 m.y., sea-floor spreading west of Greenland by c. 30 m.y. while the first of these phases predates onset of glaciation in Greenland. We conclude that the uplift had deep-rooted, tectonic causes and may have had a triggering role in the formation of the Greenland ice sheets.

Bonow, J.M. (2004). Palaeosurfaces and palaeovalleys on North Atlantic previously glaciated passive margins – reference forms for conclusions on uplift and erosion. PhD-thesis no 30, Stockholm University, 91 p.

Japsen, P., Green, P.F., and Chalmers, J.A. (2005). J. Geol. Soc., London 162, 299–314.

Fluvial response to climate and sea level change during the last interglacial – glacial cycle, Arkhangelsk region, NW Russia

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Quaternary fluvial systems provide full-scale, natural "laboratories" for studies of alluvial architecture on timescales approaching the geological and can be linked to relatively high resolution independent records of climate change, relative sea level fluctuations and tectonic movements with absolute dating methods. Multistorey fluvial deposits have accumulated along the Severnaya Dvina and Mezen River systems in the Arkhangelsk region, Northwest Russia for at least 100.000 years and the stacking patterns are influenced by e.g. changing meltwater supply from ice sheets, damming and outburst from proglacial lakes and high amplitude changes in relative sea level. This study focus on the interplay between upstream and downstream controls and investigates how the fluvial systems responds to climate and sea level change.

Both river systems are characterised by vertically stacked fluvial deposits and a number of fluvial incision and aggradation phases of regional extent are identified from the sedimentological record. More than 200 OSL dates available from the Arkhangelsk region provides a time frame for correlating phases of fluvial incision and aggradation to fluctuating climate, sea level, lake level and isostatic movements.

Incisions are generally driven by increase in discharge associated with cold climatic stages combined with rapid base level lowering due to breaking of ice dams. Fluvial aggradation is linked to increased sediment supply and rapid sea level rise. The preserved fluvial geometry reflects the interplay between these parameters and the influence of neotectonic crustal movements.

The effect of relative sea level change is surprisingly weak. Even significant sea level changes only show minor influence on sediment aggradation but none on fluvial incision. Falling relative sea level is associated with forced regression and deposition of coastal deposits.

A revised geochronology for the Blekinge province, southern Sweden

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Blekinge and adjacent parts of Skåne form a small separate Proterozoic bedrock province in southern Sweden. By putting carefully selected pieces of Blekinge under the ion microprobe, it has been possible to obtain a revised geochronology for the Blekinge Province. Zircons from nine rock samples, including one metavolcanite sample from the Västanå formation and one 'coastal gneiss' sample from western Blekinge, four samples of gneissic granitoids from western and eastern Blekinge, one aplitic granite dyke crosscutting deformed Tving granitoid in eastern Blekinge, and paleosome and neosome from a migmatite possibly related to the intrusion of the Karlshamn granite, have been dated using the NORDSIM ion microprobe. The results suggest that most of the Blekinge bedrock was formed within a narrow time interval of 1.77–1.75 Ga, including the Västanå formation and 'coastal gneisses' previously dated to c. 1.70 Ga. One sample, the 1.81 Ga Nättraby gneissic granite, appears to represent a sliver of slightly older proto-crust. An age of c. 1.75 Ga for the aplitic granite crosscutting the deformed Tving granitoid at Hallarum would bracket the deformation to between 1.77 and 1.75 Ga, whereas zircons of similar age from the migmatite neosome at Lindö may be inherited, making the result inconclusive. Thin metamorphic zircon overgrowths and resetting of the U-Pb system in titanite indicate a regional thermal event at 1.45 to 1.40 Ga, accompanying the intrusion of the Karlshamn-type granites. Initial εNd values of –0.3 to +1.0 indicate limited crustal contributions to the 1.77–1.75 Ga magmas. The crust of the Blekinge province thus was formed in late Palaeoproterozoic time from relatively juvenile sources in a subduction-related environment along the southern edge of Fennoscandia. It was deformed and subsequently uplifted relative to the undeformed TIB-1 granitoids of the Småland block further north, prior to the intrusion of the Karlshamn-type granites at 1.45 Ga.

Late Sveconorwegian syntectonic migmatite formation along the eastern margin of the Eastern Segment, southwest Sweden

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A c. 100 km long, N-S trending, E-dipping zone of stromatic migmatite gneisses, the Bredaryd migmatite zone, occur 10–20 km west of the Protogine Zone. The zone marks a structural-metamorphic boundary that separate the high-grade metamorphic core of the Eastern Segment (670–750 C, 10–12 kbar) from a medium-grade metamorphic upper level. The rocks above (east of) the zone are recognisable TIB-rocks and hyperite dolerites that experienced high pressures (10–12 kbar) and temperatures (600–630 C). Along the Bredaryd zone, migmatites have been tightly folded along N-S-trending subhorisontal axes with steep to east-dipping axial planes. Leucosome in both folded and semi-discordant relations to the folds demonstrate that migmatisation was synchronous with the folding. N-S-stretched amphibolite boudins (metadolerite) have granitic melt as neck fillings. Zircons from paleosome, neosome and granitic neck fillings have been dated by ion-probe (Nordsim). Igneous zircon cores yielded a protolith age of 1732±15 Ma. Metamorphic zircon occur as rims on protolith zircon and as unzoned grains, and dates the migmatisation and folding at 955±13 Ma. This age is identical with the 956±7 Ma age of granitic dykes crosscutting deformed and retrogressed eclogite and metagranite in the core of the Eastern Segment. The migmatisation was synchronous with intrusion of dolerite dykes parallel to the Protogine Zone and is suggested to reflect late-orogenic, decompression-induced melting and uplift of the Eastern Segment.

Pyhä-Luosto National Park – proposed inclusion to the European Geoparks Network

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The Pyhä – Luosto range of fells with surrounding low moraine hills and wet aapa mires form a national park of 142 km^2. It lies in Finnish Lapland. Pyhä was turned into a national park in 1938, one of the first in Finland. In March 2005 it was increased to three times its former size, as the Luosto area was included. It is popular with nature tourists and summer hikers. Various structures have been made to facilitate hiking, such as information boards, cabins, shelters, wooden walkways and steps.

The National Park contains geological monuments and sites with special scientific importance in sedimentology, glacial geology, geomorphology and aesthetic value. The fell range itself (highest tops over 500 m), consisting of about two billion year old quartzite and conglomerate, form the backbone of the area. Often surprisingly well-preserved sedimentary structures exist, such as current bedding and ripple marks occuring on quartzite layers and precipitate structures and dendrites on schist surfaces. Rugged canyons divide the fell range like huge cuts into several peaks. The most remarkable canyon, Isokuru, is with its depth of 220 metres Finland's deepest. Preglacial weakness zones in the bedrock together with weathering and glacial erosion influenced the formation of canyons. Finally subglacial and proglacial meltwater streams have cleaned the canyon floors, carrying away loose rock material and spreading it at the canyon mouths. The aapa mires are the geologically youngest attractions of the area.

As eastern Lapland has many socio-economic problems, the growth of geotourism has had a welcome effect on the development of the area. Including Pyhä – Luosto in the European Geoparks Network would promote the consciousness and awareness of the public towards the protection of geological and geomorphological heritage and to improve the quality of services offered to tourists. In 2004 the Pyhä – Luosto national park was visited by 25 000 persons. In the Visitor Centre there is a permanent exhibition of the geological history. Changing exhibitions, geological lectures and guided tours related to the national park are held there as a tool for environmental education.

Stratigraphy and age of Quaternary sediment in the Middle Swedish End Moraine zone

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Recent drilling and geophysical studies in the moraine ridges of the Middle Swedish End Moraine Zone show them to be made primarily of clay, but also to contain coarser sediment (sand and some till) particularly on their proximal slopes. Resistivity measurements reveal structures in the clay that are interpreted as thrusts. The moraines are interpreted to be thrust moraines, formed subaqueously at the margin of the Scandinavian Ice Sheet. In addition to the thrust ridges, numerous sites along the former ice-margin positions reveal proximal meltwater sediment deposited in ice-contact deltas that were fed by subglacial meltwater channels.

Recent drilling in the intermorainic flats reveal 20 to 30 m of stratified fine sediment (gray to brown silt and clay) overlying till or bedrock. The fine sediment is capped by sand and gravel that contains abundant shale and sandstone clasts eroded from Mt. Billingen. The fine sediment is similar in color, grain size, and sedimentary structure to the clay in the moraine ridges; however their stratigraphical relationship is unclear. That is, it is not clear if the clay in the intermorainic positions is a younger, an older, or the same stratigraphic unit as the clay in the thrust ridges.

Two OSL dates on sand grains from the clay in the thrust-moraine ridges yield preliminary dates of 45±5 ka and 67±8 ka, similar to previously reported luminescence ages on the same clay (Ronnert and others, 1992). These dates suggest the clay in the ridges to have been deposited before the Late Weichselian.

Ronnert, L., Svedhage, K. & Wedel, P.O. (1992). GFF 114, 323–325.

Factor analysis of multi-component borehole logging data for fracture zone identification and classification

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Geophysical borehole data provides essential information in addition to core and hydrological data for identification of fracture zones in crystalline bedrock. The results of this study indicate that factor analysis can be used to select the most valuable data sets for an independent method for fracture zone identification.

An extensive set of data from borehole OL-KR4, Olkiluoto, Western Finland, has been analysed using factor analysis. The analysed borehole section is at the depth of 100–900 m. The borehole penetrates only few considerable fracture zones as well as some unclear features, which may be also identifications of fractured rock.

In factor analysis, the correlations between different variables are indicated by their relative values of importance. In an ideal case, the analysis results in a number of new principal components, which is much lower than the number of original data sets. After analysis, each original data set has a value of importance regarding to all new principal components. This way we can find the most valuable data sets.

In the Olkiluoto case, the first principal component correlates strongly with water-bearing fractures. The S-wave velocity has the highest importance in this component and due to strong contrast between fractured and intact rock it forms a practical data set for the localization of fracture zones. Another data set with high importance is long normal resistivity data. It interacts with a large volume around the borehole and therefore highlights effectively extensive fracture zones. Applying these two geophysical measurements with suitable triggering limits of anomalies provides a pragmatic method for fracture zone identification.

Metamorphosed U-Nb-Ta-REE-bearing alkaline rocks from the Swedish Caledonides in Jämtland

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Alkaline intrusive rocks comprise a rare component of Sweden´s geology, and metacarbonatitic rocks have, until now, not been described. The presently studied alkaline rocks occur SE of the Grong-Olden window in the Caledonides of Jämtland county. U-Nb-Ta mineralisation was discovered at Prästrun in the late 1970s (Löfroth & Pettersson 1982), while the Åkersjön occurrence was recognized during recent mapping by the SGU, and subsequently studied in some more detail (Jonsson & Stephens 2004).

The Prästrun rocks comprise mainly gneissic syenitic rocks with local pegmatites. The Åkersjön rocks are more carbonate-rich, lack pegmatites, and are partly less tectonically deformed. The presence of cancrinite and nepheline at Prästrun and sodalite at Åkersjön is consistent with a magmatic foid syenitic association. Furthermore, the REE-fluorocarbonate bastnäsite has been confirmed. The primary carrier of U-Nb-Ta mineralisation at Prästrun is betafite, whereas the radioactive host mineral(s) at Åkersjön has yet to be identified. The intimate association of carbonate units with foid syenitic rocks implies that the former represent metacarbonatites. Field relations suggest that the alkaline rocks occur as a part of the Särv Nappe. The presence of some metadiabases with an alkalibasaltic character in this nappe (e.g. Solyom et al. 1979a; Stephens et al. 1985), compared to the entirely tholeiitic character of the mafic rocks in the Seve Nappe Complex (Solyom et al. 1979b; Stephens et al. 1985), reinforces this interpretation.

All observations indicate that these alkaline rocks formed as intrusive rocks that were subsequently metamorphosed and deformed during the Caledonian orogeny. Most likely, they represent spatially restricted, deformed lenses located close to the tectonic contact between the Särv Nappe and the Seve Nappe Complex.

Jonsson, E. & Stephens, M.B. (2004). SGU report 08-1129.

Löfroth, B. & Pettersson, B. (1982). SGU report BRAP 82018.

Solyom, Z., Andréasson, P.-G. & Johansson, I. (1979a). SGU C756, 1–38.

Solyom, Z., Andréasson, P.-G. & Johansson, I. (1979b). GFF 101, 17–25.

Stephens, M.B., Furnes, H., Robins, B. & Sturt, B.A. (1985). In: Gee, D.G. & Sturt, B.A., The Caledonide orogen-Scandinavia and related areas. J. Wiley & Sons, Chichester, 109-133.

Gently dipping fault zones in Palaeoproterozoic rocks, central Sweden: Evidence from reflection seismic and cored borehole data

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A complex deformation belt is present in the coastal area north of Uppsala, central Sweden, in the accretionary Svecokarelian orogen. Bedrock domains that strike WNW to NW, dip steeply and are affected by high ductile strain are conspicuous. These domains anastomose around tectonic lenses that are up to a few tens of kilometres in length and are a few kilometres wide. The bedrock within the lenses is folded and, in general, affected by lower ductile strain. The north-western part of one of these lenses at Forsmark has been chosen as a possible site for the storage of high-level, radioactive nuclear waste.

Approximately 16 km of high resolution seismic data were acquired in 2002 along five separate profiles varying in length from 2 km to 5 km at the Forsmark site. The upper 1000 m of bedrock is much more reflective in the south-eastern part of the site compared to the north-west.

In the south-east, reflection orientations are well determined where profiles cross one another. In this area, there is a nearly one to one correlation of distinct reflections on the seismic sections with fault zones in cored boreholes that have been drilled to c. 1000 m depth. The reflectors dip gently to the SSE or SE, and the zones in the boreholes are dominated by fractures that show the same dip direction or are more gently dipping (sub-horizontal). The fault zones show a high frequency of open fractures as well as high groundwater transmissivity values.

A working hypothesis for the gently dipping fault zones suggests that these structures formed as minor thrust faults during the later stages of the Svecokarelian orogeny (Stephens and Simeonov, this meeting). However, mineral coatings and fillings in these zones indicate later reactivation. The large aperture values of the fractures in these zones and their high groundwater transmissivity values may be explained by a combination of factors that include: 1. the initial, high intensity of gently dipping and sub-horizontal fractures along the zones; 2. the current, compressive stress field; and 3. the high, in situ differential stress that was established after the latest Weichselian glaciation.

Post impact deposits in the Gardnos impact structure, Norway

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The Precambrian Gardnos impact structure is (French et al., 1997) formed a bowlshaped sedimentary basin of 5 to 6 kilometer diameter. The crater was excavated in crystalline gneisses, and some of the post impact sediments are still well preserved. The sediments are exposed in the Northern half of the structure, and in a core drilled in 1993. A maximum sedimentary column of about 150 meters is present. The sedimentary infill succession has been studied in order to understand the mechanisms of infilling.

Initial post impact sediments of coarse grained material deposited just after impact, directly on the still not solidified suevite. Coarse angular fragments of locally derived bedrock dominate first post impact sediments, indicating short clast transport. The sediments were most likely derived from local bedrock fractured during the excavation phase, avalanching down the steep crater walls.

Locally the avalanche deposits were overlain by more matrix rich conglomerates, occasionally by relatively clean sandstones. Mapping of the clast content in the conglomerates shows stratigraphical variations, indicating periodic deposition. The thickest conglomerates are formed along the lower part of the crater wall. Debris flows are proposed as the main depositional process for the conglomerates, probably building out as fan-like bodies at the slope break.

Sandstones dominated areas are interpretated as interfan areas. The individual sandstone beds are commonly separated by thin clay seems, indicating short quiet periods between the main depositional episodes.

These presented observations contradicts the scenario of one major surge event where the sea returns and fill the crater. More likely the Gardnos crater sedimentation and filling took place over some (but still short) time.

French et al. (1997). Geochim. et Cosmochim. Acta 61, 873–904.

Sedimentology and structural geology of glacigenic sediments in Sensala outcrop, western Latvia

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At the nearly 3km long cliff section south west of town Ventspils at the Latvian coast of the Baltic Sea mostly layered fine sand sediments below uniform till layer are exposed. But at one 500 m long section heavily contorted sand, gravel, silt and two distinctive diamicton units (lower and upper till) are visible.

At this section association of proglacial lake sediments were identified: fine sand, waterlain or flow till and sand and gravel. Using OSL dating technology sands were established to be last exposed to daylight ~44 ka ago.

Micromorphological investigation of upper till in thin-sections shows evidences of poliphase deformation. Diamicton has acted as more competent layer during deformation forming in cases boudin-like structures. Probably fine sand matrix was deposited by subglacial melt water. Investigation of lower till unit in thin section revealed lamination due to partial sorting of sediments, microlineation in plane of lamination and abundance of small diamicton spherules. It is concluded that it formed as waterlain or flow till.

Fold structures below upper till are indicating glacial stress direction from NE to SW. However till fabric in upper till are indicating local ice movement direction from W to E.

An up 4 m high and approx 2 km wide till ridge stretching from the outcrop to the SE was identified during geological mapping in the vicinity of the outcrop. Ridge orientation coincides with orientation of fold hinges below the upper till and seemingly glaciotectonicaly disturbed sediments are forming a core of it. It is supposed that it formed during glacial advance as an interlobate, glaciotectonic ridge between two ice masses or on the edge of ice tongue as a lateral moraine.

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Provenance of Middle Jurassic strata in the Tornquist Zone, southern Sweden

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The aim of this study is to investigate the provenance of the Jurassic Glass Sand Member and the underlying Fuglunda Member in the Mariedal formation (Ahlberg et al., 2003) in the Tornquist Zone and to compare the provenance of the two different units. The Fuglunda Member is believed to represent deposition in tidal channels and the Glass Sand Member a fluvial-dominated part of a delta plain. The provenance techniques used are SIMS U-Pb and Pb-Pb dating of single detrital zircon (Whitehouse et al., 1999) and Ar-Ar dating of detrital muscovite. Trace element composition of rutile is also considered as these may give important information on the metamorphic source terrain.

SIMS U-Pb and Pb-Pb dating of detrital zircon grains shows trends of provenance of a western source, such as the Sveconorwegian Orogen. The results also show a difference in provenance between the two studied members of the Mariedal formation. The Pb-Pb dating of detrital zircons of the Fuglunda Member reveals a major peak at 900 Ma to 1000 Ma while the detrital zircons of the Glass Sand Member has three major peaks 900 Ma to 1000 Ma, 1450 Ma to 1550 Ma and 1600 Ma 1700 Ma. Four zircons from the Fuglunda Member and three zircons from the Glass Sand Member with low Pb-Pb ages were reanalysed with U-Pb single zircon dating. The $^{206}Pb/^{238}U$ detrital zircon ages of the Fuglunda Member all resulted in the range Mississippian to Lopingian. The $^{206}Pb/^{238}U$ detrital zircon ages from the Glass Sand Member are of early Permian, Neoproterozoic and Sveconorwegian eras.

Ahlberg A., Sivhed U. & Erlström M., (2003). The Jurassic of Denmark & Greenland. p. 527–541.

Whitehouse M.J., Kamber B.S & Moorbath S. (1999). Chemical Geology, 16, 201–224.

Erlström, M., Thomas, S.A., Deeks, N. & Sivhed, U. (1997). Tectonophysics 271, 191–215.

U-Pb and Sm-Nd data for eclogites of the Wide Salma Area (Kola Peninsula): implications for evolution of the Belomorian Belt

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Archean eclogites of the Wide Salma area (Kola Peninsula) found in 2.8–2.6 Ga TTG gneisses of the Belomorian complex (Geological Map of the Kola region, 1986; Konilov et al., 2004) were analyzed by U-Pb and Sm-Nd methods. An age of eclogite-facies conditions was dated by U-Pb method on metamorphic zircons. According to U-Pb zircon dating, eclogite formation (Grt +Omp (Jd 0.25-0.32) + Qtz + Ru) during prograde metamorphism (~700°C and P - 14-15 kbar (Konilov et al., 2004) occurred 2.7–2.8 Ga ago. The obtained Archean time of the eclogite formation confirms manifestation of deep subduction in the Late Archean. Decompression (Cpx-Pl symplectites replacing Omp and Cpx-Pl coronas between Grt and Qtz, T = 727±24°C and P = 10.7±0.7 kbar (Konilov et al., 2004)) has been dated at 1.89 Ga (Sm-Nd mineral isochrone for Grt, Cpx and WR). So, exhumation of eclogites took place in the Svecofennian time probably as a result of the Lapland collision. U-Pb dating of the zircon rims shows that eclogites have been undergone the final stage of metamorphic alteration (Amp-Pl rims between garnet and symplectites at 650–700°C and 7–9 kb) together with TTG gneisses at 1.9–1.8 Ga; metamorphic zircons from the TTG gneisses have the same age (Bibikova et al., 2004). Rutiles from eclogites as elsewhere within the Belomorian belt (Bibikova et al., 2001) have an age of 1.79–1.80 Ga, reflecting time of rock cooling to 450°C (closure temperature for the U-Pb rutile system). The work is supported by RFBR grant 04-05-64059 and Scientific School – 2305.2003.5

Geological Map of the Kola region. (1986)
Bibikova E.V. et al. (2001). Geochemistry. 8, 842–857.
Bibikova E.V. et al. (2004). Petrologija.12, 227–244.
Konilov A.N. et al. (2004). 32 IGC Florence. Abstracts. I, 108.

A novel examination of the 3D form of till pores using x-ray computed microtomography (µCT)

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The aim of this research is to examine bulk porosity and pore shape, size and connectivity in 3D from a selection of Pleistocene basal and flow tills with diverse properties from a field area in the Irish midlands. This research follows an initial study by the authors' of pore shapes and configurations in 2D using thin section microstructure analysis, scanning electron microscopy (SEM), and digital image analysis to quantify bulk porosity.

The research now investigates the use of x-ray computed microtomography (µCT) to describe the pores in 3D and calculate their volume to an accuracy that has hitherto been impossible. µCT reveals the structure of samples as determined by variations in density. The study of porosity is therefore an obvious application because there is a strong contrast between solid phases of till and the pores. Many one dimensional radiograph sections are obtained during rotation of the sample around a central axis, the tomograph interpolates 2D images and these are then stacked to give a 3D block. The images have a high resolution of up to 5µm in three dimensions. The development of these pores is investigated within the context of tills as deforming glacier beds.

Till pores, together with most other till microstructures, are indicative of plastic and brittle subglacial deformation. The type and extent of till deformation affects bulk porosity, pore type, size and connectivity as subglacial particle motion results in formation and destruction of pores. From till pores, and other structures, it is possible to infer deforming bed behaviour.

We have given the first description of till microstructures in 3D, specifically of pores, and shown that knowledge of the pore form is central to the elucidation of mechanisms of subglacial particle dynamics. The methods developed are important advances in subglacial till dynamics research and are beneficial for mapping and describing tills for applied as well as academic purposes. This research demonstrates the excellent capability of µCT for the description of till pores. There is great potential for using microtomography to describe other till microstructures and this is the next step that our research will take.

The Kalak Nappe Complex, Arctic Norway: The Middle Allochthon of the Scandinavian Caledonides reassessed

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The Kalak Nappe Complex (KNC) in Finnmark, Arctic Norway, has been regarded as a major component of the middle Allochthon in Finnmark, and has been subject to radically different interpretations for its tectonic evolution. A late Neoproterozoic history is now unequivocally established through dating of granites that cut early structures (Kirkland, 2005). Granites dated at 976±3 Ma (n=3) are found in the lowest structural levels. Deformation of the enclosing psammite is constrained between c. 980 Ma and c. 1025 Ma. Within the higher nappes Neoproterozoic deformation events at 709±4 Ma (Snøfjord) and pre dating 840±5 Ma (Porsanger) are indicated. Deposition of the upper nappes occurred between 840–910 Ma. Sedimentary units cannot be regionally correlated across nappe boundaries. These disparate terranes were juxtaposed during the Porsanger Orogeny.

Based on the detrital zircon populations and the age of deformation the upper nappes bear striking similarity to those from the Moines of the NW highlands of Scotland. The lower nappes show strong correlation to the Krummedal supracrustal sequence of Greenland. The sediments of the KNC and most likely the correlative Seve nappe, were not deposited within an opening Iapetus Ocean. The sediments in all these nappes are distinctly older. The detrital zircon populations of the KNC indicate some Laurentian affinity.

The evolution of the KNC likely involved a sequence of volcanic arcs that rimmed the Rodinian margin in the earliest Neoproterozoic. Erosion of material from these uplifted arcs produced new successor basins that themselves were tectonically shortened. The classic model for the development of the Scandinavian Caledonides must now recognise that the middle allochthon represents exotic Neoproterozoic Rodinian margin sediments that formed a distinct mobile belt that was only later accreted onto Baltica.

Kirkland, C.L. et al. (2005). Precambrian Res.

Geochemistry and age of the Baltic Sea brown and red quartz porphyries.

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The petrography, geochemistry and U-Pb zircon age of the Baltic Sea brown and red quartz porphyries have been investigated from erratic boulders. The plutons are exposed only under the sea between the Gotland island and Åland archipelago (Milthers, 1933, Koistinen, 1996) and thus the rocks can be found on the mainland only from glacial fans. The samples were collected from the islands of Gotland and Saaremaa and from the coast around Riga Bay.

Both the brown and red quartz porphyry are felsic volcanic rocks with SiO_2 content about 67 and 74 wt.%, respectively. The brown quartz porphyry consists of <1 cm size phenocrysts of sericitized oligoclase and perthitic orthoclase, chlorite-calcitic pseudomorphs (after olivine and pyroxene) and finer phenocrysts of idiomorphic quartz in cryptocrystalline groundmass with reticular quartz. More fine-grained, brick- red quartz porphyry has phenocrysts of idiomorpfic quartz and perthitic orthoclase up to 5 mm long in a cryptocrystalline groundmass with fine-grained quartz, hematized K-feldspar and chloritized biotite. Abundant mafic enclaves, up to few cm in size, exist.

The major and trace element contents of brown quartz porphyry overlap with those of typical Finnish and Estonian rapakivi granites, while the red quartz porphyry is more enriched in Be (up to 50 ppm), Nb (250 ppm), Rb (560 ppm) and REE (with increased Eu negative anomaly) and shows characteristics of more fractionated magma.

In the Rb vs. (Y+Nb), Ga/Al vs. Zr etc. tectonomagmatic discrimination diagrams the compositions of quartz porphyries lie in the field of within plate or anorogenic, i.e., A-type, granites.

The U-Pb zircon age for both brown and red quartz porphyries overlap yielding a common concordant age of 1573±14 Ma.

Milthers, V. (1933). GFF, B55, H1, No 392, 19–28.
Koistinen, T. J. ed. (1996). Geol. Surv. Finl. Spec. Paper 21, 141.

Porosity, an important property of dimension stones

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At the Geophysical Laboratory of the Geological Survey of Finland (GTK) rock porosities have been measured since 1985. Comprehensive experience has been gained both on the measurement procedures and on the behaviour of rock samples under influence of moisture and water. A major conclusion is that in many applications the effective porosity is much more important than the total porosity.

The porosities are determined by water immersion method. In general after 3–5 days´ soaking in water, the surface-dried wet sample is weighed in air and in water. After 2–3 days´ drying in an oven at 105–110 °C temperature the sample is immediately weighed. The measuring program calculates the effective porosity and the dry, wet and grain densities. Measured effective porosities are underestimates because only the interconnected pores and fractures are reached during the immersion.

Estimates of total porosities can be calculated from the measured effective porosities and densities of a homogeneous matrix material, which contains different amount of pores. There is a linear relationship between densities and porosities. The slope between dry bulk density and porosity is equal to grain density, and the slope between wet bulk density and porosity is equal to grain density minus water density. Target rocks of meteorite impacts serve as good examples for total porosity calculations. For example in granites from Karikkoselkä, about 10% of the volume of pores was not filled, while in the mica schists from Paasselkä the corresponding value was only 4%. (Kivekäs, 2005)

The saturation and drying properties are important for the behaviour of dimension stones as to explain their resistance to climate and chemical influence. During immersion the volumes of some soft rock materials even grow remarkably while most plutonic rocks are very stable. The porosity affects strongly many other physical rock properties. Thus saturation and drying properties can be monitored also by resistivity measurements.

Kivekäs, L. (2005). XXII Geofysiikan Päivät, 77–82.

Was shelf-ice collapse triggered by rapid sea-level rise in the Barents Sea during MIS 3?

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The Arkhangelsk region in northern Russia holds a strategic position facing the Barents Sea, north of the ice sheet terminations. Thus, sediment successions from the Weichselian are expected to record the marginal behaviour of all major ice sheets and their mutual interaction. The stage 3 scenario associated with the junction between the Barents and Kara Sea ice sheets is poorly understood, and recent literature has even ceased to distinguish between the two ice sheets.

New evidence from Arkhangelsk identified the widespread occurrence of marine tidal sediments deposited at c. 60 ka BP up to 40–50 m above present. The deposition of the tidal unit is corresponding to rapid eustatic sea level rise and inundation of the sea. We consider this tidal succession an important stratigraphical marker as it divides Barents Sea dominated glaciation, and subsequent Kara Sea dominated glaciations during MIS 3. The Barents Sea glaciation is associated with regional ice flow from NW and the Kara Sea glaciation with ice flow from NE. Both directions are recognized in southward positioned ice marginal moraine system and we suggest that this Markhida moraine and its western continuation are composite in nature over a longer time span. As tidal sediments contain no signal of ice proximity and considering the marginal position of Arkhangelsk relative to open marine conditions, we speculate that the fast eustatic sea level rise – c. 20 metre pr. 1000 years, triggered a rapid ice shelf collapse.

Fast ice flow sustained by its coupling to a decoupled substrate

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In 1890 and again in 1964, the 50 km wide surge-type Brúarjökull on Iceland advanced 10 and 8 km during a few months before it turned into quiescence. During these short surge events ice velocities in the order of 100-200 metres pr. day were reached. The enigma is to understand how such extreme ice velocities were sustained while a streamlined glacial landscape was being re-moulded underneath the ice. The sediment archive in the foreland of Brúarjökull provides the basis for a new model for surge mechanism, which has significant wider implications for ice sheet stability and the mode of operation for fast flowing ice.

The Brúarjökull model: usually, ice velocity distribution during the surge phases includes internal ice deformation – fracturing and sliding at the base – decoupling. Thus, movement across the ice-bed interface accommodates the high ice velocity, probably associated with reorganization of the subglacial hydraulic system. However, subglacial generated landforms at Brúarjökull show distinct evidence of subglacial deformation during the entire surge phase e.g. flutes, therefore a coupling must have existed between the glacier and its substrate. New sedimentological investigations reveal a large system of water escape structures (WES) trending parallel on top of impermeable bedrock, but beneath a 3–4 metre thick ductile deformed sediment succession. This implies that principal ice movement took place beneath this sediment succession that in turn was coupled to the ice and landforming processes. Well drainage areas or 'sticky spots' might have acted as zones of compression within the dislocated sediment succession leading to glaciotectonic ridges such as push moraines and probably concertina 'eskers'.

Controversy on subglacial behaviour driving Antarctic ice streams are intimately linked to ice-bed interaction. We propose the Brúarjökull model might be applied outside Iceland, where ice and its immediate substrate overlie an aquitard.

A need for a new national data model for geological information

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Geological Survey of Finland (GTK) has decided to support and participate in the development of a National Geological Data Model based on conceptual model (NADM-C1). We present: (1) background of the initiative, (2) justification for a new model and (3) challenges identified during the preparatory phase of the project.

Conceptual models are an essential part of scientific understanding and geological observations depend on the objective of the study and knowledge of the observer. The various fields of geology have produced a wide spectrum of terms, classifications and variable database structures form a massive challenge for the organisations responsible for the management of geological information. When aiming to a uniform national database a national data model appears to be a prerequisite.

In addition, the pressure to provide 'harmonised' geological information has been increasing due to: (1) developing information technology, (2) globalisation and demand for 'cross-border' use of geological databases, and (3) new non-geologist users.

Geological information is intrinsically difficult to store in structured databases: geology is a descriptive 3D-science and many features are fundamentally hard to classify. Furthermore, the nationwide data collection can never be a strictly formulated routine process. The key word for the future is flexibility.

Ideally the new National Geological Data Model will exhibit most of the following features:

– it is based on scientifically solid real-world geological concepts and relationships
– it is capable to accommodate (and integrate?) the huge amount of existing heterogeneous and poorly classified geological data/information
– it is flexible enough to handle geological information from various sources
– it can be modified/extended with gaining knowledge and evolving user demands
– its continuous improvement is seen to be in harmony with long-term strategies of GTK
– it is widely accepted by the Finnish geological community and forms a basic framework for data collection in the future.

Sedimentary rocks in Finnish impact structures – pre-impact or post-impact?

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Currently there are nine confirmed impact structures in Finland, and six of them contain remnants of unmetamorphosed sedimentary cover. The age of the sedimentary sequence provides either maximum (pre-impact sequence) or minimum (post-impact sequence) age of the impact event. Careful study of the sedimentary rocks is critical, because convincing radiometric dating is available only for few of the Finnish impact structures.

All the sedimentary rock occurrences are reviewed in order to assess, whether the reported geological features indicate rather pre- or post-impact origin of the sequence. Certain criteria – like presence of fall-back breccia, structural characteristics and presence of shock-lamellae – are applied to assess the nature of the reported sedimentary sequence. The well studied Lappajärvi and Kärdla impact structures are used as references when considering the relative age of the sedimentary units and the impact event.

Most of the geological data concerning the sedimentary rocks in impact structures are from drill cores. This appears to bring some uncertainty to the geological interpretations: (1) blocks are easily misinterpreted as continuous units, (2) fall-back breccia is not easy to distinguish from autochthonous breccia, and (3) large-scale primary structures are difficult to outline. Nevertheless, the results of the review indicate that in most impact structures the pre-impact nature of the sedimentary rocks seems most probable. If the interpretation is true, many impact structures may be considerably younger than the previously presented estimates.

Magnetic record of ordinary chondrite chondrules

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The magnetic record of individual chondrules has been examined on two low-metamorphic grade ordinary chondrites – Bjurböle (L4) and Avanhandava (H4).

The chondrule magnetic conglomerate study was done by removing oriented chondrules from the meteorite matrix and comparing the direction of their (NRM Natural Remanent Magnetization) with respect to each other and to the matrix. The direction of the NRM of the chondrules seems to be randomly oriented within the meteorite.

The low-filed magnetic contamination test was performed on the chondrules and significant fraction of uncontaminated chondrules was selected for further investigations.

The paleofield method (Kletetschka et al., 2003) based on the REM ratio (NRM/SIRM; Saturation Isothermal Remanent Magnetization) reveals approximate paleofields between 5 μT and 20 μT (REM ~ 0.002) for Avanhandava chondrules and between 12 μT and 45 μT (REM ~ 0.0015–0.0048) for Bjurböle chondrules.

We were able to select a significant fraction of chondrules that contains stable remanent directions that is unlikely to be contaminated by exposure to artificial and geomagnetic field and terrestrial temperatures. That suggests together with random orientation of NRM directions that chondrules acquired their NRM prior their aggregation to the meteorites parent bodies at much higher fields that in present interplanetary space.

Kletetschka G. et al. (2003). Meteoritics & Planetary Science 38, 399–405.

New observations of the Au and PGE nuggets in the Ivalojoki and Lemmenjoki areas, Finnish Lapland

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Placer gold and platinum-group element (PGE) mineral nuggets were studied from Ivalojoki and Lemmenjoki tributaries of the Paleoproterozoic ca. 2 Ga granulite belt in Finnish Lapland. The nuggets were recovered from glaciofluvial river gravels, sands and terraces, poorly sorted sandy till and weathered bedrock (Saarnisto et al., 1991). The NE-SW trending river valleys define the main fault and shear zones that cut the general strike of the strongly strained metasedimentary and magmatic rocks. Smaller creeks define shear zones sub parallel to shallowly NE dipping foliation. The mean Au content of the different soil types sluiced is 0.35 ppm (N=251, claims and mining concessions in 2004), standard deviation is 0.71 ppm and Au content in the weathered bedrock 11 ppb (N=54)(Saarnisto et al, 1991).

A total of 40 platinum group minerals (PGM) were recognized with gold and Au-Ag alloy nuggets in the heavy mineral black sands. The PGM exist as individual grains or as inclusions in larger PGM grains (Törnroos & Vuorelainen, 1987; Kojonen et al., 2005).

The great variety of PGM suggests a complex and multi-stage mineralization in the source rocks and a close origin. Gold and PGM concentrated during weathering, erosion, glaciofluvial and fluvial processes from the layered amphibole-pyroxene rocks, volcanogenic greenstones and hydrothermal quartz-carbonate veins. The microscopic intergrowth textures of limonite with native gold inclusions suggest secondary nugget growth in the regolith profile during weathering and short transport from the source (Lawrance, 2001).

Kojonen, K. Tarkian, M., Knauf, V.V. & Törnroos, R. (2005). 10th Int. Platinum Symp. Oulu, Finland, Abstract Vol., 145–149.

Lawrance, L.M. (2001). Geochem. Exp. Env. Anal. 1. 323–339.

Saarnisto, M., Tamminen, E. & Vaasjoki, M. (1991). J. Geochem. Expl. 39, 303–322.

Törnroos, R. & Vuorelainen, Y. (1987). Lithos 20, 491–500.

Nd isotope variation across terrane boundaries in the North Ladoga Area, Russian Karelia.

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In order to investigate the nature of terrane boundaries in the area north and west of lake Ladoga, 20 samples of mostly granitoid rocks, collected along the 180 km-long profile, were analysed for their Nd isotopic composition. About 35 previously published Nd data were incorporated in the dataset. It was established that gneisses from the mantled domes around the town of Sortavala have very low ε_{Nd} values and represent reworked Archaean basement. North of the Kirjavalahti Dome, the presence of Archaean basement under Kalevian sedimentary cover is registered by low ε_{Nd} values in the rocks of the 1874+13 Ma-old Alattu dyke complex. The transition from Archaean to Proterozoic crust is registered by a shift from very low to Bulk-Earth-type ε_{Nd} values and occurs within a 10–20 km-wide zone corresponding to the suture between the Archaean Karelian Craton and Paleoproterozoic Svecofennian Orogen. The rocks of the Svecofennian Orogen south of the suture are characterized by relatively uniform initial Nd isotopic composition (average ε_{Nd} value at 1880–1860 Ma +0.3, n=24). In terms of Nd isotopic composition, the Svecofennian terranes in the North Ladoga area are comparable to the Svecofennian terranes to the west: the Central Finland Granitoid Complex and the Accretionary Arc Complex of Southern Finland. The Primitive Arc Complex of Central Finland has, in contrast, significantly more juvenile Nd isotopic composition.

Magnetic signatures of Archean and Proterozoic magmatic and metamorphic events in the Lieksa area, eastern Finland

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Geophysical data, in particular airborne magnetic surveys, are increasingly valued in regional geological studies. However, caution is required in interpretation, not only due to the ambiguity in modelling depth and dimensions of anomaly sources but also in understanding the extent to which primary magnetization is influenced by subsequent geological processes. This latter issue can be turned to advantage, by careful documentation of hydrothermal and metamorphic mineral parageneses together with petrophysical and paleomagnetic analysis. In an ideal case, it may then be possible to correlate diagenetic, metamorphic and hydrothermal events in relation to large scale geodynamic or metallogenic events and processes (cf. Idnurm, 2000; Airo, 2002).

Here we report results of a study from eastern Finland, where Neoarchean granitoids recording a prograde lateral metamorphic gradient from upper greenschist to granulite facies were overprinted by a Paleoproterozoic thermal event which invariably reset K–Ar systematics in biotite and commonly in hornblende (Kontinen et al., 1992). We find that strong regional magnetic anomalies coincide with the presence of magnetite and pyroxene in granulite facies assemblages. Some localities within granulite facies granitoids retain a distinctive Archean remanence component carried by recrystallized pseudo-single domain (PSD) magnetite produced by clinopyroxene alteration. In contrast, areas of regional retrogression or structurally focussed fluid-rock reaction correlate with absence of pyroxene and recrystallized magnetite, destruction and alteration of coarse-grained magnetite, and overall magnetic instability; provisional paleomagentic data are consistent with a late orogenic Svecofennian, rather than younger age for this hydrothermal overprint.

Airo, M-L. (2002). Surveys in Geophysics 23, 273–302.
Idnurm M. (2000). Australian J. Earth Sciences 47, 405–429.
Kontinen, A., Paavola, J. & Lukkarinen, H. (1992). Geological Survey of Finland Bulletin, 365, 31 p.

Tectonic stacking and collapse of the upper crust along FIRE 1

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The 500 km long FIRE 1 deep seismic reflection profile crosses over a major Paleoproterozoic plate boundary in the Fennoscandian Shield – the Svecofennian – Karelian suture zone, where Archean Karelian craton and its cover have been juxtaposed with the Paleoproterozoic Svecofennian island arc rocks during the Svecofennian Orogeny, c. 1.9 Ga ago.

The uppermost 8 km of the crust along FIRE 1 is composed of ten units belonging to three tectonic domains: Archean nucleus, A-P boundary zone and Proterozoic Central Finland. During the continental arc/continent collision the Western Kianta block, Kainuu Belt, Kajaani, Rautavaara, Iisalmi Complexes as well as Savo Belt belonging to the Archean Proterozoic boundary zone were all thrust sequentially on the Eastern Kianta block belonging to the Archean Nucleus. The scale of thrusting varies from less than 1 km to 10–20 km thick stacks where the deformation is concentrated mainly to the block boundaries.

In the collision, also the Proterozoic Central Finland (Keitele) was thickened due to westward stacking of 25 km thick crustal slices. In the upper crust, gravitational collapse is displayed in the Central Finland Granitoid Complex, a shallow (3–8 km) upper crustal unit, whose lower surface is a detachment zone. The detachment surface is associated with upper crustal graben and horst -structures.

Electrical conductivity of the Scandinavian Caledonides and the underlying lithosphere, Jämtland, Sweden

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We use five component magnetotelluric data from 60 sites along a 175 km long profile across the Caledonian orogen to explore electrical conductivity beneath the Central Scandinavian Caledonides in Jämtland, north-central Sweden. Data were collected in two phases. First phase provided AMT-MT data from 0.001 s to 100/1000 s and the second phase long period data reaching periods up to 10000 s. Combined data, covering period range from 0.001 s to 10000 s, yield information from near-surface to upper mantle. Our study focuses on determining the electrical conductivity of the (near-surface) accretionary wedge of the Caledonian orogen as well as the underlying autochthonous/parautochthonous carbonaceous alum shales. We investigate also the electrical conductivity of the Precambrian crust beneath the Caledonides and the deep margin of the Fennoscandian lithosphere.

The resulting model reveals remarkable subsurface resistivity variations ranging from less than 0.1 Ωm to over 100000 Ωm in the accretionary wedge and in underlying Precambrian basement. Main features of the model are:

(1) an electrically highly conducting layer beneath the Caledonides that images alum shales, the autochthonous Cambrian carbon-bearing black shales on top of the Precambrian basement,

(2) to the east of the Caledonian front, the autochthonous Precambrian basement is highly resistive with resistivities exceeding 100000 Ωm. The resistive unit extends far to the west beneath the Caledonides suggesting the presence of resistive basement granites under the Caledonides,

(3) a region of enhanced conductivity is detected at the depth of c. 150 km under the Caledonides in the western border of the Fennoscandian Shield yet the conductor is absent beneath the eastern part of the profile in the Fennoscandian Shield, proper.

Surface and groundwater quality in the Aijala and Hitura sulphide mines – AMD versus NMD

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Chemical quality of surface and groundwaters in the surroundings of the Hitura Ni mine and the abandoned Aijala Cu-Zn-Pb-Ag mine were compared. In Aijala, tailings have been dammed in a topographic depression. The upper part of the mine waste is oxidized which results in elevated metal and sulphate concentrations in tailings waters and groundwaters close to the facility, reflecting a rather typical AMD (Acid Mine Drainage). Surface waters discharging from the facility area are slightly acid and contain less sulphate and metals than the tailings waters due to precipitation in brooks. In Hitura, the wastewater and tailings are pumped as a slurry into an impoundment located near the mill. Groundwater contamination with sulphate, nickel and chloride close to the tailings facility has been reported (Heikkinen et al. 2002). Surface and groundwaters discharging from the tailings area represent NMD (Neutral Mine Drainage) influence (pH near neutral).

In both sites the main anion-cation relationships show that the impact of the mine can be detected in water chemistry even in low concentrations. Waters discharging from the tailings areas are of Mg-SO_4 – type, and in the surroundings, contamination is seen as a change from Ca-HCO_3- type water towards Ca-Mg – HCO_3-SO_4 –type water. This study shows that in environmental studies of mine areas, it is essential to understand the general chemical composition of the surrounding waters, affected by the ore type and the milling process.

Heikkinen, P.M., Korkka-Niemi, K., Lahti, M. & Salonen V-P. (2002). Environmental Geology 42, 313–329.

OSL chronology for a sediment core from the southern Baltic Sea; a complete palaeoenvironmental record since deglaciation?

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The post-glacial history of the Baltic Sea is characterized by large water level and salinity changes related to opening and closing of the connections between the Baltic basin and North Atlantic Ocean. Previous studies to date these changes in the southern Baltic were mainly conducted in coastal settings with abundant organic material for ^{14}C dating. Many of these records are, however, discontinuous due to the large water level fluctuations as the connections opened and closed. In contrast, in the 45 m deep Arkona basin, the sediment record is thought to be continuous. Few studies have been carried out in this region, partly because low organic carbon contents and lack of macrofossils impeded dating of these sediment records.

We report on investigations of a 10.86 m long sediment core from the centre of the Arkona basin. We have investigated palaeoenvironmental proxies for water level and salinity as indicators of the North Atlantic linkage. Chronological control is based mainly on Optically Stimulated Luminescence (OSL) ages. Internal tests of luminescence characteristics confirm the suitability of the material for OSL dating and the resulting OSL chronology compares satisfactorily with the more restricted set of radiocarbon ages on shells. The Baltic Ice Lake drainage appears to occur ~11.6 ka, agreeing with other published evidence. However, the main marine Littorina transgression appears in our core at ~6.5 ka, which is ~2 ka younger than suggested by terrestrial-coastal sites (Yu et al., 2005), but consistent with other marine studies (Moros et al., 2002).

Moros, M., Lemke, W., Kuijpers, A., Endler, R., Jenssen, J.B., Bennike, O., Gingele, F. (2001). Boreas 31, 151–162.

Yu, S., Andrén, E., Berglund, B.E., Sandgren, P., Fritz, S.C. (2005). The Holocene 15, 278–292.

HRSC mapping of crater floor depressions in Hellas region, Mars

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The region surrounding the 2000 km Hellas impact basin on Mars is dominated by ancient highlands, almost saturated with impact structures of various sizes. These craters have been modified by later processes, e.g. sedimentation/erosion. This study uses HRSC data and focuses on the distribution of craters with anomalous depressions (CWD), which create a major cluster near Hellas (Korteniemi et al., 2005).

The depressions in question are usually small and irregular collapses (width <10% of crater diameter) found on the crater floor. Similar features do not occur outside of craters and usually the CWDs are not connected to fluvial channels or other material transport ways. In our previous studies using Viking images (e.g. Korteniemi, 2003), we found 78 CWDs in the Hellas region, with a clear concentration (70%) on the western side of the basin.

The HRSC data set (by 9/2005) does not extend into the W Hellas rim cluster. Instead, it covers the E/N rim. Here, in contrast to the 23 CWDs found from Viking, HRSC images show 113 examples. Two types of depressions previously unknown to exist in the region were recognized. 1. Rugged/etched depressions (on Hellas rims), interpreted to be result of erosion of sedimentary materials with varying durability (i.e. yardang-like features). 2. Web-like fissures (crater-concentric/radial, found on Hellas floor) are similar to those commonly found near the dichotomy boundary. Those have been suggested to be result of deformation by fluvial and/or volcanic activity.

The depressions are located in areas with no major volcanism or glacial/fluvial activity. The amount of collapse features in Hellas rim craters is overwhelming compared to the surrounding regions, indicating major differences in surface processes and/or materials. This probably relates to a higher rate in both sedimentation and subsequent erosion around Hellas. The depressions are preliminarily thought to be result from water/ice escaping from the old sediments, creating karst-like sublimation pits. This may indicate that large water reservoirs still exist in the ground around Hellas.

Korteniemi J. (2003). 3rd Conf. on Large Meteorite Impacts, Nördlingen, Germany, abstract #4091.

Korteniemi J. et al. (2005). JGR Planets, In press.

Analysis of the Reull Vallis fluvial system, Mars

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The region between Hesperia Planum and Hellas basin is one of the main areas with outflow channels on Mars. One of these channels, Reull Vallis, begins in Hesperia Planum and runs from east to west across the northern portion of Promethei Terra. In this work we present a new hypothesis for the evolution of Reull and its complimentary fluvial system. Our analysis suggests that the fluvial system consists of several distinct parts that have different origin and age.

Morphologic characteristics and topographic configuration of the different parts of the fluvial system suggest the following sequence of major events during its formation: The oldest parts of the system appear to be: 1) the Teviot-lower Reull Vallis (beginning at ~44°S, 258°W) and 2) the provisionally named subsystem of Morpheos Trough–Vallis–Basin (beginning at ~31°S, 246.5°W). These two oldest parts probably formed independently as they are not connected; relative ages between them cannot be established. The last episode of the evolution of the Reull Vallis fluvial system was formation of the upper Reull (beginning at ~37.5°S, 247°W) due to discharge of the Morpheos Basin reservoir. Topography along the upper Reull and secondary channels near its end suggest that water was ponded during formation of the upper Reull. This ponding may have resulted in erosion, deposition, and resurfacing of an area around both the upper and lower Reull. Note that the volume of water that potentially may have been stored within the Morpheos Basin is about an order of magnitude larger than the volume of material removed from the upper Reull.

The whole evolution of the system appears to be consisted of three major episodes: (1) formation of the lower Reull (apparent beginning of it is the Teviot Vallis), (2) formation of the Morpheos fluvial subsystem (these two episodes may or may not be contemporaneous), and 3) formation of the upper Reull that connected the Morpheos sub-system with the lower Reull. The crater retention ages we are consistent with apparent sequence of events during formation of the Reull Vallis fluvial system.

Granitoid intrusion emplacement geometry in the Karstula area of the Central Finland Granitoid Complex – evidence from geophysical data

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The Central Finland Granitoid Complex (CFGC) is transected by two deep seismic reflection profiles, FIRE 1 and 3. The SW-NE running FIRE 1 crosses the NW-SE trending FIRE 3 at Karstula in the NW part of CFGC. This, combined with other geophysical data and geological field observations, enables 3-dimensional study of granitoid intrusion emplacement geometry in the area.

The rocks of the Karstula – Saarijärvi area comprise 1.89–1.88 Ga synkinematic granodiorites and granites, 1.88 Ga postkinematic granites, minor mafic intrusions and volcanic to subvolcanic rocks. The granitoid intrusions appear as featureless, poorly reflecting areas in the seismic sections, separated by more reflecting crustal material and locally outlined by poorly reflective lineaments interpreted as shear zones. In the aeromagnetic anomaly maps the more magnetic mafic and supracrustal rocks of the area form local anomaly maxima in the background composed of granitoid intrusions. The postkinematic Karstula and Saarijärvi granites are displayed as featureless magnetic minima and as shallow (3–4 km), bowl-shaped intrusions in the seismic sections.

Several NW-SE trending shear zones are clearly defined in the aeromagnetic anomaly maps and are found on FIRE 1 as relatively steep, NE or SW dipping lineaments transecting the uppermost 8 km of the crust. Southwest of Karstula, one of these shear zones defines the edge of the postkinematic granite and, contrary to the aeromagnetic evidence, at least one of the shear zones also truncates the Karstula postkinematic granite. FIRE 3 is characterized by shallow, SE dipping listric structures, which flatten out between the depths of 8 km and 10 km; these structures seem to be associated with NE trending changes in magnetic anomaly levels. It seems likely, that these shear zones and listric structures controlled the emplacement of at least the postkinematic granites, probably under transtensional or extensional tectonic regime.

Subarctic aeolian deposits – forecasting stable dune environment with global warming

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Global climate change is affecting the arctic region extremely intensively with increasing temperatures and precipitation rates (ACIA, 2005). Holocene aeolian activity is indicative of climate change, especially in the arctic and subarctic regions (*e.g.* Koster, 1988). The interaction between climate and aeolian activity is sensitive even to small changes in precipitation (Stetler & Gaylord, 1996).

We have studied two dune fields from Finnish Lapland to reveal subarctic aeolian history during the Holocene and thus to provide future changes in wind stress in these fragile regions. A total of 75 dune sections were studied and 54 conventional radiocarbon dates and 4 AMS dates of buried charcoal horizons were used for reconstructing the detailed aeolian reactivation chronology (Kotilainen, 2004).

The results suggest that five reactivation phases occurred during the Holocene and several of them can be connected with other climate proxies. During warmer climate phases the dune fields have been more stable, *e.g.* during the Medieval Warm Period.

The aeolian stability during warm and moist conditions suggests that as a result of future global warming the stability of subarctic dune fields could be enhanced, which is good news for their preservation. Global warming causes severe problems in the high latitudes (ACIA, 2005) but at the same time the forecast for the preservation of aeolian landforms becomes better. However, extra care should be taken in land use management of this fragile subarctic aeolian environment in the future.

ACIA Scientific Report (2005). 952 p.

Koster, E.A. (1988). Ancient and modern cold climate aeolian sand deposition: a review. Journal of Quaternary Science 3, 69–83.

Kotilainen, M. M. (2004). Dune stratigraphy as an indicator of Holocene climatic change and human impact in northern Lapland, Finland. Annales Academiae Scientiarum Fennicae, Geologica-Geographica 166, 154 p.

Stetler, L. D. & Gaylord, D. R., (1996). Evaluating eolian-climatic interactions using a regional climate model from Hanford, Washington (USA). Geomorphology 17, 99–113.

Geographical Variation of Acute Myocardial Infarction (AMI) and Geochemistry of Ground Water in Rural Finland

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The incidence of coronary heart disease (CHD) is high in the Finnish population. Within the country, the high CHD incidence in eastern Finland compared to southwestern Finland is well recognized. The conventional risk factors (serum cholesterol, hypertension and smoking) explain only part of this variation. In this small area study the relationship between acute myocardial infarction (AMI) risk and content of Ca, Mg and Cr in local ground water in Finnish rural areas was examined using Bayesian modelling and geospatial data aggregated into 10 km x 10 km cells. The well water data on Ca, Mg (mg/l) and Cr (µg/l) were obtained from the database of the Geological Survey of Finland (GTK). The data on men aged 35–74 years with the first AMI (14495 cases) in the years 1983, 1988 and 1993 from rural Finland were obtained from the National Death Register and the Hospital Discharge Register. The data on population at risk were obtained from Statistics Finland. Data for three cross sectional years were pooled. The age group and Ca, Mg, Cr concentrations and Ca/Mg ratio in the well water were included in the model as covariates.

We estimated that other things being equal a one-mg/l increment in Mg concentrations in ground water decreased the AMI risk by 4.9 % an average while one unit increment in Ca/Mg increased the AMI risk by 3.1 %. Ca and Cr did not have any additional effect on the spatial variation of the AMI incidence. Results of this study support previous findings of a protective role of Mg and low Ca/Mg against coronary heart disease but do not support the hypothesis of a protective role of Ca. The results also confirm the previous findings that drinking water was not an important source for Cr supply.

The availability of geo-referenced (health) data and advancing spatial statistical methodology provide valuable tools for study of spatial pattern of disease incidences in public health research and for finding etiologic clues about risk factors causing the disease.

Impact Craters on the Northern Lowlands of Mars.

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The Northern Lowlands of Mars contain the Vastitas Formation (VF), the largest uniform geomorphologic unit on Mars having a uniform age of ~3.1 Ga corresponding to the Hesperian/Amazonian boundary in the Martian geochronology. We report on conclusions derived from our systematic surveys of morphology and morphometry of the impact craters and other circular features within this unit.

Craters larger than 5–10 km form an accumulation population. Their modification reflects the alteration processes that occurred through the Amazonian epoch. Wall erosion by debris flows occurred probably during brief rare episodes of suitable climate. The latest series of such episodes is related to a series of spin obliquity peaks 5–10 Ma ago and recorded in numerous recent gullies. Craters are progressively filled with slowly creeping icy material that form concentric and arcuate crater fill patterns and large polygons with typical ice-wedge morphology. Trapping of migrating sand could also contribute to the crater filling. Both wall degradation and crater filling occur at ~1 Ga time scale. Smoothing of crater ejecta is much quicker process operating at 10–100 Ma time scale. The mechanism of smoothing is fill of small-scale local lows with icy material.

There is a relative shortage of smaller craters. However, there is a large population of quasi-circular features that represent strongly modified and completely filled craters. These features down to ~0.5 km diameter may still represent accumulation crater population. Old smaller impact events are completely erased from geological record. Some 100s of meters wide quasi-circular features may have non-impact origin.

The surface of the VF at high latitudes (>55°N) is almost completely covered by icy mantle with specific patterned surface. The number of impact craters superposed over this pattern is very small, and the uppermost mantle layer is very young. It may be related to the latest moderately high obliquity peaks 0.5–1.5 Ma ago and/or to the gradual transition from generally high obliquity 2–4 Ma ago.

A new Internet based information system GeoTIETO for land use planning in the Helsinki capital region, Finland

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The Helsinki Capital region covers the most densely populated part of Southern Finland. Several infrastructural projects are planned in this region. At the same time there is an increasing demand for sustainable development and land use planning by society. Traditional geological maps do not meet these needs and new mapping concepts are required in urban areas. Another problem in some cases is that even though important information has already been acquired, access to that information can be difficult.

In order to improve geodata quality, the Geological Survey of Finland is currently undertaking new styles of bedrock, Quaternary deposits and urban geochemical mapping in the Helsinki region. In addition to mapping, a project was initiated in 2003 together with nine public and private organisations to develop a completely new geological information system (GeoTIETO) for land use planning. The basic idea is to offer users continually maintained and updated geological data and supporting material from the desired area and at the desired scale, directly through an Internet-based GeoTIETO-portal. The datasets will include geological maps (bedrock maps at 1: 50 000 and Quaternary deposit maps at 1: 20 000) and uniform geological databases such as soil and bedrock drillings, rock aggregates, geophysical data, relief models, topographic maps, aerial photographs and land use information. Users will be able to easily combine and display several data layers, make searches and analyse geological information using a Web browser. In addition to the new urban bedrock maps, new kinds of Geomodels (maps of soil and bedrock quality for construction purposes) at scales 1: 20 000 and 1: 5 000 have been developed in the project.

The GeoTIETO information system is already being utilized by the participants of the project. The system will be complete in 2006 and later its geographical coverage will be extended to other densely populated areas in Finland.

Outokumpu Deep Drilling Project: First results and status of research

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The Geological Survey of Finland is carrying out a deep drilling research project at Outokumpu, eastern Finland. In January 2005, the Outokumpu deep drill hole reached the final depth of 2516 m within a Palaeoproterozoic metasedimentary and ophiolite-related sequence. The basic drilling program included continuous coring and borehole geophysics with 20 different methods, as well as fluid sampling and hydraulic conductivity measurements in the hole.

The main criteria that motivated the Outokumpu Deep Drilling Project are as follows:

(1) Understanding the deep structure of a classical ore province in Precambrian terrain. The Cu-Co-Zn deposits of the Outokumpu district, hosted by a distinct 1.96 Ga old ophiolitic assemblage formed an important mining area for about 80 years. The ore potential is still considered high; (2) Understanding the composition and origin of the saline fluids and gases identified in earlier drill holes in the Outokumpu region, and studying the deep biosphere;

(3) Investigating the vertical variation of different geological and geophysical parameters and correlating geological, geophysical and petrophysical data sets;

(4) Using the Outokumpu hole as a deep geolaboratory for various in situ experiments, fluid sampling and monitoring.

The Outokumpu Deep Drilling Project has already produced several important observations regarding the nature of seismic reflectors, deep gas-bearing fluids, and detection of a thick layer of pegmatitic granite at depths of 2.0–2.5 km and extending probably much deeper, previously unknown in the Outokumpu area.

Research projects in the framework of the Outokumpu Deep Drilling Project are currently in preparation or already being carried out by several teams representing Canada, Czech Republic, Finland, Germany, Netherlands, Norway, Russia and Sweden. The Outokumpu project is receiving support from ICDP, and geophysical logging, stress field studies, hydrogeological studies, a VSP seismic experiment, and a fluid injection experiment are being planned for 2006–2008.

FIRE reflection seismic transects: New images of the crust in the Fennoscandian Shield

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The FIRE (Finnish Reflection Experiment) consortium – consisting of the Geological Survey of Finland, and Universities of Helsinki and Oulu, with Russian company Spetsgeofizika S.G.E. as a contractor, carried out a total of 2165 km of Vibroseis measurements in the central part of the Fennoscandian Shield in 2001–03. The four FIRE transects run over the most important geological units of the central Fennoscandian Shield with crustal ages ranging from about 2.8 to 1.6 Ga. As expected in any areas previously not covered with crustal scale reflection profiles, the FIRE transects have opened a completely new perspective for the understanding of the crustal structure in the Fennoscandian shield. Domain boundaries between the Archaean and Proterozoic rocks show both extensional features due to break-up of the craton, and subsequent collional stacking during the Svecofennian orogeny (about 1.9–1.8 Ga). Major boundaries within the Proterozoic are also clearly imaged. A good example is the boundary between the Central Finland Granitoid Complex and the Tampere Schist Belt in southern Finland which shows reflectors with opposed dips and contrasting structures on different sides of the boundary.

This presentation provides an overview of the project and reviews some of the most important results.

Let the PC do your teaching

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Today, most students at the universities of the Nordic countries have their own computers with high-speed access to the web. The computers are highly advanced multimedia machines and our students use them when they are chatting with friends on the internet, watching movies, playing games, reading newspapers, and so on. Would it not be great if some of the time that our students are spending in front of their computers could be used for learning geology? They could for example follow an *electronic lecture*!

Nearly everything that is presented in a traditional lecture can be digitalized and presented as an electronic lecture. But electronic lectures, or *e-learning modules*, may have many other types of contents than traditional lectures, including video clips and animations. These types of contents should not be incorporated in e-learning modules in order to make the modules look fancy. The prime reason for incorporating video clips and animations in e-learning modules is that such contents make it much easier for the teacher to explain and the students to understand complex geological processes.

This talk will give some examples on the types of content that are possible in e-learning modules, and some examples of e-learning modules will be demonstrated. Completely computer-based internet courses including exams will also be addressed.

U–Pb constraints on the Archean and Early Proterozoic evolution of the West Troms Basement Complex, North Norway

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The Precambrian rocks of the West Troms Basement Complex (WTBC) occur on the islands along the west coast of the Troms region of northern Norway. The north-eastern part of the complex is dominated by tonalitic to anorthositic and gabbroic migmatitic gneisses. These gneisses are tectonically overlain by the Ringvassøy Greenstone Belt. The central and south-western parts of the WTBC are dominated by migmatites and granitic rocks that have intruded the surrounding gneisses discordantly. Earlier reconnaissance studies have documented the presence of both Archean and Proterozoic components within the WTBC (e.g. Andresen, 1979; Zwaan & Tucker, 1996).

New U–Pb zircon data show that the tonalitic gneiss that dominate in the northernmost part of the WTBC intruded c. 2885 Ma ago. Two intrusive rocks belonging to the overlying Ringvassøy Greenstone Belts yield U–Pb zircon ages around 2830 Ma. Granite pegmatites (U–Pb zircon) and a nepheline syenite (U–Pb titanite) that crosscut the tonalitic gneiss give ages around 2700 Ma. Similar U–Pb zircon ages are recorded from granitic and dioritic gneisses on southern Kvaløya and from a tonalitic gneiss on western Senja. Mafic dykes that crosscut the tonalitic gneiss on Ringvassøya were emplaced c. 2400 Ma ago (U–Pb zircon and baddeleyite). These dykes correlate broadly with a global Paleoproterozoic magmatic event that formed extensive bimodal intrusive and extrusive suites in most Archean cratons including the northeastern Fennoscandian Shield. On Vanna, dioritic sills that intruded metasedimentary rocks yielded a U–Pb zircon age of c. 2220 Ma. These sills may be correlated to some of the Paleoproterozoic suites in Finland (Kuusamo) and in Canada (Nipissing diabase).

Andresen, A. (1979). Geol. Fören. Stockh. Förh. 101, 291–298.

Zwaan, K.B. & Tucker, R.D. (1996). Abstract, 22nd Nordic Geol. Winter Meeting, p. 237.

The lateorogenic granites of southern Finland—A belt of igneous activity over a period of at least 60 Ma

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Prolonged, exclusively felsic magmatism occurred in southern Finland after the ~1.89–1.87 Ga collision of the arc complex of southern Finland and the collage of previously accreted Paleoproterozoic and Archean blocks of Fennoscandia, resulting in the late Svecofennian granite migmatite zone (LSGM). Considerable age differences are observed along the zone. Both ID-TIMS and ion microprobe U-Pb mineral ages obtained from 24 granite samples from the LSGM zone cover a continuous range of emplacement ages from ≥1.85 Ga to about 1.79 Ga. Hence, they significantly overlap in time with the ~1.81–1.77 Ga postorogenic granitoid rocks. Nevertheless, these two groups can be easily distinguished on the basis of their mode of occurrence, lithology, and geochemistry.

The youngest ages within the LSGM zone are found in the east, but generally, the geographic distribution of the ages is fairly irregular. Also, the amount and ages of inherited zircons with preserved U-Pb isotopic ratios seem to vary considerably. In the western part of the LSGM zone, the dated zircon domains almost invariably display mutually similar ages, mostly about 1.84–1.83 Ga. In the east, however, the cores commonly display U-Pb ages between 2.7 Ga and 1.87 Ga, whereas the rims are typically of the order of 1.82–1.80 Ga. Also, the distribution of inherited ages in individual samples varies from diverse to bimodal and even single-stage. The differences in zircon inheritance patterns could indicate that the granites were derived from different types of source rocks.

Composition and Microstructure of Soapstone – Base to Material Sustainability and Thermal Shock Resistivity

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The AGI glossary defines Soapstone as "a metamorphic rock of massive, schistose, or interlaced fibrous or flaky texture and soft, unctuous feel, composed essentially of talc with varying amounts of micas, chlorite, amphibole, pyroxenes, etc. and derived from the alteration of ferromagnesian silicate minerals. It may be sawed into … special-purpose dimension stone". This kind of broad definition collects very wide range of different rock types under the all-purpose name "soapstone", and thus more detailed practice to naming and classification is required.

Finnish soapstones contain, in addition to talc, carbonates, chlorites, serpentines or amphiboles as the most essential constituents but element proportions may vary widely. Requirements for material properties are based on the wishes from soapstone utilizing industry while mineral specific properties such as e.g. hardness, elasticity, solubility, coefficient of heat expansion, specific heat and temperature of thermal decomposition define physical property limits for every type of mineral aggregate. Due to wide variation in mineral composition, variation in properties of different soapstone types is very wide and this variation is augmented by extensive variation in the microscopic textures, which increases the need to clarify the soapstone concept.

Utilization of soapstone as a building material of furnitures is economically the most important branch in the usage of Finnish soapstone. Warming up a furniture gives always a thermal shock to the components of it and good resistance against that physical exertion is one premise for acceptable building materials. Standardized test, "Determination of resistance to thermal shock", is an excellent, integrating method to classify soapstone materials. Weak soapstone types yield actually low result in this test while strong variants may give the highest grade. Good understanding of this behaviour would be essential for specialists planning furniture structures as well as common, extensive knowledge of soapstones for development of sustainable and versatile economic usage of soapstone materials.

Structural Evolution of the Olkiluoto Site – One Precursor to Factors Controlling the Bedrock Usability as a Nuclear Waste Disposal Site

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The Olkiluoto Site in the SW Finland is a part of Paleoproterozoic, Svecofennian migmatite complex of metasedimentary and metavolcanic origin. Supracrustal rocks underwent a thermal event, leading to the high grade amphibolite facies assemblages biotite-cordierite-sillimanite and to dehydration melting reactions at 4–6 kbar and 700+/-50 °C, followed by retrogression in greenschist and lower facies.

During the Svecokarelian orogeny, ca. 1910–1870 Ga ago, the domain has been subjected to ductile deformation, including five stages. Relicts of lithological layering with (sub)parallel S_1 foliation represent the oldest observed structural features. Stage D_2 is characterized by tight to isoclinal, thrust related folding and leucosome production, followed by stage D_3 leading to rotation and refolding of earlier structures and generation of ductile D_3 shear zones dipping gently to the SSE. Subsequently the D_3 and earlier elements were redeformed by stage D_4, which produced zones dominated by close to open F_4 folds with axial planes dipping to the SE. These deformation zones have been localized in the central and eastern part of the Olkiluoto study site where also coplanar, gently SE dipping D_4 shear zones seem to occur. The latest ductile structures are the very open F_5 folds with axes plunging to the ESE and axial planes dipping to the SSW.

In the metamorphic evolution, the last cooling below 300 °C took place ca. 1600 Ma ago leading to long standing period of brittle deformation. Recent studies have shown evidently that majority of brittle fault planes is coplanar with gently dipping, pervasive (S_2 .. S_4) foliations. Detailed analysis of kinematic indications show that the number of cogenetic phases of brittle faulting will be rather big and the final system of brittle faults intersecting the central part of the Olkiluoto study site will be more complex than shown in previous bedrock models.

Fracture and talus breccia zone at the base of the Svinsaga Formation, central Telemark, South Norway indicators of Mesoproterozoic frost weathering action

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The ≥1155 Ma angular sub-Svinsaga unconformity (SSU) subdivides the Mesoproterozoic Telemark supracrustal belt into the Vestfjorddalenian (c. 1500 – ≥ 1155 Ma) and Sveconorwegian sequences (c. 1155 – 1145 Ma). The uppermost part of the Vindeggen group (1500 Ma) is made up of laminated red orthoquartzite named informally as the upper Brattefjell formation (uB) and overlain unconformably by the breccias, conglomerates and quartzites of the Svinsaga formation (Sf). The SSU is exposed well at several localities, but the unique fracture and breccia zone has been found only at Meien, Sjånuten and Svafjell.

The unconformity starts with a 1–3 m thick fracture zone in laminated uB orthoquartzite. Few mm – cm wide fractures are filled by mudstone or mud-matrixed conglomerate. They have neither preferred orientation nor evidence of tectonic origin. Upwards, the fractures become wider and their margins may be smooth or corroded and the fracture zone passes into basal breccia.

Several meters thick basal Sf breccia and pillow breccia zone consist solely of tightly packed uB quartzite fragments. Up to boulder size fragments may be either sharp (mostly), rounded or corroded. Fragments in the lowermost part of the breccia zone area either *in situ* or have been rotated only slightly by frost heaving and contains only little mudstone matrix. Upwards, the size and sorting of the breccia fragments decrease and the inter-fragment spaces widen and are filled by mudstone or mudstone-matrixed uB orthoquartzite clasts. Here the rock resembles a talus breccia. The breccia zone is overlain by conglomerates and debris flow deposits which passes into parallel-laminated red Sf quartzite.

Both the basal fracture zone and talus breccia fragments are interpreted as products of frost weathering, likely in ancient alpine environment.

The Mesoproterozoic Svinsaga Formation, central Telemark, South Norway: Sedimentological researches and paleocurrent analysis indicate periglaciofluvial braided river depositional environment affected by talus breccia input

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The 150–200 m thick Svinsaga Formation (Sf) is part of the Mesoproterozoic Telemark supracrustals, southern Norway, which start with the 1500 Ma old volcanic-sedimentary Rjukan group. The Sf is overlain by the 1155 Ma old volcanic-sedimentary Ofte Formation and younger supracrustals.

Sf starts with a several meters thick basal fracture and breccia unconformity zone where few cm wide fractures are filled by mudstone or mudstone-matrixed orthoquartzite clasts. In upper parts size and sorting of the breccia fragments degrease and the rock resembles a talus breccia. Basal fracture zone and talus breccia fragments are interpreted as products of frost weathering in ancient alpine environment.

The breccia zone passes into 20–30 m thick debris flow deposits where muddy conglomerate and pebbly sandstone beds consist some minor purple mudstone interbeds. Debris flow deposits are overlain by 50–80 m thick parallel-laminated sandstones with some 1–2 cm thick muddy interbeds.

The upper part of Sf consist about 100 m thick large-scale trough cross-bedded quartzite with channel lag gravel and conglomerate beds wich is interpreted to be Scott type gravelly braided stream in a ancient periglasiofluvial alpine environment.

The Paleoproterozoic Orakoski and Ellitsanvaara formations, northern Finland: a change from fluvial to shallow marine settings

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The Orakoski (OF) formation starts the 2.44 - < 2.22 Ga Sodankylä Group, northern Finland (Räsänen & Huhma, 2001). The OF consists of the lower member (200 m) of feldspathic quartzite with numerous mudbeds, hummocky crossbedding (HCS) and horizontal lamination indicating deposition in shallow shelf settings. Upper OF member (650 m) consists of trough cross-bedded, coarse – granule arkosite, which is interpreted to being deposited in braided river system.

The OF is overlain conformably by the Ellitsanvaara formation (EF) (1500 m), which starts with a 25 m thick transitional quartzite member with HCS stratification passing to graded bedded metapelite with occasional thin HCS and combined flow rippled quartzite beds. The EF represents shallow, storm-effected shelf.

As a whole the OF-EF couple represents a transition of fluvial environment to shallow shelf (cf. Saverikko, 1988).

Räsänen J & Huhma, H (2001). U-Pb datings in the Sodankylä schist area, central Finnish lapland. In: : Radiometric age determinations from Finnish Lapland and their bearing on the timing of Precambrian volcano-sedimentary sequences, ed by Matti Vaasjoki. Geological Survey of Finland, Special Paper 33, 153–188.

Saverikko M. (1988). The Oraniemi arkose-slate-quartzite association: an Archaean aulacogen fill in northern Finland. Julkaisussa: Sedimentology of the Precambrian formations in eastern and northern Finland. Geological Survey of Finland Special Paper 5, 189–212.

Analysis of an enigmatic crater in Arabia Terra, Mars

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This Mars Express HRSC study discusses the characteristics and evolution of a crater located in Arabia Terra, Mars (36,0°N/351,8°E). It is just south of the dichotomy boundary, which divides the planet to lowlands (N) and highlands (S). The crater diameter is ~25 km. Its appearance has been shaped by mixture of aeolian, fluvial, possibly volcanic and lacustrine processes. The crater floor is highly modified.

The W part of the crater floor is rather smooth and featureless. It is likely composed of sedimentary materials, accumulated onto the original floor and later eroded. As maybe part of this erosion, the central floor is intensely fractured. It appears chaotic, especially at the contact with the 'smooth' W crater floor. The fracture walls exhibit distinct layering.

Almost the entire central-eastern crater floor is occupied by a ~100 m deep depression, which has a significantly lower albedo than the surroundings (i.e. western floor and the highlands around the crater). Additionally, the central area of the depression has two separate large bulges. The bigger rises 300 m above the depression floor with a total volume of 6 km^3; smaller is 70 m high and has a volume of 400 m^3. Even though the bulges lie in the depression, they reach higher than all the rest of the crater floor. If the albedo would be caused by aeolian accumulation of dark volcanic dust, it should follow the topography and cover mostly the lower parts of the crater. This indicates that the color is a feature of the bulge itself, preliminarily interpreted to be of volcanic origin.

Additionally, two fluvial channels enter the crater. These channels are quite small and their short and stubby appearances indicate forming by sapping processes. No crucial evidence of past lacustrine environment has been found on preliminary study.

This study is still in its early phases. The major guidelines for the future research are more detailed analysis of the crater's characteristics with wider areal mapping to identify which of them are due to local phenomena and which part of the large-scale regional evolution.

Analysis of the BEAR magnetotelluric data: Implications for the upper mantle conductivity in the Fennoscandian Shield

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Long period magnetotelluric (MT) and geomagnetic depth sounding data (GDS) have been acquired on the Fennoscandian Shield under the framework of the Baltic Electromagnetic Array Research (BEAR). The field campaign was carried out in the summer of 1998 when variations of the natural electromagnetic field were recorded simultaneously at 46 MT and 20 GDS stations. The key targets of the project are to investigate the electrical properties of the upper mantle and to determine the depth to the lithosphere-asthenosphere boundary in the Fennoscandian craton.

The decomposition analysis of the long period (T > 3000 s) MT impedance tensors yields a set of smoothly varying electrical conductivity strike directions. Yet strike angles vary significantly in the scale of the BEAR array and have abrupt regional changes in some areas. The spatial behaviour of strike angles cannot be connected with large-scale crustal geological units. Moreover, strong variation of strike azimuths over the BEAR array convincingly shows that the strike angles cannot be associated with present day plate motion or mantle convection, because that would require a consistent strike azimuth over the whole array. Observed long period strike angles indicate mainly upper mantle 2-D and 3-D structures or frozen in anisotropy induced by several Palaeoproterozoic and Archaean events.

The dimensionality analysis of the BEAR data shows that in the northeastern part of the array the regional conductivity structure is approximately one-dimensional. One-dimensional inversion of selected data from the western Lapland-Kola Domain reveals a conducting layer in the middle crust. An increase of conductivity is required also at depths greater than 170 km providing a minimum estimate of the lithosphere thickness beneath the target area. Partial melts or dissolved water in olivine are most plausible sources for increased conductivity at such depths.

Paleoproterozoic continent-continent collision zones – a secular change in the Archean to Neoproterozoic tectonic style

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The Earth has cooled from Archean to Present by the loss of original heat and by decreasing production of radiogenic heat. This has led to secular evolution from depleted low-density Archean lithospheric mantle (SCLM) to more fertile denser Phanerozoic lithospheric mantle beneath continents. It is controversial whether modern subduction-type tectonics begun during Archean, Paleoproterozoic or during Neoproterozoic era when first abundant eclogites occur.

The Svecofennian Orogen is one of the largest Paleoproterozoic orogens in the world covering over 1 mill. km^2. It is atypically non-linear and is suggested to have formed in four partly overlapping orogenies (1.9–1.8 Ga) and to form the core or one of the cores of a 1.8 Ga supercontinent. Seismic reflection data reveal a "crocodile structure" within the thickened Archean-Proterozoic boundary zone; rigid Karelian passive margin wedge has split the young and hot island arc to an upper part, thrust on the Karelian plate, and a lower part, buried under the stacked continental edge. Similar structures are found at many 1.9–1.7 Ga Archean-Proterozoic boundaries (Snyder, 2002). This type of collision prevents the exhumation of subduction-related eclogites characteristic to modern collision zones. A net result of collision is thickened lithosphere that is often attenuated during subsequent extension. During long-lived convergence and associated cooling the thick crust and the lithospheric mantle may be stabilized (e.g. Svecofennian Orogen and Yavapai province, USA).

Subduction-related processes operated already in the Paleoproterozoic but the buoyant nature of the Archean lithosphere in combination with hot and denser Paleoproterozoic lithosphere cause the differences between Paleoproterozoic and Neoproterozoic-Phanerozoic continent-continent collision zones.

Snyder, D.B. (2002). Tectonophysics 355, 7–22.

Mineralogy of the Yermak Plateau sediments in the Arctic Ocean: Implications for the Mid-Pliocene climate in the North

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The studied Ocean Drilling Program Site 911 is located on the shallow southern part of the Yermak Plateau, Arctic Ocean, north-west of Svalbard at a water depth of ~900 meters. The sediments consist of clayey silts and silty clays, aged from Pliocene to Quaternary. The study interval is located at a depth of 384.19–440.50 mbsf, including sediments from the Pliocene.

The main interest of this study is the possible provenance variability of the sediments drilled from the Yermak Plateau, and the occurrence of sea-ice transport, studied based on heavy and clay minerals. Other topics of special interest are the Pliocene climatic conditions and the signs of Mid-Pliocene global warmth (MPGW), a period when the global average temperatures were significantly warmer than the present. In the Northern Hemisphere, MPGW could have been one decisive trigger for the intensification of glaciation at 2.7 Ma.

Several studies have been made of the modern heavy mineral distribution of river discharge in the Arctic region, and a comparison will here be made between the modern situation and the situation that prevailed in the MPGW. Nowadays, large amounts of sea-ice develop in the broad and shallow Eurasian shelf regions, of which the Laptev Sea is believed to be the most important source of sea-ice crossing the central Arctic Ocean (Schoster et al., 2000). Due to the large fresh-water input from the great Siberian rivers into the Laptev and Kara Seas in the interglacial times, salinity is lowered in the surface water masses, which allows extensive production of sea-ice and thus causes an increase in the transportation of terrigenous material in the sea-ice. We hypothesize that, during the MPGW, the enhanced fresh-water input from the Siberian rivers was also of major significance in producing sea-ice and hence had implications on the amount of terrigenous material transported to the Yermak Plateau.

Schoster, F., Behrends, M., Müller, C., Stein, R. & Wahsner, M., (2000). Int. J. Earth Sciences 89, 486–495.

3D inversion of gravity data from southern Finland using GRAV3D Program Library

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The aim of our study was to demonstrate the use of GRAV3D Program Library, a suit of algorithms for inverting gravity data gathered over a three dimensional earth. The basic components of this inversion methodology are the forward modelling, a model objective function, a data misfit function, a regularization parameter that determines how well the data will be fit, and the logarithmic barrier method to obtain the solution with bound constraints.

The example data consisted of gravity measurements from West Uusimaa in southern Finland measured by Geodetic Institute. There exists a strong gravity anomaly associated with granulite facies rocks. The initial model presents the mean density difference between amphibolite and granulite facies domains in southern Finland. The region was divided into a set of 3D prismatic cells by using 3D orthogonal mesh and it was assumed a constant density within each cell. The corresponding gravity anomaly was calculated and it shows that the observed gravity anomaly may be produced by a crustal block having a density contrast of 0.05 g/cm^3.

Using GRAV3D Program Library the inversion was constrainted by minimum and maximum density contrasts inferred from statistical analysis of rock densities in southern Finland. In our model, the cells near the surface were given almost constant density contrasts but, in depth, the given density contrasts were between 0 and 1.0 g/cm^3. The inversion gave the density distribution that produces the observed anomaly within given petrophysical constraints, in this case dense rocks at the base.

The use of 3D mesh and a possibility to constraint the inversion by known or statistically inferred density data made it easy to include geological information into the gravity inversion.

Web-based teaching of geology at Helsinki University of Technology

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Web-based teaching of geology can be so much more than simply accessing and exchanging information in the form of lectures and exercices. Although it can never fully compete with direct contact teaching, particularly when learning to identify minerals and rock types, it is nevertheless an effective way of conveying the fundamentals of the subject. It also provides a ready access to geological information for people outside the university system.

These two aspects provided the impetus for establishing the virtual teaching pages at the Helsinki University of Technology. Web-pages developed in the labortatory of Geoenvironmental Technology (http://www.opigeologiaa.fi) include interactive exercises, a guide to using the polarizing microscope, help with mineral identification, practical advice on mathematical modelling applications and a small rock gallery. They also provide ready access to geological information for schools and for individuals with an interest in geology as a hobby.

The Mesoproterozoic Snaunetten basin, central Telemark: insights for TIB in Telemark supracrustals as derived from detrital zircon U-Pb and Hf-isotopic studies

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This study concerns a Proterozoic metasedimentary rock unit occurring in central Telemark, southern Norway, which is informally named as the Snaunetten basin. It has previously been included into the >1.15 Ga Seljord group (Dons, 1962, 1963, 1972) and later into the underlying, ca. 1.5 Ga Rjukan group (Dons, 2003). Detrital zircons from two samples were analysed by MC-LA-ICP-MS-technique at the University of Oslo. An orthoquartzite sample taken from the bottom of the basin gave clear modes at ca. 1400 Ma and ca. 1150 Ma, corresponding to well known volcanic events, while TIB-related 1800 Ma component was anomalously low. Another sample was taken from orthoquartzite conglomerate clasts from the upper part of the basin, which gave similar age distribution including a very significant TIB-component, as verified by Hf-isotopes (cf. Andersen et al., 2006). The meager TIB-influence at the bottom of the basin could be explained by increased tectonic activity in the area of sedimentation and subsequent dilution of the zircon population with more local sources. Tectonism could also have changed the catchment area of the sedimentary systems towards more westerly sources. An alternative explanation could be that the rock unit in question is younger than any known formation and the signal for TIB has gradually vanished in the Telemark supracrustals' rock record.

Andersen, T., Andersson, U.B., Graham, S. (2006). Hf isotope variations in Transscandinavian Igneous Belt Zircons. Abstract. This Volume.

Dons, J. A. (1962). Geol. Rundsch. 52, 261–268.

Dons, J. A. (1963). Norges Geologiske Undersökelse 216.

Dons, J. A. (1972). Sciences de la Terre 17, 25–29.

*Dons, J. A. (2003). **Berggrunnskart ÅMOTSDAL 1514 II – M** 1:50 000. Norges Geologiske Undersökelse.*

Field evidence from Tepsanniemi formation (Tepsanniemi, Sodankylä) indicating beach depositional system

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The 2.44 – < 2.22 Ga Tepsanniemi (TF) formation, Sodankylä Group, northern Finland (Räsänen & Huhma, 2001) was previously included into Sodankylä quartzite formation, but later taken apart and renamed as Tepsanniemi formation (Evins & Laajoki, 2002). The TF is 1500 m thick sandy formation and characterized by low-angle tabular cross-bedding and horizontal lamination. The TF quartzites differ markedly from the Orakoski quartzites and their stratigraphic position is much higher.

Previously the TF has been interpreted as a floodbasin (Saverikko 1988). However horizontal lamination, low-angle cross-bedding and lack of suspension sedimentation support deposition in foreshore setting. Processes were dominated by high energy wave swash and therefore deposits lack wave ripples and suspension mud layers are rare. Excellent sorting of the sands also indicate wave related processes.

*Evins P. M. & Laajoki K. (2002). **Geological Magazine 139,** 73–87.*

Saverikko M. (1988). Geological Survey of Finland Special Paper 5, 189–212.

The Mesoproterozoic Brattefjell formation, Telemark, South-Norway: a tidally influenced shoreline

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The Mesoproterozoic Brattefjell formation, which is best exposed in Brattefjell, central Telemark, shows well preserved sedimentary structures indicating rapid shallowing and deepening of a tidally influenced shoreface. Based on distinct facies assemblages it is subdivided into the lower- (LB), middle- (MB) and upper-Brattefjell (UB) formations. The LB represents low energy upper shoreface with abundant wave ripples and sand ridges. Thin mud layers are relatively common in the LB and occasionally drape foreset laminae. The MB is characterised by tidal related structures including herringbone cross-bedding and mud-draped foreset laminae. Transition from the LB to the MB is shown by a rather abrupt reduction of set height in cross-strata, increase of mud and the abundance of small scale erosional structures in the MB indicating shallowing and rapid fluctuations of sea level. Shrinkage-cracks in the MB indicate an occasional sub-aerial exposure. Transition from the MB to UB is characterized by a regionally important marker-bed of a thin quartz-pebble conglomerate interpreted as a ravinement surface indicating one regression-transgression cycle. The UB consists almost exclusively of wave-ripple lamination and parallel lamination, and is characterized by the absence of mud. Cross bedding is rare although where present, is large scale and tabular. The UB is interpreted as upper shoreface in a more open shoreline than the LB. As a whole the Brattefjell formation represents a regression-transgression cycle, where the relative sea level began to fall during the deposition of the LB and MB. Falling sea level isolated a lagoon, which deposited the mud-rich MB. Incision of the shoreface resulted in the deposition of a coarse ravinement surface present in the lower-UB and the erosion/filling of the closed lagoon. Following transgression deposited the open-marine wave-rippled sands of the UB.

Relationship of mesothermal gold deposits and orogenic granitoids of the Karelian and Svecofennian terrains: Geochronological and isotopic data

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There are many examples of close spatial connection of Early Precambrian mesothermal lode-gold deposits with orogenic granitoids. Could it suggest for genetic relationship of these gold deposits with granite magmatism? This question has been studied on two lode-gold deposits located within Neoarchaean and Paleoproterozoic orogenic granitoid massifs of the Russian part of Karelia.

The Taloveis deposit is localized in Archaean (2715 ±5 Ma) diorite-granodiorite massif (Kostomuksha district, Karelian terrain). Rb-Sr studies of minerals of granitoids from proximal (WR, muscovite, biotite) and distal (WR, plagioclase, microcline, biotite) alteration zones define an isochrons with ages of 1719±60 1717±27 Ma. The obtained Paleoproterozoic age for ore-related metasomatic alteration allows explaining a large scattering of Rb-Sr isotope data for whole-rock granitoid samples around 2700 Ma magmatic reference-line.

The Pyakulya lode-gold deposit is localized in Paleoproterozoic (1874±13 Ma) diorite and granodiorite massifs (NW Ladoga district, Svecofennian terrain). Rb-Sr isochrone ages for granitoids and metasomatic rocks of distal alteration zones (1872±90 Ma) and for rocks of proximal alteration zones and ore bodies (1857±34 Ma) suggest for closed temporal and probably genetic relationship between the Pyakulya lode-gold deposit and hosted orogenic granitoids.

The results suggest for different type of relationships of lode-gold deposits and hosted orogenic granitoid massifs. The obtained Paleoproterozoic age for Taloveis lode-gold deposit gives us additional evidences on very complicated Early Precambrian tectonic and metallogenic history of the Karelian (?)Achaean terrain.

Late Pleistocene palaeoenvironmental changes in NW Russia; Shifting ice sheet domains and proglacial lakes

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Five indedpendent and regional significant Weichselian glacial events are recorded in northwest Russia. The first glacial event took place in the Early Weichselian. An ice sheet centered in the Kara Sea dammed up a large lake in the Pechora lowland. Across a threshold on the Timan ridge and via an ice-free corridor between the Scandinavian Ice Sheet and the Kara Sea Ice Sheet, water was discharged to the west and north into the Barents Sea. At c. 75–70 ka BP a local ice cap developed over the Timan ridge. Shortly after deglaciation of the Timan ice cap, an ice sheet centered in the Barents Sea reached the area. The configuration of this ice sheet suggests that it was confluent with the Scandinavian Ice Sheet to the west. Consequently, a huge ice dammed lake formed in the White Sea basin, only now the outlet across the Timan ridge was leading water eastward into the Pechora area. This Barents Sea Ice Sheet suffered marine down-draw and rapid collapse, and the White Sea Lake was discharged into the Barents Sea. This was followed by marine inundation and interstadial conditions between c. 65–55 ka BP. The glaciation to follow this marine phase, was centred in the Kara Sea and took place around 55–45 ka BP. Northward directed fluvial run off in the Arkhangelsk region indicates that the Kara Sea Ice Sheet was disconnected from the Scandinavian Ice Sheet and that the Barents Sea remained largely ice free. This glaciation was succeded by a ca. 20 ka long ice-free period with periglacial conditions before the Scandinavian Ice Sheet invaded from the west, and joined with the Barents Sea Ice Sheet in the northernmost areas of northwestern Russia.

The Arkhangelsk region is the only area that was invaded by all the three ice sheets during the Weichselian. Thus the glacial record is more complex here than in regions both to the east and west. The record shows a general increase in ice sheet size with time, and a progressive shift in dominance from eastern towards western centered ice sheets. This series of events was interrupted by a set-back to an easterly ice sheet domain. The complex glacial history resulted in a likewise complex lake history with spillways being re-used and ice dammed lakes appearing at different places along the ice margins.

A comparison of microstructures from basal tills and synthetically deformed sediments and its implications for till formation

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The effect of subglacial shearing in the formation of basal tills is assessed by comparing microstructural assemblage from basal tills with those formed in laboratory experiments using a ring-shear apparatus. Intact samples were collected in flutes, ploughing marks and other landforms at a contemporary glacier and in massive and bedded Pleistocene tills. Synthetic till samples were created by shearing sediments under fully saturated conditions with stress parameters corresponding to a natural environment.

Brittle and ductile deformation structures are present in both natural and synthetic till samples. Rotation structures, lineations, grain bridges and crushed grains are found in nearly all thin sections, whereas plasmic fabric and dewatering structures are relatively rare or absent. The most common association of microstructures does not differ significantly between the sites with basal till and the synthetic till samples, but the number of observed microstructures does. In coarse-grained homogenous tills fewer microstructures are present compared to more fine-grained heterogeneous tills.

The ring-shear experiments have showed that microstructures start to develop immediately after the shearing commence, and further shearing (higher strain) does not produce any new association of microstructures. Other experiments illustrate the evolution from a heterogenic sediment (layers of sand and till) to a completely massive sediment (till) – again under relatively low strain.

These results have implications for the understanding of till formation because they show that the number of microstructures depends more on the sediment properties than strain. The results also suggest that it is not possible to identify different subglacial processes such as ploughing and subglacial deformation based on till microstructures.

Is there any alternative to infiltration metasomatism in layered intrusions?

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Irvine (1980) proposed an elegant mechanism termed "infiltration metasomatism" to explain upward displacement of discontinuities in mineral compositional trends relative to contacts between cyclic units in the Muskox intrusion. It was concluded that the offsets of Mg/(Mg+Fe) discontinuities in olivine and chromite resulted from reaction between the cumulus minerals and intercumulus liquid that was frontally displaced upwards from the underlying crystal pile as a result of compaction. We reinterpret this feature in the Muskox and other layered intrusions as basal reversals that do not require involvement of intercumulus liquid migration. Our explanation is based on the concept of Soret fractionation (Latypov, 2003) and implies that basal reversals result from a temperature gradient-driven flux of low melting point components from the hot magma parental to cyclic units towards a relatively cold cumulate floor. Basal reversals are thus a primary magmatic feature rather than a secondary postmagmatic one.

Irvine, T. N. (1980). In: Hargraves RB (ed.) Physics of magmatic processes. Princeton University Press, Princeton, NJ, United States, p. 325–384.

Latypov, R. M. (2003). J. Petrol. 44, 1579–1618.

U-bearing leucogranites in southern Finland

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The arc complex of southern Finland (Korsman et al., 1997) extends from the archipelago of Turku in the west to the Puruvesi area in the east. This ca. 150-km-wide zone is characterized by migmatizing microcline granites that are 1.85–1.79 Ga in age and thus lateorogenic relative to the main Svecofennian deformation (e.g., Kurhila et al., 2005). These granites constitute a clear positive overall anomaly in radiometric maps and are known to host some uneconomic U and Th deposits.

The appearance of the lateorogenic granites varies from dikes and small pods to larger, fairly homogeneous batholiths that grade into granitic migmatites. The main mafic silicate in these granites is biotite, although muscovite, garnet, and cordierite are also common. Zircon and monazite are typical accessory minerals.

Geochemically, the lateorogenic granites have >72 wt.% SiO_2. They are peraluminous with A/CNK values between 1.01 and 1.38 FeO and MgO contents are low, commonly <1 wt.% and <0.5 wt.%, respectively. U content of the granites varies from <1 ppm to >50 ppm and Th content is between <1 ppm and >60 ppm. Th/U ratios vary from >10 to <1.

Compared to many U-bearing leucogranites (e.g., the Hercynian leucogranites of French Massif Central – Turpin et al., 1990; and the Rössing granites, Namibia – Cuney, 1980; Basson and Greenway, 2004), the lateorogenic granites of southern Finland show little evidence of hydrothermal alteration. Based on field measurements of radiation, radioactive minerals (e.g., monazite, pitchblende, zircon) seem to be relatively evenly distributed in the larger granite masses that commonly also show higher overall radiation levels. Thin dikes and small plutons host patches with higher concentrations of these minerals, but the size of the radioactive spots is commonly some tens of cm^2 only.

Basson, I.J. & Greenway, G. (2004). J. Afr. Earth Sci. 38, 413–435.

Cuney, M. (1980). Trans. Geol. Soc. S. Afr. 83, 39–45.

Korsman, K., Koistinen, T., Kohonen, J., Wennerström, M., Ekdahl, E., Honkamo, M., Idman, H. & Pekkala, Y. (eds.) (1997). Geol. Surv. Finland.

Kurhila, M., Vaasjoki, M., Mänttäri, I., Rämö, O.T. & Nironen, M. (2005). Bull. Geol. Soc. Finland, in press.

Turpin, L., Cuney, M., Friedrich, M., Bouchez, J.-L. and Aubertin, M. (1990). Contrib. Mineral. Petrol. 104, 163–172.

Geochemical constraints on the evolution of Archean TTGs in Koillismaa, eastern Finland

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The Koillismaa area belongs to the northernmost part of the Archean Karelian craton in Finland. This relatively poorly studied area consists mostly of migmatitic amphibolites, TTG gneisses, and leucogranites (Räsänen et al., 2004). The TTG gneisses and amphibolites are at least ~2.8 Ga in age and the leucogranites show ages around ~2.7 Ga (Lauri et al., 2005). The peak metamorphic grade in the area extends to upper amphibolite facies–granulite facies and the age of metamorphism is ca. 2.69 Ga based on U–Pb ages of monazite (Lauri et al., 2005) and K–Ar ages of hornblende and biotite (Kontinen et al., 1992).

The Koillismaa TTGs have SiO_2 values between 65 wt.% and 75 wt.%. Mg# is mostly <48, Cr <30 ppm and Ni <15 ppm, thus indicating that the Koillismaa TTGs do not belong to the adakite series that represents melting of subducting basalt (e.g., Martin et al., 2005). The Koillismaa TTGs are strongly enriched in the LREE compared to the HREE. Eu anomaly varies from slightly negative to strongly positive, implying for varying amounts of plagioclase fractionation/residual plagioclase in the source.

Based on preliminary trace-element modeling, it appears that *in situ* partial melting of local garnet-free amphibolites cannot produce the REE fractionation present in the Koillismaa TTGs, which need garnet as a residual phase. This observation is congruent with the model of Martin (1987) on the tonalites of Kuhmo. The possible source of the Koillismaa TTGs is melting of garnet amphibolite in the lower crust.

Kontinen, A., Paavola, J. & Lukkarinen, H. (1992). ***Geol. Surv. Finland, Bull. 365.***

Lauri, L.S., Rämö, O.T., Huhma, H., Mänttäri, I. & Räsänen, J. (2005). ***Lithos, in press.***

Martin, H. (1987). J. Petrol. 28, 921–953.

Martin, H., Smithies, R.H., Rapp, R., Moyen, J.-F. & Champion, D. (2005). ***Lithos 79, 1–24.***

Räsänen, J., Iljina, M., Karinen, T., Lauri, L., Salmirinne, H. & Vuollo, J. (2004). ***Geol. Surv. Finland.***

Release of metals from weathering black shale – A case study from Öland, Sweden

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Black shale is a type of rock found in many parts of the world, usually containing high amounts of trace elements. Black shale is readily weathered when exposed to air and water and since many of its elements have toxic properties such weathering can constitute a considerable source for contamination of soils and waters. A study aiming at assessing the release of metals to the environment in an area with outcropping black shale and heaps of burnt shale was conducted. The study was performed by elemental analysis and leaching experiments of the shale together with analysis of groundwater and surface water samples.

The metal concentrations in non-weathered black shale were much higher than in weathered or burnt shale, e.g. for cadmium, nickel and zinc, indicating a loss of metals during weathering or burning of the shale. This was also confirmed by the leaching experiments, where a decrease in pH and a significant increase in metal concentrations in the leachate were observed.

The metal concentrations in the groundwater were related to the pH. At sampling points where the groundwater pH was low the metal concentrations were strongly elevated, observed mainly in areas with heaps of slightly burnt shale, facilitating infiltration of both air and water and thus creating good conditions for weathering processes. At other sample points the pH was higher and the metal concentrations were often low. Concentrations in surface waters were generally high compared to background values, but due to limited water flows the annual metal flows in these surface waters are relatively small.

Based on an environmental risk analysis of the metal flows suggestions are to be made for possible measures to reduce the pollution from the shale to the local environment and exposure to biota.

Natural and anthropogenic sources of elements in biogeochemical samples

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The biogeochemical mapping programme of the Geological Survey of Sweden has resulted in 37 000 samples of stream living plants (roots, water moss). In comparison with inorganic sampling media used (glacial till), the plant samples display both natural and anthropogenic signatures. However, anthropogenic signatures are easily obscured by geological sources.

A number of methods have been devised in order to detect polluted samples. Chromium shows excellent correlation with elements such as titanium, silica and aluminium. Normalisation with any of these elements efficiently removes effects related to mineral matter and potential species dependent differences. Samples with anomalously high Cr:Ti ratios are rare, but almost always located in areas where human activities are likely to cause pollution.

The biogeochemical samples can also be used in order to detect active, acid sulphate soils and streams subject to eutrophication.

Tectonic subdivision of Kalevian mica schists and Archaean "domes" in Karelia

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Palaeoproterozoic Kalevian mica schists and their relation to Archaean "dome structures" have been studied near the national border of Finland and Russia. The study area includes Kitee and Tohmajärvi in Finland as well as Latvasyrjä, Matkaselkä and Pälkjärvi in Russian Karelia.

The investigated Kalevian mica schists form part of the North Karelia Schist Belt, which developed in the Höytiäinen and Savo Provinces (Ward, 1987; Kohonen, 1995). This schist belt is tectonically underlain by the Archaean craton and associated Jatulian platform sediments.

As a result of this study, at least six informal tectonic units have been distinguished. 1. the Pälkjärvi unit, dominated by biotite-staurolite-andalusite-(cordierite) mica schists (Kalliiset fm). 2. the Ruokojärvi unit, dominated by cordierite-andalusite-staurolite mica schists (Potoskavaara fm), but also containing arenitic sediments, graphitic schists and amphibolites. 3. the Kirjavalahti unit, comprising a lens-shaped core of Archaean crust and surrounded by a rim of graphitic schists, mafic volcanics and carbonates. 4. the Kangasjärvi unit, consisting of arenitic sediments, amphibolites, graphitic schists as well as small lenses of Archaean crust near Jaakkima (Matkaselkä). 5. the Höksölä unit, consisting of arenitic sediments (Karhulanmäki fm) as well as 1.9 Ga intrusions (the Vaitjärvi diorite and Närsäkkälä quartz-diorite). 6. the Latvasyrjä unit, consisting of Archaean orthogneisses.

A 2.7 Ga age for the Latvasyrjä orthogneisses and a less precise, but still Archaean age for the Jaakkima gneisses were obtained by the U-Pb method at the NORDSIM laboratory (Stockholm).

All tectonic units (including the Archaean "domes") are interpreted as allochthonous slabs, which were emplaced onto the Archaean craton margin during the Svecokarelian Orogeny.

*Kohonen, J. (1995). **From continental rifting to collisional** crustal shortering – Paleoproterozoic Kaleva metasediments of the Höytiäinen area in North Karelia, Finland. **Geological** Survey of Finland, Bulletin 380, 79 p.*

Ward, P. (1987). Early Proterozoic deposition and deformation at the Karelian craton margin in southeastern Finland. Precambrian Research 35, 71–93.

Comparison of Catalogue-Induced Heat Loss in Venusian Coronae

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The surface heat flow on Earth is dominated by three mechanisms: plate-tectonics, hot-spot volcanism and thermal conductivity. On Venus, where plate-tectonics is not present, besides thermal conductivity only an equivalent to terrestrial hot-spot volcanism (Leitner et al., 2005) could be responsible for the present surface heat flow: Corona volcanism. Concering the total number of Coronae und related structures on Venus several different databases exist, which offer quite different numbers of Coronae and their subtypes (Arachnoids and Novae). In this paper we present a comparison of our calculations on the contributions of Coronae to the total surface heat loss with the assumption that Coronae represent the surface manifestation of Venusian mantle plumes. Using the catalogue of the Brown University (http://www.planetary.brown.edu/planetary/databases/venus_cat.html), which shows Coronae and its subtypes (206 Coronae, 256 Arachnoids and 63 Stellate Fracture Centers = Novae), a value for the fraction of global heat loss of 3.3±0.8 mW m^{-2} results. While for the USGS catalogue (http://planetarynames.wr.usgs.gov/venus/venucoro.html), which includes no Corona-subtypes (328 Coronae), a heat loss of 2.6±0.6 mW m^{-2} is achieved. Contrary the similarly structured catalogue of Stofan et al., 2001 (409 type 1 and 106 type 2 Coronae) yields an amount of 3.4±1.0 mW m^{-2}. Finally the catalogue of Kostama et al., 2001, which comprises 344 Coronae, 70 Arachnoids and 55 Novae leads to a value of 2.6±0.8 mW m^{-2}. All the databases were restricted only to the presumably active structures, which show a domal or circular shape and/or a raised interior (De Laughter et al., 1999 and Smrekar et al., 1997). Comparing the various catalogue-results our calculations show that the present mean heat loss due to Coronae/hot-spot volcanism in all catalogues are very similar. If additionally large and intermediate volcanoes (at all 457) are regarded to be caused by mantle plumes then the present mean surface heat flow results in 6.0±1.4 mW m^{-2}.

Leitner J.J. et al. (2005). ***36th LPSC, Abstr. # 1058.***
Stofan E.R. et al. (2001). Geophys. Res. Letters 28, 4267–4270.
Kostama V.P. et al. (2001). ***32nd LPSC, Abstr. # 1185.***
De Laughter J.E. et al. (1999). ***Icarus 139, 81–92.***
Smrekar S.E. et al. (1997). Science 277, 1289–1294.

Cenozoic landscape development in northern Scandinavia

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The morphometry of major bedrock landforms in a part of northern Scandinavia was examined for a reconstruction of the long-term landform development. Reconstructions of palaeo-surfaces and palaeovalleys were undertaken based on digital elevation data and GIS analysis. Remnants of four major erosion generations are identified within the Northern Scandinavian mountains (the Northern Scandes). The palaeosurfaces are all inclined to the ESE. Within the mountains they are vertically separated by 300–400 m, while east of the mountains they are merging close to each other in the Muddus plains. The results indicate the development of a fluvial landscape with a distinct stepped relief associated with a landmass tilting towards ESE during the Cenozoic. Furthermore, the reconstructed fluvial erosion generations were used for a preliminary calculation of the combined amount of glacial/fluvial erosion since the beginning of the Late Cenozoic glaciations. Values of 120–300 m of erosion down to the present lake levels are common in the valleys and along the mountain front, while it may amount to 500 m in certain valley locations.

Proton-beam analysis of sulphur isotopes: Accuracy and applicability in geosciences

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Proton-induced-gamma-ray emission was used to determine the $^{34}S/^{32}S$ and $^{33}S/^{32}S$ ratios in sulphides and sulphates. Polished sample surfaces of the minerals were irradiated in situ using a 4.5 MeV proton beam from a cyclotron. The prompt gamma radiation from the sulphur nuclides was used to determine the relative abundance of the sulphur isotopes in the minerals. The accuracy and precision of the method were first determined by analysing a set of samples with similar low-background matrices. For this purpose a series of silver sulphides, which had been prepared for mass-spectrometer (MS) analysis were utilised. Due to the low gamma background from silver also $\delta^{33}S$ could be measured and the data could be evaluated using a three-isotope plot. The samples were first analysed with MS and then subsamples of them were analysed with PIGE. The precision for this sample series and our PIGE set-up was about ±10 $\delta^{34}S$ units. The poor precision is due to low sulphur content and low signal/background for ^{34}S in the samples with strongly negative (<-18) signatures. After this a series of natural sulphides and sulphates were analysed using both MS and PIGE. The samples included 3 pyrites (FeS_2), one sphalerite Zn(Fe)S, one galena (PbS) and 2 gypsums. For these samples the precision was around ±3 δ units depending on the sample matrix but ^{33}S could not be measured in samples with a high iron content due to a spectral overlap. The analyses were severely disturbed by the presence of chlorine, which have spectral overlaps with both ^{32}S and ^{34}S.

The Middle Ordovician sand-rich Föllinge turbidite, Swedish Caledonides

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The Föllinge Greywacke occupies about 4,500 km^2 of the easternmost Caledonian overthrust terrain in central Sweden. The sediments came mainly from the west, from the nascent Caledonian mountain chain. They are sand-rich turbidites according to the definition by Matter (2005). Thus, they are dominated by sandy beds, rather than by the pelagic-type mudstones that separate these beds from one another. Quartz, feldspar and lithic fragments are dominant components, and deposition took place over continental basement. Fine to medium sand dominates, and the environment is characterized as lower fan.

The adjacent basin plain domain, to be expected east of the turbidite fans, is represented by the organics-rich Andersön Mudstone. To the east of the basin plain was the very gentle rising orthoceratite limestone sea-bed of peribaltic type. Not far from its passage westwards into the basin plain, the ortoceratite limestone domain was hit by the Lockne impact at a sea-depth at least 500 m, a minimum depth also for the adjacent basin plain.

According to Matter (2005) sand-rich fans form in the immediate vicinity of active tectonism and normally extend 15–85 km. This places Caledonian tectonism, not younger than early Middle Ordovician, at a maximum distance of about 85 km from greywacke localities like Hallen and Föllinge.

Greywacke domain, basin plain and orthoceratite limestone domain are a functional continuum, through which it is not stratigraphically necessary to assume major overthrusts. Our study indicates that the Ordovician along the 100 km long NW-SE transect from Åre to Brunflo was shortened tectonically by less than 50% .

Matter, F. (2005). Earth-Sci. Rev. 70, 167–202.

Possibilities and pitfalls in using pollen percentages for investigating tree abundance: a literature review

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It is well known that fossil pollen percentage data provide only limited information about the actual abundance of trees in the landscape. In this connection the question of what pollen percentage relates to the presence, absence and dominance of a tree species has been widely discussed in the literature. Empirical evidence of pollen-vegetation relationships can be obtained by looking at present day forests and the associated pollen deposition.

As early as 1971, Davis *et al.* delimited significant pollen percentages in relation to tree abundance on the basis of modern lake sediments in North America. Hicks (1986), when presenting pollen accumulation rate results from terrestrial pollen traps in Finland also summarized percentage values for tundra and boreal forests sites in Europe, Greenland and N. America. She gives values for spruce dominated forests in Northern Finland of: *Pinus* - 31%, *Picea*- 10%, *Betula* - 59 % (%AP). Results from surface lake sediments on the Kola Peninsula (Gervais & MacDonald 2000) show a rather different picture, however: *Pinus* – 54 %, *Picea* – 6 %, *Betula* – 29 %, even though the forest type is mostly similar in composition.

These differences in pollen percentages result from 1. differences in sediment type, 2. local conditions at the sampling site, and 3. difference of vegetation. Wilmshurst & McGlone (2005) investigated differences in modern pollen accumulation in a range of mosses and in lake sediments and concluded that, for the same vegetation type the difference in pollen assemblages between some of mosses samples was greater than between mosses and lake sediments.

The significance of using percentage thresholds to investigate the migration of tree species or forest limits as climate indicators is discussed.

Davis, M.B., Brubaker, L. B. & Beiswenger, J. M. (1971). Quaternary Research 1: 450–467.

Hicks, S. (1986) Grana 25:183–204.

Gervais, B.R. & MacDonald, G.M. (2000) Rev. Palaeobotan. Palynol. 11: 223–237.

Wilmshurst, J.M. & McGlone, M.S. (2005) Rev. Palaeobotan. Palynol. 136: 1–5.

An 11,000 year long pollen record from Nightingale Island in the South Atlantic displaying recurring periods of rapid vegetation change

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This study is part of the ATLANTIS project, which aims at correlation of the late Quaternary climatic development in the northern and southern hemispheres. Previously underexploited paleoclimatic archives, such as lakes and bogs, can be found on volcanic islands in the North and South Atlantic. These archives give direct information on past atmospheric changes and enable comparisons between the climatic development along a north-south transect through the Atlantic Ocean. With the aid of detailed radiocarbon dating, leads and lags between the hemispheres will be detected.

During fieldwork in 2003, sediment sequences were retrieved from four sites on the islands Tristan da Cunha and Nightingale Island, situated in the South Atlantic some 2800 km west of Cape Town. The longest sequence, extending back 11,000 cal yr. BP, was found on Nightingale Island. Records of pollen and spore content, total carbon, nitrogen and sulphur content, and magnetic susceptibility have been obtained and radiocarbon dated. The preliminary pollen data indicate that the site has been subject to significant hydrological changes. The oldest part of the sediment sequence, 11,000 to 9800 cal yr BP, consists of fen peat which implies low lake levels in the early Holocene. After 9800 cal. yr BP the sediment consists of gyttja up to the final over-growing of the basin in the last centuries. From 9800 cal. yr BP recurring periods of high minerogenic content and high frequencies of tree pollen and fern spores indicate higher lake levels and increased erosion of the catchment. Whereas intervening episodes of high frequencies of sedge pollen indicate an increased littoral zone dominated by sedges and low lake levels. The lake-level changes were probably caused by precipaition changes. The underlying mechanisms behind the precipitation variations are probably related to oceanographic changes possibly linked to atmospheric circulation changes in the South Atlantic. We think that these may be of hemispheric/global climatic significance.

Highly-potassic sanukitoid Panozero pluton (Baltic Shield): implication to Archaean mantle metasomatism

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The Panozero composite pluton (2735 Ma) represents polyphase central type intrusion of potassic ultramafic to feldspar-rich plutonic igneous rocks. It has been formed three magmatic cycles separated by lamproitic and lamprophyric dykes. The calculated initial melt corresponds to monzogabbro differentiation of that gave the monzonite-quartz monzonite intrusive phases. All rocks are highly enriched in K, Sr, Ba, LREE, Cr, Ni and have high *mg*-value evidencing their origin from enriched mantle (1). We suggest a two-stage process for the genesis of the sanukitoid magma: mantle metasomatism through crust-mantle interaction at ~2.8 Ga ago; partial melting of enriched mantle 2.74 Ga ago. So, the mantle metasomatism is separated from the origin of initial Panozero magma in 60 Ma (2). The Pb isotope characteristics of KFsp, Sm-Nd and Rb-Sr Cpx and Ap isotope data, O and C isotope composition of carbonate implay the mantle source region for the initial Panozero melt.

The Sr_I value (0.7017) in the primary minerals (Ap, CPx) evidences that the mantle source region was substantially enriched in Rb/Sr (0.12–0.33) compared with DM and PM (0.016–0.03) at the stage of mantle metasomatism ~2.8 Ga.

The εNd (t) values of the CPx and Ap with lowest Sr_I range from +0.7 to +1.4 and a mean value +1.1 might be considered as the initial. Pb isotope ratios (KFsp) indicate on the low U/Pb and high Th/U ratios in the source region of the Panozero magma.

δC^{13} (PDB) values range from -5.6 to -8.1‰ corresponding initial carbonatites, δO^{18} (SMOW) vary from 10.5 to 12.5‰ that exeeds PM value.

Lobach-Zhuchenko et al. (2005). Lithos 79, 107–128.
Kovalenko et al., (2005). Lithos 79, 147–160.

Vaikijaur Cu–Au–(Mo) deposit, northern Sweden: Preliminary results from fluid inclusion and (O, H) isotope studies.

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The Vaikijaur Cu–Au–(Mo) deposit is located in the ca. 1.88 Ga calc-alkaline Jokkmokk granitoid near the Archaean–Proterozoic palaeoboundary within the Fennoscandian shield in northern Sweden. The Vaikijaur deposit occupies an area of 2×3 km within the Jokkmokk granitoid and includes stockwork quartz-sulphide veinlets and disseminated sulphides and gold. The mineralized area is characterized by potassic, phyllic and propylitic alteration. A conductive pyrite-rich central part is surrounded by a conductive and magnetic zone with pyrite, chalcopyrite, and gold. Analyses of one metre drill core sections have shown up to 5% Cu and 7 ppm Au. Molybdenite is distributed irregularly in the deposit. Re–Os age data suggest that primary porphyry-style mineralization was associated with the calc-alkaline magmatism at ca. 1.89–1.87 Ga. Molybdenite records also a later metamorphic event at about 1750 Ma (Lundmark et al., 2005).

Preliminary fluid inclusion data reveal no evidence for the involvement of high-salinity fluids typically for the Norrbotten Fe oxide-Cu-Au ores. By contrast, fluid inclusions in quartz veinlets associated with the sulphides at Vaikijaur indicate deposition from inflowing low- to medium-salinity aqueous and carbon dioxide-rich fluids. Oxygen and hydrogen isotope compositions of quartz, biotite, chlorite and amphibole in ore-related samples have mixed magmatic and seawater signatures.

Lundmark, C., Stein, H., Weihed, P. (2005). The geology and Re–Os geochronology of the Palaeoproterozoic Vaikijaur Cu–Au–(Mo) porphyry-style deposit in the Jokkmokk granitoid, northern Sweden Min. Dep. DOI: 10.1007/s00126-005-0003-0.

The Sveconorwegian history of the Upper Jotun Nappe, SW Norway; deformation, anatexis and retrogression

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The Jotun Nappe Complex makes up the greater part of the south western Caledonides in Norway. The recent determination of a Caledonian origin of granitoid dykes present in the upper units of the complex (Lundmark and Corfu, 2005) supports a subdivision into an Upper and a Lower Jotun, juxtaposed during Caledonian SE translation. Very little is known of the pre-Caledonian history of the Jotun Nappe Complex in general, and the Upper Jotun in particular. New U-Pb age data from the Upper Jotun constrain its Proterozoic history and possible origins.

Towards the end of a regional Sveconorwegian high grade metamorphism and gneissic fabric forming event, local anatexis leading to the formation of U-rich zircon took place at ca 950 Ma in ca 1638 Ma felsic protoliths in the Hurrungane area, with local mobilisation of granitic melts forming veins and pegmatites in the surrounding rocks. Syn- to post anatexis shear zones cross cutting the gneissic fabric oriented the intrusion of younger (ca 950–940 Ma) pegmatites. Locally, re-hydration of granulite facies rocks in amphibolite facies is interpreted to be coeval with the intrusion of the youngest pegmatites, suggestive of a tectonic sequence starting with deep burial followed by amphibolite facies retrogression.

The age of the Sveconorwegian zircon formation in the Upper Jotun is comparable to ages reported from the southern Western Gneiss Region (Skår & Pedersen, 2003) as well as the Lindås Nappe (Bingen *et al*., 2001) and Dalsfjorden Nappe (Corfu & Andersen, 2002).

Bingen, B., Davis,W.J. & Austrheim, H. (2001). Geological Society of America Bulletin 113, 640–649.

Corfu, F. & Andersen, T.B. (2002). International Journal of Earth Sciences 91, 955–963.

Lundmark, M and Corfu, F. (2005). Tectonics, submitted.

Skår, Ø. & Pedersen, R.B. (2003). Journal of the Geological Society of London 160, 935–946.

Characterization of fracturing in selected rock types with GPR and detailed mapping

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The ground penetrating radar (GPR) or geo-radar is widely used in assessment of rock quality, especially regarding fracturing and soundness. Based on a principle, that when an electromagnetic pulse is sent into rock and when the pulse reaches a layer (fracture or an object with deviant electronic properties) some of the energy will be reflected back, a reasonably accurate survey of mainly horizontal fracturing can be done, covering large areas. The applicability of the method depends on the electrical material properties of the rock. For example, presence of conductive minerals and water content can affect the wave penetration and increase pulse attenuation, lowering the effective measurement depth. Furthermore, the internal structure of the rock can be prominently seen in the results, confusing the interpretation.

GPR measurements to characterize fracturing were executed in selected sites located in southern central Finland. Rock types were a coarse porphyritic post-kinematic granite on the south-eastern margin of Central Finland Granite Complex (CFGC) and a highly deformed and metamorphosed garnet-cordierite gneiss. On both sites a detailed structural mapping was also carried out to achieve an overview of fracture pattern of the areas.

GPR and mapping data was combined in some selected sub-areas to build up a model of fracturing characteristics and the rock soundness as well as to compare the benefits of visual mapping and GPR techniques in detailed site investigation. The preliminary results show the importance of complementary methods for the modelling. Structural elements, like faults and shear zones affect the total quality of a rock deposit but are elusively detected by quick GPR measurements.

Correlation of the Kopparnäs diabases with 1.25–1.67 Ga dyke swarms of Fennoscandia using geochemical fingerprints

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The Svecofennian basement of southern Finland is crosscut by numerous mafic dykes which define three distinct swarms; 1) the Suomenniemi swarm, 2) the Häme swarm, and 3) the Åland–Åboland swarm. Furthermore, scatterd Post-Svecofennian mafic dykes have been found across southern Finland. The above-menioned three swarms are collectively grouped as "Subjotnian" dykes and are coeval (1.67–1.64 Ga) with the spatially associated rapakivi granite complexes. Age data for the scattered dykes are lacking, but they are traditionally regarded to be Subjotnian. The well-exposed Kopparnäs basalt dykes, located ~30 km west of Helsinki, have been a popular excursion target over the past decades. The dykes make up a minor E-W trending swarm that is at least ~2 km long and ~200 m wide. The geochemically uniform swarm is typified by high concentrations of HFS elements (e.g. TiO_2 ~5%, Nb ~40 ppm, Zr ~530 ppm) at MgO of ~5% and it can be readily distinguished from the Häme, Suomeniemi, and Åland–Åboland swarms. Overall, the geochemical fingerprint of the Kopparnäs swarm is unlike those of Subjotnian dykes. For example, the latter have high Ce/Nb values (3–6) typical of crustally contaminated continental basalts, whereas the Kopparnäs dykes have low Ce/Nb values (2–3) that approach those of modern uncontaminated ocean island basalts. Some of the "Postjotnian" ~1.25 Ga intrusions of the Satakunta region exhibit similar, low Ce/Nb, but their compositions are otherwise quite different. The closest geochemical correlatives to the Kopparnäs dykes are the recently studied volcanic interbeds (Salmi basalts) in the Lake Ladoga basin. These basalts were erupted during a rifting episode between the emplacement of the Salmi rapakivi granite at ~1.55 Ga and the intrusion of the Valaam diabase sill into the rift sediments at 1.46 Ga. The results on the Kopparnäs swarm imply that at least some of the scattered diabase dykes of southern Finland probably do not belong to the Subjotnian age group and are more likely associated with ~1.46 Ga rift magmatism in the Lake Ladoga region and in central Sweden.

The last deglaciation and Holocene period in western Norway; fjord and lake sedimentation in the Nordfjord area.

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The more than 100 km long Nordfjord and its surrounding area have been investigated by acoustic profiling in the fjord, and sedimentary coring in the marine and lacustrine environments. The fjord lies in a high-relief area, with mountains peaking nearly 2000 m a.s.l. in the easternmost part close to Jostedalsbreen. Westwards, and towards the coast, mountains rise up to 400 m a.s.l. Maximum water depth in the fjord is down to 600 m in the outer part.

The coastal area was deglaciated before ca. 12,320 ±120 BP (Mangerud et al., 1979; Larsen et al., 1984). A submarine moraine at the outlet of Nordfjord may have been formed close to this age as we know that the glacier was about 50 km further westwards on the shelf during the Bremanger Event between ca. 15,000 and 13,300 BP (Nygård et al., 2004). As the glacier continued to retreat, a stillstand or readvance resulted in formation of a moraine crossing the fjord before the conspicuous Younger Dryas moraines were formed. Further eastwards, there is no indication of glacier stillstand or readvance until a moraine ridge was formed during the early Preboreal age (Fareth, 1987) in the innermost part.

The Nordfjord basins host large volumes of sediments, mainly of glacial character. In the main basin up to 450 ms TWT of sediments have been accumulated just distal to the Younger Dryas moraine, but thicknesses are generally lower.

The sedimentary environmental changes since the deglaciation have so far not been deduced, but e.g. submarine slides, large rock avalanches and many debris flows entering the fjord are encountered throughout the sediment package, indicating a highly variable environment throughout this period. Results from the cores are suggested to give new insight into both the sedimentary environment and the deglaciation chronology of the area.

Fareth, O.W. (1987). NGU Bull. 408, 55 p.
Larsen, E. et al. (1984). Arctic and Alpine Research 16, 137–160.
Mangerud, J. et al. (1979). Boreas 8, 179–187.
Nygård, A. et al. (2004). Boreas 33, 1–17.

The Mesoproterozoic growth of Fennoscandia – exotic or not?

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During the latest years a wealth of U–Pb ion-microprobe and laser ablation ICP-MS analyses of both magmatic and detrital grains of pre-Sveconorwegian rocks in the Southwest Scandinavian Domain (SSD) has opened a possibility to trace the evolution of the oldest crust here. Age determinations of individual rock units can often be difficult to interprete due to later high grade metamorphism. However, ages treated in groups or clusters can retain statistically significant regional bedrock forming ages, ages that may be traced across major Sveconorwegian boundaries.

Work at NGU and elsewhere (Bingen et al., 2005) has shown that the northern part of the SSD bears a detrital zircon memory that suggests an affinity to the Svecofennian and Transscandinavian Igneous Belt. Rocks in the Iddefjorden terrane or Western Segment of Sweden reveals on the other hand a mixed detrital memory imprint, partly exhibiting pre 1.6 Ga detrital ages and partly (juvenile) c. 1.6 Ga ages. Rocks further to the southwest have a more mixed detrital zircon population, with e.g. a higher number of Archaean ages than elsewhere, but without a significant 1.9–1.8 Ga population. The boundary zone between these areas crosscut major Sveconorwegian crustal structures, suggesting that it predates the peak of the Sveconorwegian Orogeny.

Metasediments within this transition zone was analysed using an ion-microprobe. The detrital grains exhibited a pattern as described above, with one sample comprising Svecofennian detrital material, and one sample containing only 1.7–1.6 Ga zircon grains. Furthermore, in one sample most of the investigated grains exhibited thick metamorphic rims. Analyses of these gave a well constrained U–Pb age of 1520±10 Ma. The rims are suggested to have formed during a tectonothermal event during docking of an outboard terrane to the Fennoscandian Shield, i.e. it could represent traces of a (late) Gothian orogeny. The boundary zone can thus represent the remains of a true Mesoproterozoic terrane boundary within the Southwest Scandinavian Domain.

Bingen et al. (2005). Norwegian Journal of Geology 85, 87–116.

Plume related MORB and high-Ti basalts in the Kalix greenstones, northern Sweden

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Paleoproterozoic greenstones are widely distributed in the northeastern part of the Fennoscandian Shield. Due to obvious similarities of the local stratigraphy and the mainly tholeiitic character of the mafic volcanic rocks, Pharaoh (1985) suggested these greenstone areas to be coeval and representing a major tholeiitic province. Based on petrological and chemical studies of the mafic volcanic rocks and associated sediments, a continental rift setting is favoured for these greenstones. According to the present distribution of Archean rocks the paleocontinent was rifted in a northwest-southeast direction from Lofoten to Ladoga and a passive margin with deposition of greywacke developed at 2.1–2.0 Ga.

In the Kalix area in northern Sweden well preserved Paleoproterozoic greenstones occur 100 km inland from the rift margin. Basaltic lava interlayered with volcanoclastic rocks and dolomite is exposed in a more than two km thick sequence that is overlain by graywackes.

The chemostratigraphy of the Kalix greenstones including Sm-Nd isotopes suggest variable magma sources and progressive changes during magma evolution. Most of the basaltic lava and the volcanoclastic rocks have a depleted mantle source, a low to moderate content of Ti, and a chemical composition resembling MORB. However, extremely TiO_2 rich (5.0–6.0 %) basaltic lava and tuff occur in a 150 m thick unit in the upper part of the greenstone pile. These are succeeded by basalt with a transitional character interlayered with stromatolitic dolomite. A major change in depositional environment is then recorded by the overlying graywackes.

The lithostratigraphy and the chemostratigraphy of the greenstones are suggested to monitor the magmatic evolution during the final stage of continental break up and the interaction with a mantle plume that caused extrusion of thick units of volcanic rocks in the Kalix-Kiruna-Kautokeino-Kittili area.

Pharaoh, T. (1985). J. Geol. Soc. London 142, 259–278.

Detailed Investigation of Fault-slip Data from Drill Cores and the ONKALO-Tunnel of the Olkiluoto Investigation Area, SW Finland

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Site investigations aiming to verify the suitability of the bedrock of Olkiluoto Island for the final disposal of spent nuclear fuel have been ongoing already since 1983. A new phase in the investigations was launched in August 2004 as the construction of the underground rock characterisation facility, ONKALO, was started. The forward geological characteristics of the ONKALO tunnel are continuously assessed through so-called predictive studies. In order to decrease the uncertainty of these predictions, the geological model of the area must be continuously revised with detailed new geological data. As a consequence, a continuous process of data collection is a necessity.

The modelling of brittle deformation structures is a demanding task and a variety of data must be taken into account during the work. As part of the building of the brittle deformation model, a methodology for the measurement of fault-slip data was established and detailed fault-slip data including fault-plane and fault-striation orientations and sense-of-shear were measured from existing drill cores and the ONKALO underground rock characterisation facility. So far more than 1600 fault-slip measurements have been made and an extensive kinematic database has been produced. Based on statistical analysis of the measured orientation data, three main fault populations were distinguished: 1. Subhorizontal faults with slip lineation plunging gently towards south 2. Vertical to subvertical faults with slip lineation plunging gently towards northeast and 3. Subhorizontal faults with slip lineation dipping gently towards east-southeast.

Collected fault-slip data will be used in the modelling of brittle structures and in the reconstruction of paleostress orientations using stress tensor inversion. Using this data, a detailed kinematic history of different fault populations may be established.

Contrasting fragmentation depths in two Icelandic tuff cones: Sæfell and Hverfjall

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The fragmentation depth in phreatomagmatic eruptions that build tuff cones has been suggested to be shallow-seated (Lorenz, 1986; Houghton et al, 1999).

However, studies of two tuff cones in Iceland, Hverfjall in northern Iceland and Sæfell on Heimaey (south Iceland) indicate very different fragmentation depths.

At the Hverfjall tuff cone the explosions (occurring at the fragmentation level in the conduit) have excavated a small fraction of country rock. All lithic fragments in Hverfjall are derived from a shallow-seated source. At Sæfell, on the other hand, the fragments of country-rock that are found embedded with the deposits were derived from depths exceeding 820 m (Mattsson et al., 2005) and carried to the surface during diatreme formation in a similar manner as that proposed for maar volcanoes.

In addition to this, the Hverfjall tuff deposits contain abundant reticulite fragments a feature that is not shared with Sæfell deposits. The prescence of reticulite suggests that the Hverfjall magma was already vesiculated prior to contact with the water. Magmatic vesiculation occurs in shallow levels in the conduit, thus supporting the shallow-seated level of fragmentation for the Hverfjall magma. The Sæfell ash is poorly vesicular and appears to have been quenched and fragmented at greater depth.

Houghton, B.F., Wilson, C.J.N. & Smith, I.E.M. (1999). J. Volcanol. Geotherm. Res. 91, 97–120.

Lorenz, V. (1986). Bull. Volcanol. 48, 265-274.

Mattsson, H.B., Höskuldsson, Á. & Hand, S., (2005). J. Volcanol. Geotherm. Res. 145, 234-248.

Geology and eruption chronology of the Hverfjall fissure eruption, northern Iceland

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The Hverfjall eruption occurred ~2500 BP in the southern part of the Krafla fissure swarm in northern Iceland. Detailed fieldwork and stratigraphic mapping conducted during the summer of 2005 show that the eruption occurred along a NNE-SSW trending fissure and that at least two vents were active during the eruption.

The initial activity was concentrated at the Hverfjall vent at the southern part of the fissure. The southern part of the fissure was at that time covered by a shallow lake and deposits generated during that phase are mainly of phreatomagmatic fallout origin. Some time into the eruption a new vent opened up at Jarðbaðshólar (located approximately 3.5 km NNE of Hverfjall). The Jarðbaðshólar vent was situated on land and formed a scoria cone with associated lava flows. Activity was presumably ongoing at the Hverfjall vent during this time. After the cessation of activity at the Jarðbaðshólar vent the focus shifted to the Hverfjall vent once again. However, the Hverfjall deposits that formed after the Jarðbaðshólar scoria cone are almost exclusively base-surges (with minor fallout). The change from fallout to base-surges is probably the result of lowering of the eruption rate at Hverfjall (as two vents drawing from the same magma reservoir are active simultaneously).

The base surge deposits are found both north and south of the Hverfjall crater and can be traced as far as 5 km from the vent (and up to ~100 m uphill on Námafjall). The base-surge deposits display a "drying-up" with distance from the vent. The surges display wet features within a radius of approximately 2 km from the vent (plastering, accretionary lapilli, and soft sediment deformation). Surges found at distances exceeding 2 km from the vent all display dry features such as strongly grain-segregated layers.

Mixed fragmentation during the initial phase of the emergent Capelas eruption, São Miguel (Azores)

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The Capelas eruption started in the sea just off the north coast of São Miguel island (Azores). The eruption built a tuff cone and a nested scoria cone with associated lava flows. Although the first phase of the eruption had access to abundant seawater the deposits consist of a mixture of fragments generated by both magmatic and phreatomagmatic fragmentation processes. Magmatic fragmentation produced ragged scoriaceous fragments with high vesicularity, whereas the phreatomagmatic fragmentation produced dense, splintery shaped particles with low vesicularity.

We interpret the mixed fragmentation in the initial phase as being a result of fire-fountaining activity in a shallow marine environment. The shallow-marine setting is also indicated by the abundance of broken marine shell fragments (molluscs) within the initial phase deposits. During this phase, water was only allowed to interact with the magma to a limited extent along the edges of a magma jet or continuous up-rush, thus producing fragments with magmatic fragmentation characteristics inside the jet and phreatomagmatic fragmentation at the edges of the jet due to quench-interactions with the seawater. Once the initially high eruption rate dropped, more efficient mixing of magma and water occurred and the eruption was from that point onward dominated by normal phreatomagmatic fragmentation.

Comparison of the lithology, geochemistry and stromatolites of the Paleoproterozoic Peräpohja Schist Belt in Finland and Soanlachti Formation in Russian Karelia

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Subdivision and correlation of Palaeoproterozoic terrigenous-carbonate successions is a difficult task. There are no fossils like in the Phanerozoic, where paleontological methods are the base of stratigraphy. Stromatolites are organo-sedimentary structures, which can be distinguished in the field and be used for subdivision and correlation of the Precambrian. Recently, the analysis of carbon isotopic composition of carbonate rocks appeared as a new tool for stratigraphical correlation of Palaeoproterozoic sequences.

Carbonates of the 100 to 300 m thick Rantamaa Formation of the Peräpohja Schist Belt in northern Finland were deposited after the extrusion of the Jouttiaapa metalavas, dated at 2090±70 Ma by Sm-Nd method. The upper part of the Rantamaa Formation that contains carbonates with $\delta^{13}C$ values plunging down to 3 ‰ is overlain by the Väystäjä Formation that includes carbonates with $\delta^{13}C$ values close to 0 ‰. Most of the Rantamaa carbonates are shallow-water sediments deposited on a tidal flat. Soanlahti Formation (SW part of Russian Karelia) comprises light-grey fine-grained thin-bedded dolostones. It overlies 2090±70 Ma (Pb-Pb carbonate age) Upper Jatulian formation that is composed of an 800 m-thick magnesite-dolostone-red bed succession and contains abundant stromatolites. The Upper Jatulian dolostones are enriched in ^{13}C ($\delta^{13}C$=8–10 ‰). The carbonates of Soanlachti Formation are "normal" in respect to the $\delta^{13}C$ values ($\delta^{13}C$=0 ‰). The dolostones contain stromatolites of the genera *Soanlachtia*.

In the Peräpohja Schist Belt there are four genera common with the Karelian ones: *Omachtenia, Colonella* (widespread in the Rantamaa Formation), *Djulmekella*, and *Soanlachtia*. The distance between the Peräpohja Schist Belt and the Janisjarvi area in SW Karelia is 600 km, but stromatolite associations still show striking similarities.

Archaean–Palaeoproterozoic transition: emerging modern Earth system

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The development of new analytical techniques, and improved models for planetary evolution, has intensified research into the evolution of the Earth System and targeted several critical intervals in Earth history when the biota, hydrosphere and atmosphere were experiencing global-scale changes. It is common knowledge that the Archaean Earth System (> 2500 Ma) functioned differently from that in the recent past because of the absence of an oxygen-rich atmosphere. Oxygen-rich habitats were restricted to microbial mats or perhaps ephemeral oxygen oases in the surface ocean or in lakes, and so biogeochemical recycling of buried organic matter in the Archaean largely depended on fermentative decomposition. Given the lack of oxidative weathering, it remains unclear how organic matter preserved in marine sediments was recycled upon uplift and exposure.

The first 500 million years of the early Palaeoproterozoic was a time of environmental upheaval that heralded the emergence of the modern, aerobic Earth System. The Earth System experienced a series of fundamental upheavals through the Archaean-Palaeoproterozoic transition (c. 2500–2000 Ma). Most important of these were the establishment of an oxygen-rich atmosphere and the emergence of an aerobic biosphere. Fennoscandia provides a fairly complete record of the hallmark events of that transition, i.e., the global Huronian glaciation, a rise in atmospheric oxygen, the protracted and large-magnitude Lomagundi – Jatuli carbon isotope excursion, a possible upper-mantle oxidizing event, a substantial increase in the seawater sulphate reservoir, changes in the sulphur and phosphorus cycles, a radical modification in recycling of organic matter, and the Shunga Event – the accumulation of an unprecedented organic-matter-rich sediments and the oldest known inferred significant generation of petroleum. A fundamental problem remains, namely, how exactly did the aerobic Earth System emerge out of this suite of global-scale biogeochemical perturbations?

Magmatic lobes as key locations for unraveling complex internal processes in magma chambers: an example from the Tuolumne Batholith, Sierra Nevada, California, USA

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Geochronology of batholiths, representing large frozen magma chambers, has shown that they may form over millions of years during the assembly of a few to many episodically intruded pulses. Dependent on the size of the magma chamber and the frequency, number and size of pulses replenishing the chamber, the area of interconnected melt can be large and the crystallization time long. Thus, internal contacts between individual pulses and physical and chemical processes like fractionation, mixing and mingling, and different emplacement processes can be extremely complex during a batholith's growth.

Magmatic lobes of individual batholith units are key locations for understanding internal processes in composite batholiths because they represent one stage of magma chamber construction: 1) Lobes cool much quicker than the main batholith and thus preserve shorter increments of host rock material transfer processes (MTP's) and internal processes; 2) preserved strain within the lobe is less likely to reflect regional deformation; 3) lobes are chemical aliquots of individual pulses because they are less contaminated by subsequently intruding pulses. Therefore, in lobes we can better evaluate 1) the extent of interconnected melt between units; 2) the role of fractionation vs. mixing and mingling; 3) emplacement mechanisms as the chamber grows. Here we focus on the growth and internal processes of the Kuna Crest granodiorite lobe, which extends laterally SE of the ~1000 km^2 (94-85 Ma) Tuolumne Batholith, CA. Processes associated with this lobe are: a) lobe-wide fractionation and local mixing/mingling, the former of which forms: Hbl-Bt-cumulates, wide, gradational transitions between units and the change from a mafic margin towards a more felsic center; b) multiple, contemporaneous MTP's such as stoping, subsolidus deformation, shearing, and downward flow at the lobe margin; c) a final increment of lobe growth associated with widespread stoping as late fractionated magmas migrated out the tip of the lobe.

Paleomagnetic evidence for Mesoproterozoic – Paleozoic reactivation of the Paleoproterozoic crust in southern Finland

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Paleomagnetic and rock magnetic studies on fault and shear zones in the capital area of Finland give evidences of multiple reactivation of the Paleo-proterozoic crust. Some of the studied locations have preserved the original Paleoproterozoic remanent magnetization component A that was acquired during cooling of the crust in the late stages of the Svecofennian orogeny at ca. 1.9–1.8 Ga. The frequent occurrence of a Mesoproterozoic remanence component SB1 implies that the emplacement of the rapakivi granites and associated dykes at ca. 1.64–1.63 Ga has affected the shear zones all over the study area as new magnetic material was precipitated from hydrothermal fluids circulating in the fault structures. Based on comparison to the known Fennoscandian Precambrian key poles, the most extensive structure, the Porkkala-Mäntsälä shear zone, was remagnetized some 50 Ma later, at ca. 1.58 Ga when component SB2 was acquired. Alternatively, based on comparison of pole SB2 to the Fennoscandian Paleozoic APW path (Torsvik et al., 1996), component SB2 was acquired during Early Silurian at ca. 440 Ma. This interpretation lends support from the most common remanence component C of the studied shear zones, the pole of which matches well on the Silurian – Devonian APW path and gives an age of ca. 415 Ma. A weakly defined component B was obtained sporadically in some of the studied sites, and it is interpreted to be ca. 300–230 Ma. These are the first indications of Paleozoic remagnetizations in the Paleoproterozoic crust of southern Finland. It is suggested that tectonic reactivation, coupled with sedimentation following the Caledonian orogeny, are mainly responsible for their occurrence. It is implied that the remagnetizations are especially seen in crustal weakness zones which have been most vulnerable to later reactivation due to fluid migration.

Torsvik, T.H., Smethurst, M.A., Meert, J.G., Van der Voo, R., McKerrow, W.S., Brasier, M.D., Sturt, B.A. & Walderhaug, H.J. (1996). Continental break-up and collision in the Neoproterozoic and Palaeozoic – A tale of Baltica and Laurentia. Earth-Science Reviews 40, 229–258.

Education for Sustainable Development, a challenge for Geology

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An internet based support network for schools is established by the Directorate for Primary and Secondary Education in Norway. The national webside www.miljolare.no and the international webside www.sustain.no are the main portals to the program. The websides are learning resources, organized in several activities for schools. All informations and support tools are found on internet, but the work done in the field with hands-on involvement by students. The websides provide schools with methods , background information and data-bases. Schools develop their own projects using guidelines on the internet. Students learn through field work, analyses of findings, discussion of results and writing of reports.

The superior aim of the program is to provide a system for knowledge building that contributes to sustainable development. It is important to recognice the connections and interactions between social, economic and ecological development. The program aims at all levels of the ecucation system. It is cooperation on the development of the network, webpages, background material, guidelines, databases, reports and quality control etc between central authorities, research institutions and schools. The Geological Survey of Norway is now a part of this network, and will develop activities and campaigns.

In the national program it is 12 thematic categories, and in the international program it is only 6 categories. Of most interest for activities regarding geology are the categories: Biological diversity, climate and air quality, comsumption and resources, energy and water. It is a challenge to include relevant activities from different parts of "geology for a chaging society" into this program. Hopefully this will encourage future students to become scientists.

Rheology, stress and deformation in the lithosphere of the central Fennoscandian Shield revealed by numerical modelling

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Understanding rheological conditions through the entire lithosphere and even deeper is the key for understanding the deformation of the lithosphere. Thus investigating the rheological structure of the lithosphere and possible consequences resulting from tectonic loading are in some amount required when interpreting geophysical data into tectonic models.

In this paper the rheological structure is obtained by calculating rheological strength in different locations of the central Fennoscandian Shield. These are mainly located along the different deep seismic sounding (DSS) profiles as they provide necessary information for constructing the models. Modelling is done in two- and three dimensions and it begins by solving the thermal structure of the lithosphere with the finite element method, as rheological calculations require knowledge of the temperature. Results of the rheological calculations show that the rheological structure depends strongly on the thermal conditions resulting in significant areal variations. Generally the central Fennoscandian Shield can be considered rheologically rather strong. Rheologically weak layers are however usually found in the lower crust. Correlation of the rheological structure with the earthquake focal depth data shows that the brittle fracture is the relevant mechanism in the earthquake generation and that non-occurrence of the deep earthquakes implies low stress or high strength conditions deeper in the crust. Calculated rheological structure is furthermore used as a material parameter in the structural finite element models. These results suggest that it is highly unlikely that any considerable ductile deformation in the crust of the central Fennoscandian Shield exists and it seems that the present-day thermal and mechanical conditions in the investigated area do not favour such processes in significant amounts.

Features of chromite mineralization composition in Paleoproterozoic Monchegorsk layered intrusion (Russia, Kola Peninsula)

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The chromite deposit of the Monchepluton is confined to the southwestern part of the so-called Dunite block (Smolkin et al., 2004). The chromitite layer has a lens form, limited at the NE and SW part by the two main faults. The ore layer length is about 1 km and the width ranges from 160 to 280 meters. It has southeastern dipping and maximum thickness is about 50 m. The northern part of the layer is obliterated by erosion. Based on the morphological and compositional investigations of chromite, some morphological types were distinguished, such as early chromite, forming micro-inclusions in olivine, ore chromite, crystallized simultaneously with olivine, and late chromite, confined to interstitials between olivine.

According to microprobe analysis the accessory chromite corresponds to magno-alumo-chromite and magno-chromite. The ore chromite is the relatively uniform magno-chromite, unaltered by metamorphism, which causes it's high quality. Ore chromite coexists with high-magnesian olivine (4–6 % Fa), enriched by nickel, 0.6–1.2 wt.%. In accessory early stage chromite, found in all rock types, the Cr_2O_3 and MgO contents are low, and Al_2O_3 is high, caused by the more basic host rock composition and high-temperature conditions of the chromite crystallization. Chromite composition varies with the physical-chemical conditions, such as melt temperature, and component activity. Chromite crystallization occurred during a slow temperature decreasing, and relatively low and constant oxygen fugacity, which is characterize the close system. The chromite deposit is orthomagmatic segregate deposits, which have formed during the early magmatic stage as a result of gravitational differentiation and subsequent recrystallization. This genetic ore type also includes chromite deposits of the layered intrusions – Kemi and Burakovskaya.

*Smolkin, V.F., Fedotov, Zh.A., Neradovsky, Yu.N., et al. **Layered** intrusions of the Monchegorsk ore region: petrology, mineralization, isotopy, deep structure. – Apatity: Kola Science Centre RAS, (2004). 367 p.*

The Massignano Eocene-Oligocene Global Stratigraphic Section and Point revisited

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In common practice, the Eocene/Oligocene (E/O) boundary is linked to the Oi-1 $\delta^{18}O$ benthic isotope event (magnetosubchron C13n). The IUGS-ratified the E/O GSSP at the pelagic Massignano Quarry section, central Italy, at metre 19 of the 23 m section, which is within the older magnetosubchron C13r. To extend the lower Oligocene record, the Massicore was drilled about 110 m south of the stratotype section. By means of high-resolution organic-walled dinoflagellate cyst (dinocyst) analysis, combined with the stratigraphic correlation of biotite-rich horizons an almost perfect linear correlation between the core and the quarry was obtained, resulting in the Massignano GSSP composite section, spanning from magnetosubcrhon16-2n to 12r (van Mourik & Brinkhuis, 2005).

Using the paleomagnetic ages from Ogg et.al. (2004), we made an age model of the composite section, along which the paleoecological dinocysts proxies were plotted. This enabled straightforward correlation of the (relative) Sea Surface Temperature (SST) curve to the 400 ky eccentricity curve of Laskar et al.'s (2004). In one interval, 17 to 35 m, the correlation could be made to the 100 ky eccentricity curve (Laskar et al., 2004).

This would give the Eocene/Oligocene GSSP (19 m) an age of 33.96±0.05 Ma. The age of the onset of the Oi-1 event appears around 33.55±0.01 Ma, and towards the top of the section the cooling peaks in the SST get more and more pronounced. The cooler conditions are substantiated by the occurrence of restricted high latitude dinocyst species.

Laskar,J., Robutel, P., Joutel, F., Gastineau, M., Correia, A. C.M., & Levrard, B. (2004). A long term numerical solution for the insolation quantities of the Earth. A&A 428, 261–285

*van Mourik, C.A. & Brinkhuis, H. (2005). **The Massignano** Eocene-Oligocene golden spike section revisited. Stratigraphy 2, 13–30*

Ogg, J.G. & Smith A.G. (2004). The geomagnetic polarity time scale. In: Gradstein, F.M., Ogg J.G. and Smith A.G. (eds.) A Geological Time Scale, 63–86.

U/Pb-ages for Proterozoic crust in Northwestern Spitsbergen & timing of Caledonian events in Svalbard.

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ID-TIMS U/Pb-ages from felsic gneisses, granitic neosomes of migmatite and granitic batholiths give new insight into the tectonic history of Svalbard in general and Northwestern Spitsbergen in particular. The results indicate the presence of Mesoproterozoic protoliths, Grenvillian (962+/-6 Ma) continental magmatism and a two-stage (430+/-1 Ma & 418+/-1 Ma) Caledonian magmatic history. This tectonic fingerprint is similar to that observed in the East Greenland Caledonides (Watt et. al., 2001), (Kalsbeek et. al., 2000). Svalbard's pre-Devonian basement consists of several blocks with contrasting geology separated by major north-south-trending fault zones (summarized by Gee et al., 2004). The major blocks are the Western Terrane, the Ny Friesland Terrane and the Northeastern Terrane, but further subdivisions can be made. Some of the terranes (i.e. the Northeastern Terrane) can be correlated with East Greenland based on stratigraphy and tectonic evolution (Andresen, 2004; Johansson et. al., 2005). An integrated model for the Caledonian evolution and amalgamation of the blocks can be inferred based in part on the new ages. The Caledonian development of Svalbard included the formation of HP-rocks on the eastern Laurentian margin at c. 450 Ma. (Motalafjella complex (Dallmeyer et al. 1990, Peucat et al., 1990) & Biscayarhuken complex (Gromet and Gee, 1998)), subsequent crystallization of granites now found in Svalbard and E. Greenland at 435–430 Ma and finally crustal melting in NW Svalbard at 418 Ma.

The terranes were then detached from Laurentia and amalgamated into the present configuration by translation along left-lateral transcurrent faults during the time interval from the upper Silurian to the Early Carboniferous.

Andresen (2004). GFF, 126, 77
Dallmeyer et. al. (1990). Geol. Soc. Am. Bull. 102(5), 653–663.
Gee et al. (2004). Geol. Soc. L. Mem. 30, 191–206.
Gromet et.al (1998). GFF, 120, 199–208.
Johansson et. al. 2005. Terra Nova 17, 317–325.
Kalsbeek et. al. (2000). J. Geol. Soc. L.157, 1215–1225.
Watt et. al. (2001). Prec. Res. 110, 165–184.

Chemical exploration of quartz resources in the Froland pegmatite field, Southern Norway

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The Sveconorwegian pegmatite field of Froland is located at the western edge of the Bamble terrane in southern Norway. The field comprises different pegmatite types which can be roughly classified as follows in order from older to younger stages: (1) deformed, simple zoned Na-Ca-rich pegmatites (NaP), (2) complex zoned K-rich pegmatites consisting of a wallzone of pegmatitic granite, a transitional blocky zone and massive K-feldspar and/or quartz cores (KP), (3) small (<100 m^3) zoned K-rich pegmatitic tongues and pockets hosted in the Herefoss granite (KPH) and (4) crosscutting, Na-rich pegmatite dykes up to 1 m in thickness (PD). NaP and KP form lens-shaped bodies with a thickness of several decametres and up to 1 km along strike. Type (1) to (3) containing predominantly Mg-siderophyllite have a relative less-evolved chemistry in the sense of granitic differentiation, whereas type (4) has an evolved chemistry reflected by zinnwaldite and albite.

Trace elements (Li, B, Be, Na, Al, P, K, Ti, Fe, Ge) of pegmatite quartz were analysed by laser ablation ICP-MS in order to classify the resources into low-, medium- and high-purity quality quartz raw material. Quartz from NaP and KP has a relative uniform chemistry. Concentrations vary between 2.0 to 14.3 ppm for Li, 0.7 to 2.2 ppm for Ge, 21 to 62 ppm for Al and 0.7 to 10.7 ppm for Ti. The sum of measured trace elements of quartz in NaP and KP is 58 to 103 ppm. Quartz from KPH has higher Ti (15.1 to 24.9 ppm) and Al (37 to 77 ppm) and the sum of measured trace elements amounts 68 to 133 ppm. Concen-trations in PD quartz range from 1.6 to 9.5 ppm for Li, 2.0 to 2.5 ppm for Ge, 17 to 164 ppm for Al and 3.0 to 17.7 ppm for Ti. The sum of measured trace elements of quartz in PD varies from 48 to 243 ppm.

The pegmatites of Froland can be classified as resources of medium-purity quartz raw material, whereby PD's have the lowest quartz quality. K-feldspar has generally a good economic quality (K_2O >13 wt.%), particulary K-feldpar in KP. Plagioclase of NaP, KP and KPH has no economic importance due to CaO concentrations >2 wt.%. Albite in PD has <2 wt.% CaO but the PD's are only <1 m thick.

Peräpohjola interstadial – A Middle Weichselian interstadial

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The Quaternary stratigraphy of Finnish Lapland is well defined where till deposits are concerned, but the comparative ages of the interstadial deposits between till beds have long been the subject of inconclusive research. It is not possible to define more than one series of interstadial deposits (=Peräpohjola) in SW Lapland on the basis of their position in the stratigraphic sequence and their pollen flora. The Peräpohjola Interstadial has been correlated with the Brörup or Odderade Interstadials of the southern edge of the Scandinavian ice sheet.

The dating results obtained for the interstadial deposits of SW Lapland using modern methods do not support the hypothesis that the deposits were deposited during marine isotope stages MIS 5c (Brörup) and MIS 5a (Odderade). Datings obtained using the ^{14}C, TL and OSL methods tend rather to indicate that the Peräpohjola-type interstadial deposits were formed during MIS 3. Of a total of 43 dating results only 9 exceed 59 ka in age (Mäkinen, 2005). Results obtained using ^{14}C dating are located at the limit of the method's range of accuracy, so some results are finite, while others are infinite. These results may necessarily not be erroneous; rather they may indicate that the deposits were actually deposited towards the end of the Middle Weichselian about 45 – 59 ka ago. Datings obtained using TL and OSL methods were much younger than the expected ages corresponding to the Early Weichselian.

Till bed II, which overlays the dated organic and sorted deposits, was deposited during the Late Weichselian (MIS 2). It has previously been assumed that till bed III was deposited during MIS 5d, but if the Peräpohjola Interstadial deposits of Finnish Lapland are interpreted as having been deposited during MIS 3, this would infer that till bed III may only have been deposited during MIS 4. This would indicate that Lapland was continually free of ice from the Eem Interglacial until the end of the Odderade Interstadial (MIS 5a).

Mäkinen, K. (2005). Dating the Weichselian deposits of southwestern Finnish Lapland. In Ojala, A. (ed.) Quaternary studies in the northern and Arctic regions of Finland. Geological Survey of Finland, Special Paper 40, 67–78.

National inventory of moraine formations in Finland

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The inventory of moraine formations is a nation-wide (Åland excluded) study, which serves the aggregate extraction planning purposes. In the future the aggregate in moraine formations may become increasingly important as a resource replacing the sand and gravel in eskers. The inventory study also serves the purpose of sustainable development by locating and assessing the moraine formations that are valuable with regard to geology, biology, the landscape and their environment as is referred to assignificant natural value in the Land Extraction Act.

The inventory of drumlins, hummocky moraines and end moraines is carried out by the Geological Survey of Finland (GTK) and the Finnish Environment Institute (SYKE) under a supervisiory body consisted of national interest group. The project is funded by GTK and the Ministry of the Environment. The formations to be inventoried were preliminary chosen based on the existing geological information. These formations were then inspected in the field by both a geologist from GTK and a biologist from SYKE. The outlines of the formations were checked and the formations were evaluated on the basis of their geological, biological and scenery values. The data acquired was stored both in a database and a GIS-format.

The geological fieldwork was finished in 2004 and the biological fieldwork by the end of the 2005. However, some introductory results already exist. Finland has ca. 1500 moraine formations that were inventoried at the field during the project. The total area of inventoried moraine formations covers over 85 000 hectares of land. Of all these formations about 600 has such value as is referred to as significant natural value in the Land Extraction Act. A nation-wide report will be compiled and published by the end of the project in 2006.

Direct dating of Sveconorwegian north-south compression in the southern Eastern Segment – ion probe dating (Nordsim) of zircon

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In the southern Eastern Segment upright to overturned folds, with E-W-trending subhorisontal axes and wavelengths of c. 4–15 km, form a conspicious magnetic anomaly pattern. The pattern reflects tightly folded migmatitic orthogneisses and garnet amphibolite layers that have been folded or stretched and boudinaged. Leucosome in both folded and semi-discordant relations to the folds demonstrate that migmatisation took place synchronous with the folding. Three zircon samples from a folded and migmatised granitic gneiss were examined: (1) gneiss without vein segregations, (2) gneiss with 3–15 mm wide segregations, and (3) folded and semidiscordant dm-wide leucosome. All samples contain c. 1.67 Ga igneous protolith zircon (Th/U>0.69, U=50–1700 ppm). Protolith zircon in samples 1 and 2 has thin, 5–20 μm, BS-bright rims. In sample 3 protolith zircon has up to 75 μm wide, BS-bright rims (Th/U<0.02, U=1300-4400 ppm). Rim analyses date migmatisation and synchronous E-W folding at 976±7 Ma (n=11, weighted average concordant $^{207}Pb/^{206}Pb$-age, 2σ errors, MSWD=1.7).

The age of leucosome formation and folding is identical with the 972±14 Ma age of eclogite metamorphism recorded from a dismembered and retrogressed eclogite unit (Möller 1998, Johansson et al. 2001) that is similarly affected by tight folding along E-W axes. North-south compression at 0.98–0.97 Ga call for a different Sveconorwegian tectonic scenario than previously envisaged. North-south thrusting and extrusion of eclogite and other units is suggested, followed by tight to open folding and high-grade metamorphism in a similar stress field.

East of the Protogine Zone Sveconorwegian shortening has not affected the bedrock. During the N-S compressional stage stress was probably taken up as strike-slip along the Protogine Zone, by analogy with strike-slip zones bounding present India.

Möller, C. (1998). J. Met. Geol. 16, 641–656.

Johansson, L., Möller, C. & Söderlund, U. (2001). Prec. Res. 106, 261–275.

Ion probe zircon dating of polymetamorphic gneisses, southeast Sveconorwegian Province – defining 1.44 Ga migmatisation, 1.40 Ga granitic dyke intrusion, and post-1.40 Ga folding

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The southern part of the Eastern Segment, Sveconorwegian Province, has undergone regional Sveconorwegian high-pressure granulite facies metamorphism, deformation and migmatisation but also experienced an older migmatisation event at c. 1.44 Ga. Distinction between Sveconorwegian and Presveconorwegian structures and metamorphic features is therefore difficult. In order to date characteristic migmatite and deformation structures, zircon from migmatitic "Hallandia" gneiss and granite dykes at a well-exposed quarry north of Halmstad was investigated by imaging and U-Pb ion probe analysis (NORDSIM, presented as weighted average concordant $^{207}Pb/^{206}Pb$-ages with 2σ errors).

Samples selected for analysis are (1) gneiss paleosome, (2) granitic vein material, (3) crosscutting folded granitic dyke, (4) crosscutting undeformed granitic pegmatite dyke (not yet analysed).

Igneous c. 1.67 Ga protolith zircon occur in both gneiss (1) and vein material (2) (n=15, Th/U=0.20-1.50, U=40-640 ppm). Up to c. 70 μm thick secondary rims are abundant in sample 2 (vein) and date Presveconorwegian migmatisation at c. 1.44 Ga (n=17, Th/U=0.02–0.11, U=800–2800 ppm).

The deformed and folded granite dyke (3) contains three different zircon phases. Simple igneous zircon date the dyke intrusion at c. 1.40 Ga (2 grains, n=3). Zircon xenocrysts include igneous c. 1.48 Ga zircon cores (2 grains, n=4) and c. 1.44 Ga secondary zircon (rims and simple grains, n=8). Both gneiss and deformed dyke have been folded tightly along SSW-plunging axes and developed a steeply SE-plunging, axial-planar-parallel stretching lineation. The age of the deformed granite dyke sets an upper age limit of 1.4 Ga for the fold structures and fabric formation.

Melting of lower crustal mafic granulites – a source for tonalitic melts?

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Mafic granulites occur within banded amphibolitic migmatites in the Iisalmi block, central Finland. Ages of 3.2–3.1 Ga are obtained from the granulites and migmatite mesosomes from the area surrounding granulites (Hölttä et al., 2000). In this work we have modelled the melting processes that caused migmatisation in these mafic rocks during granulite metamorphism.

Trace element contents of mafic granulites are consistent with an origin as restites of partial melting of basaltic source rocks. Amphibolites from the lower grade area have flat to slightly LREE enriched REE pattern. They are suitable source rocks yielding residues of similar composition to mafic granulites after 10% batch melting leaving ~10% gt in the residue. Some strongly REE-fractionated granulites require up to 25% melting, higher amounts of gt and lower modal plg consistent with observed mineralogies. Low modal plg results from consumption of plg >10 kbar in melting reactions (Patiño Douce & Beard, 1995). Corresponding model melts are slightly to strongly REE-fractionated, comparable with trace elements in leucosome samples.

Leucosomes in granulites and lower grade migmatites are predominately tonalitic, few approach trondhjemitic or granodioritic composition. They usually consist of large subhedral plg crystals floating in a matrix of qtz, indicating growth from a melt. Mafic minerals occur in small amounts and most likely represent entrained restitic material. Granulitic leucosomes are richer in CaO and poorer in Na_2O and K_2O compared to leucosomes from the amphibolite grade area. They may represent late refractory melts that where not expelled from the granulitic matrix. However, metabasalts with higher CaO but similar trace element contents as the amphibolites from the low grade area may be potential sources for the granulitic residues. Wolf & Wyllie (1994) showed that an initial CaO content of 14 wt.% results in strongly tonalitic liquids.

Hölttä et al. (2000). Lithos 50, 97–120.
Patiño Douce & Beard (1995). J. Petrol. 36, 707–738.
*Wolf & Wyllie (1994). **Contrib. Min. Petrol. 115, 369–383.***

Accuracy of Rietveld refinements of alkali feldspars

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The Rietveld method has found great use in analysis of powder diffraction data. Crystal structures can be refined by fitting the entire diffraction pattern to a calculated pattern. The calculated pattern is based on a crystal structure, which has to be close to the real structure in order for the calculation to succeed.

Although the Rietveld method treats full sets of structural parameters like the single crystal method, the accuracy is lower because of the unavoidable overlap of diffraction maxima, and involvement of a number of additional refinable parameters related to the powder measurement method. However, this is not reflected fully in the calculated standard deviations which always give an over-optimistic picture due to a high ratio between observables and parameters.

In this study we attempt to define the intrinsic possible accuracy of the method in treating complicated important mineral structures. Rietveld refinements on alkali feldspars and their mixtures are made with the program TOPAS. Instead of experimental patterns, the theoretical ones calculated from the single crystal data are used in order to remove the influence of experimental factors. The results from this study define in this way the best accuracy of the Rietveld analysis which can be realistically expected in the case of alkali feldspars, and define realistic determination errors for various structural parameters. The results can be used in the structural analysis of feldspars which are not amenable to single crystal studies, and to combined quantitative and structural analyses of mixtures of minerals.

Age and significance of trondhjemite-diorite-gabbro complexes in the southern Trondheim Region, central Norwegian Caledonides

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Large bodies of trondhjemite, up to 200 km2 in outcrop size, locally coexisting with diorite and gabbro, are an important element in the Köli Nappes of the Trondheim Region. In the Trondheim Nappe Complex they intrude metasedimentary and metavolcanic rocks and correspond geochemically to high-Al continental-margin types. Zircon (and titanite) U-Pb geochronology shows that they formed in the Early Silurian starting with the emplacement of the trondhjemitic-dioritic Høg Gia complex at about 438 Ma. Ages between 437 and 433 Ma characterise a number of other plutons including Vålåsjø, Reitstøa, Innset and Nyvollen (Nilsen et al., 2003). Mafic and felsic magmatic activity of this age is characteristic of the upper part of the Upper Allochthon (i.e., Köli Nappes) throughout the Scandinavian Caledonides, although the setting varies from the extensional environments characteristic of some of the complexes (e.g. Solund-Stavfjord) to the transpressional to transtensional settings recognised in the Köli nappes of Nordland, Troms and Finnmark. The overall timing of this widespread magmatism corresponds to the terminal stages of Iapetus Ocean closure, immediately prior to the peak of Scandian metamorphism. Geochemical studies (Dunning & Grenne, 2000; Pannemans & Roberts, 2000) have indicated that the trondhjemites are likely to have formed by partial melting of garnet-amphibolite grade, deep-crustal mafic precursors in association with mantle-derived mafic magmas in segmented transtensional settings, as an anticlockwise-rotating Baltica collided with Laurentia.

Dunning,G.R. & Grenne, T. (2000). Nor. geol. unders. Bull. 437, 57–66.

Nilsen O., Sundvoll B., Roberts D. & Corfu F. (2003). Nor. Geol. Unders. Bull. 441, 5–16.

Pannemans, B. & Roberts, D. (2000). Nor. geol. unders. Bull. 437, 43–56.

Late Svecofennian sedimentary-volcanic association at Pyhäntaka, southern Finland

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At Pyhäntaka, near the city of Lahti, there is a sedimentary-volcanic sequence that includes a quartzite. The Pyhäntaka quartzite is one of the small quartzite occurrences in the northern part of the Late Svecofennian granite-migmatite zone (1.85–1.80 Ga) in southern Finland. These quartz-rich sands (quartzites) were deposited in late Svecofennian time (< c. 1.88 Ga) on the basis of their detrital zircon ages (Lahtinen et al., 2002). A new detrital zircon study yielded a c. 1860 Ma age for the youngest zircon at Pyhäntaka (Bergman et al., 2006).

Few cross-bedding observations in quartzites and field relations indicate a depositional sequence starting from K-feldspar-cordierite gneiss (pelite) with mafic volcanic rocks as an interlayer, followed by quartzite, arkosic gneiss, tuffite and mafic volcanic rock, and on top K-feldspar-cordierite gneiss. The sequence has been overturned, and the only tectonic contact that may be associated with major displacement is between the lower K-feldspar-cordierite gneiss and the quartzite. The lower volcanic rocks have a calc-alkaline affinity whereas the upper tholeiitic volcanic rocks suggest rift-related magmatism affected by crustal contamination.

The structures within the area comprise four deformational phases that post-dated the deposition of the quartzite. Overall, the sequence at Pyhäntaka express post-1.86 Ga deposition in a shallow rift basin. The extensional stage and associated mafic magmatism provided heat to the thinned crust leading to voluminous granite magmatism and migmatization. The emplacement of the 1.85–1.82 Ga granites started during the extensional stage and continued during subsequent transpressional stage as the result of compression from the southeast.

*Lahtinen, R., Huhma, H. & Kousa, J. (2002). **Precambrian** Res. 116, 81–109.*

Bergman, S., Högdahl, K., Nironen, M., Lundqvist, L., Sjöström, H., Ogenhall, E. & Lahtinen, R. (2006). This Volume.

Isotope U-Pb zircon dating of the earliest and the next Pt-bearing rocks in the Federovo Pansky layered intrusion (N-E Baltic Shield).

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This work focuses on the precise U-Pb isotope zircon dating of different rocks in the layered Federovo Pansky intrusion, which is one of the largest Pt-bearing layered intrusions in the northern Kola belt. The intrusion includes Federov, Lastjavr, West-Pansky and East-Pansky blocks (Schissel et al., 2002). The massif consists of marginal zone, taxitic gabbronorite zone, norite zone, main gabbronorite zone, lower layered zone, gabbro zone, upper layered zone and uppere gabbronorite zone according to Dokuchaeva (1994).

Zircons from ortopyroxenite and gabbro of the earliest phase and norite of the next phase were dating in the Federov block. The mineralogical research of the zircon shows that all crystals are characterized by magmatic features. The U-Pb age, which was obtained from the four zircon populations from orthopyroxenites, is 2526±6 Ma (MSWD=1.70), which is interpreted as time of rocks emplacement. The lower concordia-discordia interception is at the point of 700±50 Ma. The coordinates of three points describe a discordia for gabbro, which intersects the concordia at the point of 2516±7 Ma, MSWD=0.52 and can most likely indicate time of its crystallization. The lower concordia-discordia interception is at the point of 854±50 Ma. Norite zircon populations yielded the U-Pb age of 2485±9 Ma, MSWD=1.2, which shows crystallization time. The lower concordia-discordia interception is at the point of 360±50 Ma.

The geochronological zircon U-Pb data from three different rock of Federov block of Pt-bearing layered Federovo Pansky intrusion show that the orthopyroxenite and gabbro of the earliest phase were formed at 2526–2516 Ma and norite of the last Pt-bearing phase were originated at 2485±9 Ma.

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Dokuchaeva, V.S. M. (1994). Nauka, p. 87–100.
Schissel, D. (2002). Economic Geology 97, 1657–1677.

Late Archaean magmatism in the Sørvaranger area, northern Baltic Shield

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In the Sørvaranger and adjoining areas of the Kola Peninsula, different types of igneous rocks including grey gneisses (TTG), enderbites and various monzonitic to granitic plutons are associated with greenstone belts and medium- to high-grade metasedimentary rocks.

The oldest rocks (c. 2.9–2.8 Ga) are tonalitic grey gneisses (Kirkenes, Varanger and Svanvik Complex) and hypersthene-bearing, igneous gneisses (enderbites) with bimodal gabbroic and tonalitic composition. The massifs have concordant, tectonic contacts towards the enclosing metasedimentary rocks of the Jarfjord Gneiss (the equivalent of the Kola Gneiss in Russia) together with which they were metamorphosed in the amphibolite (west) to granulite facies (east). The composition of the rocks is consistent with derivation from a depleted mantle or a mafic lower crustal source. In eastern Sørvaranger, locally abundant peraluminous, garnetifeous granites were probably derived by partial melting of metasupracrustal rocks.

Hypersthene-bearing granodioritic rocks with calc-alkaline composition occur as plutons, small stocks and sheets which have intruded the Jarfjord Gneiss in the border zone and in Sørvaranger. U-Pb dates of c. 2.73 and c. 2.76 Ga for two of the plutons show that they are younger than the tonalitic gneisses and enderbites. The textures of the rocks indicate that they were emplaced during the waning stages of granulite-facies metamorphism in the area. High-K, alkali-calcic monzonitic and quartz syenitic rocks (c. 2.73 Ga) are present as small plutons intruding the Varanger Complex and the Jarfjord Gneiss in Sørvaranger. The textures of the rocks are magmatic and they probably post-date the granulite-facies metamorphism. The granodioritic and monzonitic rocks were probably formed by partial melting of a variably enriched, peridotitic mantle source.

In the western part of Sørvaranger, c. 2.5 Ga-year-old granites and granodiorites, including the Neiden and Geahcoaivi plutons, were derived from mixed sources and represent the final stage of Archaean intrusive activity in the area.

The Scandes: In between the margin and the shield

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We present a series of overview studies on the Fennoscandian shield and its passive margin. These studies seek to link the deep lithosphere to morphological and topographic features.

Structural, thermochronometric, and topographic data suggest that the latest Cretaceous/Cenozoic uplift of western Norway was associated with normal-sense reactivation of the Møre-Trøndelag Fault Complex. The asymmetric topographic profile of Fennoscandia is reflected in the apatite fission-track data and suggests that lithospheric flexure and glacial relaxation place a first-order control on the shape of the Scandes Mountains and the central Fennoscandian craton. For the Southern Scandes isostatic considerations and gravity modelling show that the density distribution within the lithospheric mantle is isostatically balancing the lithosphere.

However, despite new knowledge obtained from surface geology and subsurface geophysical studies, our understanding of the deep crustal and upper lithospheric mantle structure remains opaque. A number of passive and active seismic experiments in the central Baltic Shield provided an image of the lithospheric structure: But further to the west, beneath the Scandes, only a limited number of experiments with relatively low resolution are available.

Given the impoverished nature of the Fennoscandian lithospheric database, a new, detailed study of lithospheric structures in Norway is eminently justified. NGU is currently planning cooperative efforts to provide this critical "missing link" between the well-known offshore areas to the west and the central Fennoscandian shield to the east.

Ground penetrating radar as a tool to study internal structures of the glaciofluvial aquier area between Vihanti and Piippola, Western Finland

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Ground penetrating radar (GPR) is a geophysical method that is used to detect electrical discontinuities in the shallow subsurface. The GPR data combined with other geophysical and geological data can be used to build three-dimensional images of the subsurface of the earth. The low frequency antenna gives a deep depth penetration while the higher gives better resolution. Combining these gives us a tool which can be used solving sedimentology problems.

The work was carried out between Vihanti and Piippola in northern Finland in different areas consisting several sedimentary sequences. In every sequence, the GPR sounding was done with Ramac X3M control unit utilising 100 MHz and 250 MHz antennas. The time windows were varied between 200 and 500 nanoseconds depending on the site and the antenna. The line locations were defined with Garmin GPS receiver and the GPR data was recorded with field computer. All sedimentary sequences were also investigated using conventional sedimentological techniques in order to establish the architectural elements of the deposits.

The GPR is extremely useful in showing the architectural elements of the glaciofluvial formations. In all GPR sounding sites selected for this study, the subsurface architectural elements were reliably identified.

In many occasions data obtained by GPR alone is not sufficient to make reliable estimations of grain size variations within a glaciofluvial deposits although their internal elements can be deduced from GPR images. GPR data combined with sedimentological and borehole data can give valuable information on the internal structure of a glaciofluvial accumulation and its origin. This knowledge can be used to reconstruct a geological model for aquifer areas.

Geophysical surveys for archaeological studies in Oulu area

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Dielectrical properties of soil differ from the dielectrical properties of rocks, bricks and wood. This ables the usage of ground penetrating radar (GPR) in distinguishing old settlements from the soil. Also it ables to use other geophysical methods in certain conditions. Small metallic objects are usually corroded in acidic soil and their detection is normally impossible. If the soil has a low content of oxygen and the metal objects are large enough, they can be detected by the GPR signal.

The utilisation of GPR sounding in arcaeological studies in Finland has been few. Only some cases have been published eventhough there has been several trias, even in Oulu. The research data from the Viking age town of Birka has been published in Sweden.

All research sites were situated near Oulu. Some sites were in the heart of the city. In these sites the aim of the research was to find remains of old settlements or graves. From the bottom of the river Oulu, old cannons dating back to the Finnish War between Russia and Sweden, were searched for. Various places were also investigated to find settlements from the stone age. The most popular site was Kierikki in Yli-Ii, about 50 kilometers from Oulu. In some sites magnetic and electric measurements were made in addition to GPR.

The GPR data was collected between 2003 and 2005 utilising Ramac Radar equipment and different antennas (250 MHz, 500 MHz and 800 MHz). The electrical and magnetic measurements were made in 2005. In GPR data, there were many structural sites, some previously unknown. The final results from these studies will be published in two MSc thesis at the end of 2005.

Conceptual prospectivity analysis for IOCG mineralisation in Finland

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Conceptual approach used in this study incorporates spatial analysis techniques for data integration and analysis to perform mineral prospectivity mapping for iron-oxide-copper-gold (IOCG) mineralisation in Finland.

The IOCG occurrences in Finland are characterised by the following features: epigenetic magnetite rock host; commodity association Fe-Cu-Au±Co, U; main ore minerals are magnetite, chalcopyrite, pyrite or pyrrhotite, and native gold; gangue is dominated by Ca amphibole±diopside, albite, biotite; enrichment in Ag, Au, Bi, Ca, CO_2, Cu, Fe, S, Te±As, Ba, Cl, Co, K, LREE, Mo, Na, Pb, Rb, Sb, Se, U; multi-stage alteration; formation in the P-T range of 400–600°C, 1.5–3.5 kbar; a distinct structural control in regions experienced both extensive compression and extension.

The variables used for the prospectivity analysis include 1:1 M scale geological map, high-resolution airborne geophysics, regional gravity and regional-scale multi-element till geochemistry data, and a mineral indications database. High-resolution airborne geophysical surveys have been flown at low-altitude (30 m) with average line spacing of 200 m and measurement points every 10–50 m. The gravimetric survey density is one point/km^2. For the regional geochemical survey till c-horizon was sampled with one sample per four km^2. The mineral indications database includes about 9800 records for the entire country.

A conceptual fuzzy logic overlay (Bonham-Carter, 1994), was used to predict and locate the most prospective or favourable areas for IOCG exploration within the study area using the above-mentioned criteria and evidential data. The models identified several permissive and high-potential areas with past and future exploration interests and significantly reduced the potential exploration area.

Bonham-Carter, G. (1994). Geographic Information Systems for Geoscientists. Modelling with GIS. Pergamon, New York, 398 p.

Spatial modelling as a tool for mineral prospectivity analysis in Finland

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Spatial modelling techniques, including empirical weights of evidence and conceptual fuzzy logic overlay, have been used in this study for mineral prospectivity analysis to identify favourable areas for exploration. We present examples on their utility in different scales from regional- to target-scale mineral exploration projects and also discuss the importance of validation of the modelling results.

In mineral exploration, typical numerical data sets used are categorical geological maps and their derivatives, ordered or ratio-scale data from from geophysical and geochemical surveys processed in various ways, in addition to other possible relevant spatially referenced pieces of geoscientific information. Spatial analysis in geoscience information systems is an efficient and accurate way to quantify relationships between the existing mineral deposits and the various geoscientific data sets and to produce a quantitative measure of the favourability of the desired feature, typically a specific mineral deposit type.

Validation is an essential but often neglected step in a spatial modelling project. In one of the examples given here, the validation of the modelling results was conducted with an empirical 'jack-knife' or 'leave-one-out' method by calculating successive models while leaving out each of the deposits, respectively. The prospectivity value of each of the model was associated with the deposit point left out of the model and was then compared with those of the original model including all the training sites.

In addition to statistical validation, a considerable amount of field testing has been completed by diamond drilling and field sampling with substantial success. Several promising new targets have been detected for future exploration and investment by the exploration industry have been stimuated by these analyses.

New kimberlite discoveries in Kuusamo, northern Finland

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Five kimbelitic bodies have been recently (2004–2005) discovered south of Kuusamo by Tertiary Minerals plc. and its associate, Sunrise Diamonds plc. Four of the kimberlites are classified as Group I kimberlites and the fifth as a Group II. The former rocks consist of serpentinized olivine macrocrysts and phenocrysts in a fine-grained matrix. The matrix is composed of microphenocrysts of phlogopite, perovskite, apatite and spinel. Three of the Group I kimberlites are hypabyssal varieties with late stage carbonate and serpentine filling grain interstices. The fourth Group I body is a tuffisitic kimberlite with abundant pelletal lapilli as well as other characteristics of the diatreme facies. The Group II kimberlite appears to be similar to the Ti phlogopite-rich dike rocks in the Kuhmo area that show mineralogical similarities to both olivine lamproite and Group II kimberlite (O'Brien and Tyni, 1999).

The ages of the Kuusamo kimberlites are still to be resolved. The Group II kimberlite is believed to represent another member of the c. 1200 Ma group of dike rocks known in the Kuhmo-Lentiira-Kostamuksha region. The Group I kimberlites may be considerably younger based on their mineralogy and their proximity to the Devonian Kola alkaline province. In this case they may have a similar age (~365 Ma) to the Lomonosov and Grib kimberlites, 550 km to the east. Another possibility is that they are the same age as the Neoproterozoic Kaavi-Kuopio kimberlite cluster (589–626 Ma), 350 km to the southwest. Regardless of their age, the Kuusamo kimberlites mark the third known kimberlite locality in Finland, and emphasize the potential of even more undiscovered kimberlites in the country.

O'Brien, H.E. & Tyni, M. (1999). ***Mineralogy and Geochemistry*** *of Kimberlites and Related Rocks from Finland. In: J.J. Gurney, J.L. Gurney, M.D. Pascoe and S.H. Richardson (eds.) Proceedings of the 7th International Kimberlite Conference, Cape Town. Red Rood Design cc, Cape Town, South Africa, p. 625–636.*

Plate tectonic settings of the Svecofennian volcanic rocks at Hamrånge and Loos, central Sweden

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The Palaeoproterozoic Hamrånge and Loos formations in central Sweden contain similar metavolcanic and sedimentary rocks that have been considered to make up the upper part of the Svecofennian stratigraphy. Both formations occur in kilometer scale refolded synforms with similar deformation history, rock types, stratigraphy and metamorphic grade.

The surrounding granitoids (of Ljusdal type) are interpreted and partly demonstrated to be somewhat younger than the supracrustal rocks dated at 1.86 Ga in Loos, and 1.89 Ga in Hamrånge (Bergman et al., this volume), and consequently inferred to intrude the latter. The ca. 1.85 Ga Ljusdal granitoids, referred to as calc-alkaline, early orogenic tonalite to granodiorite, is somewhat younger than similar rocks in the Bothnian basin to the north and in the Bergslagen arc to the south that have been dated at 1.89–1.87 Ga.

The supracrustal sequences of both Hamrånge and Loos show primary features like pillows and amygdules in the basalts and cross-bedding and ripple marks in the sediments, revealing that they were deposited in water. Geochemical analyses of the basalts show that they are altered and spilitic to some extent.

The volcanism at Hamrånge was probably a continuous felsic to mafic extrusive event, rather than bimodal like in Loos and western Bergslagen. The rocks from both areas show all signatures of being tholeiitic, but the geochemical results show no signs of a continental extensional setting like that interpreted for the western part of Bergslagen.

The geochemical signatures of Hamrånge basalts suggest a volcanic arc (VAB) setting, probably of oceanic origin. Similar rocks from Loos show several features indicating a mid ocean ridge (MORB) environment but also some signatures of a volcanic arc setting. The results from Loos can be explained by a transitional setting with a VAB influenced MORB, found in back arc basins (BAB) or intra arc basins.

Bergman, S., Högdahl, K., Nironen, M., Lundqvist. L., Sjöström, H., Ogenhall. E. & Lahtinen, R. (2006). Detrital zircons in late Svecofennian metasandstones in central Sweden and southern Finland. This volume.

Neoglacial activity and the occurrence of permanent snow in the Halti-Ridnitšohkka area in NW Finland

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At present, the harshest climatic conditions in Finland are found at the highest fell summits of the, north-west of Enontekiö municipality in Lapland. The summit region of Ridnitšohkka is an extensive area of basal till representing morphological features related to recent periglacial activity. At the end of July during several summer seasons, frozen ground conditions have been found in the till at a depth of 1.3–1.7 m. Typical morphological features of the slopes are solifluction terraces and lobes. The eastern flank of Ridnitšohkka has the most extensive, 6 m thick area of permanent snow (3 km^2) in Finland. According historical records and aerial photographs, the snowfield has existed for at least one hundred years, but during the last few years the size has considerably diminished.

During deglaciation of the Weichselian ice sheet the ice terminus retreated to the south, leaving small mountain glaciers in the area. The most distinct morphological feature is the cirque on the eastern flank of Govddoskaisi. The valley glacier that occupied the Govdajohka valley is well indicated by a set of more than ten end moraines occurring opposite direction to the main ice flow of the Scandinavian ice sheet in the area. The so-called Halti glacier has been recognized as the only independent glacier in Finland that has been active since the disappearance of the Scandinavian continental ice sheet at approximately 10,000 years ago

Palaeomagnetic dating of proglacial sediment sequences from lakes Pihtsusjärvi and Haltijärvi provided a preliminary chronological framework to study the history of the Halti valley glacier. The physical properties of these downstream lacustrine sequences provided evidence of post-glacial activity of the Halti Fell ice tongue. The results indicated that the Halti glacier was active soon after the continental ice sheet had retreated from the area at around 10,000–9,000 years ago, during which the Govdajohka valley endmoraines were formed. In addition, results indicated minor, short-term neoglacial activity in the Halti Fell vicinity between ca. 3,000 BC and the HTM (ca. 5,500-3,500 BC) in the Fennoscandian region.

Mechanical and acoustic properties of the Outokumpu mica schist

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The Outokumpu deep drill hole was excavated into the geologically classic area in Eastern Finland from 2004 to 2005. We have performed rock deformation tests on the recovered drill core. The tests were carried out under in-situ temperature and pressure conditions at a depth of one kilometer. Axial stress, the volumetric strain, p-wave velocities and acoustic emissions were monitored both continuously and contemporaneously during each test. The results of the constant strain rate tests show that the Outokumpu mica schist is very brittle with a dry triaxial compressive strength varying from 300 to 350 MPa at a confining pressure of 25 MPa. The macroscopic failure of the rock sample is preceded by a decrease in the elastic wave velocities and relatively few acoustic emissions due to the growth of microcracks parallel to the direction of maximum compressive stress. The sample failure is associated with a large stress drop that is followed by frictional sliding along the newly created fault. The experimentally determined p-wave velocities correlate with the seismic logs for the drill hole.

Orogenic gold prospectivity mapping of the Central Lapland greenstone belt, Northern Finland

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Research and exploration during the since 1970's has indicated that the Proterozoic Central Lapland greenstone belt in the northern Fennoscandian Shield has the potential to become a significant gold producer. The most significant discovery is the Suurikuusikko deposit, which is the largest undeveloped gold deposit in Europe (published resource over 3 Moz). Research into the formation of gold deposits, and especially on the orogenic gold deposits has been particularly important for the recent exploration success. In this study, the prospectivity of the Central Lapland greenstone belt for orogenic gold deposits was assessed using spatial analysis techniques.

The Central Lapland greenstone belt consists of Palaeoproterozoic volcanic and sedimentary succession (2.5–1.97 Ga) on the Archaean granite gneiss basement (3.1–2.6 Ga). The orogenic gold occurrences and deposits in the CLGB have strong structural control and their alteration zones may extend tens of meters across strike and hundreds of metres along strike of the hosting structure.

The data incorporated for the conceptual prospectivity analysis were the 1:250k geological map, structural interpretation, palaeo-stress model, high-resolution airborne geophysics, regional gravity and regional scale multi-element till geochemistry. High-resolution airborne geophysical survey was flown at low-altitude (30 m) with average line spacing of 200 m and measurement points every 10–50 m. The regional gravimetric survey density is one point/km^2. For the regional geochemical survey till c-horizon was sampled with one sample per four km^2.

Two used spatial modelling techniques; empirical weights of evidence and conceptual fuzzy logic models predict the known deposits. The weight-of-evidence model located all and the fuzzy logic model 89% of the training sites. In addition, the models highlighted several targets with past exploration interest and generated new exploration targets. Importantly, the potential exploration area was reduced considerably. Field evaluation of the targets generated indicates that the models predict new genuine gold anomalies for further exploration.

A variety of glacial landforms and ice-flow indicators in the Kvarken Archipelago in Western Finland

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A detailed mapping of the Quaternary deposits and glacial landforms to a 1:20 000 scale was carried out in the Geonat -project in the Kvarken Archipelago in the Gulf of Bothnia, the Baltic Sea on the Western coast of Finland. The area is a part of shallow submarine sill between Finland and Sweden with approx. 7000 islets and islands. The present rate of the glacial land up lift is 8–8.5 mm/y. The project (2003–2005) was partly funded by European Union.

The main glacial landforms discovered in the Kvarken Archipelago are De Geer moraines, larger transversal moraines (Rogen like), hummocky moraines, drumlins and flutings.

The most prominent glacial landforms are De Geer moraines forming large fields with hundreds of ridges and with a great variety of morphological features. De Geer moraines extend on the sea bottom where they are partly covered by glacial and postglacial silts and clays. Most of the De Geer moraines are orientated from SW to NE, but there are also many ridges at right angle to this main direction.

Other main types of the formation are larger transversal moraine ridges and hummocks and minor areas of typically boulder-rich hummocky moraines. All these features are commonly mixed, which makes the interpretation difficult. Small areas of drumlins and flutings were also found. Occasionally De Geer and Rogen-like moraines occur in the same localities.

Hundreds of striations and cross-striations were measured during the fieldwork. The variety of directions is amazing. The ice-flow direction in same outcrop can vary from the Northwest–West (from 240°) to the East (85°). At least three and up to five different ice flow directions could be measured from many outcrops. Also facets could be found.

At the Kvarken Archipelago a set of glacial moraines of subglacial origin and a wide variety of ice-flow indicators were mapped. In conclusion the deglaciation history of this area is more complex than known earlier. The interpretation work on the deglaciation history will be continued.

Onshore-offshore heat flow studies in Norway

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NGU and Statoil have established a joint research project (Kontiki – Continental Crust and Heat Generation In 3D) to improve the understanding of heat flow variation on the Norwegian continental margin. This knowledge is of vital importance for the success of petroleum exploration campaigns. The heat generation of the mainland basement rocks has been calculated from chemical analyses of U, Th and K content in c. 3000 bedrock samples (1000 samples acquired within NGU's Lito Project). Thermal conductivity of a selection of the Lito samples has been measured with a transient method. Heat flow data for Fennoscandia, the Norwegian continental margin, and the Norwegian Sea have been compiled into a common database. Temperature has been logged in a total of 8 deep wells (c. 500–900 m) in southern Norway to study the heat generation and heat flow within the mainland basement rocks. Currently, another 5 deep wells (500–1000 m) are planned for temperature logging in northern Norway. One of the wells is located on the Lofoten archipelago that represents an uplifted part of the thin crust on the continental shelf. A second well is located further to the east, in the Tysfjord Granite Complex that constitutes a part of the Trans-Scandinavian Igneous Belt, TIB. The TIB continues below the Caledonian Nappes and the offshore sedimentary basins and constitutes the largest granite complex in Norway. The thickness of 15–20 km is expected to generate high heat flow values.

A 3D model of the Mid Norwegian continental margin has been established from gravity, magnetic, seismic and bedrock maps. The next step will be to attribute heat production values to each of the rock bodies to calculate theoretical surface heat flow values that can be compared with the observed values. The heat flow related to the shallower asthenosphere towards the continent-ocean boundary will also be estimated.

Aeromagnetic mapping of deep-weathered fracture zones in the Oslo Region – a new tool for improved planning of tunnels

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Rock instability and water leakage are causing increased problems during tunnel constructions in the Oslo Region of southeastern Norway. The weakness zones consist partly of clay minerals such as kaolinite and smectite and are to a large extent the result of chemical weathering during tropical conditions in the Jurassic. The weathering occurred originally across the entire paleo-surface, but gradually penetrated deeper into pre-existing fracture zones. This chemical weathering was preserved below shales and carbonates deposited during the Late Jurassic and Cretaceous transgression (c. 400 metres higher sea level). During the Early Cenozoic exhumation of southeastern Norway was initiated, and the erosion and uplift accelerated during the extensive Pleistocene glaciations. Although the glacial erosion removed the bulk of the chemical weathering, the clay zones occurring to depths of 200–300 metres along the fracture zones were preserved.

During tropical weathering, iron oxides such as magnetite alter to iron-hydroxides at the same time as silicate minerals are converted into clay minerals. The deep weathering will therefore produce a negative deviation in the Earth's magnetic field. We have developed a filtering technique to enhance the magnetic signal from the weathering zones. Coinciding negative anomalies in the high-pass filtered topography/bathymetry and magnetic data are used as indications of deep weathering. The resulting signal is classified as probable or possible weathering depending on the signal/noise ratio. The results from the new Amager method (AeroMagnetic and Geomorphologial Relations) have helped to detect more than 90% of the known fracture zones in the Lieråsen and Romeriksporten railway tunnels. Modelling of the observed magnetic field shows that some of the low-magnetic zones continue to a depth of c. 300 metres below the surface.

As a consequence of this Tigris research project (The Intergration of Geophysical Relations Into Society), the engineering geologist has acquired a new tool which will facilitate the mapping of potential clay-bearing weakness zones for tunnel planning.

Crystal structures of Pb-Bi sulfosalts under high pressure

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Sulfosalts contain cations with stereochemically active lone electron pairs which are an interesting object for high-pressure structural investigations. Being based on octahedral and higher number coordination polyhedra, sulfosalts are also good model structures for silicates at ultra-high pressures corresponding to the lower-mantle conditions.

In the present work high pressure experiments in diamond anvil cells are carried out on Pb-Bi sulfosalts. The crystal structures are investigated by in-situ x-ray diffraction on single crystals. Pb^{2+} and Bi^{3+} are isoelectronic and both have lone electron pairs. High resolution data obtained in this study enable us to quantitatively compare the activity of their lone electron pairs and their behaviour under rising pressure, calculate pressure moduli for their respective coordination polyhedra with different coordination numbers, and relate them to the bulk pressure modulus of the crystal structure.

Galenobismutite ($PbBi_2S_4$) which contains three distinct cation sites with different coordination numbers at room pressure is investigated as the first example, and its characteristics under the high pressure conitions will be presented.

Fennoscandian M-L Weichselian glacial variations – much more than just local ice-margin fluctuations

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During the last two to three decades numerous papers have been published dealing with large-scale glacial variations. It has been shown from field data, such as ice-cores from Greenland and marine sedi-ment cores, as well as from several ice-sheet model-ling studies, that such variations took place at several times during the last glaciation, also including the interval 10 000 – 70 000 yr BP. It has been realised that the ice sheets were not huge and stable for tens of thousands of years, but rather highly dynamic ice-sheet systems working through a balance between fast-moving ice-streams and parts of the ice with less rapid ice movement. These systems were significantly influenced by moderate climatic variations in combination with sea-level fluctuations and various topographic conditions, and the ice sheets were therefore fluctuating in size over time.

It has been known for a long time that ice-margin fluctuations occurred during the Fennoscandian Middle to Late Weichselian, particularly in the shelf to coastal area in the SW, W and NW. Here, a synthesis will be presented of a recent compilation from Norway of regional Quaternary stratigraphy, with fossil content (marine mollusc shells, foramini-fers, dino-cysts, pollen, etc.), some palaeomagnetic data, and more than 300 datings (^{14}C, U/Th, TL, OSL, AAR) of various materials. Together, these data show both ice-marginal fluctuations of 'late-glacial Bølling - Younger Dryas' dimensions, but also much larger ice-sheet variations in the western part of the Fennoscandian Middle to Late Weichselian ice sheet.

The ice advances are thought to have had a mainly time-transgressive character, e.g. reaching a maxi-mum position earlier in the west than in the east, whereas the ice retreats may have been more syn-chronized, at least in the parts influenced by sea-level changes. Previously reported interstadials are extend-ed to include larger inland areas, indicating extreme fluctuations at several times both in extent and volume of the ice. It is suggested that, in addition to precipitation, the mountainous fjord and valley topography, glacial isostasy and relative sea-level changes were probably more important for the size of the glacial fluctuations than the air-temperature changes.

Olsen, L., et al. (2001). Norw. Journal of Geol. 81, 93–118.
Olsen, L., et al. (2002). Polar Research 21, 235–242.

Influence of target on the cratering process: Laboratory experiments, field observations and numerical simulations

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We are using high-velocity impacts to investigate certain features of craters from impacts into wet and porous targets. Preliminary tests have been carried out in an outdoor test bed [1]. The results from these tests were used in this study as reference for numerical simulations with 2-D hydrocodes. The goal is to complement the experimental results with numerical simulation. When agreement is achieved between the results from the two methods, we will be able to analyze a greater number of cases more conveniently (i.e., the effect of different water depths in our experiments). The experimental and numerical simulations will help us understand the behavior of different materials and the formation of certain features at, first of all, wet-target craters where the water affects the excavation (e.g., concentricity due to layered target), ejecta formation (e.g., rampart), and modification (e.g., collapse and resurge erosion). Of special interest is also the formation of small meteorite impacts (i.e., craters in crater fields formed after atmospheric break-up of the projectile) where the projectile may fragment or penetrate the ground to form a funnel-shaped crater. These examples are types of craters that may show features that provide information on the target properties, which in turn can assist in paleoenvironmental reconstructions.

The experiments were carried out with a CHUTA IB-060 gun loaded with a 0.50 cal cartridge. The projectiles are of steel, 4x7 cm, and cylindrical. Results from the experiments were received through filming with high-speed camera as well as direct measurements of the resulting craters. The preliminary results will be improved with the new indoor ex-perimental laboratory presently under construction at Centro de Astrobiología that will allow better control of the test bed set-up, better velocity determination for the projectile, and up-dated numerical code allowing simulation of porous and multi-layered targets.

Ormö, J., et al. (2004). Abstract #1276. 35th Lunar & Planetary Science Conference, Houston, Texas.

Geological models and their application on Käppäläisenmäki aquifer

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The Käppäläisenmäki aquifer area is located in the Vihanninharju esker that in turn belongs to an extensive Siilinjärvi-Outokumpu-Raahe esker chain. According to Punkari (1979) Vihanniharju accumulated in an interlobate zone between an active North Karelian lobe to the north and passive Middle Bothnian triangle to the south.

In this study the three dimensional model of the Käppäläisenmäki were constructed using RockWorks2002, geological data management and visualization software. Borehole and Ground Penetrating Radar data, obtained from the Geological Survey of Finland and Vihannin Vesi Ltd., were used for reconstructing the model. The model and the visualizations based on the model were used for 1) the estimation of ground water volume and the amount of stratified sediments, 2) to visualize the position of the different sedimentary elements and ground water flow paths, 3) to define the style of the aquifer and 4) to discuss contemporary palaeoenvironments and sedimentary processes that operated during the deposition.

The volume of sand was estimated to 23,29 million m^3, and gravel to 0,46 million m^3. The ground water volume was estimated to 2,97–4,77 million m^3 depending on the porosity minimum and maximum used. The style of the aquifer was interpreted to be mostly anticlinal. There are transverse moraines covered by stratified sediments in the Käppäläisenmäki area. The aquifer seems to be synclinal near the transverse moraines. The transverse moraines represent most likely Rogen-moraines and they deposited before the primary deposition of the esker. The primary deposition occurred in the subglacial tunnel, in the proximal part of fan delta at the front of the tunnel mouth or as a subaquatic fan delta.

Punkari, M. (1979). Skandinavian jäätikön deglasiaatiovaiheen kielekevirrat Etelä-Suomessa. Geologi 2, 22–28.

Glaciotectonic deformation of till covered glaciofluvial deposits in Oulu region

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Till covered glaciofluvial deposits are common in Pohjanmaa area, western Finland. In this area the sediments older than the Late Weichselian have escaped the glacial erosion and are found slightly or severely deformed beneath till (e.g. Nenonen, 1995). In this study glaciofluvial deposits covered by till in the Oulu region are studied, the style of the glaciotectonic deformation defined, till genesis considered and contemporary palaeoenvironments and sedimentation processes discussed.

The sites in Isoniemi in Haukipudas commune and in Hangaskangas in the City of Oulu were studied using conventional sedimentological techniques including clast fabric measurements of till units and structural measurements on existing fold and fault structures beneath the uppermost till unit.

On both study areas the sediment sequence beneath till consists mainly of deformed sand and gravel. Structural measurements applied on folds show that glacial shear directions were from between 180° and 330°. The deformed structures consist mainly of tight to isoclinal and gently inclined to recumbent folds and thrust faults.

The directions of till fabric measurements in Isoniemi and Hangaskangas areas indicate ice flow directions from between 220° and 310° and 250° and 320° respectively. Striae measurements north of the Isoniemi area indicate ice flow from 260° and 290° and measurements south and east of the Hangaskangas area indicate ice movement from direction 290° (Hirvas & Nenonen, 1987). The lower contact of till, exposed in Hangaskangas area is deformed. Tectonic "dropstones" in till are visible in the Isoniemi area.

The stratified sediments beneath till could represent remnants of glaciofluvial delta deposits or most probably fan delta sediments deposited in deep water. The till is interpreted to represent deformation till which consists of reworked stratified and sea floor sediments. Based on structural evidence, folding and thrusting occurred subglacially.

*Hirvas, H. & Nenonen, K. (1987). **The till stratigraphy of** Finland. Geological survey of Finland, Special Paper 3, 49–63.*

Nenonen, K. (1995). Pleistocene stratigraphy of southern Finland. In: Ehlers, J., Kozarski, S. & Gibbard, P.L. (eds.). Glacial Deposits in North-East Europe. Rotterdam, Balkema, 11–28.

Using 3D geological modelling of basic deformation data to visualise shear-hosted gold deposits: An example from the Suurikuusikko deposit (northern Finland)

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Common approaches to creating 3D geological models for ore deposits include constructing solids for features such as element and alteration distribution, and for host rock units. Grade distribution models have specific uses, but are not sufficient representations of deposits when not supported by additional geological data addressing the reasons for the distribution. Grade models do not usually provide concrete 'geological' information that is detailed enough to form the basis for exploration model development, or for research into a deposit's genesis. Additionally, shear-hosted deposits are often difficult to model using host rock distribution, as original rock types have often undergone significant deformation, alteration, and dislocation that has changed the original spatial connectivity of specific lithologies.

The Suurikuusikko refractory gold deposit is an example of a deposit that is difficult to clearly depict using conventional lithological and alteration modelling. This short presentation will show that by selecting one element that has a distinct association with mineralisation, a more detailed model of deposit geometry was obtained. Unlike rock type and alteration solids, deformation-based solids of this deposit clearly show the distribution and disruption of ore zones, and also allow identification of individual ore zones with slightly different geological controls. The use of this type of information has applications to both exploration and ore extraction planning.

Riddarhyttan Resources AB has kindly given permission to use data extracted from the Suurikuusikko database for this presentation.

FIRE seismic reflection profiles 4, 4A and 4B: Insights into the bedrock geology of northern Finland from Ranua to Näätämö

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The acquisition of excellent quality reflection seismic data for northern Finland is a welcomed opportunity to better understand a complex and economically significant region of Finland's bedrock geology, in an area where direct observation is often hampered by poor exposure. FIRE 4 runs from Ranua to Sirkka in Kittilä, FIRE 4A from Sirkka to Näätämö and 4B from Sirkka to Muonio. These three crossing FIRE profiles enable crustal scale studies in three dimensions. The profiles successfully image major bedrock geology divisions and boundary structures, both confirming and challenging existing ideas on the evolution of the lithosphere in this region.

The FIRE profiles cover bedrock components of the Fennoscandian Shield with ages from Neoarchean to 1.74 Ga, including greenstone belts, granulite belts, schist belts, and multiple intrusive phases. The Archean areas (Pudasjärvi Complex and Inari Area) include remnants of the cratonic nuclei of the Fennoscandian Shield (the Karelian and Kola Cratons) and amalgamated exotic terranes. The Paleoproterozoic components include autochthonous and allochthonous components (Peräpohjä Schist Belt, Central Lapland Granitoid Complex, Central Lapland Greenstone Belt, and the Lapland Granulite Belt).

The profiles display crustal structures associated with Proterozoic collisional and extensional events. All bedrock units have been variably modified by complex Paleoproterozoic deformation and magmatic events occurring from 2.5 Ga to the end of widespread thermal activity in the northeastern Fennoscandian Shield at ~1.78–1.76 Ga. Information from the FIRE profiles has implications for geological research in both Finland and northern Sweden.

Petrology and 3D lithological model of Olkiluoto, the disposal site of spent nuclear fuel in Eurajoki, SW Finland

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According to bedrock mappings, drill core loggings and related mineralogical and geochemical investigations, the rock types of Olkiluoto can be divided into five major classes: 1) migmatitic gneisses, 2) homogeneous mica-bearing gneisses and quartzitic gneisses, 3) homogeneous tonalitic-granodioritic-granitic gneisses, 4) amphibolites and other mafic gneisses, and 5) pegmatitic granites. In addition, narrow metadiabase dykes occur sporadically. The migmatitic gneisses can be divided into three subgroups in terms of their structural types: veined gneisses, stromatic gneisses and diatexitic gneisses.

The supracrustal rocks of Olkiluoto can be divided into four series by reference to whole rock chemical composition: a T series, P series, S series and basic, volcanogenic gneisses. The members the T series form an alteration series, the end members of which are often cordierite-bearing mica gneisses and migmatitic gneisses with less than 60% SiO_2 and quartzitic gneisses with more than 75% SiO_2, representing clay mineral-rich pelitic materials and greywacke-type impure sandstones, respectively. The members of the P series are mostly tonalitic-granodioritic-granitic gneisses, the P_2O_5 concentrations of which exceed 0.3 %. The S series is composed quartzitic gneisses, mica gneisses, migmatitic gneisses and mafic gneisses with high calcium concentration, which typically exceeds 2 %, the maximum concentrations being over 13 %. A relatively low alkali content and high manganese content are also typical of this series, the members of which are assumed to have originated from calcareous sedimentary materials.

An assumption has been adopted in the 3D modelling of the lithologies that in the rock volumes between boreholes the foliation is rather constant over large distances. Thus, lithological correlations from borehole to borehole and from borehole to surface has been carried out as simple extrapolation, using the foliation measurements as guide.

A Baltica provenance for the Kara terrane, Eurasian Arctic

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The Novaya Zemlya archipelago lies between the Barents Sea and Kara Sea on the Russian Arctic Shelf. The archipelago is generally considered to be part of the Uralian Orogen, which stretches from the Caspian in the south to the Arctic Ocean in the north, and records the Late Paleozoic collision of Baltica with Siberia. In the northern part of the orogen, an additional independent crustal block, the Kara Terrane, has been invoked by some authors to be involved in the collisional events. Understanding the nature and extent of these basement provinces in the high Arctic is, however, hampered by lack of data.

In the southernmost part of the Novaya Zemlya archipelago, an angular unconformity beneath Early Ordovician coastal and shallow marine sediments is well-exposed at a number of localities. To understand the affinities and age of strata above and below this angular unconformity, samples of sandstone were collected for detrital zircon provenance investigations at regular stratigraphic intervals. Preliminary results indicate that the unconformity does not document typical Late Precambrian Timanide orogeny, but rather a relatively short-lived tectonic event of end Cambrian age. This suggests affinities with an unconformity of identical style, age and duration recognized to the northeast on Severnaya Zemlya, a key component of the so-called Kara Terrane. However, because the cumulative probability curves indicate a clear Baltica signature for southern Novaya Zemlya, we regard this as further evidence that the Kara Terrane is a northeast continuation of Baltica.

International Geoscience Program (IGCP), Sweden and a Nordic consortium

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IGCP is a cooperative effort between the United Nations Educational, Scientific and Cultural Organisation (UNESCO) and the International Union of Geological Science (IUGS). It was created in 1972 to advance geological cooperation between nations, as geologic processes and structures do not recognize such boundaries. IGCP is interdisciplinary, including all sub-disciplines of geoscience, and has established links to other UNESCO programs.

Recent changes to IGCP include an expanded Working Group (WG) structure which, in addition to pre-existing working groups (WG1- Stratigraphy, Sedimentology, Palaeontology, Fossil Fuels, WG2- Quaternary, Environmental and Engineering Geosciences, WG3- Mineral Deposits, Petrology, Volcanology, Geochemistry, and WG4- Geophysics, Tectonics, Structural Geology), now includes WG5- Hydrogeology. Changes in program demographics in recent years suggest that biodiversity and natural hazard mitigation will play increasingly important roles in IGCP's future activities.

Projects are accepted on the basis of available funding and peer-review by the Scientific Board. New projects, in addition to meeting the established criteria, need to address education and training, sustainability, and capacity building in developing countries. Establishment of WG5 suggests that proposals associated with hydrology are likely to be prioritized in the future.

IGCP's Scientific Board is responsive to community membership. This suggests that, rather than a National Representative acting singly, a 'consortium' approach may be more effective in influencing the scientific range and priorities of IGCP projects. A consortium of Nordic members might have a 'stronger voice' in dealing with the IGCP Scientific Board, as well as with UNESCO and IUGS steering committees.

How old is the continental mantle of the Karelian Craton?

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Mantle-derived xenolith and xenocryst studies have indicated that the subcontinental lithospheric mantle of the Karelian craton shows considerable vertical and lateral heterogeneity (Peltonen et al., 1999; Lehtonen et al., 2004). At the craton margin adjacent to the Svecofennian mobile belt, the mantle is stratified into three distinct layers labeled A, B, and C. In order to constrain the origin and timing of this stratification, we have determined Re-Os isotopes of well characterised mantle xenoliths that represent these three layers of the Karelian lithospheric mantle.

Shallow *layer A* (at ~60–110 km depth) has a knife-sharp lower contact against underlying layer B. Layer A peridotites have "ultradepleted" compo-sitions, and have been metasomatised by radiogenic $^{187}Os/^{188}Os$, presumably from slab-derived fluids. Layer A is interpreted to represent fragment of Proterozoic arc wedge mantle that became underthrusted beneath the craton margin during the Svecofennian–Karelian collision event.

Mantle xenoliths derived from the middle *layer B* (at ~110–180 km depth), which is the main source of diamonds in Finnish kimberlites, are characterised by unradiogenic Os isotopic composition. $^{187}Os/^{188}Os$ shows a good correlation with indices of partial melting implying an age of ~3.3. Ga for melt extraction. This age corresponds with the oldest formation ages of the overlying crust (e.g. Mutanen & Huhma, 2003), suggesting that layer B represents the unmodified continental mantle that was stabilised during the Paleoarchean.

The osmium isotopic composition of mantle xenoliths derived from the layer C (at 180–250 km depth) is more radiogenic compared to layer B samples, yielding only Proterozoic T_{RD} ages. Layer C is interpreted to represent a melt metasomatised equivalent to layer B. This metasomatism most likely occurred at c. 2.0 Ga due to a mantle plume at the base of proto-craton.

Lehtonen, M. et al. (2004). Proc. 8th Intern. Kimberlite Conference, Vol. 2., Lithos 77, 593–608.

Mutanen, T. & Huhma, H. (2003). Bull. Geol. Soc. Finland 75, 51–68.

Peltonen, P. et al. (1999). Proc. 7th Intern. Kimberlite Conference, Vol. 2., Red Roof Design, Cape Town, p. 664–676.

Outokumpu revisited: New mineral deposit model for the mantle peridotite -associated Cu-Co-Zn-Ni-Ag-Au sulphide deposits

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The metasediments of the Jormua – Outokumpu thrust belt in eastern Finland enclose meter to kilometer size ultramafic massifs being distributed over an area of more than 5000 km^2. These bodies, which almost entirely consist of highly depleted oceanic mantle peridotites (now metaserpentinites), are intimately associated with massive to semimassive, polymetallic Cu-Co-Zn-Ni-Ag-Au sulphide deposits, that sustained mining in the region between 1910 and 1988.

The origin of these Cu-Co-Zn-Ni±Au deposits is now reinterpreted to be polygenetic. First, their formation require the deposition of a Cu-rich proto-ore within peridotitic sea floor at c. 1950 Ma. Close modern analogues for proto-ore include e.g. Logatchev and Rainbow fields at the Mid-Atlantic Ridge, where high-T, low-pH fluid venting resulted in accumulations of Cu-Zn-Co-Au sulphides on serpentinised ultramafic seafloor. However, the Ni-rich composition of Outokumpu sulphides calls for an additional source for nickel. Some 50 Ma after the deposition of the Cu-rich proto-ore – concomitant with the obduction of the ultramafic massifs – disseminated Ni-sulphides formed through chemical interaction between obducting peridotite massifs and adjacent black schists. This process led to listwaenite-birbirite type carbonate-silica alteration at the margins of the ultramafic massifs (Kontinen, 1998). Due to such alteration, silicate nickel was released from the primary Fe-Mg silicates and redeposited as Ni-sulphides in the alteration fringes of the massifs.

We propose that syntectonic mixing of these two "endmember" sulphides, i.e. the Cu-rich proto-ore and the secondary Ni-sulphide disseminations, resulted in the uncommon metal combination of the Outokumpu-type sulphides. Further solid state remobilization, accompanied by duplexing of ore by isoclinal folding, upgraded the sulphides into economic deposits.

Kontinen, A. (1998). ***Geological Survey of Finland. Special*** *Paper 26, 33.*

Modelling groundwater flow under the Elsterian ice sheet in Poland: Did the drainage system affect the ice sheet behaviour?

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Large Pleistocene ice sheets are known to have profoundly affected groundwater flow in Europe and North America. Local subaerial catchment areas were replaced by orders-of-magnitude larger catchments controlled by ice sheet topography, and pressurized groundwater flowed much faster and deeper than during the interglacial conditions. Glacially-fed groundwater flushed deep aquifers and penetrated aquitards leaving a characteristic isotopic and chemical signature. Subglacial groundwater flow, by evacuating meltwater from the ice-bed interface may have strongly influenced ice sheet stability.

In order to reconstruct subglacial groundwater drainage under the Elsterian ice sheet in Poland, we have constructed a complex numerical model using the FD MODFLOW code. The model is a 3D, steady-state simulation performed for different palaeo-glaciological scenarios involving a range of realistic ice thicknesses. The model comprises an area of about 300.000 km^2 between the present Baltic Sea in the north and the Karpathian/Sudetian Mountains in the south and it consists of 6 major hydrogeological layers down to the impermeable substratum (Permian salt or bedrock) at a maximum depth of ca. 4.6 km.

The most likely simulation scenario shows a total re-organization of the groundwater flow field under the ice sheet as compared to the modern (interglacial) situation. The groundwater flowed from the Baltic Sea towards the mountains in the south (i.e. in the opposite direction than today) and disacharged at the ice sheet margin. Due to generally low hydraulic conductivity of the substratum, only a fraction (ca. 4%) of basal meltwater could have been drained as groundwater flow which, in the light of the surprising lack of large subglacial channels (tunnel valleys) strongly suggests a possibility of wide-spread basal de-coupling by pressurized subglacial water. This in turn implies instabilities in ice sheet behaviour leading to surges and ice streaming.

Soapstone in Eastern Finland

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Soapstone is a metamorphic alteration product of ultramafic volcanic and igneous rocks containing talc, carbonate and usually some chlorite. It is formed through ultramafic host rock carbonatisation(Amin, 1952; Wiik, 1953; Chidester, 1962; Naldrett, 1966; Jahns, 1967; Sanford, 1982) or through dolomite quartzitisation (Brown, 1973; Blount & Vassilou, 1980; Prochaska, 1989). Metamorfic prosesses have occurred in greenschist-amfibolite fasies conditions (Groves et al., 1974; Sanford, 1982). Magnetite, serpentine and amphiboles are common accessory minerals in soapstone. Carbonate is usually magnesite, but occasionally dolomite, even calcite. Soapstone is grayish in colour. Usually talc is in fine grained matrix and carbonate is occurring as fine to medium grained, sometimes even coarse grained chrystals. Sometimes thin carbonate veins are crisscrossing across the soapstone. It is usually schistose but massive types can be found also. Over 100 occurences of soapstone and talc schists are reported in Finland (Vesasalo, 1965). Most of them are situated in archean greenstone belts or the proterozoic schist belts in eastern Finland. Almost all of them have been formed through ultramafic host rock carbonatisation.

Major soapstone deposits in proterozoic formations: 1. Lahnaslampi deposit in Kainuu schist belt (municipality of Sotkamo). 2. Horsmanaho and Pehmytkivi deposits in Outokumpu association (municipality of Polvijärvi). 3. Alanen deposits in Kainuu schist belt (municipality of Sotkamo).

Major soapstone deposits in archean formations: 1. Nunnanlahti deposits in greenstone belt (Sorjonen-Ward 1997) (municipality of Juuka). 2. Kivikangas deposit in greenstone belt (municipality of Suomussalmi). Verikallio and Juurikkaniemi in greenstone belt (town of Kuhmo).

Amin, M.S. (1952). ***Geol. Mag. 89, 97–105.***
Blount, M. A. & Vassilou, A. H. (1980). Econ. Geol. 75, 107–116.
Brown, C. E. (1973). U.S. Geol. Surv. Prof. Pap. 820, 619–626.
Chidester, A. H. (1962). U.S. Geol. Surv. Prof. Pap. 345, 207 p..
Naldrett, A. (1966). J. Petrol. 7, 489–499.
Prochaska, W. (1989). Appl. ***Geochem. 4, 511–525.***
Sanford, R. F. (1982). Amer. Jour. of Sci. 282, 543–616.
Wiik, H. B. (1953). ***Bull. Comm. Geol. Finland. 165, 57 p.***
Vesasalo, A. (1965). Bull. Comm. Geol. Finland. 216, 75 p.
Niemelä, M. (2001). Mineralia Slovaca 33, 561–566.

Constrained inversion of gravity data

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Computer software (Grablox and Bloxer) has been developed for modelling and interpretation of gravity data using a three-dimensional (3-D) block (voxel) model. The volume of the earth below the study area or profile is discretized into smaller prism-like elements inside each of which the density is constant. The gravity field is computed as a superposition of all the individual prisms (Hjelt, 1974). The sizes of the blocks can vary so that the topography and layer boundaries can be modeled better.

Gravity inversion is performed either by optimizing the density value or the height (depth to the bottom) of the blocks. The first method suits interpretation of large research areas when information about the geometry and inner density structure or model is not available. In this case the depth weighting can be used to enhance the sensitivity of the blocks at successively greater depths (Li & Oldenburg, 1998). The latter method suits interpretation of the thickness variations of an overlaying soil or sedimentary.

Two-layer interpretation is performed by optimizing the height of the blocks of the overburden layer while the density contrast is kept fixed. In practice it is necessary to add margins to the model to minimize edge effects. Moreover, the base level of the regional gravity field needs to be optimized according to measured gravity field and assumed density and thickness values. External regional gravity field can be used to represent the effect of more complex density and topography variations.

Constrained inversion is accomplished by optimizing the roughness of the model together with the data error (Li & Oldenburg, 1998). The model roughness is defined as the difference of the density (or height) of a block from the mean value of the surrounding blocks. In 3-D density inversion this kind of Occam's method allows constraining the inversion based on *a priori* petrophysical data. In two-layer interpretation the data from drill holes can be used to constrain the depth to the layer boundary.

Hjelt S.-E. (1974). Geoexploration 12, 29–39.
Li Y. & Oldenburg D.W. (1998). Geophysics 63, 109–119.

The Ilumetsa meteorite crater field, SE Estonia – results of the geophysical campaign

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The Holocene (~6600 years old; Raukas et al., 2001) Ilumetsa impact crater field consists of two well-preserved simple structures, named Põrguhaud (Hell's Grave) and Sügavhaud (Deep Grave) with diameters of 75–80 and 50 m, respectively. In August 2005, a field campaign, aimed to study the Ilumetsa structures and learn geophysical approaches in impact studies (see Bäckström et al., this issue), was organized by the University of Tartu. Magnetic, seismic, electrical and ground penetrating radar (GPR) methods were applied.

The Ilumetsa structures were formed into the sedimentary target where glacial sands and tills with thickness of ~6 m overlie the Middle Devonian weakly cemented silt- and sandstones of the Burtnieki Stage.

Our measurements show that the structures exhibit distinct magnetic (positive and negative magnetic anomalies associated with the rims and central depression, respectively) and electrical features (reduced resistivity of the fractured silt- and sandstone compared to the unfractured target). Seismic profiles show deepening of the refractor associated with the upper surface of the groundwater level under the impact structures. In radargrams, the rims of structures lack major reflections.

Additional smaller pits (e.g. Devil's grave) have been described in the vicinity by earlier studies (Aaloe, 1961). Using the GPR, we profiled several locations, but our results show no indications of crater-like features in those areas.

Aaloe A. (1961). Eesti Loodus 5, 26–31.
Bäckström A., Öhman T., Versh E. & Plado J. This volume.
Raukas A., Tiirmaa R., Kaup E. & Kimmel K. (2001). Meteoritics & Planetary Science 36, 1507–1514.

Acknowledgements: We are grateful to Wihuri foundation for the financial support, and the associated institutes for supplying the necessary instruments.

Proterozoic-Archean boundary in the upper mantle of eastern Fennoscandia as seen by seismic anisotropy

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Lateral variations of seismic anisotropy of body waves allowed us to detect the Archean-Proterozoic boundary in the upper mantle beneath the south-eastern Fennoscandia, though isotropic P-velocity perturbations in teleseismic P tomography or shear-velocity variations retrieved by inversion of surface waves by other authors do not noticeably differ in the Proterozoic and Archean mantle beneath the SVEKALAPKO array. The boundary seems to be inclined to the SW, in general, and very complex, forming a broad transition zone. This zone appears in the P residuals, which accumulate the velocity deviations along the ray path, as almost isotropic structure due to superposition of pieces of the mantle lithosphere with differently oriented anisotropy. The shear-wave splitting is consistent for groups of stations within the Archean and Proterozoic domains, and detects anisotropy even in the central transitional domain, which may reflect anisotropy of the thickest lithosphere wedge. In general, variations of the splitting parameters indicate a very complicated structure, which cannot be approximated by a single layer with horizontal symmetry axis or a simple contact of two mantle lithosphere blocks. We propose three potential candidates for a mantle lithosphere model around the Proterozoic-Archean contact.

Rare earth element geochemistry of the Cumbre Vieja Volcano, La Palma, Canary Islands

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The active Cumbre Vieja Volcano occupies the southern part of La Palma, the northwesternmost island in the Canarian Archipelago, situated on oceanic crust 600 km off the coast of NW Africa. La Palma, cored by a submarine seamount complex, is built up of overlapping volcanic shields derived from southward propagating volcanic centres fed from the Canary mantle plume. All historic eruptions in La Palma issued from the Cumbre Vieja Volcano. Exposed Cumbre Vieja volcanics comprise predominantly ultrabasic to basic OIB-type basanitic to tephritic lava flows. Intermediate compositions appear scarce, although highly fractionated phonolitic erosional remnants locally are prominent. The mafic volcanics (including the historic lava flows) are usually moderately fractionated (5-8 % MgO), having experienced low pressure crystal fractionation, assimilation and mixing. Recently discovered primitive high-MgO (10-12 %) basanite flows have been interpreted (Prægel, in press) as partial melts, having fractionated olivine only during ascent from their mantle source. The high-MgO flows have lower REE abundances [$(La)_{cho}$=163–265] and lower LREE-enrichment [$(La/Nd)_{cho}$=1.9] than the majority of Cumbre Vieja basanites with [$(La)_{cho}$=336–464] and [$(La/Nd)_{cho}$=2.4]. High-MgO rocks have fractionated HREE abundances with high [$(Dy/Yb)_{cho}$=2.6], suggesting melt extraction at around at 3 GPa. The highly fractionated phonolites display LREE enrichment $(La)_{cho}$=750 and $(La/Nd)_{cho}$ =4.3–6.2 and marked depletion of MREE. The phonolites reflect substantial crystal fractionation involving clinopyroxene, amphibole, sphene and apatite. Modelling suggests an enriched mantle source [$(La)_{cho}$=7–12] for the high-MgO volcanics, displaying higher than chondritic MREE/LREE [$(Gd/Nd)_{cho}$=1.6] and MREE/HREE ratios. East La Palma basanite flows with high fractionation-corrected $(LREE)_{cho}$ ratios, suggest derivation from a more enriched source or that smaller melts fractions were generated for this part of the Cumbre Vieja.

Prægel, N.-O. (in press). J. Volcanol. Geotherm. Res.

Mineralogy and geochemistry of restite enclaves in the peraluminous Lipnice granite, Moldanubian batholith, Czech republic

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The metamorphic restite in the Lipnice granite typically makes nodules several cm in size. They consist of biotite, sillimanite, quartz and minor muscovite; feldspars occurr in accessory amounts, whereas ilmenite is relatively abundant. Apatite forms very small grains in comparison to the "normal" granite. Monazite and zircon are less abundant than in the granite groundmass as well, and contrasting zones in monazite were documented - they probably represent metamorphic and magmatic stages of growth.

The occurrence and composition of individual minerals suggest that apatite and feldspars were completely or nearly completely melted, whereas some portion of monazite was preserved. In ilmenite and rutile there are abundant inclusions of silicate minerals, which were entrapped during metamorphic growth. These inclusions were often partially melted into microcrystalline masses, or even melted completely, forming melt inclusions with bubbles of fluid phase. Also, rounded inhomogeneities which strongly resemble melt inclusions were found in ilmenite, but they have the same composition as the ilmenite. This suggests that the conditions of granitisation were very close to the solidus of ilmenite.

Petäjälehto: A new Gold Prospect in Sodankylä Finnish Lapland.

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The Pätäjälehto prospect is situated 80 km north of the Sodankylä municipality Finnish Lapland. The acces to the prospect is 100 km along the highroad 4 from Sodankylä and 10 km north of the Vuotso village 40 km to west along a gravel road. There are no outcrops in the prospect area.

High gold and copper anomalies of the regional geochemical mapping of till and N-S-orientated magnetic anomalies of the airborne survey encouraged to start exploration in the area. Detailed ground geophysical study revealed cross cutting NNE and NNW low magnetic anomalies. The results of the detailed geochemical study of till show a pattern of NNW-ternding gold anomalies. Anomalies of copper and iron are associated with gold in many of the sampling sites.

A heavy mineral study of till was made aross the gold anomalous area. Ten samples each of 10 kg were taken from each sampling site. The samples were combined and enriched using sluice and panning generally down to magnetite weight. Most of the concentrates contain fresh gold grains of 10–50 microns in size.

A pilot drilling program is going on and assay results have been received yet. The first drill cores intersected biotite altered mafic volcanic rocks with weak pyrite and chalcopyrite dissemination. Host rock contains garnet indicating amphibolite facies metamorphic grade.

Alluvial fan in Icaria Planum, Mars.

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The Mars Express HRSC data were used in finding details of fluvial history of the southern Claritas-Thaumasia area on Mars. Volatiles cumulated on the peaks were transported down to the main basin (Raitala et al., 2005). The resulted paleolake breached through the lowest saddle valley and formed a channel from the middle basin to the west into the direction of Icaria Planum. Along the channel, sapping provided additional water. Close to Icaria Planum, the channel broke into a 30-km wide impact crater and formed a temporary lake and a delta at the channel mouth. The neck of the flow out of the crater further into the west is higher than the crater floor and the delta was formed in a standing body of water. The crater rim has terraces and its floor was smoothened by sedimentary deposits. After breaching through the western crater rim, water spread onto the Icaria Planum lowlands to form an alluvial fan.

The alluvial fan in Icaria Planum was studied using the MEX HRSC color data set in order to map units and deposits of water-carried particles in the Icaria Planum lowlands in front of the short channel out of the crater. The alluvial flood deposits are made visible by an unsupervised four-channel HRSC image classification approach. Some sedimentary lacustrine deposits in the crater are also identified.

The alluvial structures reflect topography and regional slopes as well as the amount of available water. The hi-res multi-channel HRSC data give advanced views into these structures, erosion and sedimentation in the channel formation. Remote sensing approach will also facilitate the mapping of certain characteristic phases in faulting, volcanism, morphology and general geology within the area studied.

Raitala, J., Aittola, M., Korteniemi, J., Kostama, V.-P., Hauber, E., Kronberg, P., Neukum, G. & the HRSC Co-Investigator Team (2005). Claritas paleolake studied from the MEX HRSC data. LPS XXXVI, #1307.

Multichannel analysis of surface waves for shear waves velocity profile

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The multichannel analysis of surface waves method (MASW) is a nondestructive seismic method to evaluate pavement thickness as well as to evaluate linear elastic modulus of ground and materials under pavement. MASW techniques of estimating shallow shear velocities for assessment of earthquake site response are too costly for use at most construction sites. This method in most surface seismic surveys that use a vertical seismic source like sledge hammer, more than two-thirds of total seismic energy generated is imparted into Rayleigh-type surface waves the principal component of ground roll.

Second step is analysis dispersion properties of certain types of seismic surface waves (fundamental mode Rayleigh waves) propagating horizontally along the surface of measurement directly from impact point to receivers. It gives the shear-wave velocity (Vs) information.

Conventionally, two types of multi-channel processing method have been used in this paper: SFR (Swept Frequency Record) method and cross correlation method in frequency domain. Decomposition of a multichannel record into a time variable-frequency format, allow each frequency component to be separately and continuously displayed (Swept Frequency record, SFR). In the cross correlation method the phase difference between a pair of receivers is recorded as a continuous function of frequency (wrapped phase spectrum). This function, together with receiver spacing is used to calculate phase velocity at different frequencies (dispersion curve). Finally, the combined dispersion curve from several receivers spacing is inverted for a shear wave velocity profile (V_S) with depth.

We applied both methods dispersion curve of field data. Back calculation of the Vs profile (inversion of the dispersion curve) is accomplished iteratively, using the measured dispersion curve as a reference for either forward modeling or a least squares approach. Values for Poisson's ratio and density are usually estimated during this step.

A Tsunami in Lyngen, Northern Norway – a regional or local event?

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Three coastal basins in Lyngen, Troms, Norway (69°45'N, 19°55'E) were cored in April 2005. In the two lowermost basins (20 and 24,4 m.a.s.l.), a chaotic stratigraphy comprises erosional lower boundaries and large scale deposition of sand beds, gravely shell layers and clasts of peat and gytje. This is a characteristic signature of tsunami deposits (e. g. Bondevik et al., 1997). In the uppermost basin (30 m.a.s.l.), a thin lens of very coarse sand/very fine gravel is embedded in a fresh water gytje.

In the lowermost basin the Preboreal Isolation and the onset of the Tapes Transgression are located beneath the tsunami deposit. However, the final isolation from the marine environment is evident above the tsunami deposits. Clasts of gytje occur within the tsunami deposits. They have been eroded from a brackish-/fresh water basin at a higher elevation and redeposited in the marine basin. In the intermediate basin, the isolation contact has been partly eroded by the tsunami. Three distinct sand layers separated by organic matter are interpreted to represent pulses of water flowing in and out of the basin. The sand/gravel lens in the upper basin is assumed to represent the very peak of the tsunami wave. The mean sea level at the time of the tsunami was approx. 21 m.a.s.l., indicating a maximum run-up height of 8–9 metres.

Two ^{14}C dates constrain the event between 6500 and 7900 ^{14}C years BP (Corner and Haugane, 1993). We aim to narrow this time window in order to test the hypothesis that these deposit could be the result of the Storegga tsunami or whether a more local event should be considered. An explanation for finding these tsunami deposits at such a distance from the Storegga Slide could be the formation of an edge-wave, caught along the west coast of Norway, travelling both North and South from the initial site of impact (cf. Lynett & Lui, 2005).

A re-evaluated sea-level history of the Lyngen site, as well as the timing, source area and scale of the tsunami will be discussed.

Corner, G. D. & Haugane, E. (1993). Norsk Geologisk Tidsskrift 73, 175–197.

Bondevik, S et al. (1997). Sedimentology 44, 1115–1131.

Lynett, P. & Lui, P.L.-F (2005). Journal of Geophysical Research 110, 1–16.

Base metal and gold exploration in the Khuni area, Anarak, Iran; an exploration case study in an arid environment

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The ancient Khuni polymetallic base metal mine is located in central Iran, near town of Anarak. This mine is situated in an arid area with very low precipitation and density of vegetation. The Khuni region is considered as one of the most important areas for gold exploration in Iran. Polymetallic (Pb, Cu, Au) mineralization occurs mainly in vein system, as well as in skarns and liswonites within marbles of the Anarak metamorphic complex and to a lesser extent in Eocene volcanic rocks and related tuffite. The fault-controlled ore assemblages indicate that the mineralizing fluids were low temperature, and resulted in very limited geochemical and alteration haloes, which makes exploration difficult. Our petrogenetic studies indicate that the mineralization processes were related to the Kal-e-Kafi granodiorite intrusions in the southwestern part of the Khuni mountains.

Based upon fieldwork and previous studies (Nezampour & Rassa, 2005) that show that mineralization in this area is typically related to specific structures and lithologies, reconnaissance geological mapping at a scale of 1:5000 had been carried out and areas that were expected to contain evidence of mineralization were indicated. Geochemical surveys and sampling were focused on dykes, apophyses, volcanic and tuffite rocks, linear structures, lithologic contacts, limited alteration selvages of veins, limonite and silicification, facies changes of rocks, and old mining works.

Analyzing and processing of this data indicate the presence of three new mineralized area; one located in the north and two in the south. The northern anomaly contains high grades of lead (10 to 40 wt%) and zinc (5–40 wt%) and those in the south are rich (up to 14 ppm) in gold.

Nezampour, M.H. & Rassa, I. (2005). Using Remote Sensing Technology for ***Determination of Mineralization in Kal-e-Kafi Porphyritic Deposit, Anarak, Iran.,*** *9th SGA Symposium, China.*

Prograde garnet-bearing ultramafic rocks from the Tromsø Nappe, Northern Scandinavian Caledonides

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Garnet-bearing peridotitic rocks closely associated with eclogites within the HP Tromsø Nappe of the northern Scandinavian Caledonides show evidence of prograde metamorphism. Early stages are recognized as inclusions of *hbl* and *chl* in the central parts of large *grt* poikiloblasts. Closer to the *grt* rim *cpx* and Cr-poor *spl* appear as additional inclusion phases. The *spl* inclusions can be separated into 4 suites based on optical properties and chemical composition. The innermost inclusion suite (suite 1) has the lowest *Cr#* and highest *Mg#*. Toward the garnet rim spl inclusions become gradually lower in *Mg* and richer in *Cr*. *Grt* poikiloblasts are always rimmed by kelyphite: an outer zone consisting of hbl + Cr-poor *spl*, or *opx* ± *cpx* + Cr-poor *spl*, and locally an inner zone of Na-rich *hbl* + *chl*. The matrix assemblage in the garnet-bearing peridotitic rocks is *hbl* + *chl* + *cpx* + *ol* ± *Cr-rich spinel*, defining a strong foliation wrapping around grt and associated kelyphites. Thin recrystallized layers of *grt*-orthopyroxenite and *grt-hbl-zo* rocks are presumably coeval with the foliated matrix assemblage of the peridotitic rocks.

In dunitic to harzburgitic compositions large undulatory grains of *fo* + *en* ± *chl* + *spl* apparently define the maximum-*P* conditions. This assemblage is succeeded by a recrystallized assemblage of *fo* ± *tlc* ± *mgs*, which again is overgrown of strain free poikiloblasts of *en*, indicating a temperature increase. This is further postdated by *tlc* + *anth* ± *mgs*, and finally *serp*.

P-T estimates for the inclusion suites of *cpx* and *spl* clearly indicate *grt* growth and *spl* consumption at increasing *P*. The inner suite of spinel apparently was in equilibrium with *grt, cpx* and *ol* at 1.39 GPa; 677 °C, while included spinel with maximum Cr-content indicates 2.38 GPa at 742°C. Recrystallized *grt* + *opx* in *grt*-orthopyroxenite give 740–775°C at 1.47–1.90 GPa, interpreted to represent post max-*P* conditions during uplift.

The ultramafic rocks in the Tromsø nappe were locally strongly hydrated before they were subducted along with adjacent eclogites and meta-sedimentary rocks during early stages (452±1.7 Ma; Corfu et al., 2003) of the Caledonian orogeny.

Corfu, F., Ravna, E.J.K. & Kullerud K. (2003). Contrib. Mineral. Petrol. 145, 502–513.

Submarine De Geer moraines in the Kvarken Archipelago, the Gulf of Bothnia

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One of the largest De Geer moraine fields in Finland is situated to the Kvarken Archipelago, the Gulf of Bothnia. Present study provides detailed information on submarine De Geer moraine formations in the area. The study area (2 km x 1 km) was surveyed with acoustic-seismic methods (high-resolution echo-sounding, side scan sonar imaging, seismic reflection profiling) using 50 m track lines and seafloor sampling (e.g. vibrohammer coring). As a result a series of parallel, elongated and indented moraine formations were observed. Formations are rather short (<400 m), but they leave the impact that separate formations would constitute bigger entities. These formations were interpreted as De Geer moraines.

Average height of submarine De Geer moraines is 4 m, width is 43 m and length is 136 m. Inclinations vary around 10 degrees (Reijonen, 2004). Submarine De Geer moraines are larger (height and width) and more symmetrical than their terrestrial counterparts. They have not undergone coastal deformation (eroded) like terrestrials formations. This and the location at the land uplift-area enable us to study ongoing geological process, the succession of the De Geer moraines from seafloor to shore. Their orientation (205–262°) and appearance at ~100 m intervals offers information on the deglaciation pattern in the Kvarken Archipelago. Survey area contained also clays, boulders, crags and moraine formations that are entirely covered by sediments. The Kvarken Archipelago is considered as a very unique, constantly changing area and it was recently nominated for the inclusion on the World Heritage List on the basis of the geological features.

Reijonen, A. (2004). Vedenalaisten moreenimuodostumien monimuotoisuus Merenkurkun Saaristossa. Department of Geology, University of Helsinki, Finland. Unpublished M.Sc. Thesis 102 p.

Spirit's Exploration into the Origin and Evolution of the Columbia Hills, Mars

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As of this writing the Mars Exploration Rover, Spirit, has been exploring the Columbia Hills for over 470 sols (since sol 156 on June 11, 2004). The Columbia Hills form a rugged ridge complex comprised of 7 peaks spanning some 3.5 km in length and reaching a maximum height of 106 m (Husband Hill) above the plains of Spirit's landing site. Thus far the origin of the Columbia Hills has remained elusive despite detailed analysis of numerous rock and soil targets, including outcrops. The chemical differences among the 6 distinct rock classes attest to the lithologic diversity and geologic complexity of the Hills.

Several hypothesis have been put forth to explain the origin of the Columbia Hills: Old eroded partially buried impact crater rim(s), central peak, residual intracrater fill material, volcanic construct, wrinkle ridge, delta and or combinations of the above. Observations that support various aspects of these multiple hypotheses will be discussed.

Numerous buried craters are observed on the floor of Gusev lending credence to the idea that the Columbia Hills are the remains of an ancient impact crater rim or possibly a central peak. Morphologic evidence of the rim of Thira crater and the Columbia Hills appears to support this hypothesis. The Aeolis region contains numerous craters that contain layered materials in the absence of any major fluvial systems. This could imply that the Columbia Hills are the remnants of a formerly extensive unit(s). Gusev contains many hills scattered across its floor such as Grissom, White, Chaffee and numerous other buttes and mesas that may be remnants of a former extensive intracrater deposit.

Another possibility is that the Columbia Hills are composed of volcanic materials (cinder cones and associated ash and lava flows) derived either locally or from Apollinaris Patera located 300 km to the north. Several depressions are located in the Columbia Hills. These features could be calderas but are most likely impact craters. The most obvious large depressions have diameters that range from 350 to 820 m.

Intrusive gabbros interlayered with late-orogenic 1.83 Ga granitic sheets in South-western Finland

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The late Svecofennian granite – migmatite zone (LSGM-zone) in southern Finland is a large crustal segment characterised by roughly E-W trending sub-horizontal S-type migmatites and granites along a 100 x 500 kilometre long zone. It is a tectonic and metamorphic zone that crosscuts the earlier Svecofennian granitoids. Combined ductile E-W shear movements and NNW-SSE compressional movements partitioned into transpressional, ductile shear zones throughout the southern Svecofennian domain. This tectonic event is related to the intrusion of a belt of migmatites and granites that around 1.83 Ga ago discordantly transected the earlier Svecofennian crust. Partial melts that moved upwards through the crust formed either granitic massifs in the middle and upper crust or froze as migmatites.

The Nagu synform in SW Finland is a perfect area to study these tectonically banded and fractionated late-orogenic granites. In the area, occasional layers of undeformed gabbros of apparently same late-tectonic age are exposed.

Structural observations indicate that the gabbroic layers are intruded simultaneously with the banded and sheared granites. Because the late-orogenic granites and migmatites in southern Finland were transported and emplaced as small batches over an extended time interval, the internal relationships between these two types of melts produced, in places, complex patterns. Some gabbros are discordant against the banding in sheared granites, while sometime granitic back veining along cracks in the gabbro sills can be seen. Due to the temperature difference between granite and gabbro, the small gabbroic bodies quenched fast against the granites and were therefore better preserved during the synchronous deformation.

The large quantities of ductilly deforming granites forced smaller pulses of gabbro to intrude along the E-W trending layer-parallel shear zones of the synform, thus creating sill-like bodies, whereas larger bodies collected to form small local intrusion-fingers.

It has been suggested that mafic intrusives caused the temperature anomaly needed to produce the high-grade metamorphism and the late-orogenic granites in southern Finland.

Fluid in or fluid out? Oxygen isotopic study of incipient charnockite in Söndrum, SW Sweden

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High grade metamorphic rocks occurring in the Eastern Segment of the Sveconorwegian orogen, SW Sweden are dominated by migmatised granitic gneisses which are locally charnockitised. At the Söndrum quarry, charnockite forms distinct ca. 2 m wide symmetrical margins to a ca. 0.5 m wide pegmatitic dyke. Charnockitisation is dated by newly formed zircons in the pegmatite and metamorphic zircon rims in the charnockite zone and surrounding gneisses at 1397±4 Ma.

In this study we present $\delta^{18}O$ data for whole rock and mineral separate including ion probe determinations of $\delta^{18}O$ from single crystals of zircon. In addition samples for oxygen isotopic analyses of quartz and ilmenite were collected in a continuous section through the pegmatite-charnockite contact into charnockite with a sample interval of 1 cm, based on which, we may be able to distinguish between charnockite formation due to (1) melting-induced dehydration, whereby water is "sucked" from the charnockitising zone into a mobile melt phase (represented by the pegmatite) or (2) "flushing" of the gneiss by a CO_2 rich fluid.

Harris and Bickle (1989) studied the advective-diffusive transport of isotopic ($\delta^{13}C$, $\delta^{18}O$) and charnockitisation fronts, which they interpret to result from infiltration of a CO_2 bearing fluid. Based on their results, we calculated that the expected advective displacement of the $\delta^{18}O$ front at Söndrum for the CO_2-"flushing" model was ca. 6 cm away from the pegmatite. No such front was observed.

Instead, by comparison with a theoretical $\delta^{18}O$ profile for the melting-induced dehydration, we conclude that fluid was lost from the charnockite and "sucked" into the pegmatite.

Haris, N.B.W. & Blink, M.J. (1989). Earth and Planetary Science Letters 93 151–156.

Geomorphometry in landslide research – the use of region descriptors for landslide description and analysis

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The spatial organisation of a landform object is one of its most characteristic properties. This can be the shape of an object, the orientation, the elevation distribution or spatial context in the terrain. In the case of landslides such properties can be used to both describe and to analyse the geomorphic control of the slide. For example a slide that has the shape of an elongated hourglass indicate that a channelling of debris has occurred and the slide will typically have had a higher mobility than a slide that is tongue shaped.

In this presentation we first review the morphometrical control of topography for landslides, and potential applications. As a case study we then show how the spatial organisation of landforms can be parameterised using a number of region descriptors, each describing some spatial property of the landform. 18 historical landslides in Norway were mapped in a GIS, and with the help of a digital elevation model (DEM) descriptors were calculated for each slide. The descriptors were then evaluated for their ability to differ between different types of slides and to properly indicate different physical characteristics of the slides.

Shear zones and fluids at nappe boundaries in the central Scandinavian Caledonides

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The Lower, Middle, Upper Allochthons (LA, MA, UA) of the Scandinavian Caledonides display an inverted metamorphic gradient with very low-grade in the LA, upper greenschist in the MA and amphibolite, granulite to eclogite grade in the UA.

In order to characterize fluid-rock interactions and deformation processes in shear zones between and within these nappes we studied the evolution from near peak metamorphic conditions until the final emplacement in major nappes. In addition to field- and micro-structural work, fluid inclusion studies on quartz aggregates of different ductile shear zones and related low strain lenses are the main focus of this work, using microthermometry, Raman Spectroscopy and a combination of both. Low temperature Raman Spectroscopy yielded NaCl, $MgCl_2$ and $CaCl_2$ as major solutes within the aqueous and brine-gas inclusions. Fluid inclusion densities and isochors were calculated.

Relatively higher homogenization temperatures at shear zones in anchimetamorphic rocks than those obtained from low-salinity fluid inclusions in the MA mylonites probably reflect fluid pathways along out-of-sequence thrusts.

Most carbonic fluid inclusions within the UA mica schist and metapsammite have a high density indicating changes after the metamorphic peak conditions. Shear zones at the margin of low-strain lenses within the high-grade nappes show temperatures similar to the UA, implying that these lenses are an integral part of the high-grade nappe.

Combining geomorphology, geophysics and computational evidence to elucidate the evolution of Cenozoic Wales, U.K.

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Following the demise of denudation chronology as the overriding paradigm in British geomorphological research in the 1960s there have been few studies of palaeogeomorphology in the U.K., despite the significant implications of the plate tectonic concept. In areas of great crustal heterogeneity, such as Wales, evolutionary models based on time-related landform development leading to planation fail to fully explain the present landscape. This heterogeneity can be ascribed to the juxtaposition of various terranes accreted during successive tectonic events. Once formed, faults and thrust planes are preserved permanently in the brittle crust, and may be subject to reactivation, controlling landform development over geological timescales. The brittle crust is therefore comprised of numerous 'blocks', each having a unique isostatic response to those forces exerted upon it, with permanent instability existing along the hinge-lines that separate adjacent units. Therefore old palaeoforms are able to survive adjacent to areas that have undergone rapid changes in the geologically recent past. Consequently many of the traditional hypotheses regarding the origin of the present Welsh landscape can no longer be maintained. Recent advances in G.I.S. and modelling techniques now provide an opportunity to analyse and interpret high resolution DEMs at a regional scale, thereby providing impetus to reassess preceding models of landscape development. This presentation integrates known geological and geophysical records with computationally-derived data for three areas of Wales (Snowdonia, the Brecon Beacons and Ceredigion) to produce a coherent evolutionary model of Cenozoic landform development. From the integration of these datasets it appears that morphological progression is not wholly predictable: each terrane unit reacts differently to forces exerted, leading in some cases to planated surfaces and in others to orogenic events. In conclusion, an *'Accumulative Geomorphic Evolution Model'* suggests that any previous geological event may contribute to the contemporary geomorphological system and thus provides a template for the study of evolutionary geomorphology within passive continental margin regions.

Holocene slope activity impacting lacustrine sediment archives in alpine environments

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Lacustrine sediments are increasingly used as palaeoarchives of physical and ecological environmental change. However, spatial and temporal variations in relative composition of autochthonous and allochthonous sediments may significantly affect palaeoenvironmental interpretations.

Here we analyse geomorphological setting and sediment physical properties in two non-glacial alpine lakes in Abisko, northern Sweden, surrounded by morphologically active and passive slopes respectively.

Comparison of several Holocene sediment cores showed significant differences in both organic and minerogenic sedimentation rate in both studied lakes. The unexpected degree of spatial variability in the lake with geomorphologically passive setting (gentle slopes) has important implications for chronological control in lake sediment archives.

The spatial sediment variability in the lake with active slopes is pronounced and especially evident in the minerogenic sequence. This leads us to suggest that a single rapid mass-movement event (e.g. debris flow, slush-flow) close to a lake-shore can create very different sediment patterns in different parts of even small lakes. Hence, palaeoenvironmental interpretations based on mass movement deposits in lakes may differ significantly depending on core location.

This study also shows that fine-grained minerogenic layers of similar physical characteristics occur in different geomorphological lake settings. The genesis of such layers is hard to determine using only a few physical sediment parameters (LOI, magn.susc, grain-size). Good knowledge of the geomorphological setting, together with multi-proxy sediment analysis, is necessary when linking fine-grained minerogenic laminaes to specific input processes, and thereby climate causal mechanisms.

Gravity survey of the Keurusselkä meteorite impact structure

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Finnish Geodetic Institute (FGI) carried out gravity measurements at the Keurusselkä meteorite impact structure recently discovered by amateur geologists (Hietala et al., 2004). The original 5 x 5 km gravity net of FGI showed the Bouguer anomaly minimum approximately 5 km east of the shatter cone area.

Four profiles (E-W, N-S, NE-SW, NW-SE) across the crater area were measured in 2005 using Scintrex CG-5 gravimeter, and Leica SR530 GPS receiver with VRS technique for positioning. In the profiles, in the shatter cone area and around the Bouguer anomaly minimum, the gravity net was densified with average point distance 1–2 km. FIN2000 geoid model (Ollikainen, 2002) was used to convert heights in national N60 height system.

Gravity value for the nodal station were tied from the Finnish First Order Gravity Network (FOGN) (Kiviniemi, 1964) and the Bouguer anomalies were computed in Geodetic Reference System 1980 (GRS80). Thus the newly determined anomalies refer to same gravity and geodetic reference system as the national 5 x 5 km grid (Kääriäinen & Mäkinen, 1997).

The densification of gravity network revealed some further details around the main minimum, which, however, remained in its place east of the shatter cone area. Bouguer residual anomaly shows –8.5 milligal local minimum and –3.5 and –4.5 milligal local maximums inside the larger anomaly area. The diameter of the residual Bouguer low is estimated to be about 22–28 km.

Hietala, S. & Moilanen, J. (2004). Keurusselkä – a new impact structure in Central Finland, LPSC XXXV, Houston, Texas, USA (cd-rom).

Kiviniemi, A. (1964). The First Order Gravity Net of Finland, Publ. No 59 of the Finnish Geodetic Institute,Helsinki, Finland

Kääriäinen, J. & Mäkinen, J. (1997). The 1979–1996 gravity survey and the results of the gravity survey of Finland 1945–1996. Publ. of the Finnish Geodetic Institute, no 125. Kirkkonummi, Finland.

Ollikainen, M. (2002). The Finnish Geoid model FIN2000. Proc. of the 14th General Meeting of the Nordic Geodetic Commission, Espoo, Report of Finnish Geodetic Institute, Kirkkonummi, Finland, p.111–116.

Geochemistry and Nd, Sr isotopes of mafic plutonic rocks in south-central Sweden; implications for mantle character and tectonic setting in the Fennoscandian Shield at c. 1.8 Ga

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The whole rock and isotope geochemistry of mafic intrusions in the Fennoscandian shield of south-central Sweden was studied, including the 1.79–1.78 Ga Järna, Säfsnäs and Filipstad suites of the Transscandinavian Igneous Belt (TIB), as well as c. 1.87 Ga mafic plutonic rocks of the Hedesunda intrusive complex.

Rock types vary from gabbros/norites to qtz diorites. Mg# range between 76 and 49, and the SiO_2 contents between 43 and 54 wt%, with one more felsic exception, indicating some variation in evolutionary level. Some rocks are cumulus-enriched, e.g. in plagioclase, cpx, Fe-Ti oxides and apatite. Geochemical signatures are predominantly calc-alkaline, LILE and LREE enriched, of continental arc type.

The $\varepsilon_{Nd}(t)$ vary between +1.1 and +2.7, and $^{87}Sr/^{86}Sr(t)$ between 0.7020 and 0.7028, except for a leucogabbro from Järna (-2.7 and 0.7038). There is no systematic correlation between chemical parameters and isotope ratios. These isotopic data overlap with those of mafic TIB rocks further south. A weak trend of overlap with the c. 1.7 Ga basic Dala lavas of TIB, which show slightly elevated $^{87}Sr/^{86}Sr(t)$ values, is discerned for the Järna rocks. With two exceptions, these rocks conform to the isotopically 'mildly depleted' character ($\varepsilon_{Nd}(t)$ +1 to +2) that seem to be typical for southern TIB. Only few values in the range $\varepsilon_{Nd}(t)$ +2.0 to +3.5 have been reported (DM at 1.80 Ga=+3.9). The isotopically enriched leucogabbro has a primitive geochemistry (Mg# 73), and derive likely from a relatively more enriched mantle section.

The sources are inferred to represent depleted mantle wedge material that was subjected to variable fluid-induced enrichment during the immediately preceding (c. 1.9 Ga) arc subduction, and/or during the TIB magmatism itself. The calc-alkaline, LILE-LREE-enriched, HFSE-depleted signatures suggest magma generation in a continental arc environment.

Re-use of leftover stones from natural stone quarries in southeastern Finland

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The recovery rate of natural stone quarries can be as low as 10 % of the original volume of extracted rocks. It has been estimated that there are > 10 million tons leftover stones stored and partly rehabilitated next to natural stone quarries in southeastern Finland. Visual pollution is the most obvious defect of natural stone quarries. However, it is more important that rock materials are utilised according to principles of sustainable development. All extracted non-renewable natural resources should be used efficiently and economically partly to prevent establishment of unnecessary aggregate quarries.

In the first stage we will use aerial photographs and field investigations in order to model volume and distribution of leftover stones. Mechanical-physical properties of aggregates will be determined in order to evaluate potential end-use applications as well as logistic investigations for various transport ways.

Re-use of inert leftover stones has often been neglected due to high transport and crushing costs, and also because marketing activities has been lacking. Therefore, one of the main aims of this study is to develop economical production methods in order to increase productisation of leftover stones and to change the status of "leftover stones to by-products". Potential large-scale applications for leftover stones are aggregates for civil engineering and environmental construction works in Finland, Russia, and Baltic countries. Furthermore, new business ideas (e.g. by-product and aggregate terminals) and means to increase the degree of processing are studied in this project. Thus, it will be possible to add value to end-products and to prepare a potential way for longer distance transportation.

Late Cretaceous–Middle-Miocene granitic magmatism in the Newberry Mountains, Colorado River extensional corridor, Nevada, USA

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The Newberry Mountains in the south-central part of the Colorado River extensional corridor (CREC) host three late Phanerozoic granite plutons (Haapala et al., 2005): peraluminous White Rock Wash (WWP; ~65 Ma) and metaluminous/marginally peraluminous Spirit Mountain (SMP; ~20 Ma) and Mirage (MP; ~15 Ma). These plutons are distinct in their Nd, Sr, and Pb isotopic and elemental composition, and reveal substantial compositional variation in the deep crust in this region.

WWP has ε_{Nd} (at 65 Ma) of –16.2±0.3, Nd model ages averaging 1766±100 Ma, Sr_i of 0.7119±0.0006, and μ_2 (Stacey and Kramers, 1975) of 9.71±0.04. SMP is clearly more juvenile with ε_{Nd} (at 20 Ma) of –10.1±0.8, Nd model ages of 1222±74 Ma, Sr_i of 0.7098 ± 0.0002, and μ_2 of 9.65±0.04. MP is more heterogeneous than, and intermediate between, WWP and SMP, with ε_{Nd} (at 15 Ma) of –11.4 to –14.2, Nd model ages of 1338 to 1512 Ma, Sr_i of 0.7109 to 0.7115, and μ_2 of 9.61 to 9.67. Of the three plutons, SMP shows the highest K/Ca and lowest Ba/Rb and Eu/Eu*, MP the highest Ca, Fe, and Mg, and WWP the highest Na/K, Ba/Rb, and Eu/Eu*. The WWP granite was probably derived by a relatively large degree of melting of a largely cratonic feldspar-dominated (sedimentary?) source, whereas SMP and MP tapped clearly younger K-feldspar (SMP) or plagioclase (MP) dominated, probably hybrid (Falkner et al., 1995) sources. The ~65-Ma WWP belongs to a suite of late Mesozoic two-mica granites that register the waning stages of convergent processes along the eastern flank of the US Cordillera. As it appears to have been derived from an almost pure cratonic source and as it is spatially intimately associated with SMP and MG, the hybridization of lower crust probably took place after the Late Cretaceous plutonism, possibly during Miocene extension that commenced ~20 m.y. ago in this part of CREC.

Falkner, C.M. et al. (1995). J. Geophys. Res. 100, 10453–10476.

Haapala, I. et al. (2005). Lithos 80, 1–32.

Stacey, J.S. & Kramers, J.D. (1975.) Earth Planet. Sci. Lett. 26, 207–221.

Preferable use of unconformity bounded (allostratigraphic) units to create stratigraphical order in glaciated Quaternary terrains

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Formal lithostratigraphical procedures to create usable stratigraphical frameworks for glacited cratonic regions like the Fennoscandian shield have not been widely used (Gibbard, 1992). Only sporadically papers where lithostratigraphical formations have been properly defined and named has been published (e.g. Aario & Forssröm, 1979). Instead Quaternary deposits have been mapped according to their descriptive lithologic characteristics or interpreted lithogeny (e.g. Virkkala, 1972).

This has left countries like Finland and Sweden without a more detailed descriptive stratigraphic framework which would promote closer scientific research of the Quaternary evolution of the areas. Also various practical applied needs would largely benefit from a usable stratigraphic framework.

It seems evident that stratigraphical frameworks based solely on lithostratigraphy do not function well in glaciated areas, where accomodation space and sediment input systems have for a great degree been related to advancing or retreating glacial margins and where bedrock topography has played a significant role in controlling the deposition. As the North American Comission on Stratigraphic Nomenclature (1983) already suggested, the construction of a stratigraphic framework for this type of area could benefit from the application of unconformity bounded units.

A preliminary proposal for the formal use of preferably unconformity founded (allostratigraphic) formations and allomembers, together with the use of lithostratigraphic formations and members is here presented. The proposed combined use procedure possibly diverts from the practicies of strict allostratigraphy or lithostratigraphy as presented in the NACSN but it is thought to be more applicable for glaciated cratonic terrains.

Aario, R. & Forsström (1979). Fennia 157, 1–49.
Gibbard, P . (1992). Bull. Geol. Soc. Finland 6, 125–134
North American Commission on Stratigraphic Nomenclature (1983). Am. Ass. Petrol. Geol. Bull. Vol. 67, No. 5, 841–875.
Virkkala, K. (1972). Geologian tutkimuslaitos, Opas 4, 37p.

The impact of tourism and reindeer herding on the forest vegetation at Saariselkä, Finnish Lapland: a pollen analytical study of a high resolution peat profile

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A high resolution peat profile (sampled continuously in 2 mm slices to a depth of 22 cm) from the vicinity of a large tourist centre in northern Finnish Lapland was analysed in order to investigate the pollen evidence for changes in vegetation due to human interference and reindeer grazing. The area is particularly interesting since the tourist resort was established in an almost uninhabited wilderness and has grown explosively over the last 50 years. The peat profile was carefully dated with 15 AMS ^{14}C analyses, the results of which were wiggle-matched with the atmospheric ^{14}C curve. The resulting age-depth model gives the possibility of calculating pollen accumulation rates, which, in turn, enables the fine-scale human impact to be interpreted much more precisely than the pollen percentages do.

The results confirm that the pollen diagram based on percentages does not reveal human precence in areas like Saariselkä, where *Pinus* and *Betula* pollen (from the regional forest) is abundant and masks the variation of low pollen producing taxa such as non-arboreal species which indicate human impact. The diagram based on pollen accumulation rates, however, shows an increase in Gramineae and other apophytic pollen taxa coinciding with the development of the tourist resort since 1940. The growth in the number of reindeer in the surrounding reindeer herding district during 1980 can be detected from the diagram as a striking increase in fungal spores, i.e. the fungi growing on reindeer dung.

The slightness of the evidence of human impact in this northern boreal environment is an important feature to notice. If the pollen assemblages reflect only poorly the building of such a massive tourist centre, how well can we expect human impact to be seen in pollen diagrams from sites near a small village or a seasonal settlement?

Concentrations and fractionation patterns of rare earth elements in surface waters and groundwaters in a carbonate-rich boreal environment, Forsmark, E Sweden

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Understanding the geochemistry of rare earth elements (REE) in natural waters, both surface water and groundwaters, have been of great scientific interest since the 1980s. It is important to know the processes and reactions of REEs for investigating water-rock interactions as well as for tracing groundwater flow. The REEs have also been used as analogues for the actinide elements (Am, Cm) in studies related to radioactive waste disposal.

The aim of this study is to characterise four different natural waters: lake waters, stream waters, near-surface groundwaters and deep groundwaters with focus on spatial and temporal variations of concentrations levels and fractionation patterns of REEs.

The study area is situated in Forsmark, eastern Sweden and is a carbonate-rich boreal environment. The Forsmark area belongs to the Swedish Nuclear Fuel and Waste Management Co (SKB), which is currently conducting site investigations at two sites, Forsmark and Oskarshamn, in order to test the suitability of the area for a deep repository of nuclear waste.

Water samples were collected between 2002–2005 from ca 45 sampling sites and analysed by ICP-MS. The preliminary results show that the concentration of La differs largely between the different water types. Near surface groundwater shows the highest concentration followed by deep groundwater, stream water and lake water. Heavy REE (HREE) enriched, shale (NASC)-normalised REE patterns are found in most of the water samples, which are also expected in a carbonate-rich environment. Surprisingly enough there are some samples that show a depletion of the HREE. All water types except the deep groundwater exhibit negative Ce anomalies which may be due to oxidative scavenging on the surface of soil-forming Fe or/and Mn oxy-hydroxides.

Structural geology of the Riukka and Satulinmäki gold deposits in the Häme Schist Belt, southern Finland

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The Somero-Tammela gold critical zone south of Forssa town comprises calc-alkaline amphibolite facies metavolcanic and metasedimentary rocks of the Forssa Group which is part of a continental volcanic arc complex. The gold occurrences are hosted by quartz veins and shear zones truncating a sequence of felsic and intermediate metavolcanic rocks in the Satulinmäki area and uralite porphyry and tonalitic rocks with minor intermediate to felsic tuffites in the Riukka area. The layering represents a first foliation, S_n, parallel to the primary bedding due to isoclinal folding (F_n). The second deformation, D_{n+1}, was an isoclinal folding, F_{n+1}, with development of a penetrative, axial-planar foliation S_{n+1}. The SSE-plunging stretching and mineral lineation, $L_{n+1,}$ is parallel to the F_{n+1} fold axes. The pervasive mylonitic microfabrics suggests that F_{n+1} folding was associated with ductile shearing. A spaced, though penetrative, SW-NE striking foliation, S_{n+2}, is parallel to the fold axial planes of open to locally tight F_{n+2} folds. The folds in the outcrops are second order folds to regional scale SW-NE to W-E striking fold structures. Small-scale dextral strike-slip offset can be locally observed along the S_{n+2} planes.

Several generations of quatz veins can be identified ranging from strongly deformed, pre- to syn-D_{n+1} veins to late- to post tectonic veins associated with brittle fracturing of the host rock. In the Riukka deposit, alteration and mineralisation occurs mainly within steeply-dipping, SW-NE to E-W striking auriferous, tourmaline-bearing quartz veins, which post-date D_{n+1}. The veins are affected by open, regional-scale F_{n+2} folding. In the Satulinmäki deposit, thick quartz veins strike parallel to S_{n+2} cleavage planes and D_{n+2} shear zones. Alteration and mineralisation also occurs in late tectonic quartz veins accompanied by brittle fracturing of the host rocks. The pattern of various veins and faults indicate multiple-stage quartz vein formation associated with shearing and faulting in various stress regimes. This might imply more than one event of gold mineralisation. Nevertheless, chemical analyses of drill cores show a general SW-NE trend of gold mineralisation favouring a syn- to post- D_{n+2} formation.

The spatial distribution of mineralizations in the Rappen area, NW Sweden: Applications of Fry Analysis

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The spatial distribution of mineralizations is a primary concern in regional exploration, research, and resource assessment. Here we use Fry analysis as a complement to structural geology and geostatistical methods in order to investigate the mode of occurrence for molybdenum, uranium, iron oxide and precious metal deposits in the Rappen area, north-western Sweden. Fry analysis uses a geometrical method of spatial autocorrelation for point data (Fry, 1979), and is an alternative to variography for directional studies. The 22 molybdenum mineralizations, 30 uranium mineralization, 4 iron oxide and 7 precious metal occurrences in the Rappen area are plotted and they have 462, 870, 12, and 42 spatial relationships, respectively. The relationships are summarized in rose diagrams. Fry analysis and the derivative rose diagrams show the join frequency versus direction to determine similarities in the distribution of the deposit types. A comparision between the distribution of molybdenite occurrences in the Rappen area and the geophysical interpretation shows that mineralizations are located at the supracrustal belts (Öhlander & Nisca, 1985). In the Rappen area, molybdenite occurrences of aplitic type are located at the contact zones of granite intrusions (Walser & Einarsson, 1982) whereas molybdenite in altered volcanic rocks is associated with faults (Öhlander & Nisca, 1985). The major mineral occurrences in the Rappen area are distributed along N-S to NE-SW striking lineaments. The trends identified by means of Fry analysis correspond to aeromagnetic linear trends which, when identified in outcrop, are faults. These faults are systematically well-developed and often mineralized. The observed distribution of Mo, U, Fe-oxide, and precious metal occurrences is a function of the structural controls on mineralization, thickness of till cover, and the extent and effectiveness of exploration. According to the Fry analyses in the Rappen area there is a clear correlation between faults, lineaments and many ore occurrences.

Fry, N. (1979). Tectonophysics 60, 89–105.
Walser. G. & Einarsson, Ö. (1982). Geol. Rundsch 71, 213–229.
Öhlander B. & Nisca D.N. (1985). Economic Geology 80, 505–512.

New data for calibrating Kaapvaal craton's apparent polar wander path - Vredefort impact crater, South Africa

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The 2.023 Ga complex and deeply eroded Vredefort impact structure is situated in the central part of the Kaapvaal craton of South Africa. Structure's original diameter was ca. 250–300 km (Gibson & Reimold, 2001).

The Vredefort dome, the central part of the structure, has a diameter of ca. 90 km. The dome exposes a ca. 40 km wide crystalline basement core of granites and gneisses of mostly 3.1–3.2 Ga age. The core is enclosed by a 15–20 km wide collar of Meso-Archean to Paleoproterozoic supracrustal strata of the Witwatersrand (ca. 2.9–2.7 Ga), Ventersdorp (ca. 2.7 Ga) and Transvaal supergroups (2.6–2.25 Ga). Younger, Kibaran age (1.2–1.0 Ga) magmatism and tectonic activity related to the Namaqua-Natal Orogeny have left widespread evidence in the central part of the Kaapvaal craton (Friese et al., 2003).

As the Vredefort structure covers lithologies of ages ranging from ca. 3.2 to 1.0 Ga, paleomagnetic results are relevant to the calibration of the apparent polar wander path (APWP) and tracing the drift history of Kaapvaal craton through Precambrian. The most consistent result of this paleomagnetic study is the Vredefort direction, obtained from the impact related lithologies (melt, pseudotachylitic breccias), which provide a reliable paleopole at 2.023 Ga. The other result is a widespread ca. 1.1. Ga overprint in some of the rocks in the area. Petrophysical studies revealed that, some of the lithologies in Vredefort and Johannesburg dome showed high Q-values. Possible reasons for high remanent magnetization values of these lithologies will be discussed.

Friese et al .(2003). S. Afr. J. Geol. 106, 41–70
Gibson & Reimold (2001). Council for Geoscience, Pretoria, Memoir 91, 110 p.
Lana et al. (2003). Meteorit. Planet. Sci. 38, 1093–1107

Recent large-scale geochemical mappings in Europe

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Two large-scale regional geochemical mapping projects have been recently finalized in Europe. Barents Ecogeochemistry project covered the area of 1.5 million km^2 in NW-Russia and Finland, and Foregs Geochemical Baseline Mapping Programme covered the area of 4.2 million km^2 in 26 European countries. Despite of minor differences, the methodology was same in both projects including samples from stream water, organic and minerogenic soils, and sediments; in Barents Ecogeochemistry project was also collected terrestrial mosses. The number of sampling sites was 845 (4360 samples) in the Foregs project and 1365 (5410 samples) in the Barents project, respectively. Samples were analyzed for some 50 elements and other parameters using both total and partial digestion. In both projects, all soil and sediment samples were prepared at one laboratory, and all samples of particular sample types were analysed by the same method at the same laboratory.

Results were published as geochemical atlases (Salminen et al, 2004; Salminen (chief-ed.), 2005) which include respectively 190 (Barents project) and 360 geochemical maps (Foregs atlas). The distribution patterns show continent wide anomalies, partly anthropogenic in origin (moss and partly stream water), but mainly the anomalies are geogenic ones showing in many cases large tectonic provinces. Some of the anomalies show values which are at the risk level for human health (Sr in stream waters in Russia), point out emissions from industry (Kola Peninsula, Central-Europe), do not support the idea of long range airborne transportation of heavy metals, reveal unknown geochemical provinces (REE in northern Central and northern Europe). Results give valuable information about the base line levels of heavy metals and other elements in the surficial deposits and waters in Europe to be used as background data in national and EU legislation.

Salminen, R., V. Chekushin, M. Tenhola, I. Bogatyrev, S.P. Glavatskikh, E. Fedotova, V. Gregorauskiene, G. Kashulina, H. Niskavaara, A. Polischuok, K. Rissanen, L. Selenok, O. Tomilina, & L. Zhdanova (2004). Elsevier BV, Amsterdam (Reprinted from Journal of Geochemical Exploration, vol. 83), 548 p.

Salminen, R., Chief editor (2005). Electronic publication http://www.gtk.fi/publ/foregsatlas/, ISBN: 951-690-913-2

Two Weichselian glacial cycles recorded in the Hitura open pit sections, Ostrobothnia, Finland

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Central Ostrobothnia is one of the key areas for glacial stratigraphical studies in Finland. There exists a large number of occurrences correlated to Eemian interglacial or Brørup interstadial, but the Weichselian glacial record is more incomplete including important unresolved questions. For example, the extent and age of Early and/or Middle Weichelian stadials has not been defined. The Hitura exposure is a large open pit, which exposes an exceptional thickness (up to 70 m) of Quaternary sediments. One of the earlier studies suggests that there is a pre-Eemian esker system overlain by one Weichselian till complex (Ignatius & Leskelä, 1970). In contrast to that, Kokkola (1975) identified six distinct Weichselian till units from the same sections.

The sedimentary record from the Hitura open pit was re-examined in summer 2005. Studied sections display a sequence from glaciofluvial and deltaic sediments to early Holocene clays. The topmost portion of the glaciofluvial sediments bears marks of cryoturbation and strong glacial deformation. In places a podsolic soil horizon has been developed in fine grained sands. In addition, an allochtonous geosol was discovered, having been developed in fluvial sands. There were also traces of allochtonous organic forest soil. Soils were overlain by sediments related to two Weichselian glacial episodes. The lower till is inmature and clast supported. It is covered by a succession of glaciolacustrine and littoral deposits indicating deglaciation. Based on deformation structures, the lower till was deposited by a glacier flowing from the north. The upper, massive matrix-supported till can be devided into lodgement- and melt-out –facies. It has a fabric indicating a northwest direction of glacier flow.

Ignatius, H. & Leskelä, S. (1970). Geologi 22, 61–64

*Kokkola, M. (1975). **IMM, London 1975, 149–154***

Sanukitoids as a marker of Neoarchean lithospheric mantle and crust heterogeneity: Isotope-geochemical evidences

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New isotope and geochemical data suggest that mafic and felsic magmas for Neoarchean sanukitoid series of the Karelian granite-greenstone terrain (GGT) came from two contrasted sources: enriched lithospheric mantle and lower crust. So sanukitoids are able to supply us information about the geochemical structure of Archean lithosphere, which is a reflection of crust-forming tectonic processes. This point is illustrated by isotope-geochemical studies of 2715–2740 Ma old sanukitoids from Eastern-, Western- and Central-Karelian domains that had different crust-forming history.

In the Western domain sanukitoids show long-term enriched mantle source (εNd_{2715}=-0.48±0.22) and young juvenile TTG crust (εNd_{2715} up rise to +1.2). In the Eastern domain mantle source of mafic sanukitoids had slightly-term enriched history (εNd_{2740} =+1.58±0.01), whereas felsic magmas came from old crustal source (εNd_{2740} down to -3.0). Sanukitoids of the Central domain were generated from short-term enriched mantle source (εNd_{2725}=+2.05±0.15) with minor influence of juvenile TTG crust (εNd_{2725} lowered to +1.7).

The results obtained for crustal-derived felsic sanukitoids are in a good agreement with available data for crustal rocks of the domains. Possible reasons for lateral isotope-geochemical heterogeneity of the lithospheric mantle source for the studied sanukitoids have been tested using REE and Sm–Nd isotope modeling. TTG with adakite affinities ca 3.2 and 2.8–2.9 Ga old, which are regarded as subduction-related slab-derived melts (Martin, 1999; Samsonov et al., 2005), was taken as a possible agent of mantle metasomatic enrichment. Calculations suggest that input of different abundances of 3.2 and 2.85 Ga TTG (total ca. 30 wt.%) into the DM-mantle source might provide the observed isotope variations of the mafic mantle-derived sanukitoids.

Martin H. (1999). Lithos 46, 411–429.
Samsonov A., et al. (2005). Lithos 79, 83–106.

The occurrence and potential origin of asphaltite in bedrock fractures, Forsmark, central Sweden

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Occurrences of asphaltite in fractures in the Svecofennian basement have been documented in drill cores from the site investigation for a deep repository for nuclear waste in Forsmark, central Sweden. The carbonaceous material has been found at depth down to 124 m. It appears as hardened black fracture fillings but is also manifested as viscous material especially in connection with the drilling

The $\delta^{13}C$ values of the asphaltite are relatively uniform showing values between -29.5 and -30.1 ‰ PDB indicating organic origin. These results are consistent with previous analyses of asphaltite from Sweden (e.g. Welin, 1966). One sample collected from a fracture in the Ordovician limestone in Kinnekulle, South-west Sweden, has been analysed for comparison and shows similar $\delta^{13}C$ signature (-29.5 ‰ PDB). Biomarker analyses of the asphaltite samples confirm an organic origin and further link the Forsmark sample with the Kinnekulle sample by the presence of e.g. cyclohexane and octadecanoic acid. Trace element enrichment related to the asphaltite are S and Pb.

The most plausible source of the asphaltite, especially considering the similarity between the Kinnekulle and Forsmark occurrences, is the organic rich late Cambrian to lower Ordovician alum shale that covered most of southern Sweden during the Paleozoic. Downward migration of hydrocarbons into the crystalline basement due to the presence of an overpressured basin as described by Gleeson et al. (2003) is a possible process for the emplacement of the asphaltite in the bedrock fractures. It is suggested that the heat source responsible for the migration of the asphaltite is the overburden of the Caledonian foreland basin. This sedimentary cover reached a maximum at c. 350 Ma (Larson et al., 1999).

Gleeson, S.A., Yardley, B.W.D, Munz, I.A. & Bouyce, A.J. (2003). Geofluids 3, 33–48.
Larson, S.Å., Tullborg, E-L., Cederbom, C. & Stiberg, J.P. (1999). Terra Nova 11, 210–215.
Welin, E. (1966). Geologiska Föreningens i Stockholm Förhandlingar 86, 509–526.

Tracing mineralized boulders and till in the ribbed moraine area of Misi, northern Finland

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The glacial transport distance and the deposition processes of mineralized boulders and till were studied in the area of Misi, northern Finland. Ore prospectivity of the area is considered high due to the great number of ore boulders found at the surface in different moraine formations (Sarala and Nenonen, 2005). Aerial photographs and digital elevation models were used to interpret glacial morphology, and detailed field studies using tractor excavations were carried out at several test sites to study till stratigraphy and to get till samples. The fine fraction of till (<0.06 mm) was analyzed using ICP-AES, and the heavy mineral fraction of till was microscopically examined.

The glacial morphology of the Misi area is mainly composed of transversal (to the latest glacial flow direction) moraine ridges. These occur as part of an assemblage of active-ice moraine formations like longitudinal drumlins and flutings, and closely related to WNW-ESE oriented esker complex. Ribbed moraines consisting of hummocky ribbed moraine type and Rogen moraine type are characteristically covered with boulders with transport distances not more than some tens to some hundreds of meters. High metal contents of till debris in the uppermost till units also indicate short transport distance of rock material. Mineralized bedrock exists next to the anomaly in till, towards the glacial flow direction.

Results of the study strengthen the suitability of ribbed moraines for prospecting work and give new information of the ore potential in the area. Boulders within the till and at the surface of the ridges reflect the variation of local bedrock composition. Also, the till geochemistry strongly reflects local element variation in the bedrock. These factors are common for all ribbed moraine types in southern Finnish Lapland (Sarala, 2005). Prospecting for ore differs quite a lot in the areas of ribbed moraines compared to areas of drumlins and flutings due to different formation processes. The special characteristics of different moraines must be taken account when choosing the equipment for geochemical sampling.

Sarala, P. (2005). Applied Geochemistry 20, 1714–1736.
*Sarala, P. & Nenonen, J. (2005). **Geological Survey of Finland,** Special Paper 38, 25–29.*

Exploration results and geology of the Lumikangas apatite-ilmenite gabbro, Kauhajoki, western Finland

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Lumikangas area was selected as a target for Ti-P-exploration on the basis of a high magnetic and gravity anomaly and its location in the Kauhajoki apatite-ilmenite gabbro province.

The Kauhajoki gabbro province is situated in the western part of Central Finland Granitoid Complex (1870–1890 Ma), between the synorogenic granitoids and the late orogenic Lauhanvuori granite. The mafic-ultramafic intrusions; Honkajoki, Kauhajärvi, Hyyppä and Lumikangas are layered and contain considerable amounts of ilmenite, apatite and magnetite, averaging 18–22 wt.% together.

Magnetic and gravity interpretations indicate that the Lumikangas deposit extends to a depth of 300–500m and total length of the anomaly is five kilometers. According to the seismic profile, the overburden is 30–70m thick over the intrusion.

Drilling results show that the apatite-ilmenite gabbro is suhorisontal and its thickness is at least 200 m. The structure of the intrusion is clearly layered but the compositional variation ranges from Fe-Ti-rich dark gabbros to apatite-rich leucogabbros. The basal part is composed of dark medium-grained gabbro or gabbronorite, hornblende gabbro and olivine gabbro, and the upper part is medium to coarse-grained leucogabbro or monzogabbro.

Disseminated ilmenite and magnetite occur as separate crystals, anhedral to subhedral granular aggregates and range in size from 0.1 to 1.5 mm.

Apatite, ilmenite and magnetite were crystallised at the same time at a very early stage of magmatic differentiation, because they have a good correlation with magnesium.

The Lumikangas apatite ilmenite monzogabbro may be a potential ore resource in the future, containing an average of 19 % ore minerals: 8.7 % (max. 21 %) ilmenite, 4.8 % (max. 17 %) magnetite and 5.4 % (max. 17 %) apatite. The inferred and possible resources based on geophysics and two drilling sections (totalling 1308 m) include 230 million tons of oxide gabbro. The drilling profiles did not intersect pyroxenites, in which the highest ore contents could be hiding.

Mass changes in alteration zones of the Petiknäs South volcanic-hosted massive sulfide deposit, Skellefte district, Sweden

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Petiknäs South is a producing underground mine in the eastern part of the Skellefte district and contained 6 Mt of pyritic massive sulfide ore grading 5 % Zn, 1 % Cu, 1 % Pb, 2.5 g/t Au and 105 g/t Ag prior to mining. The deposit is hosted within volcanic rocks of the Paleoproterozoic Skellefte Group and consists of several stacked ore lenses (from oldest to youngest: C, B, D and A). The mine sequence comprises coherent and volcaniclastic units of rhyolitic to basaltic andesitic composition, and post-ore andesite sills and mafic dykes. The mine stratigraphy dips subvertically and youngs consistently southwards and the volcanic rocks have been metamorphosed to greenschist facies. Application of immobile-element lithogeochemical methods to 469 samples has allowed classification of the mine sequence into a series of chemostratigraphic units, while the degree of hydrothermal alteration of these units has been quantified using mass change methods. The main alteration minerals are sericite, chlorite, garnet, quartz and locally carbonate. Intense chlorite-garnet alteration occurs immediately below the A and D ore lenses, and in the distal footwall of the C and B ore lenses. A synvolcanic felsic sill was emplaced in the proximal footwall slightly after formation of the massive sulfide lenses. Consequently, a major part of the proximal footwall is only weakly altered and zones of strong alteration are truncated by the sill. The alteration zones are interpreted as hydrothermal upflow or feeder zones. Haloes of serizitization occur around the ore lenses and are wider than the zones of chlorite-garnet alteration and alteration zones with Na_2O and CaO depletions occur on a semi-regional scale, but are most intense close to the ores. Alteration zones below and around the ore lenses are characterized by large mass gains of FeO, MnO, MgO and K_2O together with large mass gains or losses in silica. The latter alteration zones are approximately three times larger than the actual ore lenses, and consequently could provide a good exploration guide to ore.

Formation and melt-out of multiple generations of ice-cored moraines at Brúarjökull, Iceland

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In the Brúarjökull glacier forefield, East Iceland, several generations of ice-cored moraines are present. The dead-ice originates from the last Brúarjökull surges in AD 1810, 1890, and 1964. The quiescent phases in the surge cycles are shorter than the time required for a total melting of the dead-ice bodies in the present climatic setting. Therefore, older dead-ice bodies are overridden during the surge advances, and new sediments may be deposited on top of the dead-ice. The sediments are subject to resedimentation due to melting of dead-ice from previous surges. Thus, the resulting landform-sediment associations are those of complex hummocky dead-ice moraines. Transitional-state landforms, such as ice-cored drumlins and ice-cored outwash, may also evolve into hummocky moraine (Schomacker et al., 2005).

The analysis of the dead-ice melting and associated resedimentation is based on multi-temporal high-resolution digital terrain models (DEMs), geomorphological mapping, Ground Penetrating Radar (GPR) surveys, and sedimentological field investigations. Furthermore, the rates and processes of dead-ice melting were monitored in the field 2003–2005. Continuous measurements from automatic meteorological stations in the forefield link the dead-ice melting to the present climate. The meteorological data suggest a mean annual air temperature at or slightly below 0 °C, indicating that sporadic perm-frost may occur. The downwasting below c. 1 m of diamict sediment amounts < 5 cm/yr, and the ablation season is limited from mid-April to mid-September.

Mapping the location of ice-cored moraines and dead-ice moraines in the surging glacier forefield reveals at least two distinct patterns of dead-ice location: in narrow belts behind the marginal moraines and as larger bodies in the major valleys. This pattern appears to be consistent in the last two surge cycles.

Schomacker, A., Krüger, J. & Kjær, K.H. (2005). Journal of Quarternary Science, in press.

Stable isotope evidence for Ba–Pb–Zn vein mineralizations by fluid circulation in the sedimentary basin at Svalbard

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Numerous hydrothermal vein fillings of (in a generalized crystallizing sequence; only some of these minerals coexist) calcite [magnesian], dolomite, barite, sphalerite, galena; fluorite; chalcopyrite; witherite, strontianite; and occasional late quartz with barite and dolomite occur at Bjørnøya (B) and along the western part of Spitsbergen (S) in the Svalbard archipelago of the Arctic. The age and genesis of these veins are unknown. Flood (1969) assumed a pre-Devonian, Caledonian, age. We have found these epigenetic vein fillings cutting sedimentary strata through the complete stratigraphy, from Late Precambrian through Permian; hence field evidence shows a Triassic or younger age. The heat source may have been the adjacent Tertiary Vestbakken volcanism associated with the Atlantic continental rifting.

Fluid inclusions have so far been found to be too small for microthermometry. $\delta^{18}O$ of coexisting calcite – dolomite yielded an equilibrium temperature of 180°C for a vein at B. $\delta^{34}S$ in all sulfides range -0.6 to 12.7‰; in all barites 13.4 to 27.0‰. Coexisting sulfides – barite show $\Delta^{34}S$ of -0.2 to 26‰; no equlibrium values, as expected from the relatively low hydrothermal temperature. B and S show different $\delta^{34}S$. B barites have high $\delta^{34}S$ like Precambrian – Ordovician sea water, expected from the local Hecla Hoek wallrocks. Estimated $\delta^{34}S$ of H_2S in equilibrium with sulfides reach the value of Permian evaporites, making these a possible source of S in H_2S. Similar low $\delta^{34}S$ is found at Sigurdfjell and Sinkholmen in S. Barite from Ridderborgen and Zeipeldalen in S show intermediate $\delta^{34}S$ typical of their wallrock Devonian sulfate. Early vein carbonates at B show relatively high $\delta^{18}O$ and $\delta^{13}C$ like for wallrocks, while later vein carbonates show low $\delta^{18}O$ and $\delta^{13}C$, indicating mixing with a different fluid carrying oxidized coal carbon.

A deep crustal fluid with metals, Ba, and Cl, was mixed with a descending fluid carrying dissolved evaporite sulfate, partly reduced to H_2S by local coal beds; depositing the vein barite and metal sulfides.

Flood, B. (1969). Norsk Polarinstitutt – Årbok 1967, 109–128.

Comparative study of tectonomagmatic evolution of the Earth and the Moon

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Comparative study of tectonomagmatic evolution of the Earth and the Moon showed closeness of the lunar magmatism to the Palaeoproterozoic terrestrial one. Geological development of the both bodies became after solidification of their global magmatic oceans, which resulted in appearance the primordial sialic crust on the Earth and anorthositic on the Moon. The further tectonomagmatic evolution of the both bodies occurred in two major stages. On the Earth magmas, derived from depleted mantle sources, predominated in Archean and, especially, in the early Paleoproterozoic (2.5–2.2 Ga) when magmas of siliceous high-Mg series (SHMS) were common. At c. 2.2–2.0 Ga they were globally replaced by geochemically-enriched magmas (Fe-Ti picrites and basalts as well as high-Ti alkaline rocks); it was followed by changing of plume-tectonics to plate tectonics regime (Bogatikov et al., 2000).

On the Moon magmatic activity began on the highlands c. 4.4–4.35 Ga from the magnesian suite, which was rather close to the terrestrial SHMS on its geochemistry and isotopy. Such activity lasted till ~3.9 Ga and was changed by plume-related basaltic volcanism including low- and high-Ti varieties, occurred within large maria depressions with thinned crust at the boundary 3.9–3.8 Ga. These magmas were close to MORB and OIB consequently.

Thus, the Moon, as compared to the Earth, evolved more quickly and by shortening scenario: on the both bodies a new enriched mantle-derived magmas began to involve in the processes on their outer shells at the middle stages of their evolution.

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*Bogatikov, O.A. et al., (2000). **Magmatism and Geodynamics.** Terrestrial Magmatism throughout the Earth's History. Gordon and Breach, 511 p.*

Two different Palaeoproterozoic large igneous provinces, eastern Fennoscandian Shield

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Two Paleoproterozoic large igneous provinces (LIPs) of different composition and age occurred on the eastern Fennoscandian Shield in form of lava successions in riftogenic structures, dyke swarms and layered mafic-ultramafic intrusions. The first one is composed by rocks of the siliceous high-Mg (boninite-like) series (SHMS) of 2.5–2.36 Ga age, and the second - mainly by Fe-Ti basalts and picrites of 2.3–1.95 Ga age. Both types of the LIPs evolved within rigid Kola and Karelian cratons, divided by Lapland-Umba granulite belt (LUGB) with crustal-derived enderbite-charnockite magmatism. Belomorian and Tersk-Umba mobile belts occurred between cratons and LUGB; specific disseminated intrusive magmatism, the same type as in cratons, evolved here. All major tectonic structures evolved simultaneously and situation could be described in plume-tectonic terms: cratons developed above extended plume heads and LUGB - on place of the mantle descending flows.

It is important that on the boundary 2.3–2.2 Ga sharp changing of magmas composition occurred without changing of tectonic situation: both cratons and the LUGB continued their development in the same way. Newly formed basalts build up the lava successions in the same riftogenic structures, new dyke swarms and layered titaniferous mafic-ultramafic intrusions were generated. Probably, that it means that the mantle superplume, which provided existence of the early Paleoproterozoic LIP, continue to exist in the middle Paleoproterozoic, but it's composition was change, may be as a result of the mantle metasomatism activization.

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Probing the hidden Archaean-Proterozoic boundary in Karelia using zircons in lamprophyres

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In North Ladoga, lamprophyres occur in a 40 km wide dyke swarm trending NW parallel to the Archaean craton margin. On surface, the dyke swarm cuts Svecofennian gneisses. Laprophyres are known to contain zircon polulations representing their surrounding lithologies. A SIMS-survey for these rocks was undertaken to trace Archaean lithologies hidden beneath Svecofennian formations close to the Arhean-Proterozoic boundary in North Ladoga region. The zircon populations obtained from the dykes can be divided into five groups, two archaean (c. 2830 Ma and 2680–2730 Ma) and three proterozoic (c. 2450 Ma, 1870–1850 Ma and 1770+/-30 Ma). The youngest age obtained from overgrown tips of the zircon crystals is interpreted as the intrusion age of the dykes. The dykes most distant from the Archaean craton contain Archaean zircons but towards northeast, Archaean zircons disappear from lamprophyres and appear again in dykes situated more close to the craton margin. In combination with published isotope data (Konopelko et al., 2005), it seems that fragments of the Archaean basement exist beneath the Svecofennian rocks as far as 40 km southwest of the inferred suture. Even if the lamprophyres contain Archaean zircons, Sr and Nd data idicate that they stem from a mantle that was enriched during the Svecofennian subduction (Kononova et al., 2000).

Kononova, V.A., Pervov, V.A. & Parsadanyan, K.S. (2000). Sr-Nd isotopy, age and geochemistry of the megacryst-bearing lamprophyres of the Ladoga region: evidence of their lithospheric source. Doklady Earth Sciences 370, 157–159.

Konopelko, D., Savatenkov, V., Glebovitsky, V., Kotov, A., Sergeev, S., Matukov, D., Kovach, V. & Zagoranya, N. (2005). Nd isotope variation across the Archaean-Proterozoic boundary in the North Ladoga Area, Russian Karelia. GFF 127, 115–122.

Isotope characteristics of Paleoproterozoic (ca. 1.8 Ga) mafic and ultramafic rocks of the central part of the Ukrainian shield, Ukraine

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Dikes of mafic and ultramafic compositions are widely distributed within the Paleoproterozoic Kirovograd domain of the Ukrainian shield. The age of these rocks is estimated to ca. 1800 Ma (K-Ar method) (Tsymbal et al., 1999). We have studied Nd, Sr and Pb isotopic compositions of six samples representing kimberlite (1 sample), dolerite (2 samples) and peridotite xenoliths found in a kimberlite (3 samples). The dolerites reveal very similar Sr and Nd isotopic compositions with εSr_{1800} and εNd_{1800} values 10.5 and 1.2, respectively, and these data are almost identical to those of one kimberlite sample studied by Yutkina et al. (pers. comm.). Thus, these samples plot in the quadrant where Sm/Nd and Rb/Sr ratios are both greater than their respective values in a chondritic reservoir. This also holds true for still another kimberlite sample analyzed by Yutkina, as well as our kimberlite analysis. The peridotite xenoliths display large irregular variations in isotopic compositions (εNd_{1800}=2.6, 6.6, 2.5 and cor-responding εSr_{1800}= -43.5, 17.1, 12.2), and leaving out the sample with the exceptional Sr signature these samples confirm a general affiliation to the first quadrant in the Nd-Sr correlation diagram. Although only few data are available, it is suggested that the mafic rocks in the study area were derived from a moderately depleted sublithospheric mantle which was contaminated with radiogenic ^{87}Sr. Furthermore, when data are plotted in isochron diagrams, emplacement ages close to 1.8 Ga are supported, although certain samples appear to have suffered some open-system behaviour. Moreover, variable εNd_{1800} values and the range in apparent initial Pb isotope ratios imply heterogeneities in the mantle source at the time of magma generation.

This is a contribution to the Swedish Institute' research network "Precambrian Evolution of Western Baltica" and the project of the Swedish Royal Academy of Sciences "Isotopic composition of mantle heterogeneity in the Ukrainian Shield".

Tsymbal, S. M. et al. (1999). Mineral. J. 21,. 22–38.

Clay minerals in Neogene sediments off Prydz Bay (Site 1165), Antarctica: implications for Middle Miocene and Middle Pliocene glacial evolution

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The reconstruction of the climatic and glacial history of Antarctica is important, as the past conditions may be a key for anticipating future developments. After the Middle Miocene climatic optimum, further cooling and development of Antarctic ice sheets occurred. This study reports some information of the glacial and climatological conditions prevailing during the Middle Miocene and the Middle Pliocene Global Warmth as revealed by clay mineral analyses.

Ocean Drilling Program Site 1165 was drilled on the continental rise, proximal to the East Antarctic Ice Sheet (EAIS) off Prydz Bay. Site 1165 records a history of sedimentation on the continental rise, extending back to the earliest Miocene times (c.a. 22 Ma).

This study covers two sediment intervals that are of special interest: 1) the Middle Miocene sediment sequence at 150–326 meters below sea floor (mbsf) (~10–15 Ma) and 2) the sediment interval between 25 and 34 mbsf representing the Middle Pliocene time (~3.2 Ma).

The clay mineral assemblages of the sediments around Antarctica generally consist of illite, chlorite, smectite and minor kaolinite, and these minerals are mostly of detrital origin (Ehrmann et al., in press). The main objective of our study was to use the percentage distribution of these clay minerals for reconstruction of the palaeoclimatic and glacial conditions of East Antarctica during the Middle Miocene and the Middle Pliocene. The fluctuating trend, which increases upwards in the clay mineral assemblages in the Middle Miocene sediment sequence, can be explained by the repeated advance and retreat of grounded ice masses consequent to changes in EAIS volume. The increased smectite content in the Middle Pliocene suggests that the ice sheet at that time may have been more dynamic.

Ehrmann. W., Setti, M. & Marinoni, L. (in press). Clay minerals in Cenozoic sediments off Cape Roberts (McMurdo Sound, Antarctica) reveal palaeoclimatic history. Palaeogeography, Palaeo-climatology, Palaeoecology.

3-D gravimetric modelling of Kuhmo Greenstone Belt area, Eastern Finland

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3-D density model was compiled for upper crust (to the depth of 16 km) in the Eastern Finland on the area of 130 km (in N-S direction) x 150 km (in E-W direction). Main modeling target on the area was Kuhmo Greenstone Belt because of its sharp Bouguer anomaly. Another reason was pronounced change in the Moho boundary in the area. The basis of modeling was earlier 3-D gravity model for SVEKALAPKO research area (Kozlovskaya et al., 2004).

Mainly petrophysical, mineralogical and seismic data were used as reference data when approximating the densities for the Greenstone Belt and rocks surrounding it for the model. Its shape on the surface was taken from the geological map of Finland. Shape under surface was found by building the starting model by hand and using trial and error method to find good correlation between calculated and measured Bouguer anomaly data. The two computer programs used in this work were Bloxer, an interactive visualization and editing tool for 3-D block models, and Grablox, a gravity interpretation and modeling software (Pirttijärvi, 2004a; Pirttijärvi, 2004b).

After the model was build with trial and error method, inversion possibilities of Grablox were also tested for this kind of structure. The sharp Bouguer anomaly of Kuhmo Greenstone Belt was a bit problematic for block based inversion. Inversion parameters had to be chosen carefully to get possible result.

Based on both forward modelling and inversion, Kuhmo Greenstone Belt is a surface structure with depth less than 7 km and average density of 2,84 g /cm3.

Kozlovskaya, E. & al. (2004). Geophys. J. Int. 158, 827–848.
Pirttijärvi, M. (2004a). GSF Report Q16.2/2004/1.
Pirttijärvi, M. (2004b). GSF Report Q16.2/2004/2.

Structurally controlled metamorphic variations in east central Sweden

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Metamorphic changes in east central Sweden often coincide spatially with ductile shear zones. Most of these are steep, oblique-slip zones but also thrusts appear to exist.

Across the Hassela Shear Zone (HSZ), dated at 1.82–1.80 Ga, mid-greenschist metasedimentary rocks (Naggen) exist adjacent to garnet-cordierite-melt granulites. Towards the coast, there are stromatic migmatites and diatexites.

In the east, depleted granulites and c. 1.85 Ga charnockites at Hornslandet exist in the hanging- wall of a shallow dipping (older?) shear zone with amphibolite facies migmatites in the footwall. West-verging folds in the granulites, and L-tectonites between similar shear zones, suggest that the granulites were juxtaposed by thrusting.

The 1.81 Ga Hagsta Gneiss Zone (HGZ), along the southern boundary of the c. 1.85 Ga Ljusdal Batholith, is located between 1.88-<1.85 Ga mid-amphibolite facies supracrustal rocks (at Hamrånge) and migmatites to the south. The dextral kinematics of the HGZ, including an extensional component, suggests uplift of the footwall-migmatites.

The HGZ merge with the steep E-W Gävle-Rättvik shear zone (GRZ). In the west, the HGZ separates the mid-amphibolite facies rocks of Bergslagen from migmatites to the north. The steep stretching lineation of the GRZ indicates mainly vertical movements. This is typical for shear zones in northeastern Bergslagen suggesting that the GRZ outline the tectonic boundary (terrane boundary?) of Bergslagen, at least in its western part.

Also the Ornö Banded Series SE of Stockholm coincides with a metamorphic break. Migmatites in the footwall to the NW have been uplifted by oblique sinistral/SE-down shear. Together, the OBS and the GRZ control the change from Mu+Qz Sil+Kf previously interpreted to be an isograd (Stålhös, 1991).

Stålhös, G. (1991). SGU serie Af 161, 166, 169. 172, 1–249.

The relative rates and mechanisms of a dissolution and precipitation at a reaction front

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Chromatographic modeling using the quasi-stationary state approximation of Lichtner (1988) was used to constrain the relative rates at which amphibole and epidote were consumed and calcite, chlorite and quartz were produced by the reaction: 3 amphibole + 2 epidote + 10 CO_2 + 8 H_2O = 10 calcite + 3 chlorite + 21 quartz, which resulted from infiltration of a metabasaltic sill by a CO_2-bearing hydrous fluid at greenschist facies P-T conditions. Calculated Damköhler numbers indicate that dissolution of reactant amphibole and epidote occured approximately four times faster than precipitation of product chlorite, calcite and quartz. We interpret that (1) dissolution of reactants is controlled by the availability of reactant CO_2, which is governed by the fluid flux rate and fluid composition, and (2) precipitation of products is controlled by the competing rates of chemical transport, nucleation and growth. We further note that the dissolution fronts for amphibole and epidote are non-coincident, and that the epidote front lags behind the amphibole front. We conclude that epidote dissolution occurs in a flow regime which is advection-dominated relative to that of amphibole. This is confirmed by its order-of-magnitude larger Peclet number. That amphibole dissolution could occur in advance of epidote dissolution is supported by petrographic data. In partially reacted samples, calcite growth is observed on the rims, within the cores and along cleavage planes of amphibole crystals. This might indicate that the surface area of amphibole which is exposed to the infiltrating fluid exceeds that of epidote. Based on our analysis, we conclude that slow nucleation in a moving fluid can result in precipitation of product minerals ahead of an advancing front. This will not only influence the mineralogy of portions of the Earth's crust, which are exposed to fluid flow, but also its bulk chemistry. The corollary is that chemical redistribution at reaction fronts can provide a minimum estimate of the extent to which the Earth's crust can be regarded as a truly open system.

Lichtner, P.C. (1988). Geochim. Cosmochim. Acta 52, 143–165.

Constraining the rate and extent of mantle serpentinization from seismic and petrological data: implications for chemosynthesis and tectonic processes

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We used seismic velocity as a proxy for serpentinization of the mantle, which occurred beneath thinned but laterally continuous continental crust during continental break up, prior to opening of the Atlantic Ocean. The serpentinized sub-continental mantle is now exhumed, beneath the Iberia Abyssal Plain and was accessed by scientific drilling on Ocean Drilling Program legs 149 and 173. Chromatographic modelling of kinetically limited transport of the serpentinization front yields a front displacement of 2197±89 m, a time-integrated fluid flux of 1098±45 $m^3.m^{-2}$ and a Damköhler number of 6.0±0.2. Whether either surface reaction or chemical transport limit the rate of reaction, we calculate timescales for serpentinization of approximately 10^5–10^6 years. This yields time-average fluid flux rates for H_2O, entering and reacting with the mantle, of 60–600 $mol.m^{-2}.a^{-1}$ and for CH_4, produced as a by-product of oxidation of Fe^{++} to magnetite and exiting the mantle, of 0.55–5.5 $mol.m^{-2}.a^{-1}$. This equates to a CH_4-flux of 0.18–1.8 $Tg.a^{-1}$ for coeval serpentinization of the mantle that was exhumed west of Iberia. This represents 0.03–0.3% of the present-day annual CH_4-flux from all sources and a higher fraction of pre-anthropogenic (lower) CH_4 levels. CH_4 released by serpentinization at or beneath the seafloor could provide substrate for biological chemosynthesis and/or promote gas-hydrate formation. Finally, noting its volumetric extent and rapidity (<10^6 years), we interpret serpentinization to be a reckonable component of tectonic processes, contributing both diapiric and expansional forces and helping to 'lubricate' extensional processes. Given its anisotropic permeability, actively deforming serpentinite might impede melt migration which may be of interest, given the apparent lack of melt in some rifted margins.

Tellus – teaching Earth systems science on the Internet

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Tellus (www.earth.geo.su.se) is a 15 credit 100% web-based course in Earth system science. The course is available in Swedish and will soon be available English. It was developed by Stockholm University and will now form the basis for a parallel course at Edinburgh University. Its essential and *proven* features are:

- An introductory, access-level course at the final school year/first-year undergraduate level.
- Uses the specific capabilities of the internet (e.g. animation, auto-response, drag-and-drop interaction) as a learning tool (not simply lecture notes published on the web)
- Fully-supported by internet lectures which use video streaming for rapid download
- Attracts lifelong learners
- Provides both a sampler to those new to the subject and a credit-earning "alternative quali-fication" as a stepping stone to undergraduate study
- Provides an update in knowledge and understanding for professionals such as teachers (and possibly those in the cultural heritage, conservation and tourist industries)
- Includes a shorter start up module in geology, which provides a "way in" for time-committed teachers or curious students
- Includes an optional follow-on intensive two week conversion course with hands-on practical laboratory and field-based study to attain certification before admission to undergraduate study
- Those proceeding into undergraduate study will have proved their enthusiasm and commitment, and will be self-selecting motivated students

In three years (2002–05) the course in Sweden has undergone "proof of concept", generating impressive start-up statistics for uptake and university recruitment. Following adaption of course material and assessments to match UK educational curricula, the course will be launched in Edinburgh in 2006.

U-Pb zircon SIMS dating of deformation in the Orijärvi area, southern Finland

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The Orijärvi area (OA) has a key role in resolving the tectonic evolution of the Palaeoproterozoic Svecofennian orogen in southern Finland because of the well-preserved primary and the early Svecofennian deformation structures. The OA is divided into the Kisko (KI), the Kuovila (KU) and the Fiskars (FI) subareas. Bimodal metavolcanic rocks with some metasediments surround the centrally located c. 1.90 Ga Orijärvi composite pluton (Väisänen et al., 2002). The KI and the KU consist of non-migmatitic rocks, whereas rocks of the FI indicate upper amphibolite migmatization. The Jyly shear zone (JSZ) and the Kisko shear zone (KSZ) separate the OA from the late-Svecofennian high-grade migmatites and granites.

The main deformation stage, D2, is characterized by upright ~E-W trending F2 folds, which in the lower grade KI and KU areas contain a penetrative axial planar S2 cleavage and a weak bedding-parallel S1. In contrast, within the migmatitic FI area, strong S1 is folded around the isoclinal F2 folds. Therefore, the intensity of the S1 cleavage becomes stronger as the metamorphic grade increases. Regional late-Svecofennian D3 deformation shows minor intensity within the OA, as it dominantly has been partitioned into the KSZ and the JSZ. Kinematic indicators along the JSZ show east side up movements, consistent with the jump in metamorphic grade across the JSZ.

Zircons from two syntectonic intrusive rocks were dated using ion microprobe. In the KU area, a syntectonic granodiorite intrudes into F2 fold hinge and along the axial planar S2 cleavage defining an age of 1877±3 Ma for the D2 deformation. In the FI area, an 1876±3 Ma old syntectonic intermediate dyke, axial planar to F2 folds and containing an S2 cleavage, cuts migmatitic metasediments with strong layer-parallel S1. This indicates that the migmatisation took place at ~ 1876 Ma, pre-dating the dominant late-Svecofennian migmatisation at 1830–1815 Ma in the adjacent granulite area (Mouri et al., 2005).

Mouri, H., Väisänen, M., Huhma, H. & Korsman, K. (2005). GFF 127, 123–128.

Väisänen, M., Mänttäri, I. & Hölttä, P. (2002). Prec. Res. 116, 111–127.

The Archean Belomorian collisional orogen (Baltica): does it have an extension in Greenland?

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The Belomorian mobile belt (BMB) consists of Neoarchean (NAR) TTG-gneisses (ca. 83%) and Meso- and NAR greenstone and paragneiss complexes. They were highly metamorphosed in the NAR and Paleoproterozoic time. No complexes older than 2.9 Ga have been identified in the BMB. It has important complexes-indicators of geodynamic settings, such as ophiolites (Bibikova et al., 1999; Shchipansky et al., 2004), island-arc volcanic rocks, forearc basin sediments, eclogite-bearing mixtites (Volodichev et al., 2004), collisional granites and volcanogenic coarse clastic rocks. Such complexes are characteristic of Phanerozoic orogenic belts.

Four main stages in the Meso- and NAR evolution of BMB (Slabunov, 2005) can be distinguished: (1) an early subduction-accretion stage (2.88–2.83 Ga); (2) a late subduction-accretion stage (2.80–2.75 Ga); (3) a pre-collision stage (2.73–2.71 Ga); and (4) a collision and postcollision (2.71–2.58 Ga) stage. As a result, the NAR Belomorian collisional orogen was formed.

BMB (Baltica) and Nagssugtoqidian MB (Greenland) were part of the Paleoproterozoic (ca. 1.9 Ga) Torngat-Nagssugtoqidian-Lapland-Kola collisional belt (e.g. Bridgwater et al., 1996). However, little is known about the Archean evolution of the belt. At the same time, the evolution of the Tasiusarsuaq Godthabsfjord belt (McGregor et al., 1991) has much in common with that of BMB: 2.92–2.81 Ga – a subduction-accretion stage, Ca. 2.72–2.7 Ga – a collision stage, 2.7–2.49 Ga – a postcollision stage.

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Bibikova et al. (1999). Petrology 6, 540–560.
Bridgwater et al. (1996). 2nd DLC Workshop on Nagssugtoqidian geology, Copenhagen, 8–19.
McGregor et al. (1991). Bull. Geol. Soc. Denmark 39, 179–197.
Shchipansky et al. (2004). Precambrian Ophiolites and Related Rocks. Elsevier, 425–486.
Slabunov A. (2005). Belomorian mobile belt and its analogues: geology, geochronology, geodynamics and metallogeny. Petrozavodsk, 277–282.
Volodichev et al. (2004). Petrology 12, 540–560.

Did hot, high heat-producing granites determine the location of the Oslo Rift?

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The Late Carboniferous–Early Permian Oslo Rift formed in apparently cold, stable lithosphere of the Fennoscandian Shield in a tensional stress regime widely documented in Northwest Europe at that time. The Rift formed obliquely to older, crustal structures that display only limited Permian reactivation, and, although numerical modelling suggests that the present-day lithospheric structure would serve to focus tensional stresses in the Oslo region, the assumption that no lithospheric evolution has occurred since the Palaeozoic is by no means obvious. Here, I show that up to 5 km thick, regional-scale late- to post-Sveconorwegian granites in the vicinity of the Oslo Rift, with heat production rates averaging *c.* 5 $\mu W/m^3$, nearly three times higher than the surrounding Sveconorwegian gneisses, would have increased the temperature in the lower crust and lithospheric mantle by up to 100°C, resulting in significant thermal weakening of the lithosphere in this area. Given a tensional stress regime, weakening by these high heat producing element-granites would have made the Oslo area a favoured site for passive rifting and may have been a first-order parameter locating rifting to this part of the Fennoscandian Shield. The thermo-rheological effects of such granites must be considered along with other factors in future models of initial rift mechanisms in the Oslo Rift, and probably in other rifts elsewhere.

Deep lithosphere structure is a target for electromagnetic arrays. Electromagnetic Mini Array (EMMA) project in Fennoscandia.

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Primary goal of the project is to apply electro-magnetic arrays for studying deep lithospheric conductivity structure in Fennoscandia. The following research is undertaken:
(1) extend traditional 1D horizontal spatial gradient method for 3D environment and apply the new method for estimating static free responses in order to derive background inductive response for the Fennoscandian Shield,
(2) improve existing multi-site magnetotelluric data processing methods and apply these for the data from EMMA arrays and
(3) investigate possibilities to separate induced and remanent magnetization in crustal magnetic field.

The results of the data processing and inversion will be used for deep studies with control over 3D structure, source effects and temporal variation of the estimated responses. Particularly we expect to trace lateral continuity of a conductor detected in some BEAR sites at the depths between 80 and 120 km. The first version of Fennoscandian conductance map (SMAP) will also be updated.

Currently twelve magnetotelluric instruments are simultaneously recording five components of Earth's natural electromagnetic field in the Archaean part of the Fennoscandian Shield. The first array with the site distance of about 30 km was installed in August 2005 and will be running until May 2006. The baseline of magnetic field components is measured at each site to facilitate the separation of induced and remanent magnetization. Multi remote reference long period responses are estimated for the first one to two month recordings and 1D models are obtained for each site.

Magnetotelluric measurements across the Sorgenfrei-Tornquist Zone in Denmark and Southern Sweden

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The Sorgenfrei-Tornquist Zone makes up the transition between the Proterozoic Baltic Shield and the Paleozoic North-Central European province. STZ is an inversion structure were major changes in crustal thickness occur. The area was one of the targets of the European GeoTraverse EGT program. Seismic, gravity and magnetic data showed that STZ is an inversion structure with a major jump in crustal thickness. More recently the seismic tomography project TOR indicated that even the lithosphere thickens abruptly towards the North

In this study we use the MT method to provide additional knowledge of this major discontinuity. Basically we tackle two problems. Firstly to improve the model of the crust in the transition zone and secondly to add constraints to the thickness of the lithosphere from an electromagnetic perspective.

MT measurement started in year 2002 and continued during three years period. All together around 50 MT-AMT sites were measured along the profile crossing the STZ. Dimensionality analysis, involving phase sensitive parameters shows that most of the data have clear 2D characteristics.

The main features of derived model are (i) a vertically dipping conductor is identified at the northern border of the STZ, which is not seen from the other methods; (ii) lithosphere beneath Proterozoic shield is more resistive than lithosphere of Paleozoic central Europe units; (iii) about 12 km thick Proterozoic conductive sediments in Danish basin are very well resolved.

Crustal features are very well correlate with the joint model derived by Thybo. The resolution of the asthenosphere below conducting sediments of the Danish Polish Basin prevents good resolution of the deep structure. Nevertheless synthetic models study shows that the resolution power of the method is enough to confirm one order difference in conductivity between Paleozoic and Proterozoic parts of the profile.

Age and geochemistry of partial melting of high-grade metamorphic rocks in the Estonian basement

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The rocks of the crystalline basement of the East European Craton in southern Estonia show effects of partial melting under granulite facies conditions. Zircons extracted from partial melting products (tonalite from the Tapa Zone – 1824±26, tonalite from the South Estonian Zone – 1788±16 Ma and charnockite from the Tapa Zone – 1761±11 Ma) yield U-Pb crystallisation ages that span over ca. 80 Ma, suggesting a prolonged high grade metamorphism or several separate events. U-Pb zircon age of one sample of charnockite is concordant with the Nd model age of partial melting of its host mafic granulite facies gneiss (intercept at 1.76 Ga). Linear geochemical trends and similar initial Nd isotopic compositions of mafic granulites and charnockites suggest their possible parent-daughter relationship.

From new and published data it follows that the peak granulite metamorphic conditions and formation of tonalites and charnockites (850°C and 6 kbar) in the Estonian basement occurred at 1788–1778 Ma. Both mafic and felsic magmatism was active during the 1775–1760 Ma period. The mafic magmatism may be related to the source of heat for the granulite facies metamorphism through underplating. Then the rocks cooled passing through the garnet closure temperature of 650–700°C at 1728±24 Ma.

The age of metamorphism of the Estonian granulites is lower than the metamorphic ages known from southern Finland, but it is similar to the age of metamorphism reported from the Belarus-Baltic Granulite Belt in Latvia. The lack of the 1770–1790 Ma old magmatic/metamorphic events in northern Estonia may point to a possible terrane boundary between the northern and southern Estonian complexes, which possibly follows the Paldiski-Pskov Shear Zone. However, more age, petrological-geochemical and geophysical data will be needed to further constrain the terrane boundaries in the Estonian part of the East European Craton.

Melt extraction and accumulation from partially molten source: numerical and analogue modelling approaches

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The last decade has witnessed an increasing use of non-linear and chaotic dynamics and fractal approaches in Earth sciences. A large number of geological objects show a power-law or fractal distribution. Fractals can be used in studies of magma mixing and mingling, mantle convection, lava flows and ore mineralization etc. It is shown that the width of migmatitic leucosomes in the Estonian and Southern Finish basement rocks follow power-law distributions and show fractal properties. Despite the differences in size and number of measured leucosomes and veins, differences in host rock types and formation conditions, the studied leucosome/vein data set shows good power-law distributions with exponents, m, usually between 1.0 and 1.9. Knowing the power-law size distribution for the melt batches allows us to estimate the total volume of the melt phase, as well as the relative contributions of the largest batch and of the smallest batches.

Current models for melt segregation and ascent are not adequate to accurately describe transport and accumulation in combination. We propose that transport is discontinuous and in batches. Melt accumulation occurs by stepwise merging of batches. Results of the numerical model indicate that such a system may quickly develop into a self-organised critical state. In this state, the distribution of melt batch volumes can be described by a power law, with an exponent m that lies between 2/3 and 1. Once a self-organised critical state is established, the system is capable of discharging any additional melt without further change to itself. Deformation commonly promotes melt extraction efficiency, as it increases the mobility of hydrofractures, enhances accumulation, and hence lowers the exponent m. The chemical evolution of melt from source to emplacement level will be governed by the discontinuous mixing and mingling of batches, each with different histories, and continues changes in the source.

Development of east Estonian lakes in early Holocene, based on subfossil ostracod data

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Ostracods are a group of micro-arthropods, which subfossils occur calcareous Holocene sediments. Three sequences of lacustrine sediments in the eastern part of Estonia were studied: (1) the Pikkjärve sequence of calcareous mud and peat, (2) Elistvere sequence of gyttja, calcareous mud and peat, and (3) Pedja section of the Holocene calcareous sediments of the former Lake Suur-Võrtsjärv.

Distribution of several ostracod species is environmentally controlled (temperature, depth, trophy): *C. ovum, C. vidua, C. candida, L. inopinata, M. cordata, Scottia* cf. *pseudobrowniana* are considered as characteristic of littoral zone in warm and eutrophic water bodies (Meisch, 2000). Ostracod data from Pikkjärv suggests a regression of the Lake Pikkjärv at the end of the Preboreal climate stadium.

In the Elistvere section the ostracod material is recorded from the deposits of the Atlantic climate period, which was characterized by low water level. The ostracod succession is indicative of progressive eutrophication of the lake. The same process is well reflected in the ostracod succession at Pedja. In the Preboreal, the Lake of Suur-Võrtsjärv comprised a shallow water body with rich vegetation and nutrient supply. During the Boreal stadium the water level rose and the conditions changed to mesotrophic. The appearance of *S.* cf. *pseudobrowniana,* related to eutrophic to semi-terrestrial environments (Meisch, 2000), in the topmost part of the Pedja section is interpreted as indicative of deep eutrophication and terrestrialisation of the studied area.

Meisch, C. (2000). Freshwater Ostracoda of Western and Central Europe. Süßwasserfauna von Mitteleuropa 8/3. Spectrum Akademischer Verlag GmbH, Berlin, 522 p.

A new Archean anorthosite complex in south-west Greenland

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During the first season of the 2005/2006 mapping campaign of GEUS (Geological Survey of Denmark and Greenland) in the Kapisillit area we discovered a new anorthosite complex. The Godthåbsfjord/Nuuk region of south-west Greenland is thought to consist of at least six terranes developed and metamorphosed in the Archean period (Friend and Nutman, 2005). In the region, several other anorthosite bodies/ complexes occur and a comparison of the rare earth element signatures and new geochronological data should reveal if this well-exposed complex is an extension of a known terrane or part of a new terrane. The studied sheet-like anorthosite complex is situated in the SE corner of the area and is larger than 10 km^2. It is dominated by tight kilometer scale folds with a general (gentle to moderate) plunge to the SE. The anorthosite and associated rocks (leucogabbros, meta-/gabbros, minor ultramafic bodies and amphibolites) intruded into a heterogeneous, metasedimentary amphibolite unit. Primary magmatic textures such as cumulates and layering (rarely displaying younging directions) are found in some localities. The anorthosite and amphibolite were later intruded by orthogneisses. Orthopyroxenes occasionally occur in the matrix of metagabbros, amphibolites and orthogneisses but most commonly in partial melt veins where they are generally replaced by amphiboles. This suggests that the area has experienced granulite facies but now is partly retrogressed to amphibolite facies.

The area exhibits extraordinary outcrop qualities that enable future detailed studies of field relationships, chemical signatures and deformation structures of Archean sheet-like anorthosites. Such studies are expected to advance our understanding of the mantle and crustal development of the early earth.

Friend, C.R.L & Nutman, A. (2005). New pieces to the Archean terrane jigsaw puzzle in the Nuuk region, southern West Greenland: steps in transforming a simple insight into a complex regional tectonothermal model. Jour. Geol. Soc. London 162, 147–162.

The role of impermeable seals in convective hydrothermal systems – numerical models and field examples

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Theoretical, experimental and natural studies indicate that hydrothermal fluid flow can be initiated by density and thermally driven buoyancy in porous rocks (Garven et al., 2001) or by tectonically driven fracturing in the crystalline bedrock (Sibson, 2001). Such studies also emphasize the importance of low-permeability layers in localizing and containing convective hydrothermal systems. Here we use the reactive transport code OS3D (Steefel and Yabusaki, 1996) to produce simple convective thermal numerical models to demonstrate the potential effect of a relatively impermeable sedimentary sequences on the formation and containment of hydrothermal systems in underlying oceanic lithosphere. Blanketing sediments appear to be effective in promoting subseafloor hydrothermal convection (and by inference, replacement style mineral deposits). Results draw attention to the potential significance of the stratigraphical transition from volcanic-dominated to epiclastic sediments, which should be amenable to targeting by lithofacies mapping, as well as geophysical and geochemical detection.

Model results can also be applied to other layered systems where marked transient thermal gradients are generated within permeable sequences, such as the intrusion of subvolcanic mafic or felsic sills in sedimentary basins. We illustrate the model concept with several natural ancient examples, at different scales, including the Archean Panorama Zn deposit in the Pilbara craton of Western Australia, and the Skellefte and Tampere districts in the Fennoscandian Shield.

Garven, G. et al. (2001). Geofluids 1, 289–312.

Sibson R. H. (2001). Reviews in Economic Geology 14, 25–50.

Steefel, C. I, & Yabusaki, S. B., (1996). OS3D/GIMRT, software for multicomponent-multidimensional reactive transport, user manual and programmer's guide PNL-111666, Pacific Northwest National Laboratory, Richland, WA.

Further steps towards a synthesis for the late Archean of eastern Finland

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It has proven difficult to formulate a coherent and consistent model for the Archean evolution of eastern Finland. However, the recognition of the 2.78–2.81 Ga Khizovaara and Iringora bimodal associations with boninitic and adakitic affinities in Russian Karelia (Shchipansky et al., 2004), together with documentation of 2.72 Ga eclogite assemblages at Gridino in the Belomorian Mobile Belt (Volodichev et al., 2004), now provides us with a broader framework for interpreting the nature, timing and polarity of late Archean orogeny in eastern Finland.

Volcanism in the Kuhmo greenstone belt was broadly coeval (2.78–2.80 Ga) with Khizovaara and Iringora, though komatiitic compositions rather than boninitic are characteristic. The Ilomantsi greenstone belt is distinctly younger, and volcanic ages (2.75 Ga) overlap with the earliest sanukitoid plutons, which form a distinctive 2.70–2.75 Ga magmatic association throughout the Karelian craton, attributed to fluid-modified melting of mantle above active subduction zones (Halla, 2005; Lobach-Zhuchenko et al., 2005). If this genetic inference is correct, then the wide distribution of sanukitoids implies westwards rollback away from the Belomorian collision zone, or a more complex scenario involving multiple subduction zones; in the latter case, Lieksa complex sanukitoids are most likely related to E-vergent underthrusting of Nurmes paragneisses. E-vergent asymmetry is also recorded by 2.71–2.68 Ga late orogenic, thermal-peak granitic migmatites, from Ilomantsi to Kuhmo.

While evidence from Fennoscandia increasingly favours the operation of modern-style tectonic processes back to at least 2.8 Ga, the nature and extent of late orogenic thermal equilibration and crustal reworking needs to be better constrained for robust comparison of Archean and modern processes.

Halla, J. (2005). Lithos 79, 161–178.

Lobach-Zhuchenko et al. (2005). Lithos 79, 107–128.

Shchipansky, A.A. et al. (2004). Elsevier Developments in Precambrian Geology 13, 425–486.

Volodichev, O. I. et al. (2004). Petrology 12, 540–560.

Structural framework of the Outokumpu ore deposits – geological and numerical modelling constraints

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The Paleoproterozoic Outokumpu Cu-Co-Ni-Zn-Au deposits (of which the main ore body yielded 28.54 Mt or ore grading 3.8% Cu, 0.24% Co, 0.12% Ni, 1.1% Zn, 8.9 ppm Ag and 0.8 ppm Au) lie within an allochthonous nappe sequence that was emplaced onto the Karelian craton margin during the early stages of the Svecofennian Orogeny. The timing of this event is constrained between 1.94–1.92 Ga for detrital zircons in enclosing turbidites, and 1.885 Ga, for granitoids truncating deformed and metamorphosed fabrics. While the highly strained and allochthonous nature of the Outokumpu assemblage, and tectonic remobilization of the ore have long been recognized, the prevailing interpretation has been that the Outokumpu deposits originally formed as massive sulfide accumulations, related in some way to submarine hydrothermal processes. Here we present a revised kinematic interpretation of regional to local structural evolution, illustrated with numerical simulations performed with the finite element code FLAC (Itasca, 1998).

The current position of the main Outokumpu ore zone can be modelled as discordant within a structurally duplexed lense of serpentinite, even if this represents solid-state remobilization, rather than synmetamorphic structurally focussed precipitation of sulfides from hydrothermal fluids. By combining down-plunge projections with the results of the recently acquired FIRE deep crustal and high resolution seismic data, we can trace prominent reflectors from the surface to depths of more than 5 km beneath the Outokumpu district, allowing a more precise large scale structural framework to be defined. Thus the duplex formation can be related to late orogenic contractional deformation, subparallel rather than orthogonal to the Karelian craton margin, accompanying the emplacement of granitoid magmas derived from melting of the underthrust Archean crust at about 1.87–1.85 Ga.

Itasca (1998). FLAC: Fast Lagrangian Analysis of Continua, Version 3.4. Itasca Consulting Group, Inc., Minneapolis.

Variation in weathering rates within a small forested catchment in eastern Finland

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Weathering in soils represents an important flux of alkaline earth and heavy metals and acid neutralizing mechanism in the biogeochemistry of forested catchments. Runoff fluxes of alkaline earth metals can give an integrated measure of weathering rates, but weathering rates can be expected to vary within the catchment due to differences in mineralogy, texture and topographic position for example. Elemental losses from primary minerals in the uppermost layers of soil can be estimated using so-called depletion methods (Starr et al., 1998). The aim of this study was to examine the depth distribution of Zr, CaO and MgO concentrations in 11 soil profiles taken within a small forested catchment and to assess the variation in weathering rates (alkaline earth metal losses) between the profiles.

The study was carried out in the Hietajärvi catchment located in eastern Finland (Bergström et al., 1995). The catchment became free of ice ca. 10,200 years ago. The upland podzolic soils are developed in till or in a thin layer of glaciofluvial material that overlies the till in some places. Cores were taken down to a depth of 3.5 m at 11 points in the upland area of the catchment. Elemental concentrations were determined from the <2 mm fraction of soil material using the XRF.

Zr concentrations were higher and CaO and MgO concentrations lower in the E and Bs horizons compared to the C horizon in all 11 soil profiles, indicating a weathering loss of alkaline earth metals and loss of acid neutralizing capacity in the upper layers of these podzolic soils. The weathering loss from the topmost soil layers was reflected as elevated (Zr/CaO+MgO) values. Variations in weathering rates between the profiles are being compared.

Bergström, I., Mäkelä, K. & Starr, M. (eds.). (1995). Integrated Monitoring Programme in Finland, Minist. of the Environ., Helsinki, Report 1, 1995.

Starr, M., Lindroos, A-J., Tarvainen, T. & Tanskanen, H. (1998). ***Boreal Environ. Res. 3, 275–285.***

Site investigation, Forsmark: Ductile and brittle structures and a conceptual model

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Penetrative ductile deformation under amphibolite facies conditions has affected the meta-igneous rocks at Forsmark, Sweden. This area has been chosen as a possible site for the storage of high-level, radioactive nuclear waste. A significant variation in the style and degree of deformation is apparent at the site. Tubular folding of both a tectonic foliation and high-strain segments with a dextral component of displacement characterise a tectonic lens that is elongate in a WNW direction and, at the surface, is c. 25x4 km in size. The lens is enveloped on both sides by complex high-strain zones. These zones strike WNW or NW and dip steeply to the SW. A tectonic banding that formed under amphibolite facies conditions, low-T mylonites, cataclasites, coherent fault breccias and different generations of fractures filled with epidote, quartz, chlorite and calcite witness the complex deformation along at least one of these zones, under ductile and brittle conditions. Mineral lineations and fold axes at the site plunge moderately to gently to the SE.

By contrast, the tectonic lens is transected by at least two sets of minor fault zones that have been identified as fixed point intersections along cored boreholes. One of these sets strikes NE or ENE, dips steeply and can be correlated with low magnetic lineaments. The fault rocks include cohesive fault breccias, fractures sealed by laumontite, chlorite, calcite and quartz, and prominent hematisation. Locally, adularia, prehnite and epidote are present. The second set dips gently to the SSE or SE and can be correlated with seismic reflectors (Juhlin and Stephens, this meeting). Relative to the steeply dipping set, the fault rocks are characterised by an increased frequency of non-cohesive fault breccias and open fractures, especially at higher (< c. 200 m) crustal levels. Fracture coatings and fillings are dominated by chlorite, calcite and clay minerals. Prehnite and epidote, for example, are again locally present.

A conceptual model for the development of these structures will be presented that allows for their formation during different stages of the Svecokarelian, accretionary orogenic event. Reactivation during several younger tectonic events is inferred. Kinematic data and geochronological data from the fracture minerals need to be assembled to test this model.

Implications of sediment composition changes for onset of glaciation and glacial dynamics in Prydz Bay continental margin, Antarctica

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The Antarctic continent and its margins play a central role in the climatic and geodynamic evolution of the Earth. This presentation will discuss the sediment sequence development on the continental shelf and rise settings off Prydz Bay, Antarctica, with reconstruction of the onset of glaciation and ice sheet evolution in certain time windows, including the Eocene/Oligocene and Miocene/Pliocene periods. During Ocean Drilling Program Leg 188, the sites 1165 and 1166 were drilled on the continental rise and shelf, proximal to the East Antarctic Ice Sheet (EAIS) off Prydz Bay, respectively.

The results of microtextural analysis of quartz grains have been used to verify the transition from East Antarctic preglacial to glacial conditions on the continental shelf, which occurred the Middle-Late Eocene. Thus, the inland ice sheet reached sea level as early as ~37 Ma. This is clearly connected to the global Eocene/Oligocene climate evolution (cf. Zachos et al., 2001), but active tectonism in the East Antarctic interior might also have influenced the initiation of early glaciers. The clay mineral assemblages and variabilities in sediment composition in the East Antarctic continental rise recorded the dynamic behaviour of EAIS in the Middle Miocene and Middle Pliocene. In a climate history perspective, the Neogene period represents a time of progressive cooling of the Earth, although there were also warm periods during that comparable to the present climate.

Records of the onset of glaciation and glacier dynamics concerning East Antarctica, however, are still relatively sparse. New values can be obtained and discussion stimulated by carrying out comparative studies of Circum Antarctic, e.g. the Weddel Sea and Wilkes Land margins.

Zachos, J., Pagani, M., Sloan, L., Thomas, E. Billups, K. (2001). Science 292, 686–693.

Plate spreading and isostatic rebound, result from the nationwide 1993 and 2004 ISNET campaigns in Iceland

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We present here the results of the first repeat survey of the geodetic reference network of Iceland (ISNET), which was installed in 1993. The net was remeasured in 2004 in a cooperative effort of many Icelandic institutions. The network consists of 120 GPS-points evenly distributed across Iceland. It spans the mid-Atlantic plate boundary and extends up to 200 km into the plates on either side. The horizontal displacement field is dominated by the divergent motion of the North America and Eurasia plates across the plate boundary. The observed spreading rates are in the range 20–23 mm/a, 5–15% faster than prevailing plate motion models predict. The two principal plates are separated by a 50–100 km wide deformation zone where strain accumulates and the displacement field is disturbed by tectonic and magmatic events. These include an inflation episode of the Hengill volcanic system in 1994–1998 and an earthquake sequence in 2000 in a transform zone, the South Iceland Seismic Zone, which contained Mw 6.5 earthquakes and several events of Mw-5. Large displacement is observed at Grímsvötn volcano in central Iceland. This volcano erupted in 1998 and the inter-eruptive uplift rate has been observed to be ca. 50 mm/a. The vertical displacement field shows high uplift rates, up to about 25 mm/a, with maximum in central and central-east Iceland, but subsidence is observed in the Reykjanes Peninsula. We suggest that a large part of the vertical deformation signal can be attributed to glacio-isostatic rebound, due to recent reduction of ice mass. Ice-caps in Iceland have retreated significantly since 1895 due to climate warming, resulting in current uplift rates.

Ordovician Escanaba type VMS deposits in the Scandinavian Caledonides

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Numerous deposits of Zn-Cu-bearing massive sulphides occur in metamorphosed Ordovician gabbro-intruded calcareous turbidites in the Köli Nappe Complex of the Scandinavian Caledonides. This ore type was of major economic importance for more than 300 years at Røros (Norway) and is also well known from elsewhere in the orogen, including Ankarvattnet (Sundblad, 1981), Usmeten and Ruonasvagge (Sundblad, 1991), thus constituting a tectonostratigraphic key unit for more than 600 km along the orogen. Violating earlier theories on an ophiolite association for the Sulitjelma sulphide ores, it is suggested that also these ores belong to the same ore type as in Røros and Ankarvattnet. Pyrrhotite, sphalerite and chalcopyrite are the dominating sulphide species while pyrite, galena and arsenopyrite occur in variable amounts. The alteration patterns, as documented at Ankarvattnet, grade from a chlorite quartzite, close to the pyrrhotite-rich assemblages, to a sericite quartzite close to the pyrite-rich assemblages.

The ore lead isotopic composition for this ore type is very homogeneous on orogen-scale and slightly more radiogenic ($^{206}Pb/^{204}Pb \approx 18.15$) than true VMS deposits, interpreted that the main metal derivation was from hydrothermally active underlying ocean floor volcanics with a small contribution from Precambrian crustal sources, derived via detrital grains in the turbidites (Sundblad & Stephens, 1983).

It is suggested that this ore type represents an ancient analogue to the Escanaba type sulphide ores, as documented by Morton et al. (1994) in the present Pacific. This implies that the sedimentary and ore-forming environment for the gabbro-intruded calcareous turbidites in the Scandinavian Caledonides can not have been dramatically distant from a Precambrian continent prior to nappe transport. Furthermore, comparisons between the Escanaba type of sulphide deposits (in the Pacific or in its ancient analogue in the Caledonides) and the obscure "Besshi type deposits" should be avoided.

Morton et al. (1994). USGS Bull. 2022, 359 p.
Sundblad, K. (1981). Mineralium Dep. 16, 129–146.
Sundblad, K. (1991). Geol. Fören. Stockholm Förh. 113, 65–67.
Sundblad, K. & Stephens, M. (1983). Econ. Geol. 78, 1090–1107

Source of lead in Mesozoic baryte-galena-sphalerite mineralization at Svalbard

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Veins of baryte, galena and sphalerite are abundant in the southern part of Bjørnøya in the southernmost part of Svalbard (74° 22' N). Most veins occur in Late Precambrian to Ordovician sandy and calcareous sedimentary successions while occassional veins occur in Late Devonian to Early Carboniferous siliciclastic Red Bed deposits. Baryte veins have also been recorded in Devonian strata on northern Spetsbergen (400 km north of Bjørnøya); at Sigurdfjellet (79° 15' N) with a Cu-Pb-dominated sulphide assemblage as well as at Zeipeldalen (78° 55' N) and Ridderborgen (79° 03' N) without sulphides. All veins were formed in the Mesozoic, or even Tertiary (cf. Segalstad et al., 2006) and are spatially (and genetically?) related to large-scale post-Devonian faults (at Spetsbergen separating the Devonian from Palaeoproterozoic metamorphosed continental crust).

The Pb isotopic compositions of 27 galenas from Bjørnøya and Sigurdfjellet were determined yielding two homogeneous populations with respect to the $^{206}Pb/^{204}Pb$ ratio; on average 18.180 and 18.346, respectively. This indicates that, in spite of a huge hydrothermal system, the fluids must have leached a relatively homogeneous source within a short time. A Precambrian basement is an unlikely lead source since such ancient crust is unknown under Bjørnøya. Furthermore, such a hypothetical source should also have created significantly more radiogenic isotopic signatures if it was activated in the Phanerozoic.

The preferred interpretation is that eroded Caledonian crust, well-mixed and homogenized during its transport to Devonian sedimentary basins, was the lead source in the veins. Since most veins occur *under* the Devonian strata, the hydrothermal fluids must have leached lead while percolating towards lower stratigraphic levels where galena preciptated in fractures together with sphalerite and baryte. The bimodal isotopic pattern is explained by two hydrothermal cells of slightly different sizes that were activated shortly after each other.

Segalstad et al. (2006). This Volume.

Evidence for volcanic-hosted Ag-Pb-Zn-Cd-As-Bi-bearing hydrothermal mineralization in southern Sweden

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The Lenhovda region, southeastern Sweden, is dominated by well-preserved 1.8 Ga felsic volcanic rocks and presumed comagmatic granitoids belonging to the Transscandinavian Igneous Belt. Andersson & Nilsson (1992) noted in a regional survey of till geochemistry that significant anomalies of Pb, Zn and As occur east of Lenhovda. This anomaly has been interpreted in different ways. A common opinion is that it is related to adjacent glass factories (e.g. www.sgu.se, Jan. 2005). In an investigation of the only known sulphide mineralization in the region (Ålatorp), Sundblad (1997) suggested, however, that the anomaly was related to natural concentrations of metals in the bedrock. Glacial transport directions precluded Ålatorp to be responsible for the entire anomaly and Sundblad (1997) thus concluded that several (if not many) volcanic-hosted Pb-Zn-Cu-(As-W)-bearing sulphide occurrences exist in the area.

As part of an inter-nordic course in exploration for mineral resources, organized in Lenhovda by the universities in Turku during 2002 and 2003, c. 600 till samples and c. 30 mineralized boulders were collected and processed for geochemistry. In this way, widespread Pb-Zn-Cd-Bi-As-Ag-bearing sulphide mineralization in hydrothermally altered volcanic rocks was confirmed. Although only few mineralized outcrops were identified, six targets (Ålatorp, Östraby, Västra Mark, Svartkärrsbäcken, Helvetets trappor and Sjöasjö) have so far been recognized. These targets provide strong evidence for the presence of a previously unknown mineralization type and were considered enough promising for continued mineral exploration. Since most of the area is protected by EU:s Natura 2000 programme, all further actions for mineral exploration were, however, stopped in 2004. In spite of this, further academic studies of this unique ore type is recommended, not the least in order to balance uncritical evaluations with respect to natural and human-induced till anomalies.

Andersson, M. & Nilsson (1992). Sveriges Geologiska Undersökning Rapporter och Meddelanden 73, 60 p.
Sundblad, K. (1997). GFF 119, 103–108.

Geology and metallogeny of "mantled domes" in Karelia

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The geology and metallogeny of "mantled domes", along the Archaean/Proterozoic border in Karelia, has been studied together with the Institute of Geology (Petrozavodsk), SC Mineral (St. Petersburg), Geol. Survey of Finland and St. Petersburg University.

From this study, we conclude that the main crustal components include an Archaean (Karelian) craton with a Proterozoic autochthonous cover and an allochthonous complex of Proterozoic supracrustal units belonging to the Savo and Höytiäinen Provinces, as well as lens-shaped and root-less slabs of Archaean crust (Lehtilä & Sundblad, 2006; Torvinen & Sundblad, 2006). All units were intruded by 1.89 Ga granitoids, prior to Svecokarelian accretion to the Karelian craton, and by various magmatic events at 1.88, 1.80 and 1.55 Ga.

Five types of mineral deposits can be recognized: 1. Cu-bearing massive sulphides of uncertain age and origin at Hammaslahti and Vissu in (or near) graphitic schists within the Suhmura thrust zone, 2. Au-bearing quartz veins in Proterozoic rocks at Alattu and Raikonkoski. 3. W-Cu-bearing skarn and Mo-bearing pegmatites related to 1.8 Ga granites. 4. alluvial diamonds, most probably derived from 1.8 Ga shoshonitic rocks at Elisenvaara and 5. Sn-Pb-Cu-Zn-bearing skarn at Pitkäranta, related to 1.55 Ga rapakivi granites. Types 1, 2 and 4 are considered to have the highest potential for further exploration activities.

The recognition of the allochthonous nature of the Archaean crust in the "domes" implies that the concealed southwestern limit of the Karelian craton may run much closer to its exposed limit than often assumed (e.g. along the Meijeri thrust). The old crustal isotopic signature in stitching plutons/dykes (Nd data; Konopelko et al., 2005) and associated ores (Pb data; this project) is thus interpreted to be due to influence from allochthonous slabs of Archaean crust, not the craton as such. The geological scenario in Karelia can be compared with central/northern Finland, implying a major terrane boundary, extending from northern Ladoga, via the Kainuu Schist Belt into Lapland.

Konopelko et al. (2005). GFF 127, 115–122.
Lehtilä, T. & Sundblad, K. (2006). This Volume.
Torvinen , A. & Sundblad, K. (2006). This Volume.

Glacial morphology and paleohydrography suggest three Weichselian ice advances in northern Finland

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Ground penetrating radar data, airborne radiometric measurements, and digital elevation model (DEM) are presented as an evidence for three Weichselian (equivalent to Wisconsinan) glacials in northern Finland. Due to low electrical conductivity, low dielectric permittivity and high gamma-ray flux from the glaciofluvial materials reliable landform idenfication and determination of meltwater paleoflow directions in eskers and end moraines is possible. DEM was applied to reconstruct paleoflow patterns of the Fennoscandian Ice Sheet (FIS) in northern Finland.

The Pudasjärvi End Moraine, roughly 150 km south of the Arctic Circle marks the termination of the early Weichselian stage. No morphological or stratigraphic evidence has been found beyond this end moraine. The Ranua Drumlin Field displays one of the most striking evidence for the Early Weichselian ice flow pattern fanning out to the Pudasjärvi End Moraine. Subfossil Eemian sediments buried beneath late Weishselian till have been found at the Puhosjärvi site, just outside the Pudasjärvi End Moraine. At the Saarenkylä site, located on the Arctic Circle, the Eemian sediments were found beneath two Weichselian till units.

The second Weicselian ice advance, tentatively Mid-Weichselian, is demarcated by the end moraine system, located roughly 150 km north of the Arctic Circle. The morphology and paleoflow pattern of the Porttipahta End Moraine, as a part of the Mid-Weichselian advance, suggest ice flow from north. During the Late Weichselian Finland was entirely covered by FIS, hence the older deposits were partially eroded and/or covered by till.

Saarijärvi – a new Cambrian paleontological site at Kilpisjärvi, Finnish Lapland

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The Ediacaran-Lower Cambrian Dividalen Group, occupying an autochthonous position, crops out in narrow SW-NE trending zone, usually < 200 m thick, along the Caledonian front in northern Sweden, Norway and Finland. A detailed description of the geology of the Kilpisjärvi area is given by Lehtovaara (1995 and others). Paleontological finds are not very common in Finnish Lapland.

During field-work in 2003 along the Halti-Kilpisjärvi hiking route, as part of the LAPBIAT project, abundant trace fossils were found in bedrock fragments in the Duolljehuipojohka stream bed, as well as in situ on the walls of the stream valley.

The oucrop is located 500 m from Finnish-Norway border on the SW slope of Mt. Duolljehuipput. This area is outside the map lists of Lehtovaara (1995). Since the new paleontological site is located 3,5 km from cottages on the Lake Saarijärvi to the NNE, we named it the Saarijärvi site.

A typical section of Dividalen Group consists of a thin basal conglomeratic unit, followed by alternating sandstone and siltstone. In outcrop brownish siltstones prevail (60 %), while andstone intercalations are 1–5 cm thick, sometimes up to 20–80 cm, and often with ripple marks on the upper surface. Cross-bedding in sandstones and desiccation cracks on the top surface of muddy layers were found in other outcrops.

Most of the trace fossils consist of the vertically orientated spiral *Gyrolithes polonicus,* and large trace fossils with a three-lobed lower surface occur in the upper 2–3 cm thick zone immediately below the sandstone horizons. The trace fossils at Saarijärvi are forms widely encountered in pre-trilobite Lower Cambrian strata of Baltica.

Field work was done with financial support of the LAPBIAT grant HPRI-CT-2001-00132.

Lehtovaara, J.J. (1995). Kilpisjärven ja Haltin kartta-alueiden kallioperä. Geol. Survey of Finland, Espoo, 1–64.

Volcanic ash intercalations in the Kilpisjärvi Caledonian nappes, Finland

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In the Kilpisjärvi area, Caledonian nappes have been thrust onto the autochthonous foreland, which consists of the deeply eroded Archean basement and a thin Neoproterozoic-Cambrian sedimentary cover. The Jerta Nappe was only transported for a relatively short distance and is characterized by clayey slate, bluish quartzite and micritic dolomite. The Nalganas Nappe was transported much further, and represents the lowest thrust sheet of the Middle Allochton, consisting of quartzite with narrow biotite- and chlorite-rich intercalations. The lower parts of the overlying Nabar Nappe include amphibolites, which locally preserve amygdales, commonly with Cu-minerals, indicating a volcanic flow origin. The uppermost part of this nappe is represented by garnet-bearing mica gneiss. The uppermost unit in the Finnish Caledonides is the Vaddas Nappe, which is composed of mafic-ultramafic magmatic rocks (Lehtovaara, 1995). All these nappes belong to the Middle Allochthon (Gee & Sturt, 1985).

Volcanic ash was found in weakly metamorphosed quartzites of the Nalganas Nappe, sometimes with up to 5–6 intercalations of thickness 1–10 cm in the 2,5 m of sequence. When volcanic ash forms thicker (20–25 cm) horizons, distances between them also correspondingly increase. All ash layers can be distinguished from quartzite by their dark colour, mineralogy and chemical composition.

Analyses (n=21) fall into two main groups, with SiO_2 contents 43–50 wt.% and 56–68 wt.%, and Na_2O+K_2O contents 1.5–5.3 wt.% and 4.6–8.0 wt.% respectively. Members of both groups can be found in all analyzed series, although one of them usually dominates.

Field work was done with financial support of the LAPBIAT grant HPRI-CT-2001-00132 and ongoing research is supported by Estonian Science Foundation grant No 5921.

Lehtovaara, J.J. (1995). Geol. Survey of Finland, Espoo, 1–64.

Gee, D.G. & Sturt, B.A. (1985). Scandinavian Caledonides tectonostratigraphic map. Sveriges Geol. Undersökning ser. Ba No 35.

Unique aspects of the geological heritage of the Republic of Karelia, NW Russia

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The Republic of Karelia is located on the Archean part of the Fennoscandian Shield (Systra, 1999). Several geological sites have a unique value for understanding the evolution of the oldest crust. The eastern part of the shield comprises 3 major NW-SE trending crustal provinces, which record a geological history of Karelia.

The Karelian Craton forms the oldest (3.5–2.7 Ga) and most stable nucleus of the shield. It consists of Late Archean (3.0–2.8 Ga) greenstone belts and granitic gneiss terrains with Early Archean relicts, overlain unconformably in synclinal folds by Early Proterozoic (2.5–1.9 Ga) greenstone facies volcano-sedimentary sequence with numerous examples of stromatolites. Near the village Hirvas, 90 km N of Petrozavodsk, three volcanic centres of a different age (3.0, 2.4 and 2.1 Ga) occur within a ring 3 km in diameter. This small area records three unconformities: one between Archean and Proterozoic, two between regional Early Proterozoic stratigraphic units. The Early Proterozoic Kukasozero and Paanajärvi synclines relate to the formation of shear zones, duplexes and continental rift along province boundaries.

The Karelian Craton is flanked to the NE by the Belomorian Fold Belt, which represents a Late Archean collision zone, composed of strongly (high pressure granulites and eclogites) and multiply metamorphosed migmatic gneisses (3.0 Ga) and amphibolites, partly of ultramafic composition. Sites near the villages Pongoma and Gridino show exhumated multiple folded and reworked in the deep level up to eclogites continental crust.

The Early Proterozoic Svecofennian Fold Province flanks the craton to the SW and represents the progressively metamorphosed margin of the collision zone with granitic gneiss domes, low pressure granulites, multiple folded volcano-sedimentary rocks, cut by mafic, acid and alkaline intrusions and dykes.

Systra, Y.J. Mem. Descr. Carta Geol.d'It. LIV (1999), 361–366.

The tectonic division and structural evolution of the eastern Fennoscandian Shield

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The eastern part of the Fennoscandian Shield (Karelian Region) comprises three major NW-SE trending geostructures: the Karelian Craton (KC) in the centre is flanked to NE by the Belomorian Fold Belt (BFB) and to SW by the Svecofennian Domain (SD). Each of them has different structural evolution.

The Archean basement of the KC was formed 3.5-2.65 Ga and its Early Proterozoic volcano-sedimentary cover, preserved in relict synclinal cores, 2.5–1.75 Ga ago. Four regional fold generations occur in cover rocks: the oldest with axial planes (AP) striking 10-20° NE were likely formed during 1.95 Ga rifting, when the Jormua ocean on the western margin of craton opened. Three other generations with AP 310–330° NW, 10–50° NE and 275–295° NW belong to the Svecofennian orogeny (1.9–1.8 Ga). In the SW part of KC, where the litosphere has maximum thickness (Lehtonen et al., 2004), no Svecofennian fold was found. The Archean basement has common folds with near N-S axial planes, and NW striking folds. Near the contact with BFB, E-W folds are also developed. The SW and NE margins of KC are complicated by 1.8 Ga thrusting, the NW margin by shear duplex and drag folds.

The strongly folded and highly metamorphosed 3.0–2.8 Ga BFB represents the oldest orogenic belt of the Fennoscandian Shield, and is composed by migmatized gneisses and amphibolites. A system 1.9–1.8 Ga conical folds with AP 10–50° NE is superposed on E-W Archean folds with curved axial planes.

The SD has a complex folded structure: 5 systems of linear and conical folds with AP 290–305°, 315–340°, near N-S, NE and near E-W are found here (Koistinen, 1981), some of which can be correlated with folds in KC. In addition, domal structures occur.

Magmatism in the KC and BFB is similar in age and composition, while in the SD is significantly another.

Koistinen, T.J. (1981). T. R. Soc. Edin. Earth Sci. 72 115–158.

Lehtonen, M.L. et al. (2004). Lithos 77, 593–608.

Pukala intrusion, its age and connection to the hydrothermally altered domains in Orivesi, southwestern Finland

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The acid subvolcanic Pukala intrusion, its age and connection to hydrothermal alteration have been investigated by studying the petrology, chemical composition, and isotopic age of the granitoid. The intrusion mainly comprising porphyritic granodiorite and trondhjemite is located in the center of the Paleoproterozoic Svecofennian domain between the Central Finland Granitoid Complex and the Tampere Belt. The halo of the hydrothermally altered rocks around the late Kutemajärvi gold mine is in contact with the Pukala intrusion.

Geochemically, the Pukala intrusion is a peraluminous volcanic-arc granitoid and it was emplaced into volcanic sequence in an island-arc or fore-arc setting before or during the earliest stages of the Svecofennian orogeny.

The zircon U-Pb and titanite U-Pb ages for the Pukala intrusion are 1896±3 Ma and 1851±5 Ma, respectively. After the crystallization at 1896±3 Ma, the intrusion was subjected to metamorphism and deformation, which tilted the intrusion steeply towards south.

The Pukala intrusion is surrounded by hydrothermally altered areas located in the metavolcanic rocks of the Tampere Belt. The alteration is divided into three basic types: partial silica alteration, chlorite-sericite±silica alteration, and sericite alteration in shear zones. The first two types are linked to the emplacement and crystallization of the Pukala intrusion, the third is linked to late shearing. The alteration trends, geometry of geology, and the presence of the comb-quartz layers in the contact zone of the Pukala intrusion and the hydrothermally altered area at Kutemajärvi suggest that the hydrothermal system was driven by the Pukala intrusion.

Hydrothermal alteration along the Ataneq fault in the Nuuk region, Westgreenland

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The Archaean rocks in the vicinity of the Ataneq fault in the Nuuk region, Greenland, show strong hydrothermal alteration. This means, the possibility for extensive mineralization exists. Here, the potential of gold-bearing occurrences has greatest attention. All the more, since the Nuuk region appears lithologically and structurally similar to the area of the gold-bearing deposits of Timmins in Canada and to the Archaean greenstone belts in Australia.

Lithologically, the Ataneq region is mainly characterized by felsic rocks of tonalitic composition. Minor parts consist of ultramafic and mafic rocks. Four main rock types can be distinguisehd within the tonalitic sequence resulting from hydrothermal activity: 1) slightly altered tonalite, 2) altered tonalite with epidote and chlorite, 3) silicified tonalite, 4) hydrothermally formed quartzite. In these rocks, disseminated copper- and iron sulfides are observed, mainly pyrite (up to 2 cm large crystals). Trace element analyses yield some copper but do not suggest the hydrothermal system to be gold-bearing.

Despite the apparent lack of gold, the Ataneq area is still of interest because it contains other hydrothermal alteration products: Fieldwork in the area (Summer 2005), carried out by GEUS, has led to the discovery of a major soapstone deposit related to a high strain/shear zone located between the Ataneq fault and the Ivinnguit shear/fault zone. The hydrothermally altered zone varies in thickness from 5–40 meter wide and is more than one km long. The hydrothermally altered ultramafic rocks are sandwiched between tonalitic rocks and high strain gneisses. The alteration products are talc (soapstone), serpentine, epidote and chlorite. The soapstone occurs both in form of 2–5 m wide, massive bodies and as 'pillows' of partially altered ultramafics, where the core is unaltered, and the altered rim consists of talc, serpentine, and biotite.

In conclusion, the Ataneq fault zone is a prominent alteration zone; it is strongly silicified, but low in metals except unevenly distributed Cu. Parallel to the Ataneq fault, large amounts of soapstones are formed due to hydrothermal alteration of ultramafic rocks.

Light mantle carbon: Evidence from carbonatites in Finland

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The isotope ratios of carbon in most Fennoscandian carbonatites fall in the range of typical mantle carbon, with $\delta^{13}C$ varying from -3 to -7 per mil (PDB). Two ca 1.8 Ga carbonatite occurrences in eastern Finland, however, show a strong depletion in ^{13}C relative to the average mantle value. Carbonate samples from a carbonatite dike at Halpanen show $\delta^{13}C$ values ranging from -12.2 to -12.4 per mil (n=7) and those from a carbonatite dike swarm at Panjavaara display an even stronger depletion in ^{13}C, with values varying from -15.9 to -16.4 per mil (n=16).

The carbonatite dike at Halpanen is 7 m wide and up to 1.5 km long, crosscutting the surrounding 1.9 Ga Svecofennian gneisses. In addition to calcite, the dike contains scattered apatite phenocrysts and accessory barite, magnetite and monazite. The chemical composition of the dike is characterized by high contents of SrO, BaO, REE (up to 3.63, 0.63 and 0.65 %, respectively) and Y (up to 130 ppm).

The Panjavaara carbonatite dike swarm is located in the Archean Karelian Province, some 180 kilometers NE of Halpanen. In total, 50 carbonatite dikes and veins have been observed in an area of 100 square kilometers. The dikes are 2–60 cm wide and from meters to tens of meters in length. In addition to calcite, the dikes contain apatite, barite, and several Sr- and REE-minerals such as bastnäsite, carbocernaite, monazite, strontianite, and ancylite. The dikes are bordered by a 1 to 10 cm wide zone of fenitic alteration in the host rock, with bluish alkaline amphibole, aegirine, phlogopite, microcline, and calcite. Similarly to Halpanen, the carbonatites of the Panjavaara dike swarm are highly enriched in SrO, BaO and REE, with concentrations reaching 2.3, 3.9 and 10.0 %, respectively.

Sr and Nd isotope data from both Halpanen and Panjavaara suggest an enriched source for Sr and a nearly chondritic source for Nd. The mineralogical, chemical and textural characteristics of the Halpanen and Panjavaara carbonatite dikes suggest a mantle origin for these rocks. The depletion in ^{13}C relative to the average mantle value could be related to subduction of organic-rich crustal material.

Styles and timing of deformation within the South Finland shear zone, SW Finland

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A major ductile shear zone, "the South Finland shear zone" (SFSZ) extends for almost 200 km through the Åland archipelago and along the southern and southwestern coast of Finland. The > 1 km wide zone appears to have been repeatedly reactivated, starting with a period of regional, ductile dextral shearing that produced banded granodioritic and tonalitic gneisses. The ductile phases are locally followed by semi-ductile deformation that produced mylonite zones of variable width. The latest stage of activity along the shear zone is recorded by brittle pseudotachylites.

Within this study, we dated zircons (ion microprobe U-Pb) and sphenes (ID-TIMS U-Pb) from eight rock samples in order to outline the time span over which the crustal-scale SFSZ was active. An additional goal was to try to distinguish the ages of the different deformation phases (ductile gneisses – semi-ductile mylonites – brittle pseudotachylytes) that have been observed in the field.

The obtained U-Pb age results suggest that the ductile deformation along the shear zone initiated at 1.85 Ga, while a more extensive, regional deformation phase existed from 1.83 Ga to 1.79 Ga. The ca. 1.79 Ga metamorphic sphene ages from a wide mylonite zone and from a semi-discordant diabase dyke that continued to deform ductilely until at least that time, set the maximum age for the mylonitic deformation, assuming that the semi-brittle phase was temporally subsequent to the ductile deformation. The maximum age of the pseudotachylites is likewise 1.79 Ga, determined by the magmatic ages of the pegmatite dykes cut by the pseudotachylites.

The Tohmajärvi igneous and tectonic complex, eastern Finland

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The Palaeoproterozoic metamorphosed igneous and sedimentary rocks in the Tohmajärvi area, eastern Finland, are known from the work by e.g. Nykänen (1971). Reinvestigation of the area demonstrates that these lithological units constitute a lens-shaped structure within the Höytiäinen Province with complex internal igneous, stratigraphic and structural relationships. The Tohmajärvi complex is bordered towards the east by staurolite-andalusite-garnet-bearing mica schists of the Pälkjärvi unit (also within the Höytiäinen Province). In the west, it is separated from the Savo Province by the Suhmura Thrust Zone.

The igneous rocks of the Tohmajärvi complex display a L-shaped pattern and comprise mafic tholeiitic volcanic and intrusive units. Volcanic rocks include lavas (partly with well-preserved pillows), volcanic breccias and plagioclase porphyries. The intrusive rocks consist of gabbros (also referred to as "metadiabases" in previous literature) and were dated at Oravaara by Huhma (1986) at 2.1 Ga. The main parts of the sedimentary units occur to the southwest of the igneous rocks (the Akkala orthoquartzite, displaying another L-shaped structure) and to the east (mica schists as well as quartzite, arkose, dolomitic marble and highly magnetic graphitic schists with 1–5 % C_{tot}). Slices of graphitic schist, staurolite-bearing mica schist, conglomerate, quartize, and arkose are also found as lenses inside the igneous-dominated structure, indicating an imbrication structure. Such a tectonic pattern is supported by well-developed schistosity planes along the margins of individual igneous units, often associated with irregular-shaped white alteration rocks. Furthermore, cm-sized porphyroblasts of anthophyliite, cummingtonite (and locally biotite) are noted in banded rocks along the contact between the Oravaara gabbro and structurally underlying staurolite-bearing mica schists.

Although the Tohmajärvi complex constitutes an allochthonous tectonic complex, each rock unit has an apparant affinity to units further to the east, either in the Höytiäinen Province or in the authochtonous successions along the Archaean/Proterozoic border, suggesting moderate transport distances for this tectonic complex.

Nykänen, J. (1971). Bull. Geol. Soc. Finland 43, 93–108.
Huhma, H. (1986). Geol. Surv. Finland, Bull. 337, 48 p.

Age and isotopic (Nd and Sr) characteristics of the ultramafic alkaline rocks of the north-western region of the Ukrainian shield

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The North-Western region of the Ukrainian Shield hosts the small hypabyssal Glumcha (600×180 m) and Gorodnitsa (200×250 m) intrusions, and the Pokosha dyke (0.2–1.5 m wide and 1.5–1.7 km long) swarm of the ultramafic alkaline composition. These cut and cause fenitization of Paleoproterozoic granites. Intrusions are composed of olivine jacupirangite, melteigite and ijolite. Dykes of the Pokosha swarm consist mainly of amphibolitized olivine melanephelenite. Forsterite, diopside, Cr-diopside and aegerine-diopside, Na-Ti hastingsite and edenite are major minerals. Accessories are represented by Cr-spinel (including chromite with 62.0 % of Cr_2O_3 and 14.6 % of MgO), ilmenite enriched with MnO up to 16 %, garnets (andradite and melanite), perovskite, rutile, zircon, apatite, titanite, etc.

These rocks have been dated with the NORDSIM facility in Stockholm and produced the following $^{207}Pb/^{206}Pb$ zircon ages (Ma): the Pokosha dykes – 2051±12, the Gorodnitsa- and Glumcha intrusions – 2111±12 and 2151±15, correspondingly. εNd_{2100} for the Glumcha intrusion is of +1.6 and for the Gorodnitsa intrusion of +3.5 that indicates depleted mantle source for the initial melts. Measured $^{87}Sr/^{86}Sr$ values are 0.706367 and 0,708515, respectively, whereas $^{87}Sr/^{86}Sr_{2100}$ values are 0.702054 and 0.696875. The latter low value was caused probably by alteration of the primary Sr isotopic characteristics during superimposed (fluid?) processes. Similarities of isotopic and geochemical characteristics of the studied rocks (i.e. Mg, Cr, Ni, and Co-enrichment, low abundance of K, Ti, P, Nb, Ta, Zr, Hf, REE etc.) bear evidence of origin from a common magmatic source that developed due to partial melting of depleted upper-mantle peridotites virtually without involvement of incompatible components.

This is a contribution to the Swedish Institute' research network "Precambrian Evolution of Western Baltica" and the project of the Swedish Royal Academy of Sciences "Isotopic composition of mantle heterogeneity in the Ukrainian Shield".

Planar deformation features in quartz phenocrysts from Palaeoproterozoic felsic tuffs at Pechenga, Kola Peninsula, Russia

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The uppermost volcanic rocks of the Pechenga Group are assigned to the ca. 1.97 Ga Pilgujärvi Volcanic Formation, which reaches a thickness of ca. 3.0 km. The formation is mainly composed of massive and pillowed tholeiitic lavas and subordinate ferropicrites. At a level of ca. 0.5 km from the base of the volcanic unit, there exists an extraordinary felsic tuff layer having a thickness of less than 50 m. Due to their contrasting appearance and a strike length of ca. 20 km, these tuffs serve as an excellent marker horizon within the voluminous mafic volcanic pile. Previous work has revealed that the felsic rocks ranging from dacites to rhyolites have an age of ca. 1.97 Ga and initial ε_{Nd} close to zero excluding a direct derivation from the Archean basement. The genesis of the rocks has been controversial with the proposed models including fractional crystallization (Hanski, 1992), silicate liquid immiscibility (Skuf'in, 1993), or a meteorite impact (Jones et al., 2003).

In support of the last-mentioned view, we present evidence for the presence of planar deformation features (PDFs) in quartz phenocrysts of the felsic tuff unit, which has not undergone any notable tectonic deformation. The crystallographic orientation of the planar structures were measured from two thin sections using a *universal stage* microscope. The most common and extensive sets occur at ~23 and ~32 pole angles to the quartz c-axis corresponding to the (10$\bar{1}$3) + (01$\bar{1}$3) and (10$\bar{1}$2) + (01$\bar{1}$2) crystallographic forms. Minor sets occur at ~48 , ~66 , ~77 and ~88 pole angles to the c-axis. The sets and their distribution are similar to those found in quartz suffered from high pressure (>16 GPa) shock deformation, such as related to the most extensive meteorite impact events during the Earth's history. Similar lamellae distributions have so far not been reported to be results of normal rock deformation.

Hanski, E. (1992). Geological Survey of Finland, Bulletin 367.

Jones, A.P. et al. (2003). Trans. Inst. Min. Metall. B, 112, B149–150.

Sku'fin, P.K. (1993). Geol. Rud. Mestorozh. 35, 271–283.

Origin and evolution of igneous rocks in high-grade terrains: constraints from the Lapland Granulite Belt

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The Lapland granulite belt (LGB) consists of migmatitic metasedimentary granulites and, noritic to enderbitic igneous rocks. Crystallization age of 1920–1910 Ma is obtained by SIMS U-Pb method from zoned zircons of the large enderbite intrusions. Slightly younger (≤1900 Ma) rims found in many of the zircons in these intrusions may be linked to the post-peak metamorphic cooling of the LGB. A few, inherited, mostly Neoarchaean cores are found in zircon grains, indicating some interaction of the magmas with the Archaean crust before intrusion to the metasedimentary sequence.

The smaller biotite-garnet granodiorite body has a zircon populations ranging from cooling stage rims (<1900 Ma) to inherited Palaeoproterozoic and Archaean grains. The inherited population is similar to the detrital grain population in surrounding metasediments and the magma was probably partly derived by migmatization and melting of the metasediments and partly from enderbitic magmas. A narrow quartz-norite vein has similar population which indicates that narrow synmetamorphic veins may be easily contaminated by the metasediments.

The Sm-Nd model ages (T_{DM}) of the igneous rocks vary from 2.1–2.2 Ga, which is in accordance with a small amount of contamination by the Archaean crust in the case of large intrusion and, moderate influence by Palaeoproterozoic metase-diments in the case of the granodiorite.

The igneous rocks of the LGB are geochemically similar to arc magmas and slab derived adakites. It is possible, that the subducted slab was partly composed of Archaean crustal material, which could explain the inherited zircon grains. The granodiorite is slightly enriched in LIL elements and depleted in Ti and P relative to other igneous rocks which could be explained by the influence of metasediments.

The zircon age data in the LGB show that zircon ages may be good indicators of melting, contamination, crystallization and post-peak cooling history of the igneous rocks in high-grade terrains.

Morphological and topographical characteristics of Epona Corona, a multiple corona on Venus

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Coronae are large volcano-tectonic structures with concentric and/or radial structures and associated volcanic features (e.g. Head et al., 1992). Coronae are proposed to form as a result of buoyant mantle diapirs deforming overlying lithosphere (e.g. Stofan et al., 1992; Squyres et al., 1992; Koch & Manga, 1996). We include 67 coronae into the multiple corona population from a survey of Magellan radar data.

Epona Corona (28°S, 208.5°E; D~225x500 km) is a two-part corona with topographic rims surrounding interior lows and central domal highs. Geologic mapping of Epona reveals evolutionary sequence where both parts of Epona started forming at about the same time or western part more likely earlier. After initial radial fissure and fracture formation (caused probably by uplift and dike propagation) followed emplacement of interior plains by volcanic eruptions, and formation of the topographic rim and associated tensional fracturing. Later stages involved fracturing and graben formation associated with trough formation in the S part of western Epona as well as continued volcanism in the interiors.

The sequence of events in general agrees with the diapir model of corona formation. Whether the interior dome and trough/rim formation require delamination (Smrekar & Stofan, 1997) is not certain in this case. Dome topography may be produced by accumulation of volcanic materials and edifice building rather than as a consequence of delamination. The two parts of Epona Corona appear to be produced by two close diapirs, which may have started deforming the crust at about the same time or the eastern one slightly later. It appears that the western part of Epona has either relaxed further or did not produce as pronounced topography as the eastern one.

Head, J.W. et al. (1992). J. Geophys. Res. 97, 13153–13197.
Stofan, E.R. et al. (1992). ibid., 13347–13378.
Squyres, S.W. et al. (1992). ibid., 13611–13644.
Koch, D.M. & Manga, M. (1996). Geophys. Res. Lett., 23, 225–228.
Smrekar, S.E. & Stofan, E.R. (1997). Science, 277, 1289–1294.

A review of the native Au and PGM nuggets in the Ivalojoki and Lemmenjoki tributaries, Finnish Lapland

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Placer gold was first discovered in Finnish Lapland in Ivalojoki 1870 and later in Lemmenjoki 1945. The total amount 0f gold since 1870 panned is ca. 1000 kg. The nuggets occur in glaciofluvial river gravels, sands and terraces, till and weathered bedrock. In 2004, 29.75 kg gold was produced from the placers of the Finnish Lapland.

The form of Au nuggets is angular, rounded or flat. The Au content ranges 85–98 wt.%, Ag 2–15 wt.% and Cu in average 0.2 wt.%, some Pt, Pd and Hg is also contained. The rims are depleted in Ag. Au-Ag alloy nuggets occur in Lemmenjoki tributary. The inclusions consist of native Bi, Bi tellurides, Fe-Ni-Co arsenides and sulfarsenides, Fe-Cu-Mo-Pb sulfides, Cr-Fe-Ti oxides and hydroxides, mafic silicates, quartz, siderite, chlorite, and kaolinite. Some nuggets are covered with limonite or Mn oxide crust containing microscopic gold inclusions.

The platinum-group minerals (PGM) occurring with heavy minerals (Törnroos & Vuorelainen 1987; Kojonen et al., 2005) are sperrylite, native Pt, Pt-oxide, isoferroplatinum, Pt-Fe alloy, moncheite, platarsite, rustenburgite, Pt-Pd alloy, guanglinite, arseno- and stibiopalladinite, braggite-cooperite, hongshiite, Pt-Cu-Fe, Pt-Cu-Au, kotulskite, keithconnite, stillwaterite, isomertieite, mertieite I and II, vincentite, Os-Ir-Ru-Rh alloys, hollinworthite, xingzhongite, laurite, osarsite, irarsite, ruarsite, erlichmanite, cuproiridsite and cuprorhodsite. Undefined new mineral phases are $Pd_{11}Sb_3As$, $Pd_{11}Te_2As_2$, Pd_3As_2, Pd_6TeSe, $Pd_3(Sb,As,Sn)$, PtTe, and Au-Ag-Cu-Pd alloys.

The paragenesis of PGM, native Au, Au-Ag alloy and their inclusions suggest a multi-stage crystallization from magmatic to hydrothermal conditions, followed by secondary weathering, oxidation and nugget growth in the regolith profile.

Kojonen, K., Tarkian, M., Knauf, V.V. & Törnroos, R. (2005). 10th Int. Platinum Symp., Finland, Abstract Vol., 145–149.
Törnroos, R. & Vuorelainen. Y. (1987). Lithos 20, 491–500.

Electric resistivity tomography (ERT) and CPTR-bore logging method in geotechnical soil investigations

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Geotechnical soil investigations have utilized traditionally a lot of drillings and soil sampling. The drilling programs use usually fixed point interval and the amount of drillholes is set in advance. The Finnish Road Enterprise has started to use geophysical methods in order to get a continiuos profile of the soil layers and thus guide the detailed investigations to the most relevant places. The cone penetration test (CPT) is used in the investigations of soft soil areas (Lunne et al., 1997). When extended with resistivity sensor (R) the elecrical properties can also be measured. In this study the accuracy of the two measurements, ERT and CPTR were studied and compared in order to find the most effective way to perform geotecnical soil investigations. Induced polarization effect was also measured to get more information of the soil types.

ERT and CPTR measurements seem to correlate well at peat land and the thickness of the peat could be defined quite accurately.

At the clayey formation the results from resistivity imaging seem to differ from the values measured with the CPTR-drill. The IP-effect gave slight indication on the correctness of some features of the resistivity interpretation.

The ability of using these methods to define the corrosion risk for bridge structures is also discussed.

Lunne, T., Robertson, P. & Powell, J. (1997). Cone penetrating testing in geotechnical practice. Blackie Academic & Professional, 312 p.

High-resolution magnetotelluric studies of the Archaean-Proterozoic border zone in Fennoscandian Shield, Finland

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In our current MT-FIRE project we have carried out audiomagnetotelluric (AMT) and magnetotelluric (MT) measurements along the key parts of the FIRE (FInnish Reflection Experiment) reflection seismic lines. One of the primary aims of the project is a high-resolution study of electrical conductivity across the Archaean-Proterozoic border in the central Fennoscandian Shield. Also we have investigated the possibility of subsurface continuation of conductors detected at the surface in Kainuu Belt and Outokumpu area.

With the periods from 0.001s to 1000s we mainly cover crustal depths, but depending of the local conductivity our research depth varies from tens of kilometres in areas of higher conductivity to below hundred kilometres in areas of lower conductivity. Due to the wider range of periods and shorter distances (2-7 kilometers) between the sites in the new data in comparison to the older electromagnetical studies, we gain a much more detailed picture of the crustal conductivity.

Results of 2D inversion show that both the Kainuu and Savo Belts are highly conductive, and the crust to the east of the Kainuu Belt is very resistive in comparison to more conductive crust to the west. However, the upper part of the Iisalmi complex is resistive but underlain by a highly conductive layer in middle to lower crust. It seems that the crustal scale electrical border of Proterozoic/Archaean is much more to the east than the litological border on the surface. Although upper litosphere in the Archaean domain is extremely resistive, there are indications of a conductor at the depth of around 90–100 km at several sites.

Liquid water as far as the -30 degrees C isotherm in Antarctica

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While working in the Allan Hills in December 2001 we concentrated on exposures of Tertiary Sirius Group diamicts in two canyons on the S side of Trudge Valley. The Allan Hills (76º S) form a low nunatak, are part of the Transantarctic Mountains, are situated about 80 km inland and the lowest point is just below 1600 m asl.

During our regular visits to the canyons we observed distinct traces of activity by running water: alluvial fans with crusted surfaces, incised channels, iced-up channels, finegrained pond deposits, one marked by shorelines. All of these fluvial phenomena are topped by intense wind activity, while most surfaces also show frostcracks.

The presence of running water is the most remarkable as the air temperature in the Allan Hills has not been recorded reaching above zero C. The apparent source of the water is melting snow, glacier ice has not been observed to be melting. Within the Allan Hills there are also some frozen lakes, which can only remain in existence is regularly replenished by running water. Consequently the presence of frozen lakes anywhere in Antarctica indicates the occasional occurrence of running water.

Examples of specific landforms will be demonstrated and the consequences of the observations will be discussed. Consequences do not only relate to local longterm landscape stability, but have implications for geomorphological activity in all cold areas, including extraterrestrial ones. Furthermore it has microbiological implications, including claims of biological material in meteorites.

New natural stones from Northern Finland through a regional exploration project.

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An exploration project, "Dimension Stone Project in Central Lapland" was started in 2002 to find new rock types for the natural stone industry. The exploration area consisted of two large municipalities in Northern Finland, Kittilä and Sodankylä, the first taking care of the project administration. The project was financed mainly by the EU (50 %) and Finnish state (20 %), both governed by the Council of Lapland. The rest of the costs was financed by the municipalities (20 %) and the Geological Survey of Finland, GTK (10 %), who was also responsible for the exploration work. The project was completed in spring 2005 and more than 1000 outcrops were examined during summers 2002–2004. The main attention was drawn to special stones but also more traditional stones like granites were observed during the field work.

Besides mapping the field work also included uncovering and washing of the outcrops and sampling. More than 30 test blocks for polishing tests were taken by boring and wedging. In five targets also drilling was used.

As a result of the project nine occurrences were estimated to be potential for dimension stone purposes. In Sodankylä municipality the most interresting occurrences are the black pyroxene gabbro of Virnikkaselkä, the "glittering" schist of Mutsoiva and the albite breccia of Kelujärvi.

In Kittilä, the most potential stones include the Hanhivaara and Honkavaara granites and the green chromian marble in Soretiakumpu.

Two potential slate deposits were also discovered, the other one being test quarried in 2004–2005 at Palovaara, Kittilä.

Development of potential ecological niches in IHT systems: the small-to-medium size impacts

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Effect of meteorite impacts on the biological evolution is usually considered by their catastrophic consequences. However, they can also create opportunities for other organisms and the structures themselves can serve as suitable ecological niches (oases) for life. In this contribution we present results of modeling of an impact-induced hydrothermal (IHT) system in a small-to-medium sized impact crater, where the development of zones habitable for primitive hydrothermal thermophilic and hypethermophilic microorganisms was studied. The impact and geothermal modeling was verified against the 4-km diameter Kärdla complex structure, Hiiumaa Island, Estonia.

The results of transient fluid flow and heat transfer simulations in Kärdla suggest that immediately after the impact the temperatures in the central area, which contains the most hydrothermal alteration, were well above the boiling point. However, due to efficient heat loss at the groundwater vaporization front, the vapor-dominated area disappears in few decades. In the central uplift area, the conditions favorable for thermophilic microorganisms (temperatures <100°C) were reached in 500–1000 years after the impact. The overall cooling to ambient temperatures in the deeper parts of the central uplift lasted for thousands of years. In the crater depression and rim area the initial temperatures, suggested by the impact modeling, were much lower – from 150°C to ambient temperatures, except in fracture zones and suevite pockets.

Our data suggest that in small-to-medium size impact craters with insignificant melting, the suitable conditions for hydrothermal microbial communities are established shortly (tens to few hundreds of years as maximum) after the impact in most part of the crater. In the central uplift area the microbial colonization is inhibited for about a thousand years. However, this is the area which retains the optimum temperatures (45–120°C) needed for hydrothermal microorganisms for the longest period. Geochemical and mineralogical data suggest neutral pH 7(±1) fluid and rather high oxygen level environment of the impact-induced hydrotherms. This suggests the preference for sulphur and Fe^{3+}-reducing microorganisms in the possible IHT communities.

Dating gold mineralization: Xenotime, monazite and zircon U-Pb geochronology

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Precise dating of gold-related minerals is of major significance to the understanding of auriferous hydrothermal systems. However, determining direct dates for gold-only mineralization provides a challenge for most ore deposit researchers. The majority of available U-Pb age constraints are generally based on zircon dates from igneous rocks that host, or cross cut, the gold ore, or in a few cases, hydrothermal zircon. Zircon geochronology can be complicated by inheritance from the source region or inclusion of zircon contaminants along the path of magma ascent/ emplacement. Metamorphic, hydrothermal or other geologic events can cause further growth complexities. Such processes can result in multiple age populations in the data, or enhance metamictization leading to data degradation. Thus, knowledge of the growth history of the dated zircons, as well as the timing relationships between gold deposition and zircon growth are critical for an accurate interpretation of the calculated dates.

More recently, mineralization-related hydrothermal monazite and xenotime have been identified in a range of gold ore environments. They commonly overgrow, or are intergrown with, zircon, or occur as discrete grains that are intimately associated with ore or other hydrothermal minerals. In gold ores, hydrothermal monazite and xenotime grains rarely exceed ~10µm, are very irregular in shape, with abundant inclusions and generally lack internal zoning. Differentiation of multiple generations is not straightforward based on morphology alone, but different generations within one sample typically have significantly different geochemical compositions. Most hydrothermal grains are depleted in U and Th relative to magmatic grains.

Therefore, geochemical, mineralogical and morphological analyses of zircon, monazite and xenotime should be used in conjunction with age data for definitive interpretations. The most reliable test of the interpretations is via cross-correlation between dates obtained on different minerals, preferably by different methods. The availability of U-Pb dating of these minerals provides the ore deposit researcher more options for such cross-correlations in order to accurately date gold mineralization.

Popigai impact fluidizites: new data on opaques

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Earlier, the Popigai impact fluidizites, described in the terrestrial impact structures for the first time, were characterized in terms of their bulk geochemistry, petrology, mineralogy, volatile content and water fluid inclusions (Vishnevsky et al., 2003; 2004; 2005a; 2005b). Below, data on some accessory opaques in the rock glasses are presented.

In general, these opaques form minute immiscible particles and are represented by magnetite (globules of up to 30–50 μ in size), native Ni-bearing iron (globules of 0.4 to 2.3 μ in size; up to 1.44 wt. % of Ni), zircon (globules of 8 to 35 μ in size), ruthile (up to 10 μ in size), troilite-pyrrhotite (globules and schlieren of 1.5 to 60 μ in size; Ni-content of 0.3 to 7.91 wt. % is common, but some segregations are barren of Ni) and pentlandite (globules of 2–4 μ in size; up to 23.99 wt. % of Ni). "Shadows" of ruthile, garnet (?) and sphene (?), traced by aggregates of minute crystallites of TiO_2, high-aluminium Mg-Fe pyroxene (?) and Ca-Ti-enriched phases, as well as monazite fragments are also present in some glasses.

Immiscible particles of the opaques described are the result of shock melting/decomposition of parental minerals and, together with earlier described silica glasses, are the evidence of high temperature of the melt (>1590°C, >1530°C, ~1800°C, >1850°C and ~1200°C for the magnetite, native iron, zircon, ruthile and troilite/pyrrhotite segregations, correspondingly). Most of the opaques, including Ni-bearing Fe-sulphides, were derived from the target gneisses. However, globules of Ni-bearing native iron may be the condensation products derived from the Popigai asteroid. This conclusion is supported by a complex dynamic interaction of impact products derived from various target units during the origin of the fluidizites.

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Vishnevsky, S.A., et al. (2003). Lunar and Planetary Institute, Contribution #1167 (abs. #4034).

Vishnevsky, S.A., et al. (2004). Meteoritics and Planetary Science, 39, Supplement, A109.

Vishnevsky, S.A., et al. (2005a). Lunar and Planetary Institute, Contribution #1734 (abs. #1145).

Vishnevsky, S.A., et al. (2005b). Meteoritics and Planetary Science, 40, Supplement, A162.

Fennoscandian dyke swarms database

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This database development has originated in the framework of the finished project financed by Academy of Finland and later continued at the Geological Survey of Finland (GTK). The aim of the database is to give a clear picture of the spatial and temporal distribution of mafic dyke swarms, their geochemical characteristics, geochronology and relationship to ore critical magmatic events.

The first GIS database (the Global Mafic Dyke GIS Database) was produced in Ottawa, Canada, funded by LITHOPROBE Canada and included information on more than 300 dyke swarms, ≈30 mantle plumes and isotopic ages. An updated dyke swarm map of northern North America and Greenland has been published by Buchan and Ernst (2004). The ongoing "Large Igneous Provinces in Time and Space" project will update this Global Dyke Swarm map (Ernst & Buchan, 2005) and the Fennoscandian database will be a part of this compilation.

The databases include both vector and raster spatial data and a large amount of attribute data. All 192 of the 1:100 000-scale Finnish geological bedrock maps have been digitized (for dykes), and so have many detailed maps. The observation point database (GTK obs. point and Drill databases and University projects) includes 23881 points in both Finland and Russia, while the petrophysical database extracted from the national database of the GTK consists of 4627 observation points. There is also a geochronological database that includes more than 60 U-Pb and 20 Sm-Nd age determinations for diabases of different types and ages all over the area. The geochemical database consists of more than 1500 whole-rock analyses and numerous REE and PGE analyses. A totally updated Eastern Fennoscandian dyke swarm map (area of Finland) has been digitized (1:50 000) with the aid of all these databases and generalized 1: 2000000 maps will be published together with an IDC5 proceeding publication.

Buchan, K. & Ernst, R. (2004). Geol. Surv. Canada, Map 2022A

Ernst & Buchan, (2005). In: Vuollo, J. and Mertanen, S. (eds.), IDC5, 31 July–3 August 2005, Rovaniemi, Finland, Abstracts and Programme, p. 13.

Svecofennian calc-alkaline vs. adakite-like 1.90–1.86 Ga magmatism in SW Finland

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Diorites, granodiorites, tonalites, trondhjemites and other related rocks are important crust-forming igneous rocks that cover large areas in the Svecofennian domain. In southern Finland, these rocks have been traditionally called early-orogenic, synorogenic, syntectonic or synkinematic magmatic rocks. Recent radiometric dating and field relations have demonstrated that their ages span from c. 1.90–1.88 Ga synvolcanic stage to c. 1.88–1.86 synorogenic (syntectonic) stage (Väisänen et al., 2002; Ehlers et al., 2004; Skyttä et al., 2006).

We have analysed synvolcanic and synorogenic intrusive rocks from the Orijärvi, the Enklinge (Åland), the Turku and the Uusikaupunki areas in SW Finland. Previously published analyses by Arth et al. (1978) and Van Duin (1992) were also used. The data show differences in compositions between the 1.90–1.88 Ga (Orijärvi/Enklinge) and the 1.88–1.86 Ga (Turku/probably also Uusikaupunki) intrusions. Contents of Cr, Ni and Sr are generally higher and HREEs and Y are lower in the younger than in the older intrusions. Therefore, using e.g. $(La/Yb)_N$ and Sr/Y diagrams, the 1.90–1.88 Ga rocks often plot in the calc-alkaline (volcanic arc) field while the 1.88–1.86 Ga rocks often plot in the adakite field.

Petrogenetically, the compositional differences can be explained by the depth and the site of melting along a subduction zone. The older calc-alkaline intrusions were probably formed by melting of the mantle wedge while the younger adakite-like intrusions require deeper sites of melting. Therefore, slab melting or combination of slab melts contaminated by mantle wedge is suggested as a source for these rocks.

Arth, J.G., Barker, F, Peterman Z.E. & Friedman, I. (1978). J.Petrol. 19, 289–316.

Ehlers, C., Skiöld, T. & Vaasjoki, M. (2004). ***Bull. Geol. Soc. Finland 76, 63–91.***

Skyttä, P., Väisänen, M. & Mänttäri, I. (2006). This Volume

Väisänen M., Mänttäri I. & Hölttä P. (2002). Prec. Res. 116, 111–127.

Van Duin, J.A. (1992). ***PhD thesis, Vrije Universiteit,*** *Amsterdam, 234 p.*

Geological factors in planning sustainable development at tourist centres

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Increasing tourism in North Finland produces challenges for tourist centres, their land use plans and sustainable development. The project Landscape Lab investigates environmental effects on the areas which are sensitive to changes, from the point of view of esthetic nature, image and wearability. The main target of the project is to find out solutions to sustainable land use, and to plan ecologically, culturally and visually sustainable built-up areas, where disadvantages, caused by tourism, would be minimized. The main research areas are the fells of Ylläs and Levi, popular tourist centres in western Lapland. The project is partly financed by EU LIFE Environment. The beneficiary is the Arctic Centre of the University of Lapland. Geological Survey of Finland is a partner of the project.

The knowledge of the quality and composition of bedrock and Quaternary deposits, and consequently wearability of the terrain, is important in planning hiking and recreation areas, as well as the situation of settled areas. The village of Äkäslompolo is situated on the delta deposit, for instance. The flat delta deposit is a good load-bearing foundation for houses and roads. Good foundation is also frost-resistant, consisting of gravel, sand or coarse grained till. The opposite is strongly frost-susceptible and weakly load-bearing foundation like peat and clay.

Mires are a significant part of the Finnish landscape. The mires in western Lapland represent the aapa bog type of Peräpohjola. Their common features are wetness and wide open watered flarks and strings in between flarks (rimpineva). The original mire types near the tourist centres have partly changed, due to ditching, hiking and ski-ing routes. The vegetation of ground cover has changed there, too.

Mapping of groundwater areas and research of water quality are necessary for water supply of tourist centres, they are also an important part of land use planning. In nature tourism people can exploit springs situated at hiking routes, and consequently it is important to keep the springs clean and in their natural state.

Can large-scale historical changes in effective humidity be traced from mire sequences?

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EU-funded ACCROTELM-project (Abrupt Climate Changes Recorded Over The European Land Mass) aims to produce high-resolution, exceptionally well-dated, multi-proxy data from mire sites in transects across Europe, to detect climate variability during the past 4500 years. The research will combine proven techniques (plant macrofossils, pollen, testate amoebae, humification) with innovative development of biomolecular technologies. Wiggle-match dating will be applied for high-resolution dating of 3 key core seqtions.

For Finnish contribution, one 5-m-long peat sequence from Kontolanrahka in southern Finland, was examined for plant macrofossils. The coring point was located at the wet end of a lawn habitat, *Sphagnum rubellum* and *Mylia anomala* being the most prevailing bryophyte species. The high-resolution analysis revealed two wet periods when hollow species *S. balticum* and/or *S. tenellum* became dominants. These wet shifts took place at ca. 3500–2500 and 1000–100 cal BP. The observed wet periods are concurrent with many earlier mire studies, showing shifts towards wetter conditions at these times. On the other hand, widely recorded wet shifts starting around 4500 and 1800 cal BP were not detected from Kontolanrahka. By contrast, frequent layers with macroscopic charcoal particles found from the bottom part of the core, corresponding the time period ca. 4500–3800 cal BP, indicate dry surface conditions. Furthermore, during the last 4500 years the coring point has for long periods been a drier habitat than it currently is. This is indicated by remains of *S. fuscum*, dark roots, lichens and *Eriophorum vaginatum*.

In the near future, when all the data from all the ACCROTELM sites (8) will be available, we will hopefully be able to contribute to the debate whether the observed changes in mire plant communities are related to any larger-scale climatic shifts or whether they are only or mostly indications of autogenic peatland succession.

Bedrock geology and rock domain modelling in the Simpevarp-Laxemar area, southeastern Sweden

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In connection with SKB's (Swedish Nuclear Fuel and Waste Management Co) site investigation programme for a deep repository for nuclear waste, detailed bedrock mapping has been performed in the Simpevarp-Laxemar area, c. 20 km northeast of Oskarshamn in southeastern Sweden. The bedrock in the area consists of different varieties of gabbroid-dioritoid-syenitoid-granite rocks that belong to the c. 1.81–1.76 Ga generation of the Transscandinavian Igneous Belt. The dominating rock types are a porphyritic granite to quartz monzodiorite and an equigranular quartz monzodiorite. Field relationships and mineralogical and geochemical similarities indicate that all rock types are genetically related and were formed more or less synchronously. The latter is confirmed by U-Pb zircon and titanite ages.

All rock types are relatively well preserved, but a weak foliation, which has a consistent orientation that is concordant to the lithological boundaries, is locally developed. AMS measurements of rock samples that are seemingly undeformed supports this, but the degree of anisotropy is low to moderate. This anisotropy is inferred to be related to magmatic flow. However, a tectonic overprinting in the form of subvertically to vertically dipping, low-grade ductile shear zones, mostly of mesoscopic character, has affected the bedrock. The NE-trending so-called Äspö shear zone, which constitutes two shear belts that are characterized by a high concentration of ductile shear zones, is the most conspicuous.

Available data from the surface, detailed mapping of drillcores and geophysical modelling have been utilized in order to construct a 3D rock domain model of the bedrock in the site investigation area.

Apart from the Laxemar-Simpevarp area, SKB is also performing a site investigation in the Forsmark area, c. 120 km north of Stockholm. A comparison of the composition, age and broader tectonic setting of the bedrock in the two areas will be presented.

Precambrian geodynamics and ore formation: the Fennoscandian Shield

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The complex geodynamic evolution of the Fennoscandian Shield from 2.06 to 1.78 Ga involved rapid accretion of island arcs and several microcontinent–continent collisions in a complex array of orogens. With a few exceptions, all major ore deposits formed in specific tectonic settings between 2.06 and 1.78 Ga and thus a strong geodynamic control on ore deposit formation is suggested.

All orogenic gold deposits formed syn- to post-peak metamorphism and their timing reflects the orogenic younging of the shield towards the SW and west.

The ca. 2.5 to 2.4 Ga Ni–Cu±PGE deposits formed in basins formed during rifting of the Archaean craton at ca. 2.5 to 2.4 Ga, while Svecokarelian ca. 1.89 to 1.88 Ga Ni–Cu deposits are related to mafic–ultramafic rocks intruded along linear belts at the accretionary margins of microcratons.

All major VMS deposits in the Fennoscandian Shield formed between 1.97 and 1.88 Ga, in extensional settings, prior to basin inversion and accretion. This occurred in primitive, bimodal arc complexes during extension, in strongly extensional intra-arc regions that developed on continental or mature arc crust or in intra-continental, or continental margin back-arc, extensional regions developed on older continental crust.

Of the iron oxide-copper-gold deposits the oldest deposits formed in continental arcs or magmatic arcs inboard of the active subduction zone. Younger mineralization took place during cratonization distal to the subduction zone.

Finally, the large volumes of anorthositic magmas formed a major concentration of Ti under granulite facies conditions, about 40 million years after the last regional deformation of the Sveconorwegian Orogeny.

Geological applications of the Nordic ion microprobe (Nordsim) – past, present and future

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The Nordsim ion microprobe project was boldly conceived in 1992 and the chosen instrument was a large geometry Cameca IMS1270. Installation at the the Swedish Museum of Natural History commenced in early 1995 and the instrument became fully operational during 1996. Since that time, Nordsim has developed as an essential infrastructure in the Nordic earth sciences and, recently, as a partial EU facility. Initial demand was overwhelmingly for a U-Pb geochronology facility. Addition of the versatile Faraday and electron multiplier configured multicollector in 2001 catalysed an expansion of analytical techniques. As well as geochronology on zircon and other minerals (now approximately 70% of the analytical demand), the following techniques are routinely available to the community: O isotopes in silicates, oxides, and carbonates, multiple S isotopes in sulphides, C isotopes in graphite, Pb and B isotopes in volcanic glasses, trace elements in a wide variety of materials and, most recently developed, Fe isotopes in Fe-rich minerals. More esoteric applications include Hf-W systematics in eucrite meteorite zircons. All of these methods are performed with a spatial resolution of 10 to 20 µm and a depth penetration of less than 1 µm. Since 1997, the facility has contributed data to over 130 peer-reviewed journal articles, an output that currently represents roughly a third of the total number of analyses performed (hint!).

Minimal analyte consumption and unique negative ion capability means that demand for ion microprobe analysis remains high, despite obvious advances in complementary methods such as laser ablation. Indeed the Cameca IMS1270/80 remains a popular instrument as shown by recent academic acquisitions in Edinburgh (2003), Wisconsin (2005) and Hawaii (2006). Long term (>10 years) operation of the Nordsim facility can be guaranteed by a complete electronics upgrade to bring the instrument to the standard of the most recent instruments.

Micro-scale sulphur isotope evidence for late Archaean rise in shallow oceanic free oxygen

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The increase of free oxygen in Earth's atmosphere 2.3 billion years (Gyr) ago fundamentally affected the biogeochemistry of iron and sulphur. Biological innovation involving these elements significantly predated this time but reasons for the delay in atmospheric oxygenation remain unclear. Sulphur isotopes provide an attractive means to investigate this question because sulphur metabolising bacteria from deep branches of the Tree of Life can impart characteristic mass dependent fractionation (MDF). These biological effects are superimposed on mass independent fractionation (MIF) signatures unique to the ancient anoxic atmosphere. Although distinctive isotope effects have previously been shown from rocks older than 2.3 Gyr, the extent of isotopic fractionation and its significance have remained elusive. Here we report in situ, high spatial resolution secondary ion mass spectrometry (SIMS) measurements of 2.52 Gyr sedimentary sulphides that reveal unprecedented variability in sulphur isotope composition within specimens on a very fine scale (<25 microns). The results prove bacterial sulphur isotope fractionation, as well as implying that it depended on sedimentary facies and was limited by available sulphate. Correlated MDF and MIF arrays provide a novel method for robustly estimating the extent of fractionation to nearly double that of previous estimates. Our results show that by 2.52 Gyr, microbial sulphate reduction, elemental sulphur and sulphide oxidation (and implicitly oxidative photosynthesis) as well as water column sulphate reduction were all operating in a shallow stratified water column.

Role of Geology in Nuclear Waste Management Programmes in Nordic Countries

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Finland and Sweden are the only Nordic Countries producing electricity by nuclear power plants. Both these countries are planning and, in the future, also implementing the geological disposal for the high-level, radioactive nuclear waste.

In Finland Posiva Oy is the nuclear waste management organisation and it has selected the Olkiluoto site for further investigations and for a future repository site. Olkiluoto is located in the SW Finland and its geological setting is a Paleoproterozoic, Svecofennian micmatite complex. At the moment Posiva is building the investigation tunnel called ONKALO in the central part of the Olkiluoto island.

In Sweden, Swedish Nuclear Fuel and Waste Management Company, SKB, is responsible for the nuclear waste disposal. At the moment SKB is performing site investigations in two areas, a Forsmark area, south-central Sweden, and a Laxemar-Simpevarp area, in southeastern Sweden. Based on these investigations SKB will in 2008 select one of the sites for further investigations and for a future storage site of the high-level nuclear waste. The geological setting of Forsmark area is a tectonic lens consisting of meta-igneous rocks. The bedrock in Laxemar-Simpevarp area consists of different varieties of gabbroid-granitoid-syenitoid-granitic rocks.

Geological data is the basic information used for the understanding of the sites. The geological data is further used as such or further analysed and used for constructing a geological model of the investigation area. The geological model, in turn, is used as a basic geometrical data for the hydrogeological, hydrogeochemical and rock mechanical modelling. The results of all these models including geological model, are used for designing and constructing the investigation tunnels and the future repository, and last but not least, to assess the long-term safety of the repository in the area of question.

One of the most difficult future tasks for the geologists working with the repository projects is to achieve a predictive capacity of geological features to accommodate the construction of the repository in each site. It will be one of the key issues for the safe construction of the repository.

Radiogenic isotope systematics and the age of the Naantali Carbonatite

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The Naantali Carbonatite is a small swarm of alvikite dykes located approximately 20 km west of Turku in southwest Finland. The petrography and geochemistry was described by Woodard (2005), who suggested an association with a belt of Svecofennian post-collisional shoshonitic intrusions. This conclusion was based entirely on field relationships and geochemical similarities. Isotopic determinations for Sr, Sm, and Nd have been made on ten whole-rock samples from the dykes and contact fenites.

The $^{87}Sr/^{86}Sr$ isotope ratios for the dyke samples fall within a narrow range of 0.7030–0.7031. This range also shows good agreement with the initial $^{87}Sr/^{86}Sr$ ratios given by Andersson et al. (in press) for the post-collisional shoshonitic intrusions. The Halpanen Carbonatite in southeast Finland, also associated with the shoshonitic intrusions, has an identical (0.7031) $^{87}Sr/^{86}Sr$ ratio to that of the Naantali dykes (Hugh O'Brien, unpublished data).

Eklund & Shebanov (2005) give an emplacement age of 1.76 Ga for the Åva ring complex, the closest of the shoshonitic intrusions to Naantali. *T*-CHUR model ages were calculated for the Naantali dykes from the Sm-Nd results using the formula given by Rollinson (1993). The model ages for most samples fall within a range of 1.80–1.81 Ga, although two samples have 1.77 Ga model ages.

A U-Pb age determination using titanites as well as apatites rich in monazite inclusions is in progress. Additional Rb-Sr and Sm-Nd work on a variety of mineral separates is also in progress. The results of these determinations will be presented at the meeting.

Andersson, U.B., Eklund, O., Fröjdö, S., & Konopelko, D. (2005). Lithos, in press.
Eklund, O. & Shebanov, A. (2005). Lithos 80, 229–247.
Rollinson, H. (1993). Using geochemical data, 352 p.
Woodard, J. (2005). Unpublished Master's thesis, 79 p.

Origin and geodynamic setting of the Archean alkaline complexes from the Baltic-Greenland Shields

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Baltic-Greenland Archean complexes are represented by the Skjoldungen alkaline province in SE Greenland (syn- to post-kinematic pyroxenites, hornblendites, norites and diorites, monzodiorites, monzonites, syenites, nephelinitic rocks and carbonatites of 2670–2665 Ma age) and by Tupertalic carbonatites in West Greenland (Blichert-Toft et al, 1995; Larsen and Rex, 1992). The Baltic examples are represented by the Siilinjärvi carbonatite-glimmerite complex in Finland of 2610 Ma age and by the Keivy alkaline province (anorogenic peralkaline granites, syenogranites, syenites and massif-type anorthosites of 2650–2670 Ma age; OIB-like nepheline syenites of 2610 Ma age) in the Kola Peninsula, Russia (Zozulya et al., 2005).

Geochronological and geochemical studies of the Archean alkaline complexes from the Baltic and Greenland shields provide some evidence for their combined geological development in the time span 2.7–2.6 Ga. From the similar geochemical signatures it is suggested that the Archean alkaline magmatism resulted from the plume development in sublithospheric mantle having the enriched characteristics due to subduction processes. The observed differences in geochemical features are in accordance with sequence of magmatic events during the plume development: 2.70–2.66 Ga – initiation, slightly enriched reservoir due to subducted and recycled oceanic crust, mafic shoshonitic parental magma; 2.65–2.61 Ga – evolved enriched reservoir, OIB-like and Na-rich parental magma.

Blichert-Toft, J. et al. (1995). J. Petrology 36, 515–561.
Larsen, L. & Rex D. (1992). Lithos 28, 367–402.
Zozulya, D. et al. (2005). J. of Geology 113, 601–608.

Petrology and geochemistry of the Näsberget layered intrusion, Skellefte district, Northern Sweden

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The Näsberget gabbro is a layered intrusion, about 9×4.5 km large, situated in the northern part of the Skellefte mining district, northern Sweden. The intrusion was emplaced within the Jörn Granitoid Complex between 1.90 and 1.87 Ga. The latter comprises a large composite early Svecofennian granitoid batholith composed of four main phases (GI to GIV), ranging in composition from tonalite to granite and in age from ca. 1.90 to 1.87 Ga.

Iron ore was found in the Näsberget intrusion already in 1832, and mined in periods until 1906. The mined magnetite ocurrs in veins (associated with actinolite±quartz±K-feldspar±apatite±sulphides) within the gabbro. In the mid 1980:s Sveriges Geologiska AB explored for platinum group elements in the gabbro and found a boulder containing 1.2 ppm Pt, 3.9 ppm Pd and 0.2 ppm Au (Filén, 2001).

In the southern part of the intrusion, where the layering strikes NE-SW and dips moderately towards NW, three different megaunits are suggested. These are referred to as the Lower Zone, the Main Layered Zone and the Upper Zone, forming a ca. 3–4 km thick layered sequence. The Lower Zone and the Upper Zone are poorly defined due to limited exposures, cumulate texures are sparse and the rocks consist of gabbronorite, hornblende gabbro and quartz-bearing gabbro. The Main Layerd Zone, on the other hand, is characterised by cumulate textures, well developed layering and the occurence of cumulate olivine. It range in rock composition from mela- to leuco- olivine gabbronorite. The transitions between the megaunits are characterised by Fe-Ti oxide rich gabbroic and ultramafic rocks. These horizions were recently explored for their precious metal content, however, without sucsess.

Filén, B. (2001). SGU C 833, 33–45.

Dark veinlets in the granitoids of Saarijärvi, Söderfjärden and Lappajärvi impact structures

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The Saarijärvi impact structure in northern Finland, and Söderfjärden and Lappajärvi impact structures in western Finland have little in common regarding e.g. their diameter (~1.5–2 km, ~6.4 km, ~17–23 km, respectively) or age (~1980–600 Ma, ~530 Ma, ~73 Ma, respectively). In all these impact structures, however, there are unusual dark veinlets intruding the target granitoids. In these areas such veinlets are only found in connection with the impact structures, thus possibly implying a genetic link.

In Saarijärvi the veinlets occur in the central island (not a true central uplift, but merely an elongated block tectonically uplifted probably well after the impact), at the contact of brecciated granodiorite and metadiabase. As the breccias including the 2–3 mm thick veinlets with massive rims and granular interiors have undergone significant hydrothermal alteration (e.g. chloritisation and hematisation), the veinlets' original composition or texture are quite difficult to decipher. Despite the fact that the veinlets have elevated Ni, Co and Cr contents and interelement ratios, the veinlets are probably unrelated to the impact, except for that the impact-induced fractures and stresses have possibly affected the post-impact tectonic movements. (Öhman et al., 2003).

Söderfjärden impact structure presents dark veinlets both in boulders and in outcrops. Especially interesting are the hydrothermally altered sphene-rich veinlets, with their accompanying prehnite-calcite-quartz veinlets, on the eastern rim in the village of Solf (Öhman & Raitala, 2005). The veinlets are associated with offsets of tens of cms, and they are tentatively interpreted as originating from the modification of the crater rim. Thicker kaolinitised veins found in boulders resemble breccia dykes encountered in cores drilled inside the structure.

More details on the long-known, but as yet mainly unstudied >5 cm thick fragment-rich blackish veinlets from the eastern rim of the Lappajärvi structure will be presented at the meeting.

Öhman, T. et al. (2003). Meteorit. Planet. Sci. Suppl. 38, A52.
Öhman, T. & Raitala, J. (2005) 26th LPSC, #1738 (CD-ROM).

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Polygonal craters of Argyre region, Mars – Clues to cratering mechanics?

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Polygonal impact craters are a common feature on the surfaces of various planets, moons and asteroids throughout our Solar System (Öhman et al., 2005). We studied the polygonal craters in the Argyre region, Mars, in order to better constrain the origin of the polygonal plan view impact craters, and therefore understand the effects of pre-existing structures of the target material during the formation of impact craters. We also wanted to see how polygonal craters reflect the complex geotectonic history of Argyre impact basin's surroundings.

Differential erosion is still sometimes regarded as the cause for crater's polygonality, although already Eppler et al. (1983) demonstrated that erosion actually increases the circularity, not the polygonality of impact craters. Our preliminary work reveals that both heavily eroded (no rim wall), moderately–slightly eroded (rimmed), and fresh (preserved ejecta blanket) craters all display the same amount of polygonality when measured by the number of straight rim segments. In addition the strikes of the rim segments in all erosional stages are statistically the same. This suggests that the fracture systems these crater rims apparently reflect have quite ancient origins. It's very hard to explain these findings by erosion, but they are a natural outcome if the polygonal plan view stems from the formation of the crater in a fractured target.

The currently favoured acoustic fluidisation model of impact crater formation assumes that the rim material is nearly strengthless during the collapse stage, and thus can not "remember" the pre-existing crustal structures (e.g. Melosh & Ivanov, 1999). In the view of polygonal crater data, this is not the case. Therefore, in order to correctly describe nature, at least a slight modification is required to the current ideas of impact crater formation.

Eppler, D. et al. (1983). Bull. Geol. Soc. Am. 94, 274–291.

*Melosh, H. J & Ivanov, B. A. (1999). **Ann. Rev. Earth Planet. Sci. 27, 385–415.***

*Öhman, T. et al. **(2005). Koeberl, C. & Henkel, H. (eds.): Impact Tectonics, Springer, 131–160.***

A computer model, simulating fine gravel distribution in tills in Denmark

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Results from a computer model simulating 2D(3D) transport and deposition of fine gravel in Quaternary tills from Denmark, are presented. The model is tested against field data acquired over the last three decades. The main principle is based on an exponential loss of fine gravel particles, along the linear flow line of the ice. The ice movement is deduced from fabric measurements in tills and orientation of fold axes of deformed Quaternary sediments. The preliminary results enables us to plot ice flow lines and compositions of fine gravel in all major till units across Denmark. In the latest 4 years the amount of petrographic data from Quaternary sediments in Jutland and on the island of Funen has increased dramatically as a result of an ongoing cooperation between 8 Danish counties and the Department of Earth Sciences, University of Aarhus with the aim to locate and preserve good quality groundwater as a source for drinking water in Denmark.

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