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1st Finnish National Colloquium of Geosciences
Espoo, 19-20 March 2014

Joonas Virtasalo and Mari Tuusjärvi (eds)



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Edited by

Joonas Virtasalo and Mari Tuusjärvi

Unless otherwise indicated, the figures have been prepared by the author of the publication.

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PREFACE

Since 2001, the Finnish Graduate School in Geology has been a nationwide post-graduate program, based on close co-operation between all universities training geologists in Finland. One of the important activities has been the Graduate School annual colloquiums (tutkijapäivät in Finnish), which have been organized during the last nine years.

The graduate school system in Finland was changed in 2013, and each university currently has its own, in some cases multi-scientific graduate schools. In order to maintain and further develop co-operation within the Finnish geoscience community, it was decided to continue the tradition of the annual seminars by organizing the First Finnish National Colloquium of Geosciences on 19–20 March 2014 at the Geological Survey of Finland (GTK) in Otaniemi. The Finnish National Colloquium of Geosciences aims to provide a forum to present and discuss current research topics important for Finnish geoscientists, and to meet one another, exchange ideas and build co-operation. One of the important tasks is to offer an opportunity particularly for young scientists to present their research and to learn more at short courses and technical sessions.

The special focus areas of the 2014 Colloquium are mineral systems and bed-rock geology, the Baltic Sea, and groundwater. Research on these topics is tackling major global challenges related to the availability of raw materials, global change and urbanization, and they are among the key areas of interest of the Finnish geoscientific community. We are very pleased to have prominent researchers of the selected focus areas, Prof. Shaun Frapé from the University of Waterloo, Dr Matthias Moros from the IOW Institute, and Research Prof. Ferenc Molnár and Dr Muhammad Sayab from the GTK, as our keynote speakers.

On behalf of the organizing committee and GTK, acting as the host organization, it is my great pleasure to wish you all a warm welcome to attend and enjoy the First Finnish National Colloquium of Geosciences.

Pekka A. Nurmi, PhD, Prof.
Chairman of the Organizing Committee

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Pekka Nurmi
Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland
E-mail: Pekka.Nurmi@gtk.fi

QUANTIFYING THE PAST, PRESENT AND FUTURE AT THE LABORATORY OF CHRONOLOGY

by

Laura Arppe, Kari Eskola, Markku Oinonen and Antto Pesonen

*Laboratory of Chronology, P.O. Box 64, 00014 University of Helsinki, Finland
E-mail: laura.arppe@helsinki.fi*

The Laboratory of Chronology (formerly the Dating Laboratory) at the Finnish Museum of Natural History, University of Helsinki, transforms natural and man-made samples to numbers in a multidisciplinary field of science based on three cornerstones: ^{14}C -AMS dating, luminescence dating and stable isotope measurements.

During its >40 years of existence, over 6500 radiocarbon analyses have been processed, and the collaborative efforts of the Laboratory of Chronology together with the Department of Physics (Univ. of Helsinki) have led to the establishment of Radiocarbon Analytics Finland (RACAF), a common umbrella under which all the phases of ^{14}C analytics (sample pretreatment, carbon extraction, graphitization, AMS measurement, result analyses) are now performed. The radiocarbon method is no longer only for timing past events, but also a tool for our future: it allows quantification of the biobased contents of any substance involved in the carbon cycle (Oinonen et al. 2010). Furthermore, molecular sieve-based radiocarbon methodology pioneered by our laboratory (Palonen & Oinonen 2013) for soil organic carbon has revealed needs to upgrade present climate models (Karhu et al. 2010) – and the research will continue broadly within the future carbon monitoring schemes.

Stable isotope measurements are a staple of modern scientific research. The main avenues of investigation at the Laboratory of Chronology comprise climate and ecology in the past, present and future. We routinely measure water ($\delta^{13}\text{C}$, $\delta^{18}\text{O}$ and δD), carbonate ($\delta^{13}\text{C}$, $\delta^{18}\text{O}$), gaseous CO_2 ($\delta^{13}\text{C}$, $\delta^{18}\text{O}$) and organic samples (plant tissues, bulk organic matter, skeletal samples, hair; $\delta^{13}\text{C}$, $\delta^{15}\text{N}$), and have TC/EA (high-temperature conversion elemental analyser) capabilities for simultaneous $\delta^{18}\text{O}$ and δD measurement of all organic compounds and water, as well as selected inorganic compounds (nitrates (N and O), phosphates (O) and sulphates (O)). Current major projects deal with: 1) carbon isotope measurements of the supra-long *Pinus sylvestris* tree-ring chronology from Finnish Lapland (Eronen et al. 2002), with the ultimate goal of reaching 7500 years back in time; 2) the life and times of the Iron Age Levänluhta people; 3) the palaeoecology of the Wrangel Island mammoth population; and 4) the temperature sensitivity of soil organic matter decomposition.

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ARTIFICIAL NEURAL NETWORKS FOR MAPPING AND MITIGATION-ORIENTED CHARACTERIZATION OF ACID SULPHATE SOILS

by

*Beucher, A.¹, Siemssen, R.¹, Fröjdö, S.¹, Österholm, P.¹, Martinkauppi, A.² and
Edén, P.²*

¹ Åbo Akademi University, Geology and Mineralogy, Domkyrkotorget 1,
20500 Åbo, Finland

E-mail: abeucher@abo.fi

² Geological Survey of Finland, P.O. Box 97, 67101 Kokkola, Finland

Finnish acid sulphate (a.s.) soils originate from sulphide-bearing sediments deposited at the bottom of the Baltic Sea since the Litorina Sea stage (Holocene). These soils constitute a major environmental problem, as they can release a toxic combination of acidity and metals in the recipient streams and estuaries, causing severe ecological damage. Small a.s. soil areas may affect large water bodies, and pinpointing these hotspot areas is critical for effective mitigation. A cooperation network headed by the Geological Survey of Finland was established in 2009 in order to create a nationwide a.s. soil map. Conventional mapping and sampling in the field is expensive and time-consuming. Complementary spatial modelling techniques may be used in order to define and narrow down areas of interest. Among the diverse spatial modelling techniques available, a method utilizing an artificial neural network (ANN) was selected, in particular owing to its good pattern recognition and classification tools with the ability to generalize from imprecise input data. The method is implemented within the R environment and its results can be visualized within a geographic information system (GIS). The aim of this study is to assess the predictive classification abilities of ANN not only for a.s. soil mapping, but also for a more elaborated mitigation-orientated characterization of these soils (i.e. modelling different soil parameters). The selected study area is the Sirppujoki catchment (460 km²), located in southwestern Finland. This study is also being conducted within the framework of the VALUE doctoral programme, which focuses on integrated catchment and water resources management.

A radial basis function (RBF)-based ANN is being applied in order to create probability maps both for a.s. soil occurrence in the study area, and for modelling the contents of organic matter and sulphur, and the risk depth. The network requires aerogeophysical, Quaternary geology and elevation data, as well as data on known occurrences of a.s. and non-a.s. soils. The a.s. soil occurrences are defined by soil profiles containing sulphides within 3 m depth (i.e. profiles comprising an oxidized acidic layer as well as underlying transition and reduced sulfidic

horizons, and/or a decrease in pH after incubation by 0.5 units to a value lower than 4.0). The known occurrences are divided into two sets: the training and validation points. First, the RBF network is trained, basically by associating the different data layers with the training points and learning to classify these points accurately. Then, the accuracy of the classification is assessed using the validation points: the more points are correctly classified, the more accurate is the classification. Finally, the neural network classifies the rest of the study area in the same manner, which leads to the creation of a probability map. Among the modelled soil parameters, the organic matter content (%) is determined by loss on ignition, and the sulphur content by a CHNS Elemental Analyzer (i.e. flash combustion followed by gas chromatography). The risk depth is here defined as the upper limit of the sulphidic soil material, which has a field pH higher than 4.5 due to limited oxidation, but will reach a pH lower than 4.0 upon 19 weeks of incubation.

The use of a probability map of a.s. soil occurrence in conjunction with the modelled soil parameters may allow a more precise characterization of a.s. soils in the study area. The development of further levels of modelling could enable a mitigation-orientated identification of a.s. soils, which would constitute an advance in future soil and water management.

A SURVEY ON MINERAL EXPLORATION COMPANY WEBSITES AND SUSTAINABILITY REPORTING IN FINLAND: PRELIMINARY RESULTS

by

Toni Eerola

*Geological Survey of Finland, P.O. Box 96, 02151 Espoo
E-mail: toni.eerola@gtk.fi*

Honest, transparent, consistent and systematic sustainability reporting according to industry standards is one of the main components of corporate social responsibility (CSR). It provides those who are interested an opportunity to follow the activities of companies and shows how they fulfil their CSR. Mining is one of the sectors where standardized disclosure has been a subject of growing interest due to pressure from society, which requires transparency and CSR from companies. Therefore, several different reporting systems have been created and developed. Their adoption by companies is very variable. Companies listed on the stock market have a duty to prepare and present their sustainability reporting in an accessible and transparent way according to certain industry standards. Usually, such reporting can be found on company websites, which also have an important role for those searching for information on mining companies. The websites are especially followed by investors and environmental non-governmental organizations, but they are also useful for the general public and residents of an area where a mining company is starting mineral exploration.

The recent mining boom and its associated problems has led social scientists and environmental activists to show interest in the sustainability reporting of mining companies operating mines in Finland. However, mineral exploration, with a crucial role in the construction of the company–community relationship, has not attracted attention. This follows an international trend in CSR studies on mining, which have also mainly focused on developing countries.

This presentation provides the preliminary results of a survey on the websites and sustainability reporting of 51 mineral exploration companies with applied or valid claims and claim reservations in Finland, listed by the Finnish **Safety and Chemicals Agency (Tukes)**. Both foreign and national industrial and metallic mineral exploration companies were considered in the survey.

The first impressions from the data are that most of the company websites are written in English, based abroad and mainly focused on international investors. There are short descriptions of the companies' projects in Finland, focusing on geology, mineralization and its exploration, with nice pictures of nature, winter and landscapes. Few of the websites are written in Finnish. Complete sustainability disclosure according to the Global Reporting Initiative is found on the

websites of the major foreign and Finnish companies, whereas the minor ones may not even have their own website at all, or this information may only be provided by the parent company. In some cases, only the company's contact information is provided on the web.

Some large and small companies have their websites both in Finnish and English. Small companies do not present sustainability reporting at all, if they are not listed on the stock market. Some of the websites may only provide sparse, generalized and positive comments on the company's values and its community relations. When found, the stakeholder engagement activities that are described generally consist of regular meetings with communities, hiring of local people and purchasing of local goods and services as much as possible, sponsorship of local sports and cultural associations and events, as well as the offering of scholarships for local students to study geology or mining engineering in universities.

The existence of a website written in Finnish is recommended by the Mining Academy's model for stakeholder engagement in mineral exploration. It is important to provide information on a company and its operations in the form of transparent communication and public relations, complementing the proactive encounters with the local stakeholder groups that already occur at the reconnaissance stage.

This is a contribution to the Mining Academy and SAM (Sustainable Acceptable Mining, WP4) projects, in which the Geological Survey of Finland (GTK) participates

RESEARCH AND PROMOTION OF CORPORATE SOCIAL RESPONSIBILITY AND THE SOCIAL LICENSE TO OPERATE OF THE MINING INDUSTRY IN FINLAND

by

Toni Eerola

*Geological Survey of Finland, P.O. Box 96, 02151 Espoo, Finland
E-mail: toni.eerola@gtk.fi*

The mineral potential of Finland has attracted mining industry, especially in northern and eastern Finland. Foreign companies are investing in Finland, exploring mineral deposits and opening mines. However, this is not happening without problems. Mining has impacts and risks, causing concerns among the general public. In the order to earn the social license to operate (SLO), mining companies should apply the best practices, respecting the environment and local communities.

Due to the environmental problems of the Talvivaara mine, a discussion on corporate social responsibility (CSR) and the SLO of mining has also started in Finland. Mining has become a subject of public discussion and a target of academic interest. In a short time (2010–2013), a number of projects have been conducted to investigate and promote sustainable mining in the country. A chronological overview of projects dealing with CSR and the SLO of mining in Finland is provided.

There have been a total of eleven projects and two professorships. Three projects were completed and several started last year. The promotional projects are public initiatives (4), whereas the research projects have been managed by universities and research institutions (7).

The Green Mining Program of the Finnish Agency for Funding of Innovation (Tekes) has been the main source of funding for the research projects. The individual budgets have varied from some hundreds of thousands of euros to one million euros, the total amount being €5M. There is certainly a need for academic research on the subject. The European Union is dependent on imports of minerals and it has decided to promote sustainable mining in its territory. Finland considers the mining industry as an important economic activity for the country, and intends to become a leader in sustainable mining. The SLO of mining has an important role to play in this sense. However, a large number of similar projects and goals can cause concurrence and confusion between them. There have been numerous events and working groups mostly attended by the same people, burdening authorities, specialists, researchers and company staff. Although there has been participation by many companies, mining professionals have been strongly under-represented in the research projects. This may cause misunderstandings

and problems in the interpretation of results. Their greater participation should be encouraged.

The research projects have been in the social sciences, their main method being qualitative (thematic interviews). In order to avoid overlapping and interviews with the same people and companies repetitively by separate projects, good coordination and cooperation between projects is needed.

Due to their environmental, economic and social impacts, mines are the focus of Finnish social research on mining, following an international trend. Although mineral exploration has an important role to play in the company–community relationship as a part of CSR, it has received little attention. The discussion on CSR has also only concentrated on companies, although there are reasons to consider the CSR of anti-mining activism, too. There is additionally an urgent need to increase the public awareness of mining.

It would be interesting to observe how the financial crisis and low metal prices influence mining industry and its research. Is all this focus on mining exacerbated by the mining boom and Talvivaara's problems just a momentary enthusiasm, or a more permanent phenomenon? Whatever the case, a flood of publications and guidelines would appear in the near future. Everybody wants to offer their advice to the mining industry. However, the discussion on the CSR of mining is a common learning process, which involves companies, authorities, citizens, professionals, the media, NGOs and the research community. Hopefully, it will occur in peaceful and balanced way, benefitting the mining industry by improving its activities and enabling it to earn the SLO, as well as society as a whole, which needs minerals.

CHALCOPHILE ELEMENT GEOCHEMISTRY OF KOMATIITES AND BASALTS IN GREENSTONE BELTS OF RUSSIAN KARELIA

by

*Fang-Fang Guo¹, Sergei Svetov², Wolfgang Maier³, Sheng-Hong Yang¹,
Vladimir Kozhevnikov² and Zuoya Rybnikova²*

¹ *Department of Geosciences, University of Oulu, P.O. Box 3000,
FI-90014 University of Oulu, Finland
E-mail: Fangfang.guo@oulu.fi*

² *Institute of Geology, Karelia Research Centre of Russian Academy of Science,
Russia*

³ *School of Earth and Ocean Sciences, Main Building, Park Place,
Cardiff CF10 3AT, United Kingdom*

Komatiites and komatiitic basalts from the Hautavaara, Koikary, Palaselga and Sovdozero structures in the Mesoarchean Vedlozero-Segozero greenstone belt (VSGB), and the Irinozero and Khizovaara structures in the Mesoarchean Northern Karelian Greenstone Belt (NKGB) have PGE contents in the range of S undersaturated komatiites and komatiitic basalts globally (Fiorentini et al. 2011), at 5–20 ppb Pt and Pd each, with Pt/Ir ratios of 1–41 for komatiites and 3–333 for komatiitic basalts. The Iridium-group platinum group elements (IPGE) (Ir, Ru, Os) generally show a compatible signature, decreasing with a falling MgO content, whereas Pt, Pd and Rh (PPGE) exhibit incompatible behaviour. Pd, Cu and Au have behaved variably mobile during alteration and metamorphism.

Some samples from the NKGB have low Pt/Ti_N ratios, low Ni and high La/Sm, suggesting localized sulphide saturation in response to crustal contamination. However, the potential of the Russian Karelian belts for Ni-sulphide mineralization is considered to be moderate. This is due to the apparent paucity of sulphide-rich sedimentary rocks in the region, the lack of chalcophile element enrichment in any of the samples analysed and the paucity of dynamic lava channel environments, as indicated by a lack of Mg rich olivine adcumulates (Barnes et al. 2011, Maier et al. 2013). Amongst the analysed belts, lavas in the Khizovaara structure are considered the most prospective target for Ni sulphide mineralization due to their relatively enhanced crustal contamination and greater depletion of PGE.

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SHEAR STRENGTH MEASUREMENTS OF THE SEDIMENTS OF THE ARCHIPELAGO SEA: A FIELD STUDY

by

Jyrki Hämäläinen, Joonas J. Virtasalo and Antti E. K. Ojala

*Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland
E-mail: jyrki.hamalainen@gtk.fi*

In marine geological studies concerning underwater installations, such as cables and pipelines, the geotechnical properties of the sediment play a key role. Grain size, water content and organic content are easily analysed from sediment samples obtained from the seabed. However, measuring the shear strength of the sediment is more challenging, as *in situ* measurement is virtually impossible in deep water and the collection of undisturbed sediments and their transportation to the laboratory are also very difficult. Shear strength values are needed, for example, to assess the bearing capacity of the seabed and to select a suitable method for cable trenching.

Several shear strength studies have been carried out onshore in Finland, but only a few have been conducted offshore (Gardemeister 1975, Virtasalo 2001). To obtain an overview of the shear strength values of the sediments of the Archipelago Sea, bottom sediment samples were collected on R/V Geomari and the shear strength values were measured onboard using a hand vane.

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HIGH-ALUMINUM ORTHOPYROXENE MEGACRYSTS (HAOM) IN THE 1.64 Ga AHVENISTO ANORTHOSITE COMPLEX, SOUTHEASTERN FINLAND

by

*Aku Heinonen, Heli Kivisaari, Riikka Fred, Radoslaw M. Michallik and
Pasi Heikkilä*

*Department of Geosciences and Geography, P.O. Box 64,
Gustaf Hällstöminkatu 2a, 00014, University of Helsinki
E-mail: aku.heinonen@helsinki.fi*

High-aluminum (up to ~13 wt% Al₂O₃) orthopyroxene megacrysts (HAOMs) are a characteristic feature of the so-called Proterozoic massif-type anorthositic complexes (Emslie et al. 1994). Their primitive geochemical nature (high Mg# and juvenile radiogenic isotope signature), aluminium content and characteristic plagioclase exsolution lamellae have been taken as evidence of polybaric crystallization of Proterozoic anorthosite massifs.

Orthopyroxene megacrysts have also been identified from the 1.64 Ga Ahvenisto rapakivi granite–massif-type anorthosite complex, which is a part of the mid-Proterozoic rapakivi suite of southern Finland (Heinonen et al. 2010 and references therein), but they have not been systematically studied or mapped before. Recent fieldwork in the northwestern part of the complex has revealed new outcrops on which two types of HAOMs are recognized embedded in leucogabbroic rocks. Type 1 megacrysts are autonomous, usually euhedral to subhedral, and up to 15 cm in diameter. Type 2 megacrysts occur in pegmatitic pockets with megacrystic (up to ~30 cm long) plagioclase laths. Morphologically, these types are similar to the high-Al type 1 and low-Al type 2 orthopyroxene megacrysts, respectively, reported by Emslie (1975) from the Nain massif-type anorthosite complex in eastern Canada.

Some of the Ahvenisto orthopyroxenes show optical evidence of minute exsolution lamellae. However, except for secondary amphibole and carbonate, XRD analysis of the megacrysts did not unambiguously confirm the presence of other phases than orthopyroxene. Some of the megacrysts also display complex rim structures comprised of plagioclase+orthopyroxene symplectites, clinopyroxene and (somewhat altered) olivine intergrowths that may be the result of a low-pressure equilibration reaction. Preliminary EPMA analysis of a type 1 megacryst (En₆₅) recorded an elevated abundance of aluminium (up to ~4 wt% Al₂O₃), which corresponds to crystallization pressures of 0.6–0.7 GPa and depths of ~21–23 km (calc. after Emslie et al. 1994).

These observations suggest that at least the type 1 Ahvenisto orthopyroxene megacrysts are similar to the high-Al orthopyroxenes (type 1) described by

Emslie (1975), and that they initially crystallized in the lower to middle crust before emplacement of the host anorthositic magmas at more shallow crustal levels.

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WHAT IS THE ROLE OF THE LITHOSPHERE IN THE GENERATION OF THE LARGEST VOLCANIC ERUPTIONS ON EARTH?

by

Jussi S. Heinonen and Arto V. Luttinen

*Finnish Museum of Natural History, P.O. Box 44, FI-00014 University of Helsinki,
Finland*

E-mail: jussi.s.heinonen@helsinki.fi

The origins of continental flood basalts (CFBs), manifestations of large-scale mantle melting events associated with global mass extinction events and continental breakup, are not well understood. Characteristically, CFBs show considerable geochemical heterogeneity, even within a single province. In general, the geochemical variability has been linked to heterogeneities in the underlying continental lithosphere (crust + lithospheric mantle), often also thought to be the major source contributor for the voluminous magmas (Fig. 1a).

Our studies in the Antarctic portions of the Jurassic (~180 Ma) Karoo CFB province (original volume > 2 000 000 km³) have revealed magma types that show compositional evidence of derivation from the convecting mantle: depleted types that are isotopically (Sr, Nd, Pb, and Os) indistinguishable from mid-ocean ridge basalts and enriched types (e.g., high Nb and Ta) that derive from sources probably affected by crustal recycling processes (cf. oceanic island basalts; e.g., Hawaii). Our energy-constrained assimilation fractional crystallization modelling further indicates that the geochemical lithospheric affinities of many CFBs can be

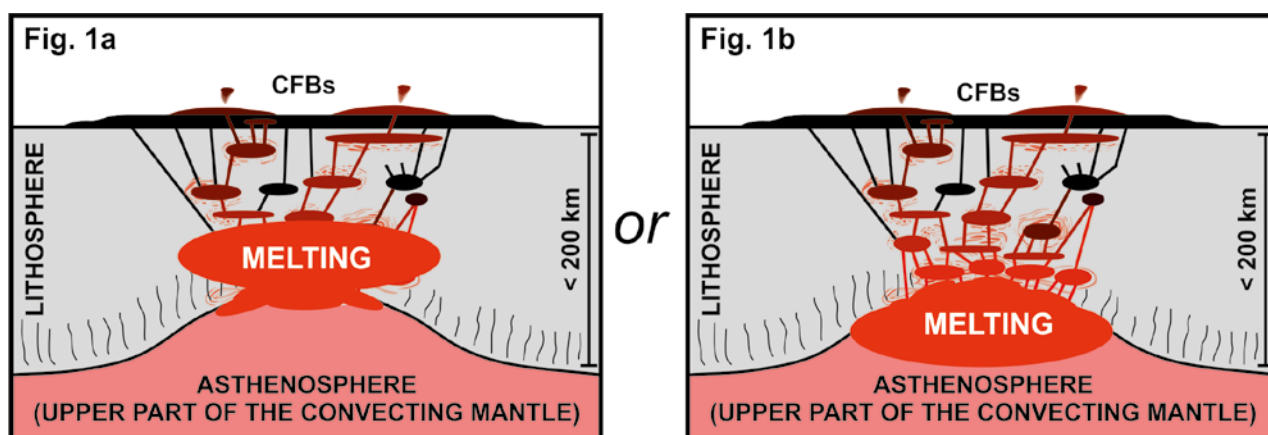


Fig. 1. Generation of CFB primary magmas in (a) lithospheric or (b) asthenospheric mantle.

explained simply by minor assimilation of such magmas with lithospheric materials (Fig. 1b). In fact, the overall contribution of the continental lithosphere to the Antarctic Karoo CFBs is probably less than 10% by volume.

Our results suggest that the importance of the continental lithosphere as a major CFB source contributor may well have been overestimated in several cases. Instead, the continental lithosphere may act as an effective insulator of the deeper mantle, and thus promote considerable build-up of heat and partial melting in the asthenospheric mantle beneath large continental masses (cf. Coltice et al. 2007).

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RAUTUVAARA: A CONCEPTUAL MODEL APPROACH TO ENVIRONMENTAL MANAGEMENT WITHIN THE HANNUKAINEN MINING PROJECT, FINLAND.

by

Peter Howett, Kirsti Korkka-Niemi and Veli-Pekka Salonen

*Department of Geosciences and Geography, P.O. Box 64,
00014 University of Helsinki, Finland
Peter.Howett@helsinki.fi*

This project is the product of joint cooperation between the company Northland Mines Oy and the University of Helsinki. It brings together the inevitability of an increased demand for resources with the importance of identifying and maintaining impacts on the surrounding geo-environment; one that is culturally, recreationally and biologically valuable and sensitive.

The overall aim of this project is to assess the suitability of the Rautuvaara site as a tailings facility, from an environmental perspective, which is a challenge because of the complex geological history and the unknown groundwater conditions. This means ensuring that the surface/subsurface architecture is recognised, in terms of groundwater, surface water, stratigraphy and morphology, and that the potential impacts from the operations are identified and managed.

To achieve this aim, a conceptual digitized model of the subsurface was produced, using the MOVE™ model, to project and analyse the different data sets collected. These data sets include: ground penetrating radar data (bedrock, groundwater and stratigraphy); borehole logs (bedrock); test pits (stratigraphy); groundwater piezometers (geochemistry, elevations); surface water analysis (elevations, geochemistry, discharge rates); infra-red mapping (discharge); digital elevation model data (DEM); and peat thickness measurements.

This 3D model provides a platform for identifying any potential contaminant pathways within the surface water and ground water domains, for which a flow model can then be applied to simulate potential contaminants from the tailings source. This is under way using MODFLOW.

The model, in its current form, suggests that both groundwater and surface water systems are contained within the Niesajoki valley, and that waters can effectively be managed in the south of the area. There is a narrow passage where the flow paths concentrate, therefore supporting the current planned site and ongoing water management facilities laid out by the company.

ISOTOPE GEOLOGY AND CRUSTAL GENESIS

by

Hannu Huhma, Yann Lahaye, Irmeli Mänttari and Hugh O'Brien

*Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland
E-mail: Hannu.huhma@gtk.fi*

Since the early 1960s, the isotope laboratory at GTK has provided key parameters for modelling the age and genesis of the Fennoscandian Shield. The principal dating method has been U-Pb TIMS on zircon, monazite and titanite, and essential genetic information has been obtained using Pb-Pb and Sm-Nd methods. However, conventional multi-grain TIMS data have only yielded average ages, which may lead to biased interpretations. Together with SIMS, spot analyses by laser ablation MC-ICPMS have been very successfully applied in recent years. According to the register of the laboratory, U-Pb data are currently available on ca. 1800 samples from Finland (TIMS 1500, SIMS 300, LA-MCICPMS 300). Sm-Nd isotope data have been obtained since the early 1980s from more than 2000 samples. The main picture from the isotope results was briefly summarized in Huhma et al. (2011), and for the Archaean crust in more detail by Huhma et al. (2012a,b).

The recent fruitful isotope research on crustal genesis has largely been a result of co-operation with ca. 50 geologists at GTK and various universities. The new results, mostly from LA-MC-ICPMS, have been outstanding and in some cases have confirmed the old estimates produced by TIMS (some examples in Huhma et al. 2012a). However, they have also frequently provided a completely new picture of the complex crustal history. Many problems had already earlier been solved by SIMS, but the powerful capacity of MC-ICPMS has now really made it possible to focus, for instance, on sedimentary rocks with complex detrital zircon populations. Representative examples of the recent results will be discussed.

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NEW THERMAL SHOCK RESISTANCE TEST METHOD FOR SOAPSTONE TYPES

by

Anne Huhta

*Department of Geosciences, Chemistry and Physic, P.O. Box 3000,
FI-90014 University of Oulu, Finland
E-mail: anne.huhta@oulu.fi*

The concept of 'soapstone' includes a large number of different soapstone types in which the mineral composition and the microstructure varies in several intensities and forms. In particular, the microstructural diversity of soapstones substantially affects their thermal properties. Obtaining more information on the thermal properties of soapstone types would enable the soapstone industry to manufacture more effective and environmentally friendly fireplaces.

Different features are required from the material used in various parts of the fireplace construction. Some components warm up by only a few tens of degrees, whereas other parts of fireplaces are exposed to combustion gases with a temperature of over 1000 °C. Soapstones are also in general much more resistant to thermal shock than most other natural stone materials. Because of these facts, the existing thermal shock resistance test methods developed for ceramic or natural stone materials are cannot as such be utilized for testing the capacity of soapstones to resist thermal shock. It was therefore necessary to develop a new thermal shock resistance test method that would be suitable for the purpose.

The existing methods measuring thermal shock resistance are based on heating-cooling-drying cycles, where the cooling is executed with a given medium. The most functional and appropriate method to determine the thermal shock resistance of soapstone was found to be heating of the material in an electric kiln and cooling of it in water. The test arrangements resemble those described in the standard DIN 51068. This was also a fundamental principle for the new thermal shock resistance test method developed for different soapstone types. In addition, due to the large number of mineral compositions and structural varieties of soapstone, the new method had to be constructed to cover the eligible and extensive temperature range instead of using just one instructed temperature. The goal is to standardize the new thermal shock resistance test method. A suitable test protocol will help the natural stone industry to use its products in the most suitable parts of the fireplaces or other constructions based on the thermal shock resistance test results.

On the basis of several thousands of test rounds, we can conclude that the microstructure of soapstone has the greatest significance in terms of thermal shock resistance. In general, the soapstone types that are homogeneous and fine grained

are more resistant to rapid temperature changes than those types that have more heterogeneous and coarse-grained structures. Intensive foliation was found to reduce the stress durability of soapstones exposed to rapid temperature changes, but weak crenulation cleavage usually strengthened it. The mineral composition of the stone material has also a very strong influence on the thermal shock resistance.

ASPHALT QUALITY EVALUATION WITH GPR AND THE EFFECT OF AGGREGATE PERMITTIVITY PROPERTIES

by

Eeva Huuskonen-Snicker¹, Terhi Pellinen¹, Martta-Kaisa Olkkonen² and Pekka Eskelinen²

¹ *Aalto University, Department of Civil and Environmental Engineering,
P.O. Box 12100, FI-00076 Aalto, Finland
E-mail: eeva.huuskonen-snicker@aalto.fi*

² *Aalto University, Department of Electrical Engineering and Automation,
P.O. Box 13340, FI-00076 Aalto, Finland*

Ground penetrating radar (GPR) is an electromagnetic method for studying and imaging subsurface features. It has been used in Finland since the 1980s for various civil engineering applications. One application of GPR is evaluation of the air void content of asphalt pavements. The air void content (%) is used as a quality measure of pavement condition for both new and old asphalt pavements (Saarenketo & Scullion 2000). GPR results can be presented as the bulk dielectric value of the pavement layer, and the air void content is then calculated from the dielectric value with the help of a calibration factor (Roimela 1998). Calibration is based on drilled cores from the pavement. However, the accuracy of the method is questionable, because changes in other factors apart from the air void content affect the bulk dielectric value of the asphalt layer. For example, changes in aggregates and their mineralogy lead to variations in the bulk dielectric value, since dielectric properties are dependent on the mineralogy of the rock (Nabighian 1988). This study is part of a research project aiming to investigate whether the existing GPR technique is accurate enough to be used as QC/QA tool in assessing the air void content of asphalt pavements. The project is funded by the Finnish Transport Agency.

Asphalt concrete is essentially a mix of bitumen and aggregates. The bulk dielectric value of the asphalt is affected by the dielectric properties of its components. According to Roimela (1998), the dielectric value is usually 4.5–6.5 for aggregates and 2.6–2.8 for bitumen. The dielectric value of the air is close to 1. In this study, the dielectric properties of rock samples are being measured in the high frequency range of 6–8 GHz in the laboratory with different methods. One method is the resonator method and another is based on the waveguide cutoff frequency principle. According to the first laboratory results, the dielectric values clearly differ for pegmatite and metavolcanic rock. These two types of rock samples were collected from a quarry located northwest of the city of Tampere in Finland. This particular quarry was chosen because crushed aggregates from

there are used for asphalt. The measured dielectric values will later be used in modelling the bulk dielectric value and the air void content of the asphalt.

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CORE-LEVEL STUDIES OF CALCITE AND DOLOMITE

by

Lauri Järvinen¹, Jarkko Leiro² and Markku Heinonen²

¹ *Geology and mineralogy, Department of Natural Sciences, Åbo Akademi University, Tuomiokirkkotori 1, FI-20500, Turku, Finland*

E-mail: lauri.jarvinen@abo.fi

² *Department of Physics and Astronomy University of Turku, Vesilinnantie 5, FI-20014, Turku, Finland*

Detailed knowledge of chemical bindings on the surface of a mineral is required for theoretical modelling of dissolution processes. For example, Stipp & Hochella (1991) used X-ray photoelectron spectroscopy (XPS) to study bonding environments on the calcite surface. Based on their results, Van Cappellen et al. (1993) created a surface complexation model that postulated the formation of two primary hydration species: $>\text{CO}_3\text{H}^0$ and $>\text{MeOH}^0$, where $>$ represents the mineral lattice and Me is the mineral cation. Our motivation has been to extend the knowledge of chemical bonding on the surfaces of calcite and dolomite.

Both conventional (XPS) and synchrotron-based XPS (SRXPS) were used to record spectra from (104) surfaces of calcite and dolomite that were cleaved in an ultra-high vacuum (UHV) to minimize surface contamination. Surface sensitivity was altered by changing either the measurement angle (XPS) or photon energy (SRXPS). An electron flood gun (Huchital & McKeon 1971) and a conductive mask (Moulder & Hook 1997) were used for charge neutralization.

We discovered that with successful neutralization, it is possible to use SRXPS to obtain peaks that are narrower than the ones obtained with XPS. Narrower peaks enable the elucidation of minor features and acquisition of more accurate results. Surface core-level shifts (SCLS) were found to be between 0.6 and 0.8 eV for Ca 2p (in calcite) and Mg 2p (in dolomite). Some of the satellites in the Ca 2p, C 1s and O 1s spectra of calcite have been interpreted to be bulk plasmons (i.e. collective excitations of electrons) because of their consistency with the density functional theory calculations of Medeiros et al. (2007). A peak in the C 1s spectrum of calcite that is usually attributed to carbide (CaC_2) is suggested to indicate beam-assisted interaction with the hydrocarbons found on the surface.

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CHARACTERISTICS OF THE NATURAL SORBENTS SIDERITE AND GOETHITE BASED ON THEIR GEOCHEMISTRY AND PROPERTIES

by

Hanna Junttila¹, Seppo Gehör² and Jaakko Rämö³

¹ *Department of Geosciences, Chemistry and Physics, P.O. Box 3000,
FI-90014 University of Oulu, Finland
Email: hanjuntt@cc.oulu.fi*

² *Oulu Mining School, P.O. Box 3000, FI-90014 University of Oulu, Finland*

³ *Thule Institute, P.O. Box 3000, FI-90014 University of Oulu, Finland*

The study of natural iron precipitates as adsorbents has focused on the siderite and goethite bog iron occurrences at Vihanti, Northern Ostrobothnia, Finland. The iron precipitates have formed in sandy-bottomed mires of Kukonharjunneva, Vaippanevea and Hukkannevea. Siderite (FeCO₃) forms in reducing freshwater sediments that are poor in sulphur and under neutral pH conditions. Goethite (FeO(OH)) forms from sedimentary iron minerals either by the weathering of iron compounds in crystalline bedrock or in sediments, or by precipitation from groundwater. Sorption studies were performed using batch tests in conditions with a selected pH, dosage of the sorbent and metal concentration of the solution. Twelve polished epoxy moulds were prepared from the filtered samples: 2 samples were made of the bulk mineral material, 8 were filtered from the Ni batches and 2 from the Cu batches.

The characteristics of Ni²⁺ and Cu²⁺ sorption were investigated using SEM-EDS and FE-SEM. The results so far indicate that siderite tends to either form an aggregate with unidentified silicate phases or to occur as porous accumulations with a minor concentration of silica precipitate. Small grains tend to take up more metals than the larger ones. The sorption capacity appears to be favoured by a high F content rather than a high Si content. The grain types can be separated according to their Fe vs. Si patterns: the siderite that forms an aggregate has linear Fe vs. Si patterns, while in the porous type the Fe vs. Si patterns are irregular.

Goethite is divided into three grain types based on their physicochemical properties. Grains of type 1 are plane at the surface and contain some phosphorus. Type 2 grains are more porous-looking and have an irregular surface. Type 3 grains are ferruginous peat flakes with iron (hydr)oxide precipitated on the surface. Types 2 and 3 were found to be the best sorbents for Ni and Cu.

EMODNET-GEOLOGY: A SEABED SUBSTRATE MAP FOR EUROPEAN MARINE AREAS

by

*Ulla Alanen¹, Anu Kaskela¹, Aarno Kotilainen¹, Alan Stevenson² and
EMODnet-Geology partners*

¹ *Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland
E-mail: anu.kaskela@gtk.fi*

² *British Geological Survey (BGS), Murchison House, West Mains Road,
Edinburgh, U.K.*

The European Union's (EU) Marine Strategy Framework Directive aims to achieve a good environmental status in its marine waters by 2020. At the moment, the lack of coherent data across Europe's seas makes pan-European marine assessments difficult. In order to execute effective marine management, spatial datasets covering all European marine areas are urgently needed. In response, the European Commission has established the European Marine Observation and Data Network (EMODnet) to assemble fragmented marine data products into publicly available datasets covering broad areas. The programme includes information on bathymetry, geology, seabed habitats, chemistry, biology, physics and human activities.

The marine departments of the geological surveys of Europe (through the Association of European Geological Surveys – Euro GeoSurveys) initiated the preparatory phase of the EMODnet-Geology Project (2009–2012) to compile and harmonize information from the Baltic Sea, Greater North Sea and Celtic Sea at the scale of 1:1 000 000 (<http://www.emodnet-geology.eu/>). The next phase of the EMODnet-Geology project will compile marine geological data from all European sea areas (e.g. the White Sea, Barents Sea, the Iberian Coast, the Mediterranean Sea within EU waters, and most of the Black Sea). The second 3-year phase of the project started in October 2013, involving 36 members from 31 countries.

The project will compile and harmonize the first complete seabed substrate map for the European seas. Seabed substrate data are important for geologists and also for others interested in marine sediments such as marine managers and habitat mappers. A more detailed (1:250 000) spatial data layer/map of the seabed substrate will be delivered in the EMODnet-Geology portal, replacing the existing 1:1 million scale map from the previous phase. In addition, a confidence assessment will be applied to all areas to identify the information that underpins the geological interpretations.

BENTHIC MARINE LANDSCAPE APPROACH PROVIDES SPATIAL KNOWLEDGE FOR MARINE SPATIAL PLANNING

by

*Anu Kaskela¹, Georgy Gogoberidze², Aarno Kotilainen¹, Igor Neevin³,
Marina Orlova⁴, Minna Ronkainen⁵, Heta Rousi⁵, Daria Ryabchuk³,
Vladimir Zhamoida and³Alexander Sergeev³*

¹ Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland
E-mail: anu.kaskela@gtk.fi

² Russian State Hydrometeorological University (RSHU), 98,
Malookhtinsky prospect, 195196, St. Petersburg, Russia

³ A.P. Karpinsky Russian Research Geological Institute (VSEGEI), 74,
Sredny prospect, 199106, St. Petersburg, Russia

⁴ Russia Zoological Institute RAS, Universitetskaya emb., 1, St. Petersburg,
199034, Russia

³ Finnish Environment Institute, Mechelininkatu 34a, FI-00251 Helsinki, Finland

Spatial knowledge that informs about marine nature values at the regional scale is important in the ecosystem-based management (ESBM) of marine areas. The benthic marine landscape approach aims to provide knowledge on the marine environment for marine spatial planning. It involves a combination of ecologically relevant hydrographical and geological spatial datasets that characterize potential broad-scale habitat distribution patterns. At best, benthic marine landscapes describe both the habitat distribution as well as the characteristics of the physical environment. The overall aim is to allocate conservation efforts to diversity and spaces instead of single species. Here, we will present the benthic marine landscapes of the Eastern Gulf of Finland at the scale of 1:500 000 and explain the underlying methods.

The Eastern Gulf of Finland is a transboundary marine area shared by Finland and Russia. The HELCOM Baltic Sea Action Plan, along with EU, Finnish and Russian legislation, requires both countries to identify and assess the state of the marine environment in the Gulf of Finland. There is a need for shared knowledge on the marine environment, its state, physical characteristics and the distribution of habitats, among others. In order to produce ecologically relevant marine landscapes, we have collected geological, hydrographical and biological data and studied their correlation with statistical methods.

The study is a part of an ENPI CBC-funded Finnish–Russian co-operation project, TOPCONS. The project aims to develop innovative spatial tools for the regional planning of the sea areas in the Gulf of Finland, the Baltic Sea. The objective is to create the methodology and tools to map the locations of the most diverse and sensitive marine areas. These will help society when striving for the

sustainable consolidation of human activities and marine nature values. The TOPCONS project has been implemented in close connection with the Finnish Inventory Programme for the Underwater Marine Environment (VELMU).

METHANE IN A DEEP CRYSTALLINE ROCK BIOSPHERE: THE OUTOKUMPU DEEP DRILL HOLE, FINLAND

by

*Riikka Kietäväinen¹, Lotta Purkamo², Lasse Ahonen¹, Malin Bomberg²,
Mari Nyssönen², Merja Itävaara² and Ilmo T. Kukkonen^{1,3}*

¹ *Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland
E-mail: riikka.kietavainen@gtk.fi*

² *Technical Research Centre of Finland VTT, Tietotie 2, FI-02044 VTT, Finland
E-mail: lotta.purkamo@vtt.fi*

³ *University of Helsinki, Department of Physics, P.O. Box 64, FI-00014 Helsinki,
Finland*

Most studies on deep hydrocarbons have dealt with sedimentary formations, because the large reservoirs of natural gas and oil make them economically important. However, methane is also found from fracture fluids in metamorphic and igneous rocks, such as those throughout the Outokumpu Deep Drill Hole, located in the Precambrian Fennoscandian shield in eastern Finland.

The origin of methane in Outokumpu is still not understood. While low-grade metamorphosed organogenic carbon substrates are ubiquitous in the sedimentary environments, in crystalline rocks graphite and carbonate carbon are the dominant forms available. Due to the wide variety of geological, chemical and biological processes that have an impact on the deep carbon cycle, no single indicator can be used to exclusively reveal the methane producing mechanisms present. However, a combination of compositional and isotopic analysis of methane and longer chained hydrocarbons, together with isotopic analysis of related compounds (e.g. dissolved inorganic carbon, hydrogen gas and water) and microbiological evidence, can help to resolve the pattern.

In the Outokumpu Deep Drill Hole, an extensive sampling campaign was conducted to retrieve water, gas and biomass samples covering the entire length of the drill hole down to 2480 m depth. The sampling methods comprised long-term (up to 2 months) pumping from packer-isolated fracture zones, pressurised sampling in the open drill hole and tube sampling.

Analysis of the dissolved gases revealed methane concentrations of up to 32 mmol l⁻¹, with minor amounts of ethane and propane also present. The isotopic composition of methane ranged from -13 to -40‰ VPDB for δ¹³C and from -136 to -404‰ VSMOW for δ²H. Microbiological results demonstrated that methanogenic as well as methanotrophic microbes were present in the drill hole water, as well as in the bedrock fracture fluids. However, these populations represented only a minor part of the whole microbial community, whereas heterotrophic

microbes possibly utilizing other small organic molecules as a carbon source dominated in the community.

Our preliminary results suggest that several sources of methane exist in the crystalline bedrock of Outokumpu. These include both biogenic and abiogenic processes, the latter being more important at greater depths. Furthermore, deep bedrock-dwelling microbes can either produce or consume methane, depending on the environmental conditions, but heterotrophic metabolism appears to be more frequent in the Outokumpu deep biosphere.

USE OF MODERN 3D MODELLING IN RESEARCH ON THE DUCTILE AND BRITTLE STRUCTURAL EVOLUTION OF VEKARA ISLAND, SW FINLAND

by

Jussi Kinnunen¹, Timo Kilpeläinen¹ and Pietari Skyttä^{1,2}

¹ *University of Turku, Department of Geography and Geology, FI-20014 Turun yliopisto*

² *University of Helsinki, Department of Geosciences and Geography, P.O. Box 64, FI-00014 Helsinki*

E-mail: jpkinn@utu.fi, timo.kilpelainen@utu.fi, pietari.skytta@utu.fi

Vekara is an island located along the western coastal region of the Bothnian Bay, approximately 25 km from Uusikaupunki and the mainland. About half of the island (136 ha) is composed of well-exposed bedrock with distinctively abundant deformation structures (Suominen et al. 1994, 2006, Kilpeläinen 2009). These structures, both ductile and brittle, in Vekara and the nearby islands are one of the subjects of this research. An important part of this investigation is the implementation of up-to-date digital mapping techniques and modelling applications. The background data already imported into the GIS software comprise a topographic database, orthophotographs, a digital elevation model at 2 m resolution from the National Land Survey of Finland, sea floor elevation contours and depth-sounding points from the Finnish Transport Agency, and bedrock and geophysical maps from the Geological Survey of Finland.

To enhance the digital mapping of the island, 1) new aerial photographs will be taken with the equipment consisting of a helium balloon, a Garmin action camera and an iPad as a remote controller. An eligible accuracy of aerial photography is correspondence between 1 cm and 1 pixel. This resolution will allow the recognition of structures from the images and, hence, field mapping of structures directly onto the rectified and georeferenced orthophoto raster mosaic without the need for constant GPS positioning. 2) Terrestrial laser scanning will be implemented in the most interesting parts of the research area. The most hunted properties of laser scanning in geological applications are the ability to produce extraordinarily accurate (<1 cm) digital elevation models (DEM) with photographed texture for 3D rendering and to distinguish different rock types and structures. Furthermore, we aim at investigating the usefulness of laser scanning in supporting bedrock mapping, e.g. in the recognition of lithological units. Obvious matters in these are the dependence on resolution and signal processing, i.e. it is strongly based on the apparatus technique. 3) Finally, data integration and structural modelling of both the ductile and brittle evolution of the island will be carried out in the MOVETM software package (Midland Valley Exploration Ltd.).

This research was initiated in the autumn 2013. The first field trip is planned for April to May 2014 and fieldwork will start in the summer of 2014. The first preliminary results will be available after the summer of 2014.

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BALTICA DURING THE NEOPROTEROZOIC AND CAMBRIAN: A PALEOMAGNETIC STUDY ON HAILUOTO SEDIMENTS

by

Robert Klein¹ and Satu Mertanen²

¹ *University of Helsinki (Department of Physics), P.O. Box 33, 00014 University of Helsinki, Finland*

E-mail: robert.klein@helsinki.fi

² *Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland*

The Late Neoproterozoic to Early Cambrian is a fascinating time interval in Earth's history. It includes global scale glaciations (Hoffmand & Schrag 2002), the break-up of the supercontinent Rodinia (e.g. Bingen et al. 1998) and the diversification of early life (Knoll 1992). Reconstructing the paleogeography is crucial to understand these conditions.

The bulk of the paleomagnetic data for Baltica and Laurentia show the co-existence of two magnetization components very close in age– one shallowly and the other steeply inclined. Both components are thought to be primary magnetizations, which suggest rapid changes in the position of continents. Explanations for this phenomenon include true polar wander, high plate velocities and alternation between axial and equatorial configurations (Abrajevitch & Van der Voo 2010).

In our study we present preliminary results from an ongoing paleomagnetic study on sedimentary rocks from a drill core in Hailuoto, Northern Ostrobothnia. Based on the fossil record, the Hailuoto sediment have an age of ca.650-570 Ma (Tynni & Donner 1980) .The objective of this study is to obtain a new Neoproterozoic pole to better understand the movement of Baltica during this time.

We have isolated a characteristic remanent magnetization (ChRM) for the Hailuoto sediments, using thermal and alternating field demagnetization methods. This magnetic component is of dual polarity; the normal (N) and reversed (R) magnetic directions pass the reversal test of McFadden and McElhinny (1990). A preliminary conglomerate test suggests that the ChRM can be a primary component formed during the deposition and compaction of the sediment.

The combined (N and R) component – $D = 153.4^\circ$; $I = -44.6^\circ$; $\alpha_{95} = 7^\circ$; $k = 16.7$ – yields a paleomagnetic pole of $Plat = -48.6^\circ$, $Plon = 62.3^\circ$, $A95 = 7.9^\circ$, $K = 13.3$. This is distinct from other Neoproterozoic poles for Baltica. A discussion on these results will be presented in the poster.

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IODP EXPEDITION 347: STRATIGRAPHIC CORRELATION TOWARDS AN INTEGRATED BALTIC SEA BASIN STRATIGRAPHY

by

*Aarno Kotilainen¹, Outi Hyttinen², Thomas Andrén³, Carol Cotterill⁴,
Walter Hale⁵, and the IODP Expedition 347 Science Party⁶*

¹ Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland

² Department of Geosciences and Geography, P.O. Box 64, 00014 University of Helsinki, Finland,

³ Södertörn University, School of Life Sciences, 141 89 Huddinge, Sweden,

⁴ British Geological Survey, Murchison House, West Mains Road, Edinburgh UK.

⁵ IODP Bremen Core Repository (BCR), Universität Bremen, Leobener Str, D-28359 Bremen, Germany,

⁶ Integrated Ocean Discovery Program (IODP)

During International Ocean Discovery Program (IODP) Expedition 347 – “Baltic Sea Palaeoenvironment” – a total of 1623 metres of sediment cores from 9 sites (M0059–M0067) were successfully recovered. These sites were located in different Baltic Sea sub-basins, potentially yielding high-resolution data from Lille Belt, the Kattegat, Ångermanälven estuary, Landsort Deep, Hanö Basin and Bornholm Basin. The expedition used a geotechnical drillship, the Greatship Manisha, equipped with a Geoquip Marine coring rig. The aim of the expedition was to produce new information on the history of the Baltic Sea and its response to climate change during the last glacial cycle. Some preliminary results on stratigraphic correlation and splice results for the expedition are presented here. This information provides a working basis for stratigraphical and high-resolution palaeoenvironmental studies in the area.

Stratigraphic correlation consisted of the following: (1) ensuring the maximum core recovery on-site and (2) seismic-core (lithology) correlation. Correlation between seismic profiles and cores used a simple estimation of sediment type vs. sound velocity. The acquired depth was tested by comparison with the Multi-Sensor Core Logger (MSCL) logs (density and magnetic susceptibility), natural gamma and major core surfaces. The integration of data required interpretation of sedimentary units, seismic velocity values measured for each unit and comparisons with physical property boundaries.

To obtain a continuous sedimentary record, multiple adjacent holes were cored with an offset in depth of 0.5–1.5 m between cores from different holes. The continuity of recovery was assessed by generating composite sections that align prominent features in physical property data from adjacent holes. With the information gained from Fast Track MSCL data, it was possible to adjust the coring

plan on-site to ensure that intervals missing in previous cores could be recovered from an adjacent hole.

MSCL physical property measurements were correlated (using Correlator software) to align similar features in physical (geological) properties between different holes, which resulted in a composite depth (mcd) scale. When possible, the mcd scale was checked against downhole logging data. Splice records were generated by selecting sections from adjacent holes to avoid core gaps or disturbed sediment, resulting in a continuous record that formed the basis for onshore sediment sampling and post-cruise research.

U-PB ZIRCON AND MONAZITE AGES OF GRANITOID-XENOLITH PAIRS IN THE VAASA COMPLEX, WESTERN FINLAND: A PROGRESS REPORT

by

Anna K. Kotilainen¹, Irmeli Mänttari² and O. Tapani Rämö¹

¹ *Department of Geosciences and Geography, P. O. Box 64, 00014-University of Helsinki, Finland*

E-mail: anna.kotilainen@helsinki.fi

² *Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland*

The Vaasa complex in western Finland hosts a sequence of high-grade metamorphic rocks and granites formed by crustal anatexis during the culmination of the ~1.9 Ga Svecofennian orogeny. The complex consists of a ~8000-km² granitoid batholith (the Vaasa batholith, Mäkitie et al. 2012), surrounding diatexitic and metatexitic migmatites as well as the metasedimentary rocks of the Bothnia Belt. The contact between the batholith and the migmatites is gradual and the metamorphic grade of the Bothnia Belt metasediments decreases away from the batholith. The bulk of the Vaasa batholith consists of garnet-bearing K-feldspar-megacrystic and even-grained granodiorites, while smaller bodies of pyroxene granitoids (tonalite, granodiorite) and biotite granites are also found. The granitic rocks frequently contain xenoliths of metasedimentary rocks as well as calcareous concretions.

We report the age results from an ongoing study focused on the geochronology and P-T evolution of granitoid-xenolith pairs in the Vaasa batholith. Zircons from six granitoid-xenolith pairs from the batholith were dated using the U-Pb LA-MC-ICPMS method. The granitoid samples indicate crystallization ages of 1.88–1.87 Ga, whereas inherited zircon cores and grains are typically 2.05–1.9 Ga; Archaean ages from 2.9 to 2.5 Ga were also detected. Three of the xenoliths examined yielded maximum sedimentation ages of ~1.93 Ga and have the main detrital zircon age population in the 2.02–1.92 Ga range. In addition, Archaean and ~2.1 Ga zircon ages are present. The granitoid hosts of the three xenoliths show similar inheritance patterns and thus imply derivation of the granitoids from metasedimentary sources, akin to the xenoliths. U-Pb ID-TIMS monazite ages from the granitoid and xenoliths are 1.87–1.86 Ga and presumably date the metamorphic culmination of the Svecofennian orogeny in the western-central part of the Svecofennian orogeny.

New age results from early 2014 (still in progress) for the Vaasa batholith will also be presented.

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THE LANSKERI RHYOLITE DYKE, WIBORG BATHOLITH, EASTERN GULF OF FINLAND: PRELIMINARY OBSERVATIONS ON STRUCTURE AND PETROGRAPHY

by

Kirsi M. Larjamo¹, O. Tapani Rämö¹, Sanni T. Turunen¹ and Pentti S. Pitkänen²

¹ Department of Geosciences and Geography, P.O. Box 64, 00014 University of Helsinki, Finland

E-mail: kirsi.larjamo@helsinki.fi

² Isoympyräkatu 38 12 B, 49400 Hamina, Finland

The mid-Proterozoic locus classicus Wiborg rapakivi granite batholith in south-eastern Finland and its vicinity includes a wide variety of granitic rock types that were mainly emplaced at 1645–1625 Ma. Most of the currently exposed part of the batholith consists of coarse plutonic rocks loaded with alkali feldspar megacrysts. In a few locations within the batholith, and more abundantly on its northern flank, high-level dyke rocks are found. These were crystallized from rapakivi granite magmas emplaced in fractures formed in the batholith after a period of erosion. We have studied one of these dykes in the southern, offshore part of the batholith on Lanskeri Island. The island is 1 km long and 100–250 m wide and consist of wiborgite. Along the northeastern shore, a vertical, northwest-striking,

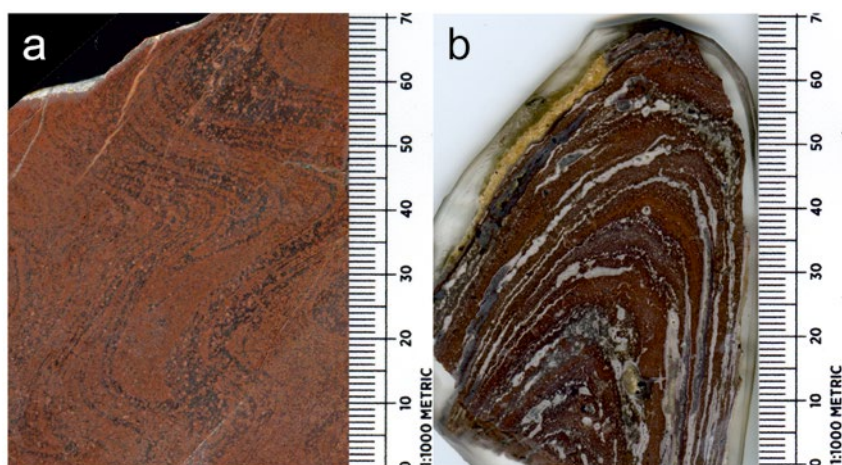


Fig. 1 a) A polished slab of flow-folded, spherulitic rhyolite from the northwestern part of the mid-Proterozoic Lanskeri dyke exposed along the northeastern shoreline of Lanskeri Island in the eastern Gulf of Finland archipelago. b) A polished slab of a flow-folded rhyolite from the interior part of a ~13-m-thick, Miocene (10 Ma) rhyolite flow in Dublin Hills, eastern Death Valley, south-eastern California.

3- to 15-m-wide rhyolite dyke, exposed for about 120 m along strike by the waterfront and continuing underwater for at least 150 m to the southeast, is found cutting a sparsely megacrystic wiborgite and equigranular biotite granite. The margins of the dyke are aphanitic, striped with planar spherulite textures, and devoid of phenocrysts. Short-prismatic (volcanic) quartz microphenocrysts and corroded, tabular sanidine phenocrysts (length ≤ 1 cm) along with rare plagioclase phenocrysts are found in the central part of the dyke. In the northwestern, 3-m-wide part of the dyke, conspicuous flow fold structures are present (Fig. 1a). They are marked by spherulites and mm-scale colour bands that form cm-scale plastic folds; these are quite reminiscent of flow folds observed in the interior parts of young silicic lava flows (Fig. 1b). Now completely devitrified, this segment of the Lanskeri dyke probably flowed as a near-liquidus silicic melt through the fracture in wiborgite and solidified, strongly undercooled, as rhyolitic glass in close proximity to the contemporaneous erosional surface. Autochthonous, positively volcanic rocks (silicic lavas and fragmentary rocks, basalts) associated with the Wiborg batholith are found on Suursaari Island, about 40 km southwest of Lanskeri. The (almost subareal) Lanskeri dyke will be an important piercing in the study of the supracrustal evolution of the Wiborg magma system.

CONNECTIONS ACROSS THE BALTIC SEA: RECENT ARCHAEOLOGICAL RESEARCH ON DIFFERENT PERIODS DURING THE HOLOCENE

by

Mika T. Lavento

*Department of Philosophy, History, Culture and Art Studies, P.O. Box 59
(Unioninkatu 38F), 00014 University of Helsinki
E-mail: mika.lavento@helsinki.fi, tel: +358-9-191 23578*

Research on the Baltic Sea with its coasts and archipelago has been important since the beginning of Finnish archaeology. Many cultural phenomena have evidently spread through the sea during the entire Holocene, and in the early decades of the 20th century, archaeologists were already able to connect archaeological sites with the shore levels, for which it was possible to give relative datings. The data collected together with geologists enabled the construction of typologies for the different material groups. A constructive chronology was created that could be used in all parts of the Baltic Sea.

From the 1970s, research interests in archaeology changed and the question framing covered micro- and macrofossil analysis. In addition to understanding the history of the environment and the development of the Baltic Sea, interest also focused on understanding the history of human habitation, fishing, hunting and agriculture. All these questions were approached by the analysis of human and animal bones. The use of these methods has continued, and several archaeologists and sometimes also geologists have specialized in these topics since the turn of the 2000s.

Since the 1990s, more emphasis has been placed on locating new sites by the seashore, as well as in the archipelago. Together with the new sites, their environment has also been at the centre of interest. Several projects have involved fieldwork carried out together with geologists, which has produced multifaceted data to address the questions posed in the projects.

Maritime and marine archaeology are an essential part of research into the past of the Baltic Sea. Because the preservation of shipwrecks is often good, the number of preserved wooden ships is considerable. The study of wrecks starts with diving and all the associated methods. Together with these, marine archaeologists rely on a large number of geoscientific approaches for dating and studying the objects inside wrecks. A variety of methods are also utilized when studying sedimentation, preservation conditions and currents around the locations of finds.

Archaeologists are conducting interdisciplinary and international research together with geoscientists in Finland and other countries in the Baltic Sea region. What has been done and what is currently the focus of attention will be discussed and illustrated through examples in this presentation.

IN SITU STRONTIUM AND SULFUR ISOTOPE STUDY OF THE NI-CU-(PGE) ORE-BEARING KEVITSA INTRUSION, NORTHERN FINLAND

by

*Kirsi Luolavirta¹, Eero Hanski¹, Wolfgang Maier², Hugh O'Brien³, Yann Lahaye³,
Frank Santaguida⁴ and Teemu Voipio⁴*

¹ Department of Geosciences, P.O. Box 3000, FI 90014 University of Oulu, Finland
E-mail: kirsi.luolavirta@oulu.fi

² The School of Earth and Ocean Sciences, Cardiff University, Main Building,
Park Place, Cardiff CF10 3AT, United Kingdom

³ Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland

⁴ First Quantum Minerals Ltd, FinnEx, Sodankylä, Finland

The 2.05 Ga mafic-ultramafic Kevitsa intrusion is located in Central Lapland, ~40 km north of Sodankylä. The ~1-km-thick ultramafic lower part of the intrusion is composed of pyroxenites, olivine pyroxenites and discontinuous interlayer(s) of plagioclase-bearing (olivine) websterites. Olivine pyroxenites are the dominant host rock of a large, disseminated Ni-Cu-(PGE) deposit. The mineralization can be divided into two economic end-member ore types: 1) the regular ore with Ni/Cu <1 and 2) the Ni-PGE ore with Ni/Cu commonly >5. Metal-poor false ore and contact mineralization also exist, which are uneconomic.

For this study, a representative drill core from the current resource area was sampled for mineral chemistry and *in situ* Sr and S isotope analyses by LA-ICP-MS. The large geochemical dataset provided by the Kevitsa mine was also utilized in order to constrain the origin of the internal lithological and geochemical stratigraphy of the intrusion, including potential multiple episodes of magma replenishment, and to assess the ore-forming processes.

Mineral compositions of olivine (Fo% 75–89), pyroxenes (Cpx Mg# 82–91, Opx Mg# 77–87) and intercumulus plagioclase (An% 28–63) vary as a function of depth, and the observed reversals correlate with selected trace element abundances. The lowest Fo% in olivine and lowest Mg# in pyroxenes were measured from plagioclase-bearing (ol) websterites, but the An% content of plagioclase is dominantly higher in these rocks compared to olivine pyroxenites. $^{87}\text{Sr}/^{86}\text{Sr}_{(i)}$ values are highly radiogenic, ranging from 0.705 to 0.711. The highest $^{87}\text{Sr}/^{86}\text{Sr}_{(i)}$ values were measured from Ni-PGE ore samples (0.709–0.711), while samples from the regular ore yielded lower values of 0.705–0.707. The marked difference in $^{87}\text{Sr}/^{86}\text{Sr}_{(i)}$ values between the different ore types is consistent with previous studies indicating isotopic differences between ore types (Hanski et al. 1997). $^{87}\text{Sr}/^{86}\text{Sr}_{(i)}$ values in samples of plagioclase-bearing (ol) websterite record the widest variation within a single sample (0.706–0.708) and also record grain-scale

isotopic heterogeneities. $\delta^{34}\text{S}$ values range from -0.4 up to 12.4‰ and vary with depth. $\delta^{34}\text{S}$ values show no correlation with $^{87}\text{Sr}/^{86}\text{Sr}_{(i)}$ values. Ore-bearing samples yielded $\delta^{34}\text{S}$ values of ~4 and ~2.7‰ for regular and Ni-PGE ore, respectively.

The isotope data together with mineral and whole-rock chemistry demonstrate that the mineralized part of the intrusion represents a dynamic system with multiple emplacements of variably contaminated silicate magma and sulphide liquid. Based on the isotope data, the origin of the plagioclase-bearing (ol) websterite layer(s) cannot be explained by simple differentiation processes.

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MODELLING IMPACTS OF CLIMATE CHANGE AND SEA LEVEL RISE ON GROUNDWATER RESOURCES OF A SHALLOW COASTAL AQUIFER IN HANKO, SOUTH FINLAND

by

Samrit Luoma¹ and Jarkko Okkonen²

¹ *Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland
E-mail: samrit.luoma@gtk.fi*

² *Geological Survey of Finland. P.O. Box 97, FI-67101, Kokkola, Finland.*

A three-dimensional transient groundwater flow model, MODFLOW 2005, coupled with the unsaturated zone flow UZF1 Package and models of the initial infiltration water received from snow and potential evapotranspiration, was utilized to assess the impact of climate change and sea level rise on groundwater resources of a shallow unconfined low-lying coastal aquifer in Hanko, south Finland. The A1B and B1 climate and sea level rise scenarios were used for two periods, 2021–2050 and 2071–2100, and were compared with the present data from 1971–2000. The results not only provide knowledge on the impacts on groundwater resources, but also information on surface leakage, which is important for a permeable shallow low-lying aquifer, where the groundwater table is close to the surface and groundwater recharge has a direct effect on the groundwater level.

Groundwater simulations indicate 24% to 33% increases in recharge compared to the present for all scenarios except B1 (2021–2050), in which recharge decreases by 14% from the present due to lower precipitation. A change in the recharge pattern is predicted during 2071–2100 in both scenarios, with no peak recharge during late spring, but recharge occurring earlier during the winter and a month earlier during the autumn. The warmer future climate, especially during the winter and early spring, could cause more snowmelt and reduce soil frost, which would further increase recharge to the aquifer. A continued increase in evapotranspiration during late spring and a reduction in precipitation would cause a reduction in recharge during the summer. The impacts of climate change on groundwater recharge are more significant when considering the seasonal variations, as flooding will be induced by surface overflow during the winter and early spring, and drought during the summer. Predicted decreases in water storage of up to 17.8% from the present indicate a critical potential for water shortage in Hanko. An increase in the sea level to 0.51 m a.s.l. by the end of 2100 would cause some parts of the aquifer be under seawater, which could pose a contamination risk for groundwater quality due to seawater intrusion. A rise in the sea level together with an increase in groundwater recharge would cause an increase in

the groundwater level and consequently contribute to more surface leakage and potential flood-prone areas around the low-lying aquifer.

LONG-TERM CHANGES IN AQUATIC INVERTEBRATE COMMUNITIES IN A BIRD-IMPACTED HIGH ARCTIC POND

by

Tomi P. Luoto¹, Mimmi Oksman^{1,2} and Antti E. K. Ojala³

¹ Department of Geosciences and Geography, P.O. Box 64,
00014 University of Helsinki, Finland
E-mail: tomi.luoto@helsinki.fi

² Geological Survey of Denmark and Greenland, 1350 København, Denmark

³ Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland

A 100-cm sediment core from bird-impacted Lake Fugledammen in Hornsund, Svalbard (77°N), was examined for fossil invertebrate communities and geochemistry. The aim of the palaeolimnological study was to track long-term changes in the community structure, biodiversity, food web and controls of biological production in this extremely sensitive landscape. The lowermost (oldest) part of the sediment profile was characterized by dominance of the chydorid cladocerans (Crustacea: Cladocera) *Chydorus sphaericus*-type and *Acroperus harpae*, which are common littoral scrapers/filterers, while the chironomid (Diptera: Chironomidae) community was dominated by vegetation-associated *Psectrocladius sordidellus*-type. In the mid-part of the sediment sequence, the above-mentioned taxa decreased in abundance and the invertebrate community became less diverse. The most abundant taxa in the mid-core were the predacious tadpole shrimp *Lepidurus arcticus* (Notostraca), which is a keystone species in High Arctic ponds and a 'living fossil'. Of the cladocerans, *Daphnia pulex*-type dominated and another planktonic filter-feeder, *Bosmina longirostris*, also had a briefly successful period in the mid-part of the sediment core. The chironomid community was dominated by the collector-gatherers *Orthocladus consobrinus*-type, *Hydrobaenus lugubris*-type and *Limnophyes*. In the upper part of the sediment core, invertebrate diversity further decreased. The cladoceran community was dominated by *D. pulex*-type and the chironomid community by *O. consobrinus*-type. The increase in *Daphnia* is typical in Arctic ponds in Svalbard, where nutrient loading has increased due to growing bird populations in the catchment. The decreases in vegetation-associated invertebrates and biodiversity suggest that turbidity has increased and oxygen availability decreased in the lake. These changes are concurrent with recent climate warming, suggesting that the increased air temperatures have indirectly influenced the aquatic community through changes in bird population size and the length of the open-water season by increasing biological productivity. Changes are also apparent in the functional diversity of the lake, impacting on ecosystem functioning and biogeochemical cycles.

ANALYSIS OF AMBIENT SEISMIC NOISE USING MULTICHANNEL 3-COMPONENT SEISMIC EQUIPMENT: RESULTS OF TEST MEASUREMENTS AT PYHÄJÄRVI AND HAUKIPUDAS

by

Jouni Nevalainen, Elena Kozlovskaya and Janne Narkilahti

*Sodankylä Geophysical Observatory, Laboratory of Applied Seismology,
University of Oulu, Finland, Pentti Käiteran katu 1, 90570 Oulu
E-mail: jouni.nevalainen@oulu.fi*

The goal of our study was to test the ability of a new type of multichannel seismic system to record ambient seismic noise in a wide frequency range. Currently, ambient seismic noise is used in a number of “passive” seismic methods aiming to obtain the 2D and 3D structure of the subsurface. In these methods, seismic vibrations caused by wind, ocean waves or anthropogenic activity are used as a source of seismic energy. The ambient seismic noise was recorded using a Sercel (2014) UNITE multichannel seismic system consisting of forty pairs of Sercel wirelessly controlled RAU ex-D dataloggers and 3-component DSU3-SA accelerometer sensors based on MEMS (Micro-machined Electro-Mechanical Sensor) technology. For testing, we selected sites at Annalankangas, Oulu, and at Pyhäjärvi around the Pyhäsalmi mine. The bedrock topography at the Annalankangas test site has been investigated and presented in a Master’s thesis (Nevalainen 2013), so the site is ideal for both testing the new equipment (sandy soil above bedrock) and applying ambient seismic noise methods for subsurface modelling. Measurements of ground vibrations at Annalankangas have been conducted overnight along a single line. The data have been subjected to various spectral analyses, including frequency content examination and H/V analysis (Nakamura 1989). Further testing will be carried out at the same site in the near future, with stations in an array orientation to apply ambient noise seismic tomography (Shapiro et al. 2005). These array data will be used to map the bedrock surface topography and near-surface velocity structure.

A set of seismic measurements at Pyhäjärvi using the Sercel UNITE system and the Nanometrics Trillium Compact, consisting of more traditional electromagnetic force-balanced broadband 3-component seismometers, has allowed direct comparison of the equipment, as the measurements took place in same locations and with same sample rate. For this data set, spectral analysis was conducted to compare the equipment, and ambient seismic noise tomography will also be applied to explore the subsurface velocity structure as a “permanent” noise source (engines) is located in Pyhäsalmi mine.

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SPECTRAL ABSORBANCE OF FOSSIL CLADOCERAN CARAPACES AS A NEW METHOD FOR INFERRING LONG-TERM AQUATIC UV EXPOSURE

by

Liisa Nevalainen^{1,2} and Milla Rautio³

¹ Department of Geosciences and Geography, P.O. Box 64,
00014 University of Helsinki, Finland

² Department of Environmental Sciences, University of Helsinki,
P.O. Box 65 (Viikinkaari 1) 00014 University of Helsinki Finland
E-mail: liisa.nevalainen@helsinki.fi

³ Département des Sciences Fondamentales and Centre for Northern Studies (CEN),
Université du Québec à Chicoutimi, Canada

We developed a method for measuring fossil cladoceran (Branchiopoda) carapace absorbance to infer past ultraviolet radiation (UV) exposure in lakes under presumptions that cladocerans synthesize UV-protective melanin pigment, the pigment is preserved in sedimentary cladoceran remains, and it can be used to infer past underwater light and UV regimes. We extracted large-sized cladoceran carapaces (*Alona* spp.) from sediment cores of two environmentally divergent lakes: a humic northern boreal lake in Finland and a clear-water mountain lake in the Austrian Alps. We measured the carapace absorbance with a spectrophotometer under visible light and UV wavelengths using an adapter that was designed to hold the microfossils. When compared to synthetic melanin, the shapes of absorbance spectra in the 700–280 nm range suggested that the fossil carapaces contained melanin. The carapace UV absorbance throughout the cores was significantly higher in the alpine lake than in the boreal lake, reflecting differences between the sites in the general underwater UV and optical environments. In addition, carapace absorbance was significantly higher during the Little Ice Age (LIA) than during pre- or post-LIA periods in both lakes. In the alpine lake, this was most likely a response to increased underwater UV induced by reduced primary production and a more transparent water column during the cold summers of the LIA, whereas a reduced input of carbon compounds from the catchment due to elongated permafrost and ice-cover periods probably induced higher water transparency in the boreal lake during the cold LIA.

The method was further tested on other cladoceran taxa (*Chydorus* spp. and *Daphnia* spp.) in high Arctic lacustrine sediment cores from Svalbard and northern Canada. Absorbance spectra of *Chydorus* carapaces indicated that the remains of this taxon were also melanized. Absorbance spectra of *Daphnia* ephippia showed clear absorbance maxima under UV wavelengths, indicating extremely high melanization. The absorbance values of *Daphnia* ephippia additionally

increased approximately between 450–400 nm, suggesting that other photoprotective pigments (e.g. carotenoids) may be preserved in fossil *Daphnia* ephippia. These could provide a palaeoindicator of primary producers and the feeding habits *Daphnia* in different populations and through time, because carotenoids accumulate in the animals from their food sources. The stratigraphic absorbance measurements in the high Arctic cores indicated that the past aquatic communities experienced altered UV regimes throughout the time span of the sediment cores. We presume that these changes were caused by lake-specific environmental controllers such as changes in dissolved organic carbon compounds, bird-driven nutrient enrichment, and altered ice-cover periods and benthic UV refugia. However, increased UV irradiance associated with recent ozone depletion and climate warming in the Arctic should also be considered as important environmental drivers for the recent changes. We conclude that the introduced method can be used for underwater UV and palaeo-optical inferences, and that it allows assessments of long-term aquatic UV responses in northern and alpine lakes.

GEOCHEMICAL MODELLING AS A TOOL FOR MONITORING AN ARTIFICIAL GROUNDWATER RECHARGE PROCESS

by

Paula Niinikoski¹, Sami Saraperä², Nina Hendriksson³ and Juha Karhu¹

¹ *Department of Geosciences and Geography, University of Helsinki, Finland,
P.O. Box 64, 00014 University of Helsinki*

E-mail: paula.niinikoski@helsinki.fi

² *Turun Seudun Vesi Oy, Maariankatu 1, 20100 Turku, Finland*

³ *Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland*

Artificial recharge (AR) is a widely used method in purifying water for household use in areas with glaciogenic formations suitable for water supply (Kortelainen & Karhu 2006). The main purpose of AR is to reduce the content of dissolved organic carbon (DOC) to the drinking water level. At Virttaankangas in southwestern Finland, an artificial recharge plant has been planned to meet the water demand of the Turku region with approximately 285 000 inhabitants (Artimo et al. 2003). The infiltrated water is derived from the Kokemäenjoki River, 30 km north of the AR plant. Operation of the plant started with a one-year test period in 2010 and 2011. During the test phase, the infiltrated water volume was 20 000 m³ per day, but after the startup of the plant the infiltration volume was gradually raised to the full production capacity of 62 000 m³ per day in December 2013. In the AR plant area, the recharged river water mostly replaces the natural groundwater, recharging approximately 5000 m³ per day. Groundwater flow modelling results are used to control the flow directions and velocities between the infiltration and well areas.

Oxidative decomposition due to microbial activity is one of the principal processes reducing the concentration of DOC in recharged water (Kortelainen & Karhu 2006). This can be monitored by examining the isotopic composition of dissolved inorganic carbon (DIC) in the artificially recharged groundwater (Kortelainen & Karhu 2006). The degradation of DOC has an acidifying effect on the composition of water. Higher acidity will increase the dissolution of calcite minerals present in the glaciofluvial deposit at Virttaankangas. Because the calcite reservoir in the aquifer deposit will be consumed, it is essential to know for how long the natural alkalization will be effective. The geochemical modelling program PhreeqC was applied to estimate the extent of DOC decomposition and the consumption of the calcite reservoir. Unlike other AR plants in Finland, model calculations showed no evidence of oxidative decomposition of DOC in the artificial recharge system at Virttaankangas. The observed decrease in DOC concentrations could be explained to result from mixing with natural ground-

water. Accordingly, the estimated consumption of calcite was also minimal. Even in the case of complete oxidative decomposition of DOC, the amount of calcite in the aquifer would be sufficient for the alkalization of the recharged water for the lifespan of the AR plant.

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MID- AND LATE-HOLOCENE PALEOCEANOGRAPHIC CHANGES IN SEA SURFACE TEMPERATURE AND SEA ICE IN ISVIKA BAY, NORDAUSTLANDET, SVALBARD

by

Mimmi Oksman^{1,2}, Arto Miettinen¹, Veli-Pekka Salonen¹ and Antti E.K. Ojala³

¹ University of Helsinki, P.O. Box 64, FI-00014 Helsinki, Finland

E-mail: mimmi.oksman@helsinki.fi

² Geological Survey of Denmark and Greenland (GEUS), 1350 København,
Denmark

³ Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland

A 250-cm-long marine sediment core from Isvika Bay (79°57.43'N; 18°34.24E) was studied for palaeoceanographical conditions, such as the sea surface temperature (SST) and sea ice concentration, during the Holocene. Holocene climate fluctuation in Northern Svalbard is poorly understood, and most of the previous studies have focused on Western Svalbard. The palaeo-SSTs and sea ice concentrations are crucial parameters for atmospheric and ocean models assessing future climate change. Moreover, sea ice is the key component in the Arctic climate system, since it has a major effect on the albedo and exchanges of heat and gases between the ocean and atmosphere.

Marine planktonic fossil diatom assemblages were used to investigate August sea surface temperatures (aSSTs) and sea ice variability. The diatom data were converted to quantitative aSSTs by using the weighted averaging partial least squares (WA-PLS) transfer function method (Ter-Braak & Juggins 1993) and a calibration dataset consisting of 184 surface samples from the North Atlantic, Baffin Bay and Nordic Seas (Miettinen et al. *in prep*). Sea ice concentrations were reconstructed by using a qualitative method for specific diatom assemblages (*Bacterosira fragilis*, *Thalassiosira gravida* spore, *T. nordenskioldii*, *T. hyalina*, *Fragilariopsis cylindrus*, *F. oceanica*).

Due to the dissolution and poor preservation of diatoms in the early Holocene sediment, only the mid- and late Holocene were investigated. Earlier studies on marine sediment cores around Svalbard have shown thermal maximum conditions in the early Holocene, but the results for the mid- and late Holocene collide (Sarnthein et al. 2003; Hald et al. 2004, 2007; Ślubowska-Woldengen et al. 2007). In this study, the diatom assemblage suggests rather stable SSTs during the mid- and late Holocene. However, small-scale variability can be detected, indicating a slightly warmer mid-Holocene, and the temperature thereafter decreased simultaneously with an increasing sea ice concentration around 3 500–2 000 cal BP. During the last 2 000 years, the sea ice concentration has reached the lowest

values of the record, presumably due to an increased influence of warm Atlantic waters.

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PREFERENTIAL GROUNDWATER FLOW PATHS IN BEDROCK IN THE GYPSUM POND AREA OF TALVIVAARA MINE

by

*Antti Pasanen¹, Anu Eskelinen¹, Anniina Kittilä², Jouni Lerssi¹, Heikki Forss¹,
Taija Huotari-Halkosaari³, Pekka Forsman¹, Marja Liisa Räisänen¹,
Nina Hendriksson³ and Taija Lahtinen⁴*

¹ Geological Survey of Finland, P.O. Box 1237, FI-70211 Kuopio, Finland
E-mail: antti.pasanen@gtk.fi

² University of Helsinki, Department of Geosciences and Geography, P.O. Box 64,
FI-00014 University of Helsinki

³ Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland

⁴ Talvivaara Sotkamo Oy, Talvivaarantie 66, FI-88120 Tuhkakylä, Finland

Preferential flow paths in bedrock may pose an important issue when discussing mine hydrology, mine water management and the transport of adverse substances. These paths form in bedrock fracture zones or large open joints, and their hydraulic conductivities are much higher than the surrounding, relatively unfractured bedrock.

The effect of leaks from the Talvivaara Mine gypsum pond to groundwater were investigated in 2013. The aim of the study was to identify the preferential flow paths in the bedrock, pinpoint suitable bedrock coring sites, measure the hydraulic conductivities and create an interpretation of the bedrock flow patterns in the vicinity of the gypsum pond. In addition, the geochemistry, including isotopic composition, of the surface water, groundwater and process water were studied, together with the flow patterns in sediments.

This study presents the methodology used in identifying the preferential flow paths on the Archaean basement bedrock in the vicinity of the Talvivaara Mine gypsum pond and the results. Several fracture zones were identified in a lineament study, which provided a rough estimation of the fracture zones, but determination of the water content and the exact location of the water-bearing fracture zones was not accurate enough. Therefore, ground-based geophysics is needed for accurate location and water content estimation. The accurate pinpointing of the drilling sites is crucial for geochemical sampling. In Talvivaara, the geophysical investigations consisted of gravimetric, magnetic, refraction seismic, electrical resistivity tomography (ERT) and ground penetrating radar (GPR) measurements. Hydraulic conductivities were measured using the slug test. In addition, drill core logs were used to guide the geochemical sampling.

The studies performed showed and located five major water-bearing fracture zones. Eight drillings to depths of 80–100 metres were performed. Six of the drill logs showed several zones where the joint count or brecciation was high, and the hydraulic conductivity was recorded as between 1.15×10^{-4} and 2.05×10^{-5} m/s in three holes. The bedrock was mainly intact in two of the logs, and the hydraulic conductivity was measured as 6.71×10^{-6} m/s in one drill hole. The flow pattern in bedrock was interpreted from drill hole hydraulic heads. The method is not accurate in determining the bedrock flow pattern or in flow direction interpretation, because the highly jointed and brecciated zones are underlain and overlain by unfractured bedrock, and the hydraulic head is a combination of the hydraulic pressure of all the brecciated or jointed zones. The hydraulic heads indicated a flow direction from the gypsum pond towards the southeast, then turning to the southwest towards Ylä-Lumijärvi. The geochemical results and the isotopic composition of the water are being currently analysed.

HIGH-RESOLUTION SEISMIC REFLECTION SURVEY WITH LANDSTREAMER ON THE CHARACTERIZATION OF THE VIRTAAKANGAS AQUIFER, SW FINLAND

by

*Andre M. Pugin², Joni Mäkinen¹, Elina Ahokangas¹, Aki Artimo³, Heikki Vanhala⁴,
Antti Pasanen⁵ and Kari Moio⁶*

¹ *Department of Geography and Geology, 20014 Turun yliopisto, Turku, Finland
E-mail: eliaho@utu.fi*

² *Geological Survey of Canada, Natural resources Canada, 601 Booth Street,
Ottawa ON K1A0E8, Canada*

³ *Maariankatu 1, FI-20100 Turku, Finland*

⁴ *Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland*

⁵ *Geological Survey of Finland, P.O. Box 1237, FI-70211 Kuopio, Finland*

⁶ *Department of Physics, P.O. Box 9000, FI-90014 Oulu, Finland*

The applicability of the high-resolution seismic reflection method was tested in a study on the hydrogeological conditions and characteristics of the Virttaankangas aquifer in autumn 2011. This survey was conducted with a landstreamer for the first time in Finland. High-resolution seismic reflection surveys enable the study of thick and complex Quaternary deposits up to the bedrock level. The vertical resolution can be up to 1–2 m in ideal conditions, where fine-grained sediments are found on top of deposits and the groundwater level is at maximum 5–10 m from the ground surface. The Virttaankangas interlobate esker and adjacent artificial groundwater plant provided a test area with varying bedrock, surficial deposits and groundwater conditions, as well as abundant reference data (drillings, geophysics and geochemistry), including a 60-layer 3D hydrogeological model. The thickness of the esker deposits is on average 20–60 m, but occasionally over 100 m on the deep bedrock fracture beneath the Virttaankangas plain. The nature of the deposits on the bottom of the bedrock fracture was previously poorly known.

The survey produced 8 km of both P- and S-wave seismic lines. The single line lengths varied between 420–1550 m. The used frequency band was 15–250 Hz, the sweep 5+1 seconds and the offset 4 m. The total length of the landstreamer was 200 m and it consisted of 48 3-component geophones with a 1-m interval and 74 vertical component geophones with a 2-m interval. The vertical resolution of the survey was 5 m, which has not previously been achieved in the study of thick Quaternary deposits in Finland. In the case of Virttaankangas, the low-lying groundwater level reduced the resolution of the survey. The main emphasis in these conditions was on the interpretation of continuous P-wave line data. The bedrock level was detected at a depth of 6–120 m a.s.l on each survey line. The

bedrock fracture valley beneath the Virttaankangas plain was also quite distinct. Older till-like deposits were found between the bedrock and the esker core on the bottom of the fracture valley. Their thickness was up to 20 m on the basis of reference drilling. The location of the esker core was identified both directly from the seismic profiles and based on previous research data, as well as the kettle holes on the margins of the core. The fan lobes on top of the core were identified on the basis of a previous sedimentological model constructed with ground penetrating radar and drill hole data. The perched groundwater table on top of fine-grained beds was very distinct in S-wave profiles. On the basis of our survey, we conclude that the method is applicable to Finnish conditions with the main emphasis on the detection of the bedrock level and large-scale architectural elements of eskers.

PHOSPHORUS IN THE SEDIMENTS AND WATER OF THE ARCHIPELAGO SEA OF FINLAND

by

Irma Puttonen, Tuula Kohonen and Johanna Mattila

*Åbo Akademi University, Environmental and Marine Biology, Tykistökatu 6,
FI-20520 Turku, Finland
E-mail: irma.puttonen@abo.fi*

The area and intensity of hypoxia is increasing in the coastal and archipelago areas of the northern Baltic Sea. Phosphorus (P) contents are high in the coastal and archipelago sediments, and redox-sensitive, mainly iron-bound P (Fe-P) is released under oxygen deficiency. This internal P loading stimulates the productivity of N₂ fixing cyanobacteria. In water quality monitoring, water samples are generally collected (approximately) 1 metre above the seafloor. However, oxygen and P concentrations may differ from those in the water close to the sediment surface, particularly in strongly stratified waters and in areas of seasonal hypoxia, where the P flux from the sediments is high and stratification hinders mixing of the water mass. We therefore examined possible differences in O₂ and PO₄-P concentrations at the sediment–water interface and 1 m above the seafloor.

Moreover, hypoxia may result in the depletion of Fe-P at the sediment surface, since P bound in ferric oxy(hydr)oxides is released under hypoxic conditions. O₂ and PO₄-P concentrations in the water were compared with the contents of inorganic, potentially mobile P in the sediment surface layer. The sediment grain-size distribution and organic content were included in statistical analyses as conceivable factors controlling the sediment P content. Possible relationships between P forms at the sediment surface and PO₄-P concentrations in the overlying water were studied.

Water and sediment samples were analysed at 42 sampling stations in the Archipelago Sea, SW Finland, in the northern Baltic Sea. P forms at the sediment surface were determined using a sequential extraction method.

The results suggest that the inorganic mobile P content at the sediment surface alone does not necessarily reflect the bottom water oxygen concentration. Sediment P contents are controlled by multiple factors, and direct interpretations should be made cautiously. Comprehensive understanding of nutrient exchange between sediment and water requires the inclusion of concomitant sediment analyses with water quality monitoring. Sediment monitoring may help in detecting areas under gradual change towards episodic or seasonal hypoxic conditions.

AMMONIUM-DOPED VERMICULITE (NGT) AS A FERTILIZER

by

Miradije Rama¹ and Taina Laiho²

¹ *Geology and mineralogy, Department of Natural Sciences, Åbo Akademi University, Tuomiokirkkotori 1, FI-20500, Turku, Finland
E-mail: mrama@abo.fi*

² *Department of Physics and Astronomy, University of Turku, Vesilinnantie 5, FI-20014 Turku, Finland*

The Department of Geology and Mineralogy at the University of Turku has recently developed a method that improves the absorption capabilities of ammonium in vermiculite. Vermiculite is an alteration product of phlogopite, which is why it is classified as a hydromica. The selective intake of ammonium ions into the vermiculite lattice has recently been improved with a special heat treatment method (Eklund et al. 2010). The resulting product of this improved method is an artificial mica called GeoTrap that can be used to remove ammonium from various environments.

Application environments for GeoTrap are manifold. It can be used to absorb ammonium from various wastewater environments, such as reject waters of biogas plants, landfill sites, agriculture, wastewater treatment plants and dry toilets. Ammonium molecules fixed into GeoTrap cannot be rinsed off by water. However, the nitrogen in the ammonium can be used by plants as a fertilizer. The functioning of GeoTrap was tested with growth experiments. GeoTrap was doped with ammonium-rich wastewater from the VamBio biogas plant. The ensuing product is a nitrogen-rich mica that we call Nitrogen GeoTrap (NGT). Analyses confirmed that NGT did not absorb any harmful elements from the wastewater.

This NGT was used as a fertilizer in growth experiments on plants (cabbage and grass). In these experiments, the uptake of nitrogen from NGT and other nutrients was measured to determine the highest tolerable dosage for plants. Growth tests revealed that NGT is a suitable fertilizer for field crops and garden plants. It significantly increased the growth rate of Chinese cabbage and rye grass compared to a reference substrate treated with normal nitrogen fertilization. Nine-week-old Chinese cabbage grown in NGT fertilizer had a dry weight almost 19 times higher than cabbage grown in the reference substrate (36.3 and 3.8 g, respectively). Despite the high nitrogen concentration in the plants resulting from GeoTrap, this was not found to be harmful for the plants.

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THE LANSKERI RHYOLITE DYKE, WIBORG BATHOLITH, EASTERN GULF OF FINLAND: *IN SITU* U-PB- AND LU-HF-IN-ZIRCON ISOTOPE GEOCHEMISTRY

by

O. Tapani Rämö¹, Kirsi M. Larjamo¹, Tom Andersen², Aku Heinonen¹,
Irmeli Mänttari³ and Taina Karvonen⁴

¹ Department of Geosciences and Geography, P. O. Box 64,
00014 University of Helsinki, Helsinki,
Finland

E-mail: tapani.ramo@helsinki.fi

² Department of Geosciences, University of Oslo, P.O. Box 1047 Blindern,
N-0316 Oslo, Norway

³ Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland

⁴ Saanio & Riekkola Oy, Laulukuja 4, 00420 HELSINKI

The Lanskeri rhyolite dyke in the south-central, offshore part of the Wiborg batholith is one of the few silicic dykes that cut the rapakivi granites in the southern half of the batholith area. The dyke is 3 to 15 m wide, vertical, NW–SE directed, and sharply cuts across rapakivi granites. Compared to the silicic dykes described from the Wiborg batholith, Lanskeri is very high level and shows spectacular flow folding and devitrification textures (Larjamo et al. 2014, this volume). We report new LA-ICP/MS isotope data on zircons extracted from the southern

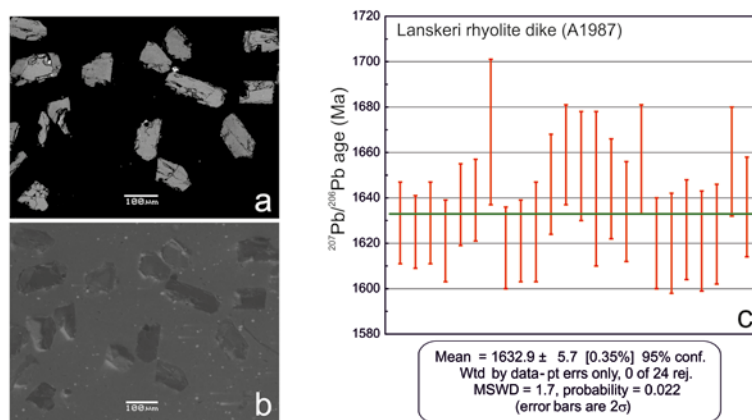


Fig. 1. Back-scattered electron (a) and cathodoluminescence (b) images of zircon crystals extracted from the Lanskeri rhyolite dyke (scale bars in mm). The zircons are small and fractured and therefore challenging to accurately date. c) A diagram showing the weighted average ²⁰⁷Pb/²⁰⁶Pb age of 24 spots measured from the Lanskeri rhyolite dyke (sample A1987).

(~15 m wide) segment of the dyke. The sample (A1987) comes from the centre of the dyke and is sparsely porphyritic with sanidine, quartz and rare plagioclase microphenocrysts in a felsitic, fine-grained to aphanitic groundmass. Zircons in it are small (100–150 μm) and fractured (Fig. 1a, b). A 4.2 g/cm³ fraction recovered was prepared for *in situ* laser analysis, and the U-Pb isotope composition was measured on 35 spots. For assessment of the crystallization age of the zircons, 11 of the spots had to be discarded because of high discordancy or high common Pb. The 24 concordant fractions define a weighted average ²⁰⁷Pb/²⁰⁶Pb age of 1633 \pm 6 Ma (Fig. 1c). This is considered a fair estimate of the emplacement age of the dyke. The same spots of the zircon grains were measured for the Lu-Hf isotope composition. Thirty-three spots imply an ϵ_{Hf} (at 1633 Ma) of -0.3 ± 1.9 (2σ). At face value, the age of the Lanskeri rhyolite dyke is identical that of the rapakivi lavas preserved on Suursaari Island (1633 \pm 2 Ma), and the dyke could actually represent a near-surface vent section of (relatively late) rapakivi granite-associated volcanism in the southern part of the Wiborg batholith. The initial ϵ_{Hf} value of the dyke is similar to that of the granites of the batholith ($+0.2 \pm 2.1$, 2σ , $n = 174$; Heinonen et al. 2010, *J. Petrol.*, v. 51, p. 1687–1708). This implies a homogeneous, juvenile source for the overall magmatic system of the batholith. The poor condition of the zircons from the Lanskeri dyke may relate to the fact that the dyke was quickly solidified to a glass-crystal mixture and probably differentially sheared thereafter.

THE ROMPAS-RAJAPALOT AU-U MINERALIZATION IN THE PERÄPOHJA SCHIST BELT AND RELATED PHD PROJECT

by

Jukka-Pekka Ranta

*University of Oulu, Department of Physics, Geosciences and Chemistry,
P.O. Box 3000, FI-90014 Oulu, Finland
E-mail: jukka-pekka.ranta@oulu.fi*

A high-grade gold-uranium mineralization was discovered in the Rompas-Rajapalot area in 2008, located in the northern part of the Palaeoproterozoic Peräpohja Schist Belt (PSB), near the bordering Central Lapland Granitoid Complex. The sedimentary and volcanic rocks of the belt range in age between ca. 2.3 and 1.92 Ga. They form a heterolithic succession consisting of an older sequence of quartzites, mafic lavas and volcanoclastic rocks and a younger sequence of carbonate rocks, black shales, mica schists and greywackes, suggesting a change in the depositional environment from subaerial and shallow-water to deeper water conditions. The rocks of the PSB have undergone polyphase deformation and are mostly metamorphosed under greenschist facies conditions, but in the north, where the Rompas-Rajapalot Au-U mineralization occurs, rocks are of amphibolite facies. The Rompas-Rajapalot mineralization is promising, as the measured gold concentrations in outcrop samples are very high, and the area where anomalous concentrations occur is tens of km² in extent. The mineralization comprises two different types: i) fracture-hosted, nugget-style native gold and uraninite associated with quartz-carbonate-calc-silicate veins in metabasaltic rocks, and ii) disseminated-style gold mineralization in highly altered rocks composed of chlorite, tourmaline, amphibole and sulphides. Gold and uranium minerals in the Rompas-Rajapalot area were precipitated from hydrothermal fluids, most likely at shallow- to mid-crustal depths. The mutual relationship and exact age of the two types of mineralization and the factors leading to the mobility and precipitation of metals are still unclear.

Over the next year, a detailed study of petrography and ore mineralogy will be conducted in order to obtain information on the mineralogical variation in the whole prospect area, as well as on a single-lode scale. In particular, the Rompas bonanza-grade nugget-style Au-U mineralization within the calc-silicate veins requires a detailed study to understand the spatial and temporal relationships of gold, uranium, calc-silicate veins and associated alteration mineral assemblages. Stable (C-O-H-S-B) and radiogenic isotope studies will probably provide an insight into the origin of the mineralized fluids.

The ultimate goal of the Ph.D. project is to develop a model for ore genesis that can be used as a guide for further mineral exploration in the Fennoscandian Shield. For this, we need to refine our understanding of the geodynamic evolution of the Peräpohja Schist Belt, determine the timing of mineralization and the nature of fluid flow patterns in the belt, and assess elemental leaching and precipitation mechanisms involved in ore formation. In addition, detailed mineralogical characterization of the Au-U deposit will provide important background information for planning environmentally safe mining and mineral processing in the future.

HOLOCENE CARBON FLUCTUATIONS IN A HIGH ARCTIC LAKE

by

*Marttiina V. Rantala¹, Tomi P. Luoto¹, Antti E. K. Ojala², Reinhard Pienitz³,
Milla Rautio⁴ and Liisa Nevalainen^{1,5}*

¹ Department of Geosciences and Geography, P.O. Box 64, 00014 University of Helsinki, Finland

E-mail: marttiina.rantala@helsinki.fi

² Geological Survey of Finland, Betonimiehenkuja 4, 02150 Espoo, Finland

³ Département de Géographie, Université Laval & Centre for Northern Studies (CEN), 2405 rue de la Terrasse, Québec G1V 0A6, Canada

⁴ Département des Sciences Fondamentales & Centre for Northern Studies (CEN), Université du Québec à Chicoutimi, 555 boulevard de l'Université Chicoutimi, Québec G7H 2B1, Canada

⁵ Department of Environmental Sciences, University of Helsinki, Niemenkatu 73, 15140 Lahti, Finland

We examined the carbon fluctuations and palaeo-optical properties of an arctic freshwater lake (Lake Einstaken, Nordaustlandet, Svalbard) since the last glacial period using a Holocene sediment sequence and multi-proxy palaeolimnological approach. Fossil diatom assemblages were used to infer past fluctuations in lake-water dissolved organic carbon (DOC), and sedimentary organic carbon (OC) and the carbon-to-nitrogen ratio (C/N) were examined to refine interpretations of long-term carbon variability. In addition, the UV absorbance of sedimentary cladoceran remains, the carbon-to-sulphur ratio (C/S) and aquatic community succession were used for the assessment of Holocene environmental change. The DOC variations throughout the sequence were subtle, yet a clear pattern could be observed, with the highest values inferred for the early Holocene and the most recent period of the sequence, and the lowest values inherent to the mid-Holocene. During the early post-glacial period, a change occurred from high DOC and low OC towards a reverse phase during which *Fontinalis* moss was abundant and the faunal communities of the lake were distinctly altered, probably due to increased light penetration in the water column. Another early Holocene phase of high DOC and low OC followed, before a shift to a more stable period with relatively low DOC and gradually declining OC characterizing the mid-Holocene. The sources of organic carbon, as reflected by the C/N ratio, varied most pronouncedly during the early Holocene, indicating periodic inputs of allochthonous carbon with little alteration during the mid- and late Holocene, suggesting both auto- and allochthonous carbon sources for the lake. The lake-water and sedimentary carbon fluctuations were supported by the cladoceran UV-absorbance

values, which were lowest during periods of high DOC and *vice versa*, suggesting that the aquatic organisms were subjected to higher underwater UV doses under low DOC conditions during the mid-Holocene. Furthermore, the occurrence of a chironomid taxon (*Micropsectra radialis*-type) associated with clear-water environments corresponded with the DOC and UV inferences. Additionally, cyanobacterial colonies of *Nostoc*, which are known to tolerate intensive UV radiation in arctic freshwaters, were established during the mid-Holocene when DOC was low and water transparency high. During the early and mid-Holocene, the studied proxies covaried in a somewhat similar manner, while these interconnections were decoupled during the late Holocene as DOC and OC began to increase simultaneously and both *Nostoc* colonies and *Fontinalis* moss became more abundant. It is likely that the changes in carbon levels and sources in the lake water and sediment and the underwater photobiological environment in Lake Einstaken changed over the Holocene as a response to post-glacial processes and Holocene climate development, which controlled sea shoreline proximity, water discharge, and limno-telmatic and littoral-benthic primary production.

QUANTITATIVE ASSESSMENT OF CU-ZN RESOURCES IN VMS DEPOSITS IN FINLAND

by

*Kalevi Rasilainen¹, Pasi Eilu¹, Antero Karvinen³, Jukka Kousa², Jouni Luukas²,
Jarmo Nikander², Pekka Sipilä¹, Peter Sorjonen-Ward², Markku Tiainen¹,
Tuomo Törmänen³ and Kaj Västi²*

¹ Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland

E-mail: pasi.eilu@gtk.fi

² Geological Survey of Finland, P.O. Box 1237, FI-70211 Kuopio, Finland

³ Geological Survey of Finland, P.O. Box 77, FI-96101 Rovaniemi, Finland

Undiscovered resources of important metals in the Finnish bedrock have been systematically assessed by the Geological Survey of Finland (GTK) using the USGS three-part quantitative mineral resource assessment method. Descriptive and grade-tonnage models developed especially for the method have recently been published for VMS deposits (Mosier et al. 2009, Shanks & Thurston 2012). These were considered to also adequately characterise the Finnish VMS deposits. Representative grade-tonnage data on well-known VMS deposits within the Fennoscandian shield were gathered from various sources. This resulted in information on 134 well-known, totally delineated deposits from Finland (20), Norway (38) and Sweden (76). Statistical tests indicate that there are significant differences in ore tonnage and metal grades between the Fennoscandian and the global VMS deposit populations. Hence, in our assessment, the Fennoscandian data were used in creating felsic, bimodal-mafic and mafic VMS deposit type grade-tonnage models for our assessment.

In total, 31 permissive tracts were delineated for VMS deposits in Finland. These tracts cover approximately 41,600 km², which is 12% of the total land area of Finland. The number of possibly existing undiscovered VMS deposits was estimated for each permissive tract in a series of workshops. The mean estimate of the number of undiscovered VMS deposits within the topmost one kilometre of the bedrock in Finland is 45, of which 18 belong to the felsic, 10 to the bimodal-mafic and 17 to the mafic type.

The assessment of metal tonnages in the undiscovered deposits was performed by Monte Carlo simulation using data from the grade-tonnage models and the estimated numbers of undiscovered deposits. Metal tonnages were separately estimated for each permissive tract. Summary values were estimated for the felsic, bimodal-mafic and mafic tracts and a grand total was estimated for all the VMS tracts in Finland. The median estimated undiscovered resources in VMS deposits in Finland are 730,000 t Cu, 1.6 Mt Zn, 150,000 t Pb, 1,100 t Ag and 16 t Au. For Cu, the largest part of the undiscovered resources resides in mafic-type deposits,

whereas for Zn, Pb, Ag and Au, the majority are in felsic-type deposits. Comparison of the known remaining and undiscovered resources of Cu and Zn in VMS deposits within the topmost one kilometre of the Finnish bedrock indicate that at least 68% of their total remaining resources are in poorly known and explored or in totally undiscovered deposits. Full details of the VMS assessment for Finland will be published during 2014 in the ‘Report of Investigations’ series of GTK.

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WATER CHEMISTRY INDICATING A GROUNDWATER COMPONENT IN THE LAKE PYHÄJÄRVI CATCHMENT, SW FINLAND

by

Anne Rautio and Kirsti Korkka-Niemi

Department of Geosciences and Geography, P.O. Box 64, FI-00014 University of Helsinki, Finland

E-mail: anne.rautio@helsinki.fi

Stable isotopes ($\delta^{18}\text{O}$, δD), the dissolved silica (DSi) concentration and the major ion composition were used to indicate groundwater–surface water (GW–SW) interaction between aquifers, rivers and a lake, and to estimate the proportion of GW in the rivers, the lake inshore area and in a water intake plant in a one-year monitoring programme conducted from 2011–2012.

The mesotrophic Lake Pyhäjärvi has a surface area of approx. 155 km², a perimeter length of 88 km, a mean depth of 5.5 m and a drainage basin area of 616 km². There are two major rivers discharging into the lake and one outflowing river. Quaternary esker aquifers are connected to the northern and northeastern sides of Lake Pyhäjärvi. There are two water intake plants: Kauttua in the northernmost corner and Honkala on the eastern shoreline of the lake.

Isotope ratios (Picarro Analyzer), DSi (ICP-MS) and major ion composition (IC) were analysed from 300, 250 and 221 water samples, respectively. The results were examined using Excel 2010, STATISTICA 9.0 and AquaChem 2010.1. Principal component analysis (PCA) was conducted with all water chemistry variables.

The baseline data on isotopic patterns and hydrogeochemistry in the hydrological cycle were provided by one year of monitoring data from the Lake Pyhäjärvi catchment. The hydrogeochemical composition of GW and SW differed, especially in DSi concentrations and isotope ratios. Moreover, $\delta^{18}\text{O}$, δD and DSi appeared to be the most applicable variables in estimating the GW–SW interaction in a binary system (lake/GW and lake/wells), but in the river environment they were more complicated to apply.

Differences in water chemistry were also observed between the two inflowing rivers. The River Pyhäjoki has a higher base flow, also observed as higher and more constant DSi concentrations and stable isotopic composition more closely resembling GW. In the River Yläneenjoki, the spring thaw (snow melt) could be more clearly seen, and lower stable isotope values and DSi concentrations were observed. In both rivers, the DSi concentrations were somewhat higher than generally in Finland, indicating a relatively high base flow.

At selected sites, the proportion of GW in inshore water samples range from 56% to 99% based on the mass balance calculation of $\delta^{18}\text{O}$ and from 42% to 81% based on DSi concentrations under calm weather conditions and in winter. Lake water infiltration into the aquifer could also be observed. The water pumped from the wells at the Lohiluoma water intake plant comprised 72–100% and 88–100% lake water, respectively.

Water in Lake Pyhäjärvi, in its catchment area and in aquifers nearby can mostly be classified as Ca-HCO₃ water, being a typical water type in Finnish Quaternary aquifers. The NO₃ concentrations were highest during high flow seasons in the incoming rivers, and some Ca-NO₃ waters could be detected, presumably indicating the nitrate load from surface runoff of cultivated fields. In some places, discharging GW also had the highest concentrations of Ca, SO₄, Na, Cl and EC. These anomalous concentrations could be due to the de-icing of roads using NaCl in winter and agricultural liming of surrounding fields.

FLUID EVOLUTION IN CRYSTALLINE BEDROCK BASED ON RESULTS FROM STABLE C AND O ISOTOPES AND FLUID INCLUSIONS OF FRACTURE CALCITE

by

Elina K. Sahlstedt¹, Jussi Rytönen¹, Petteri Pitkänen² and Juha A. Karhu¹

¹ *University of Helsinki, P.O. Box 64, FI-00014 Helsinki, Finland*

E-mail: elina.sahlstedt@helsinki.fi

² *Posiva Oy Olkiluoto, FI-27160 Eurajoki, Finland*

The geochemical evolution of palaeofluids at Olkiluoto was investigated by combining O and C isotope determinations from fracture calcite with fluid inclusion data from the same samples. The aim of the study was to investigate the earliest hydrothermal fluid circulation at the site. The information obtained is being used to evaluate the palaeohydrogeochemical history of the repository site for spent nuclear fuel at Olkiluoto.

Calcite fillings in the Olkiluoto bedrock have formed over a time period spanning from the hydrothermal circulation caused by the intrusion of the 1571 ± 3 to 1548 ± 3 Ma old Laitila rapakivi batholith (Vaasjoki 1996) into a low temperature environment similar to the present-day conditions. The $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values of calcite in different generations largely overlap (Sahlstedt et al. 2010, 2013). The earliest calcite fillings are thick and associated with sulphides, clays, quartz and minor fluorite and zeolite (Blyth et al. 2000, Sahlstedt et al. 2010, 2013). The $\delta^{18}\text{O}$ values range from -18.4 to -8.4‰ and the $\delta^{13}\text{C}$ values from 14.7 to 1.2‰ (VPDB). This calcite type formed in a temperature range of $\sim 100\text{--}250$ °C from a Na-Cl-H₂O-type, low salinity fluid. The oxygen isotope ratios of the fluid were calculated from the $\delta^{18}\text{O}$ values of calcite, using the fluid inclusion homogenization temperatures to estimate the equilibration temperature between calcite and fluid. The results indicate a mixing of magmatic waters with meteoric waters in a hydrothermal system. Hydrothermal conditions are supported by the presence of strong alteration zones associated with calcite and high formation temperatures of up to 245 °C. The hydrothermal event is probably associated with the intrusion of the rapakivi granite stock. Another possible heat source is related to the intrusion of the diabase dykes at 1225 Ma. The succession of fracture fillings indicates that the fractures reactivated when a moderate temperature ($T_h < 100$ °C), high salinity fluid circulated in the fractures. The high salinity fluid was probably basinal brine in origin, related to the Caledonian foreland basin stage at 350–250 Ma.

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SEDIMENTARY CARBONATES IN THE PECHENGA GREENSTONE BELT RECORDING THE TERMINATION OF THE LOMAGUNDI-JATULI ISOTOPE EVENT

by

Paula E. Salminen¹, Juha A. Karhu¹ and Victor A. Melezhik²

¹ *Department of Geosciences and Geography, University of Helsinki, 00014
University of Helsinki, Finland
E-mail: paula.salminen@helsinki.fi*

² *Geological Survey of Norway, Leiv Eriksson vei 39, N-4791 Trondheim, Norway*

The Palaeoproterozoic Kuetsjärvi (**KuSF**, ca. 2500–2060 Ma) and Kolosjoki (**KoSF**, 2056 Ma) sedimentary formations of the Pechenga Greenstone Belt (NW Russia) were sampled to study the termination of the global Palaeoproterozoic (ca. 2200–2100 Ma) positive $\delta^{13}\text{C}$ excursion of sedimentary carbonates. This excursion is here termed the Lomagundi-Jatuli isotope event (LJIE). The KuSF records the final part the LJIE, whereas the KoSF was deposited during the aftermath of the LJIE. The investigated samples were obtained from ICDP FAR-DEEP (Fennoscandian Arctic Russia – Drilling Early Earth Project) drillcores 5A, 8A, and 8B. Whole-rock and micro-drilled samples were analysed for $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values and elemental contents.

In drillcore 5A from the KuSF, the $\delta^{13}\text{C}$ values decrease upwards from ca. 8 to 5‰ (VPDB) (Salminen et al. 2013a). The primary isotope composition has probably been retained in most of the samples. Melezhik et al. (2005) reported a similar upwards-decreasing $\delta^{13}\text{C}$ trend from another drillcore from the KuSF. Salminen et al. (2013a) constructed a secular $\delta^{13}\text{C}$ curve for the KuSF based on the data from these two cores. This trend was suggested to represent the latest part of the LJIE.

Overlapping drillcores 8A and 8B were drilled in the KoSF. When the data from these cores were combined, an upwards-increasing trend from ca. -2 to 3‰ was found (Salminen et al. 2013b). The FAR-DEEP cores show evidence of a shallow $\delta^{13}\text{C}$ minimum after the LJIE, followed by a subtle increasing $\delta^{13}\text{C}$ trend. The primary $\delta^{13}\text{C}$ values are probably preserved; the data of Melezhik et al. (2007) from the third drillcore from the KoSF support the preservation of the primary $\delta^{13}\text{C}$ values.

Thus, the Kuetsjärvi and Kolosjoki Sedimentary Formations first record (1) a decreasing $\delta^{13}\text{C}$ trend from 8 to 5‰, and then (2) an increasing $\delta^{13}\text{C}$ trend from -2‰ up to 3‰. These $\delta^{13}\text{C}$ trends can probably be explained by variations in the burial of C_{org} . The oxidation of C_{org} could also explain the low $\delta^{13}\text{C}$ values in the KoSF.

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DECODING OROGENESIS AND MINERAL SYSTEMS THROUGH PORPHYROBLAST INCLUSION TRAILS: INSIGHTS FROM THE MT ISA INLIER, QUEENSLAND, AUSTRALIA

by

Muhammad Sayab

Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland
E-mail: sayab.muhammad@gtk.fi

Event-wise structural evolution, its regional correlation and associated mineral systems across many orogenic belts are topics of significant ongoing research. Because of the lack of a suitable reference frame and spatial scale to correlate deformation and metamorphic events, conflicting tectonic models are not uncommon in the literature for a given orogenic system. In recent years, it has been demonstrated that complex deformation and metamorphic overprinting relationships and their correlation across large regions can be resolved through careful quantitative analysis of foliations preserved within low-strain pods at different scales. The approach has successfully answered many unresolved questions regarding the genesis of mineral deposits.

Palaeo- to Meso-Proterozoic terranes of the Australian craton exhibit complex tectono-metamorphic histories that are generally considered to result from low-pressure/high-temperature (LP/HT) metamorphism. However, studies regarding the nature of the P - T history and tectonic regime that led to such a LP/HT signature have been quite limited. Foliation intersection/inflection axes within porphyroblasts (FIAs) allow the chronological and kinematic linking of deformation events with associated metamorphism. Measurement of FIAs in the Palaeo/Meso Proterozoic Eastern Fold Belt (EFB) of the Mount Isa Inlier, Queensland, Australia, has revealed phases of deformation and metamorphism that could not previously be distinguished from one another. FIAs served as an integral tectonic reference frame to correlate tectono-thermal events and mineral systems across the region.

Two independent FIA measurement techniques have been applied and revealed broadly E-W-trending structures that formed during N-S bulk shortening (D1) and associated metamorphism (M1) formed during a period of orogenesis (O1), as well as broadly N-S-oriented structures that formed during E-W bulk shortening (D2) and associated metamorphism (M2) during a second period of orogenesis (O2). Middle to upper amphibolite facies metamorphic conditions prevailed during O1 with crustal thickening followed by near isothermal decompression, leading to low-pressure/high-temperature (LP/HT) conditions with the

emplacement of Williams and Naraku Batholiths around 1550 Ma. This was followed by a second period of middle- to upper-amphibolite facies metamorphism, O2. Significantly, D1 porphyroblasts preserving E–W FIAs are minerals of the Barrovian style, whereas D2-formed porphyroblasts preserving N–S FIAs are Buchan in style. The FIA approach refined our understanding of crustal scale tectonic processes and associated polymetamorphism in the region. The important episodes of iron oxide copper-gold mineralization in the EFB are associated with the sub-events of O1 and O2 between 1595 and 1485 Ma.

CORPORATE SOCIAL RESPONSIBILITY OF MINING COMPANIES: LOCAL-LEVEL INTERACTION WITH THE MUNICIPALITY OF SODANKYLÄ, NORTHERN FINLAND

by

*Stella Selinheimo¹, Risto Kalliola¹ and
Toni Eerola²*

¹ *Department of geography and geology, University of Turku, Finland
E-mail: seisel@utu.fi*

² *Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland*

The study concerns the corporate social responsibility (CSR) of mining companies in relation to the social impacts of the mining industry at the local scale. The study area is in the municipality of Sodankylä in northern Finland. The study forms the basis of a Master's thesis in Geography from University of Turku and is being carried out in cooperation with the Geological Survey of Finland (GTK). The thesis was started in December 2013.

The mining industry causes both negative and positive impacts on the local area. Negative impacts can include damage to the environment and impacts on other livelihoods (e.g. tourism). Conversely, positive impacts can include an increased employment situation in the municipality and higher tax revenues. Because of the positive impacts of the mining industry, a local municipality may want to invest heavily in public services and housing to gain more residents, and regions often do this by taking out loans. In other words, a municipality becomes reliant on the mining company that operates in the area. Mining companies are also dependent on the municipality for the services and infrastructure that it provides.

Increasing mining activity in Finland has started a discussion about the CSR of mining companies. The discussion has led to a governmental decision to raise Finland's profile as a leader in the sustainable extractive industry by 2020. Communication between the industry and its different stakeholders is also being emphasized. Mining firms need to gain a social license to operate on a local level. This means that the community approves their operations.

The focus of this study is on the CSR of the mining firms operating in Sodankylä municipality by examining the local stakeholders' opinions on the interaction of the firms. The study also aims to determine how the mining companies have implemented their CSR in the municipality of Sodankylä in relation to regional development. The study is additionally looking into the regional development

policy and investments of the municipality of Sodankylä in relation to the increased mining activity during 1995–2013.

The study methods are interviews with local stakeholders (e.g. authorities, reindeer herders, local residents, local NGOs and indigenous Sámi people). The CSR reporting of the firms and the local newspaper's news concerning the activity of the companies operating in Sodankylä municipality will be examined to gain more information on their CSR.

TRACING THE PROVENANCE OF THE LATE NEOGENE RED CLAY DEPOSITS IN THE CHINESE LOESS PLATEAU USING ZIRCON U-PB DATING AND HEAVY MINERAL ANALYSIS

by

Yuan Shang¹, Anu Kaakinen¹, Christiaan J. Beets² and Maarten A. Prins²

¹ *Department of Geosciences and Geography, University of Helsinki,
P.O. Box 64, 00014 University of Helsinki, Finland
E-mail: yuan.shang@helsinki.fi*

² *Faculty of Earth and Life Sciences, VU University Amsterdam, De Boelelaan 1085,
1081 HV Amsterdam, The Netherlands*

The Neogene Red Clay underlying the Pleistocene loess – palaeosol deposits in northern China has been demonstrated to have a relatively continuous depositional character, at least over the past ~7–8 to ~2.6 Ma. These Red Clay deposits are not only important continental archives of late Miocene-Pliocene environmental and climatic changes, but also preserve significant information on past atmospheric circulation patterns. Although multiple competing hypotheses have been proposed for the provenance of Red Clay deposits of the Chinese Loess Plateau (CLP), none have yet been confirmed. Whether the sediments derived from single or multiple source areas still remains ambiguous. U-Pb dating of detrital zircons from clastic sediments has proved to be a powerful tool to trace sediment sources. However, this method has seldom been applied in constraining the provenance of Red Clay deposits.

In this study, we selected three typical Red Clay sections across northern China: Dongwan in the western part, Lantian in the southern part and Baode in the northeastern part of the CLP. Based on a systematic field geological survey, stratigraphic investigation and magnetostratigraphy, 15 samples in different stratigraphic levels were chosen. By applying zircon U-Pb dating and single-grain zircon morphology, combined with heavy mineral analysis of the Red Clay samples, the research aims to investigate the source and spatio-temporal evolution of Neogene Red Clay deposits of northern China. The preliminary results demonstrate that the zircons show a decreasing trend in grain size from north to south, most probably reflecting a longer distance to the source area. In addition, the visual examination of zircons shows that Baode samples contain a greater proportion of euhedral grain types than those from the southern CLP sites in Lantian and Dongwan. This suggests that a component in the Baode samples had a relatively local source and less reworking compared to the southern sites.

A 3D CRUSTAL MODEL OF NORTHERN FENNOSCANDIA BASED ON CONTROLLED-SOURCE SEISMIC AND RECEIVER FUNCTION DATA

by

Hanna Silvennoinen^{1,2}, Elena Kozlovskaya¹, Eduard Kissling³, Grigoriy Kosarev⁴
and POLENET/LAPNET Working Group

¹ Sodankylä Geophysical Observatory, P.O. Box 3000, 90014 University of Oulu,
Finland

E-mail: hanna.silvennoinen@oulu.fi

² Department of Physics, P.O. Box 3000, 90014 University of Oulu, Finland

³ Institute of Geophysics of ETH Zurich, Switzerland

⁴ Schmidt Institute of Physics of the Earth, RAS, Moscow, Russia

The POLENET/LAPNET project was a passive seismic array experiment in the northwestern Fennoscandian Shield. It was centred in northern Finland with some stations also located in surrounding areas in Sweden, Norway and Russia. The experiment was a part of the International Polar Year 2007–2009. One of the main aims of the project was to obtain a seismic model of the upper mantle using tomographic inversion of teleseismic travel times. To correct teleseismic travel times for the crustal effect, a new seismic P-velocity model of the POLENET/LAPNET study area, located between 64°–70° N and 18°–34° E, was compiled. This model was based on previously published and new results from different seismic studies in the area. There are four major controlled source seismic (CSS) profiles crossing our research area. In addition, there are some shorter profiles, but also quite large areas with no previous CSS information at all. Data gaps in these regions were filled by a new analysis of receiver functions obtained from POLENET/LAPNET data.

The CRUST3D program (Waldhauser et al. 1998) was used to compile these different types of 1D and 2D data to construct a 3D crustal model. The program is designed to take advantage of the strengths of the different seismic methods and to compile a 3D crustal model that fits all available data within its appropriate individual and methodological uncertainty limits. The original data leading to the published models were analysed to ascertain whether information was only used from locations where Moho reflectors/refractors were actually observed. The Moho interface is obtained by application of the principle of simplicity: the aim is to find the smoothest Moho interface that satisfies all data within their *a priori* estimated error bars.

On our Moho map, we can see three main units in Moho. In the southwestern part of our study area, the Moho is quite flat and shallow with an average Moho depth of 44 km, which suggests that the crust there was formed in the

Archaean. In the northern part of our study area, the Moho is also quite flat and the average Moho depth is about 47 km, suggesting that the crust there was re-worked in the Proterozoic. Two deepest Moho depressions were found in the northeastern and southeastern parts of study area, where they reach the depths of almost 60 km.

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MINERALOGICAL ASPECTS ON MINERAL CARBONATION

by

Sonja Sjöblom

*Åbo Akademi University, Geology and Mineralogy, FI-20500 Turku, Finland
E-mail: sonsjobl@abo.fi*

In this research we study the capability of waste rocks and mine tailings from active mines in Finland to be used to fix anthropogenic carbon dioxide (CO₂) into a stable carbonate, magnesite. Carbon capture and mineralisation (CCM) is the most promising way to capture anthropogenic CO₂ in Finland. The main goal of this study is to find suitable mine waste products in Finland, as well as to clarify the mineralogical features that influence the suitability of materials used for mineral carbonation. More knowledge is required in order to determine from which minerals Mg can most easily be extracted, and what features influence the urge to do so. Study materials are being provided by various mines in Finland.

A method for mineral carbonation has been developed at Åbo Akademi University. The carbonation of Mg(OH)₂ is executed in a pressurized fluidized bed for CO₂ sequestration (Fagerlund et al. 2010). In the process, Mg is extracted from ground ultramafic rock, converted into Mg(OH)₂ and subsequently fused with CO₂ in an exothermic reaction forming stable magnesite, MgCO₃.

The characterization of mine waste products is needed to clarify which features influence the extraction of Mg and the carbonation processes. Our results suggest that ultramafic phyllosilicate rocks with >17% Mg and >2.5% of crystalline H₂O make the most profitable material. The amount of crystalline H₂O in minerals plays an essential role in Mg extraction, since “wet” minerals react faster than “dry” minerals (Nduagu et al. 2012). The MgO content for a profitable material needs to exceed 17% in order to produce cost-effective amounts of Mg(OH)₂. These two features compensate each other to a certain extent, but determining the ratio at which they balance each other out needs further studies. When ammonium sulphate has been used for Mg extraction, successful samples have all been part of the hydrous magnesium iron phyllosilicate group (serpentine, talc, chlorite), while the unsuccessful samples have belonged to other silicate groups (olivine, pyroxene and amphibole). Serpentinite is the only profitable rock material at present, although talc/chlorite rocks do show results that are almost as profitable. A closer examination of serpentines suggests that lizardite is more suitable than antigorite for Mg extraction and carbonation.

Rocks with a high iron content complicate the Mg extraction. With Fe present in the extraction process, the energy consumption rises (Nduagu 2012). The problems with Fe present in ultramafic rocks may be solved by separation of Fe

oxide phases prior to Mg extraction, and extraction and precipitation of Fe phases with other methods.

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THE STRUCTURAL CONTROL OF MINERAL OCCURRENCES IN THE PERÄPOHJA BELT, NORTHERN FINLAND

by

*Pietari Skyttä^{1,2}, Ville Nieminen¹, Timo Kilpeläinen¹, Simo Piippo²,
Asko Käpyaho³, Laura Lauri³, Irmeli Huovinen⁴, Tommi Lehtilä⁵ and
Janne Kinnunen⁶*

¹ University of Turku, Dept. Geography and Geology, FI-20014 University of Turku, Finland

² University of Helsinki, Dept. Geosciences and geography, P.O. Box 64, FI-00014 University of Helsinki, Finland
E-mail: pietari.skytta@utu.fi

³ Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland

⁴ Geological Survey of Finland, P.O. Box 77, FI-96101 Rovaniemi, Finland

⁵ First Quantum Minerals Ltd., Kaikutie 1, FI-99600 Sodankylä, Finland

⁶ Mawson Resources Ltd., Lantontie 34, FI-95680 Lohijärvi, Finland

This investigation is addressing the structural control of the mineral occurrences within the prospective Peräpohja Belt, northern Finland. The evolution of the Peräpohja Belt as a Palaeoproterozoic basin is inferred to comprise syn-depositional extension in a failed rift setting (Kyläkoski et al. 2012), characterized by normal faulting. When the extension subsequently shifted to shortening, the

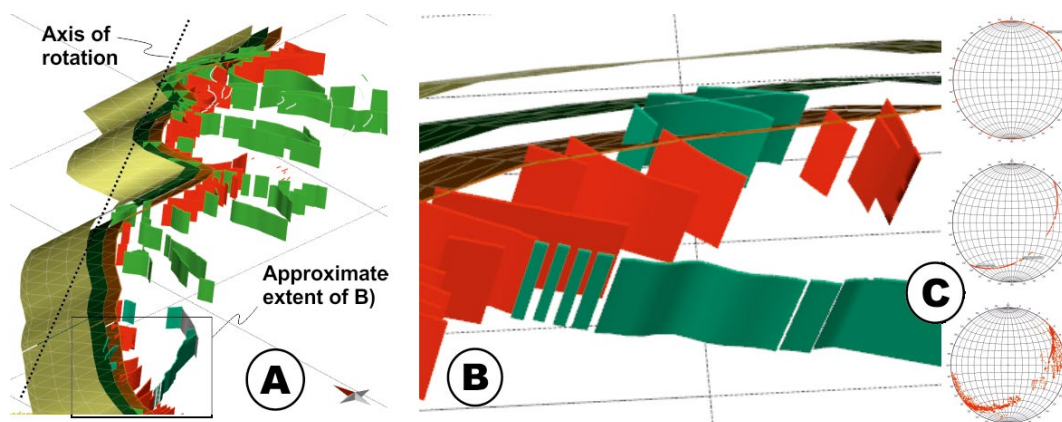


Fig. 1. A. The present-day geometry of the crust along the Archaean-Proterozoic boundary. B: The basement structures after rigid body rotation of the layered intrusions into a horizontal orientation. C: Orientation distributions of the elements in B after the subsequent unfolding (not shown).

original growth faults were inverted, which makes their identification difficult. For this reason, only 4D modelling will enable us to understand the coupling between the deformation structures and the stratigraphy, and hence outline the inverted normal faults. As the normal faults are considered the main pathways for fluid flow through the crust, they can, after successful recognition, be used as exploration targets for Cu (+Au). Furthermore, the role of the structural framework of the underlying Archaean basement for the deposition and subsequent deformation of the Peräpohja Belt rocks is being studied, with preliminary results shown in Figure 1.

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APPLICATIONS OF THE MINERAL SYSTEMS APPROACH TO FINLAND

by

Peter Sorjonen-Ward

*Geological Survey of Finland, P.O. Box 1237, FI-70211 Kuopio, Finland
E-mail: peter.sorjonen-ward@gtk.fi*

The mineral systems concept simply represents an attempt to understand mineralization processes and to improve predictive capability by studying the geological framework and event history of a prospective area, across all scales, from the terrain-scale geodynamic setting through regional area selection, to deposit scale evaluation. The concept was derived from petroleum industry systems modelling, based on the assessment of sources, migration pathways and trapping (Magoon & Dow 1994). However, magmatic and hydrothermal mineral systems may record more complex architectures and mineral assemblages (Wyborn et al. 1994), and primary systems may be affected by overprinting events that cause metal upgrading or dispersion, and structural modification and disruption of ore.

From the exploration and prospectivity perspective, it is also important to establish whether mineralization processes represent local, small-scale closed systems or responses to plate-scale or global events. The mineral systems approach provides a framework for systematically posing and addressing these questions. For example, what are the implications for Neoproterozoic gold and nickel endowment in Fennoscandia when we consider that the two premier terrains, Abitibi in Canada and the Eastern Goldfields of the Yilgarn craton, experienced significant komatiitic volcanism at 2.71 Ga, whereas this event is not recognized in Fennoscandia? On the other hand, Neoproterozoic orogenic deformation and crustal reworking in all three areas are similar, but known gold endowment is much less in Finland.

In contrast, the Palaeoproterozoic of Fennoscandia contains significant nickel deposits, in layered intrusions emplaced during episodic rifting events, as well as in the synorogenic Svecofennian orogenic context. Is there a global connection or simply a coincidence that Kevitsa and the Bushveld complex share the same 2.06 Ga age? For basin-hosted mineral systems in eastern Fennoscandia, we are also interested in how host sequences relate to global redox changes in atmospheric and ocean conditions, affecting metal transport and deposition, or whether more local magmatic events supply both metals and drive hydrothermal processes in the surrounding sediments. Structural studies and kinematic interpretations now permit reasonable and testable assumptions concerning the uniformity of far-field stress fields over extensive areas, during cratonic rifting as well as subsequent orogenic convergent deformation. For example, evidence for prolonged orogenic

shortening subparallel to the cratonic margin in eastern and northern Finland enables the distribution of orogenic gold and uranium mineralization to be assessed within their geodynamic context, and the structural reworking of syn-sedimentary and VHMS mineralization to be better understood.

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APPLICABILITY OF A TARGETED DIATOM TRANSFER FUNCTION TO PHOSPHORUS RECONSTRUCTION IN AN ENVIRONMENTALLY ANOMALOUS AREA

by

Mira H. Tammelin¹ and Tommi Kauppila²

¹ *University of Turku, Department of Geography and Geology, FI-20014 Turku, Finland*

E-mail: mhtamm@utu.fi

² *Geological Survey of Finland, P.O. Box 1237, FI-70211 Kuopio, Finland*

To achieve the “good surface water status” required by the EU Water Framework Directive, we first need to identify reference states for our lakes. Bennion (2011) suggests the time before intensifying human activity due to the onset of rapid industrialization as a reference point. In determining the past reference conditions for a lake, the lack of undisturbed reference lakes can often be overcome by using palaeoecological predictive models, i.e. transfer functions (see e.g. Anderson 1995). However, the models may suffer from poor performance in environmentally atypical areas. We propose that these challenges could be alleviated by developing a targeted model with a training set that consists of modern microfossil calibration samples and corresponding water quality data from the area of interest.

We tested this targeted approach in the Iisalmi region, central-eastern Finland, by developing a diatom-total phosphorus transfer function for the shallow, humic and conspicuously eutrophic lakes in the area. The fossil samples for determining the reference conditions were selected from below a depth where magnetic susceptibility notably increased towards the sediment surface. We interpreted this increase to represent intensified erosion caused by human activity. The resulting phosphorus reconstructions suggest that human activity has only induced significant eutrophication in a minority of the modelled lakes. However, the reconstructions for the reference conditions are mostly very high.

Our results indicate that a successful local diatom-total phosphorus model can be developed for an environmentally anomalous area. An important implication for lake restoration is that the reference conditions for the shallow, humic and eutrophic lakes in the Iisalmi region seem to be notably higher (up to 70 $\mu\text{g l}^{-1}$) than the previously reported background total phosphorus concentrations for naturally eutrophic lakes in Finland (20–30 $\mu\text{g l}^{-1}$; Vuori et al. 2006). Further research is under way to examine how well our local model reflects observations of total phosphorus in lake water, and whether it consistently shows larger variation than the previous regional model of Kauppila et al. (2002) for this lake type.

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GROUNDWATER LEVEL VARIATION AND SUBSIDENCE IN PERKKA, ESPOO

by

Tiina-Liisa Toivanen and Jussi Leveinen

*Aalto University, PL 12100, 00076 Aalto, Finland
E-mail: tiina-liisa.toivanen@aalto.fi*

In this study, various modelling approaches have been used to examine the groundwater level changes and other factors influencing subsidence and soil compaction in clay deposits characteristic of the Helsinki metropolitan area in Finland. The purpose of the modelling is to identify simple ways to estimate the groundwater level changes and subsidence caused by the changes in land use.

Finnish clay deposits, their index properties and stress deformation characteristics have been the subject of a number of studies since the 1960s. There is also abundant statistical data on the properties of the clays in the Helsinki metropolitan area. The aim of this research is to determine how reliably the existing data could be used to stochastically assess the suitability of land for construction by estimating the deformation characteristics based on the comprehensive statistical data.

The research area is Perkkaa in Espoo, located in the Helsinki metropolitan area in the coastal region of southern Finland. The total size of the research area is approximately 2.7 km². The surface of the studied area is mostly covered by clay, with a thickness varying between 5 and 15 metres. In the southern and central parts of the area, the soft soil layer can be over 20 metres thick. A silt and sand layer a couple of metres thick can be commonly found beneath the clay deposits, on top of a 1- to 5-metres-thick layer of till that overlies the bedrock. The studied area is bordered by a fill area to the east, a silt/sand moraine area to the west, and moraine/bedrock areas to the north and south.

The development of the Perkkaa area started at the beginning of 1970s. Today, the buildings in Perkkaa mainly consist of high-rise apartment buildings, but there are also a few office blocks. The hydrogeological environment in the area has been considerably altered by construction, and as a result there are large deformations, especially in the streets and yards. The largest measured deformations are up to 0.5 metres.

Using available laser scan data and GPS measurements of the levels of ditches and minor streams, as well as soil investigation data and geological maps provided by the city of Espoo and the Geological Survey of Finland, it has been possible to create a 3D model of the geological and geotechnical conditions in the research area. The 3D model was further used to model the changes in groundwater flow in the research area.

Based on this study, no significant changes in catchment scale recharge appear to have occurred. The reductions in the groundwater levels and the deformations in the streets and yards are thus caused by the local effects of street structures, the drainage systems and particularly the underground pipeline systems. The calculations performed with the statistical data on Finnish clay deposits and their stress deformation characteristics indicate that similar construction practices to those applied in the study area will probably also cause subsidence in other areas in southern Finland. In contrast to the current planning practices, the effects of lowering the groundwater levels should thus be taken into account in geotechnical design, and also in the zoning and planning processes, to avoid structural damage and expensive recurring repair work on streets and yards.

AT A CROSSROADS OF SUSTAINABILITY CHALLENGES: THE ROLE OF MINING IN MODERN SOCIETY

by

Mari Tuusjärvi

*Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland
E-mail: mari.tuusjarvi@gtk.fi*

Since the beginning of the 1970s, there has been growing global interest in the environmental effects caused by human societies, and the capacity of Earth to sustain the growing human population and increasing wealth. From this interest has grown the concept of “sustainability”, referring to the idea of balancing the functionality of human societies and the pressure they place on the natural environment. Sustainable development, usually divided into the domains of environmental, social and economic sustainability, is a process to seek this balance. Mining presents a contradiction in this context, as through mining we utilise mineral resources that may not be available for future generations. Therefore, only weak sustainability (Cabeza Gutiérrez 1996) could be supported by mining, as the natural capital is lessening on behalf of human capital (Waye et al. 2009; Prno and Slocombe 2012). However, mining is currently fundamental to maintaining modern societal structures and to supporting increased well-being in developing countries. As a result, mining is at a crossroads of two challenges: 1) the short- and long-term depletion of usable mineral resources, and 2) sustainable mining practices. The first challenge is related to *the human need for resources*, which forms a driver for the mining industry to exist, and also a driver for legislation concerning mining claims and rights to establish mining in certain regions. Short-term depletion refers to vulnerability to market disruptions, for example problems in delivery from trade partners or an imbalance in demand and supply dynamics (Crowson 2008). Long-term depletion is an ultimate type of depletion, where the usable resource of a raw material is expected to become exhausted at the global level. The second challenge is related to *the human needs for a clean environment, compensation and knowledge*, which drive the social responsibility and environmental protection goals of mining companies. Additionally, *a human need for continuation* reflects the importance of a private company to make a profit, which secures the continuation of the company’s operations (Crowson 2008), but also the employment and economic security of the surrounding community. The critical issue in mining operations is then to manage and fund all aspects of sustainability – environmental protection, social responsibility and profitability – so that they are covered at a balanced financial level.

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PHYSICAL INFLUENCES OF THE SEA DISPOSAL OF DREDGED MATERIAL IN HAMINA AND NAANTALI

by

Tiina Vaittinen¹, Veli-Pekka Salonen² and Merilin Pienimäki³

¹ *Sito Oy, Tuulikuja 2, FI-02100 Espoo, Finland*

E-mail: tiina.vaittinen@sito.fi

² *Department of Geosciences and Geography, Division of Geology, P.O. Box 64,
FI-00014 University of Helsinki, Finland*

³ *Sito Oy, Tuulikuja 2, FI-02100 Espoo, Finland*

Dredging of the seafloor is often a prerequisite for keeping seaways and harbours operational in the coastal area of Finland. This leads to a need to transport and dispose of the dredged material, which in turn creates environmental concerns. The objective of this study was to gather research data to assess the effects on sea disposal sites and define the preconditions for environmentally sustainable disposal projects. The research focused on two disposal sites for soft dredged material, located in Naantali and Hamina. The site in Naantali is very close to the mainland and a busy harbour, with heavy sea traffic. The site in Hamina is in a location with markedly calmer current conditions, within a scarce archipelago. The physical effects of the sea disposal were examined three years after the disposal operation. Special attention was paid to how well the disposed material had remained at the disposal sites.

Sediment samples were taken from both study areas. Based on sedimentation signals observed in these samples, the study aimed to determine how well the disposed material had remained in place. The movements of the material were also assessed by observing the topographical changes that had taken place at the sites over three years. The study additionally utilized monitoring reports and previous research to assess the identified effects on the environment and the factors that influence them in the context of the Baltic Sea area.

According to the results, the disposal site at Hamina is an exemplary one, because the disposed material has settled and become part of the existing seafloor. The material is also physically of a superior quality to the original surface sediment, which suffered from oxygen depletion. Sea disposal has managed to isolate the original sulphide mud from the bottom water. At the Naantali site, the disposed material appears to have stabilized rather well, but the result is not as obvious as at Hamina. This is largely due to the strong slipstreams in the area causing resuspension of the surface mud. Furthermore, characterization of the disposed material was relatively difficult at the Naantali site due to the strong physical resemblance between original and disposed sediment.

Surface sediment samples and basic physical characterization (water content, loss on ignition, magnetic susceptibility and lithofacies description) proved to be a useful method in researching the settling of disposed material. When looking for possible signs of sedimentation, the topmost surface layer of samples is especially important. Depth data can also be used in monitoring disposal sites, although based on depth alone it is difficult to draw conclusions on the reasons for changes in topography.

STORM INFLUENCE ON BRACKISH-WATER MUD DEPOSITION IN THE EASTERNMOST GULF OF FINLAND, AND THE BIRTH OF THE NEVA RIVER

by

Joonas J. Virtasalo¹, Daria Ryabchuk², Aarno T. Kotilainen¹, Vladimir Zhamoida²,
Andrey Grigoriev², Vadim Sivkov³ and Evgeniya Dorokhova³

¹ Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland
E-mail: joonas.virtasalo@gtk.fi

² A. P. Karpinsky Russian Geological Research Institute (VSEGEI),
Sredny Prospect 74, 199106 St. Petersburg, Russia

³ Atlantic Branch of P. P. Shirshov Institute of Oceanology, Russian Academy of
Sciences (ABIO RAS), Prospect Mira 1, 236022 Kaliningrad, Russia

Two replicate long sediment cores collected from the easternmost Gulf of Finland record brackish-water mud accumulation beginning at 5900 ± 60 cal. a BP. The brackish-water muds are characterized by thin beds with erosional bases, fining-upward grain sizes and increasing-upward organic contents. A storm-induced flow origin is inferred for the thin mud beds, contrasting with previous interpretations that these muds accumulated by quiescent suspension settling. The bed primary microstructures are overprinted by biodeformation and mottling by small *Planolites* and *Arenicolites/Polykladichnus* ichnofossils of the continental *Skolithos* Ichnofacies, left behind by endobenthic oligochaetes and chironomid larvae. The depositional succession is cut by an erosional hyperpycnal flow event at 3320 ± 40 cal. a BP, caused by the formation of the Neva River, which is now documented and dated offshore for the first time. Mineral magnetic properties show pseudosingle-domain magnetite as the main magnetic mineral present. Increased magnetic grain sizes and the potential admixing of higher coercivity hematite indicate a strong lithic influx immediately after the birth of the Neva River. The dominance of riverborne material in the accumulating sediments ever since highlights the strong influence of reworking in the shallow sea area. Increased diameters and the deeper penetration of biogenic sedimentary structures demonstrate improved seafloor oxygenation after the river birth. During the Medieval Warm Period and the last century, increased sedimentary lithic contents and magnetic grain sizes indicate an elevated riverine influx due to increased precipitation and/or to increased reworking of sediments by storms. The results provide a palaeoenvironmental context for the study area, and deepen the understanding of storm-induced sediment dispersal and the formation of sedimentary fabric in shallow, wave-dominated sea areas.

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CUAL APPROACH FOR THE STANDARD STRATIGRAPHIC CLASSIFICATION OF THE BALTIC SEA SEDIMENTS

by

Joonas J. Virtasalo¹, Jyrki Hämäläinen and Aarno T. Kotilainen

*Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland
E-mail: joonas.virtasalo@gtk.fi*

Late Pleistocene and Holocene sediments of the Baltic Sea basin are conventionally divided into units according to the so-called Baltic Sea stages: the Baltic Ice Lake, Yoldia Sea, Ancylus Lake and Litorina Sea. These Baltic Sea stages denote water-level and salinity changes in the basin that were originally inferred from raised shores and fossil taxa on land. Marine geological studies have later used various criteria such as lithology, microfossils, mineralogy, geochemistry, age and their different combinations to identify these stages in sediment cores. However, there has been less consideration of how well the changes documented on land are transferable to offshore sediment cores. Notably, it is unrealistic to assume that changes in various physical, chemical and biological parameters take place simultaneously and are recorded at the same stratigraphic level in the sediments. Indeed, the palaeoenvironmental inferences inherent in correlating sediments based on fundamentally different criteria contradict international stratigraphic classification guidelines as described in the International Stratigraphic Guide (Salvador 1994) and North American Stratigraphic Code (NACSN 2005).

Here, long sediment cores and seismoacoustic sub-bottom profiles are studied from an offshore area south of Hanko in the Gulf of Finland. The strata are divided on the basis of sedimentological criteria into three allostratigraphic formations with subordinate allostratigraphic members and lithostratigraphic formations, following the combined allostratigraphic and lithostratigraphic (CUAL) approach (Räsänen et al. 2009). Sedimentological features are recommended as the primary stratigraphic classification criteria, because they do not require the palaeoenvironmental inferences of salinity and water level that are inherent in the conventional classification practice. The presented stratigraphic division is proposed as a flexible template for future stratigraphic work on the Baltic Sea basin, whereby lower-rank allounits and lithounits can be included and removed locally, while the alloformations will remain at the highest hierarchical level and guarantee the regional correlatability. The stratigraphic division is compatible with international guidelines, facilitating communication to the wider scientific community and comparison with other similar basins.

This research is based on geological data collected in the FINMARINET project, funded by the EU Life+ programme (LIFE07 NAT/FIN/000151).

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MICROBIAL MAT INFLUENCE AND EVENT DEPOSITION OF PYRITIC BEDS IN THE PALAEOPROTEROZOIC TALVIVAARA FORMATION

by

Joonas J. Virtasalo¹, Jaakko Laitala², Raimo Lahtinen¹ and Martin J. Whitehouse³

¹ Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo, Finland

E-mail: joonas.virtasalo@gtk.fi

² Department of Geosciences and Geography, P.O. Box 64, FI-00014 University of Helsinki, Finland

³ Nordsim, Swedish Museum of Natural History, P.O. Box 50 007, SE-104 05 Stockholm, Sweden

The Palaeoproterozoic Talvivaara formation (2.1–1.95 Ga) in eastern Finland is a ~50-m-thick deposit of dark-grey organic-rich mud beds (Loukola-Ruskeeniemi & Lahtinen 2013). The Talvivaara formation has experienced amphibolite grade metamorphism; however, within less deformed domains, primary sedimentary structures are well preserved. In the core DDKS-010, the interval between 407 and 405 m is characterized by brass-yellow pyritic beds, a few millimetres to a couple of centimetres in thickness, that alternate with dark-grey carbonaceous beds that are some millimetres to centimetres thick. The carbonaceous beds are interpreted as fossil microbial mats; they are characterized by wavy-crinkly organic laminae that resemble laminar structures and intertwined microbial filaments in modern microbial flats. The pyritic beds are event beds; they have uneven bases with the basal depressions often filled with silt and sand-sized grains, demonstrating soft deformation but resistance of the underlying (carbonaceous bed) surface to loading by the event deposition, consistent with a surface-stabilizing microbial mat. Frequent flakes of carbonaceous matter with wavy internal layering and frayed edges ‘floating’ in the pyritic beds are microbial mat fragments that were ripped up from the mat surface by the flow and incorporated into the event deposit (Schieber et al. 2007).

$\delta^{34}\text{S}$ values of pyrite grains in the pyritic beds, determined *in situ* by SIMS at Nordsim, range between -12 and -7‰. The $\delta^{34}\text{S}$ values are shifted by more than 20‰ units from the contemporary seawater sulphate ($\delta^{34}\text{S} = +10.9 \pm 2.7\%$, Reuschel et al. 2012), consistent with the isotope fractionation by bacterial sulphate reduction. *In situ* $\delta^{56}\text{Fe}$ values (between -0.5 and -1.5‰) of the pyrites are slightly shifted from igneous rocks ($\delta^{56}\text{Fe} = +0.09 \pm 0.10\%$, Beard et al. 2003), which is in the range of the microbial reduction of Fe (oxyhydr)oxides, but may equally well be caused by purely abiotic processes.

The interpreted influence of microbial mats and flow events on the deposition of laminated pyritic lithofacies in the Talvivaara Fm, supported by $\delta^{34}\text{S}$ and $\delta^{56}\text{Fe}$

values of pyrite grains, points towards a marine sedimentary environment with anoxic (ferruginous) background conditions, where pulses of oxic (sulphatic) surface water triggered intense bacterial sulphate reduction and possible microbial iron reduction in microbial mats on the seafloor, leading to pyrite precipitation. This scenario challenges the previous model for the iron sulphide enrichment of the Talvivaara Fm by hydrothermal fluid interactions with the organic-rich muds (e.g. Loukola-Ruskeeniemi & Lahtinen 2013).

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QUANTIFYING THE EFFECT OF LANDSLIDE-DERIVED SEDIMENTS ON DETRITAL THERMOCHRONOLOGY

by

David M. Whipp¹ and Todd A. Ehlers²

¹ Department of Geosciences and Geography, University of Helsinki,
P.O. Box 64 FI-00014 University of Helsinki Finland
E-mail: david.whipp@helsinki.fi

² Department of Geosciences, University of Tübingen, Hölderlinstr. 12,
72074 Tübingen Germany

Analysis of modern river sediment using detrital thermochronology can provide a record of tectonic activity, surface denudation and sediment transport by surface processes. Ideal sediment samples contain datable mineral grains that represent bedrock exposed in the entire catchment. However, in steep mountainous catchments in active orogens, bedrock landslides can produce a significant fraction of basin sediment. Individual landslides contribute sediment from a restricted region within the catchment and may invalidate the assumption that the sediment sample represents the entire drainage area. We have used a simple numerical model of landslide sediment production in combination with the 3D thermokinematic and thermochronometer age prediction software Pecube to determine the magnitude of the influence of landslides on modern river sediment samples. Model landslides were distributed randomly in the catchment following a defined frequency–magnitude relationship, and the rate of landslide sediment production was scaled to a defined rock exhumation rate. A sample of n ages was selected at random from the catchment mouth and sub-basins after 1–1000 years of sediment accumulation to simulate variable sediment residence times within the catchment.

Bedrock landsliding strongly affects catchment detrital cooling age distributions, particularly for shorter sediment residence times. We focused on the Nyadi drainage basin in the central Nepal Himalaya, where detrital muscovite $^{40}\text{Ar}/^{39}\text{Ar}$ cooling age distributions from samples collected five years apart differ in spite of having a sufficient number of dated mineral grains to record the basin age distribution ($n = 34$ and $n = 111$). We used a Monte Carlo method to compare the observed age distributions to 10 000 predicted age distributions of n randomly selected ages and found ~97% of the predicted age distributions to be statistically equal to one observed age distribution, but only 0.1% were equal to the other. This suggests that the sampled sediment did not reflect spatially uniform basin denudation. Using the landslide sediment production model with a 1-year sediment residence time, only 0.2% of the predicted age distributions were equal to the observed distribution, which was previously fitted well by uniform basin

sediment production. Increasing the residence time to 10 or 100 years improved the fit, with ~8% and ~40% of the respective predicted age distributions equal to the observed. Surprisingly, in predicted sub-basin age distributions with and without landslide sediment production, >70% of the predicted age distributions were statistically equal, regardless of the residence time for basin areas <25 km², due to the smaller age ranges in small drainage basins. Lastly, simple mixing of fluvial (uniform) and landslide sediment production suggests that landslides affect basins when >20% of sediment is produced by landslides with a 1-year residence time, and landsliding impacts basins with 10- or 100-year residence times when ~30% and ~70% of sediment is produced by landslides, respectively.

This book contains abstracts submitted for presentation at the 1st Finnish National Colloquium of Geosciences, Espoo, 19–20 March 2014. The venue for the meeting is the Southern Finland Office of the Geological Survey of Finland (GTK). The Colloquium continues the tradition of previous Finnish National Geological Colloquiums. The Colloquium is organized by the GTK, the Finnish Doctoral Program in Geology, the University of Helsinki Doctoral Program in Geosciences, the Geological Society of Finland, and Aalto University. The abstracts in this volume include oral and poster presentations, printed in alphabetical order according to the first author. The editors would like to express their thanks to all authors for their contributions, and wish everybody a pleasant and successful colloquium.