Geological Survey of Finland 2018

Abstract Book

4th Finnish National Colloquium of Geosciences Turku, 14–15 March 2018

Edited by Pietari Skyttä and Olav Eklund

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Unless otherwise indicated, the figures have been prepared by the authors of the abstracts.

Front cover: Scanning electron micrograph of an unindentified creature in Askja (Iceland) 1875 basaltic lava flow in a 50 µm cavity approximately 2 cm from the surface. The creature was found during the study of microbe-mineral interactions in Icelandic basalts. The width of the hairy structure is approx. 20 µm. Magnification 6800x.
Photo: Anu Hynninen, University of Turku.

Layout: Elvi Turtiainen Oy

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PREFACE

Since 2001, the Finnish Graduate School in Geology has been a nationwide postgraduate program, based on close co-operation between all universities training geologists in Finland. One of the important activities has been the Graduate School annual colloquia, 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. 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. The First Finnish National Colloquium of Geosciences was organized in March 2014 at the Geological Survey of Finland (GTK), and this year's meeting is the 4th National Colloquium of Geosciences, organized in Turku, from 14–15 March 2018.

The special focus area of the 2018 Colloquium is the Baltic Sea Basin, with a special session covering the bedrock geology on both sides of the basin, seismology in and around the basin, sedimentology of the basin, environmental risks around the basin, leakage of radioactive matter into the basin and marine biology of the basin. Moreover, one of the important tasks of the meeting is to offer an opportunity particularly for young scientists to present their research and to learn more during the technical sessions and related short courses. Bearing this in mind, the 2018 meeting includes both a separate "entry-level" poster session for MSc students and a pre-conference short course on igneous petrology for PhD and MSc students given by Dr Jussi Heinonen.

It is our great pleasure to wish you all a warm welcome to attend and enjoy the 4th Finnish National Colloquium of Geosciences in Turku.

Prof. Pietari Skyttä, Department of Geography and Geology, University of Turku
Prof. Olav Eklund, Geology and Mineralogy, Åbo *Akademi University*

Organizers of the 4th Finnish National Colloquium of Geosciences

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IN SITU GEOCHEMICAL AND ISOTOPIC EVIDENCE OF COMPLEX MAGMATIC EVOLUTION RECORDED BY ZONED PLAGIOCLASE: A CASE STUDY ON THE KAROO FLOOD BASALT PROVINCE

by

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The 174 – 185 Ma Karoo continental flood basalt province extends from southern Africa to Antarctica. It is one of the most extensive large igneous provinces in the world (e.g. Jourdan et al. 2007). The great diversity of magma compositions presents an outstanding problem in the Karoo province. Picritic lavas from the Luenha River, Mozambique, may represent an important parental magma type of Karoo basalts, but their notably variable initial $^{143}Nd/^{144}Nd$ and $^{87}Sr/^{86}Sr$, in particular, probably indicate crustal contamination. This complicates the characterization of the primary magma composition (Turunen 2015).

This study addressed the magmatic evolution of the Luenha picrites using the compositions of plagioclase grains in six primitive Luenha-picrite samples from different stratigraphic units. Crystallizing plagioclase can effectively record changes in magma composition and hence reveal information on the initial composition, as well as the compositional evolution caused, for example, by fractional crystallization, new magma pulses, or crustal assimilation.

A cold-cathode cathodoluminesence microscope and electron microprobe were utilized in mapping the compositional zonation in plagioclase phenocrysts. LA-MC-ICPMS was used for *in situ* $^{87}Sr/^{86}Sr$ ratio measurements of representative phenocrysts, as well as bulk groundmass.

The anorthite content of plagioclase cores (n = 65) ranges from An_{90} to An_{62}. Core to rim variations revealed three different types of zonation: normal, oscillatory, and reverse zonation. The *in situ* Sr isotope measurements of plagioclase phenocrysts (n = 21) showed less radiogenic initial ratios (cores 0.70511 – 0.70671 (n = 10); rims 0.70539 – 0.70709 (n = 11)) than the previously determined whole-rock ratios (0.70690 – 0.71019; Turunen 2015). Furthermore, *in situ* analyses of groundmass yielded similar results to the whole-rock data (0.70660 – 0.71061, n = 12). Judging from thin-section studies, the isotopic disequilibrium between phenocrysts and groundmass was not caused by alteration. Instead, it implies the assimilation of crustal materials after crystallization of the plagioclase phenocrysts. On the other hand, the isotopic diversity within plagioclase phenocrysts may relate to magma pulses and/or convection in the magma chamber.

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INTEGRATING GEOLOGICAL 3D MODELLING AND FLOW MODELLING IN STUDYING THE HYDROSTRATIGRAPHICAL PROPERTIES OF COMPLEX QUATERNARY DEPOSITS

by

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3D modelling is an effective and increasingly applied tool in hydrogeological studies. In this study, we developed a workflow for a combination of Leapfrog Geo (ARANZ Geo) with the Hydrogeology add-inn and ModelMuse (USGS), together with MODFLOW-NWT (Niswonger et al. 2011).

Leapfrog was used along with ArcMap (ESRI) to generate a 3D model of Quaternary sediments in the Kersilö area in northern Finland (Åberg, A. et al. 2017). Sediments of the study area consist of alternating tills, sorted sediments and peat. The 3D model was constructed with a combination of explicit and implicit modelling and with a polyline tool. The constructed geological Leapfrog 3D model was applied and simplified for the purposes of groundwater flow modelling to define the groundwater flow patterns (Åberg, S. et al. 2017). The hydrogeological parameters of the 3D hydrostratigraphical model were edited with ModelMuse, utilizing the MODFLOW-NWT code (Niswonger et al. 2011).

The combination of explicit and implicit modelling appears to produce the most reliable results. The polyline tool was found to efficiently generate the 3D meshes and even improved the scattered structure of the layers. To strengthen the explicit modelling with Leapfrog, ArcMap was used to generate a more realistic shape for a peat layer in the study area.

The MODFLOW-NWT grid requires continuous layers, and Leapfrog was able to import the geological units as scattered parameter zones within the grid consisting of continuous layers. The interpolation option in ModelMuse enabled the addition of more heterogeneity within the geological units. NWT solver enabled the use of highly heterogeneous cell heights and partially dry layers without convergence errors.

The unit thicknesses of the geological model can be adjusted to improve the flow model fit. Furthermore, the flow model fit can give additional information on data gaps, as well as the distribution of the units with different hydraulic properties. However, caution is needed, since the depositional environment markedly affects the hydraulic conductivity of the units. Fractured and partly weathered bedrock can be locally seen as a poor flow model fit due to the higher hydraulic conductivity in those areas (Åberg, S. et al. 2017, Hall et al. 2015).

Modelling Quaternary sediments with Leapfrog is challenging, because Leapfrog lacks the ability to model lens-like structures that are not intrusions (cut older layers). Software with an interactive cross-section (e.g. Ming et al. 2009) would enhance the modelling of scattered data. In Åberg, A. et al. (2017), interpolation caused bullseyes at some contacts, probably due to the interpolation function being too stiff. The use of smoother interpolation would generate more realistic layers.

However, a function that takes into account the extreme values is suitable for a rugged bedrock surface.

In conclusion, Leapfrog can be used to create a geological model of surficial sediments for use in groundwater flow modelling. The created geological model interacts well with ModelMuse and enables the construction of a hydrostratigraphical model. In addition, groundwater flow modelling can be used to evaluate and improve the geological 3D model and detect missing information on the geological structure.

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GEOCHEMISTRY OF MAFIC AND ULTRAMAFIC ROCKS FROM THE MAWAT OPHIOLITE, NE IRAQ

by

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The ~95 Ma Mawat Ophiolite (MO) (AL Humadi et al. 2018) represents a fragment of the Neo-Tethyan oceanic crust within the Zagros Orogenic Belt exposed along the Iraq–Iran border (Kurdistan region), NE Iraq (Dilek et al. 2007). The MO comprises partially serpentinized peridotite enclosing chromitite, gabbro, pillowed basalt and minor felsic rocks. The basalt is mainly composed of fine-grained plagioclase, clinopyroxene, and orthopyroxene, and shows a variolitic texture. Some basalts are deformed and show a mylonitic texture. The gabbros are characterized by medium- to coarse-grained plagioclase, amphibole and minor pyroxene. The gabbros are highly deformed and crushed. The ultramafic rocks are composed of olivine and/or serpentine, clinopyroxene, orthopyroxene and chromite.

The geochemical data on the mafic and ultramafic rocks can be divided into four different groups. Three of the groups are extremely depleted in LIL and some HFS elements and plot below the N-MORB reference. This suggests that these elements have been mobile. Therefore, the multi-element diagram based on immobile elements (Pearce 2014) has been used interpret the data. In this diagram, basaltic and ultramafic rocks, including dunites, resemble arc boninitic lavas related to a subduction initiation setting (Pearce 2014). This is confirmed with the V vs. Ti/1000 diagram, in which the basalts and ultramafic rocks plot within the boninitic field. The fourth, undepleted pattern of gabbroic rocks plots parallel to the N-MORB reference line. The gabbro plots within the MORB field. This suggests these magmatic rocks were formed in the same fore-arc region. The geochemical data are consistent with the suprasubduction zone ophiolite tectonic setting.

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DEHYDRATION MELTING AND GRANITE PETROGENESIS IN SOUTHERN FINLAND

by

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Selective dehydration melting of minerals such as muscovite, biotite and amphibole is often invoked to account for the production of granitic magma in the deep continental crust (e.g. Johannes & Holtz 1996). Given that the melts produced are viscous, and that a substantial fraction of melting is required to separate melt from residue, a fractional melting scenario without equilibration between melt and residue appears unrealistic. Instead, dehydration melting must be seen as a process in which the melt + solid residue has approached chemical equilibrium.

Dehydration melting of varying assemblages of Svecofennian metasupracrustal rocks has been simulated by thermodynamic modeling using the Rhyolite-MELTS software (Gualda et al. 2012). Different combinations of source rocks give reasonable (i.e. 20–30%) fractions of melt over a range of realistic pressures (5 to 8 kbar) and temperatures (800 to 850 °C). The granitic melts produced overlap with the composition of the late Svecofennian leucogranites. The solid residual is a dry, enderbitic to charnoenderbitic ganulite (orthopyroxene, clinopyroxene, plagioclase, quartz, minor alkali feldspar). This residual is depleted in incompatible components and will not produce further melt unless heated above 1000 °C, above which rapidly increasing fractions of granodioric to tonalitic melts can be formed.

The simulations lend support to models in which the Svecofennian leucogranites are produced by crustal anatexis, whether caused by internal heating as suggested by Kukkonen and Lauri (2009) or by, for example, adiabatic decompression due to orogenic collapse. The residual left after melt extraction was infertile, and not likely to be able to produce granitic magmas similar to the rapakivi granites of southern Finland by further internal heating, as envisaged by Kukkonen and Lauri (2009, 2016). It therefore appears much more likely that the granitic fraction of the syenogranitic rapakivi complexes was formed by a different chain of processes, involving mantle-derived mafic melts and melting of crustal rock types that were not affected by the preceding late Svecofennian anatexis.

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MINERAL SHAPE-PREFERRED ORIENTATION ANALYSIS OF THE KYNSIKANGAS SHEAR ZONE, SW FINLAND

by

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The NW–SE-trending Paleoproterozoic Kynsikangas Shear Zone (KSZ) is a prominent ductile shear zone in the Svecofennian Orogen of SW Finland. The KSZ formed under high-grade metamorphic conditions in migmatitic and gneissic rocks. The shear zone is believed to have formed under left-lateral shear. A more complex kinematic, possibly transpressive, origin of the shear zone is evident from our analysis of the kilometer-scale pattern of metamorphic foliations, maximum principal stretching orientations and small-scale kinematic indicators. In order to elucidate the kinematic regime of shear zone formation, we quantify the geometry and intensity of shape-preferred orientation (SPO) of metamorphic minerals. Therefore, oriented block samples from 50 stations are cut according to the principal planes of the mineral fabric ellipsoid. Mineral shape fabrics will be analyzed from principal ellipse sections by image analysis. The data will be compared with more sophisticated 3D fabric analysis techniques such as anisotropy of magnetic susceptibility (AMS). Detailed sampling to study AMS was conducted at selected outcrops in the KSZ to examine the variation in anisotropy degree within the shear zone. The results of the mineral shape fabric analysis will be used to calibrate visual estimates of fabric intensity in the field and AMS fabrics in order to assess the variations in fabric intensity across the KSZ.

INTRODUCING THE MAGMA CHAMBER SIMULATOR

by

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Magma–wallrock interaction in crustal magma chambers (a process known as crustal assimilation) is critical to the thermodynamic and chemical evolution of a magmatic system and the formation of many of the most economically important ore deposits on Earth. Although such a generalized model is largely accepted, details on how these interactions take place are poorly characterized. The classical and widely used AFC (assimilation-fractional crystallization) model of DePaolo (1981) does not allow progressive melting of crustal wallrock or provide any hint on whether its results are thermodynamically feasible or not. Such limitations may significantly impact on the mass balance of crustal and magma sources in models of magmatic systems.

The Magma Chamber Simulator (MCS; Bohrson et al. 2014) models the effects of crystallization, crustal assimilation, and magma recharge on phase equilibria, mineral chemistry, major and trace elements, and radiogenic isotopes through mass and enthalpy balance in a multicomponent-multiphase magma + wallrock + recharge magma system. It utilizes the combination of Visual Basic coding and MELTS software (Ghiorso & Sack 1995, Gualda et al. 2012). It is a significant leap forward in modeling magmatic differentiation, and we encourage application of the MCS tool to different igneous environments and tectonic settings where crystallization, assimilation, and/or recharge take place.

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SUBSURFACE HYDROCHEMICAL PRECISION TREATMENT OF A COASTAL ACID SULFATE SOIL

by

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Coastal acid sulfate soils (CASS) are among the nastiest soils in the world, causing the acidification of agricultural fields and contributing to the majority of the mobilization of acidity and potentially toxic metals into our rivers and their ultimate deposition in our estuaries (Dent & Pons 1995, Johnston et al. 2016, Nordmyr et al. 2008). We are able to protect our waters in environmentally sustainable agriculture by combining controlled drainage, subsurface irrigation, and hydrochemical precision treatment in a novel project field in Ostrobothnia, western Finland. The PRECIKEM project field consists of nine nearly identical 1-ha subfields hydrologically isolated by a plastic film preventing the lateral by-pass flow of groundwater. Each field has a drainage system consisting of three subsurface drainpipes at 1.3 m depth, a collector pipe, and a control well enabling manual groundwater table management. During subsurface irrigation and hydrochemical precision treatment, water is pumped from the nearby River Laihianjoki to the control wells through a network of pipes.

During the project period from 2011–2016, several fields were treated with different amounts of fine-grained (d_{50} = 2.5 µm) calcium carbonate and calcium hydroxide suspensions, and the drainage waters from the fields were regularly sampled and analyzed. The excavation of several fields revealed the calcium carbonate to have formed a neutralising coating on the surfaces of hydrologically active macropores in the soil structure. This effectively resulted in a long-term situation of elevated pH and lowered acidity values, thus neutralising the otherwise acidic waters. The most prominent effect of the subsurface chemical treatments was a dramatic decrease (>90%) in the Al concentration, which is a promising step towards improving the chemical and ecological status of our CASS-affected coastal waters.

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FENNOFLAKES: A PROJECT FOR IDENTIFYING FLAKE GRAPHITE AREAS IN THE FENNOSCANDIAN SHIELD AND UTILIZING GRAPHITE IN DIFFERENT APPLICATIONS

by

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The world market for natural flake graphite is continuously increasing, since the use of Li batteries in cars is becoming more common. A good way to illustrate the forthcoming need is that the battery pack for the Tesla S-class electric car contains about 85 kg of graphite. However, this graphite product must be enriched to 99.95% pure graphite.

The aims of the FA project FennoFlakes are to:
– Find flake graphite ores in Finland and identify the geological criteria for the ore formation;
– Utilize pure flake graphite and separate flake graphite into single and multi-layer graphene;
– Test the graphite and graphene for technological applications.

We have found that flake graphite of good quality is located within the fold hinges in carbon-bearing sediments in high-grade areas (upper amphibolite to granulite facies). When heated to above 650 °C, graphite can dissolve in CO_2, which migrates towards the pressure minimum in folded rocks, where it precipitates as high-quality graphite. In areas where the carbon content in the metasediments is around 6 wt%, the carbon contents may rise to 45 wt% in the fold hinge zones.

By using flotation and NaOH solutions, we have been able to enrich graphite to >98%. However, an external commercial laboratory has been able to enrich flake graphite to >99%. Unfortunately, their methods were not reported.

In our study, Finnish flake graphite was used as a raw material for graphene production. As the exfoliation method, high shear-rate mixing was applied to separate graphene sheets from graphite. This method is based on applying shear force with a laboratory mixer to separate the sheets. In order to prevent the graphene sheets from restacking, two different surfactants were used. For practical and environmental reasons, sodium cholate and nanocellulose aqueous solutions were chosen as suitable exfoliation media.

The effects of parameters such as mixing time, initial graphite concentration, and rotor speed on the yield of few-layer graphene were studied. The concentra-

tion of the graphene dispersions was determined with UV-visible spectroscopy and a yield of 1.15% was obtained, being higher than that usually obtained by similar methods. The quality of the produced dispersions was investigated with AFM and Raman spectroscopy.

We have prepared nanocomposite films consisting of few-layer graphene and nanocellulose by using a standard airbrush to spray-coat glass substrates. This simple and cheap method produces 200-nm-thick composite films with the electrical conductivity in the upper semiconductor regime (ca. 30 S cm^{-1}). Flexible substrates can also be coated with these thin films.

In the future, we aim to use the spray-coated composite films in electrochemical sensor and energy storage applications.

ANISOTROPY OF MAGNETIC SUSCEPILITY (AMS) IN MINERALS: A TOOL TO IDENTIFY GEOLOGICAL STRUCTURES IN METAMORPHIC ROCKS

by

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Anisotropy of magnetic susceptibility (AMS) has proven to be an excellent tool for examining mineral fabrics, magma flow and rock deformation. The magnetic anisotropy of rocks depends on the anisotropy of individual grains and their spatial arrangement. It is a rapid, inexpensive method that can be systematically performed on all types of rocks. AMS is described mathematically as a symmetrical 2nd-rank tensor, which can be visualized as an ellipsoid with three principal axes: maximum (k1), intermediate (k2), and minimum (k3) susceptibility. The long axis is often referred to as the magnetic lineation and the short axis as the pole to the magnetic foliation. AMS has proven to be a good technique for 3D mineral fabric analysis, for further examinations of metamorphic rocks, such as migmatites and high-grade gneisses.

The AMS ellipsoid has been applied as a functional tool to obtain the magnetic lineation and foliation of the typical high-grade migmatites found in Olkiluoto, SW Finland (Karell et al. 2016). The AMS technique has also been utilized in more prominent geological structures such as within several shear zones in SW Finland (Mertanen & Karell 2011, 2012).

However, precautions have to be taken when interpreting the results, since the magnetic lineation and foliation can represent various structures within the metamorphic fabrics. The AMS data measured in the high-grade migmatites in Olkiluoto indicate both α-lineation and β-lineation within the metamorphic minerals in the rock (Karell et al. 2016). This verifies the importance of a detailed structural understanding of the study site prior to an AMS study, especially in a highly deformed migmatite environment. In order to better understand the deformation history and the structural control, we have found that combining AMS with X-ray computed tomography provides even more detailed information for the interpretation of metamorphic textures in 3D (Sayab et al. 2017). Nevertheless, these techniques cannot replace conventional methods, but they are very effective in complementing any structural data.

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DENTINE COLLAGEN SERIAL SAMPLING STUDY OF THE VIKING AGE POPULATION OF LUISTARI IN EURA

by

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The Luistari cemetery in Eura is a key site for research on the Finnish Merovingian (550/600–800 CE) and Viking Period (c. 800–1050 CE). Luistari is among a limited number of Finnish inhumation burial grounds dating to the last centuries of prehistoric time. During this period, the deceased were usually cremated. Luistari is also the only site that has been almost completely excavated, between the years 1969–1992 (Lehtosalo-Hilander 1982a-c, 2000). The preservation of skeletal remains has been fragmentary, but still exceptionally good, enabling osteological research (Salo 2005, 2016 unpublished). The nearby localities alongside the Eurajoki river, Köyliö, and Kokemäenjoki river are rich in Iron Age finds. The region has been an important waypoint area located between the coast and the area of Häme. Imported artefact finds point, among others, to the Mälaren area in Sweden (Arrhenius 1960, Holmqvist et al. 1961) and to the Baltic region, especially the Courland area in what is nowadays Latvia (Kivikoski 1940). Luistari is located in the contact of the Laitila Rapakivi and Satakunta Sandstone areas, the latter being the dominant bedrock type in the Pyhäjärvi lake area.

Altogether, ten Viking Period individuals, six women and four men, were selected for dentine serial sampling. Depending on the state of preservation, one to three permanent molars per individual were sampled and 3–8 microsamples were taken. A novel sequential extraction method (Sahlstedt & Arppe forthcoming) was used to separate dentine collagen and phosphate phases. Collagen samples were analyzed for both $\delta^{13}C$ and $\delta^{15}N$ in order to study the dietary development during childhood and, in cases where the third molar was also preserved, until early adulthood.

The serial samples revealed isotopic variation in carbon and nitrogen, which is probably related to both a dietary change and possible growth stress during childhood. The first molars enable the length of the breastfeeding period to be estimated (Fuller et al. 2006). High $\delta^{15}N$ values were measured in all four individuals in whom the first molar was preserved. In general, our results indicate the abundant use of high trophic level protein sources during childhood, probably the exploitation of fish. The sample set includes individuals whose $\delta^{13}C$ values are high in comparison to the analyzed bulk isotopic data. This is likely to be due to the consumption of marine fauna, but locally caught anadromous fish are another possible explanation. Based on our preliminary baseline research, $\delta^{13}C$ values are high in modern Pyhäjärvi fish. This is probably due to the presence of calcite minerals (Kortelainen et al. 2007) in the area. This feature gives a local isotopic stamp to the fauna, but is complicated to recognize in omnivorous humans by using bulk $\delta^{13}C$ analysis.

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REFINING THE THERMODYNAMIC AND GEOCHEMICAL UNDERSTANDING OF MAGMATIC SYSTEMS: TWO NEW PHD PROJECTS AT THE UNIVERSITY OF HELSINKI

by

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The recent development of numerical modeling tools [e.g. rMELTS, Magma Chamber Simulator (MCS)] in petrology has evoked new ways to study the origin and evolution of magmatic systems. MCS is an advanced modeling tool designed to quantify the impact of simultaneous recharge, assimilation, and fractional crystallization through mass and enthalpy balance in an evolving open multicomponent-multiphase magma system (Bohrson et al. 2014). MCS is being applied and co-developed in the ongoing PALIN (Partial Melting Processes at the Contact Zones of Layered Intrusions) project (PI, Jussi Heinonen) at the University of Helsinki (UH). Two PhD projects recently launched at the UH, one focusing on partial melting experiments and the other on geochemical and thermodynamic modeling, will benefit from the expertise of researchers of the international PALIN and MCS groups.

The aim of the first project is to provide detailed information on wallrock assimilation in 1.1 Ga Duluth (Minnesota) and 180 Ma Vestfjella (Antarctica) mafic intrusion complexes. Partial melting experiments on natural samples from the wallrocks of the associated intrusions (including black schists, banded iron-formations, felsic plutonic rocks, and hydrothermally altered basalts) will be performed at ETH Zürich to quantify the chemical compositions of the wall rock partial melts. Physical and chemical effects, which the adjacent mafic magma could cause to the partially melting wallrock (e.g., peritectic reactions), will be tested by adding synthetic proxies of the mafic magma to the experimental mixtures. The end products of these experiments will be analyzed with EPMA and LAICP-MS at the UH, and the results will be utilized by other PALIN project members to construct sophisticated models for the magmatic evolution of the studied intrusions with MCS. In the case of the Duluth complex, the assimilation of S-rich metasedimentary rocks appears to have played a crucial role in the generation of local Ni-Cu sulfide and PGE deposits.

The second project aims to produce a comprehensive melt evolution model for massif-type anorthosites using rMELTS and MCS. Recent studies (Fred et al. 2016) in the 1.64 Ga Ahvenisto complex in southeastern Finland have revealed that monzodioritic members of the anorthositic Ahvenisto suite show evidence of magma differentiation and, most likely, are not cumulates but represent a residual melt phase. A detailed melt evolution model of the monzodioritic rocks could be used to better constrain the parental magma composition of the Ahvenisto suite and also massif-type anorthosites elsewhere. Ore formation processes in anorthosite complexes are usually related to the most mafic members of the suites, and crustal assimilation plays an important role in their generation. The melt evolution model produced for the Ahvenisto suite will be applied to the evaluation of the NiCu ore potential of massif-type anorthosites using a geochemical database compiled from the Voisey's Bay intrusion in the Nain anorthosite complex, Labrador, Canada.

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ORIGIN, EXPLORATION POTENTIAL, AND METALLOGENY OF KOMATIITIC SUITES OF EASTERN LAPLAND

by

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Several Paleoproterozoic and Archean komatiite-hosted Ni-Cu-PGE mineralizations have been found in Finland. On a global scale, these types of deposits are important resources for base and precious metals. The Geological Survey of Finland (GTK) and the University of Helsinki launched a collaborative project regarding the exploration potential of the komatiitic rocks of the Eastern Lapland Archean Domain (ELAD) in the spring of 2017. The geology of the ELAD is rather vaguely known, partly because it is located in one of the least accessible parts of Finland. The local bedrock is characterized by three granitoid complexes and two supracrustal suites, all of which have undergone medium to high-grade metamorphism (Juopperi 1994). The stratigraphy of the main rock suites is not well understood owing to predominant thrust tectonics and poorly exposed contacts (Halkoaho et al. 1997). The volcanic rocks of the area show a bimodal (komatiitic to rhyolitic) assemblage with intermediate compositions notably lacking (Kauniskangas 1987, Sorjonen-Ward & Luukkonen 2005). The major komatiitic ultramafic bodies have been explored by Outokumpu, Rautaruukki, and GTK, mainly during the 1980s and 2000s. In addition, the University of Oulu carried out regional studies in the northern parts of ELAD as a part of their "Archean Areas" project in the 1980s. The ELAD hosts several subeconomic mineralizations, but significant Ni-Cu-PGE deposits have not been discovered. Our project aims at a more profound understanding of the petrogenesis and mineral potential of the komatiitic rocks with special interest in their geochemistry and isotope chemistry, including S and Cu isotopes and U–Pb geochronology.

A targeted mapping program was carried out in the summer 2017 in the ultramafic bodies, particularly those with a poor record of geological and geochemical data. Several new occurrences of komatiitic rocks were found. Some bodies previously considered to be ultramafic (cf. Bedrock of Finland – Digi KP) were found not to be ultramafic, despite their strong magnetic anomalies. In total, 99 rock samples were collected, from which 41 thin sections, 13 thick sections for Cu–S stable isotope studies, 52 XRF and PGE analyses, and 22 REE analyses were performed. Three age determinations from key locations are planned in search of a more robust handle on the geochronology of the area. Based on new and pre-existing data from GTK and previous studies, three Master's theses are being prepared. The topics are *"Petrological and geochemical comparison of the ultramafic rocks of Tulppio, Jänesselkä and Värriö" (Haapala, P. S.)*, *"Komatiites of eastern Lapland and their ore potential" (Höytiä, H. M. A.)*, and *"Sulphur-copper isotopes and geochronology of the komatiites of eastern Lapland" (Tepsell, J. H. M.)*.

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NATURAL STONE POTENTIAL IN FINLAND

by

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The occurrence of rocks suitable as natural stone is determined by the general regional geological history of each specific target area (Selonen et al. 2014). The Geological Survey of Finland initiated exploration for natural stone in the late 1980s with regional projects. At present, projects of this kind have been executed practically throughout Finland. Based on the results, the natural stone potential in Finland can be summarised as follows (geological features according to Lehtinen et al. 2005):

The Archaean domain (ca 3500–2500 Ma) in eastern Finland is mainly composed of migmatite-granitoid areas, greenstone belts and mica gneiss/paragneiss areas. The greenstone belts, with soapstone (and serpentinite) occurrences, are the most important natural stone resources within this domain. The migmatite-granitoid areas can have a potential for multi-colour natural stones. The cutting Proterozoic diabase dykes are sources of "black granites".

The Proterozoic formations in Finnish Lapland include the Central Lapland Granite Complex, a greenstone belt, a granulite complex, mafic layered intrusions and schist belts. The greenstone belts (massive schists), schist belts (marbles and schists) and mafic layered intrusions ("black granites") have a resource potential for natural stones. Prospects for natural stones are found in the post-kinematic granites in Central Lapland.

The Central Finland Granitoid Complex (CFGC) comprises synkinematic intrusions (1890–1880 Ma) and undeformed to deformed post-kinematic intrusions (1885–1870 Ma) along the margins of the CFGC. The CFGC, in particular the post-kinematic intrusions, holds a good natural stone potential.

In the Proterozoic schist belts (mainly meta-pelites), individual (green/red/brown) intrusions, high-grade metamorphic blocks, multi-coloured domes and massive meta-sedimentary schist units have a resource potential for natural stones.

The anorogenic rapakivi granites (1650–1540 Ma) occur as four major and several smaller batholiths and stocks in southern Finland. Regionally, the rapakivi batholiths are homogeneous and sparsely fractured and have the highest potential for natural stone. Brown, red and green rapakivi granites are the most important natural stone resources in Finland.

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TEMPERATURE OF SHALLOW GROUNDWATER IN FINLAND – THE UTILITY OF NATIONAL MAPPING TO ESTIMATE THE GEOENERGY POTENTIAL

by

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Geonergy is the combined energy from solar radiation and internal heat, which can be used as both heating and cooling energy (Juvonen & Lapinlampi 2013, Arola 2015). It can be collected from sediments, watercourses, bedrock and surface layers of the earth (Lauttamäki and Kallio 2013). It is important to recognize and utilize all renewable energy reservoirs to achieve the internationally binding climatological targets of the country. Shallow groundwater can form a significant local renewable energy resource in Finland (Arola 2015, Arola & Korkka-Niemi 2014).

The purpose of this study is to carry out nationwide mapping of the temperatures of Finnish shallow groundwaters and, based on this, to explore the groundwater energy potential in Finland. Temperature data (more than 7600 observations) have been collected from national Hertta database, as well as additional GTK databases. There have been some challenges in collecting the data. Some provinces in Finland lack stored temperature measurements. In addition, data have been collected from various databases, and there have been several temperature observers, which can mean variation in measurement procedures.

In general, the data indicate a decrease in shallow groundwater temperatures from south to north and from west to east. In addition, the urban heat island effect can be seen in the dataset, with groundwater temperatures increasing from rural to urban areas. The temperature map that has been created is an essential tool to define the groundwater energy potential in Finland.

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ACCUMULATION OF METALS AND ORGANIC MATTER IN SEDIMENTS OF THE EASTERN PART OF THE GULF OF FINLAND

by

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The Baltic Sea is susceptible to pollution for many reasons. It is relatively shallow, the drainage area is large and the residence time of water is long (HELCOM 2010). The easternmost part, the Gulf of Finland, has been considered as one of the most polluted basins of the Baltic Sea. The situation is particularly serious in the offshore areas of Kotka–Hamina along the northern coast of the Gulf of Finland, where the River Kymi was the main pollution source in the past. The pollution problems of the River Kymi were addressed several decades ago and the pollution load is generally decreasing, but it appears that sea currents transport pollutants, such as heavy metals, from the eastern parts of the Gulf of Finland, the Neva estuary and the bay of Viborg (Vallius et al. 2007). The Gulf of Finland is one of the areas of the Baltic Sea that is most affected by eutrophication, and it appears that the highest metal concentrations in the sediments are found at sites with the most intense accumulation of organic matter.

Our study area is situated in the eastern Gulf of Finland, in the offshore area between the Kotka archipelago, Klamila and Ulko-Tammio. The aim of this study is to determine the horizontal and vertical distribution patterns of metals and organic carbon in the sediments and to examine whether a correlation exists between the accumulation of metals and organic carbon. A horizontal comparison of metals in surface sediments shows the regional differences in their distribution, whereas a vertical comparison reveals the pollution history. Since local sediment quality guidelines are not available, both surface samples and samples from longer cores will be compared with Canadian sediment quality guidelines to understand the degree of contamination of the study area.

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VISUALISING MICROBES ON MINERALS USING SCANNING ELECTRON MICROSCOPY

by

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Recent rapid development in microbial ecology has uncovered rich and diverse microbial communities in environments that were previously thought to be hostile and almost lifeless. This includes rocks in dry and cold environments, where the nutrient supply is limited and living organisms rely on elements extracted from the rocks themselves. In order to understand microbial interactions with the lithosphere and their role in biogeochemical cycles, we need to recognize and study microbe–mineral interactions. Scanning electron microscopy (SEM) is one of the most important direct visualisation methods revealing microbes on mineral surfaces. It complements genetic methods that identify unculturable microbes and their potential metabolic activity, and enables, using different analytical systems attached to SEM, *in situ* geochemical analyses of mineral-rock surfaces. SEM can be used to determine whether microbes prefer certain minerals or topographic features such as ridges, cavities and cracks, and whether microbial activity causes the dissolution of substrates or secondary mineralisation.

The most straightforward method for preparing geological samples for SEM is simply air-drying or alternatively the use of a desiccator. It has been anticipated that biological samples cannot be visualized directly by SEM, as surface tension on the air–water interface during drying disrupts the cells and causes cell lysis. Therefore, extensive chemical treatment has been applied to biological samples before SEM visualization. However, excessive treatment might cause dislocation of the cells and induce chemical changes in the sample, making it impossible to evaluate microbe–mineral interactions. We compared the response of an artificial laboratory-grown bacterial community and natural *in situ* microbes on terrestrial basalt to different sample pre-treatment methods with the aim of preserving the microbe–mineral interaction interface. While chemical fixation preserved the morphology of the cells, the treatment dislocated the cells, making it impossible to evaluate their interactions with the substrate. Air-drying, on the other hand, caused the collapse of most of the laboratory-grown cells while maintaining the location of cells on the mineral surface. Natural microbial communities on dry terrestrial basalt were composed of desiccation-resistant microbes, which remained attached to the surface and partially maintained their morphology, regardless of the sample pre-treatment method, proving that chemical fixation is unnecessary. Analysis of 23 basaltic samples from Iceland and Faroe Islands confirmed the suitability of air-drying as the main sample pre-treatment method for visualising microbes on mineral surfaces. Vesicles and submillimetre cavities of all the samples contained microbial cells of different morphologies, with the most common feature being rod-shaped microbial cells on plagioclase crystals.

We suggest air-drying as the main sample pre-treatment method for visualizing microbes on mineral surfaces, since the loss of morphology is clearly secondary to the potential dislocation of cells and to potential chemical changes in the sample caused by the chemical fixation reagents.

SEAMBOTH – SEAMLESS MAPS AND MANAGEMENT OF THE NORTHERN BOTHNIAN BAY: GEOLOGICAL DATASETS

by

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In marine areas, the natural processes and the marine species living there rarely follow any human-defined borders. This is a basic idea behind the SEAmBOTH project: a joint Finnish–Swedish endeavor towards seamless maps and management of the northern Bothnian Bay. The ongoing SEAmBOTH project (2017–2020) is funded by Interreg Nord. The project partners are Metsähallitus (also coordinating the project), SYKE, GTK, SGU, Norbottens Länsstyrelsen, the North Ostrobothnia ELY Centre and Lapland ELY Centre.

Steadily increasing human pressures on the marine environment are challenging us to develop efficient tools for marine spatial planning and management in order to reduce fragmentation and pressure. One effective example is habitat and species maps, as well as nature (geological and biological) value maps. There are considerable knowledge gaps regarding both the occurrence and geographical distribution of bathymetry, different seabed substrate types, marine species and habitats in the project area. The uniqueness of the Bothnian Bay marine area (brown waters with a low Secchi depth, a large freshwater input and impact) is not satisfactorily taken into account in standard mapping methods developed on national levels. To fill these existing knowledge gaps, we need to cooperate and pool our resources. SEAmBOTH aims to create well-functioning co-operation between Finland and Sweden by sharing knowledge, harmonizing definitions and methodologies, and by creating a good, shared basis for planning and management of the sea. Field data are being used to map and model the occurrence of species, habitats and geological features.

The project's main goal is to help ensure the conservation of the Bothnian Bay's biological marine diversity, its habitats and ecosystem, and the ecosystem services it provides based on sufficient knowledge, co-operation and efficient planning and management of the area. The concrete results will be transboundary maps showing nature values, guidelines on how to use these maps, as well as guidelines on which methods work in the Bothnian Bay.

Seabed substrate data and accurate depth models function as a basis for modelling work. In addition to existing datasets, GTK's survey vessel Geomari acquired new geological field data (seabed substrate, subsurface geology and structures, bathymetry) by applying seismo-acoustic techniques (single channel reflection seismic, pinger, chirp, multibeam and side-scan sonar equipment), short core sampling and underwater videos in summer 2017. Fieldwork will continue in summer 2018, including a joint sounding area with SGU to ensure a smooth transition between national datasets. In addition, some very shallow test areas (water depth <5 m) will be mapped with GTK's Gridi vessel. This information will also be used to validate airborne LiDAR data, which will hopefully yield depth information from shallow areas.

BUILDING A DIGITAL LEARNING ENVIRONMENT TO SUPPORT FIELD TEACHING IN GEOSCIENCES

by

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Nature is the most important learning environment in geoscience studies; geological observations are made in the field. For this reason, there is a demand to increase the number of field exercises and improve the quality of field and laboratory courses. However, working outdoors is unpredictable, dependent on the seasons, and requires resources. With new digital learning materials and existing open geospatial data, it is possible to broaden the spectrum of learning environments, bring the fieldwork into the classroom, and better assist students when they are in the field so that their learning is more efficient.

The Bachelor's Programme in Geosciences at the University of Helsinki is participating in a new project, "Digiloikka" (digital leap), launched by the University of Helsinki, with the aim to provide resources for the study programs to digitalize teaching. The main aims of the geoscience project are to produce: 1) virtual field excursion materials for the key field teaching sites of the Bachelor's Programme, 2) video tutorials for laboratory and field measurement techniques, and 3) GigaPan pictures enabling virtual field observations (and related exercises) in the classroom. The outcomes of the project are not only aimed at university students: the material will be made available to a broader audience through the geologia.fi internet portal and could be utilized in marketing geoscience studies for potential applicants.

Virtual field teaching in the classroom and on the web can be achieved by utilizing panoramic GigaPan pictures and instructional videos together with geospatial elements. The GigaPan pictures are produced by combining multiple high-resolution photos taken at various magnifications, which allows students to make observations and interpretations of geological formations, such as bedrock outcrops, from up close and far away. Since the resolution is high, it is possible to distinguish fine structural details. In addition, GigaPan pictures can be used to preserve important study sites that are in danger of disappearing (for example due to human activity). Instructional videos function as a supplementary teaching method for field and laboratory procedures before and during practical work.

MAGMATIC STRATIGRAPHY AND REEF-TYPE PGE MINERALIZATION IN THE 2.44 GA MAFIC-ULTRAMAFIC NÄRÄNKÄVAARA LAYERED INTRUSION, NORTHERN FINLAND

by

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The 2.44 Ga mafic-ultramafic Näränkävaara layered intrusion is located in northeastern Finland, 100 km south of the Arctic Circle (Alapieti 1982). It belongs to a belt of 2.45–2.43 Ga layered intrusions formed during early Paleoproterozoic rifting of the Archean craton (Lauri et al. 2012). These intrusions are, in terms of their structure, typical mafic layered intrusions with marginal and layered series, and contain contact-, reef- and offset-type Ni-Cu-PGE deposits. Parental magmas of these intrusions had boninitic or high-Mg basalt affinities (Iljina et al. 2015 and references therein).

The Näränkävaara intrusion is 25 km long and 5 km wide, with a sub-horizontal layered series and steep outer contacts. Geophysical data infer a depth of 5–10 km. The intrusion has been faulted into two main blocks that dip to the northeast and to the southwest. Wall rocks are Neoarchean granites, migmatites, and gneisses. The intrusion is composed of three principal lithologic units (stratigraphic thickness in parentheses): a basal dunite (2000 m), a peridotitic-pyroxenitic unit (700 m), and a gabbronoritic-dioritic unit (600 m). There are two lithological reversals into peridotitic compositions, one in the pyroxenitic unit and one in the gabbroic unit.

Four drill holes intersect a 10–25-m-thick PGE-enriched zone located in the transition zone of the pyroxenitic and gabbroic units (Lahtinen 2005). The average intersection length is 15 m with 0.25 ppm Pt+Pd+Au, and the highest assay 0.39 ppm Pt+Pd+Au in a 1-m-long core sample with Pd/Pt ratios ranging from 2.5 to 8.7. The PGE-enriched zone is continuous along strike for at least 5 km. Host rocks are websteritic cumulates that grade into melagabbronorites. PGE enrichment comprises sub-micrometer-scale PGM associated with disseminated primary magmatic sulfides. The sulfur content is low, with the highest value at 2440 ppm associated with 262 ppm Cu.

The PGE-enriched zone probably formed through differentiation of the magma that led to sulfur saturation and separation of an immiscible sulfide melt, which scavenged the PGE. Magma mixing may have been involved in the saturation process, as the mineralization is found stratigraphically above a reversal into peridotite.

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TRACING SULFIDE-FORMING PROCESSES IN THE COASTAL BALTIC SEA FLOOR OVER THE PAST 1,500 YEARS USING THE S AND FE ISOTOPIC COMPOSITION OF FE SULFIDES

by

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Pyrite is the key sink for sulfur (S) and iron (Fe), especially in organic-rich marine sediments. In addition, in areas of rapid sediment accumulation and abundant reactive Fe input, such as the coastal Baltic Sea, metastable Fe sulfide phases (mackinawite and greigite) often comprise a prominent Fe and S sink alongside pyrite. Pyritization in such sediments is a cumulative process predominantly driven by the diagenetic formation of hydrogen sulfide upon bacterial degradation of organic matter. Changes in the biogeochemical cycling of Fe and S in coastal sediments of the Baltic Sea modulate the shuttling of reactive Fe to the central deep basins of the Baltic Proper, which potentially affects bottom water oxygenation and phosphorus and nitrogen burial in these deep areas. Therefore, changes in the diagenetic dynamics of Fe and S in coastal areas, driven by fluctuations in the delivery of organic matter to the seafloor, have the potential to modulate the nutrient pool and oxygenation of the entire Baltic Sea. In this study, we will use sediment Fe and S stable isotope measurements combined with textural pyrite analyses to elucidate how changes in the organic matter deposition and bottom-water oxygen levels over the past 1,500 years, linked to climatic oscillations and human-induced eutrophication, have affected Fe and S cycling in the coastal northern Baltic Sea. To account for the potential heterogeneity in the Fe and S isotopic signatures in these sediments, we will combine bulk sediment IRMS analyses with *in situ* SIMS measurements for different types of pyrite framboid clusters. Indeed, the markedly different pyrite morphologies that often co-occur in close contact offer an ideal archive to deconvolve complex pyritization dynamics and their potential imprint on the bulk sediment Fe and S isotope signatures at the study site. The results will be interpreted in the context of a recent multi-proxy reconstruction of fluctuations in the organic matter delivery to the basin and corresponding shifts in the near-bottom water oxygen levels over the study period. For example, we hypothesize that the improved oxygenation during the Little Ice Age due to a decline in the delivery of labile organic matter was accompanied by a decrease in the rate of bacterial sulfate reduction and sulfate-mediated anaerobic oxidation of methane, which, in turn, should be recorded as enriched $\delta^{56}Fe$ values and a depleted $\delta^{34}S$ signature in pyrite.

DEVELOPING A DISCRETE FRACTURE NETWORK MODEL FOR BEDROCK OF THE HYVINKÄÄ AREA

by

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A geological discrete fracture network (DFN) model is a statistical model for stochastically simulating rock fractures and minor faults (Fox et al. 2012). Unlike the continuum model approaches, DFN model geometries explicitly represent populations of individual or equivalent fractures (Wilson et al. 2011). Model construction typically involves stochastic approaches that create multiple deterministic realizations of the fracture network (Gringarten 1998).

Discontinuity data were gathered in the summer of 2016 from outcrops in the general area of Hyvinkää. This endeavor yielded the direction-dependent fracture density (P10), which had to be converted into the one-sided fracture surface area per unit volume (P32) for the DFN model. Wang's (2005) conversion factor approach was chosen as the best-suited method, and the model area was restricted to one sub-domain of the study area to ensure final model quality. The DFN model is part of a larger research project, along with Balogh (2018) and Ruuska (2018), which aims at more accurate depiction of the brittle and ductile structures of the bedrock surface for use in further hydrogeological modeling.

Wang's (2005) conversion factor C13 was calculated in Python by applying the methods presented by Wang (2005) and Fox et al. (2012). The script will eventually be freely available to the scientific community in GitHub. C13 is approximated by integrating over the probability distribution function (PDF) of each fracture population, also yielding Fisher statistics (mean vector, sum vector length, dispersion angle, and kappa). The most important Python package used for this script was Mplstereonet (Kington 2016), which was applied in many conversions and calculations. The package also includes a clustering algorithm that was used to create the desired number of clusters of fracture poles, translating directly to fracture populations (Figs. 1 and 2). The clustered populations were compared with the populations classified by Balogh (2018).

The final model will be a representation of the most likely fracture orientations and their relationships in the study area. While this will unavoidably be a simplification, it nevertheless provides valuable insights and can be used to more accurately model bedrock surface structures.

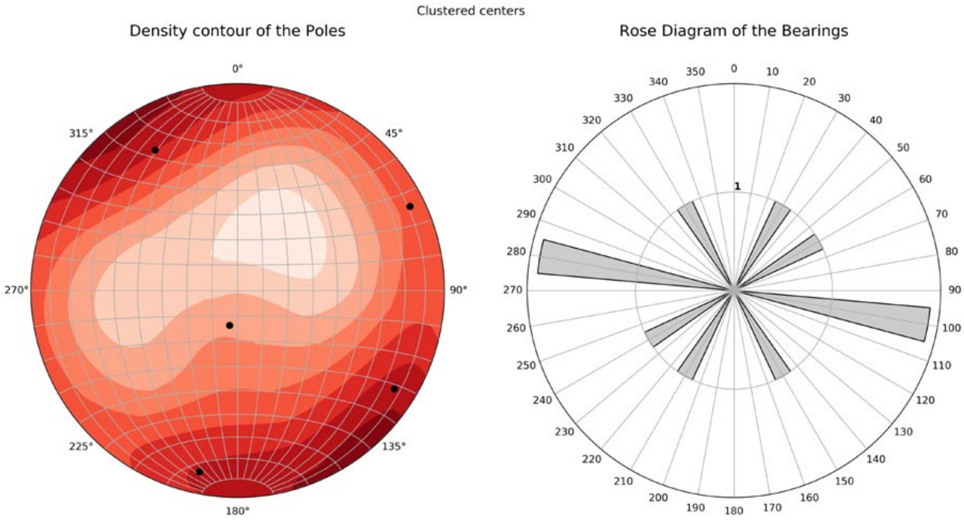

Fig. 1. Clustered centers created by the algorithm.

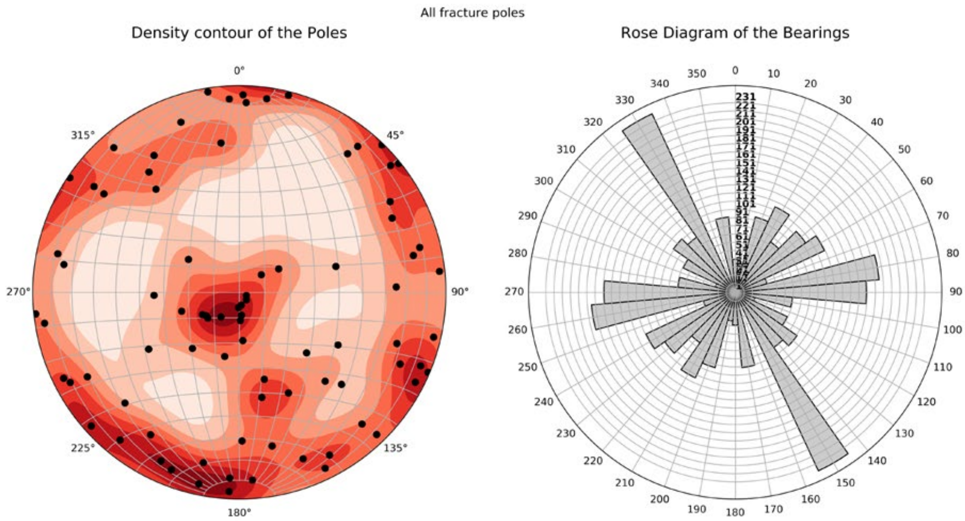

Fig. 2. All fracture poles in study area.

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EVIDENCE FOR A HIGH Nb/Ta AND Zr/Hf RESERVOIR IN THE SOUTH-CENTRAL FENNOSCANDIAN SHIELD TRACED IN 1.86-1.85 GA MONZOGABBROS

by

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High field strength element ratios, particularly Nb/Ta and Zr/Hf (~17.5 and 36, respectively; Sun & McDonough 1989), in the unfractionated Earth are assumed to follow those of the chondrites. However, the Nb/Ta ratios of the Earth's crust and mantle show subchondritic values (~ 12–15), which have led to the so-called "Nb/Ta paradox" and the search for a suprachondritic Nb/Ta reservoir and "missing Nb". Recent studies have shown that Nb/Ta and Zr/Hf can fractionate during magmatic processes, despite their similar geochemical characteristics. However, the fractionation usually lowers the ratios and suprachondritic values are rare, being restricted to rutile-bearing eclogites (Rudnick et al. 2000) and subcontinental lithospheric mantle (Aulbach et al. 2008).

Here, we present Nb, Ta, Zr and Hf concentrations of 1.86–1.85 Ga monzogabbros from southwestern Finland. The analysed rocks show OIB-like enriched geochemical features with elevated Nb/Ta (~ 16–38) and Zr/Hf (~ 41–48) ratios and high initial εHf values. This is in contrast to the older 1.90–1.88 Ga magmatism in the same area (Kara et al. 2018). Our results suggest a high Nb/Ta and Zr/Hf reservoir under the central Fennoscandian shield during the Paleoproterozoic, but the nature of the reservoir remains debatable.

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HELIUM – A RARE GAS ABUNDANT IN FINNISH DEEP GROUNDWATERS

by

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Inertness as well as a low melting point (-272 °C) make helium (He) an indispensable element for many applications. Among the raw materials, it is also exceptional in that it is constantly lost into space. The concentration of He in the atmosphere is only about 5 ppmv. The most important use of He is in cryogenics (e.g. in magnetic resonance imaging). In addition, it is used, for example, in the electronics and space industry and welding. Many types of analytical equipment, including mass spectrometers, are based on the use of gas mixtures containing He as a carrier gas. Probably the most well-known use of He, party balloons, accounts for 8% of global He consumption (Nuttall et al. 2012).

At present, practically all of the He is obtained as a by-product of natural gas production. The increased use of shale gas is expected to weaken the availability of He. Because of the diffusion of He into the atmosphere from relatively porous shale rocks, the concentration of He in shale gas is typically very low (Nuttall et al. 2012). In the long term, the replacement of natural gas with other energy sources will further hamper the supply of He. At the same time, cleantech applications, in the energy sector in particular, require more He. In 2017, He was added in the list of critical raw materials for the European Union.

Within the Earth's crust, ^{4}He forms radiogenically from the alpha decay of uranium and thorium. In addition, the content of He in groundwater depends at least on the bedrock porosity, density, grain size, as well as the accumulation time. Therefore, a potential He source would contain high concentrations of U and Th, and a suitable reservoir should be protected from He escape. The latter condition can be obtained in deep (>500 m) crustal environments, where groundwater flow is extremely low and diffusion into the atmosphere is negligible (Kietäväinen et al. 2014).

In crystalline bedrock, porosity is typically low but local fracturing can contribute to He accumulation. Considering the accumulation time, however, deep bedrock groundwaters in Finland are among the oldest in the world, in the order of tens of millions of years (Kietäväinen et al. 2014), making them potential reserves for He. For example, in the deep groundwaters of the Pyhäsalmi mine, concentrations up to 36 ml He per litre of water have been detected, and the proportion of He in the gas phase can exceed 30% (Miettinen et al. 2015). Considerable He concentrations (5–10% of the gas phase) have also been measured in deep groundwaters in Hästholmen (Haveman et al. 1999), Olkiluoto (Pitkänen & Partamies 2007) and Outokumpu (Kietäväinen et al. 2014). We suggest that further investigations could add several other locations in this list.

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GEO-HYDRO-ECOLOGICAL FACTORS AFFECTING THE DISTRIBUTION OF ENDANGERED SPECIES OF VIIANKIAAPA MIRE, AN ORE PROSPECTING SITE IN NORTHERN FINLAND

by

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The potential impacts of ore prospecting, as well as mining development activities, are often related to surface and groundwater resources and their interactions. A prominent Cu-Ni-PGE sulphide deposit named Sakatti has been discovered below the Natura 2000 protected Viiankiaapa mire in Northern Finland. It is important to understand the possible association of the mire vegetation with groundwater–surface water interactions, as well as the geochemical features of the local bedrock.

This study aims to answer the question of how much hydrological and hydrogeochemical factors determine the patterns of endangered vegetation in Viiankiaapa mire. Particularly in the areas rich in *Hamatocaulis vernicosus*, groundwater recharge–discharge patterns have been compiled on the basis of data collected from field studies, thermal infrared (TIR) remote sensing and the geochemical analysis of water samples. Groundwater flow patterns have been determined by measuring water tables in observation wells and peat layers. Water samples (N = 137) have been taken from groundwater and from the peat layer in order to determine the variations in water chemistry, including stable isotopes, dissolved silica, the main ions, pH, EC, DOC and trace elements. A TIR survey using an unmanned aerial vehicle was used to observe groundwater discharge locations in the mire and assess whether endangered species prefer groundwater-influenced habitats.

Based on the groundwater flow model, as well as observed temperature anomalies, groundwater discharges into the soil surface at some locations in the studied mire. Groundwater and surface water chemistry revealed significant vertical and horizontal variation. Geochemical stratification in the peat layers could be observed in pH, EC, stable isotopes and some dissolved elements. However, there were seasonal differences in pore water profiles, which should take into consideration.

As a conclusion, the western part of Viiankiaapa mire appears to have an environment suitable for *H. vernicosus*. The peat thickness of 2–4 m and wet conditions possibly create a stable environment for *H. vernicosus,* where the fluctuation in the water table is not too large. However, the historical effect and coverage of floods of the pre-regulated River Kitinen should be analysed in order to understand the possible effect of previous floods on the habitats of *H. vernicosus*. Groundwater discharges from minerogenic soil areas into the mire in some locations. The coarse-grained bottom sediments of the mire enable water to transfer nutrients from deeper sediments or bedrock into the mire. The geochemical surface water environment, with low DOC, metals and other trace elements, a near neutral pH, and increased alkalinity and Ca and Mg concentrations, appears to be suitable for *H. vernicosus*.

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PETROLOGY OF THE AGARAZRAZ GOLD OCCURRENCES IN THE CENTRAL REGUIBAT SHIELD OF WESTERN SAHARA

by

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The investigation area is located in the central parts of the Reguibat Shield in Western Sahara, where the rocks consist of the Sfariat series (Schofield et al. 2003), also called the Oum Abana belt (Marchand et al. 1985, Combs 2012, Lyche 2013, Lehbib 2016), as well as the Agarazraz Labiad granites. Reconnaissance mapping, carried out by Hanno Resources Limited between 2010 and 2016, has revealed an important gold target (Lyche 2012, Lehbib 2016).

In this region, the Oum Abana belt is up to 50 km wide and trends in a NW–SE direction over a strike length of 140 km. It is overlain by Devonian sediments of the Tindouf Basin in the northwest and terminates in the southeast, where several regional shears converge at the southern margin of the contact zone. The Oum Abana belt is a metamorphosed early Birimian (≥2150 Ma) (Lehbib 2016) sequence of primarily mafic meta-igneous and metamorphosed volcano-sedimentary rocks including meta-pyroxenite, amphibolite, dolomitic marble, magnetite quartzite, and migmatitic paragneiss. The southeastern section of the Oum Abana belt is characterised by a suite of intrusive rocks dominated by anorthosite and leucogabbro, termed the Elmalhat Anorthosite Complex (EAC).

Two types of gold mineralisation are distinguished: vein type and disseminated mineralisation. The vein type mineralisation is linked to a km-sized NNW–SSW-trending zone within a strongly foliated granite/granodiorite. Gold is hosted by a NW–SE-trending quartz vein system, composed of milky white and smoky grey quartz varieties. The gold contents range from 0.5 to 20.8 g/t. Gold nuggets have also been identified in shallow diggings, located at or near the base of the overburden. The associated opaque minerals are pyrite, chalcopyrite, pyrrhotite, sphalerite, galena and stibnite, together with fracture fillings and minute gold specks.

The disseminated mineralisation type is linked to massive tourmaline commonly associated with the quartz. Hydrothermal alteration of carbonate horizons was also observed. The gold is enclosed by sulphide minerals and the contents range from 0.5 to 1.32 g/t.

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PRELIMINARY MAGNETOSTRATIGRAPHIC RESULTS FROM MIOCENE SOFULAR AND YENIYAYLACIK SECTIONS, CENTRAL ANATOLIA, TURKEY

by

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The Yeniyaylacık and Sofular localities in the southeastern part of Central Anatolia are rich in well-preserved late Neogene mammal fossils. The faunal compositions of these sites are distinct from each other and their ages are still being studied. The age and correlation of the Sofular section has been contentious in previous studies (e.g. Aydar et al. 2012, Lepetit et al. 2014), and for the Yeniyaylacık section, no detailed ages have previously been published. In this study, we examined the magnetostratigraphy of the Yeniyaylacik and Sofular sites.

The sampled Sofular section (38°43'35" N, 35°00'30" E) overlies the Sofular Ignimbrite. In total, 83 samples were taken from this ca. 51-meter-thick section, which is composed of thin-layered and laminated siltstones and siliceous claystone with a few sandstone intercalations. The upper parts are more calcareous and dominated by limestone and claystone beds containing gypsum crystals. In total, 32 samples were taken from the ca. 8-meter-thick Yeniyaylacık section (38°45'35" N, 34°37'04" E), comprised of muddy-clayey sediments with a few thin limestone and sandstone units interbedded in the succession.

Rock magnetic studies revealed that samples located at higher levels were clearly less magnetic in both of the sections, which correlates well with the increased carbonate content. Samples were heated to 700 °C and cooled to room temperature, continuously measuring the susceptibility during the procedure. Heating and cooling curves indicated that the magnetic mineralogy of the samples mostly consisted of magnetite and titanomagnetite, but some of the samples also contained some hematite.

AF demagnetization results indicated that reversed polarity dominates the lower ca. 15 m in the Sofular section, with three short intervals of normal polarity. The upper 35 m of the section is dominated by normal polarity. In Yeniyaylacık section, reversed polarity dominates the whole section, with three observed intervals of normal polarity. We favor a correlation with chron 3An and 3Bn for the Sofular section, with a possible age range of the fossiliferous sites between 6 to 7.6 Ma, while chron 4n with an age range between 7.6 and 8.6 is a better match for the Yeniyaylacik section.

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COMPARISON OF LINEAR AND CIRCULAR SCANLINES

by

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Rock fracture networks have a considerable impact on rock quality, rock mechanical behavior, hydrogeology, and the migration of harmful substances. Studying and modeling these phenomena requires information on the rock fractures. A statistical approach requires abundant data to have enough observations on all of the fracture sets in a representative quantity. Scanline mapping of rock fractures can be used to collect abundant datasets for analyzing and modeling these phenomena with a statistical approach. The results can be used to analyze fracture orientation, sets, length, density, and surface properties. In this research, we compared the results of scanline mapping along linear and circular scanlines. The fracture density in linear scanlines has to be managed with Terzaghi's correction factor, whereas circular scanlines do not require corrections.

Two nearly perpendicular scanlines and one circular scanline were mapped on the shore of Kopparnäs, southern Finland. The linear scanlines were 17 m and 16 m long, striking 275° and 357°. The circular scanline of 4 m in diameter (12.6 m in perimeter) was placed at the intersection of the linear scanlines. Mapping was carried out with the form in Markovaara-Koivisto (2017). Data analysis of the circular scanline was based on Mauldon et al. (2001) and Peacock et al. (2003). Analysis of the circular scanline was problematic in two ways: the small number of observations hindered the definition of fracture sets and the calculation of set-specific densities due to the commonly defined number of fractures inside the circle.

This research is part of the KYT2018 research program. The ROSA project will provide an open source program for DFN modeling based on scanline mapping data.

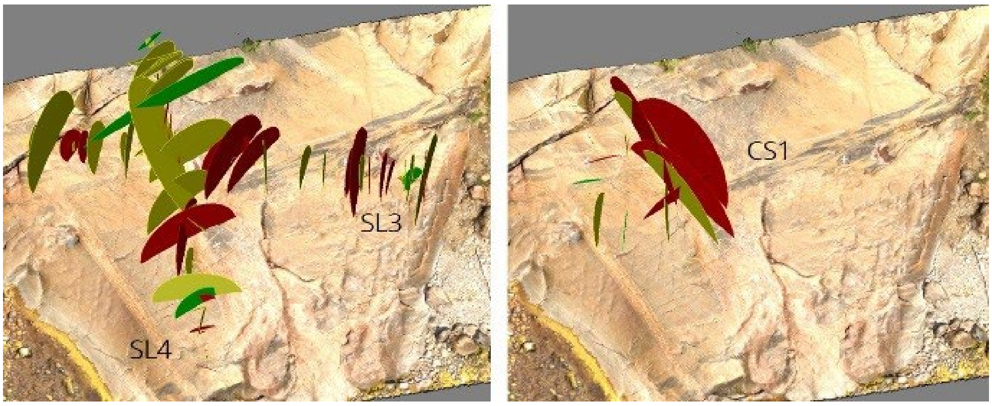

Fig. 1. Fractures from linear and circular scanlines presented as discs with Surpac Structural suite and a 3D drone image of the rock surface. Surface roughness: red = rough, yellow = slightly rough, green = smooth.

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EARTHQUAKE MOMENT MAGNITUDE ESTIMATIONS FROM LANDSLIDE AREAS AND VOLUMES IN NORTHERN FINLAND

by

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The ages and sizes of landslides occurring in seismically active areas can be used to reconstruct the seismic history of the area and estimate the maximum moment magnitudes of past earthquakes. The availability of high-resolution LiDAR-based digital elevation models (DEMs) from the Fennoscandian Shield area has enabled the detailed delineation of postglacial faults (PGFs) and associated landslides. Altogether, 144 landslides have been discovered so far from northern Finland, of which 121 identified prior to LiDAR availability in 2017 were modelled in Ojala et al. (2017). Their computed areas and volumes can be used to estimate the maximum moment magnitudes of the triggering earthquakes using the equations provided in Malamud et al. (2004). As we cannot distinguish which landslides are associated with a specific fault, from the distribution of landslide sizes we have computed the ranges of earthquake magnitudes that could have caused each landslide.

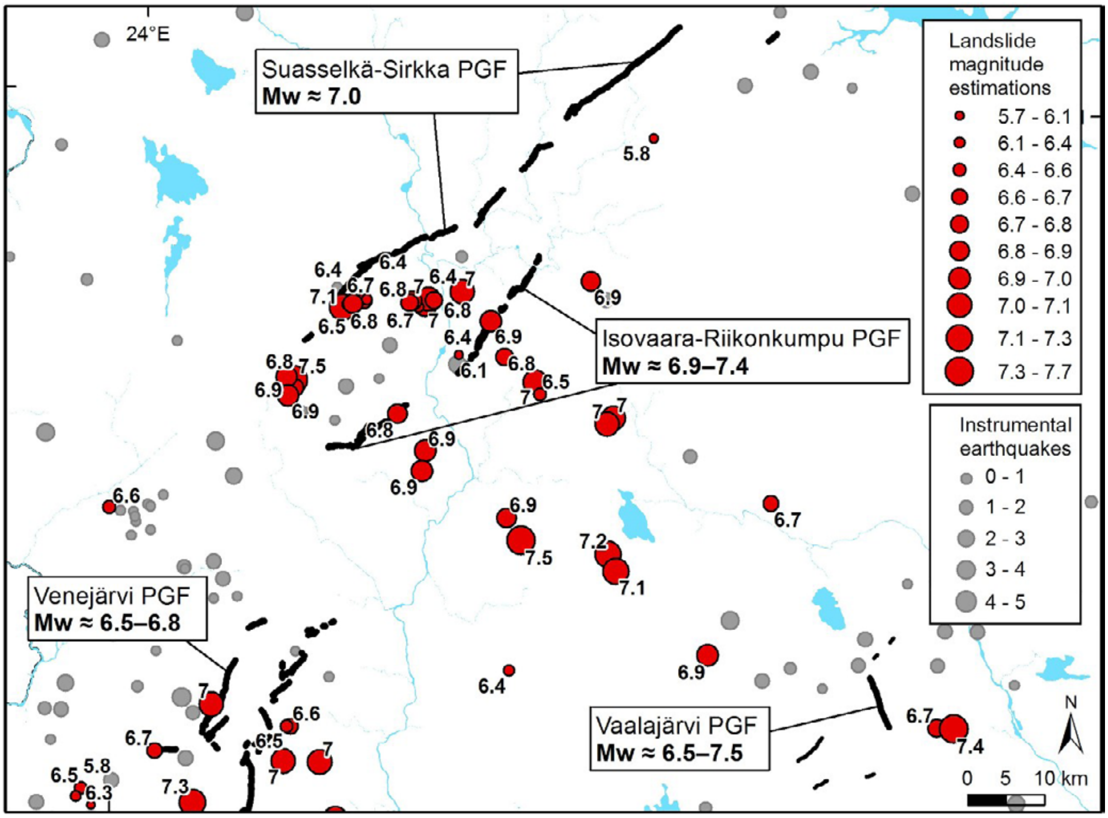

Fig. 1. Landslide-inferred maximum moment estimates in the vicinity of postglacial faults.

Area-based estimations generally yield larger magnitudes, with a mean value of $M_w \approx 6.77 \pm 0.73$ and minimum and maximum values between $M_w \approx 5.76 \pm 0.73$ and $M_w \approx 7.67 \pm 0.73$, respectively. For volume-based computations, the mean magnitude is $M_w \approx 5.92 \pm 0.72$ and the minimum and maximum values $M_w \approx 4.66 \pm 0.72$ and $M_w \approx 6.70 \pm 0.72$, respectively. These figures are in close agreement with the earlier estimated moment magnitudes from the area and indicate that an area-based approach provides more accurate estimates, while volume-based estimations give slightly lower values than those acquired from the lengths and displacement values of the faults.

This research is part of the 'Postglacial faults and dynamics' project between the Geological Survey of Finland and Posiva Oy (project 9248-14).

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POROSITY DISTRIBUTION OF A HETEROGENEOUS CLAY-RICH FAULT CORE BY IMAGE PROCESSING OF C-14-POLYMETHYLMETHACRYLATE (C-14-PMMA) AUTORADIOGRAPHS AND SCANNING ELECTRON MICROSCOPY

by

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Sedimentary clay rocks present impermeable, low-porosity formations, often having a seal function for hydrocarbon reservoirs and geological repositories. Due to their impermeable properties, these shale beds act as a barrier to fluid flow. However, shale formations are intruded by fault zones with permeabilities that can differ by several orders of magnitude with respect to the undeformed host rock. The fault core is comprised of several structures, including breccias, cataclasites and one or several slip surfaces. The slip surface of a fault consists of clay gouge that is heterogeneous material with anisotropic properties in terms of porosity and permeability. The fault core with clay-gouge can act as a barrier or as a lengthwise conduit to fluid flow, depending on physical and chemical properties of the fault. For these reasons, the distribution of porosity in the fault core is a key parameter for many applications, including the hydrocarbon reservoir capacity, geothermal energy projects and geological repositories for CO_2 or high-level radioactive waste.

The objective of this work is to use the ^{14}C-PMMA autoradiography method combined with SEM-EDS analysis to understand porosity variations in and around fault gouges and define their relationship to physical and chemical processes in a fault. The samples used in this study were taken from a small-scale vertical strike-slip fault in an argillaceous shale formation at the Tournemire underground research laboratory, Southern France. The results display significant variations in porosity and mineralogy along the studied gouge zone, most probably due to a polyphased tectonic history and paleo-fluid migrations. Moreover, the mineralogical changes indicate sealing/healing effects and past hydrothermal activities within the fault zone. Even though the observed porosity variations only occur in a centimetre-wide gouge zone, they may imply pathways for fluid flow if the fault is reactivated.

DEFORMATION HISTORY OF THE ARCHIPELAGO OF SOUTHERN FINLAND

by

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The Paleoproterozoic Svecofennian orogenic domain of southern Finland principally consists of belts of strongly migmatized infra- and supracrustal rocks and granitoids in upper amphibolite to granulite facies, with areas of less migmatized rocks in between. The tectonic setting is interpreted as an arc–arc collision, and the migmatites thus represent a deep section of the volcanic arc. Hence, the granite-migmatite belts are presumably related to each other, but their structural setting, deformation stages and thus tectonic setting are vaguely known. Our focus is the onshore area and the archipelago around the Hanko peninsula. As the site was last researched at the 1980s, the goal of this study is to update the structural and tectonic interpretations of the area. The project is ongoing and the results presented here are preliminary.

In the study area, at least three different ductile deformation stages are recognized (D1, D2, D3). During D1, the metasedimentary rocks were folded into tight to isoclinal folds with an E–W-striking subvertical axial plane (Fig. 1). The E–W-plunging horizontal to moderately mineral lineations are stronger than the foliation in places. The D2 developed open asymmetric folding with a SE-plunging fold axis. At this stage, mineral lineation is common, but the foliation is difficult to observe. The D3 is represented by crosscutting shear zones in E–W and NE–SW directions. The width, kinematics and strain of the shear zone vary in places.

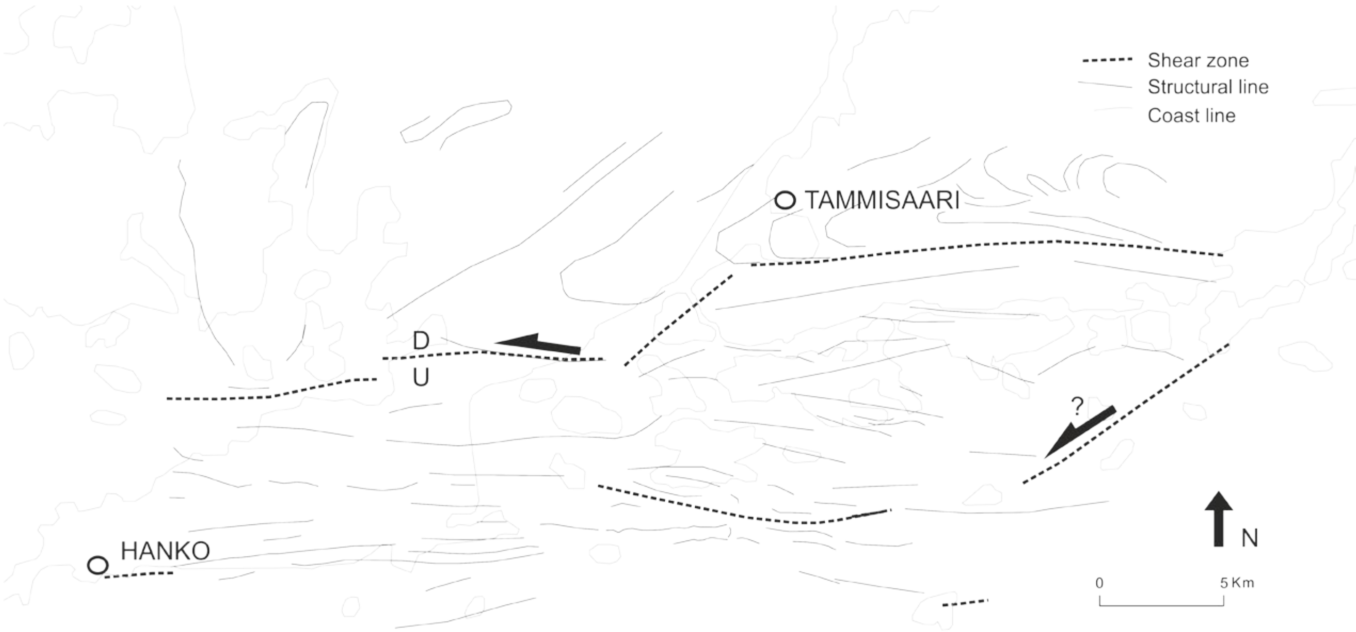

Fig. 1. The structural lines of the Hanko–Tammisaari region. The lines are based on field observations, the aeromagnetic map (©GTK) and LiDAR data. The structural lines are E–W striking south of the sinistral, main shear zone. D = down, U = up

Some of the leucosomes in the migmatites are folded twice. This suggests that melts were generated before or during D1. The E–W-trending structures indicate N–S (at present) compression in stage D1. The axial plane is subvertical today, but the axial plane has most likely rotated from horizontal-moderate to subvertical during the continued N–S compression. During D2, the main shortening direction was in the NE–SW direction, which might have been caused by the oblique collision from the SW. The shear zones at the D3 crosscut the isoclinal folds, but their relationship with the D2 is not clear. The kinematics of the sinistral shear zones corresponds to the NE–SW compression, and it is hence possible that D3 is partly coeval with the D2.

VOLATILE-INDUCED DIFFERENTIATION IN THE HAFNARHRAUN PĀHOEHOE LAVA, SW ICELAND

by

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Magmatic differentiation by fractional crystallization is one of the key processes of igneous petrology and profoundly responsible for the diversity of igneous rocks. However, it is not fully understood how magmas differentiate in various magmatic systems. To advance on the topic, we have examined the differentiation of a basaltic magma in an eight-meter-thick pāhoehoe lava lobe within the Hafnarhraun lava flow field in SW Iceland.

The Hafnarhraun lava is dominantly composed of fully crystalline olivine tholeiitic basalt, but it also hosts abundant melt segregations, i.e. porous cylindrical or sheet-like structures crystallized from residual melts enriched in incompatible elements. These melt segregations were found to be of three types: vesicle cylinders (VC), Type 1 horizontal vesicle sheets (HVS1), and Type 2 horizontal vesicle sheets (HVS2). The VCs are pipe-like structures in the lower part of the lava core, only marginally differentiated from the host lava. Their composition is best explained as a mixture of olivine crystals and residual melt after ~20 vol% host lava crystallization. Both HVS1s and HVS2s are present as horizontal lenses at the top of the lava core. While HVS1 compositions correspond to interstitial melt after 20–35 vol% crystallization of the host lava, HVS2s are considerably more differentiated, corresponding to interstitial melts after >55 vol% crystallization of the host lava. Also, HVS2s are distinct, with flow-aligned plagioclase and abundant oxides. HVS2s have a very high content of FeO_{TOT} (18.1–19.1 wt%).

We suggest that VCs formed in the lower parts of the lava core by volatile saturation-induced separation of residual melt and olivine macrocrysts in the early stages of lava core crystallization. HVS1s were formed by the accumulation of VCs beneath the roof of the lava core, and HVS2s formed by the filling of fractures and gas pockets with volatile-saturated interstitial melt during subsequent cooling of the lava flow. Volatile-induced differentiation, here documented for the Hafnarhraun lava, may also produce highly differentiated magmas in shallow crustal magma reservoirs.

HYDROGEOLOGIC FEATURES OF TAHMELANLÄHDE SPRING, TAMPERE: AN APPROACH TO A REHABILITATION PLAN

by

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The condition of Tahmelanlähde spring has been under discussion for two decades now. Between 1906-1966, water from the spring was used for the municipal water supply and water quality was good. However, the quality of discharging groundwater has since deteriorated, and it currently contains high concentrations of iron, manganese, nitrogen and phosphorus and a low dissolved oxygen. The cause of this deterioration has remained unclear. The aims of this study are to create a hydrogeological model for the Tahmela-Pispala area in order to gain a better understanding of the source of the groundwater discharging at the spring, to assess the cause for the deterioration, and finally to offer suggestions for the rehabilitation plan.

The study area covers an urbanized district of the City of Tampere, Southern Finland. Tahmelanlähde spring and several smaller groundwater discharging spots are located on clay or silt soil under artesian circumstances, down the southern slope of Pyynikinharju Esker formation. The esker forms a longitudinal neck between Lake Näsijärvi in the north and Lake Pyhäjärvi in the south, rising up to 160 meters above sea level. The water level of Lake Näsijärvi is approx. 95 m a.s.l. and the water level of Lake Pyhäjärvi approx. 77 m a.s.l. Considering the distance of only a few hundred meters between these two lakes, the difference of 18 meters in the water levels is unusual in Finland.

For the construction of the hydrogeological model we carried out a field campaign, including a ground penetrating radar (GPR) survey, a thermal infrared survey using an unmanned aerial vehicle (UAV-TIR) and measurement of the water tables, as well as water sampling from springs, surface water bodies, groundwater observation wells and groundwater discharging into Lake Pyhäjärvi. Altogether, 13 water samples were analyzed for main ion composition, stable isotopic ($\delta^{18}O$-δD) composition, pH, EC, trace elements and dissolved silica (DSi). Ten samples were additionally analyzed for COD_{Mn}, N, P, O and microbial indicators. In addition, various pre-existing data from the area were utilized.

A 3D geological model from a previous study (Ahonen et al. 2013) left open the possibility of infiltration of Lake Näsijärvi water into the esker. Our results indicate that most of the water in the main spring is, indeed, well evaporated surface water and the source is most likely Lake Näsijärvi. On the other hand, the samples taken east of the spring show an almost nonexistent surface water impact. This indicates that the regional groundwater flow patterns are complex, having at least two flow directions: one from the northwest and another from the northeast.

We are currently working on a more sophisticated geological model of the area. The target is to build a conceptual and numerical hydrogeological model using LeapFrog Geo or other 3D modelling software, as well as flow modelling tools. Groundwater discharge locations into the Lake Pyhäjärvi and on the land surface will be pointed out in order to evaluate the connections between groundwater and

surface water. Hydrogeochemical data will be added to the 3D model to understand the geochemical features and processes of the groundwater in the area. The study is a collaboration between the City of Tampere, Pirkanmaa Center for Economic Development, Transport and Environment (ELY Center), and the University of Helsinki, Department of Geosciences and Geography.

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HOW MUCH PEAT SHOULD BE LEFT TO PROTECT UNDERLYING SULFIDIC MINERAL SOIL IN PEAT EXTRACTION SITES?

by

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Large areas of sulfide-bearing sediments are located worldwide along deltas, coastal plains, and inland settings (170,000 km²), and pose a great threat (e.g. occasionally extensive fish kills) to their surrounding aquatic environment if disturbed. The oxidation of sulfides in contact with air produces extremely acidic soils (pH < 4) with increased acidity and metal loadings flushing to the recipient streams. There have been extensive studies on acid sulfate soil formation related to intensive agricultural drainage, but studies on acid sulfate soils in peat lands are scarce, because they have been of less economic importance. However, peat mining has during the last decades become an important industry in boreal environments (e.g. Finland, Russia, Ireland), and sulfidic sediments and/or sulfidic-rich black schists underlie parts of these peats. In peat harvesting, peat lands are drained with open ditches before the removal of peat, and because peat is of economic value, commonly only a shallow or no peat layer has been left, causing a risk of oxidation. In this study, the characteristics of peat and the underlying sulfidic mineral soil of 10 peat extraction sites in northwestern Finland were investigated. The peat extraction fields were drained with small c. 60–80 cm deep ditches with c. 20 m spacing connected to 1-1.5 m collector drains. We found that despite the drainage, there is commonly relatively little sulfide oxidation due to the peat layer protecting the underlying mineral soil and limited soil structure development, i.e. the acidic load was insignificant compared to the potential load still remaining in the sediments. Preliminary results indicated that there was no oxidation if the peat layer was >50 cm thick, but occasional oxidation in the riparian zone (c. 2 m from ditch wall) if the peat layer was 30–50 cm thick (Fig. 1).

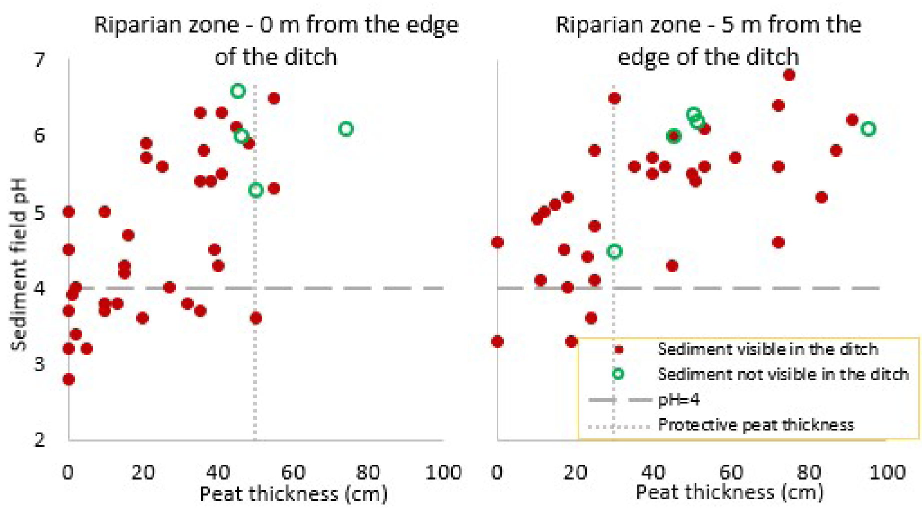

Fig. 1. There was no sulfide oxidation (pH < 4) if the peat layer was >50 cm thick, but occasional sulfide oxidation in the riparian zone (closest to the ditch wall) if the peat layer was 30–50 cm thick.

EFFECTS OF HYDROLOGY ON GRAVITY AND SPACE GEODETIC MEASUREMENTS AT METSÄHOVI GEODETIC RESEARCH STATION

by

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The Finnish Geospatial Research Institute is operating two superconducting gravimeters together with an absolute gravimeter at the Metsähovi Geodetic Research Station (MGRS). The station will be one of the Global Geodetic Observation System's (GGOS) core sites once the upcoming new Satellite Laser Ranging system (SLR) and Geodetic Very Large Baseline Interferometry system (VLBI) are operational in 2018–2019. One of GGOS's main missions is to understand changes in the Earth's shape, rotation and mass distribution and to provide necessary observations for producing the global reference frame. MGRS will address these goals by having all space geodetic techniques co-located together with absolute and superconducting gravimeters. However, local crustal deformations produce bias in the geodetic measurements, which directly contributes an error to the geodetic end products of GGOS, such as the origin of the terrestrial reference frame. To achieve GGOS's 1 mm accuracy goal for co-located space geodetic measurements, we need to better understand and model these deformations and the underlying physical processes. At MGRS, the environmental mass changes are causing most of the unknown crustal deformations, as well as the gravitational effects. The vicinity of the Baltic Sea and its non-tidal sea level variance, together with other hydrological and atmospheric mass changes, may produce a vertical displacement of more than 10 mm, as well as a change of several microGals in gravity measured at Metsähovi. To achieve GGOS's goal, the local deformations must be understood. To model the environmental effects at MGRS, we have installed a variety of meteorological and hydrological sensors at the station. We have recently studied the effect of strong rain events on the gravity measurements of the new superconducting gravimeters (Virtanen & Raja-Halli 2017), as well as the crustal loading effect on the shores of Baltic Sea caused by the sea mass changes (Nordman *et al.* 2015). We will briefly introduce the instrumentation at Metsähovi and present our latest results showing the contribution of different hydrological effects to the measured gravity and the overall vertical displacement affecting the space geodetic measurements at Metsähovi.

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CHARACTERIZATION OF MICAS FROM SOKLI AND APPLICATION FOR AMMONIUM REMOVAL FROM AMMONIUM ACETATE SOLUTION

by

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Micas from Sokli carbonatite complex in northeastern Finland were characterized in this study to determine whether the mica-rich weathered bedrock overlying the Sokli carbonatite contains vermiculite. This study also investigated ammonium sorption in the natural and nanomodified micas (NMV) from Sokli. In the present study, mica fractions separated from Sokli were investigated using electron probe microanalysis (EPMA), X-ray diffraction (XRD) and thermal gravimetric analysis (TGA). The EPMA results show that the potassium and calcium contents of the investigated mica vary between 0.31–6.20 wt% and 0.0–1.9 wt%, respectively. The XRD results provide evidence that the interlayer distance in the mica varies between 10.1 Å and 14.7 Å. TGA shows that dehydration of the samples varies between 6 and 12 wt% at temperatures of up to 170 °C. Dehydroxylation takes place in three steps. In step 1 (around 170 °C), there is a weight loss of between 1 and 5 wt% and in step 2 a weight loss of between 1 and 3 wt% (at around 600 °C). Complete dehydroxylation (step 3) takes place at temperatures of around 700 °C and above, when a weight loss of 3 to 4 wt% is indicated. The results from this study demonstrate that mica in the weathered parts of Sokli carbonatite is mostly vermiculite (low potassium content, high water content, interlayer distance 14.7, and dehydration and dehydroxylation of water in three steps). Since the results deviate from pure vermiculite towards phlogopite composition, it is concluded that the vermiculite was formed by weathering of phlogopite. In batch tests, the ammonium (NH_4^+) decrease from the ammonium acetate solution into the natural and nanomodified mica mineral (NMV) was marked. The total removal efficiency for NH_4^+ was 50% for natural Sokli micas and 60% for nanomodified Sokli micas.

U-Pb ZIRCON GEOCHRONOLOGY OF THE TAALIKKALA MEGAXENOLITH, NORTHERN WIBORG BATHOLITH: SOME NEW INSIGHTS INTO THE EVOLUTION OF GEON 16-17 SOUTHEASTERN FENNOSCANDIA

by

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The northeastern edge of the ~1.63 Ga (Heinonen et al. 2016, 2018) Wiborg rapakivi batholith reveals a shallow section with abundant country rock fragments of this epizonal intrusion complex. Four megaxenoliths/roof pendants (Hyvärilä, Ruoholampi, Toivarila, Taalikkala) are found in the Lappeenranta area and comprise varying Svecofennian plutonic and metamorphic rocks, as well as mid-Proterozoic supracrustal rocks (Vorma 1975, Vaasjoki & Rämö 1989, Harju et al. 2010). The Taalikkala megaxenolith is an ~east–west-elongated, ~10-km-long and 1–3-km-wide fragment of bedrock, surrounded by various rapakivi granite types (Harju 2014). The northern flank of the xenolith is dominated by a Svecofennian synorogenic alkali-feldspar megacrystic granodiorite. South of the granodiorite is a steeply southward-dipping, ~1500-m-thick sequence of quartzite, basaltic lavas, and silicic extrusive rocks. This is quite similar to that observed *in situ* on the Island of Suursaari on the southwestern flank of the Wiborg batholith (e.g., Pokki et al. 2013). The Taalikkala supracrustal assemblage, which lies unconformably on the Svecofennian basement granodiorite, is thermally metamorphosed but lacks penetrative deformation. The megaxenolith is thus probably a fragment of the roof of the Wiborg batholith magma system, detached during the emplacement of the batholith and flipped sideways (towards the present south) while foundering.

We report the results of a U–Pb zircon study of three rock types of the Taalikkala megaxenolith (multi grain ID-TIMS on quartz-feldspar porphyry; single-grain SIMS on granodiorite, quartzite, and quartz-feldspar porphyry). Twenty-three zircon domains, including cores and rims of eight individual zircons, were dated from the granodiorite. Six concordant zircon spots define a concordia age of 1875 ± 5 Ma. We consider this as the emplacement age of the granodiorite. The core segments of the measured grains show inheritance at 1.9 Ga, 1.93 Ga, and 2.06 Ga, whereas a 1.81 Ga rim indicates metamorphic growth on a 1.88 Ga core. Thirty-five detrital zircon domains were measured for zircons recovered from the Taalikkala quartzite. The five youngest concordant spots determine a concordia age of 1878 ± 10 Ma; this sets the maximum sedimentation time for the quartz arenite precursor. Older inheritance is marked by six distinct age groups of 1.91–1.95 Ga, 2.02 Ga, 2.20 Ga, 2.44 Ga, 2.65–2.75 Ga, and 2.94 Ga, which is a typical pattern for Svecofennian metasedimentary rocks (e.g., Claesson et al. 1993). Twenty zircon domains were dated using SIMS from the Taalikkala quartz-feldspar porphyry. Six equivalent and concordant data points define a concordia age of 1635 ± 6 Ma. Zircon recovered from the porphyry also contains cores, of which two were dated at 1.74 Ga, one at 2.0 Ga, and two at 2.5 Ga. Four multi-grain fractions from the

Taalikkala porphyry were additionally measured using ID-TIMS. They define an upper intercept age of 1638 ± 3 Ma. This is considered as the emplacement age of the Taalikkala porphyry.

The emplacement ages of the Taalikkala quartz-feldspar porphyry and a corresponding porphyry from Suursaari (1633 ± 2 Ma; Rämö et al. 2007) show that silicic volcanism occurred across the Wiborg batholith terrain ~1635 m.y. ago. As currently perceived (Heinonen et al. 2016, 2018), the Wiborg batholith was emplaced in at least two magmatic events between ~1635 Ma and ~1628 Ma. The Taalikkala and Suursaari porphyries thus represent silicic volcanic systems associated with inaugural magmatic activity of the batholith, also registered in zircon recovered from rapakivi feldspar megacrysts (Heinonen et al. 2016). Furthermore, zircon in the Taalikkala porphyry reveals Paleoproterozoic cores (1.74–2.5 Ga) and is thus the first documented case of crustal inheritance measured for the Finnish rapakivi granites. The Taalikkala and Suursaari quartz arenites/quartzites (cf. Pokki et al. 2013) imply the existence of an ultramature sedimentary cover on the Svecofennian bedrock at the outset of rapakivi volcanism. The zircon from the Taalikkala quartzite does not contain the equivalent of the rapakivi-age (~1.65 Ga) zircon population present in the Suursaari quartz arenite, which sets the deposition age of the Suursaari conglomerate at 1.65–1.63 Ga (Pokki et al. 2013). The maximum sedimentation age of the precursor of the Taalikkala quartzite (1878 ± 10 Ma) is identical to the magmatic age of the basement granodiorite (1875 ± 5 Ma), and the latter probably belongs to the provenance of the former. At the outset of rapakivi magmatism, exhumation and erosion of the Svecofennian bedrock and redeposition of the resultant detritus was rapid, reflecting large-scale doming and areally extensive uplift of the Svecofennian lithosphere in response to thermal perturbations in the subcontinental mantle.

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WERE PLIOCENE PIGS OF THE TURKANA BASIN SPECIALIZED FOR GRAZING? SURFACE MORPHOLOGY ANALYSIS OF THIRD MOLARS OF FOSSIL AND MODERN SUIDS

by

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Most of the modern suids (Mammalia: Suoidea, pigs) are omnivorous, medium sized, forest or dense vegetation inhabiting non-ruminating artiodactyls (Kingdon 1979). However, warthogs (*Phacochoerus* sp.) are adapted to an open environment and mainly consume grasses (Kingdon 1979). It has been suggested that during the Plio-Pleistocene, at least three different dominant suid genera in Africa (*Notochoerus*, *Metridiochoerus* and *Kolpochoerus*) adapted to grass eating (Harris & White 1979). Isotope studies from enamel show a strong gradual shift from a mixed diet towards grazing in all genera (Harris & Cerling 2002). In addition, their third molars become more hypsodont (i.e. a higher crown height) and enamel crenulation more complex (Harris & White 1979). Similar adaptations have already been observed in other mammals from the Miocene, when tropical C4 grasses started to spread (Cerling et al. 1997).

In many cases, the third molars are functionally the most important single teeth among suids, and suids can often be identified to the genus level with only a third molar present (Harris & White 1979, Kullmer 1999). In this study, we aimed to analyse the surface morphology of the third molars of the three Plio-Pleistocene suid genera from Turkana Basin (Kenya) and compare them with five different modern suid species from Africa (*Phacochoerus africanus*, *Potamochoerus porcus* and *Hylochoerus meinertzhageni*), Europe (*Sus scrofa*), and Southeast Asia (*Babyrousa babyrussa*) to examine whether the morphology of the third molar supports the specialization for grazing of the Turkana Basin suids.

All analysed third molars were 3D-scanned with a hand-held PlanScan (Planmeca Oy, Helsinki, Finland) surface scanner. Fossil specimens were scanned at the Turkana Basin Institute (National Museums of Kenya) in Kenya, and modern specimens were scanned at the Museum für Naturkunde in Berlin, Germany. The 3D scans were analysed with R-package molaR, ArcGIS and MorphoTester for the mean slope of the surface (topography), the relief index (2D/3D area), the Dirichlet normal energy of the surface (deviation of a surface from being planar), the orientation patch count (surface complexity) and sharpness (the areal proportion of steeply sloped elements in relation to the rest of the surface) (Evans 2013).

Our results show that the fossil suids of Turkana differ from most of the modern suids. However, the modern grazing specialist, the warthog, has the most similar profile to the fossil suids. Figure 1 presents the mean slopes of the surfaces. Here, the warthog is in the same category with the fossil suids. Our results indicate that the surface morphologies of the fossil suids are adaptations to diets containing high proportions of grass, and thus support previous studies with different methods.

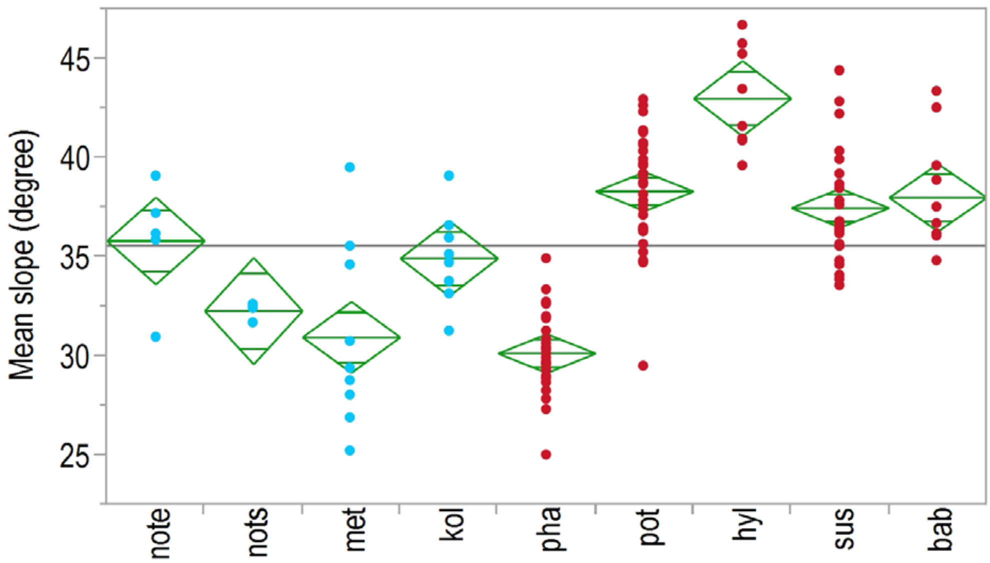

Fig. 1. Mean slopes for the third molar surfaces. Green diamonds show means and 95% confidence intervals. The black line is the grand mean. Blue indicates fossil specimens and red modern specimens. note = *Notochoerus euilus*, nots = *Notochoerus scotti*, met = *Metridiochoerus andrewsi*, kol = *Kolpochoerus heseloni*, pha = *Phacochoerus africanus*, pot = *Potamochoerus porcus*, hyl = *Hylochoerus meinertzhageni*, sus = *Sus scrofa* and bab = *Babyrousa babyrussa.*

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LASER-INDUCED BREAKDOWN SPECTROSCOPY (LIBS) AS A TOOL IN MINERAL IDENTIFICATION

by

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The strength of laser-induced breakdown spectroscopy (LIBS) is its capability to reveal the chemical composition of material simply by focusing the laser beam on it and detecting the atomic emission from the formed laser-induced plasma cloud. The spectral line locations are characteristic for each chemical element and their intensities are proportional to the content of the element. However, in the case of complex and inhomogeneous samples, such as rocks, quantitative analysis is challenging. The calibration samples should match the analyzed minerals, *e.g.* in elemental and physical composition. If the LIBS analysis project is not only focused on a certain geological site, the required calibration set can be comparably large. For example, in the case of the Mars Curiosity rover, 69 reference samples were used to build the calibration library (Wiens 2013).

Instead of exact quantitative analysis, our group at the University of Jyväskylä aims at flexible *in situ* LIBS analysis of any unknown rock sample. Multivariate analysis termed singular value decomposition (SVD) is used to divide the analyzed data into separate groups based on the full measured spectral range. Based on the major elements observed in the average spectra of each group, different minerals can be identified. Thus, a mineralogical map of the investigated area can be constructed. This is especially helpful with very fine-grained rock samples, where the visual identification is extremely challenging. In addition, the mineralogical composition of the sample at the percentage level can be approximated from this. Selected examples of REE-bearing minerals (Fig. 1) (Romppanen et al. 2017) and sulfide ores (Niilahti 2017) are presented.

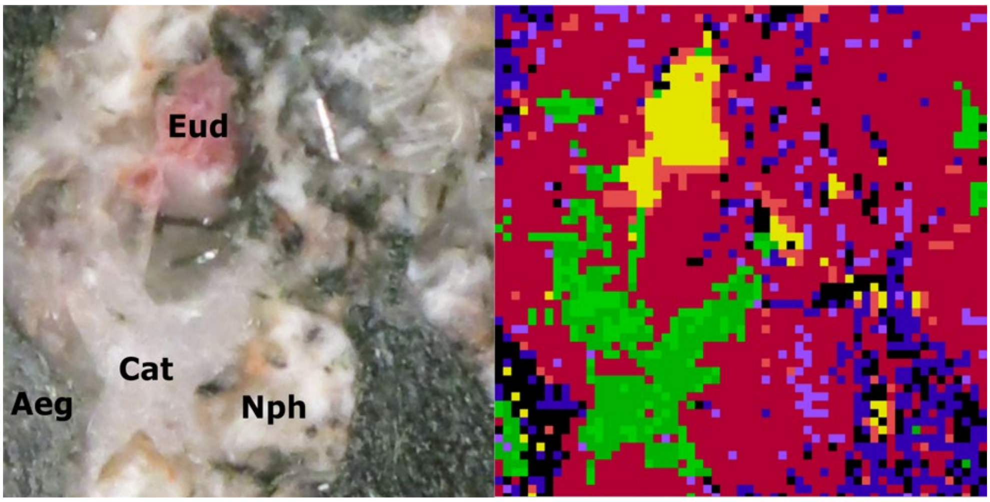

Fig. 1. Photo of an analyzed rock surface and SVD map constructed from the LIBS data.

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ELEMENT MAPS OF GEOLOGICAL SAMPLES USING MICRO-XRF

by

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A new benchtop micro-XRF spectrometer, M4 TORNADO by Bruker, was recently installed in the laboratory facilities of the Geotalo, Turku.

Micro-XRF is a powerful and fast tool for micrometer-scale geochemical analysis. Micro-XRF can be applied to a variety of geological sample types and sizes. Although minimal sample preparation is needed for spot analyses, a flat, but not necessarily polished, surface is required for element maps and line scan analyses.

Within the spectrometer, a rhodium target tube generates the primary X-ray radiation (20-50 keV), which is focused by a polycapillary lens into a ca. 25-mm-diameter beam. The M4 TORNADO is equipped with two high-performance silicon drift detectors (60 mm^2) for energy dispersive (ED) analysis. The two detectors allow for rapid analysis, as the photon-detecting area is doubled.

The maximum mapping area using M4 Tornado is 190 x 160 mm and the maximum sample weight is 5 kg. The measurement time per pixel during element mapping is typically 1–20 ms. Element maps of a million data points (1000 x 1000 pixels) can be obtained in a few hours. Elements from Na–U (20 mbar vacuum) or from K–U (atmospheric pressure) can be detected.

Each map pixel represents a complete energy spectrum, and further processing of the data can also be performed offline. Not only are image processing functions such as pixel averaging and smoothing available, but also data analysis tools such as binning of data for improved quality. Quantification can be performed on spectra obtained from the maps as selected lines, areas, or phases. Tools for thin-film analysis are also included in the software. The instrument can be calibrated against standard materials, but so-called standardless analysis can also be used in quantification.

Some of the very first results from different types of samples analyzed in Geotalo include element maps of unpolished thin sections, rock blocks, epoxy-impregnated lake sediments, and biological materials. Samples were mapped by a single scan using beam conditions of 50 kV and 600 mA, a pixel acquisition time of 5–20 ms and a pixel step size of 20–100 mm. For example, the required time for analysis of 110 x 130 mm at 100-mm resolution and 10 ms/pixel time was about 9 hours, and the total number of pixels acquired was 1.4 M. The maps can be presented as false color maps representing apparent concentrations (raw intensities) or, after quite time-consuming quantification, true concentrations.

DISTRIBUTION OF THE TRANS-SCANDINAVIAN IGNEOUS BELT IN THE BALTIC SEA REGION

by

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The Trans-Scandinavian Igneous Belt (TIB) is a major magmatic complex along the western margin of the Svecofennian Domain in the Fennoscandian Shield in which several granitoid generations (TIB 0, TIB 1, TIB 2 and TIB 3) have been recognized (Larson & Berglund 1992). Recent studies have also identified the presence of the 1.77–1.81 Ga TIB 1 generation at several drill sites below the Phanerozoic sedimentary cover in the Baltic Sea region: Kvarne on southernmost Gotland (Sundblad et al. 2003), Böda Hamn and Valsnäs on northern and central Öland, respectively (Salin et al. 2018), as well as E-7, offshore on the Latvian/ Lithuanian border (Salin et al. 2016).

In this study, we report U–Pb zircon ages from the Precambrian basement in the Baltic Sea region at two more sites: percussion drilling material from Frigsarve (southern Gotland) and drill core D1-1 from the Lithuanian offshore region. Zircons from Frigsarve yielded a LA-ICP-MS age of 1845 ± 4 Ma, which is comparable with the age of the TIB 0 generation in southeastern Sweden. According to crystal morphology and SIMS ages, the zircons from the D1-1 drill core belong to two generations. The larger zircon grains have an age of 1792 ± 8 Ma, which is similar to the TIB 1 generation. The smaller zircon grains are 1744 ± 7 Ma old and are interpreted to record a later 1.73–1.68 Ga high-grade metamorphic event, which is widespread in Western Lithuania (Skridlaite et al. 2014).

In conclusion, all data from previous and current studies show that the Trans-Scandinavian Igneous Belt extends over vast areas in the Baltic Sea region, from Öland and southern Gotland to the offshore regions of Latvia and Lithuania.

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THE VOLUME AND DISTRIBUTION OF HYPOLIMNETIC WATERS IN LAKE VESIJÄRVI, SOUTHERN FINLAND – EFFECT OF LAKE REHABILITATION ON VARVE FORMATION AND HYPOLIMNETIC HYPOXIA

by

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Lake Vesijärvi in southern Finland has suffered from eutrophication and hypoxia but has recovered due to rehabilitation actions such as diverting of the sewage load from the lake in the 1970s (Keto & Sammalkorpi 1988), the removal of fish (Horppila & Peltonen 1994), and lake aeration. However, the hypolimnion still remains hypoxic during stratification (Kairesalo & Vakkilainen 2004).

The sediment in Enonselkä basin in Lake Vesijärvi is characterized by varve preservation. Varve formation and preservation in Enonselkä basin presumably started because of anthropogenic factors, which makes Lake Vesijärvi a unique research subject compared to other varve-preserving lakes in Finland.

This study will detail how varve preservation develops from the deepest point of Enonselkä basin towards the basin margins. The aim is to emphasize spatiotemporal variations in varve preservation and therefore in hypolimnetic hypoxia. This study will show how rehabilitation actions have affected varve preservation in Enonselkä basin. One of the aims is to explain the differences in varve formation and preservation in Enonselkä basin compared to other varve-preserving lakes in Finland and to investigate the effect of climate on hypoxia oscillation.

Even though a wide variety of studies have considered varve formation and preservation, the number of studies regarding varve distribution throughout a single lake or basin is insufficient (Jenny et al. 2013, Giguet-Covex et al. 2009). However, a single varve chronology from a single point does not represent the whole lake. To obtain a comprehensive understanding of the factors influencing varve formation and, moreover, to identify the past distribution and continuation of varved sequences throughout a lake or basin, research in shallow areas is required.

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IN SEDERHOLM'S FOOTSTEPS: GRANITES AND MIGMATITES OF SOUTHERNMOST FINLAND

by

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The Paleoproterozoic bedrock in southernmost Finland varies from metatexites through diatexites to more extensive granitic areas. Bedrock maps show a 230-km-wide granite-migmatite area extending along the Finnish coast (Nironen et al. 2016), but as the area mainly lies under water and is limited by the national border, it has not been extensively researched.

The main questions in this ongoing project concern the exact formation age(s) of the southernmost granite-migmatite area, whether the whole area has the same origin, and what connection there is between the granite-migmatite area and the older rocks on the mainland side of the terrane.

Earlier age data from the area are not extensive and contain large uncertainties (Kurhila et al. 2005). In field-based research from the early 20th century, a genetic link was suggested between the leucosomes and granitic plutons in the area (Sederholm 1907), but this hypothesis has remained untested until now. Our preliminary field studies imply that granites within the granite-migmatite area are very heterogeneous. This could be due to different protoliths in the same granite generation event, but the area may also consist of granites with different origins. As there are numerous shear zones in the area, it is also unclear whether the granite-migmatite area is a direct continuation of the terrane to the north, or if it is exotic.

Newly obtained age data from zircons in the area will be presented. As the project is at an early stage, suggestions for additional research methods are warmly welcomed.

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STRUCTURAL SIGNATURES WITHIN THE PALAEOPROTEROZOIC PERÄPOHJA BELT, NORTHERN FINLAND

by

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Structural investigations within the apparently complexly deformed Palaeoproterozoic Peräpohja Belt (PB), Northern Finland, have revealed that the deformation of the Palaeoproterozoic cover sequences has an intimate relationship with the underlying Archaean basement. Recognition of the basement control provided the tools to understand how the regional structure and the stratigraphy of the Peräpohja Belt may be correlated. The main result of this correlation indicates that two major horst structures existed within the Archaean basement at the time of deposition of the Peräpohja supracrustal succession, and that these also influenced the compressional structural overprint of the belt. Moreover, the horsts were separated by an orthogonally striking central graben which, together with the horsts, is attributed to the rifting of the Archaean continent approximately at 2.44 Ga.

Recognizing the structural inheritance of older basement structures further allows the interpretation of the compressional structural evolution of the belt to be simplified. Much of the observed heterogeneity relates to the existence of the basement breaks and causes the structure to deviate from the characteristic fold-and-thrust style structural patterns observed across the belt. Overall, the compressional evolution comprised one progressive south-verging thrusting event instead of several compressional events with highly contrasting palaeostress orientations. Moreover, the development of a detachment zone within a mechanically weak stratigraphic unit controlled the deformation of the stratigraphically higher supracrustal successions of the belt. Localized deformation along the detachment zone above the funnel-shaped Archaean basement contact in the southern part of Peräpohja Belt explains i) the contrasting fold asymmetries across the Belt, and ii) the sub-vertical structural transposition within the funnel, here attributed to corner flow.

The new results significantly improve the potential for mineral targeting within the Peräpohja Belt.

OBSERVATIONS ON EPISYENITIZATION FROM A DRILL CORE IN PROTEROZOIC A-TYPE GRANITES IN SOUTHEASTERN FINLAND

by

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Numerous episyenite bodies are found within the subaluminous granites of the 1.64 Ga Suomenniemi rapakivi granite complex, SE Finland (Suikkanen & Rämö 2017). A 150-m-long drill core obtained by the Geological Survey of Finland penetrates episyenite and its host, amphibole granite, in the east–central part of the complex. The core was used in a textural, mineralogical and geochemical study to constrain the alteration from granite to a syenitic episyenite recovered from the drill core. The granite and episyenite have a similar porphyritic macrotexture. In the transition zone from granite to syenite, plagioclase is variably albitized and rimmed by alkali feldspar. Hastingsite breaks down to iron-rich augite, magnetite, fluorite and feldspar or alters to ferro-actinolite. Wormy augite forms on quartz. Fluorite and apatite are variably present in the marginal zone. Instability of magmatic zircon is implied by the presence of exceptionally large (ca. 0.5 mm) zircon crystals with dusty cores and water-clear rims. In the mid-part of the episyenite, quartz is accessory, plagioclase has recrystallized as granoblastic aggregates, and new populations of perthite, augite–hedenbergite, magnetite, and titanite have formed.

Mass balance calculations were performed utilizing the isocon method of Grant (1986). A mass transfer model based on immobile Al implies a 10–20% decrease in rock volume, which is attributed to the dissolution of quartz and removal of Si through the metasomatic column. Na, Mg, Nb, and Sn were added to the system, while Si, Rb, and F were removed. Minor enrichment of P, Y, and the REE is seen in a fluorite-rich margin of the syenitic episyenite and is marked by the presence of altered phosphate minerals; in general, this reflects the mineralizing potential of episyenitic alteration. The composition of alkali feldspar in the altered rocks (ca. $An_{<1}Ab_{50}Or_{50}$) implies high-temperature alteration (>650 °C). The compositions of co-existing plagioclase and alkali feldspar in the episyenite show that these phases did not re-equilibrate during metasomatism. The breakdown of hastingsite suggests that oxygen fugacity was above the FQM buffer during the high-temperature process. The F released by hastingsite may have been instrumental in the mobilization of Si (as well as REE+Y). The results of our work suggest that minor amounts of augite syenitic rocks with fabrics that resemble the products of magmatic crystallization can form via high-temperature episyenitization. The overall style of alteration is similar to fenitization. In SE Finland, the episyenitization was preceded by fracturing of the Suomenniemi complex, followed by the advection of high-temperature sodium-bearing fluids of unknown origin.

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NATURALLY EUTROPHIC FINNISH LAKES AND THEIR RESPONSE TO ANTHROPOGENIC FORCING

by

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Human activity has affected lakes in many lowland areas for thousands of years, but the most notable changes are often quite recent (Saulnier-Talbot 2016, Dubois et al. 2017). Cultural eutrophication, for example, still remains a largely unresolved global challenge, despite extensive research (Smith & Schindler 2009). Paleolimnological studies typically define temporal changes in the past water quality of single lakes, while spatial studies concerning the interaction between lakes and their catchments are scarce (Anderson 2014). Shallow and naturally eutrophic lakes also require further studies (Räsänen et al. 2006, Smol 2016).

In our spatial paleolimnological study, we used the top–bottom sampling approach and multivariate statistics to compare two presumably naturally eutrophic areas (Eastern and Southern Finland). Both areas have shallow lakes but different surficial geologies and land use histories. Our aims were to examine the spatial distribution of naturally eutrophic lakes and its relationship to surficial geology, as well as diatom assemblage and water quality changes due to anthropogenic forcing.

According to our results, similar pre-human disturbance phosphorus gradients exist in Eastern and Southern Finland, with naturally eutrophic lakes occurring on fine-grained till and clay-dominated catchments. Diatom assemblages have changed in most lakes, but shallow, naturally eutrophic lakes with short water residence times have been particularly susceptible to cultural eutrophication. The results also indicate salinization, alkalinization, and brownification in many of the lakes. Our results suggest that variation in glacial landforms can result in a steep natural phosphorus gradient, while lake morphology is important in explaining the sensitivity of a lake to anthropogenic disturbances.

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EUROPEAN-WIDE DATA ON ARSENIC CONCENTRATIONS IN AGRICULTURAL SOIL AND WATERS

by

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Arsenic is a toxic and carcinogenic substance. According to WHO, the greatest threat to public health from arsenic originates from contaminated groundwater. Food is another notable pathway for As exposure in humans. There are numerous arsenic-related publications and reports, but many of them focus on arsenic problems in South-East Asia or are limited to groundwater or contaminated soil. The AgriAs project (http://projects.gtk.fi/AgriAs/index.html; Water JPI 2017) has focused on European data on agricultural soils and the quality of related surface water and groundwater.

The AgriAs project has summarized European-wide databases and publications on As concentrations in soil and water. This was followed by a literature review and a questionnaire on national-level data sources for As concentrations in agricultural soil and water. A web-based AgriAs questionnaire on national and large-scale regional data sources for arsenic in soil, surface water, groundwater, and crops in Europe was sent to 23 countries. The general findings concerning As concentrations in crops were summarized from the literature. Following the assessment of data availability, a list of major data gaps was reported.

Reimann et al. (2009) have provided a comprehensive summary of the European-wide availability of data on As concentrations in soil and water. More up-to-date information on national and regional data sources was identified from the AgriAs questionnaire. The questionnaire revealed that regional-scale data are available on arsenic concentrations in soil and surface water. These data can provide a detailed insight into the European-wide anomalies found in the FOREGS (Salminen et al. 2005), Baltic Soil Survey (Reimann et al. 2003), GEMAS (Reimann et al. 2015, Tarvainen et al. 2015), and LUCAS surveys (Tóth et al. 2015a, 2015b).

There are quite extensive European-wide datasets on As concentrations in agricultural soil, but more detailed regional mapping at the national level is needed, especially in those areas where anomalously high As concentrations in topsoil have been discovered. According the AgriAs questionnaire and literature study, European-wide data as well as nationwide data on As concentrations in crops are entirely lacking. There is no up-to-date map of arsenic concentrations in European groundwater related to agricultural sites. European-wide or large-scale regional databases very seldom combine arsenic concentrations in agricultural topsoil with concentrations in adjacent surface waters or groundwater.

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LUENHA PICRITE LAVAS OF CENTRAL MOZAMBIQUE – THE LONG-AWAITED GEOCHEMICAL EVIDENCE OF A MANTLE PLUME IN THE KAROO LARGE IGNEOUS PROVINCE?

by

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A mantle plume has regularly been suggested as a likely major source component for the continental flood basalts of the Karoo large igneous province, which erupted rapidly over southern Africa and eastern Antarctica some 182 Ma ago. The regional uplift history and several triple junction structures comply with the plume concept, and there is a long-lived deep-mantle low seismic velocity zone under southern Africa. However, none of the picrite suites recorded in the area show unequivocal geochemical evidence of a mantle plume. Instead, the primitive parental melts of the previously studied major groups of Karoo picrites point to melting of depleted upper mantle (depleted ferropicrites of Vestfjella; Heinonen et al. 2010) or lithospheric mantle (Mwenezi picrites; Ellam & Cox 1989).

We propose that the Luenha picrites from Central Mozambique add a new significant mantle source component to the discussion. These picrites are close to primary melts based on their olivine phenocryst compositions of Fo_{87-89}. One of the samples lacks geochemical indications of crustal contamination and its trace element and Nd and Sr isotopic compositions show similarity to non-chondritic primitive mantle ($[\varepsilon_{Nd}]_{180\ Ma}$ = +1.9, $[^{87}Sr/^{86}Sr]_{180\ Ma}$ = 0.704). In addition to this, all samples in the Luenha picrite suite show relative abundances of Nb, Zr, and Y typical of plume magmas in Iceland (Fitton et al. 1997). These characteristics are a prominent feature of continental flood basalts within the northern Karoo sub-province. We suggest that the Luenha picrites represent parental magmas of North Karoo flood basalts and are so far the strongest geochemical indication of a Jurassic mantle plume in the Karoo large igneous province.

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WEICHSELIAN STRATIGRAPHY AND DEGLACIAL DEPOSITS FROM KUUSIVAARA, SODANKYLÄ IN CENTRAL FINNISH LAPLAND

by

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This study describes the lithostratigraphy of the Kuusivaara hill and Porokodanjänkä mire, 10 km north of Sodankylä and east of River Kitinen in Central Finnish Lapland. The area exhibits limited glacial erosion from the Weichselian glaciation. Therefore, the till units of Early and Middle Weichselian stadials are often preserved (e.g. Helmens et al. 2007, Howett et al. 2015, Lunkka et al. 2015). During deglaciation, the study area was first occupied by the Moskujärvi Ice Lake (207 m.a.s.l.) and later by the Ancylus Lake (186 m.a.s.l.).

The stratigraphy and glacial deposits of the area were studied from six test pits, M-1 to M-6, and via the collection of 15 km of ground penetrating radar (GPR) data. Sediment logs were recorded from the test sections and 14 sediment samples were analysed for their granulometric properties.

Preliminary observations from the study area suggest that weathered bedrock is covered by a lower, presumably Early Weichselian till with saprolithic material incorporated at its lower contact. Test section observations and GPR interpretation indicate that saprolith is present south of the Kuusivaara hill, as well as beneath the Porokodanjänkä mire. Weakly eroded saprolite and saprock horizons have previously been observed in other studies in the ice divide zone (e.g. Rask & Lintinen 2001, Hall et al. 2015) at an average depth of 10–20 m (Hall et al. 2015). Maximum weathering depths can reach more than 50 m (Sarapää & Sarala 2013). Sandy sediments with a distinct palaeosoil horizon were observed in test pit M-6. The upper till is a stratified, loose sandy melt-out deposit. A gravity flow deposit has eroded through the till units in test pit M-3. The upper till is overlain by aeolian sands or shoreline deposits.

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U-Pb GEOCHRONOLOGY OF INTRUSIVE ROCKS AROUND THE BARÖSUND SHEAR ZONE, SOUTHERN FINLAND

by

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The Barösund shear zone (BSZ) is a major structure in the Ekenäs archipelago, southern Finland. The BSZ can be traced for at least 35 km on aeromagnetic maps. It is interpreted that the BSZ is part of the prominent South Finland shear zone (Torvela et al. 2008). The zone is deflected from its typical E–W trend into an approximately N–S strike between the mainland and the island of Barölandet, which is our present study area. We collected three samples from the intrusive felsic rocks for U–Pb dating. Sample 1 is from a Kfs-phyric granite from Barösund island. Sample 2 was collected from a tonalite/granodiorite from the island of Barölandet. These samples were collected to determine the age of the rocks south of the BSZ. Sample 3 is from a ~30–40-cm-wide granitic dyke crosscutting the BSZ. The dyke is openly folded. The age of the dyke thus gives the age of the BSZ activity.

The preliminary results show that all the samples contain older inherited zircons of several ages. The youngest zircon population in the granite is ~1.90–1.89 Ga, and in the granodiorite it is ~1.89 Ga. These are interpreted to yield the crystallization age of these plutonic rocks. The youngest population in the dyke yields an age of ~1.84 Ga. However, it is unclear whether the zircons are of inherited or magmatic origin. It is noteworthy that the granite and the granodiorite do not show any 1.84–1.81 Ga metamorphic overprinting ages, which are common in older granites in southern Finland (e.g. Penttinen et al. 2016).

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TOWARDS A NATIONAL GEOLOGICAL FRAMEWORK - COLLABORATION OF GTK AND THE STRATIGRAPHIC COMMISSION OF FINLAND ON CONCEPTUAL MODELS AND CLASSIFICATION SYSTEMS

by

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The geology of Finland has been systematically mapped for over 100 years by the Geological Survey of Finland (GTK). Gradually, the production of traditional printed geological maps has been replaced by digital processes, products and services. Since the 1980s, field observations have been stored in a database, and since the 1990s, the GIS approach has shown the way to fully digital mapping processes. During the last fifteen years, GTK has developed a vision and a national approach for the production, storage and services for interpreted geological data (e.g. maps and models), and the map sheet-based approach was replaced in 2005 by a concept of seamless map datasets.

In 2017, GTK started preparation for a National Geological 3D-framework of Finland ('3DSuomi'). The most important aim is the creation of a conceptual and technical framework for national geological data and new geoscientific interpretations. In our approach, the first steps towards the goal are not only technology-related issues ('how'), but primarily challenges related to the overall objectives ('why') and outlines of conceptual models ('what').

Both the geological map data (spatial and non-spatial) and 3D models will ideally form parts of one 'National Geological Framework' based on solid conceptual models and classification systems. The conceptual data model must be nationally relevant and compatible with international standards. The framework must be capable of accommodating various geological themes at variable scales (e.g. tectonic modelling, mineral systems modelling). The core of the national conceptual model consists of the geological units, which link the geological map unit (e.g. a polygon) to correlatives both on maps (2D) and in depth (3D models) and, most importantly, to the published scientific definition of the unit.

GTK and the Stratigraphic Commission of Finland have collaborated for several years in improving the national practices in Finland. The stratigraphic classification into lithostratigraphic and lithodemic units is now the fundamental basis for bedrock mapping. The major lithostratigraphic and lithodemic units in Finland according to the Finstrati database are described with restriction into supergroups, supersuites and complexes within four defined tectonic provinces.

Current work is focused on: (1) the division of the Quaternary geological units using the traditional stratigraphic practices together with allostratigraphic and glacial dynamic approaches; (2) the application of the tectonostratigraphic scheme to bedrock classification; and (3) their use as a part of the 'National Geological Framework'. We present the current status and future challenges of the work and national collaboration.

All GTK's publications online at hakku.gtk.fi

This book contains abstracts submitted for presentation at the 4th Finnish National Colloquium of Geosciences, Turku, 14–15 March 2018. The meeting has been organized in Turku, at the Geohouse, which is the home of the geology units from the University of Turku and Åbo Akademi University. A specific focus within the 2018 colloquium is on MSc students, who have the possibility to present their ongoing or recently completed MSc theses within a dedicated poster session. The meeting has been organized in collaboration between the Universities of Turku and Åbo Akademi and the Geological Survey of Finland. 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 the authors for their contributions, and wish everybody a pleasant and successful colloquium.

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