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LITHOSPHERE 2021

ELEVENTH SYMPOSIUM ON STRUCTURE, COMPOSITION AND EVOLUTION OF THE LITHOSPHERE

PROGRAMME AND EXTENDED ABSTRACTS

Edited by

Ilmo Kukkonen, Toni Veikkolainen, Suvi Heinonen, Fredrik Karell, Elena Kozlovskaya, Arto Luttinen, Kaisa Nikkilä, Vesa Nykänen, Markku Poutanen, Pietari Skyttä, Eija Tanskanen and Timo Tiira

Virtual Meeting
January 19 – 20, 2021

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References of Lithosphere Symposia Publications

Pesonen, L.J., Korja, A. and Hjelt, S.-E., 2000 (Eds.). Lithosphere 2000 - A Symposium on the Structure, Composition and Evolution of the Lithosphere in Finland. Programme and Extended Abstracts, Espoo, Finland, October 4-5, 2000. Institute of Seismology, University of Helsinki, Report S-41, 192 pages.

Lahtinen, R., Korja, A., Arhe, K., Eklund, O., Hjelt, S.-E. and Pesonen, L.J., 2002 (Eds.). Lithosphere 2002 – Second Symposium on the Structure, Composition and Evolution of the Lithosphere in Finland. Programme and Extended Abstracts, Espoo, Finland, November 12-13, 2002. Institute of Seismology, University of Helsinki, Report S-42, 146 pages.

Ehlers, C., Korja A., Kruuna, A., Lahtinen, R. and Pesonen, L.J., 2004 (Eds.). Lithosphere 2004 – Third Symposium on the Structure, Composition and Evolution of the Lithosphere in Finland. Programme and Extended Abstracts, November 10-11, 2004, Turku, Finland. Institute of Seismology, University of Helsinki, Report S-45, 131 pages.

Kukkonen, I.T., Eklund, O., Korja, A., Korja, T., Pesonen, L.J. and Poutanen, M., 2006 (Eds.). Lithosphere 2006 – Fourth Symposium on the Structure, Composition and Evolution of the Lithosphere in Finland. Programme and Extended Abstracts, Espoo, Finland, November 9-10, 2006. Institute of Seismology, University of Helsinki, Report S-46, 233 pages.

Korja, T., Arhe, K., Kaikkonen, P., Korja, A., Lahtinen, R. and Lunkka, J.P., 2008 (Eds.). Lithosphere 2008 – Fifth Symposium on the Structure, Composition and Evolution of the Lithosphere in Finland. Programme and Extended Abstracts, Oulu, Finland, November 5-6, 2008. Institute of Seismology, University of Helsinki, Report S-53, 132 pages.

Heikkinen, P., Arhe, K., Korja, T., Lahtinen, R., Pesonen, L.J. and Rämö, T., 2010 (Eds.). Lithosphere 2010 – Sixth Symposium on the Structure, Composition and Evolution of the Lithosphere in Finland. Programme and Extended Abstracts, Helsinki, Finland, October 27-28, 2010. Institute of Seismology, University of Helsinki, Report S-55, 154 pages.

Kukkonen, I.T., Kosonen, E., Oinonen, K., Eklund, O., Korja, A., Korja, T., Lahtinen, R., Lunkka, J.P. and Poutanen, M., 2012 (Eds.). Lithosphere 2012 – Seventh Symposium on the Structure, Composition and Evolution of the Lithosphere in Finland. Programme and Extended Abstracts, Espoo, Finland, November 6-8, 2012. Institute of Seismology, University of Helsinki, University of Helsinki, S-56, 116 pages.

Eklund, O., Kukkonen, I.T., Skyttä, P., Sonck-Koota, P., Väisänen, M. and Whipp, D., 2014 (Eds.). Lithosphere 2014 – Eighth Symposium on the Structure, Composition and Evolution of the Lithosphere in Finland. Programme and Extended Abstracts, Turku, Finland, November 4-6, 2014. Institute of Seismology, University of Helsinki, S-62, 126 pages.

Kukkonen, I.T., Heinonen, S., Oinonen, K., Arhe, K., Eklund, O., Karell, F., Kozlovskaya, E., Luttinen, A., Lahtinen, R., Lunkka, J., Nykänen, V., Poutanen, M., Tanskanen, E. and Tiira T. (Eds.), 2016. Lithosphere 2016 – Ninth Symposium on the Structure, Composition and Evolution of the Lithosphere in Finland. Programme and Extended Abstracts, Espoo, Finland, November 9-11, 2016. Institute of Seismology, University of Helsinki, Report S-65, 156 pages.

Kukkonen, I.T., Heinonen, S., Silvennoinen, H., Karell, Kozlovskaya, E., Luttinen, A., Nikkilä, K., Nykänen, V., Poutanen, M., Skyttä, P., Tanskanen, E., Tiira, T. and Oinonen, K. (Eds.), 2018. Lithosphere 2018 – Tenth Symposium on the Structure, Composition and Evolution of the Lithosphere. Programme and Extended Abstracts, Oulu, Finland, November 14-16, 2018. Institute of Seismology, University of Helsinki, Report S-67, 134 pages.

Kukkonen, I.T., Veikkolainen, T., Heinonen, S., Karell, F., Kozlovskaya, E., Luttinen, A., Nikkilä, K., Nykänen, V., Poutanen, M., Skyttä, P., Tanskanen, E. and Tiira, T. (Eds.), 2021. Lithosphere 2021 – Eleventh Symposium on the Structure, Composition and Evolution of the Lithosphere in Finland. Programme and Extended Abstracts, January 19-20, 2021. Institute of Seismology, University of Helsinki, Report S-71, 164 pages (pdf).

Keywords (GeoRef Thesaurus, AGI): lithosphere, crust, upper mantle, Fennoscandia, Finland, Precambrian, Baltic Shield, symposia

TABLE OF CONTENTS

PREFACE

The Finnish National committee of the International Lithosphere Programme (ILP) organises every second year the LITHOSPHERE symposium, which provides a forum for lithosphere researchers to present results and reviews as well as to inspire interdisciplinary discussions. The tradition was disturbed by the Covid-19 pandemic, and the 2020 meeting was shifted to 2021. Regardless of the exceptional circumstances the symposium provides a wide selection of geological and geophysical presentations. The eleventh symposium – LITHOSPHERE 2021 – comprises 44 presentations. The extended abstracts (in this volume) provide a good overview on current research on structure and processes of solid Earth.

The two-day symposium takes place completely in the internet as a virtual meeting during January 19 – 20, 2021. The participants will present their results in oral and poster sessions. Posters prepared by graduate and postgraduate students will be evaluated and the best one will be awarded. Research Professor Peter M. Malin, Duke University, USA, will give the invited talk.

This special volume ***"LITHOSPHERE 2021"*** contains the programme and extended abstracts of the symposium in alphabetical order.

Helsinki, January 13, 2021

Ilmo Kukkonen, Toni Veikkolainen, Suvi Heinonen, Hanna Silvennoinen, Fredrik Karell, Elena Kozlovskaya, Arto Luttinen, Kaisa Nikkilä, Vesa Nykänen, Markku Poutanen, Pietari Skyttä, Eija Tanskanen, and Timo Tiira

Lithosphere 2021 Organizing Committee

Koillismaa Deep Hole – Solving the mystery of a geophysical anomaly

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Geological Survey of Finland is drilling a 3000 m long hole into the geophysically anomalous zone in the Koillismaa area. Drilling has been preceded by gravity and magnetic measurement, seismic reflection soundings and AMT measurements showing anomalous feature in depth. The aim of drilling is to find out the source of the anomaly.

Keywords: deep drilling, seismic reflection, gravity, mineral potential, Koillismaa

1. Introduction

Koillismaa area in Finland has been a geological mystery for several decades. Magnetic and gravimetric measurements show anomalous values caused by a deep unknown geological origin. In LITHOSPHERE 2018 Symposium, Gislason et al. (2018) presented preliminary results from Koillismaa Seismic Exploration Survey (KOSE) project. The KOSE seismic reflection profile revealed prominent reflectivity of the subsurface and provided new information about the deep gravimetric and magnetic anomaly zone known at the Koillismaa area. These geophysical data have motivated the ongoing ambitious drilling project that attempts to solve a mystery which has been struggling the curious minds of geoscientists already for many decades. GTK started to drill a 3000 m long drill hole in the heart of the anomaly in September 2020, to finally collect rock samples from the source of the anomalous zone. In this abstract we briefly describe the background, geophysical studies, modelling and present stage of the ongoing drilling. We also describe the specific drilling technique used in order to reach the intended target inside the Archean basement of Koillismaa area.

2. Geological framework

The Koillismaa deep anomaly is ca. 50 km long zone which connects the distant parts of the 2.45 Ga layered intrusion blocks of the Koillismaa (Alapieti 1982; Karinen 2010) and mafic-ultramafic Näränkävaara intrusion (Alapieti 1982; Järvinen et al. 2020) (Figure 1). The zone is also partly traceable by a zone of breccia outcrops (Figure 2), but the relationship of the gravimetric anomaly and the breccia is unclear, although it is known that the breccia is not the source of the anomaly and no other possible causes are noticeable on the surface either. For this reason, the anomaly has been interpreted to reflect the location of a chonolith-like feeder zone for the magmas of the exposed mafic-ultramafic intrusions in the Koillismaa. Alternatively, the anomaly could reflect the presence of mafic-ultramafic rocks representing some other magmatic episode than the 2.45 Ga intrusions, for example, the Archaean greenstone belts near the Koillismaa area. This kind of voluminous mafic-ultramafic systems are globally rare, and therefore, the target is very likely an interesting example of plume derived magmatism of Fennoscandian shield. Mafic-ultramafic rocks are very potential for several commodities such as orthomagmatic Ni-Cu-Co-PGE and Cr-V-Ti-Fe.

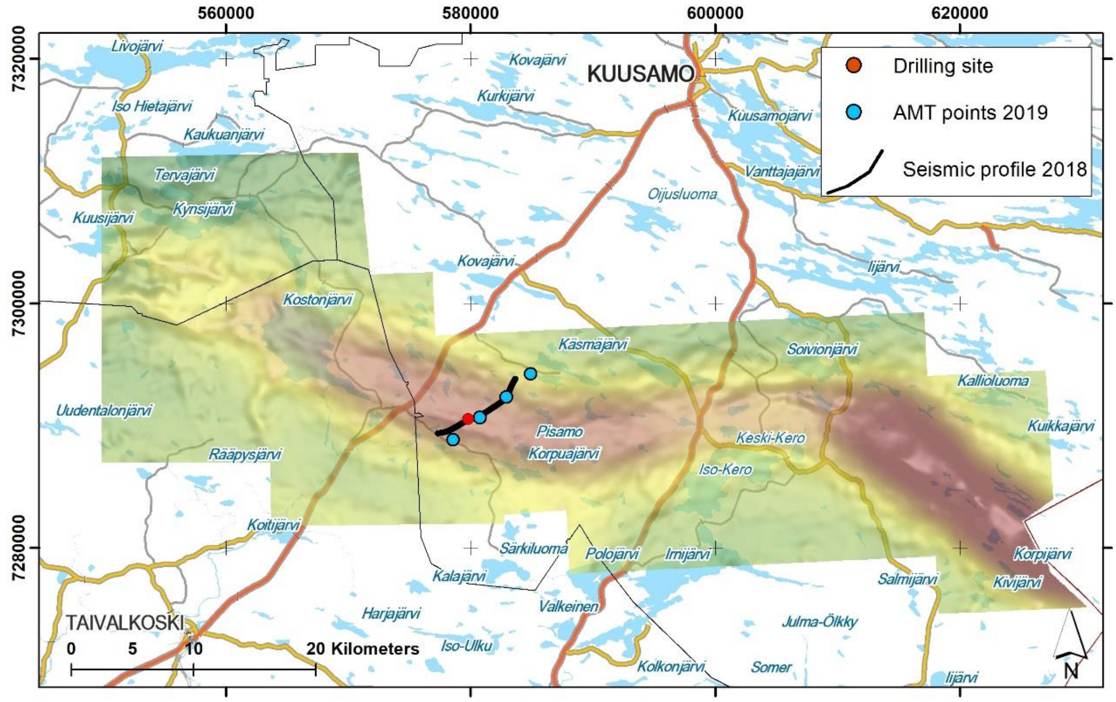

Figure 1. Drilling site on the regional gravity map. Locations of seismic profile 2018 and AMT surveys 2019 are plotted also.

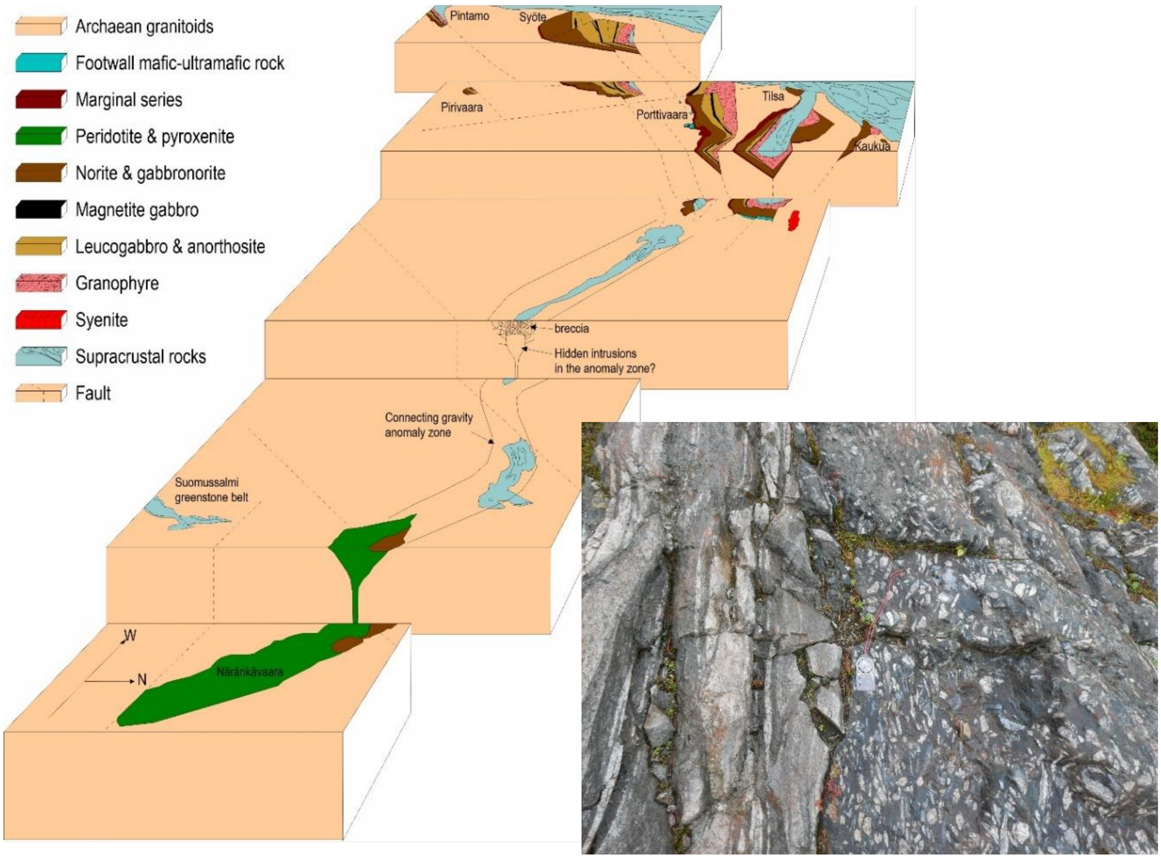

Figure 2. Geological framework of the Koillismaa area shown as exploded blocks. Photo shows outcrop containing breccia and paragneissic basement rock from Poroperä area near Lake Kostonjärvi.

3. Geophysical studies

The anomaly zone is most clearly observed by gravity and magnetic measurements, which were performed already as early as 1950s. Last geophysical surveys carried out by GTK were a seismic survey in 2018 and an audiomagnetotelluric survey (AMT) 2019.

All previous interpretation of the gravity anomaly indicate that the unexposed source is about 2.5-5 km wide and that the depth of the upper surface is between 1 and 2 km below the present erosion level depending on the location along the anomaly (Piirainen et al. 1978; Saviaro 1976). Interpretation of earliest AMT-surveys in 1970s brought up a weak conductivity anomaly located in the same area than gravity anomaly (Saviaro, 1976). The AMT surveys made in 2019 confirmed the existence of this conductivity contrast.

The KOSE seismic reflection data was acquired along the road close to the drilling site with 90 wireless geophones and explosive sources (Gislason et al. 2019). The resulting seismic reflection cross-sections show prominent reflectors that will be penetrated by the drill hole (Figure 3). These reflectors are expected to be lithological contacts or fracture zones that cause abrupt change of acoustic impedance within the subsurface. The upper boundary of the source of the gravity anomaly is expected to be at approximately 1.5 km depth based on changes in reflectivity.

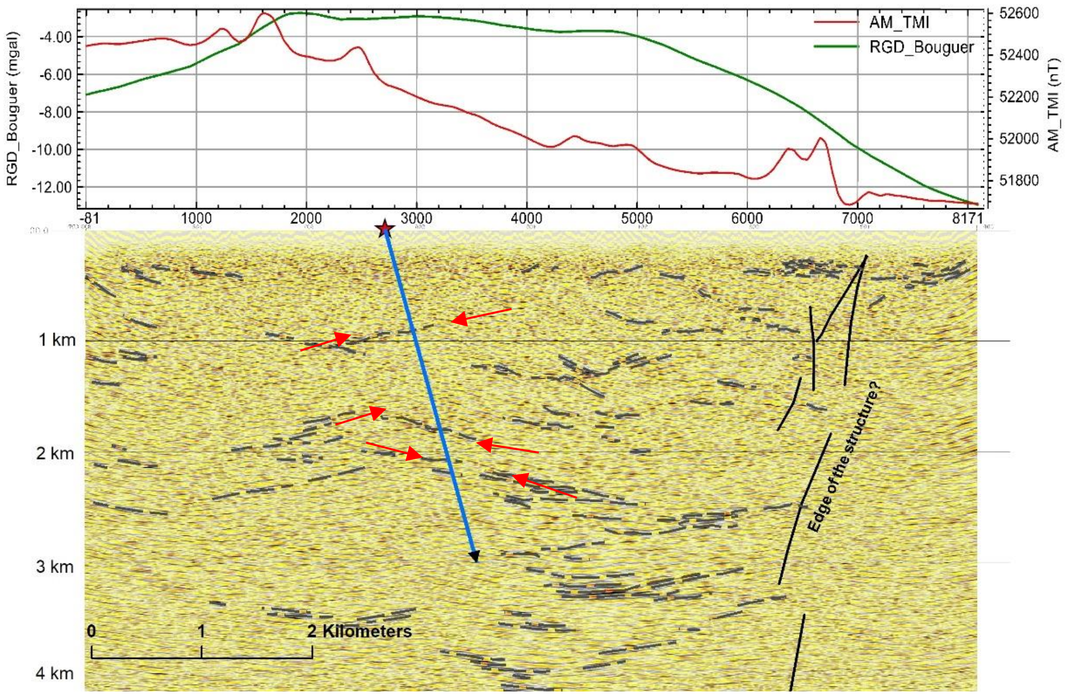

Figure 3. Planned drill hole projected to the KOSE seismic reflection profile. Red arrows are pointing to the most prominent reflectors drill hole will penetrate. Gravity (RGD_Bouguer) and airborne magnetic (AM_TMI) profiles are plotted above the seismic section.

4. Drilling technique

According to the original plan, the drilling is conducted within 5 months. The contractor to perform the drilling is Arctic Drilling Company Ltd (ADC) from Rovaniemi, who uses diamond drill rigs of their own design and manufacturing. The contractor uses best available techniques designated to these rock types based on their previous experiences in deep hole (>1500m) drilling projects. The rig has been anchored to the bedrock with a 30 m cemented anchoring hole (diameter 96 mm). This anchoring is to prevent resonation of the rig once the core reaches a certain depth. At the beginning of the drilling campaign, a fractured bedrock down to 300 m caused serious technical challenges, which showed up mostly as continuous losses of water pressure. Therefore, a decision was eventually made to use 96 mm rods as a casing for the first 300 m. If these poor rock conditions were known beforehand, the drilling could have been started with this rod size already at the beginning of the drilling campaign. The rig was changed to a more efficient version when the first half, i.e., 1500 m of the planned 3000 m length was reached in early December 2020. The change to a more powerful drill rig, to ADC's K10, ensures that project reaches the targeted 3000 m depth. The K10 is the flagship of ADC´s fleet, and in theory, with this diamond drill rig it is possible to reach depths of 3500 m. Towards the end of drilling campaign, the rods themself will eventually weigh over 20 tonnes at the depth of 3000 m. At this length of drilling, the strength of the rod will be put to a test in which their breaking strength is the limit of drilling.

5. Discussion

In addition to increased geological understanding and unique rock samples from depth, this research has impact on providing scientific platform and testing environments for future studies. These are, for example, development of survey technology, 3D modelling, studies of geothermal energy, deep groundwater and bedrock stability.

6. Conclusions and future work

Koillismaa Deep Hole is expected to shed light into the mystery of geophysical anomaly by proving rock samples from the core of the anomaly. In addition to the study of age and composition of these samples, the future work will include several different geophysical surveys, including (1) semi-passive seismic experiment where drilling noise is utilized for retrieving a model of seismic velocity in the drill hole vicinity, (2) crossing seismic reflection profile to the KOSE profile, (3) densification of AMT measurements and testing different drill hole geophysics methods.

References:

Alapieti, T., 1982. The Koillismaa layered igneous cornplex, Finland - its structure, mineralogy and i geochemistry, with ernphasis on the distrubution of chromium. Geological Survey of Finland, Bulletin 319. 116 p.

Gislason, G., Heinonen, S., Konnunaho, J., Moisio, K., Nevalainen, J., Salmirinne, H., 2018. KOSE - Koillismaa Seismix Exploration survey: Details and first results, 11-14. In: Kukkonen et al. (Eds.), 2018. Lithosphere 2018 – Tenth Symposium on the Structure, Composition and Evolution of the Lithosphere. Programme and Extended Abstracts, Oulu, Finland, November 14-16, 2018. Institute of Seismology, University of Helsinki, Report S-67, 134 p.

Gislason, G., Heinonen, S., Salmirinne, H., Konnunaho, J. and Karinen, T., 2019. KOSE - Koillismaa Seismic Exploration survey: Acquisition, processing and interpretation. GTK:n työraportti - GTK Open File Work Report, 26 p.

Järvinen, V., Halkoaho, T., Konnunaho, J., Heinonen, J., Rämö T., 2020. Parental magma, magmatic stratigraphy, and reef-type PGE enrichment of the 2.44-Ga mafic-ultramafic Näränkävaara layered intrusion, Northern Finland. Mineralium Deposita 55, p. 1535-1560.

Karinen T., 2010. The Koillismaa Intrusion, northeastern Finland – evidence for PGE reef forming processes in the layered series. Geological Survey of Finland, Bulletin 404, 176 p.

Piirainen, T., Hugg, R, Aario, R., Forsström, L., Ruotsalainen, A., Koivumaa, S., 1978. Koillismaan malmikriittisten alueiden tutkimusprojektin loppuraportti 1976. Summary: The Report of the Koillismaa Research Project. Geologinen tutkimuslaitos. Tutkimusraportti n:o 18. 51 p.

Saviaro, K., 1976. Geofysikaalisia tutkimuksia Koillismaan gabrointruusioiden alueella. Lisensiaattityö, Oulun yliopiston geofysiikan laitos. 72 S. PSMTPl/3-76-6.