

INSTITUTE OF SEISMOLOGY  
UNIVERSITY OF HELSINKI  
REPORT S-71

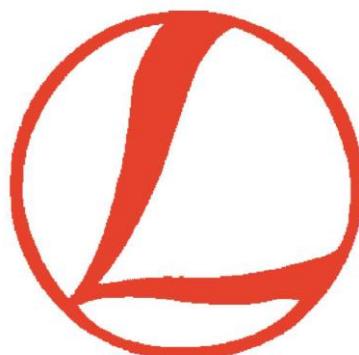
# LITHOSPHERE 2021

*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**

Series Editor-in-Chief: Timo Tiira

Guest Editors: 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

Publisher: Institute of Seismology  
P.O. Box 68  
FI-00014 University of Helsinki  
Finland  
Phone: +358-294-1911 (switchboard)  
<http://www.helsinki.fi/geo/seismo/>

ISSN 0357-3060  
Helsinki 2021  
**ISBN 978-952-10-9604-4 (pdf)**

# LITHOSPHERE 2021

## ELEVENTH SYMPOSIUM ON STRUCTURE, COMPOSITION AND EVOLUTION OF THE LITHOSPHERE

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Virtual meeting  
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Aalto University

Geological Survey of Finland (GTK)

National Land Survey of Finland, Finnish Geospatial Research Institute (FGI)  
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**Keywords** (GeoRef Thesaurus, AGI): lithosphere, crust, upper mantle, Fennoscandia, Finland, Precambrian, Baltic Shield, symposia

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## 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.

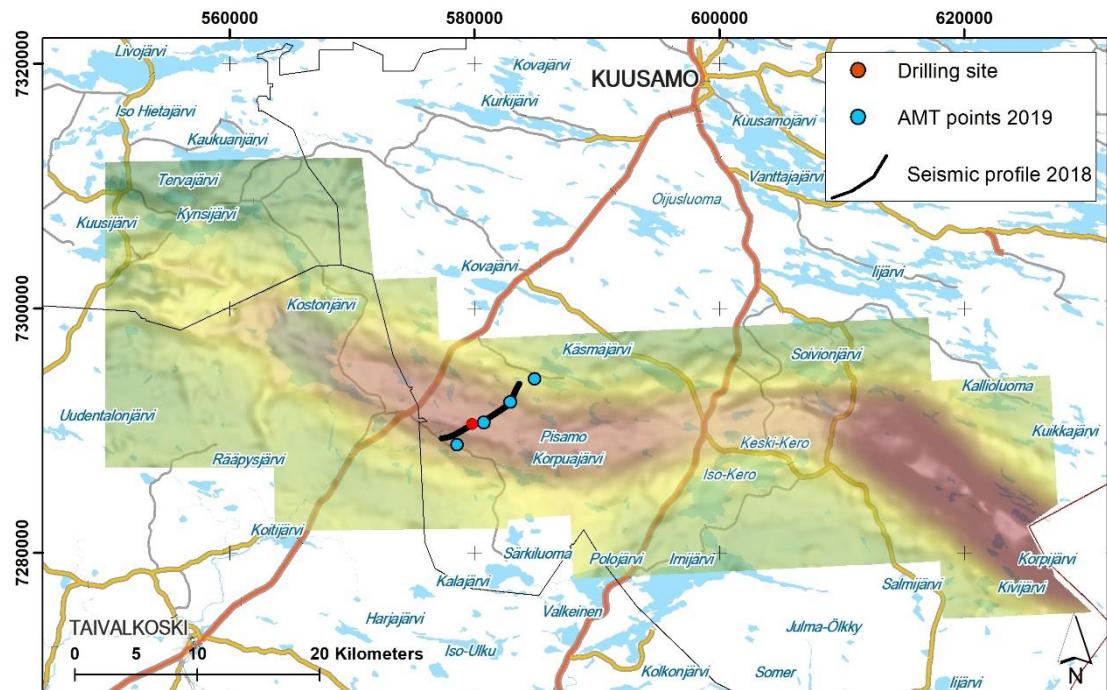
**Keywords:** deep drilling, seismic reflection, gravity, mineral potential, Koillismaa

### 1. Introduction

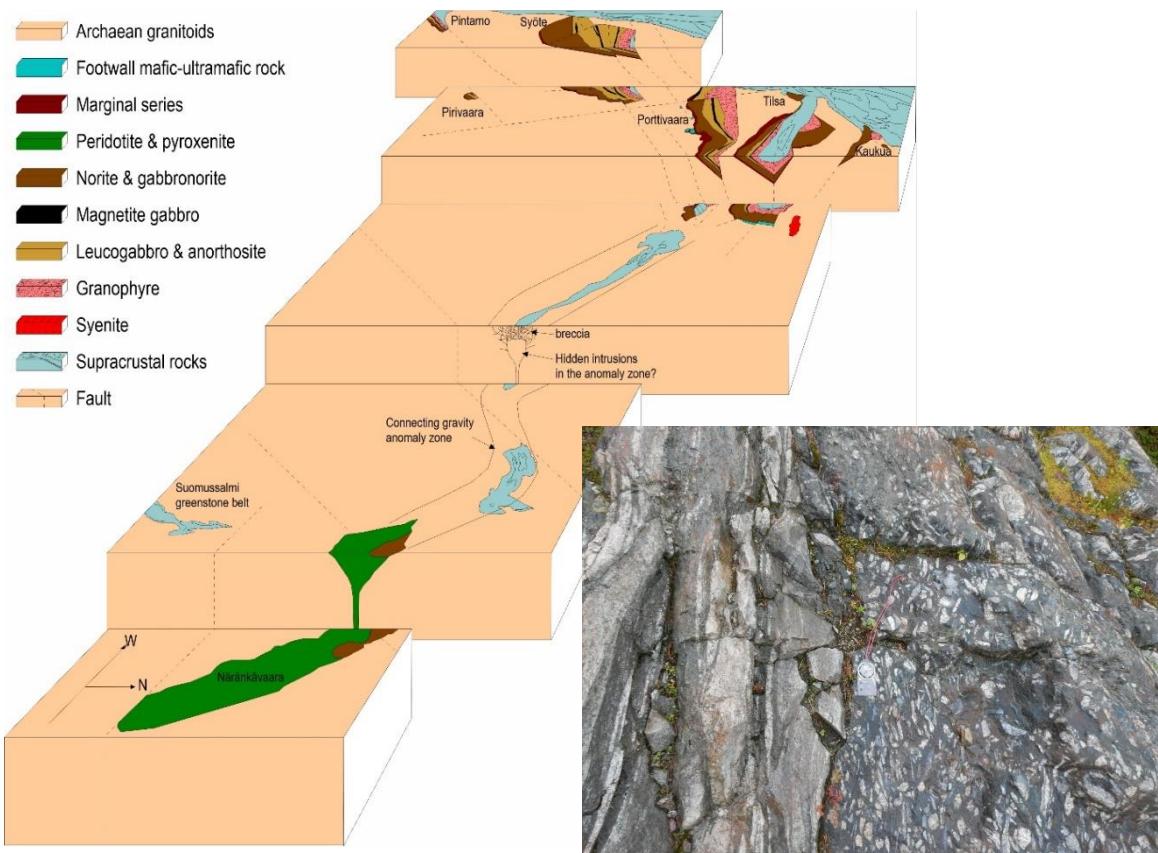
Koillismaa area in Finland has been a geological mystery for several decades. Magnetic and gravimetric measurements show anomalous values caused by a deep unknown geological origin. In LITHOSPHERE 2018 Symposium, Gislason et al. (2018) presented preliminary results from Koillismaa Seismic Exploration 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 Näränkäväära 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.



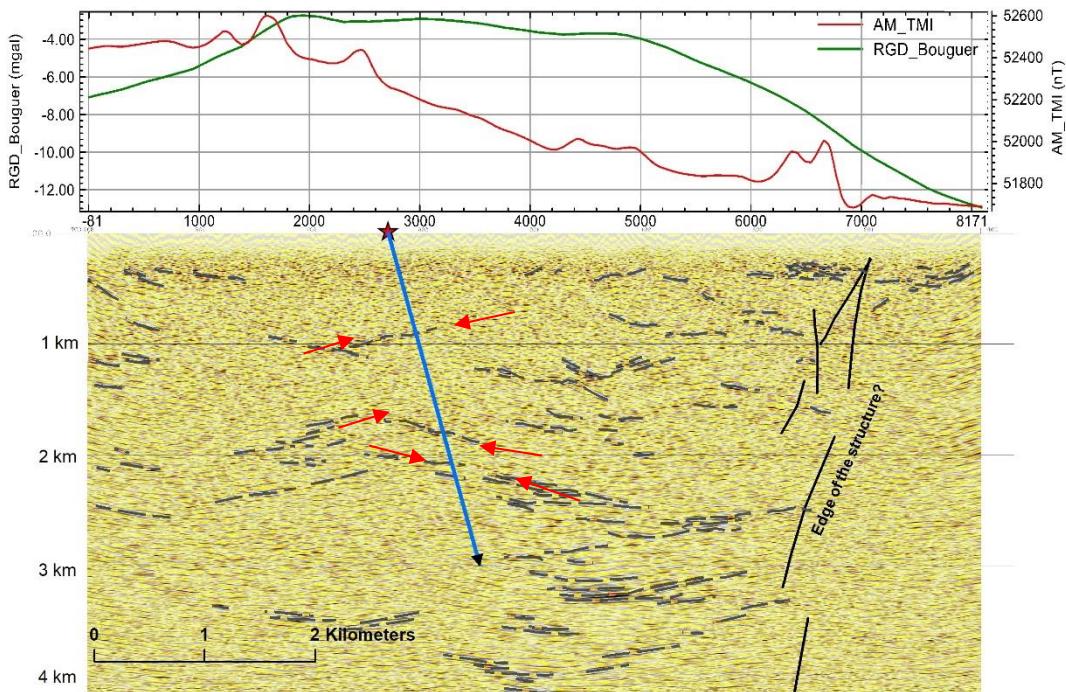
**Figure 2.** Geological framework of the Koillismaa area shown as exploded blocks. Photo shows outcrop containing breccia and paragneissic basement rock from Poroperä area near Lake Kostonjärvi.

### 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 resonance 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 themselves 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.

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