

Koillismaa Deep Hole: a window into the Archean-Proterozoic Fennoscandian Shield

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Context

Deep (>1 km) drillholes are indispensable for gaining insights into the Earth's subsurface and associated resource potential but their availability remains notably scarce within the Fennoscandian Shield. Particularly, these deep drillholes can provide substantial complementary assets when geological and geophysical research increasingly explores the deeper parts of the Earth's crust.

Exploration history

The Koillismaa area in central Finland has been a subject of scientific and economic research since the 1970s, primarily driven by the presence of the 2.45 Ga Koillismaa and Näränkäväära mafic-ultramafic layered intrusions and their associated Cu-Ni-PGE, V-Ti-Fe mineralizations. A remaining open question revolved around the origin of the 60-kilometer-long Bouguer gravity anomaly connecting these intrusive complexes. Potential field modeling has indicated that the anomaly's source lies at depths between 1 to 3 km, but direct evidence was lacking until recently. To address this question, GTK initiated the Koillismaa Deep Hole project in 2020, originally aiming for a 3 km deep borehole that could sample this anomaly. However, drilling encountered significant challenges caused by highly fractured rocks. Consequently, the borehole only reached 1724.7 m after four months of drilling. A side-track hole attempt faced similar issues and drilling was interrupted at 1594.9 m depth.

Major findings

The uppermost 658 m of the drillhole penetrated Archean (2.9–2.8 Ga) tonalite–trondhjemite–granodiorite (TTG) gneisses. The central section (658–1410 m) consists of homogeneous granites and quartz diorites dated to ~2.44 Ga. Below 1410 m these granites are alternating with mafic-ultramafic rocks. Diabase dikes of variable width and calc-alkaline affinity crosscut all other rock types. Petrophysical tests and geochemistry analysis proved that the geophysical anomaly is attributed to the presence of mafic-ultramafic rocks related to the prominent outcropping intrusions of the Tornio-Näränkäväära belt. Additionally, the granites exhibit an A-type geochemical signature and possess compositional characteristics that strongly suggest they are the result of AFC processes involving the mafic melts and the Archean crust. The relatively large volume of coeval 2.44 Ga granitoids further emphasizes the bimodal character of the early rifting events within the Archean crust in the Koillismaa area. Proterozoic granitoids are not observable from outcrops in the vicinity of the drilling site, although known from other parts of the region. Pre-drilling seismic survey and AMT soundings also indicated the presence of reflectivity and conductivity anomalies that can be associated with the mafic-ultramafic intrusions. New seismic data acquired in 2022 provided further 3D constraints on the shape of the intrusion, which was also able to image the cross-cutting dikes. Furthermore, the drillhole is intercepted by multiple strike-slip faults and zones of prophyllitic alteration resulting in high porosity and permeability in the granitic rocks, opening new perspectives for deep geothermal energy exploration. Some of these features were imaged by the walk-away multi-azimuth VSP survey acquired with the Distributed Acoustic Sensing (DAS) technology.

Future research

The Koillismaa Deep Hole has already yielded valuable insights into the formation and evolution of the Archean-Proterozoic Fennoscandian crust. Currently, the drillhole is evolving into an exceptional testbed for various geophysical and geological exploration techniques employed in numerous projects conducted by GTK and its partners. Complete 50 mm diameter cores are available for the entire length of the drillhole. Presently, the drillhole is open to a depth of 1150 m and thus can be accessed for future scientific investigations.