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Unravelling internal structures of an alkaline and carbonatite igneous complex by 3D modelling of gravity and magnetic data

Magnus Andersson and Alireza Malehmir
Dept. of Earth Sciences, Uppsala University, Uppsala, Sweden (magnus.andersson@geo.uu.se; alireza.malehmir@geo.uu.se)

Alnö igneous complex in central Sweden is among the few rare and largest alkaline and carbonatite ring-shaped intrusions in the world. Recent high-resolution reflection seismic profiles (Andersson et al., 2013) suggest a saucer-shaped magma chamber at about 3 km depth. Study of anisotropy of magnetic susceptibility (AMS) from a number of carbonatite dykes in the complex suggests a combination of laminar magma flow and sheet closure in the waning stage of magma transport for their emplacement (Andersson et al., 2015).

Since 2010 and in conjunction with the above-mentioned studies, more than 400 gravity data points have been measured on land and partly on sea-ice. In addition, the Geological Survey of Sweden (SGU) provided about 100 data points. Petrophysical measurements including density and bulk magnetic susceptibility were carried out for more than 250 rock samples; magnetic remanence was measured on 39 of those samples. The measurements for example indicate that induced magnetisation is dominant in the complex and only a few rock samples show high remanent magnetisation ($Q \geq 1$). SGU also provided airborne magnetic data (60 m flight altitude and 200 m flight line spacing) covering the complex on land and areas around it in the sea. These data show the complex as (i) a strong positive Bouguer anomaly, around 20 mGal, one of the strongest gravity gradients observed in Sweden, and (ii) a strong positive magnetic anomaly, around 2400 nT, additionally showing clear magnetic structures within the complex and adjacent to it in the sea.

3D inversion of the gravity and magnetic data was then performed using 100 m by 100 m meshes in the lateral direction and vertically varying meshes starting from 10 m at surface and increasing to 100 m in the depth interval 4250 – 8250 m. The inversion models cover an area of 17 km by 18 km. Regional fields were removed using a first-order polynomial surface for the gravity data and a constant (IGRF) for the magnetic data. Background density and susceptibility was set to 2.67 g/cm^3 and zero, respectively, for the inversion.

While potential field data do not inherently contain depth resolution and suffer from model ambiguity, among several inversion models, we chose the models that can plausibly explain the reflection seismic data and are consistent with the petrophysical observations. Both gravity and magnetic inversion models suggest dense ($>$ 2.85 g/cm^3) and magnetic ($>$ 0.05 SI) rocks extending down to about 3.5 – 4 km depths. The models suggest that two apparently separate regions within the intrusion with gravity and magnetic highs are likely connected at depth starting from 800 – 1000 m likely implying a common source for the rocks observed in these two regions. The modelling suggests that the inner part of a $>$ 3 km wide ring-shaped magnetic anomaly observed adjacent to the main intrusion in the sea extends with low-magnetic materials down to about 1.5 km depth at where magnetic materials from the rim appear to extend laterally in towards the centre and connect to the main intrusion on land.

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