# Regional magnetotelluric and potential field data analyses related to mineral exploration of the Fennoscandian Shield, Sweden

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## SUMMARY

Broadband magnetotelluric data were recorded at 104 sites between 2015-2018 in northern Sweden to image the geoelectrical upper and lower crustal structures. Data processing was performed using a robust multi-remote reference technique. The dimensionality analysis of the phase tensors indicate complex 3D structures in the area.
A 3D crustal model of the electrical conductivity structure was derived based on 3D inversion of the data. Processing of regional potential field data was performed and structural information derived from these data were compared with the 3D conductivity model.

Locations of known mineralizations are compared to the regional geophysical data in order to investigate how the regional geophysical data can be used for better informed mineral exploration. The analyses indicate that regional geophysical can provide very useful information with respect to the prospectivity of different areas.

**Key words:** Magnetotelluric; 3D inversion; potential fields; mineral exploration; Fennoscandian Shield.

## INTRODUCTION

The Fennoscandian Shield located in Northern Europe hosts economically important mineral deposits including base metals and precious metals. Regional geophysical data in combination with other geoscientific data contain information of importance for an optimized search for mineralization. This study is with a focus on Northern Sweden where Cu-Au mineralization and Iron ores are common. Mineralizations are mainly classified as iron oxide copper-gold (IOCG) and iron oxide-apatite (IOA) located within Paleoproterozoic volcanic-sedimentary sheared meta-supracrustal belts. Basement rocks are Archean granitic, tonalitic and amphibolitic rocks towards north and Paleoproterozic metasupracrustal towards south (Figure 1). Two distinct Paleoproterozoic units cover the study area. The Karelian rocks towards east along the Swedish-Finnish border are mainly composed of metasedimentary and mafic volcanic rocks and cover the Archean basement (Martinsson 1997) and felsic and mafic volcanic rocks, related intrusive and volcano-sedimentary and sedimentary rocks, dominate the Paleoproterozoic Svecofennian rocks towards south.

The geophysical data utilized in this study comprise regional broadband magnetotelluric (MT) data and airborne magnetic and gamma-ray data. Regional gravity data are also included. The MT data originate from previous studies within the MaSca project (Cherevatova et al. 2015) and some new data recorded during 2015-2018. The potential field and gamma-ray data are provided by the Swedish Geological Survey.

This study was initiated based on observations of a possible spatial correlation between deep crustal electrical conductors and mineralizations mapped at the surface in Northern Sweden. A similar correlation has been reported from studies in Australia (Heinson et al. 2006). Processing of the potential data was used to investigate further the link between regional scale crustal structures and mineralizations.

## DATA AND METHODOLOGY

A total of 104 broadband MT stations added to the existing database of MT stations in Scandinavia (Figure 1). The average site spacing is 5-10 km and data were recorded in the period range 0.003-1000s. Time series of two electric components ($E_X$ and $E_Y$) and three magnetic components ($H_X$, $H_Y$ and $H_Z$) were measured. MT impedance tensors and magnetic transfer tipper functions were estimated using a remote reference technique and by using a robust statistical processing algorithm developed by Smirnov (2003).

The MT data were analysed by calculating impedance tensor parameters like skew (β) values and phase tensor (Caldwell et al. 2004). The data quality is good except some sites which were discarded for further investigations. The apparent resistivity curves of most sites indicate a resistive upper crust (around 10000 Ωm) and conductive structures indicated at larger depth. High skew values indicated complex 3D structures and 3D data inversion was performed.

The ModEM inversion program (Egbert and Kelbert 2012) was used to determine the 3D electrical conductivity structure of the subsurface. The full MT impedance tensor in the period range of 0.003-1000s and tipper data (0.01 s to 1000 s) were inverted with four periods per decades. A relative error floor of 5% calculated from the absolute value of the off-diagonal element was used for each row in the tensor. An absolute error value of 0.05 was used for the tipper data. The model space was discretised horizontally with 2 km mesh size within the central part of the area. Vertical discretisation was done with 50 m at the surface and with increased mesh size depth wise based on an expansion factor of 1.2. A 1000 Ωm homogeneous half space was used as a priori model. The smoothing value was set to 0.5 in horizontal and 0.3 in vertical directions after performing several tests. Root mean square misfit value of 1.8 were obtained.

Gradient tensor data were calculated for the potential field data by using the method of Pedersen and Rasmussen (1990). The main purpose of these calculations is to be able to visually emphasize structures of major shear zones expected to partly control the location of mineralizations.

Data integration and interpretations are mainly performed by visual correlation between various data sets and location of mineralizations.

## RESULTS

Figure 2 shows the vertically integrated conductivity between 0 to 15 km depth and between 15 to 40 km depth for the derived 3D conductivity model. An average lower crustal conductance value of roughly 1000 S is observed. Some areas are characterized by lower crustal conductance values of roughly 30000 S. The Wiese arrows at a period of 256 s indicate presence of highly conductive structures towards west outside the area covered with MT stations.

The shear zones marked in Figure 1 are partly identified by analysis of the airborne magnetic data and partly by geological field mapping. Comparison between the conductance maps in Figure 2 and the location of the shear zones do not show a simple correlation. The Nautanen DZ shows coincidence for a short section with one of the highly conductive lower crustal structures. The two other highly conductive zones in Figure 2 do not show coincidence with the mapped shear zones.

The horizontal gradient of the estimated east magnetic component in Figure 3 delineates a number of shear zones and is useful for defining domains characterized by specific and consistent patterns of the anomalies. The locations of mineralizations correlate well with locations of shear zones and boundaries between magnetic domains. An example of the latter is the WNW-ESE trending zone with highly variable magnetic gradients that intersects the north-western corner of red polygon in Figure 3. The zone separates two areas with more gentle variations of the gradient field. The lower crust south of the zone is in general more conductive compared to the area north of the zone. A few conductive structures are modelled along this zone.

Areas with known mineralizations are in general associated with medium to high values of the conductance in both the upper and lower crust.

## CONCLUSIONS

Regional geophysical data provide valuable information about crustal structures that appear to be correlated with the locations of mineralizations. The electrical conductivity distribution with the region is highly complex and correlation with the location of the major shear zones is only observed partly.

## ACKNOWLEDGMENTS

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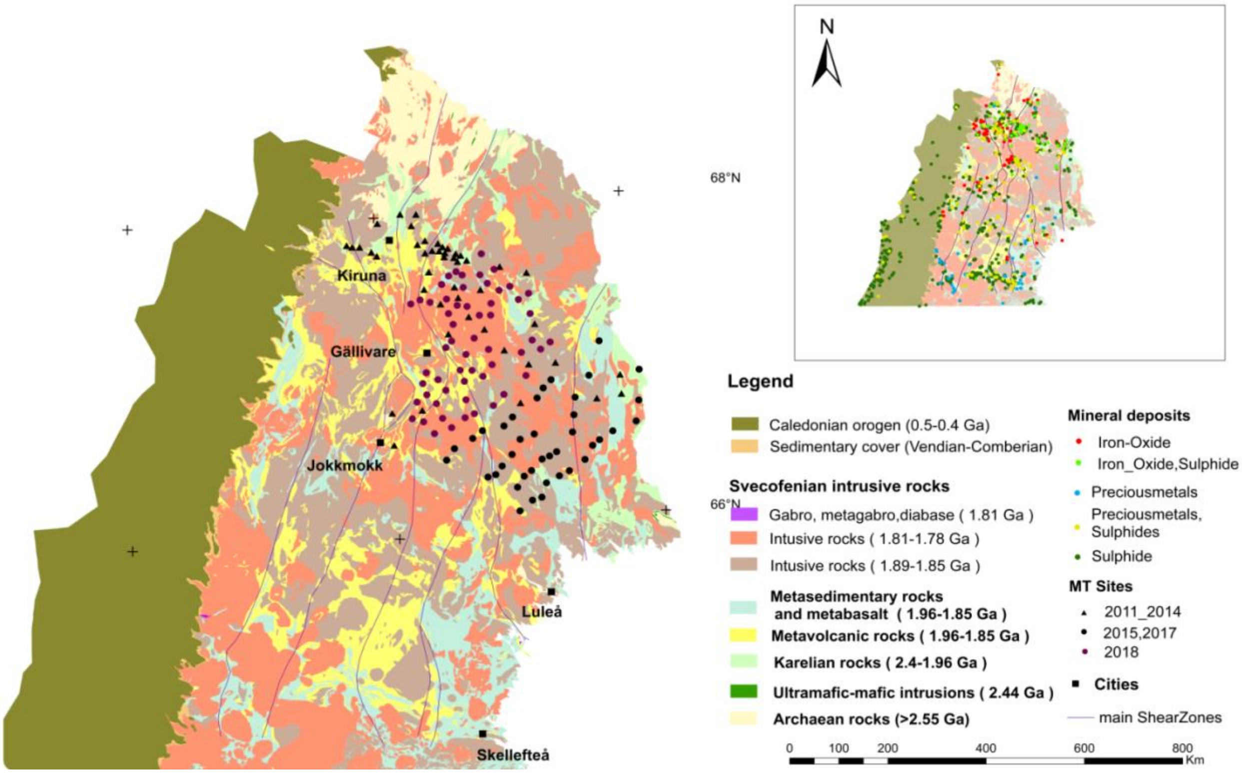


**Figure 1. Regional Geological map of the study area in northern Sweden modified from Bergman et al. (2001). Solid lines trending roughly north-south delineate major deformation zones (DZ) in the area. KNDZ: Kiruna-Naimakka DZ, KADZ: Karesuando-Arjeplog DZ, NDZ: Nautanen DZ, PDZ: Pajala DZ. Insert map shows locations of known mineralizations.**

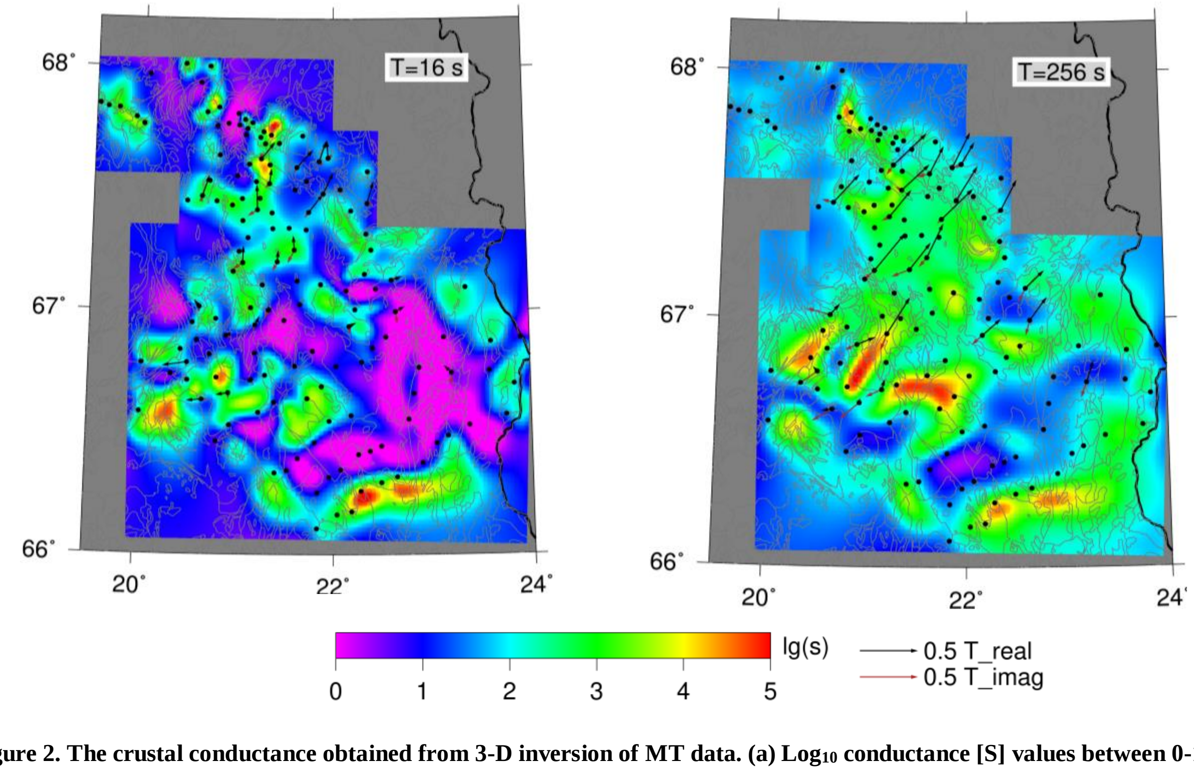


**Figure 2. The crustal conductance obtained from 3-D inversion of MT data. (a) $Log_{10}$ conductance [S] values between 0-15 km depth and (b) conductance between 15-40 km. Site locations are marked with black circles. The surface geological boundaries are indicated in grey line. Black and red vectors: measured real and imaginary Wiese tipper vectors respectively for a period 16 s on the left image and a period of 256 s on the right image.**

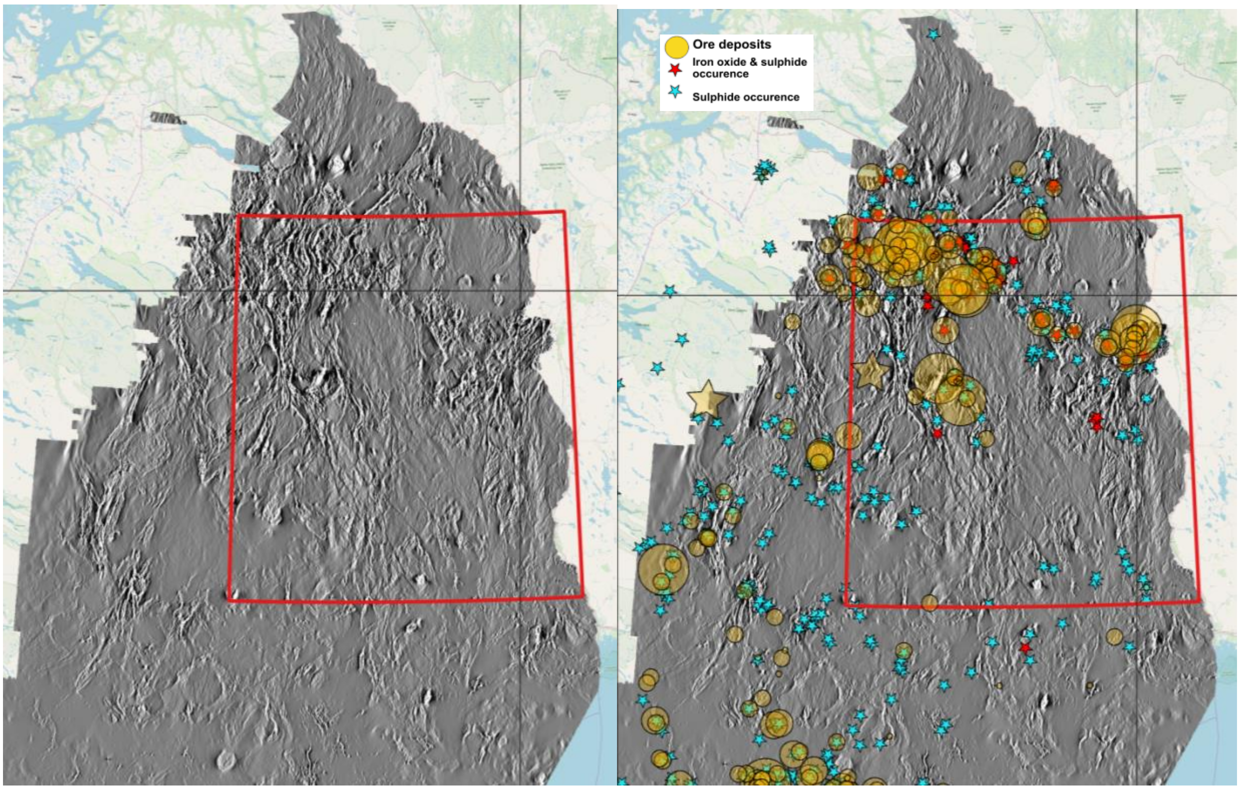


**Figure 3. Grayscale images of horizontal gradient of estimated east magnetic component calculated from airborne total magnetic field data. A linear grayscale from -0.5 to +0.5 nT/m is used. black shade shows high values. Locations of mineralizations are shown by coloured symbols on the right image. The area for the conductance map in Figure 2 is shown with the red polygon.**