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Integrated MagnetoTelluric and Seismic Reflection study: Skellefte Ore District, northern Sweden.

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Introduction

The Skellefte District is a very rich mining area in northern Sweden. The main deposits consist of volcanic-hosted massive sulphides (VHMS) rich in zinc, copper, lead, gold and silver. Since the area has been mined and explored for over a century, today's challenge is to locate deeper deposits. The VINNOVA 4D modeling project aims to address this challenge by understanding the regional setting of the district and its evolution over time.

It is in the framework of this project that new geophysical and geological data have been acquired in the western part of the district. Figure 1 shows the seismic reflection lines and the locations of the MagnetoTelluric (MT) stations.

In this study we will focus on the outcomes from the northern profile (inside the rectangle in Figure 1). It is a continuation of a previous study in the Kristineberg area (Tryggvason et al. 2006, Malehmir et al. 2009, Hübert et al. 2009) towards the mineralizations in Adak. The main objectives of the study are the thickness of the Revsund granites and the structures below them.

The main geological units in the Skellefte District are the ore bearing rhyolitic volcanic rocks of the Skellefte Group; early granitoid intrusions coeval with the Skellefte Group that are considered as a possible heat source for hydrothermal fluids; sedimentary rocks of the Vargfors Group; felsic to intermediate volcanic rocks and late granitoid intrusions known as the Revsund granites. All these units are metamorphosed to greenschist and lower amphibolite facies.

Data acquisition

Figure 2 shows the location of the 17 broadband MT stations installed along the seismic reflection profile. Some of the stations were off the profile to avoid noise sources (e.g. power lines). All five (Ex, Ey, Hx, Hy, Hz) MT channels were recorded for all sites. The periods of the obtained transfer functions are between 0.002 and 200 s.

The extent of the seismic reflection survey is shown in Figure 2 and the general acquisition parameters are listed in Table 1. For logistical reasons the acquisition line is crooked.

Figure 1. Geological map of the western part of the Skellefte District showing recently acquired geophysical data.

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Figure 2. MT stations (diamonds) and seismic reflection acquisition line. The receiver locations are in red with the shot points in yellow on top. The CDP line is shown in blue with CDP numbers indicated to the right.

Table 1. Seismic reflection acquisition parameters.

Recording system	SERCEL 408
Source type	VIBSIST
Shot spacing	25 m (with gaps)
Receiver spacing	25 m
Active channels	240-300
Number of sweeps	2-4
Sampling rate	1 ms
Geophones	Single (28 Hz)
Total length	27 km

MT processing and inversion

The quality of the MT data is remarkably good with very smooth transfer functions. The induction arrows show two distinctive directions depending on period. For shallow structures they point -30° from the north, and 30° for deeper ones. Given that a single strike direction cannot be determined, only the determinant of the data was inverted as it is less affected by 3D effects (Pedersen and Engels, 2005). The used algorithm was REBOCC (Siripunvaraporn et al. 2000) with error floors of 90% on apparent resistivities and 2.8° on phases. The data fit of the resulting model (shown in Figure 3) is within the errors (RMS of 0.95). As expected, the resulting model shows very resistive features coming to the surface (most likely due to the Revsund granites) and a strong conductor at depth, as it has been observed in all other MT studies in the region (Rasmussen et al. 1987, Hübner et al. 2009).

MT interpretation

In the inversion model there are two main features: the resistors in the shallow part and the deep conductor. The deep conductor has also been found in the MT studies carried out in the Kristineberg area to the south (Hübner et al. 2009), where the deep conductor dips to the North, beginning at 3-4 km depth for the southernmost point, and continuing below 12 km depth where it intersects with our current profile. This agrees nicely with the model presented in Figure 3.

Regarding the resistors, they most likely correspond to the postorogenic Revsund granites. They seem to extend down to 3 – 4 km depth, except below sites 7 and 8 where high resistivities extend down to 7 km. Between the resistors there are structures with intermediate resistivity, attributable to mafic volcanic rocks. Another area with intermediate resistivity is below the resistor between sites 11 and 15, perhaps indicating the presence of more volcanic rocks below the intrusions.

Seismic reflection processing

The main processing steps applied to the data include picking of first arrivals, trace editing, refraction statics, band pass filtering, spectral balancing, velocity analysis and NMO corrections. The CDP gathers were arranged in a straight line with 30° azimuth (Figure 2). Figure 4 shows the resulting stack, where it is possible to identify some reflections.

Seismic interpretation

Figure 4 shows the seismic section with the resistivity model as background. There are regions where both data

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sets correlate and also where they contrast to one another. For example, the base of the resistor to the southwest coincides with *b* or part of *a*. Reflectors *d* and *e* seem to bound the upper part of the dome-like zone of intermediate resistivity below the resistors between sites 11 and 15. In contrast, reflectors *a* and *d* seem to be minor structures in the resistivity model.

Conclusions

A stable 2D inversion model of the MT determinant data was obtained. Its most prominent features can be correlated with previous studies in the area and several reflections from the stacked seismic section. The deep conductor is found at 12 km depth and resistors show good correlation with the location of the Revsund granites. Overall, shallow resistivity structures show a good agreement with the surface geology. Nevertheless, as shown by the induction arrows the data set is not completely 2D and the obtained model may contain spurious or off-profile features. Therefore, a proper assessment of the resolution properties of the model is necessary.

Even though more work is required to fully exploit the two studied data sets, it is already possible to show the power of combining two independent methods to unravel subsurface structures. We believe that the combination of several methods and the interactive update of results is the key to success in the search for a common geological model.

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Figure 3. Inversion model for MT data.

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Figure 4. Seismic reflection stacked section with the upper part of the MT inversion model from Figure 3 as background. Note that the color scale is different from Figure 3.

EDITED REFERENCES

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