Reflection seismic imaging in the Skellefte ore district, northern Sweden

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Abstract. The Skellefte ore district is one of the major mining districts in Sweden and is well known for its volcanogenic massive sulphide and gold deposits. Mineral exploration in the area is important and has been the reason to conduct various studies e.g., reflection seismic surveys, detailed field geological mapping, magnetotelluric measurements, and potential field modeling with the aim of understanding the relationship between the ore bearing volcanic and volcanosedimentary formations and their surrounding intrusive rocks. Following a pilot project in the western part of the area, the Kristineberg mining area, a 3D/4D-modeling of mineral belts project was launched to improve the initial 3D model in the area and to provide more information in the shallow parts, but also to develop the model in the central parts of the district. Results from seismic reflection data were used as a backbone of the 3D geological modelling in the district and helped us to obtain a better understanding of the overall structures and their relationship with major mineralization zones.

Keywords. Skellefte district, 3D modelling, reflection seismic

1 Introduction

The Skellefte mining district covers an area of 120 by 30 km in northern Sweden (Figure 1) and is one of the most important mining districts in the country, producing Zn, Cu, Pb, As and Au from volcanogenic massive sulphide and orogenic gold deposits (Allen et al. 1996; Kathol and Weihed 2005). Today, mineral exploration in the district is aimed at locating deposits at deeper levels e.g., down to 2000 m. To be successful in exploration, a better understanding of geological structures and the evolution of the area is necessary. Since 2003, the area has been the subject of several geological and geophysical studies with the aim of understanding the contact relationships between the ore bearing volcanic and volcanosedimentary formations and the surrounding intrusive rocks (Tryggvason et al. 2006; Malehmir et al. 2006, 2007, 2009a, 2009b; Hübert et al. 2009, 2013; Skyttä et al. 2009, 2010, 2011, 2012; Dehghannejad et al. 2010, 2012a, 2012b; Bauer et al. 2011, 2012; Ehsan et al. 2012; Garcia et al. 2013).

Reflection seismic methods have proven to be effective together with other geophysics in imaging structures and lithological contacts in the western part of the area, the Kristineberg mining area (Tryggvason et al. 2006; Malehmir et al. 2007, 2009a, 2009b). Based on the earlier investigations, a 3D/4D-modeling project was launched in 2008. The project aims at understanding both the structure of the Earth’s crust down to a few kilometers depth, and the relationship between the structure and the mineral deposits occurring in the area (Dehghannejad et al. 2010, 2012a, 2012b; Bauer et al. 2011, 2012; Ehsan et al. 2012; Skyttä et al. 2012).

Therefore, more than 100 km of new reflection seismic data with varying resolution and research objectives were acquired in the western and central parts of the district during 2008-2010. Geological observations (Skyttä et al. 2010 and 2011), magnetotelluric data (Hübert et al. 2013; Garcia et al. 2013), as well as potential field and deep IP measurements (Tavakoli et al. 2012a, 2012b), accompanied the reflection seismic data to facilitate their interpretations. Integration of these data with mine observations allowed an improved geologic model of the Kristineberg mining area and the construction of a 3D geologic model of the central Skellefte district. Here we present results from the reflection seismic study, which was used as a backbone of the model for the area.

2 Results from the seismic reflection data

2.1 Kristineberg mining area

Since 2003, four reflection seismic profiles with a total length of approximately 70 km have been acquired in the Kristineberg mining area (Figure 1). First, Profiles 1 and 5 were acquired with the aim of providing information about major geological structures down to 12 km in the crust (Tryggvason et al. 2006; Ehsan et al. 2012). Later, Profile 2 and the HR profile were acquired with the aim of providing higher resolution images of near-surface geological structures near the Kristineberg mine (Dehghannejad et al. 2010). Dynamite as a source was used for Profiles 1 and 5 and an impact source (Cosma and Enescu 2001) was used for Profile 2 and the HR (a higher resolution profile than Profile 2) profile to
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generate the seismic signal. Data processing was carried out following a series of conventional processing steps used in the hard rock environment (for details about processing steps see Tryggvason et al. 2006 and Dehghannejad et al. 2010).

The quality of the data is good and we could image clear reflections, some of which reach the surface and allow correlation with surface geology and recent field geological mapping. Some of the reflections correlate well with known location of faults or high-strain zones and some appear to occur within a zone where the Kristineberg ore bodies are situated. Although, it is not clear if these reflections are generated from mineralization zones, a reflective package extending down to about 2.25 km can be suitable target for future deep exploration in the area. Numerical modelling results recently carried out using available geological and petrophysical knowledge support that some of the reflections could be generated from massive sulphide bodies (Dehghannejad et al. 2012b). Nevertheless, a 3D seismic survey is required to accurately locate these reflections and provide targets for drilling.

Figure 2 shows 3D views from the acquired seismic profiles (i.e., Profiles 1, 2 and HR) and the correlation of seismic events from one profile to another and also the relationship with ore horizons in the area. It also shows a 3D visualization of the seismic reflections interpreted along the HR profile, the most important geological surfaces, and the ore lenses of the Kristineberg deposit. Structurally, the reflective zones (Figure 2b) are cut by steeply south-dipping high-strain zones which locally steepen the dip of reflections. Similar to the reflective zones, the ore lenses have also been affected by deformation along the high-strain zones.

2.2 Central Skellefte district

During 2009-2010, three sub-parallel, ~ N-S trending reflection seismic profiles were acquired (Profiles C1, C2 and C3, Figure 1) to constrain a 3D geological model of the central Skellefte district (Dehghannejad et al. 2012a). Each profile is about 30 km long and approximately 3 to 7 km apart from each other. The profiles were placed perpendicular to the main structural trend of the district. To compare the results, we used the same recording system as we used in the Kristineberg mining area in 2008.

These seismic profiles resulted in imaging several steeply dipping reflections, many of which correlate with surface geological observations. The majority of the reflections that extend to the surface were correlated with geological features either observed in the field or interpreted from the aeromagnetic map of the study area. Main reflections correlate well with major faults and shear-zones and/or represent lithological contacts.
3 Conclusions

The new seismic results in the Kristineberg area confirmed some of the previous interpretations, but also provided additional and local-scale constraints on the subsurface geology. High-resolution data along the HR profile proved to be successful in imaging potentially reflections associated with mineralization zones, although this needs further support. Results from the three new seismic profiles in the central Skellefte district show a relatively different seismic character compared with those of the Kristineberg mining area, but also have helped us to understand the geological structures and significance of major shear zones in the creation of the sedimentary basins in the central Skellefte district.

Acknowledgements

We thank VINNOVA and Boliden Mineral AB for funding the project. We also thank Luleå University of Technology and the Boliden Group for their collaboration and contribution. Modeling and figure preparation benefited from using GoCad™ from Paradigm.

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