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Reflection Seismic Characterization of the Grängesberg Iron Deposit and Its Mining-induced Structures, Central Sweden

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SUMMARY

Reflection seismic investigation has been conducted on the Grängesberg apatite iron deposit. At the time of closure in 1989, the mine was operated at about 650 m below the surface. Mining activities might be resumed in the next years, which require better understanding of (1) the ore geometry and (2) the fault network which has developed up to the surface from excavated zones at depth. Two E-W oriented reflection lines with a total length of 3.5 km were acquired. The seismic lines intersect the Grängesberg ore body and open pit, as well as several of the mining-induced faults. A weight drop mounted on an hydraulic bobcat truck was used as a seismic source; both cabled and wireless receivers were used for the data recording. Preprocessing of the data first required the cable- and wireless- recorded datasets to be merged before stacking all data available at each shot point. The dataset exhibits several shallow reflections which are likely to occur on steep lithologic or tectonic structures. Other deeper reflections are recorded; careful processing will be carried out in order to preserve such events in final stacked sections and help with refining the geological model of the area.

Introduction

A reflection seismic investigation has been conducted on the Grängesberg apatite iron deposit where over 150 Mt of iron ore were produced until the mine closed in 1989. At the time of closure, the mine was operated at about 650 m below the surface. Both natural and mine induced fracture and fault systems are today water-filled (some of them extending to the surface). The disputed ore genesis of the apatite-iron ores and its exploration potential due to large remaining quantities of iron and REE (estimated to 180 Mt) once again attracts both scientific and commercial interests. A good understanding of the geometry of mineral deposits and their hostrock structures at depth is essential for optimizing their exploration and exploitation. In addition, deep understanding of the fracture system is vital if mining activity is resumed, as these may impact the terrain stability and seismicity, which may put at risk newer populated and industrial areas.

Seismic data acquisition

To address some of these challenging issues related to the past mining and also to obtain information about the depth continuation of the existing deposit, two E-W oriented reflection lines with a total length of 3.5 km were acquired in May 2013 by Uppsala University (Fig. 1). The seismic lines intersect at high angle the Grängesberg ore body and open pit, as well as several of the mining-induced structures. A weight drop mounted on an hydraulic bobcat truck (traditionally used for concrete breaking in the demolition sector) was used to generate the seismic signal. As no synchronization of the source-recorder system was available, several 20 s records were acquired at each shot point, each of them containing up to 4 impacts. A combination of cabled and wireless receivers placed at every 10 m was used for data recording. Use of wireless receivers was necessary as deploying cabled sensors was not possible due to city infrastructures, houses and busy roads.

Figure 1 Location of the two reflection seismic profiles in the Grängesberg area, superimposed onto aerial image from Lantmäteriet (to the left) and geological map (to the right). Blue: iron ore; yellow: metavolcanic host rocks. Modified after Persson Nilsson et al., [2013]).

As illustrated in Figure 1, several field-related issues such as (1) the crooked geometry of the lines (due to the available path and road network), (2) electric and vibration noise due to populated areas, traffic and a rock crusher working close to the line, (3) significant static variations (due to the variable nature of the terrain: forest, roads, open pit filled with 10s of meters of unconsolidated materials), make this dataset similar to an urban dataset.

Preprocessing and raw data analysis

Preprocessing of the data first required the cable- and wireless- recorded sub-datasets to be merged using GPS time stamps (nanoseconds accuracy) registered in the active data. In order to increase the signal-to-noise ratio, vertical shift and stack was carried out to stack all data available at each shot

point. This was done manually due to the great variability of the signal both on the auxiliary geophone and the geophones closest to the source, even after filtering.

Shot gathers exhibit a moderate to high noise level (Fig. 2). The arrival times of the first breaks show dramatic variation with offset; this correlates well with major features observed from the surface, such as the open pit of the mine filled with poorly consolidated material (Fig. 2a). Other seismic arrivals are identified after the first arrival. Their consistency over a few close shot gathers, as well as their arrival time as a function of offset, strongly suggest that they are reflections. Some of them emanate from the first arrival (Fig. 2a) and some others, arriving at much later times and with no obvious connection to the first arrivals (Fig. 2b), are interpreted as deeper reflections.

Figure 2 Shot gather examples from the southern line. a) Significant static variations due to the open pit filled with low velocity material (ellipse), and shallow reflections emanating from the first arrival (arrows). b) Deeper reflection in the vicinity of the open pit (arrow). Data are shown after applying a bandpass filter (20-30-150-170 Hz) and AGC (100 ms window)).

Conclusions

Despite a high level of noise and significant static variations, shot gathers occasionally exhibit reflections occurring at various depth levels. Comparison of the location of these reflections seen on shot gathers with a fault map at the surface will help interpreting the origin of the reflections. It is anticipated that stacked sections obtained after a careful processing, involving especially appropriate static corrections and velocity analysis, would help refining the geological model of the area.

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References

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