WS5-P05

Volumetric Interpretation of 3D Seismic Data from the Hillside IOCG Deposit in South Australia

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SUMMARY

A 3D high-resolution reflection seismic data were acquired to investigate its utilisation for exploration of typically excessively complex IOCG deposits in Hillside, South Australia. Full 3D pre-stack imaging produced results where seismic character well resembled different rock types. Further assessment of the value provided by seismic data required borehole calibration. Unfortunately only core samples were available. These information were enriched by utilising a specific gravity voxel that was extracted from the Rex supplied database. Core sample tests (velocity) and specific gravity information were utilised during the process of volumetric interpretation. We show that faults extracted from variance attribute correlate with the faults extracted using guided-tracking method. However, petrophysical data shows that the boundaries between gabbro and metasediments may not generate acoustic impedance contrast to be clearly detected by seismic reflection method. The tops to the main rock formations however are mappable in depth slices and agree very well with magnetic data. Further work involves correlation of seismic interpretation with the geological cross sections and lithological logs collected from the site.

Introduction

Geological field mapping, gravity & magnetic methods, and drilling are the methods the mining industry has been using to explore new mineral deposits, but with new discoveries of large near-surface deposits becoming increasingly rare and the known reserves of most economic minerals in decline, it is clear that new deep exploration techniques are obligatory to meet future needs (Salisbury and Snyder 2007).

High resolution seismic reflection method depicts images of the subsurface geologic structures and sometimes can successfully delineate ore bodies at depths more than a kilometre (Malehmir et al. 2012, Salisbury and Snyder 2007). In some special cases, seismic method can directly target structures at depth of 3 km, the current maximum depth of mining (Malehmir et al. 2012, Salisbury and Snyder 2007).

A number of journal articles have been published demonstrating successful application of seismic method in hard rock environment (Eaton and Salisbury 2003). Noponen et al. (1979) discussed the possibilities for observing reflections from discontinuities within crystalline rocks for drilling and mine-working and concluded that the impedance contrast of most mafic rocks and high-density ores against felsic rocks are sufficient for the generation of observable reflections. In Australia, particularly in Western Australia a lot of work has been done. A considerable number of 3D seismic surveys have been conducted in the Kambalda region of Western Australia (Malehmir et al. 2012). Several 3D surveys were conducted for nickel exploration in the Kambalda region with great success (Malehmir et al. 2012, Urosevic et al. 2012). In 2003, two orthogonal deep seismic lines, centred on the Olympic Dam deposit of the Stuart Shelf geological province in the north of South Australia were recorded (Goleby et al. 2005). In 2012, Curtin University of Technology conducted a 3D high-resolution seismic survey at Rex Minerals' Cu-Au mining project at Hillside, South Australia.

Research Methodology

In general, conventional interpretation methods produce maps while volume visualisation methods produce 3D perspectives (Kidd 1999). In seismic volumetric interpretation the interpreter directly evaluates the seismic reflectivity of the subsurface media in three-dimensional space by applying various levels of transparency filters to the data (Kidd 1999). This enables a range of predominant attribute values to be subdued or entirely switched off, giving the viewer the ability to see through an entire volume (De Pledge 2000).

The interpretation based on 2D imaging is significantly different from interpretation based on 3D imaging. The traditional approach to looking inside a data volume is to slice the volume in the x-z or y-z planes to create inline and cross-line sections (Yilmaz 1987). Time slices are created by slicing the volume horizontally. The individual slices can be interpreted using 2-D techniques but clearly valuable information gets lost when we do this since we cannot see data coherency along the axis normal to the slice plane (Wolfe and Liu 1988).

The Hillside copper-gold deposit is located on the east coast of Yorke Peninsula, about 15 km south of Ardrossan, ~70 km northwest of Adelaide, South Australia. The deposit is hosted within Paleo-to-Mesoproterozoic rocks of the Olympic IOCG province that extends along the eastern margin of the Gawler Craton (Goleby et al. 2005). In 2012, Curtin University conducted a 3D high-resolution seismic data acquisition survey at Rex Minerals' Copper-Gold mining project at Hillside. The seismic cube covers 0.44 km² area (1375m×320m). In 2013, a couple of trips to the core repository at Hillside were organised to measure petrophysical properties (e.g. P and S wave velocities, specific gravity, magnetic susceptibility) of the drilled core samples. In addition, a specific gravity voxel equal to the seismic cube was extracted from the Rex supplied pointsets specific gravity database. Recently introduced seismic volumetric interpretation approach has been taken to interpret the datasets.

The objective of this seismic survey was to investigate the usability of 3D high-resolution seismic reflection technique for exploration of IOCG type deposits.

Specific Gravity Data Analysis

A database containing specific gravity values was supplied by Rex Minerals Hillside Project to use in seismic interpretation.

A specific gravity voxel equal to the area of seismic cube was extracted from the supplied pointsets database. The specific gravity value of this extracted voxel ranges from 2.5 to 3.71 with a standard deviation 0.133 and mean value 2.76.

The voxel shows north-south trends in specific gravity distribution bordered by the faults extracted from the seismic data. The high specific gravity values are confined mostly in the central portion of the cube (Figure 1).

Figure 1 Specific gravity voxel (low and high values are clipped) draped over seismic depth slice at 500m depth from surface; grey vertical/near-vertical surfaces represent faults extracted from seismic data using guided tracking method.

Petrophysical Data Analysis

A couple of trips to the core repository at Hillside were organised on 29 July – 2 August 2013 and 4 November – 8 November 2013 to measure petrophysical properties (e.g. P and S-wave velocities, specific gravity, magnetic susceptibility) of the drilled core samples. Figure 2 shows the petrophysical properties measured from core samples from Well HDD-064.

Figure 2 Types of petrophysical properties (P & S – wave velocities, specific gravity, and magnetic susceptibility) measured from drilled core samples in Hillside (HDD-064).

On the first trip, 202 samples from 13 drill holes were analysed and 182 samples produced P and S-wave velocity data and on the second trip 289 P and S wave velocities were acquired from 303 samples measured. The scattered distributions of Specific gravity vs. P-wave velocity and P vs. S-wave velocity are shown in figure 3.

Figure 3 Scatter plot of Specific Gravity vs. P-wave velocity data (left) and P-wave vs. S-wave velocity data (right) measured from the core samples from Hillside Cu-Au Mining Project.

Seismic Volumetric Interpretation

Both structural and attribute-based interpretation approaches have been used to interpret the seismic cube. Semblance, dip, continuity, similarity, variance, RMS amplitude etc. attributes were computed to enhance lateral discontinuity to identify faults. A Geological model has been constructed based on the geological cross-sections from Rex annual reports on Hillside (Conny Kitzig, pers. Comm.). Points on faults were extracted using Goscope plugin in Paradigm GOCAD 2011.2. Fault points were extracted using guided-tracking method with a correlation window length of 20 and sliding window length of 10. Suitable pointsets were then joined together to form fault surfaces.

First horizon (base of the top cover) were extracted using 70% seed confidence and the interpolation was validated over an expansion of 3x3 volume (Figure 4).

Figure 4 Geological model shows subsurface geology of Hillside and the corresponding seismic cube shows dip variance and high specific gravity areas (top left). Geological model of Hillside and its corresponding seismic cube with extracted faults and high specific gravity zones (top right). Top horizon (base of the top cover) shows reflection from the top of gabbro zone (bottom left), and edges extracted using Ant tracking method (bottom right).

Conclusions

Specific gravity values measured from the drilled core samples and extracted voxel from the supplied database suggest that the average density of gabbro, granite, and metasediments are significantly different from each other. However, gabbro overlaps with metasediments between 2.7 and 3 suggesting that in many areas of the cube the layers may not generate enough acoustic impedance contrast at the boundaries to be detected by seismic reflection. Faults/edges extracted using Ant tracking method correlate with the faults extracted using guided-tracking method. Geological cross-sections and lithological logs were collected from Rex Minerals and will be used to correlate seismic interpretation.

Acknowledgements

This work has been supported by the Deep Exploration Technologies Cooperative Research Centre whose activities are funded by the Australian Government's Cooperative Research Centre Programme. This is DET CRC Document 2014/375. I would also like to thank Rex Minerals Cu–Au Mining Project at Hillside, South Australia for providing an outstanding support.

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