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Seismic across Different Mineral Deposits - Does It Work?

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SUMMARY

Many years of application of seismic for mineral exploration in Western Australia provided very rich data base which is used to test and optimise data processing and analysis. High signal to noise ratio enabled investigation into the performance of partial and full pre-stack imaging techniques. On the other end of the scale, very complex geologies and poor seismic response inspired the use of novel technologies and also concurrent use different geophysical techniques. Various case histories are presented and discussed.

Introduction

The performance of seismic for exploration of mineral resources appears to be still inconsistent which prevents it from becoming the primary exploration method in the mineral sector, similar to its role in oil exploration. Excessively complex geology, strong ambient noise, access restriction, weak reflectivity, high scattering are typically encountered in the application of seismic for mineral exploration. Two other factors are: a) high cost and b) lack of correlation of seismic images. The first one translates into great hesitance when it comes to deployment of seismic or even worse, scaled down operations, reduced geometries, compromised parameters, etc. Lack of correlation leads to lack of understanding of seismic images and hence their underutilisation and eventually abandonment. Some less favourable geological settings require much more comprehensive and elaborate analysis to allow seismic method to perform. In general it appears that the lack of understanding of the geological complexity, and our ability to handle and comprehend seismic responses in different geological settings work against the widespread use of this method for mineral exploration. Several examples that range from seismically favourable to poor will be shown that demonstrate that in all cases seismic created new value for mineral exploration. Specialised data processing and calibration are of ultimate importance for proper utilisation of seismic images. Surface and borehole seismic are inseparable.

Seismic response over mineral deposits in WA

Different geological settings have vastly different seismic signatures. In an ultramafic/basalt setting such as found in Kambalda, WA, a prolific gold and nickel producing region, the reflectivity of shear zones, intrusives and massive ore bodies (to a lesser extent) are often nicely expressed. High quality seismic images are often recorded in Kambalda region due to favourable geological and also near surface conditions. Outstanding seismic results were achieved over Kambalda dome (Kalgoorlie region) south in mapping structures that could provide potential hydrothermal paths for mineral precipitation and formation of gold reserves. In number of cases drilling was guided by seismic images, even 2D seismic images, resulting sometimes in new discoveries. One such example is shown in Figure 1, where down dip extension of the gold bearing shear (Victory mine) was seismically mapped and predicted as potential for gold. Despite in general good seismic response the structural complexity in Kambalda area can be such that non-standard data processing and analysis are necessary. In Figure 2, enhancement of steep dips through the application of different partial pre-stack migration methodologies was evaluated. The images produced show differences in signal to noise ratio and structural details. Considering 3D nature of the geology it is useful to analyse them concurrently. For advancing from structural to stratigraphic interpretation or rock characterisation for gold exploration additional information are needed. Core sample tests and logging showed that V_p/V_s ratio may be indicative of gold bearing shear zones (Figure 3).

In a prolific nickel/gold zone over Le Froy salt lake, exceptionally good conditions are found for the application of seismic as far as source/receiver coupling, frequency preservation and depth penetration are considered. Small Vibrators (6000 Lb), free-fall weigh drops and explosive cord of only 40-60g placed in shallow boreholes will enable generation of high frequency, clear seismic images from depths well over 1.5 Km. However ultra-saline nature of the near surface shale that typically have devastating effect on seismic equipment. Several 2D and 3D surveys from this area produced images of exceptional quality enabling detailed structural and after calibration stratigraphic interpretation. An in-line extracted from small 3D survey is shown in Figure 4 where very complex geological bodies can be directly identified from seismic data. Despite the fact that VMS deposits here are quite small, exceptional quality of seismic images enables direct targeting.

Conclusions

Long term application of seismic across WA territory came across diverse mineral deposits. It is now clear that it is always possible to extract valuable information from seismic images. Further advances are viewed through improved imaging, borehole seismology and the use of full wavefield.

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Figure 1 Victory seismic line recorded in 2002, after years of analysis and investigations was used to guide drilling target, eventually resulting in discovery of new gold reserves (Courtesy of Gold Fields).

Figure 2 2D depth migrated sections using: standard DMO (left), Common-reflection surface (CRS) (middle) and Multi focusing (right) techniques. Data courtesy of Gold Fields.

Figure 3 Vp/Vs ratio correlates with magnetic susceptibility.

Figure 4 3D depth migrated sections and underground geology from drilling.