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3D-3C Reflection Seismic Imaging of the Lalor VSM Deposit, Manitoba, Canada

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SUMMARY

A 3D-3C seismic data set was acquired over the Lalor Lake VMS deposit, located near Snow Lake Manitoba, to provide images of the ore zones and host rocks, and to assess the applicability and potential benefits of P-S waves for deep mineral exploration. An analysis of borehole logging data shows that ore zones associated with pyrite and diorite should produce strong reflection on seismic data. Clear reflections are locally observed at the location of shallower ore zones. Alteration and post-metamorphism increased the P-wave velocity and density of felsic volcanic rocks but the impact of this change has not been clearly identified on seismic data. Many prominent and continuous reflections of lithological origin are observed close to the base of the Chisel sequence. P-S results are not discussed here but will be presented at the workshop.

Introduction

As part of the methodology project of the TGI-4 program, the Geological Survey of Canada acquired a multicomponent 3D seismic data set over the Lalor Lake volcanogenic massive sulphide (VMS) deposit, located near Snow Lake, Manitoba, Canada. The Lalor Lake VMS deposit was chosen as a test site as it provided an intact, well-characterized 27 Mt deep ore deposit with a rich catalog of geological and geophysical data, as well as extensive drill-core, and drillhole geophysical and geological logs. The 3C-3D seismic data were acquired to develop and test seismic imaging methods for deep exploration of VMS deposits and in particular, the applicability and potential benefits of mode-converted shear-waves (P-S) for deep exploration. Here, we present a DMO-poststack migrated volume of P-waves observed on the vertical component of receivers. We also describe the acquisition parameters and the main steps used for the processing of the data. P-S results will be shown at the workshop.

Geological Background and Physical Rock Properties

The Lalor Lake VMS deposit was discovered in 2007 by Hudson Bay Mining and Smelting (HBMS). The 27 Mt massive sulphide deposit is located at ~800 m depth with 14.4 Mt of ore reserves grading 6.96% Zn, 0.6% Cu, 1.86 g/t gold and 23.55 g/t silver. The mineralization is found in the lower Chisel sequence near a decollement contact with the overturned hanging wall rocks of the upper Chisel sequence, and is associated with an extensive hydrothermal alteration system. The deposit comprises several mineralized zones that are stacked and embedded in moderately–dipping (between 10^o and 30^o) but highly deformed and altered stratigraphy.

An analysis of physical rock properties was conducted to assess the seismic properties of the ore zones and host rocks and their expected response in the seismic data, including effects of alteration and post-metamorphism. We use logging data acquired in 12 boreholes located close or intersecting the deposit. Results show that diorite and massive sulphides, particularly those with most pyrite content, have higher average acoustic impedances than other lithological units. Logging data and geological description of rock samples were also used to assess the effects of alteration on P-wave velocity and density of some lithological units. We observe increasing P-wave velocity and density for intervals of altered felsic volcanic rocks and argilites.

Data Acquisition and Processing

The 3D survey was conducted during the winter of 2013 over an area of approximately 16 km^2 with the Lalor VMS deposit located approximately in the center of the grid. The survey comprises 15 shot lines with a NW-SE orientation, and 16 receiver lines oriented SW-NE. Shot lines were spaced every 365 m with a source interval of 50 m, whereas receiver lines and receiver spacing were 250 m and 25 m, respectively. A total of 908 shots were fired in 5 m deep holes using a charge size of 0.5 kg and 2685 3-C digital accelerometers (Sercel DSU3) were used. All receivers were active for each shot (i.e., a single recording patch) during the data acquisition. The generally cold temperatures during the acquisition resulted in solidly frozen near-surface conditions which allowed excellent ground-to-geophone coupling.

The processing of the 3D-3C data comprises two parts; one for the conventional processing of P-wave data recorded on the vertical component, and the other for the processing of P-S mode-converted waves recorded on the horizontal components. The conventional P-wave processing results are presented here but both P-P and P-S results will be shown at the workshop. Two separate processing flows were used for the P-P data processing: prestack DMO-poststack migration (PDPM) and prestack-time migration (PSTM). The PSTM sequence provided most details in the shallow part of the data. Reflections on the PDPM data are generally smoother and subject to less migration artefacts than the PSTM data. Both PDPM and PSTM sequences show prominent and coherent reflections in the deeper part of the seismic volume, especially in the northern part of the volumes. The critical processing steps to both sequences included refraction statics and coherent noise attenuation.

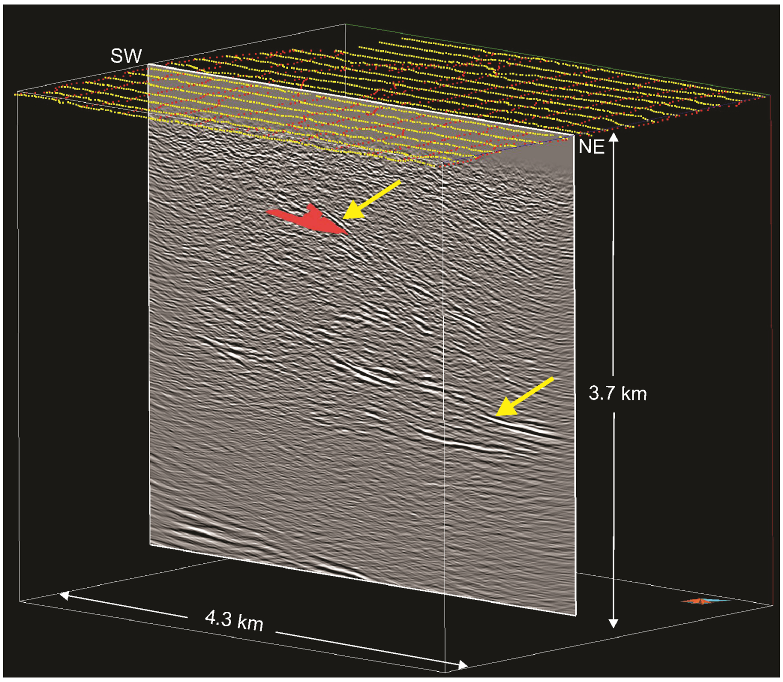

Figure 1. *Perspective view to the West of an inline (1090) from the DMO-postack migrated volume. Also shown are the outline of ore zone 25, source (red dots at surface) and receiver (yellow dots) stations. Arrows point to reflections associated with the ore (shallow) and deeper reflections near or at the base of the lower Chisel sequence.*

Results

Figure 1 presents a perspective view of an inline from the prestack DMO-poststack migrated volume. The outline of ore zone 25 is also shown on this figure. Reflections in the hanging wall above the deposit are generally short and weak. Few shallowly-dipping reflections in the hanging wall coincide with diorite units that have both high density and high velocity. The steeper stratigraphy of volcanic rocks of the hanging wall is poorly imaged on the seismic data. In contrast, the footwall is characterized by numerous reflections generally dipping to the NE. The most continuous are located near the base of the Lower Chisel sequence near the contact with the Anderson sequence. These reflections are of lithological origin but the exact units still needs to be determined. The hanging wall-footwall contact is defined by relatively continuous reflections with significant amplitude variations and some local gaps. Reflectivity along this contact depends on composition of units juxtaposed at the interface, footwall alteration, and the presence of mineralization. Clear reflections are locally observed at the location of shallower ore zones. Deeper ore zones (Au-Cu rich and disseminated zones) do not have a clear signature on the P-P seismic data.

Conclusions

A 3D-3C seismic data set was acquired over the Lalor Lake VMS deposit, located near Snow Lake Manitoba, to provide images of the ore zones and host rocks, and to assess the applicability and potential benefits of P-S waves for deep mineral exploration. An analysis of borehole logging data shows that ore zones associated with pyrite and diorite should produce strong reflection on seismic data. Clear reflections are locally observed at the location of shallower ore zones. Alteration and post-metamorphism increased the P-wave velocity and density of felsic volcanic rocks but the impact of this change has not been clearly identified on seismic data. Many prominent and continuous reflections of lithological origin are observed close to the base of the Chisel sequence. P-S results are not discussed here but will be presented at the workshop.