TGI-4 METHODOLOGY PROJECT AT LALOR: AN INTRODUCTION

GILLES BELLEFLEUR[1], ERNST SCHETSELAAR[1], AND JIM CRAVEN[1]
[1] *Geological Survey of Canada, 615 Booth Street, Ottawa, Ontario, K1A 0E9*

During the winters of 2013 and 2014, the Geological Survey of Canada conducted novel geophysical surveys over the Lalor volcanogenic massive sulphide (VMS) deposit located in Manitoba (Figure 1) to test and develop approaches leading to effective exploration of deep deposits. The geophysical data were acquired as part of the methodology project of the phase 4 of the Targeted Geoscience Initiative (TGI-4), a project that aimed to develop and improve methods for deep mineral exploration and provide a better understanding of ore systems. In addition to the acquisition and interpretation of geophysical data, a 3D common-earth model (i.e., a 3D geological grid model with inter-consistent lithofacies, lithogeochemistry, and physical rock properties) was constructed to gain a better understanding of data inter-dependencies and unravel geophysical responses caused by mineralization and hydrothermal alteration from responses produced by host rock contacts. The common-earth modelling approach greatly benefited from a rich catalog of existing geological, geochemical, and geophysical data including extensive drill-core and borehole logs available at Lalor. The 3D common-earth model provides excellent constraints on geophysical data interpretation near the deposit whereas geophysical data allows tracing the continuation of key contacts away from areas with borehole control.

The Lalor deposit was discovered in 2007 by Hudbay Minerals and is one of the largest base metal deposits (25 Mt) within the Flin Flon Greenstone Belt. The deposit was intact at the time of geophysical data acquisition and provided an ideal test bed to assess the response of the host rocks, zones of sulphide mineralization, and hydrothermal alteration. Aspects of the geology that pose a challenge to effective use of geophysical methods at Lalor include the presence of both massive and disseminated mineralized zones, their association with an extensive hydrothermal alteration system, and post-volcanic metamorphism that significantly modified the mineralogy of the alteration zones in some areas near the deposit. In addition to defining the response of the ore deposit, other important objectives of this study included the determination of the lateral continuity of the highly prospective hanging wall-footwall contact, the definition of the geometry of the footwall rocks and integration of the geophysical data with detailed three-dimensional geological information. Geophysical data acquired by the TGI-4 program to address those issues at Lalor include (Figure 1):

- 16 km^2 3-component 3D seismic data.
- 3D passive seismic data.
- Borehole gravity measurements in five boreholes.
- Collocated geochemical and petrophysical measurements on 137 rock samples.

Borehole seismic data, although not acquired at Lalor, were also studied during this project using Vertical Seismic Profiling (VSP) data previously acquired near the Flin Flon 777 mine. Results from the VSP data were also analyzed in a 3D common-earth model framework established during an earlier phase of the Targeted Geoscience Initiative. Each geophysical method above is evaluated as a stand-alone technology and as an element in an integrated workflow. All geophysical data (3D active-source seismic, 2D and 3D passive seismic, borehole gravity and petrophysical measurements on core samples) were acquired by the TGI-4 Methodology project. Other geological information including geological logs and geochemical analysis, and most of the petrophysical data were provided to the TGI-4 methodology project by Hudbay.

This Open File summarizes the results of eight papers published or in the process of being published in peer-reviewed journals and written as part of the TGI-4 methodology project. The intent here is not to reproduce the papers, but rather synthesize the key results and their impacts for exploration. Topics include 3D common-earth modelling of geological, geochemical and petrophysical data; analysis of physical rock properties; acquisition, processing and interpretation of active-source, passive seismic data, and borehole gravity data and a new method for the constrained inversion of potential field data using gradient constraints from strike-dip measurements and 3D seismic data. Readers can find further details for each topic in the original papers listed below (name in bold indicates member of the TGI-4 methodology project). The list also comprises technical papers describing methods that were critical to obtain results at various stage of the project, but that are not exhaustively discussed in this Open File:

Bellefleur, G., Schetselaar, E., White, D., Miah, K., and Dueck, P., 3D seismic imaging of the Lalor volcanogenic deposit, Manitoba, Canada. Geophysical Prospecting (in press).

Cheraghi, S., Craven, J., and Bellefleur, G., Feasibility of seismic interferometry method in mineral exploration: A test study in Lalor Lake VMS mining area, Manitoba, Canada. Geophysical Prospecting (in press).

Górszczyk, A., Malinowski, M., and **Bellefleur, G.**, Application of 2D curvelet transform for denoising 3D seismic data acquired in hardrock environment. Geophysical Prospecting (in press).

Hillier, M.J., Schetselaar, E.M., de Kemp, E.A., Perron, G. 2014. Three-Dimensional Modelling of Geological Surfaces Using Generalized Interpolation with Radial Basis Functions. Mathematical Geosciences, 46 (8), pp. 955-956.

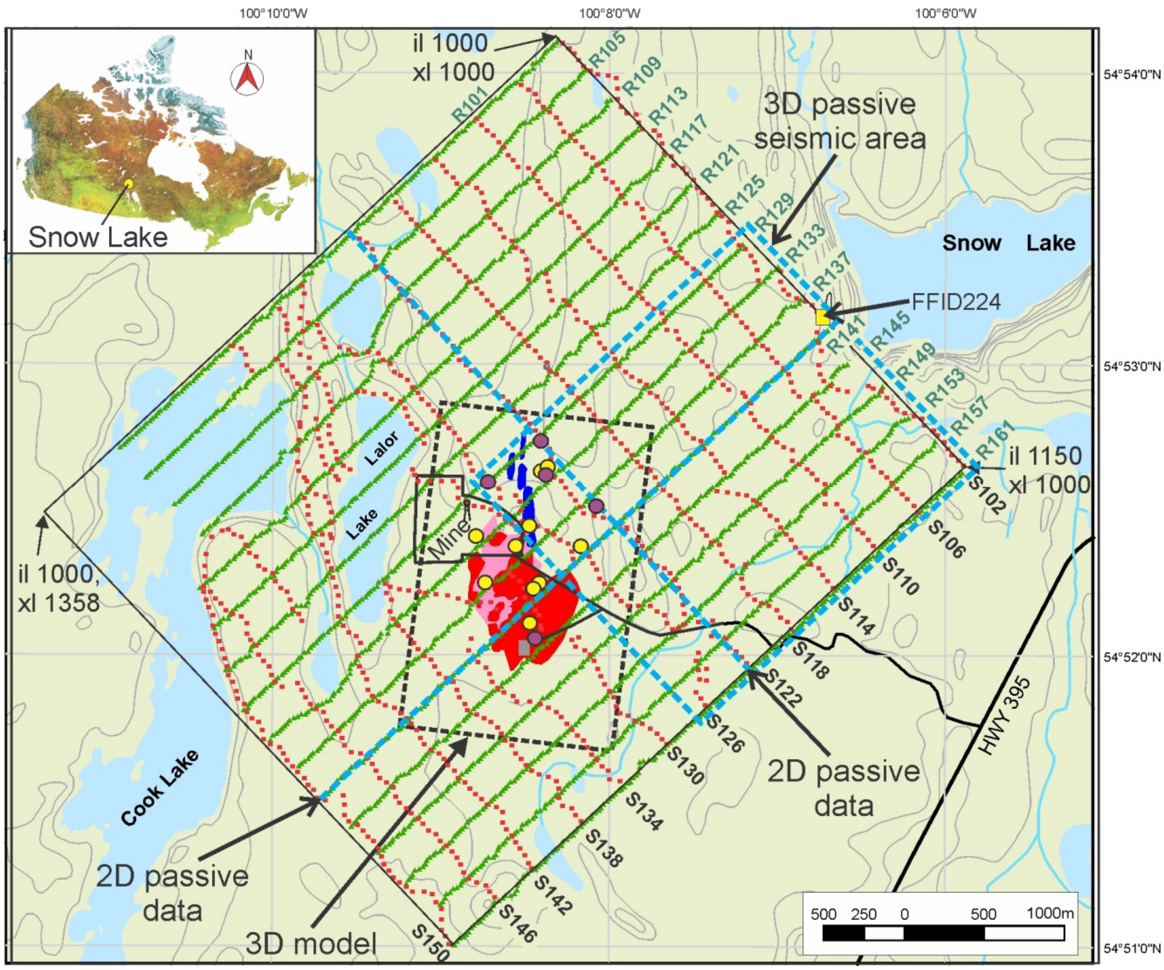

Figure 1. Location map of the 3D-3C Lalor active-source seismic survey. Receiver locations are shown as green triangles whereas shot points are shown as red dots. The mine site area and main road are shown in black (polygon for the mine site). The surface projection of the zinc, gold, and gold-copper zones are shown in red, pink, and blue, respectively. The outline of the 3D geological model used for the interpretation of the data is also shown (rectangle with dashed black line). Polygon with blue dashed line indicates the survey area for the 3D passive seismic experiment. Dashed lines in blue correspond to 2D passive seismic profiles. The yellow dots are the collar locations of drillholes with both geochemistry and wireline logging data used in the physical rock property analysis. Dots in purple indicate boreholes used for the downhole gravity measurements. Inlines (il) and crosslines (xl) for the final 3D seismic volume are indicated. FFID 224 is the location of a shot gather shown in Figure 9.

Marcotte, D., **Shamsipour, P.**, Coutant, O., Chouteau, M. 2014 Inversion of potential fields on nodes for large grids (2014) Journal of Applied Geophysics, 110, pp. 90-97.

Melanson, D.M., White, D.J., Samson, C., **Bellefleur, G., Schetselaar, E.,** and Schmitt, D.R., Mode-converted VMS ore lens reflections in vertical seismic profiles from Flin Flon, Manitoba, Canada. Geophysical Prospecting (in press).

Schetselaar, E. and Shamsipour, P., Interpretation of Borehole Gravity Data of the Lalor Volcanogenic Massive Sulphide deposit, Snow Lake, Manitoba, Canada, Interpretation (submitted to Interpretation).

Shamsipour, P., Schetselaar, E., Bellefleur, G., and Marcotte, D., 2014. 3D stochastic inversion of potential field data using structural geologic constraints. Journal of Applied Geophysics, 111, 173-182.

In this Open File, we first briefly review the geology of the deposit and provide some details on the methodology used to construct the 3D common-earth model of the Lalor deposit and how this model was used to guide and support the interpretation of the geophysical data. Then, we review the physical rock properties of host rocks and ore zones and present the acquisition, processing and interpretation of both the active-source 3D seismic data and passive seismic data. We also show a comprehensive analysis of the VSP data acquired near the Flin Flon 777 VMS deposit. We then present progress made in potential field methodology by discussing the acquisition parameters, processing and interpretation of the borehole gravity survey conducted in five boreholes surrounding the Lalor deposit. An innovative inversion method taking advantage of constraints from seismic or geological data in boreholes is introduced. Finally, we summarize the key results of this project and highlight their significance for exploration of deep-seated deposit. Although this study is site- and commodity-specific, the common-earth modelling approach and the various methods developed herein are recommended to be adopted for exploration elsewhere and are easily adaptable to other deposit types.