High-resolution 2D seismic imaging in the Noranda camp and implications for exploration

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Introduction

As part of phase 3 of the Targeted Geoscience Initiative (TGI-3), the Geological Survey of Canada obtained access to industry seismic reflection data acquired along two profiles in the eastern Blake River Group of the Abitibi Subprovince. The two seismic lines (Amulet-001 and Ribago-001) were shot by Noranda during the summer of 2000. The Amulet and Ribago seismic profiles run approximately from east to west and cross the volcanic rocks of the Noranda formation which host most of the ore deposits in the Noranda central camp (Figure 1). The two seismic profiles were re-processed to improve the reflectivity in the shallow part of the section and imaging of dipping reflectors. The seismic profiles provide new information about the geology at depth and complement information obtained previously from the high-resolution Lithoprobe seismic profile 21-1 (Figure 1). Here, we present results from the re-processing and interpretation of these profiles based on petrophysical and geological information available in the Noranda central camp. In particular, the interpretation relies on a detailed 3D geological model built from an extensive number of exploration boreholes available in this area. The integration of seismic sections into this model helps to further define the deep geological framework in the Noranda camp and to locate structures significant to mineral exploration.

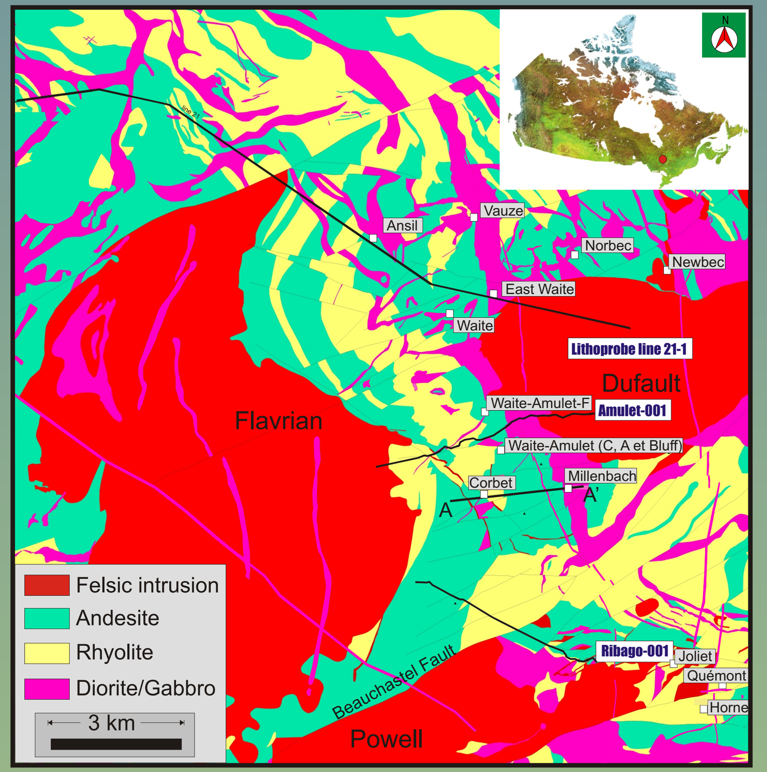
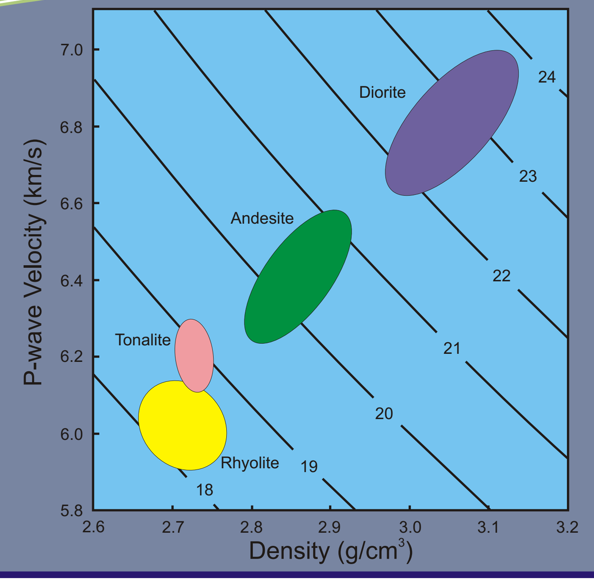


Figure 1 Geological map of the Noranda central camp showing the volcanic rocks of the Noranda formation and felsic intrusive rocks. The location of the two industry seismic profiles (Amulet-001 and Ribago-001) and Common Depth Points (CDP) of Lithoprobe line 21-1 are also shown. Geological cross-section A-A' is shown in Figure 7.

Physical Rock Properties in the Noranda Camp

Physical rock properties are key to identify probable origin of seismic reflections. P-wave velocity and density were previously obtained from borehole logs to assess the reflectivity on Lithoprobe line 21-1 (Perron and Calvert, 1998). The logs were acquired in a 1.6 km deep borehole located close to the Ansil mine (An-71). Result from this study are likely applicable to the Amulet and Ribago profiles because they intersect the same geological units as line 21-1. This petrophysical analysis shows that diorites are likely to cause strong reflections when in contact with tonalite or rhyolite (Figure 2). Several reflections on line 21-1 were associated to dioritic intrusions that form laterally continuous, shallow-dipping surfaces prone to reflect seismic waves. Log data also suggests that rhyolite-andesite contacts should produce detectable reflections. However, results from Lithoprobe show that such contacts are mostly non-reflective, possibly because they are laterally heterogeneous at the scale of the seismic waves near line 21-1 (Perron and Calvert, 1998).

Figure 2 P-wave velocity versus density from log measurements in borehole AN-71 (Ansil). Lines of constant acoustic impedance are also shown. A difference of 2.5 in acoustic impedance is the minimum required to produce a significant reflection. The ellipses represent the scatter corresponding to standard deviations of densities and velocities of specific lithological units (from Perron and Calvert, 1998)



3D Geological Model in the Central Camp

Interpretation of seismic data acquired in hard rock environment is often seen as highly speculative due to the lack of laterally extensive geological information at depth. This speculation, although inevitable, is minimized by using a detailed 3D geological model covering the Noranda central camp. This 3D model was also provided to the TGI-3 Abitibi project by Xstrata Copper Canada. The model is primarily based on exploration drill cores and comprises 3D surfaces of main lithological units (including exhalite horizons) and a detailed fault network (Figures 3, 4 and 5). Control points used to define these surfaces are also part of the model. These points provide hard geological constraints that can be used to validate interpretation of the two industry seismic profiles and to re-visit interpretation of Lithoprobe line 21-1. The model allows precise comparison between seismic reflections and subsurface geology. The 3D geological model can be used to locally confirm the reflectivity of specific lithological contacts or faults. The seismic data provides additional control in areas with no boreholes and can extend geological information at depth. Furthermore, the seismic data can help to upscale detailed geological information to a regional scale.

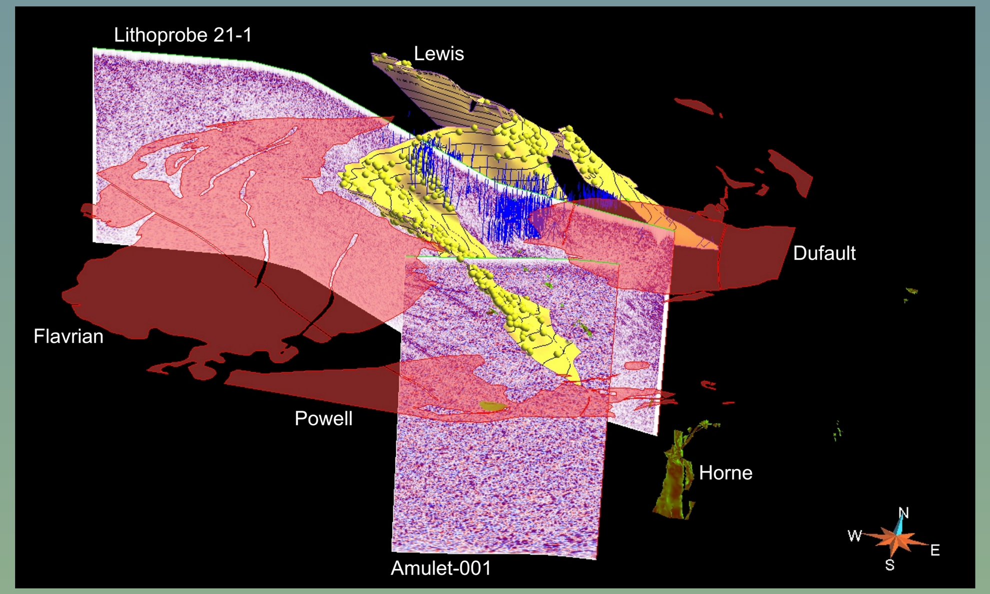


Figure 3 Perspective view of the 3D Noranda model (looking NNW) showing the Amulet and Lithoprobe 21-1 seismic profiles, three felsic intrusions, the Lewis exhalite horizon (in yellow with control points), the sulphide ores (in green - some are small at that scale) and some borehole trajectories on either side of line 21-1 (blue lines).

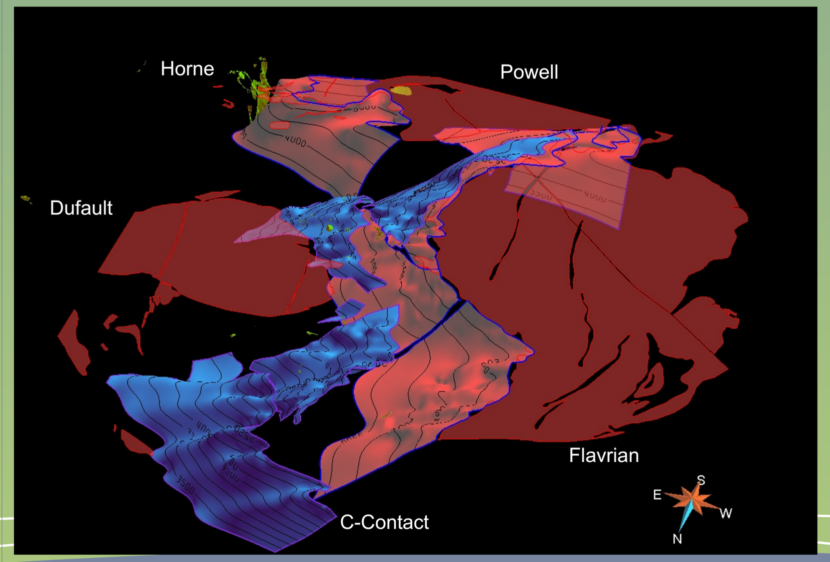


Figure 4 Cross plunge view of the model with the Flavrian and C-contact (exhalite) 3D surfaces (looking SSE). The green spheroids correspond to sulphide ores.

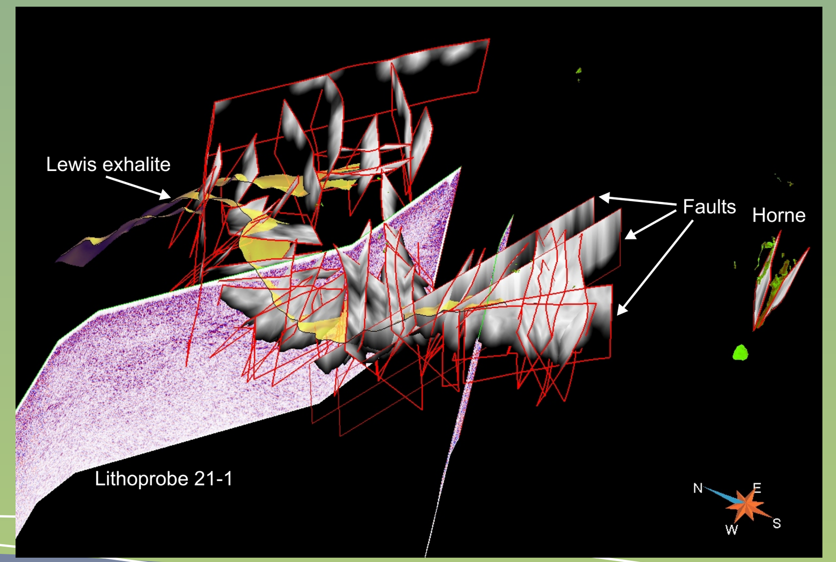


Figure 5 An example of the fault network in the 3D model. Faults are depicted by polygons with red outline. The grayscale within the polygons highlights the proximity to drill holes (control points). The Lewis exhalite horizon (yellow surface) and Lithoprobe line 21-1 are also shown. The sulphide ores are shown in green.

Some localized discrepancies are observed between the model and the seismic data. They can be explained by the lack of geological information available to constrain specific area of the model. In addition, some objects in the model are resulting from a simple spatial interpolation of borehole intersections and do not necessarily take into account displacements due to faults. Surfaces defining exhalite horizons are one example. Consequently, these surfaces may not be at their exact locations where they intersect the seismic profiles. Control points provide some confidence on the location of the surfaces near the seismic profile. Another explanation is the imaging of 3D lithological contacts or structures on a 2D profile. Some off-line reflections will likely be mis-positioned on the 2D seismic sections and will therefore not coincide with information from the 3D model. The constant velocity approximation (6 km/s) used for time-to-depth conversion can also cause mismatches between the seismic data and 3D model.

Interpretation of the Amulet profile

Changes in seismic reflectivity characteristics are used to define several geological domains. On the Amulet profile, one of these domains corresponds to the Flavrian pluton. It is characterized by strong east-dipping reflections embedded in a relatively low-reflectivity background (Figure 6). The prominent east-dipping reflections originate from contacts or structures within the Flavrian pluton (see Figure 6). The series of intrusions of various textures and compositions mapped at surface of the pluton could explain the reflectivity. In particular, the Eldrich diorite and the Méritens quartz-diorite (Richard, 1998) could likely produce reflections when in contact with the felsic intrusive rocks. The contact between the Flavrian and overlying volcanic rocks produces a weak but locally detectable reflection.

The volcanic rocks of the Noranda formation are characterized by short crossing reflections with different dips, which complicates reconciliation with the faulted rhyolitic-andesitic sequences in the area. On the Amulet profile, a package of short sub-horizontal reflections is found between the Lewis and Beecham exhalite horizons near 0.4s. The reflections could likely originate from sub-horizontal dykes and sills of gabbro and diorite mapped in the Noranda formation. The four exhalite horizons intersected by the Amulet profile do not produce clear reflections (Figure 6) except for the Lewis horizon which is locally associated with short reflections near 0.4s. One of the most prominent reflection from the volcanic rocks crosscuts almost orthogonally the shallowly-dipping volcanic stratigraphy. The reflection extends between the Flavrian Pluton and the Lewis exhalite horizon. This reflection could correspond to a feeder dyke system that channelled felsic volcanic flows and mineralizing hydrothermal fluids. Such a feeder dyke was mapped below the Millenbach mine (Figure 7).

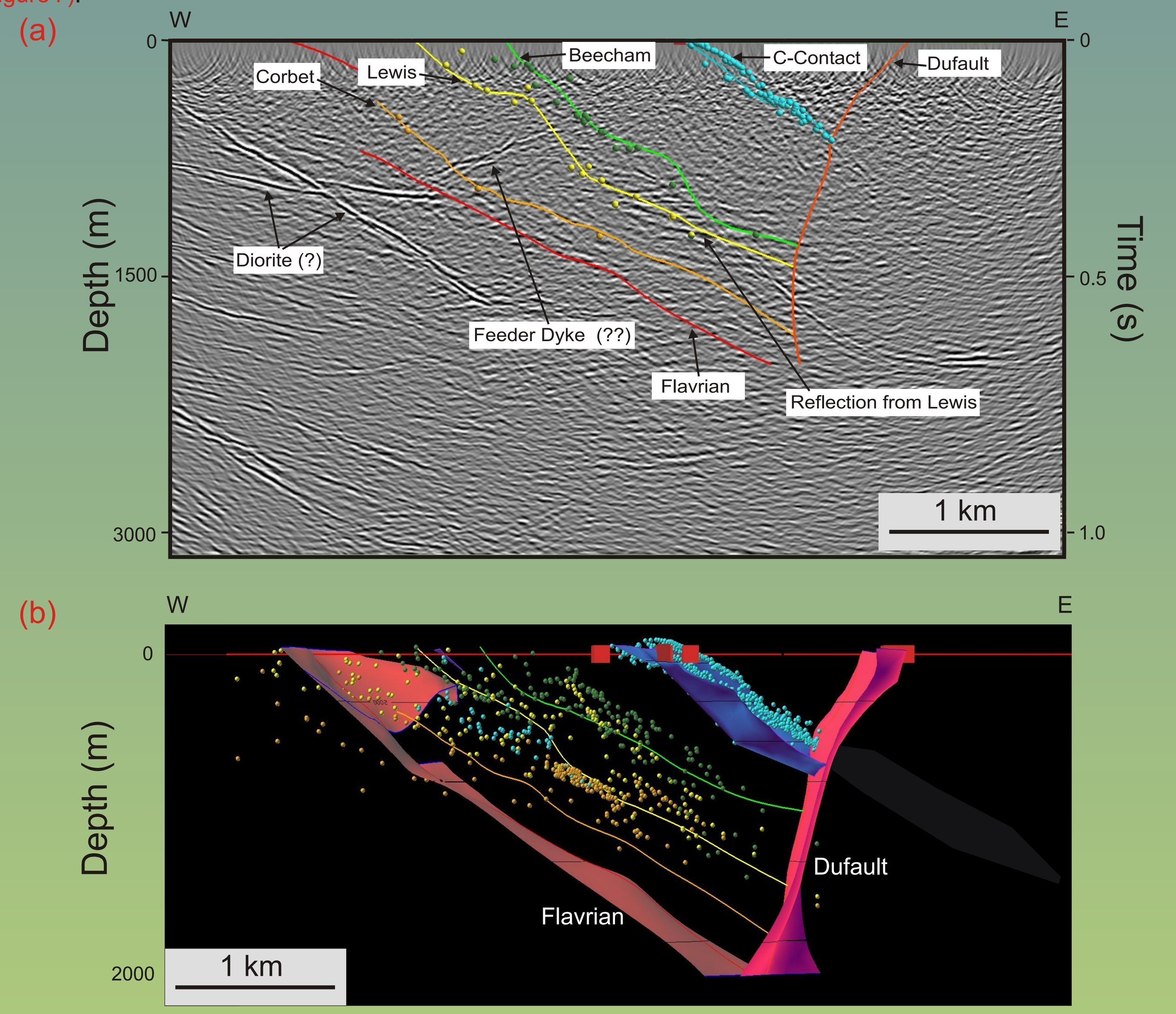
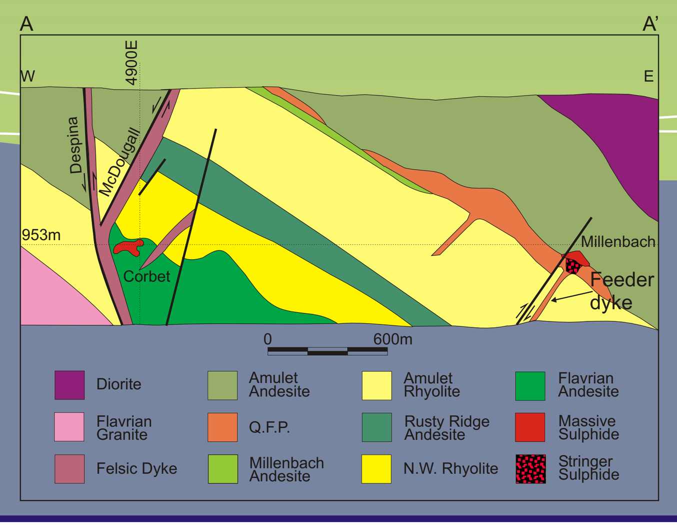


Figure 6 (a) Migrated data from the Amulet-001 seismic profile. Intersections with major lithological contacts from the 3D geological model are also shown. The control points used to define the lithological contacts (3D surfaces) are shown in (b).

Figure 7 Geological cross-section through the Millenbach and Corbet Mines (modified from Knuckey et al., 1982). The section, located approximately 1km south of the Amulet seismic section, shows a feeder dyke cross-cutting the volcanic stratigraphy beneath the Millenbach massive sulphides. A similar dyke could explain the west-dipping reflection observed on the Amulet seismic section.The Millenbach feeder dyke is composed of quartz-feldspar porphyritic rhyolite and is located within a deep-seated NE-trending synvolcanic fracture system.



Interpretation of the Ribago profile

The volcanic rocks near the Ribago seismic profile can be divided in two areas. To the west, the C-contact exhalite produces a prominent reflection (Figure 8). The moderate dips and relative lateral continuity of the contacts in this part of the Noranda formation likely explains why the C-contact is clearly observed on the Ribago profile. Just beneath the C-contact, a weaker reflection corresponds to the contact between the Flavrian pluton and the volcanic rocks. Other shallowly east-dipping reflections observed on the Ribago profile still need to be explained but could correspond to exhalite horizons. To the east, the interpretation of the seismic section is complicated by the steep dips of the volcanic rocks (west of the Beauchastel fault) and the Powell pluton located just south of the profile (see Figure 1). On the 3D model, the Powell pluton appears as a N-dipping structure that could explain some of the sub-horizontal reflections observed on the section. Sub-horizontal diorite sills directly underneath the profile could also generate a similar reflectivity. However, the 3D geological model does not reveal a significant number of diorite sills close to the Ribago line. Several exploration boreholes intersected massive or stringer of sulphides in the western part of the Ribago profile. The boreholes define small ore bodies that are producing seismic diffractions best preserved on the un-migrated structure stack section (Figure 9).

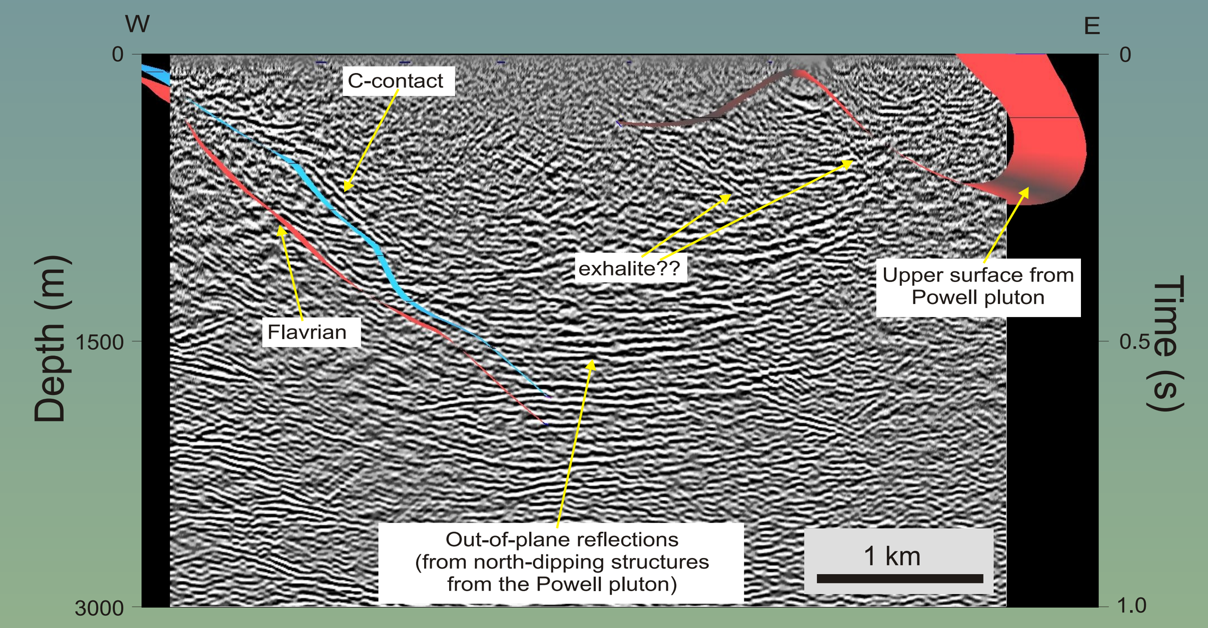
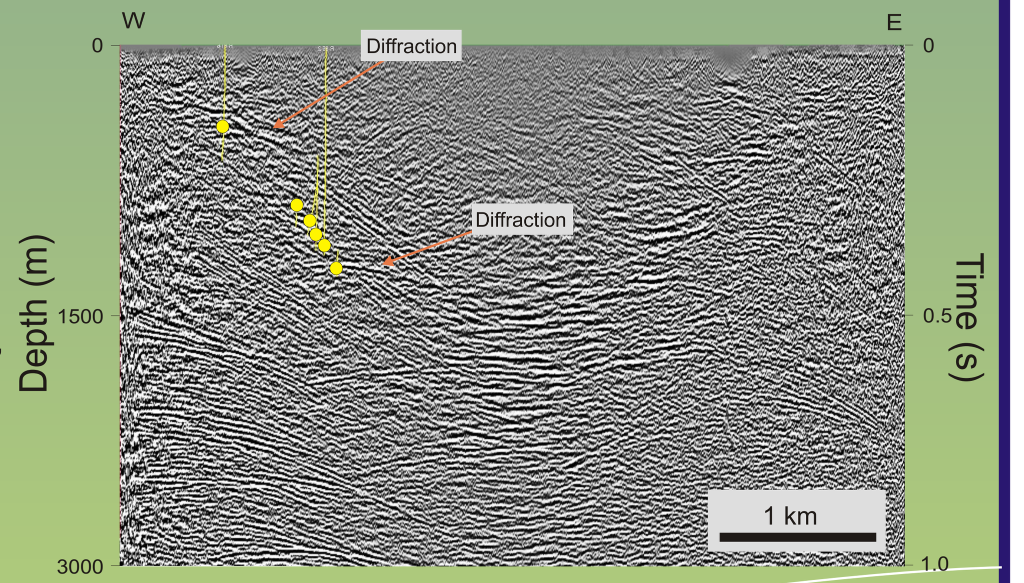


Figure 8 Migrated data from the Ribago-001 seismic profile. Intersections with major lithological contacts from the 3D geological model are also shown.

Figure 9 Un-migrated structure stack for the Ribago profile showing seismic diffractions corresponding to small sulphide bodies. The yellow dots show massive sulphide intersections in boreholes located north of the Ribago profile. Other boreholes also intesect mineralization south of the profile (not shown). On the migrated section, the diffractions collapse and produce very short reflections that are difficult to associate with mineralization (Figure 8).



Summary

The reconciliation of the detailed 3D geological model and seismic data is not necessarily a straightforward task. A significant complication results from the inaccuracies related to the 2D seismic imaging of a 3D geologic environment. Nevertheless, the integration of seismic data and 3D geological model locally provides new constraints on the deep geological framework that may help exploration in the Noranda camp. Feeder dykes, exhalites and localized massive sulphide accumulations can have a detectable seismic signature.

References

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