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An integrated geophysical study for orebody delineation, Nash Creek, New Brunswick

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ABSTRACT

An integrated study over the Nash Creek Zn-Pb-Ag deposit in New Brunswick was completed by integrating geological, petrophysical and gravity data. Density was measured on core available from seven boreholes across the area, and was complemented with density computed from geochemical assay data on boreholes. This allowed the computation of a 3D density distribution that exhibits a direct correlation with Zn-rich mineralized zones. High resolution gravity data was collected on 451 stations across the area. A constrained model was built based on gravity, petrophysics and boreholes. The model supports a NW to SE trending mineralized zone with density values from 2.6 to 3.4 g/cm^3, as predicted by the 3D density model; it is 20-30 m thick over most of the area, except on the SE border, where a ~60 m thick body was modelled.

INTRODUCTION

The shape and size of an orebody is normally constrained by means of systematic drilling and subsequent 3D imaging of the borehole stratigraphy, when available. Prior stages of an exploration project can make use of geophysical and geological data for the same purpose. However, a complete database of information derived from both surface and borehole data is necessary. Each dataset provides a means of outlining the relevant changes in physical properties in either one or two dimensions. In this article we present the results of an integrated study over the Nash Creek Zn-Pb-Ag deposit, New Brunswick (Figure 1), using geological and petrophysical borehole logs and ground gravity data. The Nash Creek deposit is located along the western margin of the Jacquet River Graben in northeastern New Brunswick (Dostal et al., 1989). The deposits in New Brunswick are a sub-group of seafloor hydrothermal deposits hosted by sedimentary and volcanic rocks in continental back-arc rifts (Goodfellow, 2002). Sulphide mineralization occurs as stratabound and laterally continuous zones of matrix filling or replacement style mineralization, as fractures fill within flow or pyroclastic units, and as discrete breccia zones. At Nash Creek, high-grade sulphides (high density, high conductivity) are imbedded in laterally extensive alteration envelopes (low density, moderate conductivity).

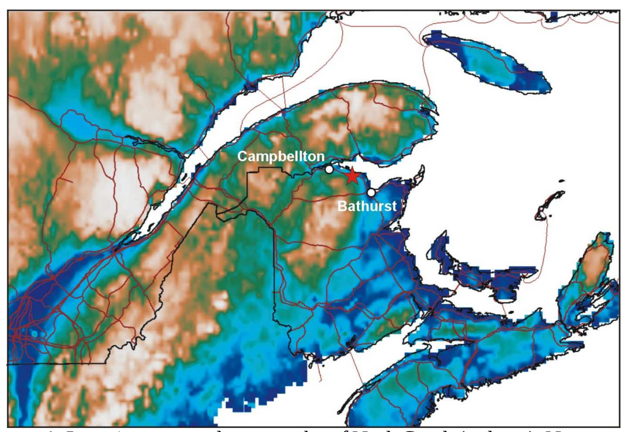

Figure 1: Location map and topography of Nash Creek (red star), New Brunswick.

Despite more than 50 years of extensive drilling exploration, which resulted in 3.4 Mt indicated resource estimate (5% Zn, 0.8% Pb, 30.9 g/t Ag), little is known about the petrophysical properties of sulphides, alteration zones and hostrocks. Ground geophysical data (gravity and magnetics) from federal and provincial databases is normally not available at the high resolution level required for such a study. Thus, a geophysical exploration program was designed to delineate the shallow mineralization at Nash Creek. First, a comprehensive petrophysical database was built to provide the necessary background information for the geophysical data acquisition program. Then, a high-resolution gravity dataset (in combination

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with borehole lithological and density logging data) was used to constrain the shape and size of near-surface massive sulphides.

PETROPHYSICS

A large number of boreholes and core were available for study in this area. The core provided a means of assessing the bulk physical properties of the rocks at Nash Creek, and thus determine what types of geophysical surveys would be most useful in constraining the size and location of any sulphide deposits. Density measurements were collected on samples from seven boreholes within the area, and magnetic susceptibility in two boreholes.

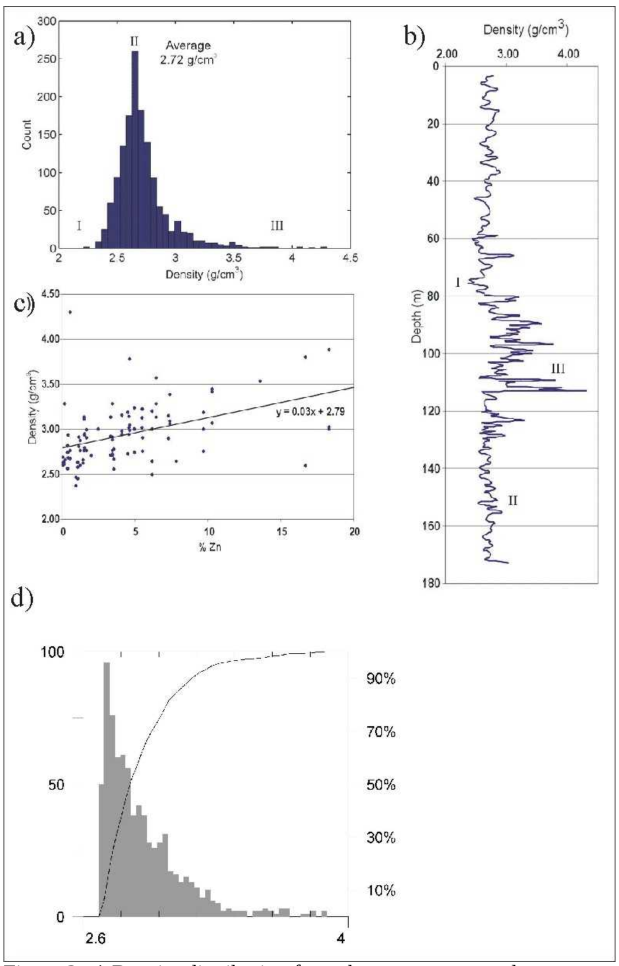

Figure 2: a) Density distribution from the measurements done on core; b) density log from one borehole. See text for details on the zones I, II and III; c) density vs. %Zn from one of the boreholes surveyed. Notice the linear relationship; d) cumulative histogram of all the density measurements, including those collected on core and those recovered from geochemical assays. Mean and median of density are 2.91 and 2.84 g.cm^3 respectively.

Magnetic susceptibility measurements sampled at 0.2 m along the boreholes indicate elevated values in mineralized zones containing 1-15% sulphides (sphalerite, pyrite and galena); however the basaltic and mafic tuff units present in the area also exhibit high magnetization. Magnetic mapping in this area will likely show anomalies in response to all of these units, and although it may help in delineating ore-bearing structures, it may, or may not reveal much useful information concerning the ore deposits themselves. Density measurements were obtained on core available from the seven boreholes selected for this purpose. 1443 density measurements were obtained at an average of 1 m in each of the seven boreholes scattered throughout the study area (Figure 2a-2c). The measurements show an average density of 2.72 g/cm^3 and a median density of 2.68 g/cm^3. The low and high tails of the density distribution (Figure 2a) correlate well with core lithologies: alteration zones are characterized by low densities (zone I), and high densities correlate with Zn-rich mineralization (> 3.0 g/cm^3) (zone III). At Nash Creek, density logs often reveal a broad alteration and mineralization envelope (Figure 2b). In addition, a minor trend of increasing density with zinc content (Figure 2c) is observable in some of the logs, with an intercept approaching the average density value of 2.72 g/cm^3.

Killeen et al. (1977) used geophysical logs to predict geological logs and assay data. Here we try the opposite: using geochemical assay data to predict geophysical data, specifically density mapping. The motivation for using density mapping instead of magnetic susceptibility, for example, lies in the fact that the expected dynamic range of a density distribution is small enough to be able to be predicted with confidence. Furthermore, due to the mafic character of the host rocks in the area, magnetic susceptibility mapping would not provide a good insight into separating host rocks from mineralized areas.

Density was computed from assay geochemical data available on most of the boreholes in the area. Given the linear %Zn-density relationship observed on Figure 2c, a similar trend was applied on the measured %Zn content on boreholes to obtain density. The linear regression used was calibrated with the known %Zn-density relationship observed on the boreholes where density was actually measured. Figure 2d shows a cumulative histogram of all the density values integrated in one group (direct measurements on core and estimates based on Zn content). Combining the measured densities with those derived from Zn content analyses increased the mean density value from 2.72 to 2.91 g/cm^3.

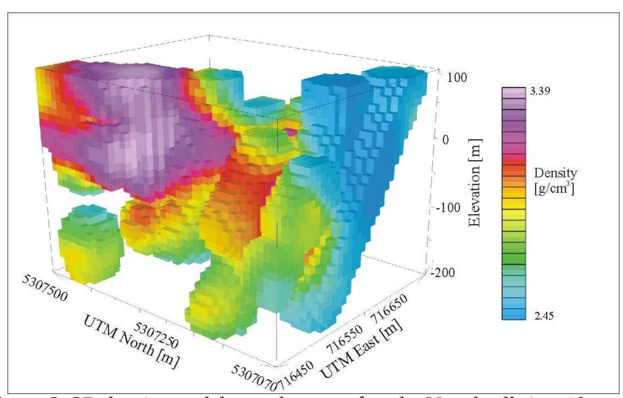

Figure 3: 3D density model over the area of study. Voxel cell size: 10 m.

Finally, this improved density dataset was gridded in 3D using a basic statistical kriging algorithm to create a 3D voxel grid model from 3D data (Figure 3). A voxel cell size of 10 m was used.

GRAVITY

The petrophysical results suggested that a ground gravity survey might be useful in delineating the extent of the mineralized zone. 451 new stations were collected during the summer of 2006 (Figure 4). Acquisition was done with a Scintrex CG-5 gravimeter, and positioning with a Thales ProMark3 DGPS system. The resolution of the DGPS was limited by the forest cover in most of the study area, resulting in a horizontal resolution varying from 0.01 m in open areas to 2-3 m in densely forested areas. Four pre-existing gravity stations from the Geological Survey of Canada (GSC) were tied into 11 new more regional-scale stations spaced ~1 km apart. In the survey area, stations were collected every 10 m over the suspected mineralization, and 20-30 m in the surrounding areas (Figure 4). In addition, 55 stations sampled every 2 m were collected in a rectangle covering a 180 m^2 area over known shallow mineralization. Station elevations were constrained by the combined use of the DGPS survey (with a vertical resolution from 0.01 m in open areas to 5 m in forested areas) and a detailed digital elevation model (DEM) from the government of New Brunswick (Service New Brunswick), with a resolution of 1.0 m on the horizontal and 0.1 m on the vertical. A borehole database was used to provide extra positioning constraints in those areas of the survey that were heavily covered by forest. Gravity data reduction was accomplished by standard procedures: drift, latitude and free-air corrections led to the Free Air gravity anomaly. A density of 2.72 g/cm3 was used for the Bouguer correction. Finally, a minimum curvature algorithm was used to create the final grid with a 5 m cell size (Figure 4).

DATA INTEGRATION, MODELLING AND CONCLUSIONS

A 3D geophysical model was developed that integrates the borehole density, geology and gravity data (Figure 5). Forward modelling was used to generate the initial geometry of the model. Strike and dip of the bodies were constrained geologically, and the densities were obtained from the 3D density model (Figure 3). This model updates a previous 2D one computed by L'Heureux et al. (2007). The final model supports a NW to SE trending mineralized zone with density values from 2.8 to 3.4 g/cm^3, as predicted by the 3D density model shown before on Figure 3. Densities decrease from NW to SE. The bodies that compose the model are 20-30 m thick over most of the area, except on the SE border, where a ~100 m thick body was modelled. However, this large body should be analyzed carefully, as the gravity data does not have the resolution to resolve heterogeneities on the density distribution, as shown on the borehole that intersects this body. Furthermore, a value of 2.6 g/cm^3 should not represent a high content of Zn, as discussed before (Figure 2c). A shallower mineralized zone is observed in

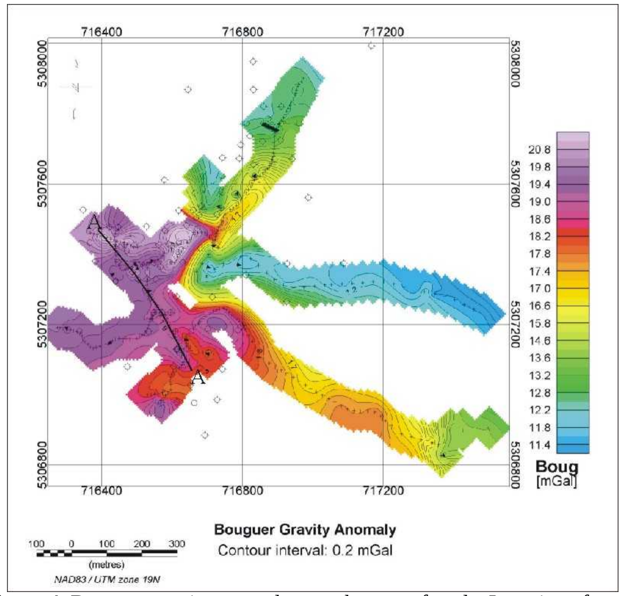

Figure 4: Bouguer gravity anomaly over the area of study. Location of profile AA' (model) is shown for reference. Borehole locations are showed as black circles/

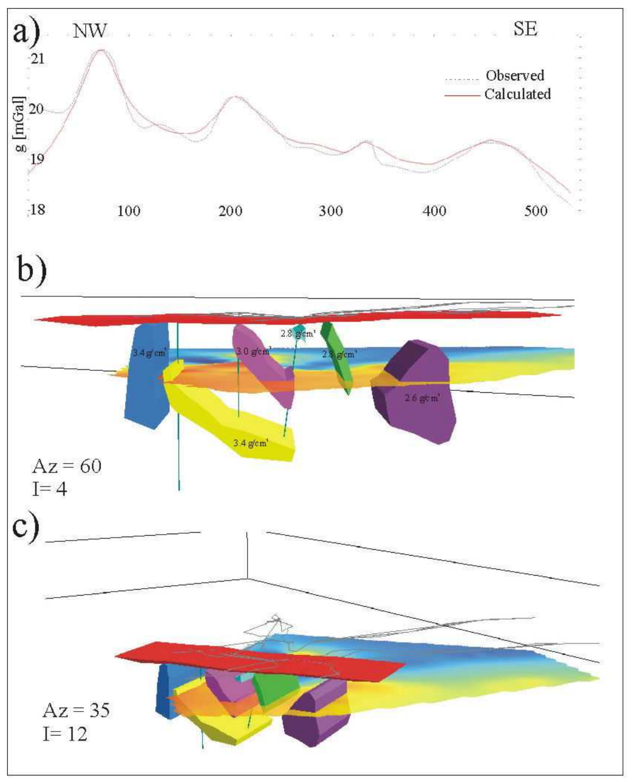

Figure 5: 3D Model of the gravity data. A) 2D section over the profile AA' shown on Figure 4. B) 3D perspective of the model from Azimuth = 60° and Inclination = 4°. The red body on top represents overburden (sediments). The coloured surface in the middle is the Bouguer gravity, for reference on the location of the bodies relative to the main gravity anomalies. C) 3D perspective of the model from Azimuth = 35° and Inclination = 12°. Same as in B), coloured surface is Bouguer gravity, for reference.

the middle of the section (green coloured body); this is supported by density logs in three boreholes in the area, which show higher than background values in the modelled sulphide zones. The model also takes into consideration the overburden thickness variations on the area, which were constrained by the multiple boreholes in the area and modelled with a body that represents the top layer of sediments (red body on top of the sequence on Figs. 5b and 5c). This 3D model does not include deeper zones of mineralization (>150 m).

Although this model is only one of many possible solutions, it is supported by petrophysical measurements in five intersecting boreholes, geological information through all boreholes, the surface gravity data, and geochemical assay data, as well as borehole electric data collected in three of the boreholes (L'Heureux et al., 2007). More borehole constraints are required to resolve the continuity of mineralized zones between the present boreholes. In the future, cross-plots of readily available assay data with petrophysical measurements from core and downhole logs may form the basis for building 3D geophysical models of massive sulphide deposits.

ACKNOWLEDGEMENTS

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