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New Eyes on Old Data: A 3-D Historical Data Integration Study in the Heath Steele Mining Camp, Bathurst New Brunswick, Canada.

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ABSTRACT

At a time when mineral deposit discoveries are becoming more challenging, explorationists need to investigate alternative ways for ore targeting. 3-D GIS provides a critical environment for understanding the characteristics and the environments of ore deposits, reducing the risk in exploration. Many larger companies have accumulated extensive databases through past exploration programs or through mergers and acquisitions of other companies. A considerable amount of archived and historical data may be available from developed mines that are now closed; although these data may have been used in earlier exploration programs, they are rarely integrated into linked data sets that can be effectively applied to follow-up ore targeting exercises. When revisiting historical data a systematic approach is required for migrating information from paper records to fully linked data sets suitable for interpretation in 3-D GIS. Examining inherent relationships between data sets, assessing spatial quality and availability of data at various scales and judging their relevance to exploration models are all critical steps in this data characterization process. As an example of the process of restoring historical mine data to a condition suitable for analysis in 3-D GIS, we have compiled records of the distribution of ore-associated iron formation from the massive sulfide deposits at Heath Steele, in the Bathurst Mining Camp, northern New Brunswick. Structural and stratigraphic interpretations from previous studies and exploration programs are incorporated in the model, along with fabric measurements, regional geology, drill core logs and geophysical data. An iterative process of classification, boundary definition and relationship mapping in 3-D GIS adds significant new value to the existing data and provides a framework for modeling that is embedded with all the original geospatial and geological knowledge available for the target zone. An important outcome of the exercise is that pre-existing 2-D interpretations of the geology of the deposit can be better constrained by all available data from the mine.

INTRODUCTION

Technology in support of mineral exploration, primarily in data acquisition and processing, has improved significantly over the years. Unfortunately, a similar effort has not been devoted to the management, characterization and integration of multiple data sets as they are acquired, especially in the 3-D environment.

Historical and mature mining camps are often warehouses of valuable data that can be used to gain new insight into the deposits of a district and their relationships to the local and regional geology. Heath Steele, in the Bathurst Mining Camp of northern New Brunswick, Canada, was chosen as a test case to investigate the benefits of restoring historical mine data to a condition that can be interrogated using new applications in the 3-D environment (Figure 1). Over 61 million of tonnes of ore were removed from the Heath Steele deposits. Heath Steele is one of 45 volcanic sediment-hosted massive sulfide deposits of the Bathurst Mining Camp; 23 of the deposits were located along a stratigraphic horizon referred to as the Brunswick horizon. Most of the deposits on this horizon are found at or near the contact of felsic volcanic and sedimentary rocks of the Tetagouche Group, composed of Ordovician bimodal siliclastic rocks (Figure 2). An iron formation occurs stratigraphically above many of the massive sulfide deposits, extending from the Brunswick #12 deposit through to the Heath Steele deposits, and is among the more identifiable exploration targets within the stratigraphy. At Heath Steele, the immediate hanging-wall rocks are quartz-feldspar porphyry, and the footwall rocks are crystal tuff. Where the iron formation is present, it is always found in the stratigraphic hanging wall of the massive sulphide deposits, between the quartz-feldspar porphyry and crystal tuff.

The major exploration challenge in the Heath Steele area, and in Bathurst generally, is to place exploration targets within the complex structural and stratigraphic framework of the regional and local geology. Stratigraphic and structural discontinuities, a lack of primary structures for resolving facing directions and complex interference folding patterns are the norm in this area, due to a complex tectonic history. The deposits are affected by five different stages of deformation; the more regional events formed the North Little River Lake fold at

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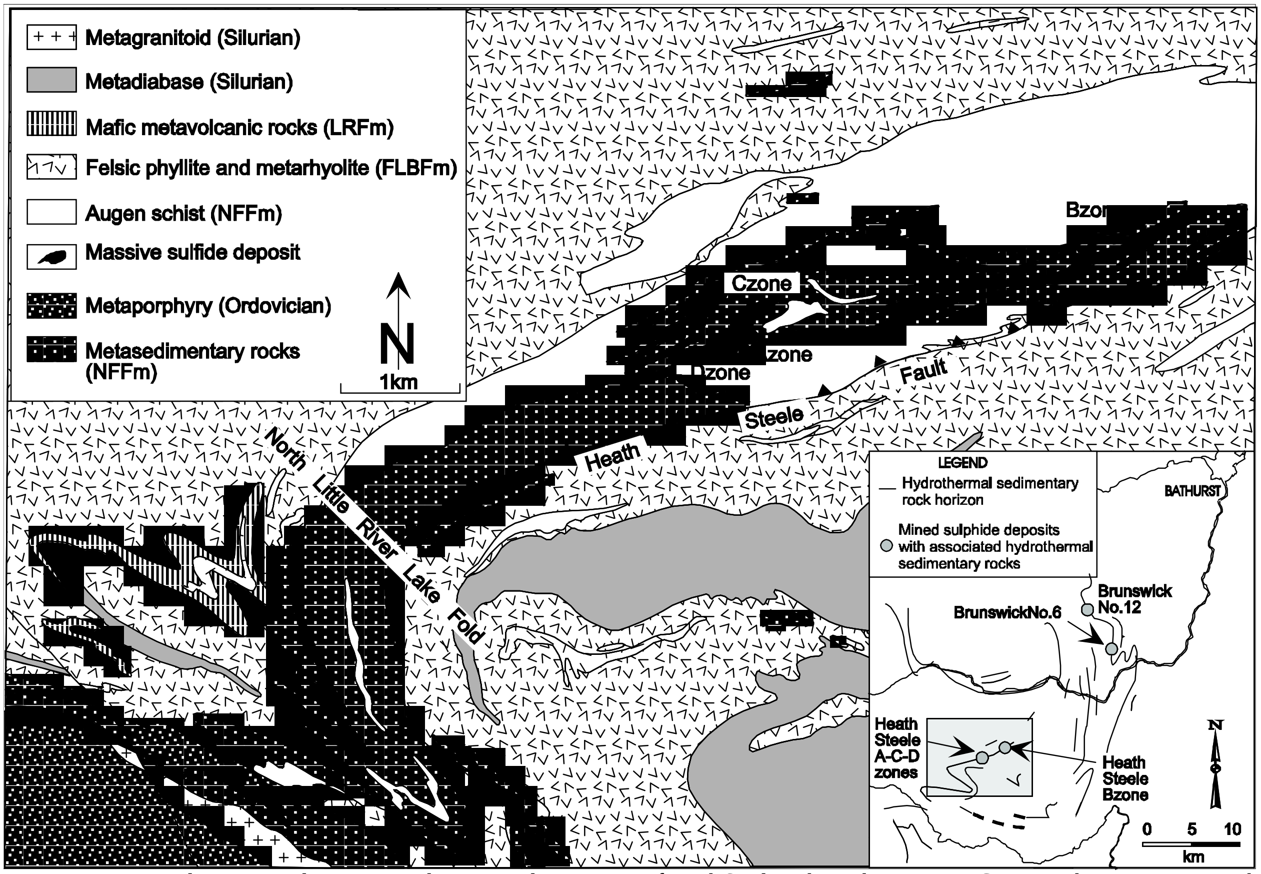

Figure 1: Location, geology, regional structures and economic deposit zones of Heath Steele in the Bathurst Mining Camp, northern New Brunswick (modified from Peter et al., 2003).

Heath Steele (van Staal 1987; de Roo, Williams et al. 1991; van Staal, Wilson et al. 2003).

Geochemistry has been used extensively as an exploration tool in the Bathurst Camp, with special emphasis on trace element concentrations and element ratios in ore-associated iron formation as vectors toward mineralization (Peter, Goodfellow et al. 1993; Peter and Goodfellow 2003; Peter, Goodfellow et al. 2003).

However, these data are normally projected to surface at the drill-collar locations, making it difficult to interpret geochemical zonation in the context of the complex structural and stratigraphic framework of the deposits. In this study, the geochemical signatures of the iron formation at Heath Steele are examined in a structural and stratigraphic reconstruction using 3-D GIS. For this project selected geochemical data from Peter and Goodfellow (2003) and Peter et al. (2003) are examined for the first time in their correct spatial context in the 3-D model.

DATA AND DATA INTEGRATION

Data and logs for more than 3000 surface and subsurface drill holes from 1954 to the late 1990s are available in the mine archives. Over the years, a small subset of these data was used in the generation of 2-D interpreted cross sections to assist in mining. These sections, together with sparse outcrop and structural measurements from local and regional-scale (1:100 000) geological maps were compiled and integrated into the 3-D environment using ArcGIS and Gocad. Data from geophysical potential field surveys that aided in locating deposits were also considered.

To better constrain the 2-D sections, drill-core data were input from column files and converted to curves (lines) and points for handling as ‘objects’, for querying in GIS, and for geostatistical analysis. The cross sections were then imported as 2D images and registered to the same projection as the drill-core data. Different stratigraphic units from the regional geology map were defined as polygons, and the structural measurements were input as point objects, converted to structural markers and assigned to different phases of the deformation. Total field magnetic data were brought into the 3-D environment to help visualize the structure and stratigraphic units; the magnetic signature can be related to intrusive rocks, volcanic rocks, and ore-bearing formations. The preliminary compilation shows clearly that early surface drilling mainly targeted magnetic anomalies.

With all the data registered in the same space and captured as objects, it was possible to generate new, fully constrained planar sections at any location perpendicular to the regional fold of the Heath Steele zone (North Little River Lake fold). These

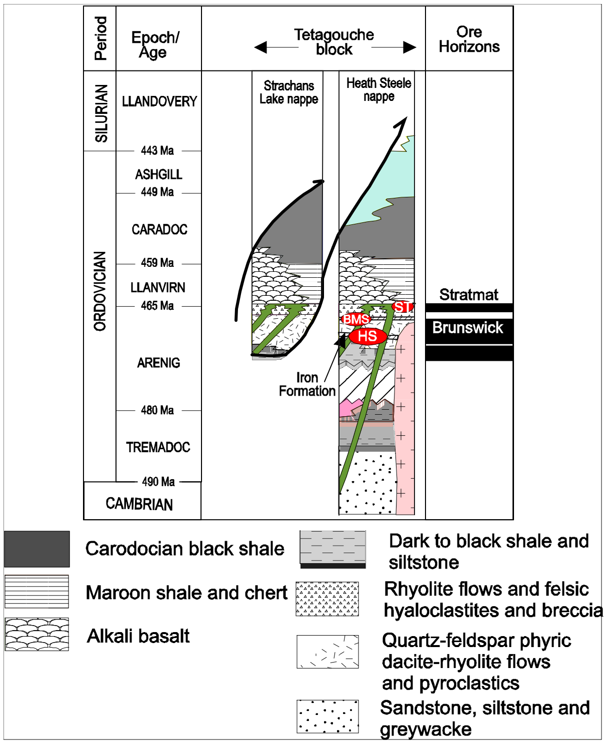

Figure 2: Stratigraphic column of the Heath Steele deposits (labelled HS), showing the dominant lithologies, age of deposits and ore horizons (modified from van Staal et al, 2003).

planar sections were used as digitizing planes to aid in defining the contact between the iron formation and the ore-bearing volcanic units (quartz-feldspar porphyry hanging wall and crystal tuff footwall; Figure 3), the key stratigraphic horizon explored for massive sulfide deposits. The iron formation is not continuous throughout Heath Steele due to the complex tectonic folding, and there are areas where no massive sulphide occurs in association with the iron formation. The new 3-D model has greatly enhanced the understanding of the spatial relationship between the iron formation and the known ore zones. Data from Peter and Goodfellow (2003) projected onto these surfaces also show more realistic spatial context. Previous projections of drill-hole geochemical data to the surface provide only a gross spatial representation of the anomalies. Projecting the geochemical data into its correct 3-D spatial context allows for more accurate vectoring and reveals that single anomalies at the surface are more complexly related to the observed iron formation/sulphide relationship in 3-D.

CONCLUSIONS

The ability to display multiple sections at any orientation in 3-D and to project data onto these sections has added new value to the historical mine data and pre-existing interpretations of the structure and stratigraphy at Heath Steele. The new 3-D model of the Heath Steele mine environment also provides a basis for refining and adding new data and knowledge from other experts.

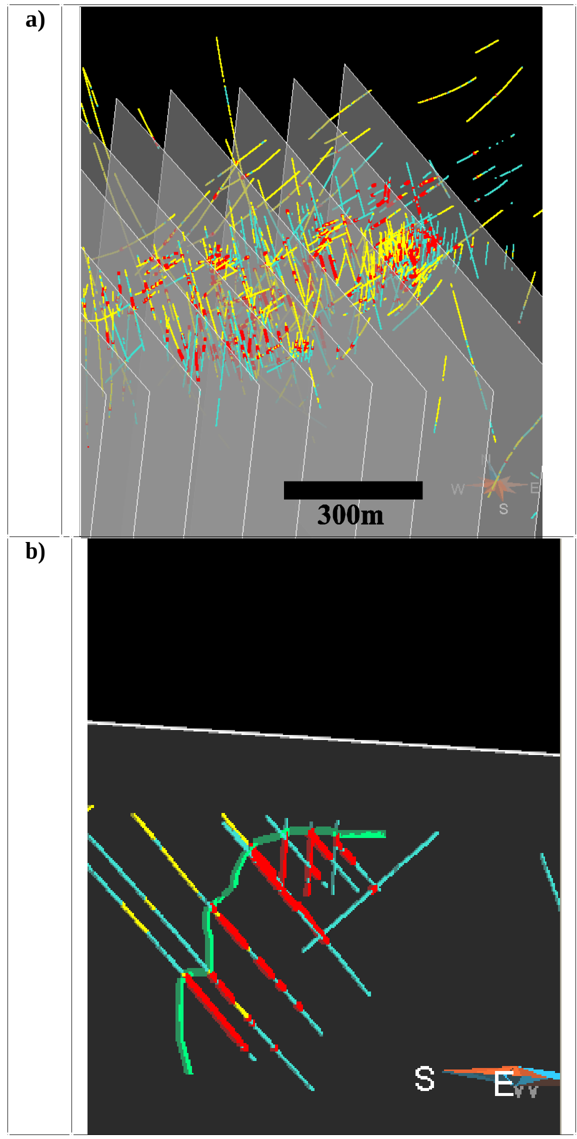

Figure 3: a) A series of cross sections in the 3-D model perpendicular to the strike of the regional fold. Data projected onto these planes are used to constrain contact boundaries (color codes for lithology same as in b). b) Interpreted upper contact of the Heath Steele massive sulphide (red) in contact with quartz-feldspar porphyry (ye1ow) and crystal tuff (blue) shown on one cross section from Figure 3a, viewed perpendicular to cross section. The upper and lower boundaries of the iron formation (green line) are digitized in multiple cross sections to create a shell of the possible extent of the iron formation horizon.

Improved mapping of key horizons, interrogation of new data sets, such as whole-rock geochemistry, and visualization of local trends from section to section in a well-constrained 3-D environment offers new opportunities for defining exploration targets. Due to the complexity of the geology, particularly the heterogeneity of the structure throughout the camp, prior knowledge of the style of folding, faulting history, and the stratigraphic relationships greatly assists in the interpretation of the model, and this knowledge can be used in the 3-D environment to provide a more accurate spatial context for investigating geochemical vectors to ore.

The Heath Steele study shows how revisiting historical mine data in a 3-D environment can generate new knowledge about an ore deposit and particularly the spatial context of features in a complexly deformed setting. This study is the first rigorous integration of the different layers of data available for Heath Steele in a 3-D stratigraphic model. The study also illustrates a useful workflow for handling, characterizing, and interrogating data sets available in mature and developing mining camps. Using a 3-D model gives explorationists an opportunity to validate interpretations with all available mine data and thereby make better-informed decisions about possible alternative interpretations, acquisition of new data, and identifying new targets. New software and tools being developed for such applications also will help to evaluate and reduce risk in target vectoring by attributing and mapping uncertainty measures, estimating spatial continuity and anisotropy of data, and integrating cross-validation experiments.

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