Study on 3D Visualization Modelling and Metallogenic Mechanism of the
Archean Blake River Group, Horne Mine, Québec

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Abstract. The 3D visualization technology integrates different data sources to establish a real and reliable geological model. It can not only display, rotate and cut geological objects at will, but also can perform logical operations and information query on geological bodies, providing a strong basis for mineral exploration. In this paper, MapGIS software is used to digitize the mining levelplans of Horne mine at various depths and obtain the grade data of AU and CU at orebody boundaries of each depth and 212864 mining sites. The three-dimensional model and attribute model of Horne mine are established by GOCAD software to analyze the main ore-forming hydrothermal faults and the original hydrothermal vent sites of Horne Mine, and then discuss the ore-forming model of Horne Mine.

Geological Survey of Horne Mine

The Horne Mine, Rouyn-Noranda, Quebec, exploited one of the largest volcanogenic massive sulfide (VMS) deposits of the world[1]. The Horne mine lies within the Horne Block, which is located in the southeastern corner of the Noranda Volcanic Complex (NVC) in the Canadian Shield[2]. The NVC consists of five volcanic cycles (cycles I to V) that young to the east, with each cycle consisting of an andesitic/basaltic lower unit and a bimodal, andesitic/basaltic and rhyolitic upper unit (Figure 1)[1,2]. The Noranda Cauldron is 15 km to 20 km area of synchronous volcanic subsidence, with Hunter Creek fault and Horne Creek fault in the north and south of the tectonic edge, respectively, Flavrian Pluton on the western edge, and Dalambert Shear/Dufault Pluton on the western and eastern edges, respectively. (Figure 1)[3].

![Figure 1. Noranda Volcanic Complex showing the location of VMS mines, major structural elements including the Horne Creek Fault (after Kerr and Gibson, 1993; Richard, 1998).](image-url)
Horne Creek and Andesite faults) (Figure 2)[4]. The Horne mine consists of three main ore bodies, namely, the Upper Horne (UH), the Lower Horne (LH) and the “No. 5 Zone” (Figure 3). The UH orebody extended from the surface to a mine depth of 395 meters, while the LH orebody extended from 365 meters to 945 meters[3]. The Horne mine yielded over 90% of the Horne mine production. The UH and LH ore bodies contain pyrite, pyrrhotite, with secondary numbers of chalcopyrite, magnetite, local sphalerite, and Au-Ag Telluride Minerals, the two orebodies have limited strike lengths (maximum 600 meters) and a subvertical plunge[3,4].

Figure 2. Perspective view of the Horne mine region, with the Horne Creek and Andesite faults. The surface traces and planes of the Horne Creek and Andesite faults define the Horne block. The Horne VMS sulfide body are shown in golden yellow color.

Figure 3. Longitudinal, vertical cross-section through the Horne mine, Upper H (UH) and Lower H (LH) massive sulfide lenses and the No5 Zone. View looking north. Isopach maps of Upper and Lower H are presented on the right (after Kerr and Mason, 1990).

Three-dimensional Modeling of Horne Deposits
Digital Horne Orebody Boundary and Internal Grade Data

In this paper, MapGIS, a general tool geographic information system developed by China University of Geosciences, is used to digitize 62 level plans at different depths and 1122 Stope plans of UH and LH deposit with interactive vectorization. First, the level plans is stored in the form of raster data, and after image processing and image fine correction, the line object is set up, and the digitized graph contains five types of lithologic profiles of massive sulfide, basalt, rhyolite, orthophyre and dike. Second, establishes the point object to collect the location of AU and CU sampling points and corresponding grade data in the level plans, so as to convert the ore body
boundary, grade point position and grade value into vector data[5]. Using the massive sulfide boundary vector line objects in each depth level plan as the orebody boundary, and selecting three times Bizer interpolation to smooth the process, finally, get different depths and parallel to each of Ore body boundary object (UH mine boundary of 32, LH mine Boundary of 30), and AU and CU sampling point grade data of 223,843 each were obtained.

Constructing Three-dimensional Model of Horne Orebody

In this paper, GOCAD software is adopted to conduct 3D modeling by using the boundary data line object and large amount of grade data obtained after digitization. In the Gocad software, the Delaunay triangulation algorithm is adopted to build the boundary Surface object of the ore body, which ensures the smoothness and authenticity of the built Surface. The parallel UH and LH boundaries are connected in the order of depth, GOCAD uses the Delaunay triangulation method to construct a triangular grid between the adjacent boundary lines, respectively, to obtain the boundary surface of the UH and LH orebody (Figure 4).

Gocad uses the discrete Smooth interpolation method (DSI) as the core technology to interpolate the data control points within the specified space range and finally obtain the block model. Firstly, according to the three-dimensional space position of AU and CU grade sampling points, the point object of sampling point is established, and the AU and CU grade values corresponding to each sampling point are used as the attribute import point object; According to the obtained UH and LH boundary surface and the grade sampling point location, the interpolation spatial range cubes of UH and LH were respectively defined (Figure 5).

Figure 4. The construction process of UH and LH orebody boundaries. outlines of each elevation (inset A), orebody surface (inset B).

Figure 5. Based on the three-dimensional space position and the CU grade value of the sampling point, defines the interpolation space range, obtains the CU cubic block model using the discrete smoothing interpolation method (inset A). Defines the interpolation space range based on the three-dimensional space position and the AU grade value of the sampling point. Obtaining the AU cubic block model using the discrete smoothing interpolation method (inset B).
The cubic volume of interpolated spatial range shall be ensured to be the minimum including ore body boundary and sampling points. The cubic of each side is divided into 50 parts, so, the cubic is divided into a total of 125,000 (50*50*50) of the same size grid cell. In the cubic, the AU and CU grade attribute value is the control point, using the discrete smooth interpolation method (DSI) to interpolate, respectively, to obtain the UH and LH, AU and CU cubic block model (Figure 5). The established UH and LH boundary surface was used to shear the cubic block model of AU and CU, and the block model of UH and LH were obtained respectively (Figure 6).

Figure 6. Cut the cubic block model with the block refined by orebody surface, obtain Horne CU block model.

Metallogenic Model

The UH and the LH orebodies and the No. 5 Zone are interpreted to have formed in a paleo-graben on the margin of a submarine rhyolitic edifice dominated by lava flows and related volcaniclastic deposits (Kerr and Mason, 1990; Barrett et al., 1991; Cattalani et al., 1993; Kerr and Gibson, 1993)[1]. Unlike most intracauldron VMS deposits that are interpreted to have formed by exhalation and precipitation of sulfides at and near the seafloor, the Horne deposit is interpreted to have formed primarily beneath the seafloor by replacement of permeable rhyolitic fragmental rocks that in-filled the paleo-graben (Kerr and Mason, 1990; Gibson and Kerr, 1990; Kerr and Gibson, 1993)[1,3]. As shown in Fig. 7 (inset A), the original metallogenic form of the Horne mine is flat, and the current erosion surface shows that the Horne mine is rotated to the seabed where it was originally formed[5]. The LH and UH orebodies are stratabound, but non-stratiform, deposits that are co-eval and co-stratigraphic but formed in two separate hydrothermal vent sites on the seafloor.[1] According to the Horne CU block model, the CU enrichment region of the Horne mine was obtained by selecting the CU grade value greater than 10%, and the CU enrichment area was inferred as the original hydrothermal vent sites. The rising hydrothermal fluids (evolved seawater) underwent sub-surface cooling due to mixing with down-drawn seawater. This resulted in the formation of a pervasive sericite-quartz-(Mg-chlorite) alteration assemblage in which the K, Si, and Mg were derived primarily from seawater (MacLean and Hoy, 1991)[6]. The Venting occurred in many highly permeable layers of sedimentary breccia that floored the subsidence structure, but is particularly concentrated in the intersected transverse faults across the axis of the graben[1]. At the end of the mineral formation, the Horne Mine formed today's UH and LH morphology followed by eastward rotation of regional compression (Figure 7. (inset B)).
As shown in the Figure 8, According to the distribution location of the Horne mine, the attribute model and the CU enrichment area, therefore, it can be initially deduced that there have a main fracture between the UH and LH, which divides the Horne mine into the UH and LH. Price (1949) observed that F2, Kerr and Mason (1990) speculated that the positions of F1 and F2 were asymmetrical paleo-graben boundaries[6]. Using the Horne block model, the CU enrichment area of the Horne Mine is observed adjacent to the asymmetric paleograben boundary (Figure 8).

Thus, the extraordinary size of the Horne deposit reflects its location in an area of high heat flow and well developed cross-stratal permeability that favored sustained and long-lived discharge (Gibson and Kerr, 1993)[1]. The final factor that likely contributed to the large size of the Horne deposit is its location along a major synvolcanic fault (the Horne Creek Fault) that defines the southern structural boundary of the Noranda Cauldron (Figure 1), which provides long-term, structurally consistent conditions for the discharge and permeability control of hydrothermal fluids[3]. The length of Horne's hydrothermal system also facilitates the formation of a large number of sulfides, while most of the sulfide mines in the seabed help to form the metal ore-controlling mechanism of the Horne mine[1,3]. Syngenetic sedimentation is an factor in the formation and preservation of large VMS and the location of the Horne mine in the ancient graben can help preserve it. The Horne mine also benefited from its location outside the Noranda Cauldron, where the hydrothermal discharge was not wiped out by interruption or overlap[1].

**Discussion and Summary**

The Horne mine is one of the largest volcanic-type massive sulfide mines (VMS) in the world. Through the Interactive Vectorization method, the level plan and stope plan of Horne mine are digitized. Through the GOCAD three-dimensional modeling software, by using the digitized boundary line and grade data points, constructed the three-dimensional model of the ore body block. By controlling the display mode of CU grade value in Horne CU block model (1%-10%), the original hydrothermal vent sites and main fracture is inferred. The previous research on the
metallogenic model of the Horne mine is further proved. That is, the hydrothermal fluid and the lower circulating cold seawater mixing bring down the temperature, and massive sulfide is formed by alteration of volcanic clastic rock under the seabed along the palaeo-fissure. The establishment of three dimensional model of the Horne deposit plays an important role in the in-depth study of the mineralization mechanism of volcanic block sulfide (VMS).

References


