Multidimensional Spatial Modeling of the May Day Mine Waste Pile, Silverton, Colorado

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ABSTRACT

Integration and synthesis of mine-site topography, geophysical, and geochemical data yields both two-dimensional and three-dimensional perspective models for the May Day mine located in the Cement Creek drainage near Silverton, Colorado. Induced polarization, geophysical data are spatially registered with geochemical data acquired from drill hole cuttings that are contoured in three-dimensional space, thereby permitting determination of the most metalliferous and sulfur rich zones of a waste pile. This spatial modeling application was developed to be a visually intuitive tool to aid in mine waste reclamation.

INTRODUCTION

There are currently about 47,000 past producing hard rock mines located mainly in the western U.S. (Ferderer, 1996) that potentially impact local water quality and that are possible candidates for abandoned mine lands reclamation by state and federal agencies. Mine waste characterization is an important aspect of this complex task and a simple, visually intuitive mine waste model is, in turn, an integral part of the mine waste characterization process. Two and three-dimensional modeling of mine wastes provides visual information that scientists and land managers can use to assess the economic and environmental pros and cons of either: (1) remediating a mine site, (2) leaving a site undisturbed, or (3) re-mining a site for unprocessed ore. Eventually, spatial models that integrate all available data for the most problematic sites will be used to evaluate the cumulative impact for an entire watershed.

The May Day waste pile was selected for spatial modeling in this study because: (1) the field leach test (Hageman and Briggs, this volume) was used to identify the waste pile as a potential acid and metals producer, (2) the drill core data is available, and (3) the Bureau of Land Management has targeted the May Day mine for remediation. The geochemical information acquired from mine wastes in abandoned mine lands studies is predominately from samples collected near the first few centimeters of a waste pile surface. Available drill hole data for the May Day waste pile made it possible to geochemically analyze the core and "view" the geochemical characteristics inside the pile to depths of approximately 5 meters.

GEOLOGIC SETTING AND MINERALOGY OF THE MAY DAY MINE

The study area is located in the southwestern part of the San Juan Volcanic Field, where Tertiary volcanics blanket Paleozoic and Mesozoic sedimentary rocks and a Precambrian crystalline basement (Steven, et al., 1974). The May Day Mine is located north of Silverton, Colorado, in the Cement Creek drainage near Topeka Gulch (Fig. 1). The mine is hosted in Silverton Volcanic Series (SVS) lavas. The SVS lavas have been regionally propylitically altered by hydrothermal activity that is associated with Tertiary, volcano-tectonic and caldera forming events (Burbank and Luedke, 1969). Quartz, incipiently altered feldspars, chlorite, epidote, opaque oxides, ± calcite, and ± pyrite comprise the propylitic assemblage. The mine was apparently, only an exploratory prospect. The May Day mine tunnel appears (based on field mapping by the authors) to have been constructed to access weakly mineralized, northeast-southwest trending veins (Fig. 2). X-ray diffraction analysis of surface samples detected the presence of quartz (> 5 weight percent) with minor amounts (≤ 5 weight percent) of muscovite, jarosite, orthoclase, sphalerite, clinochlore, and pyrophyllite (Sutley, 1999, U.S. Geological Survey, unpublished data).

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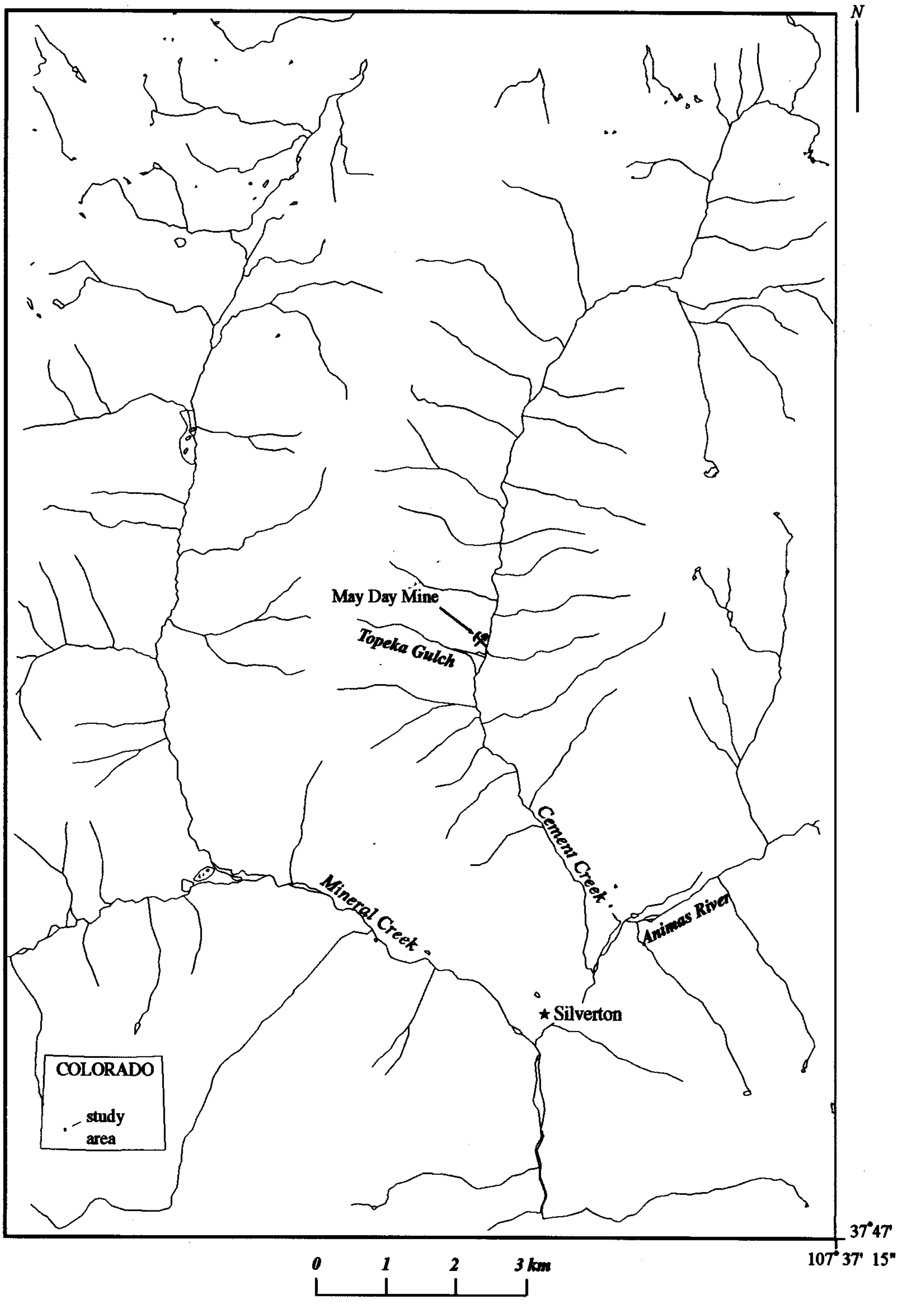

Figure 1 Drainage network for part of the upper Animas River watershed and location of the May Day mine (pick and shovel symbol) and town of Silverton (star symbol).

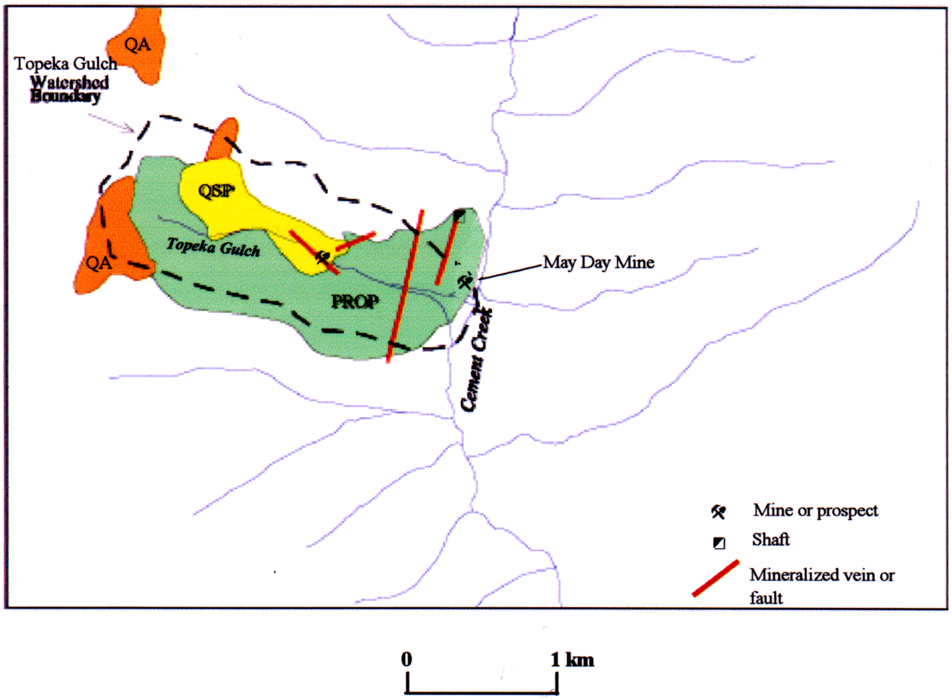

Figure 2 Generalized alteration map (by the authors) for the Topeka Gulch sub-watershed. Alteration assemblages include: (1) PROP (propylitic) chlorite, epidote, +/- calcite, +/- pyrite, opaque oxides, (2) Q-S-P quartz-sericite-pyrite, and (3) QA quartz, alunite.

X-ray diffraction analysis of drill hole cuttings from a sample with high metal concentrations from the northern part of the pile detected the presence of major amounts of sphalerite, and minor to trace amounts of plumbojarosite, quartz, gypsum, galena, muscovite, anglesite, and sericite (Stanton and Campbell, this volume). X-Ray diffraction of heavy mineral concentrates detected the presence of pyrite, galena coated with anglesite, ferberite and barite (Desborough, et al., 1999).

TWO- AND THREE-DIMENSIONAL MODELING

Methods

The mine waste pile is constructed as a series of three benches, which provide a stable platform for drill-core sampling. Six holes were drilled and continuous core sampled through the May Day waste pile in the summer of 1997. Four holes were drilled in the upper bench, and one hole in each of the middle and lower benches. Drill core splits were collected at one-foot intervals and analyzed by 40-element inductively coupled plasma (ICP) at XRAL laboratories, Canada.

Compaction corrected, drill hole geochemical data coordinates and corresponding x-y- and z-topographic surface coordinates (Hein and Fitterman, 1998) were integrated in the spatial modeling software Earth Vision[2], to construct a three-dimensional grid for the mine-site surface and subsurface (Figure 3). These geochemical grids, or contour models, are generated using a minimum tension gridding algorithm. A top-conformal gridding routine was used to map the three-dimensional block of geochemical data to the actual three-dimensional topographic profile of the waste pile. The top-conformal gridding successfully mimicked the bench and slope aspect of the waste pile surface. Ideally, a bottom-conformal grid is used to force gridding to occur above a lower bounding surface, such as bedrock. However, a bottom-conformal routine could not be used because only one drill hole pierced through the entire waste pile and the bedrock morphology could not be constrained. Three-dimensional grids in Earth Vision were rotated to view multiple perspectives.

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[2] Any use of trade names, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey.

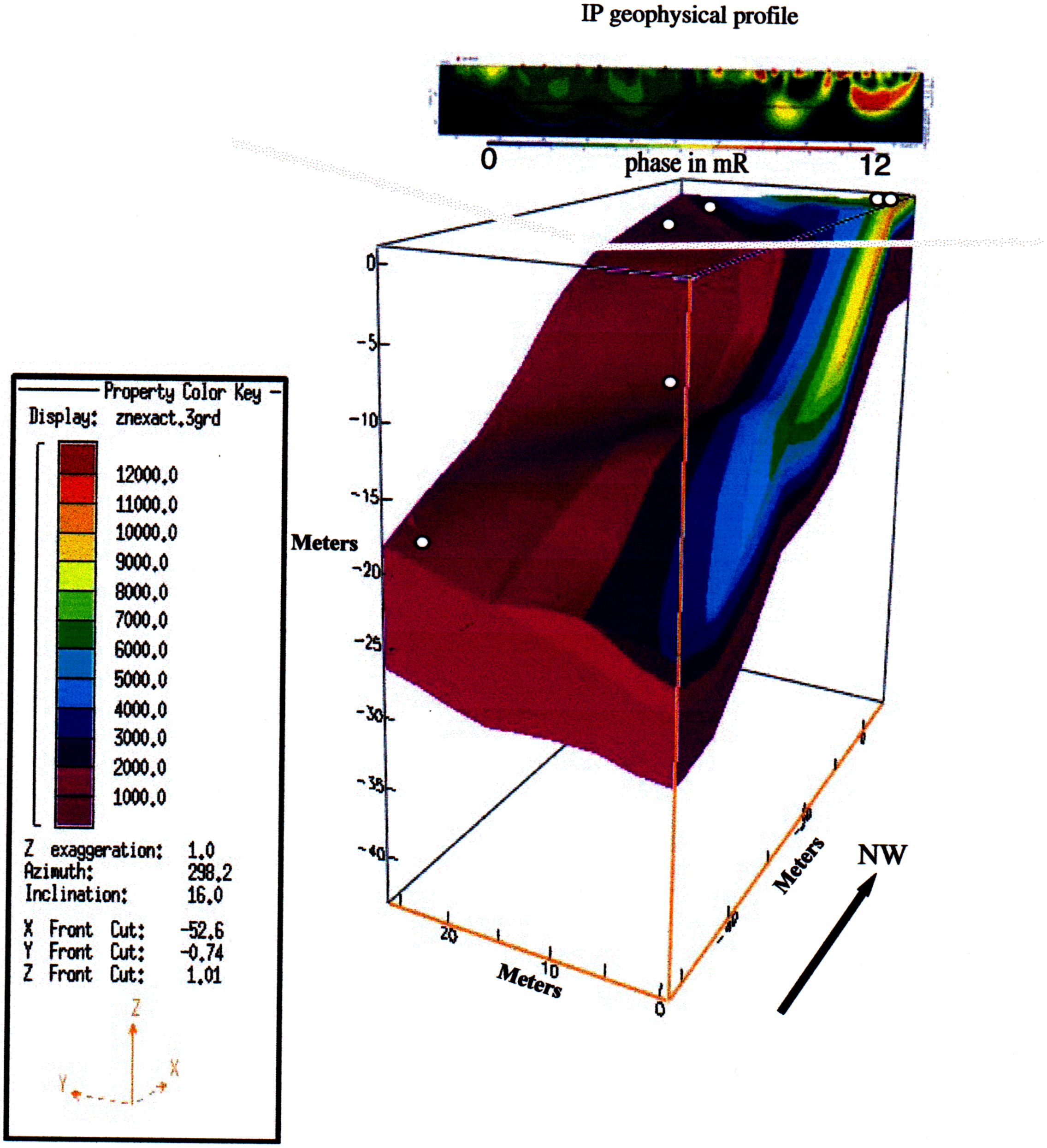

Figure 3 Synthesis of 2-dimensional topographic data, three-dimensional, geochemical gridded data for Zn (ppm) and geophysical induced polarization profile for the May Day mine. Note that high concentrations of zinc in the upper right (northern) part of the pile coincide with a relatively high IP (10 milliradian) signal (red area on right side of upper image, color version in back of this volume). Zinc alone is not responsible for the relatively high IP signal in the northern part of the pile. Therefore, other sulfide minerals such as minor to trace amounts of pyrite and galena may be responsible for the relatively higher IP signal. White line across the face of the upper bench indicates the approximate IP profile location. Drill hole locations indicated by open circles.

The various views were sliced to produce three-dimensional cross section models of the geochemical grids and to test for correspondence between model values and drill-hole geochemical values. Finally, the three-dimensional geochemical models were co-registered with 2-dimensional profiles of geophysical induced polarization (IP) data using desktop image analysis software. IP is used to measure the rates at which electrical charges build up in the ground when a voltage is applied (Campbell and Fitterman, this volume). This technique measures apparent resistivity and is successfully used to identify disseminated sulfides (Dobrin, 1976). In addition, IP provides information about the chargeability at the mineral pore-water interface, with sulfides causing a higher charge than non-sulfide minerals. The geochemical and mineralogical composition of the interior of the pile was evaluated to aid in the interpretation of IP geophysical signatures acquired (Campbell and Fitterman, this volume).

Results

The geochemical modeling routine successfully identified high concentrations of zinc (two weight percent) and sulfur (nine weight percent) near the northern part of the pile. This result is consistent with the presence of major amounts of sphalerite and minor amounts of plumbojarosite, gypsum, galena, and anglesite identified by X-ray diffraction in this part of the pile. In addition, elevated concentrations of lead (30,000 ppm), copper (4,600 ppm), and arsenic (670 ppm) were found to occur in the northern part of the pile. In contrast, geochemical contour grids show lower concentrations of metals and sulfur on the middle and lower benches. This is consistent with the predominance of weakly mineralized waste rock and propylitized volcanic host rock at the base of the pile.

Registration of the three-dimensional geochemical models with two-dimensional profiles of geophysical induced polarization data shows that the relatively higher IP signals (10 milliradians) for the northern part of the waste pile are consistent with the presence of sulfides other than sphalerite (Campbell and Fitterman, this volume). Therefore, the galena or minor amounts of pyrite, observed in heavy mineral concentrates, may be effecting the IP response.

CONCLUSIONS

Geophysical responses of rocks at a particular location at depth within a waste pile are inferred but not directly measured by such methods as induced polarization (Campbell and Fitterman, this volume). Drill core data and geochemical sampling are used to enhance the information at a known point. The geochemical gridding, or contour modeling, minimum-tension gridding algorithm used in this study successfully combined all available information to interpolate between sample locations. Integration of three-dimensional waste pile surface data with three-dimensional contour models generated from geochemical concentration data creates a realistic picture that enables the visualization of the spatial relationships of metal or sulfur concentrations (Figure 3). A greater understanding of acid mine drainage will be gleaned as we continue to develop and implement strategies that use three-dimensional modeling and geographical information systems to view and interpret data to aid in characterizing a mine-waste site.

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REFERENCES

Burbank, W. S., and Luedke, R. G, and 1969. Geology and ore deposits of the Eureka and adjoining districts San Juan San Juan Mountains, Colorado. U.S. Geological Survey Professional Paper 535, 73 p.

Desborough, G. Leinz, R., Smith, K., Hageman, P., Fey, D., and Nash, T., 1999. Acid generation and metal mobility of some metal-mining related wastes in Colorado. U.S. Geological Survey Open-File Report, 99-322, 18 p.

Dobrin, M. B., 1976. *Introduction to geophysical prospecting*. McGraw-Hill, Inc., p. 608-661.

Ferderer, D. A., 1996. National overview of abandoned mine land sites utilizing the minerals availability system (MAS) and geographic information system (GIS) technology. U.S. Geological Survey, Open-File Report 96-549.

Hein, A. S., and Fitterman, D. V., 1998. Topographic surveys of selected mine dumps near Silverton, and Leadville, Colorado. U. S. Geological Survey Open-File Report, 98-588.

Steven, T. A., Lipman, P. W., Hail, W. J. Jr., Barker, F., Luedke, R. G., 1974. Geologic Map of the Durango Quadrangle, Southwestern Colorado. U.S. Geological Survey Miscellaneous Investigation Series, I-764.