Surface Exploration Mapping at the Getchell Mine, Humboldt County, Nevada, Using GeoMapper/PenMapper, a Real-Time Digital System

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Introduction

In the summer and fall of 2000, the GeoMapper/PenMapper digital mapping system was successfully tested at the Getchell Mine, and finally used as an essential tool for detailed surface geologic mapping of the resource area proximal to the underground development. The mine was acquired by Placer Dome Corporation in 1999 and is now under development, leading to an expected production start between 2003 and 2005. As at the end of 2000, the Getchell measured and indicated resource was 23.1 Mt of ore at 12.8 g/t Au avg. grade (6.86 g/t Au cut-off) or 9.49 Moz Au (Placer Dome Annual Report, 2000). Exploration work has identified a global resource of 15 Moz Au, and the Getchell deposit ranks among the top five Carlin-type gold deposits in grade and contained ounces (Howald and others, 2000).

The GeoMapper, developed by George Brimhall and Abel Vanegas of Earth Resources, at UC Berkley, was designed to incorporate the same logic used by geologists to map with the same feel of traditional paper mapping. This paper summarizes the results of the testing of the new digital mapping technology for exploration and mining geology, with emphasis on the geologic benefits of real time digital mapping, from the point of view of a traditional paper mapper.

Summary of the geology of the mapped area

The detailed geologic mapping at Getchell during the testing period encompasses an area of very complicated geology, located above the North Mine Extension ore bodies, extending west to the Getchell Fault and east to cover the Etchart Hill. This is a good scenario to evaluate the GeoMapper/PenMapper system in the complex conditions that characterize mining districts. The mapped area is comprised of highly deformed upper plate lithologies of the Ordovician Valmy Formation, overlain by gently folded carbonates of the Pennsylvanian–Permian Etchart Formation. These rocks are intruded by altered dikes of Cretaceous age, associated with the Osgood stock. Several phases of compressional and extensional high angle and low angle faulting have displaced all of the lithologies, and acted locally as hydrothermal fluid pathways for Carlin-type gold mineralization. At the surface, the digital-mapping program successfully delineated the main structural features that control the hydrothermal alteration and mineralization associated with the N-Zone and 148 high-grade gold mineralization. As far as we know, the resulting map at 1:2,400 scale is
the first real-time digital map made in the US on a production scale, for exploration and mining purposes.

**Stratigraphy**

The Ordovician Valmy Formation is host to the low-grade oxide mineralization previously mined in the Valmy and Turquoise ridge pits, and consists of imbricated thrust sheets of siliceous and volcanic rocks of basaltic composition. The Pennsylvanian – Permian Etchart Formation is unconformably deposited on the upper basalt of the Valmy Formation. It is represented by the lowest member, which is composed predominantly of limestone with interbedded clastic carbonates. These rocks are intruded by altered diorite and dacite porphyry dikes of Cretaceous age, associated with the Osgood stock and usually aligned along NW trending extensional fault zones.

**Structure**

The general structural environment of the upper plate rocks hosting the oxide gold mineralization is very complex and includes at least two generations of readily mappable folds cut by reactivated high angle and low angle fault zones.

**Folding**

The first folding event, coeval with the Mississippian to Devonian Antler orogeny, consists of large scale to several feet amplitude gently inclined to recumbent F₁ folds, accompanied by development of axial-planar S₁ foliation that is subparallel to S₀ bedding. Measurements of B₁ fold axes and crenulation lineations show that the F₁ fold hinges plunge gently to the NNE. These older folds were refolded, probably during the Mesozoic thrusting event, forming open, upright, NE-trending F₂ folds with a moderate to locally strongly developed axial fracture set. The bulk of the oxide mineralization in the Turquoise Ridge and Valmy pits is located at the intersection of the N-S-trending fault zones and northeast trending F₂ folds, with permeability controlled by doming and axial plane faulting. The cumulated fracture controlled permeability generated by the intersection of these two structures created a favorable environment for gold deposition. The overall mineral trend follows a NNE-striking and gently NNE-plunging synform, which is flanked on the east by the Valmy Hill anticlinorium. The hinge zone of the anticlinorium was intersected at the surface in a NW-trending trench, completed on the eastern colluviated slope of the Valmy Hill. The NE-trending hinge zone affecting the siliceous siltstone and mudstone of the lower Valmy Formation is about 1,600 feet wide and is marked by the presence of systematically spaced smaller anticlines and synclines (Figure 1). These second-order folds can change abruptly in size and form, depending on rock type and faulting, locally enhancing the general permeability of the hinge zone. Measurements of fold axes and information from a “great circle”
stereographic projection across the trench, show that the fold hinge of the anticlinorium plunges very gently to the NE (N-26° to 30° E). At the surface the hinge zone shows moderate to strong hydrothermal alteration, and is anomalous in trace elements and gold.

Faulting
Four major sets of high angle fault zones, which control the strongest hydrothermal alteration and associated gold mineralization, were delineated at the surface. Low angle thrust faults are also present, bounding some of the exposed lithologic units. All faults were reactivated, showing at least two stages of movement (pre and post mineralization). The following high-angle fault zones were mapped:

- The north-trending (NNW to NNE) and west dipping EM, BBT, N Shear, Valmy, and Jasperoid extensional feeder zones, interpreted as antithetic to the Getchell Fault, located at the west margin of the mapped area. Most of the oxide mineralization was located in the hanging wall zone of these dip-slip faults. The footwall zone appears to be only anomalous in Au, but is affected by strong argillization and local silicification including jasperoidal breccias. Along the strike, these faults are locally intruded by argillized, dioritic dikes.
- The N 25° to 30° E trending and NW dipping T3 extensional fault zone, and the associated TR footwall zone of alteration and mineralization, exposed in the Turquoise Ridge oxide pit.
- The N 40° to 45° E trending and NW dipping T5 and T6 faults. These poorly exposed structural zones appear to be extensionally reactivated thrust faults, which represent structural contacts between siliceous sediments, and overlaying massive basalt flows and mafic volcanoclastics. Alteration is dominated by strong silicification, including jasperoids, especially near intersections with N-S and NNE trending faults.
- NW trending and nearly vertical faults are less developed than the previous structures, but when present, are associated with strong alteration and locally argillized Cretaceous dikes.

The coexistence of dip-slip and strike-slip motions on the exposed high-angle mineralized faults suggest that these faults are rotational. Accommodation and transfer zones are present in the mapped area and are characterized by dense fracture networks, enhancing the permeability of the reactive lithologies.

A computer stereonet analysis of intersection lineations of all faults measured during the mapping of the oxide pits shows these lineations are concentrated along a NNE-trending and WNW plunging plane of maximum intersections. Within this plane of maximum theoretical fault controlled permeability, the maximum concentration of lineation intersections plunges gently NNE, subparallel with the Turquoise Ridge–Valmy oxide mineral trend. This can be visualized as shoots that have bearings and plunges as indicated in the fault intersection stereonet. This method of analysis was
applied to actual, known ore shoots, and the results suggest that it might be predictive of intersection-controlled ore trends.

**Alteration and mineralization**

Hydrothermal alteration, mineralization and oxidation, potentially associated with Carlin-type systems, are moderate to strong overall, and are mostly present along the NNE alignment of oxide pits, major high-angle feeder faults, and along the hinge zone of the Valmy anticlinorium. Gold related hydrothermal alteration includes silicification, argillization, carbonate removal, jasperoid formation, carbon remobilization, pyritization, quartz and calcite veining. Most of the anomalous samples collected during mapping were from breccia zones affected by silicification, decalcification / argillization + moderate to strong hematite / limonite, +/- quartz veining.

The Turquoise Ridge – Valmy Hill pits were mined for low-grade oxide ore, and produced about 16,000 oz Au grading 0.04 opt Au (Chevillon et al., 2000). Based on the relationship between faulting and the distribution of the ore zones delineated on bench maps, it appears that the major ore controlling feeder structures are the long-lived north trending (N-S to NNE), west dipping high-angle fault zones which are exposed in the oxide pits. Most of the ore zones are localized at the intersections of these faults with focused NE “structural features” such as fractures/minor faults, fold hinges, bedding and foliation.

The reactive, sandy carbonates forming the base of the lower Etchart Formation, exposed in the northern part of the mapped area, are affected by contact metamorphic recrystallization as well as epithermal-type hydrothermal alteration, probably related with the later Tertiary gold event at Getchell. This alteration consists of jasperoidal silicification, decalcification, hydrothermal karst, bleaching and carbon removal, and strong calcite veining. Locally the exposed altered rocks are anomalous in gold and trace elements.

**Technology used for digital mapping**

In order to generate a high-resolution digital geological map and to carry out real time analysis, the following technology was used:
- Field portable Fujitsu Stylistic 2300 (233 MHz Pentium microprocessor, 4 GB Hard disk, 32 MB RAM) with touch sensitive screen and pen mouse.
- PenMap and GeoMapper software.
- Daylight SunScreen for mapping in direct sunlight.
- Trimble Ag GPS 132 with OMNISTAR correction for sub-meter location accuracy.
- Trimble GPS Total Station 4700 for sub-centimeter location accuracy.
Handheld Atlanta Laser Rangefinder (limited use at Getchell because of good access to exposures).

It is important to note that this 1999 technology is rapidly evolving and is becoming increasingly compact, less cumbersome and more cost effective.

**Geologic benefits of the real-time digital mapping**

The geologic benefits of the digital map generated at Getchell are presented in conjunction with the three basic elements necessary for a useful geologic map for mineral exploration: location, geology (lithology, structure, alteration and mineralization), and spatial, 3-D relationships. These benefits are clearly apparent when we examine the actual geologic map produced in the field, using this technology. The benefits to the geologist are:

- Digital mapping can be done in the field, in real-time, as is normally done on paper maps, using an electronic field clipboard with all geologic information (lithology, structure, alteration, mineralization, etc) accessible with a touch of the screen.
- Precise georeferenced location in the field in real-time.
- The geologist is free to focus on geology, not location control.
- Perfect base map control, as mining and exploration alter geologic exposures (no need for an updated map or airphoto).
- Precise and accurate correlation of faults and feeder structures in real time.
- 3D geometrical analysis of large-scale folds with centimeter accuracy readings.
- The ability to use overlays for mapping (e.g. alteration, lithology, sampling, etc.) and integrate fieldwork with evaluation of existing maps (e.g. GIS geochemistry, geophysics, airphoto, satellite imagery, etc.) in real time to maximize quality.
- The accurate delineation of intrusive trends by detailed float mapping, guided by airmag and photo linear overlays in real time.
- Mapping of inaccessible geologic features such as faults and lithologic contacts on the pit benches is made easier, by using a handheld laser Rangefinder tied to survey points (Laser Gun Mapping).
- Mapping is possible on bad weather days with lower temperatures, windy conditions, light rain, and snow.
- Total technical control of the quality of the map, creating digital geologic information in one step (no intermediaries, less cost and time).
- The map can be completed, printed, and GIS files delivered on a daily basis, with all data recorded in digital format.
- Excellent learning tool for geologic mapping, even geologists with minimal computer and GIS training.
Conclusions

- GeoMapper was successfully tested at Getchell and finally used as an essential tool for surface geologic mapping.
- We now plan to expand the use of digital geologic mapping at our other mines and exploration projects. Perhaps the most appropriate places to initiate the use of real-time digital mapping are in mine pits, where the faces change every day, and in project areas where precise and accurate structural mapping is critical for understanding the ore controlling features.

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Figure Captions

Figure 1. Example of the GeoMapper screen showing a portion of the real-time digital map off the Valmy Hill area, at Getchell. The lower hemisphere stereographic projection represents pole to S0/S1, and the orientation of the Valmy Hill anticlinorium within the siliceous rocks of the Ordovician Valmy Formation exposed in a northwest trending trench.

References:


Placer Dome Inc., 2000, Annual and Special Meeting of the Shareholders of Place Dome Inc.
