

3D Geochemical and Mineralogical Model of the Sleeper Low Sulphidation Gold System, Nevada, U.S.A.

INTRODUCTION

Hydrothermal mineral systems, including low sulphidation gold systems in Nevada, are often zoned geochemically and mineralogically. This zonation creates the opportunity to use relationships in surface and drill-hole data to vector from the periphery of a mineralized system to the location of undiscovered ore within the system. Two analytical developments have made it possible to acquire the type of data needed to define these zonation relationships: 1) the inductively coupled plasma mass spectrometer spectrometer (ICP-MS), which provides inexpensive, multi-element data with low detection limits, and 2) the analytical spectral device (ASD), capable of

identifying and estimating relative abundance of clay and other alteration minerals. The interpretation of these types of data, in excess of 60 variables, is facilitated by interpolating element or mineral distributions among drill holes using 3D gridding techniques to create 3D block models. In this form, data relationships and spatial patterns can be fully explored using 3D visualization exploration tools. Gocad 3D pattern recognition software provides a way to identify and illustrate zonation characteristics and to develop targeting vector criteria. The display of these features in relation to modeled and integrated 3D geology (lithologies, faults), 3D bodies generated from inversion of geophysical data, and surface data can further aid in identifying new exploration targets. An example of the wealth of information that can be derived from data modeling and 3D visualization is presented using data from the Sleeper deposit located in Nevada, U.S.A.

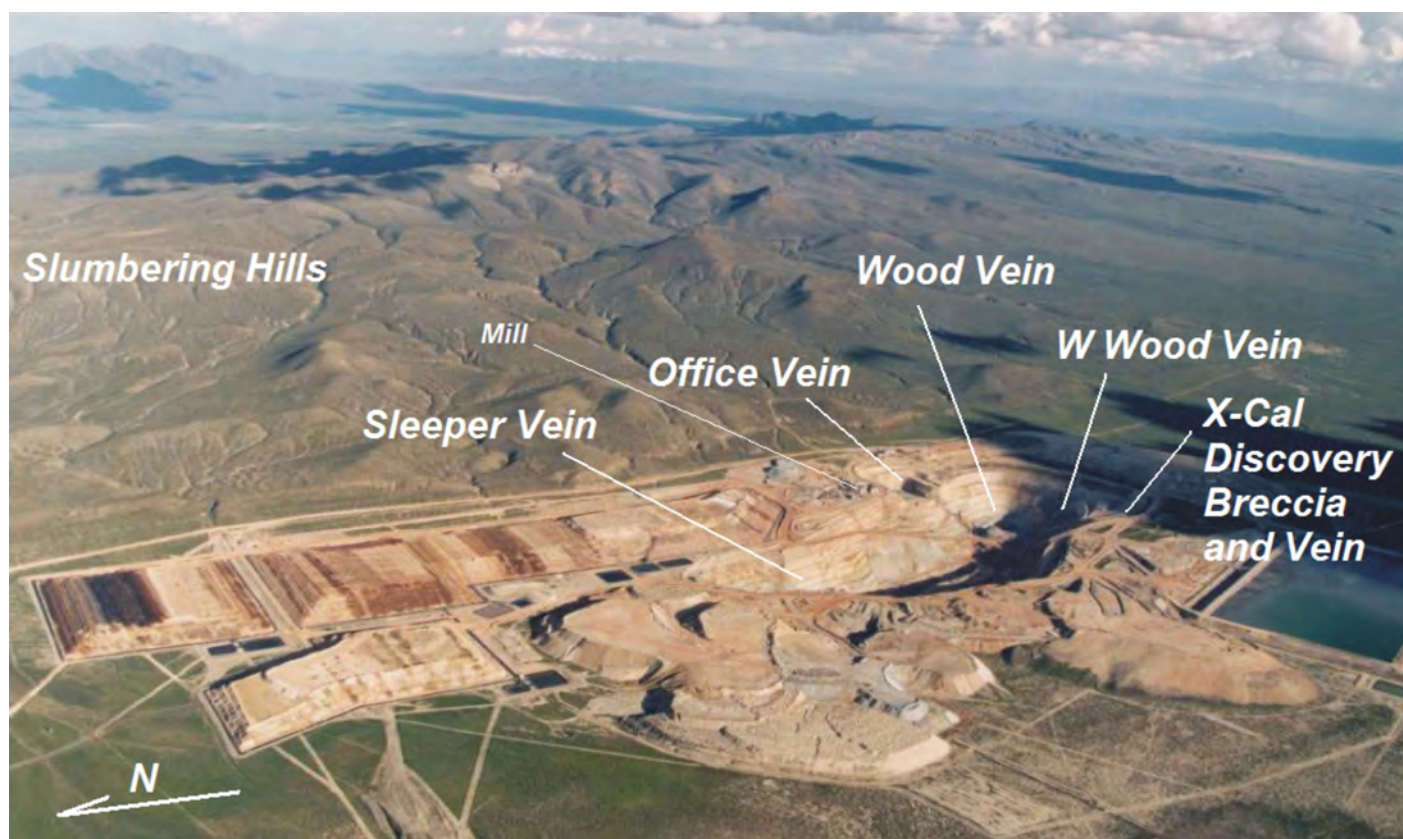


Figure 1. Areal view of the Sleeper open pit looking SE along the Cortez Gold trend of Nevada, U.S.A.

The Sleeper deposit is a low sulfidation, bonanza gold vein ore body enveloped by bulk tonnage, low grade disseminated gold ore (Wood & Hamilton 1991; Nash & Trudel 1994; Nash et al. 1995). It was a shallow, Nevada range-front, pediment discovery drilled by Amax in 1984 (Wood & Hamilton 1991). Open pit mining took place from 1986 to 1996, originally centered on the Sleeper Vein itself. Successful exploration lead to the discoveries of the Wood, Office, and West Wood Veins and the open pit was expanded to mine those ore bodies (Thomason et al. 2006, Wood & Hamilton 1991) (Fig. 1). Recorded mine production was 1.682 M oz Au, 2.8 M oz Ag (Thomason et al. 2006).

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In 1996 X-Cal Resources Ltd. (X-Cal) optioned the property from Amax, combined it with their contiguous land holdings, and began exploration for additional mineralization related to the Sleeper gold system (Thomason et al. 2006). X-Cal drilled the X-Cal Discovery Breccia just outside the SW end of the pit (Fig. 1). A 2004 to early 2006 exploration joint venture of the property produced a large volume of exploration data that has recently been integrated and synthesized with the past mine data in 3D, utilizing Gocad pattern recognition software.

Datasets include: Au and Ag data from historic mine and recent exploration drill-holes; new multi-element, low detection ICP-MS data and spectral reflectance (ASD) mineralogical data on select holes; geophysical surveys (detailed air magnetics, pre-mine IP, CSAMT, gravity), and surface geochemistry (rocks, soils, soil gas). The 3D modeling provides new insight into the Sleeper deposit, mineralization controls, alteration patterns and exploration potential. This paper presents a refined geologic framework for the Sleeper system and newly recognized multi element and alteration mineral zoning patterns related to gold mineralization.

ACKNOWLEDGEMENTS

Shawn Kennedy, President of X-Cal, is the force behind the Sleeper District exploration with his vision to fully realize the gold potential of the Sleeper district with the development of multiple open pits within the range-front pediment. He has assembled a team of experienced consultants whose observations, interpretations, and ideas have significantly contributed to the current understanding of the system. These include geologists, Dr. Ken Snyder, Robert Thomason, Winthrop Rowe, Larry Martin, Larry Kornze, Keith Blair, and geophysicist, Jim Wright. Dr. Richard Sillitoe and Dr. Jeffrey Hedenquist provided key insights and interpretations with respect to the geology and mineral potential based on site visits to the property.

LOCATION

The Sleeper deposit is located 51 miles by road, NNW of the town of Winnemucca in Humboldt County, central Nevada, U.S.A. (Lat. 41.336, Long. -118.051) on a NW extension of the Eureka, Cortez, Battle Mountain gold trend (Fig. 2).

GEOLOGY

Principle host rocks of the Sleeper veins are Sleeper rhyolite interbedded with volcanoclastic rocks deposited in a fault controlled basin along the range-front (Wood & Hamilton 1991; Nash & Trudel 1994; Nash et al. 1995). These rocks are part of a Miocene bimodal volcanic sequence dated at 16.5 Ma with mineralization and alteration in the range 14-16.5 Ma (Conrad et al. 1993). The Sleeper rhyolite has been interpreted as a flow dome complex (Conrad et al. 1993; Nash et al. 1995). A more recent interpretation based on logging of new holes and re-logging of past holes is that the Sleeper rhyolite is either

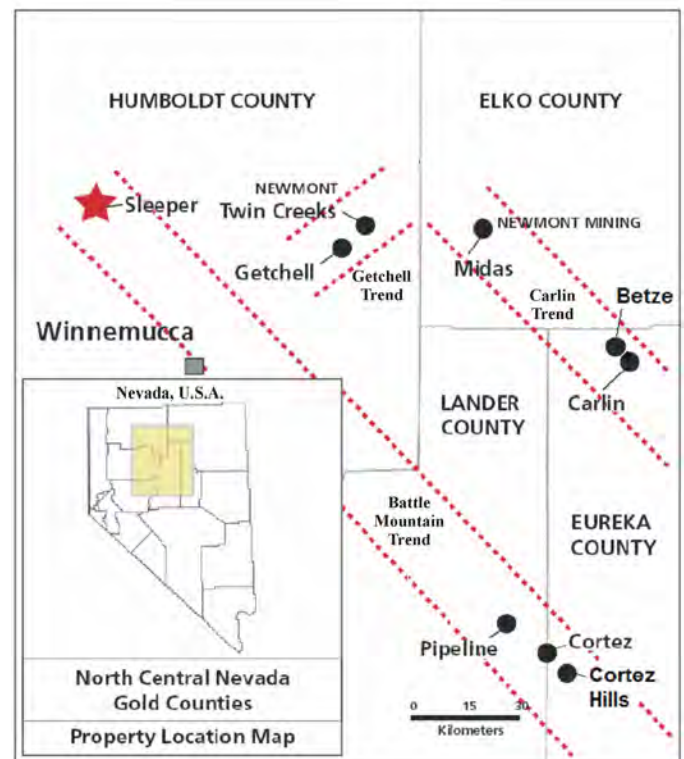


Figure 2. Location of the Sleeper Deposit in Nevada, U.S.A.

a sill or an intrusive cryptodome complex (laccolith-like) within tuffaceous rhyolites (Sillitoe 2006). Metamorphic basement rocks of the Upper Triassic and Jurassic Auld Land Syne Group (Wilden, 1964) are present beneath the volcanic sequence and are locally mineralized.

A distinctive mafic marker unit (pillow basalt) in the Miocene sequence is present beneath the Sleeper Rhyolite. Offsets on this contact provide evidence of the basin faults and recurrent faulting which controlled gold mineralization. Previous recognition of abundant and systematic relief on the hanging wall (HW) contact surface of the mafic marker unit (early cross sections of Oviedo 1998; Nash & Trudel 1994; Nash et al. 1995; Blair 2005) is clearly evident using 3D modeling (Fig. 3). The geometry (relief) of the HW contact surface is interpreted to reflect composite horst and graben structures controlled by intersecting NS, NE, EW and NW trending normal faults. Sleeper rhyolite and other subsequent Miocene

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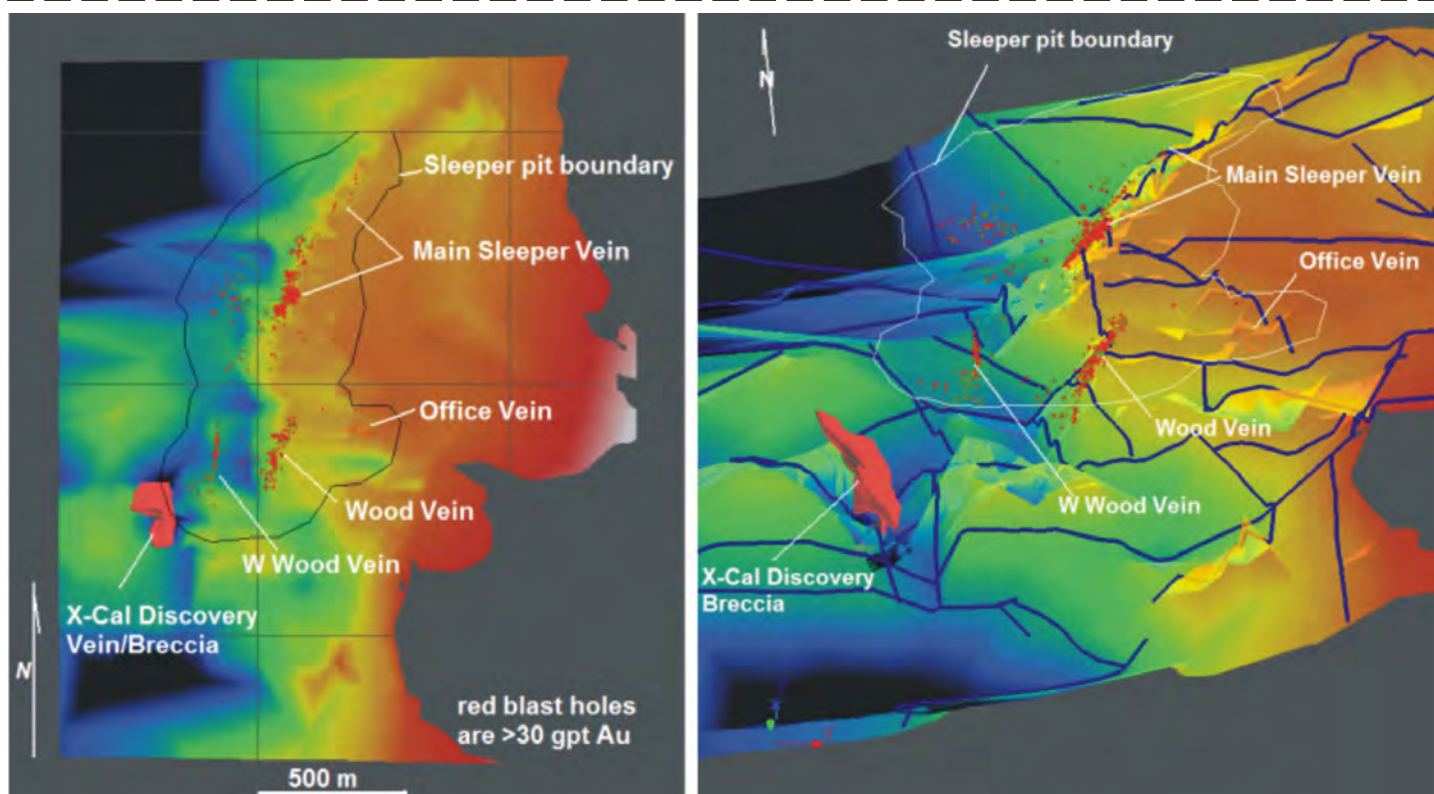


Figure 3. Left a: Structure contour map (colored by Z elevation) of modeled HW contact surface of basalt unit within host sequence beneath Sleeper rhyolite. High grade open pit blast holes defining veins and modeled surface of X-Cal Discovery Breccia are shown in red. Right b: Oblique view looking NNE illustrates the correlation of gold with interpreted graben bounding faults. The ore bodies are within Sleeper Rhyolite which overlays the modeled HW contact of the basalt unit of the mine host sequence.

basin fill units were deposited into the horst, graben, range front basin and its associated sub-basins. Gold vein, breccia and disseminated mineralization is present along reactivated, basin controlling normal faults. Known bonanza gold veins mimic the geometry of reactivated basin growth faults along composite graben boundaries (Fig. 3).

ANALYTICAL METHODS AND DATA PROCESSING

Drill-hole samples were analyzed using a near total 4-acid digestion and ICP-ES/ICP-MS determination. Partial digest aqua regia data for some drill-holes were incorporated into the database for elements that could be satisfactorily leveled with the total digest. All analyses were completed by ALS-Chemex Ltd. The geochemical data were converted to log (base 10) units to facilitate display and spatial analysis. The occurrence and relative abundance of alteration minerals were determined for selected samples using ASD (spectral reflectance) analysis. Relative abundances were converted from presence or absence to numeric values of 1 and 0. Notations of trace, weak and strong were assigned values of 2, 3, and 4 respectively. The down-hole data were gridded with GOCAD 2.07 software to produce individual element block models (xyz cell dimensions of 50x50x5 m) using: 1) an inverse distance squared algorithm, 2) an unconstrained search radius of 150 m in all directions, and 3) a restriction of gridding to the region from the surface topography to a vertical depth of 30 m below the end of drill

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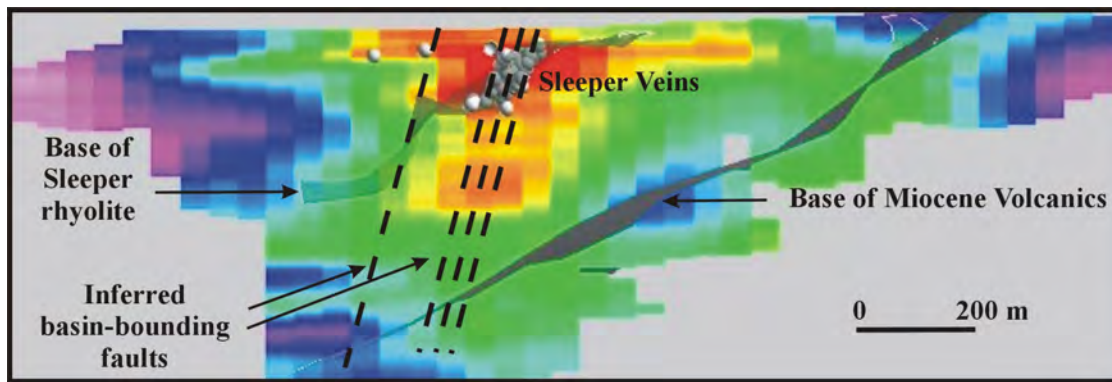


Figure 4. Gridded image of the Au distribution in an E-W section through the Sleeper Vein (yellow > 0.003 oz/ton). White spheres are Au assays > 3 oz/ton.

holes. The alteration minerals identified by ASD were gridded using a nearest neighbor categorical interpolation.

GEOCHEMICAL MODEL

The Sleeper low sulphidation Au-Ag system is related to vertical plumes in Au, Ag, and As concentration emanating from depth that trace out fluid pathways along high angle structures (Fig. 4). Within the large system plume, there is a general zonation east to west from more Ag dominated to more Au dominated. The basalts and, in some cases, the rhyolite, are altered in the area of the system plume as expressed in depletion of Na and other elements east of the deposit; Ca-Mg depletion is centered on the deposit and along a NW trending corridor, and enrichment in K and Rb occurs on the outer margin of ore to the west. The high grade Au veins are located along the western fringe of the system plume at the boundary between K-Rb and Na-Ca-Mg alteration signatures. The distributions of anomalous Ag, As, Ge, S, Se, Te, and Tl concentrations are similar to that of the Ca-Mg depletion alteration. The distributions of Sb, Mo, Re, and W are more closely associated with the K-Rb enrichment alteration.

High grade mineralization appears to have a strong elevation control that also has an expression in other elements. The base of high grade mineralization coincides with the bottom of a flat-lying, saucer-shaped zone of Zn depletion at 120-150 m depth. Above this boundary, Ba, and Mo concentrations are enriched while below it, As, S, and Zn concentrations are enriched. This feature is interpreted to be the reflection of hypogene oxidation related to a boiling horizon. The highest grade Au and Ag intercepts are generally restricted to the oxidized portion of the profile. The base of oxidation, visually, is generally at a similar depth to the lower limit of Zn depletion but can be as much as 50-60 m higher in the profile. The observed zonation sequence relative to the redox boundary is believed to be hypogene in origin as it differs significantly from that related to supergene oxidation (Jackson 2007). Supergene Au has been noted in the upper 30 m of bedrock (Saunders 1993) where a flat-lying Au layer is observed (Fig. 4).

MINERALOGIC ALTERATION MODEL

A zoned sequence of clay minerals is present from east to west in the order of illite → kaolinite-buddingtonite-

illite(NH₄) → montmorillonite → nontronite (Jackson 2007). The boundaries between the various zones are more or less vertical or steeply dipping to the west and are observed to cross-cut stratigraphy. The high grade veins are positioned within the buddingtonite-illite(NH₄) halo within the larger kaolinite zone. The distribution of buddingtonite resembles that of two vertical plumes that flatten out at higher elevations to encompass the high grade veins (Fig. 5). The location of at least one of these is spatially associated with a NW-trending structural corridor. The distribution of silica (quartz, opal, chalcedony) forms an outer boundary to the Au system and, in some areas,

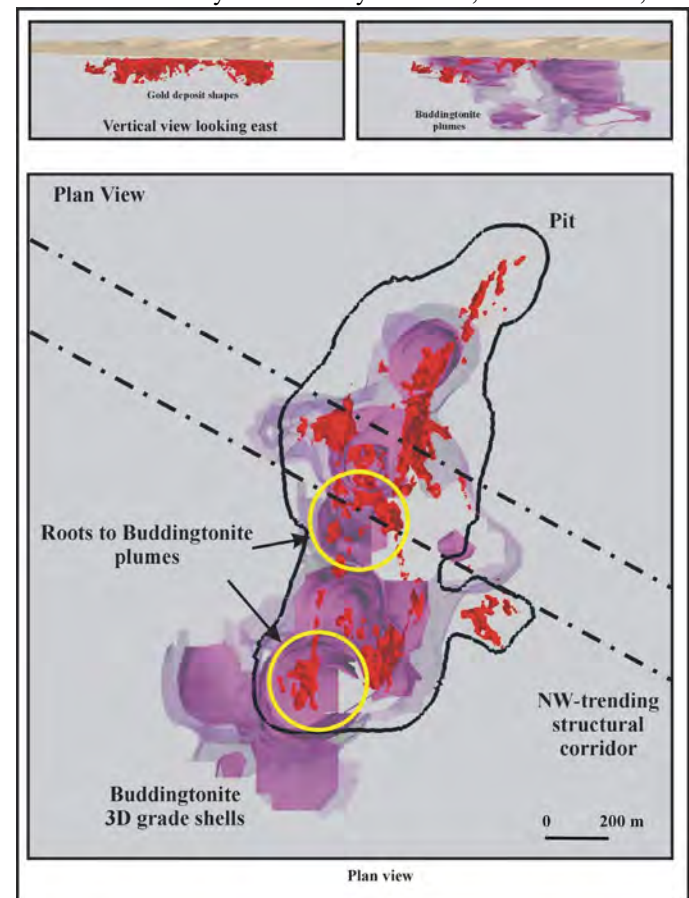


Figure 5. Buddingtonite alteration plumes associated with the Sleeper Vein gold deposits. Distribution of gold mineralization shown in red as determined from blast hole data. Part of the Au shape is obscured in the upper right inset due to the buddingtonite 3D shape.

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underlies it. The eastern margin of the silica zone is located at approximately the same location as the eastern margin of the montmorillonite halo. Chalcedony is present within a NW structural corridor that cross-cuts the range-bounding structures whereas opal is distributed to the north and south of the chalcedony zone within the quartz halo. Another zoned sequence is that of jarosite → gypsum → CO₃-bearing minerals. The distribution of jarosite is centered on the high grade veins to a depth of about 100 m below them, locally deeper. Gypsum is present in a halo marginal to the jarosite zone both laterally and beneath it. Samples with CO₃ spectra occur within the gypsum halo but exclusive to samples with gypsum. A long string of CO₃-bearing samples is located at depth between the two buddingtonite plumes. The distribution of hematite is generally restricted to above the redox boundary. However, within the oxide zone, the distribution of abundant hematite is centered on the high grade veins with possible extensions along the NW structural corridor that intersects the range-bounding structures. This relationship is likely due to the higher concentration of sulphide minerals surrounding the deposit that were subjected to oxidation. Associated with sulphide oxidation is the presence of alunite above the redox boundary in close proximity to the high grade veins.

3D SPATIAL DATA INTEGRATION AND PATTERNS

The distribution of high grade Au and Ag appears to reflect the concurrence of 3 main features: 1) a major lithologic contact, 2) high angle structures, and 3) a redox gradient. The coincidence of the oxidized zone (boiling horizon) with open high angle structures developed at the rhyolite/basalt contact created conditions favourable for the formation of high grade Au veins. Many of

the alteration zones have a geochemical expression. The distribution of illite is most similar to that of Na depletion alteration. The relative abundance of illite is closely correlated with the intensity of Na depletion. The distribution of jarosite with its peripheral zone of gypsum is similar to that of depletion in Ca and Mg and anomalous concentrations of Ag, As, Ge, S, Se, Te, and Tl. The kaolinite-buddingtonite zone is generally coincident with anomalous K, Rb, Sb, Mo, Re, and W. The opal-chalcedony zone is the host for anomalous Bi concentrations. The hematite zone is located within the shallow saucer-shaped feature defined by Zn depletion. The Sleeper system lies within the boundary of a large magnetic low. In 3D, the limits of the Ca-Mg depletion anomaly correspond closely to the boundaries of the magnetic low. This pattern suggests that the alteration process resulted in both mafic mineral and magnetite destruction.

A NW trend to Au and As anomalies observed in the 3D model is traceable further to the south-east by weak Au and As anomalies in shallow soils covering the bedrock of the adjacent range. This feature is expressed as a disruption in the strong gravity response located along the margin of the range, possibly as a result of alteration.

CONCLUSIONS

The full integration of all geologic, geochemical, and geophysical data in 3D space has contributed to a better understanding of the Sleeper mineral system including mineralization controls, alteration patterns, and exploration potential. An important component of this integration was 3D modeled down-hole geochemical data and mineralogic ASD data.

Some key observations include: 1) mineralization is focused along basin-bounding normal faults; 2) Au, Ag and

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alteration patterns are larger scale than the discrete veins and graben bounding fault controls 3) the Au core within the Sleeper graben grades eastward to a Ag rich zone beyond the pit boundary; 4) trace element signatures and alteration mineralogy are zoned in relation to the deposit in a very systematic and predictive fashion; 5) high grade Au mineralization is floored by a saucer-like zone of Zn depletion and other redox related signatures reflecting hypogene oxidation due to boiling; and 6) mineral trends and alteration signatures relate well to features in other data sets such as airborne magnetics, gravity, IP, and soils.

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