Exploration for High Sulfidation, or Enargite-Acid Sulfate, Gold-Copper Deposits

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1. Introduction

As grobal exploration for ore bodies reaches into more remote and less well - exposed terrain, geologists and geochemists must identify less obvious indicators of significant deposits. In recent years a group of gold and copper-gold deposits associated with intrusive and volcanic rocks, advanced argillic alteration minerals as defined by Meyer and Hemley (1967) high-sulfidation state copper minerals (Barton, 1970), and acid-sulfate alteration minerals has been widely discussed. Much recent literature has appeared regarding fluid genesis and general characteristics, although many papers have relied on older descriptions or sample collecting expeditions for deposit data. Data on the third or vertical dimension, as well as on features extending beyond the ore zones, are the least documented and the most useful.

In this paper selected aspects of eleven deposits or prospects studied in the field by the first author are compared, with emphasis on deposit geometry and deposit variation with host rock type (Table, below). Steam-heated zones, in which igneous rocks are converted to alunite and vuggy silica by hot vapor with no addition of ore minerals, are considered here only when they occur within metal deposits. Modeling of the interaction of various possible metal and sulfur bearing fluids with different host rocks was carried out using Chiller, a thermodynamic program developed by M. H. Reed (Reed, 1982).

2. Results

Features useful in exploration include irregular silica zones (perhaps forming topographic features), residual native gold and sulfide grains (especially of enargite), high temperature sheet silicate minerals and contemporaneous galena-sphalerite veins. In most instances the transition from strongly altered to fresh-looking wall rocks is abrupt. A rapidly-neutralized low pH chemical "front" is suggested. Association with porphyry copper systems is in places evident, both in island arc and continental environments, but

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strong evidence of direct transition from porphyry to overlying high sulfidation systems is uncommon. The transition of mineralogy and geometry with rock type is, in contrast, obvious and striking. Igneous rocks react with sulfide bearing hydrothermal fluids to yield low pH solutes, which tend to cause leaching and destruction of potassium silicates. Gold, enargite and other high sulfidation state copper minerals are readily precipitated. Vuggy silica rock forms easily, especially from porphyries and crystal tuffs in which feldspar sites become vugs. Quartzitic and argillaceous rocks support similar mineral assemblages. In contrast, limestone and dolomite reacting with the same fluids generate a steep rise in solution pH. The "high sulfidation suite" will not precipitate under these conditions, and arsenic in solution may escape to distal zones. But lead and zinc, carried to the calcareous rocks by chloride complexes, precipitate when calcium is introduced into the solution (presumably because it forms strong Ca-Cl complexes).

Rock porosity is also important in controlling reaction and precipitation. In the Nansatsu district of south Honshu, a number of enargite and acid sulfate bearing gold deposits have high grade veins at their centers. Where these structures pass through certain tuff beds, apparently with higher permeability or contained fluids, wider ore bodies and abundant vuggy silica tend to occur. There is evidence (breccias, surface materials) the deposits formed at shallow depth. Trace mineralogical variations among districts world-wide seem to be largely functions of element availability in the system and the degree of detailed study to date.

Area, region or Province and Country	Typical form mineral bodies	Vuggy Si Present?	Non CuFe in sulfides	Depth of oxidation	Limerock present?	Porphyry system?
East and Southwestern Tintic districts, Utah, USA	Veins, pods in siliceous sediments	minor	Pb,Zn,Ag	minor	abund	distant, yes
Goldfield, Esmeralda Co., Nevada, USA	Structurally controlled masses	yes	Sn,Bi,Te	~90m**	no	no
Red Mountain, Ouray Co., Colorado, USA	*Pipes, veins dying out w/depth	yes	various, W	minor	no	yes
Summitville, Rio Grande Co., Colorado, USA	Veins, pipes	yes	Pb,Zn	~50m**	no	no(?)
Nevados del Famatina dist. La Rioja, Argentina	Veins, flooded zones	yes	Pb,Zn,Mo,etc.	minor	no	yes
Cerro de Pasco district, Central Peru	Mantos, veins varying with rock type	no	Zn,Pb,Ag,etc.	~50m	abund	no
El Indio, Andes Mountains, Central Chile	Hi grades in struct.controlled masses	yes	Pb,Zn,Te	Varied**	no	no(?)
Lepanto Mine, Benguet Prov., Luzon, Philippines	Struct. controlled mantos, veins	yes	Pb,Zn,Sn,Se	minor	no	far to SE, yes
Nalesbitan dist., Camarines Norte Province, Luzon, PHI	Veins, silica flooded zones	yes	Te	~130m	no	no(?)
Motomboto, Tombulilato dist. North. Sulawesi, Indonesia	*Veins and irregular bodies	yes	Pb,Zn,Te	no	no	toside, yes
Nansatsu dist., Kagoshima Ken, kyushu Japan	Veins, silicified favorable horizons	yes	Pb,Zn,Sn	50~130m**	no	no
Hogusatsu dist., Kagoshima Ken, Japan	*Small veins and carrot-shaped pipe	minor	Te,Zn	no	no	no(?)
Chelopech district, central Bulgaria	Struct. localized irregular bodies	no	many	~20m	no	no

*prospect, not a mine

**suggestion of steam-heated zones, i.e. pre-weathering oxidation, possible enrichment