Exploration of Low Sulfidation Epithermal Vein Systems

by: Dr. Peter Megaw

Low Sulfidation Epithermal Vein Deposits (“LSEVD”) share many common characteristics whose recognition and interpretation allow explorationists to determine the magnitude of a given system and general location within the system, and thereby focus exploration. A brief review of some of these features is provided here leading to general exploration strategies to evaluate given systems. The reader is referred to Wisser (1966), Buchanan (1981), Hedenquist and others (1996), and Albinson and others (2001) for in-depth syntheses on LSEVD in general and especially in Mexico.

“Epithermal” literally means “shallow heat”, and is applied to hydrothermal systems emplaced at shallow depths (<1 km) in the earth’s crust. “Low Sulfidation” refers to a style of epithermal system developed in a geothermal or hot springs environment versus “High Sulfidation” epithermal systems which develop in the volcanic hydrothermal environment. There can be significant overlap between these two end-members.

Gold and silver mineralization in LSEVD systems occurs dominantly as veins and stockworks with minor disseminations. Major examples include: Pachuca, Guanajuato, Tayoltita, El Oro and Fresnillo, Mexico; Hishikari, Japan; and Comstock, and Tonopah, USA. Associated elements include Cu, Ag, Zn, Pb, and As.

Distinctive minerals present in LSEVD include: pyrite, sphalerite, galena, arsenopyrite and sulfosalts (complex Ag, Pb and Cu species with As and Sb as well as sulfur). Gangue minerals are dominated by quartz, adularia (hydrothermal Potassium feldspar) and calcite with some illite development (Hedenquist and others, 1996). Fluids in this regime generally do not significantly alter surrounding wall rocks at the depth of mineralization, but do effect increasingly widespread silicification, Advanced Argillic Alteration (including kaolinite, alunite and/or buddingtonite) and propyllitic alteration (chlorite, calcite, epidote and/or pyrite) above the mineralized levels.

Drilling at Juanicipio

Ore metals and gangue ingredients are dissolved in the epithermal ore fluids, which rise from depth along structural pathways at high temperatures (>200 ^{o}C) under enough pressure to preclude boiling. Mineralization occurs when the pressure drops abruptly (through faulting or other rupture), which instantly triggers boiling (“flashing”) and causes the ore fluids to “dump” their mineral load into any available open space. Metals bearing species are deposited first (and very quickly) followed by quartz, calcite and adularia gangue which grow more gradually until all open spaces are filled. When the system is again sealed, pressure begins building again until the next rupturing event occurs and the mineralizing process recurs. This vigorous episodic process rips up vein fillings deposited in previous stages and covers them with new fillings and gives epithermal veins their characteristic repeated banding and breccia textures. Generally, long-lived epithermal vein systems display more repetitions and larger metals budgets than short-lived systems.

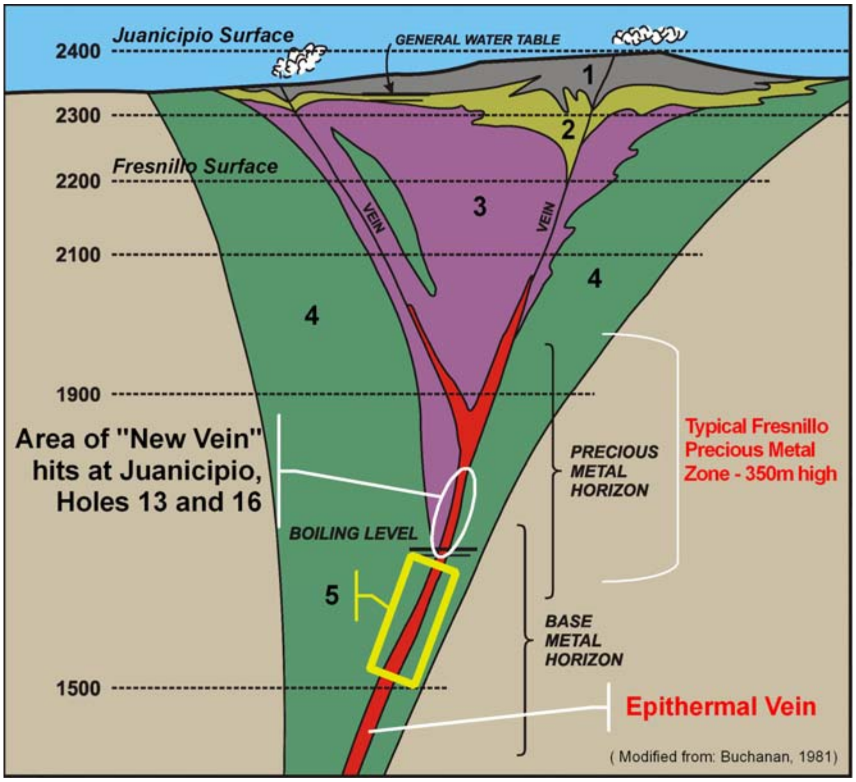
“Epithermal” literally means shallow heat

Structures are the most fundamental control on location of vein development: from providing major ore fluid ingress channels to the open spaces for ore deposition. Productive LSEVD districts typically show a “grain” reflecting opening (and reopening) of a series of roughly parallel and/or intersecting structures on a range of scales and can often be related to position within the stress fields of major regional structures. Some of these major regional structures contain numerous separate but roughly contemporaneous districts/mineralization centers along hundreds of kilometers of their length. This suggests the existence of regionally extensive ore-producing processes whose products move into shallow crustal levels in response to regional structural events.

Epithermal Vein Systems continued...

On a district and individual vein scale, the local structural regime controls which portions of which structures are opened by rupturing, and subsequently filled by mineralization. Ore shoots typically develop within "dilatent" zones developed along inflections of vein strike or dip where geometry permits maximum opening at the time of mineralization. Repetitions of these inflections along kilometers of a given structure are often each occupied by ore shoots, giving a "beads on a string" distribution to the best orebodies in these veins. In a vertical sense, many vein structures show a gradual splitting or "horsetailing" towards the surface. This reflects the shallow seated structural environment of vein fields in general and the tendency for vein openings to be best developed in areas of local extension.

The metals component of the vein filling is zoned with respect to the boiling level (Fig. 1): base metals (Pb, Zn, Cu) tend to be deposited below it, while silver and gold are dominantly deposited above the boiling level. Boiling may occur at different elevations for different mineralizing episodes (in response to the degree of pressure buildup before rupture), so a broad transition zone often exists between the precious metals rich upper part of the vein and the more base metal rich root zone. In the most extreme cases the boiling level may change abruptly by hundreds of meters during the life of the hydrothermal system (Simmons, 1991). This can result in temporally separate stages of precious metal and root zone mineralization occurring side by side in "composite veins", or repetitions of the complete zoning separated by 100 meters of barren in "stacked" veins.



Epithermal Vein Model at Juanicipio

Alteration is also zoned with respect to the boiling level and the paleosurface. Overall, the combined alteration zones tend to spread out laterally and upwards (See Figure 1), reflecting a combination of the near surface horse-tailing of the structural framework and progressive fluid migration away from the principal fluid conduits. The overall lateral progression is from silicification to propyllitic alteration (chlorite, epidote, calcite and pyrite), whereas the vertical progression is from silicification to Advanced Argillic Alteration to siliceous residue. Wallrock composition and permeability strongly affect lateral alteration development: more reactive and permeable units will show the most pervasive alteration. Intermediate volcanic and intrusive rocks (andesites and diorites), and sediments derived from these (arkoses) are especially susceptible to propyllitic alteration, so this alteration is commonly well developed in epithermal vein systems deposited in subduction related magmatic belts (c.f. most of the Western Cordillera of the Americas). Shales and fine-grained siliclastic rocks, typical of the continental side of the Cordillera are generally less reactive and permeable, and alteration halos around veins hosted in these rocks are typically much more limited. Limestones and other calcareous rocks are highly reactive and may trigger replacement reactions, creating skarns or sulfide replacements, where LSEVD fluids cut these rocks.

Near-surface alteration reflects the chemistry of the residual depleted ore fluids. These approach the acidic chemistry of high-sulfidation systems and generate many of the same Advanced Argillic Alteration minerals (kaolinite, alunite and buddingtonite). The classic "vuggy silica" residual textures of the high sulfidation systems are rare in low sulfidation systems, but a cap of fine-grained silica deposited on the surface (sinter) or just below it is common. This surficial silicification is readily distinguished from the deeper silicification zone by much finer (often colloidal or opaline) textures and the common presence of cinnabar (mercury sulfide) and very fine-grained pyrite.

The productive zones of most known vein districts have been discovered in outcrop, so little remains of the uppermost alteration zones in many major districts. Stripping off of this protective cover exposed the precious metal zones to surficial weathering processes, some of which destroy sulfide species, liberating the metals and allowing their downward transport and reprecipitation at depth. This can result in essentially barren vein outcrops overlying shallowly buried zones of high-grade secondary enrichment. Many of these provided Bonanza grade ores to the earliest discoverers.

Exploration of LSEVD involves comparing geologic observations made in the field (surface, mine and core) into an integrated district perspective with respect to the factors above to determine a given area's favorability for discovery.

First order favorability considerations include:

1. How favorably is the system located?…does it occur within a regional belt of related deposits?
2. Depth of exposure…is the precious metals zone preserved and/or inferred to lie at what depth? Has the base metal root zone been reached?
3. What was the strength/longevity of the system…how extensive is it and how many repetitions are reflected in the vein textures?

Second order favorability features include:

1. Degree of alteration development and ability to relate it to mineralization centers or controls:
2. Exposure of the regional structural fabric and ability to decipher stress regime.
3. Do possible stacked or composite vein targets exist?
4. Are parallel or intersecting structures possible?
5. Are logically "missing" parts of the system hidden by younger cover in adjacent areas?

REFERENCES

Albinson,-F., T., Norman, D.I., Cole, D., and Chomiak, B., 2001, Controls on formation of low-sulfidation epithermal deposits in Mexico: Constraints from fluid inclusion and stable isotope data. In, Albinson-F., T. and Nelson, C.E. eds.New Mines and Discoveries in Mexico and Central America Society of Economic Geologists, Special Publication No. 8., Littleton CO, p. 1-32.

Buchanan, L.J., 1981. Precious Metals Deposits Associated with Volcanic Environments in the Southwest: in, Dickinson, W.R., and Payne, W.D., eds., Arizona Geological Society Digest Vol. 14., p. 237-262.

Hedenquist, J.W., Izawa, E., Arribas, A., and White, N.C., 1996, Epithermal Gold Deposits: Styles characteristics and exploration: Society of Resource Geology, Resource Geology Special Publication Number 1, Tokyo, Japan, 24p.

Simmons, S.F., 1991, Hydrologic implications of alteration and fluid inclusion studies in the Fresnillo District, Mexico; evidence for a brine reservoir and a descending water table during the formation of hydrothermal Ag-Pb-Zn orebodies.: Economic Geology, v. 86, no. 8, p. 1579-1601.

Wisser, E.D., 1966, The Epithermal Precious Metal Province of Northwest Mexico: Nevada Bur. Mines Rept. 13, pt. C, p. 63-92.

***Dr. Megaw** has a Ph.D. in geology and more than 20 years of relevant experience focussed on silver and gold mineralization, and exploration and drilling in Mexico. He is a certified Professional Geologist (CPG 10227) by the American Institute of Professional Geologists and an Arizona Registered geologist (ARG 21613). His primary exploration foci are CRDs, Vein Deposits and Porphyry Copper Deposits. He specializes in property evaluation and acquisition for clients through collaboration with his associates in Minera Cascabel.*