STIBNITE-QUARTZ DEPOSITS
(MODELS 27d,e and 36c; Bliss and Orris, 1986a-c; Berger, 1993)

by Robert R. Seal, II, James D. Bliss, and David L. Campbell

SUMMARY OF RELEVANT GEOLOGIC, GEOENVIRONMENTAL, AND GEOPHYSICAL INFORMATION

Deposits described in this model are designated "Stibnite-quartz deposits" to describe a group of antimony deposits that share many of the characteristics of simple (vein dominated) antimony deposits (Model 27d; Bliss and Orris, 1986a,b), disseminated antimony deposits (Model 27e; Bliss and Orris, 1986c), and gold-antimony deposits (Model 36c; Berger, 1993), but have features that distinguish them from these models. The Lake George deposit (New Brunswick, Canada) is included in the "stibnite-quartz deposit" geoenvironmental model. However, it was also included by Bliss and Orris (1986a) in their simple antimony (27d) and disseminated antimony (27e) models. The most significant distinction between stibnite-quartz deposits and simple antimony and disseminated antimony models is the lack of an association with volcanic rocks and a minimal association with intrusive rocks. Stibnite-quartz deposits are hosted dominantly by shale, marl, and carbonate rocks (±quartzite and granite) or their low-grade metamorphic (greenschist facies) equivalents, whereas many gold-antimony deposits are associated with mafic and ultramafic metavolcanic rocks. Stibnite-quartz deposits are most similar to those gold-antimony deposits that are hosted by Late Proterozoic turbiditic black shale, siltstone, sandstone, and carbonate rocks; however, gold grades of the stibnite-quartz deposits are distinctly lower than those of the gold-antimony deposits. Gold has been identified in the Lake George (New Brunswick, Canada) stibnite-quartz deposit, but it is present in a minor vein set (Seal and others, 1988) and has not been extracted during mining and milling of the ore. Relative to simple, disseminated, and gold-antimony deposits, stibnite-quartz deposits lack significant copper, lead, zinc, and nickel sulfide and sulfosalt minerals. The stibnite-quartz deposits are broadly analogous to the "Quartz-Stibnite Association" of Gumiel and Arribas (1987) in Spain and Portugal.

Deposit geology

Stibnite-quartz deposits are hosted by shale, calcareous shale, limestone, quartzite, or granite (or their metamorphic equivalents). Mineralized rock, which is associated with faults that transect stratigraphy, consists of (1) massive veins (as much as 4 m thick), dominated by quartz and stibnite; or (2) massive stratiform replacement deposits of quartz and stibnite along shale/limestone contacts. Significant metallic zonation generally is absent from these deposits.

Examples

Lake George, New Brunswick, Canada; Thompson Falls, Mont.; Xiguanshan, China; Kadamdzhay, Russia

Spatially and (or) genetically related deposit types

Associated deposit types (Cox and others, 1986) include stibnite-bearing veins, pods, and disseminations containing base metal sulfide minerals ± cinnabar ± tungsten (Models 27d and 27e); gold-antimony deposits (Model 36c); low-sulfide gold-quartz veins (Model 36a); stockwork tungsten-molybdenum deposits; and less commonly, polymetallic veins (Model 22c) and tungsten skarns (Model 14a).

Potential environmental considerations

(1) The acid-generating potential of stibnite-quartz deposits is low due to the abundance of stibnite and low abundances of pyrite and pyrrhotite. However, rock surrounding the veins includes alteration zones that contain minor pyrite and arsenopyrite, which slightly increase associated acid-generating potential. Shale that hosts the vein deposits lacks significant acid-buffering capacity. However, low acid-buffering capacity may be offset by the local presence of calcite gangue. Limestone that hosts replacement deposits has significant acid-buffering capacity.
(2) Mine drainage and water from tailings ponds may contain elevated metal abundances, including tens to thousands of mg/l antimony, tens to hundreds of mg/l arsenic, and tens to thousands of mg/l sulfate.

Exploration geophysics

No geophysical investigations specific to this model are known. Induced polarization methods can provide qualitative estimates of sulfide mineral percentages and grain size.

References

Geology: Morrissy and Ruitenberg (1980), Smirnov and others (1983), Seal and others (1988), and Panov and No

(1989).
Environmental geology, geochemistry: Shvartseva (1972) and Woessner and Shapley (1984).

GEOLOGIC FACTORS THAT INFLUENCE POTENTIAL ENVIRONMENTAL EFFECTS

Deposit size
Most deposits are of small to intermediate size, <0.1 to 2.0 million tonnes.

Host rocks
Stibnite-quartz deposits are hosted by shale (Lake George, Thompson Falls), marl (Lake George), limestone (Kadamdzhay, Xiguanshan) or granite (Lake George), or low-grade (greenschist) metamorphic equivalents.

Surrounding geologic terrane
Stibnite-quartz deposits are primarily in sedimentary or metasedimentary ± granitic terranes.

Wall-rock alteration
Wall rock for vein deposits (Lake George, Thompson Falls) is altered to sericitic and siliceous assemblages. Rock altered to sericitic assemblages, which surrounds veins out to distances of tens of meters, is dominated by quartz and sericite, with minor pyrite and arsenopyrite, whereas that altered to siliceous assemblages is dominated by quartz with lesser pyrite, arsenopyrite, and stibnite and extends only several centimeters into wall rock. Replacement deposits (Kadamdzhay, Xiguanshan) are typified by silicification that extends tens of meters into the host limestone.

Nature of ore
Vein deposits are overwhelmingly dominated by veins of quartz cored by massive stibnite. Most replacement deposits form lenticular bodies of quartz and stibnite within limestone, at contacts with overlying shale, near high-angle faults.

Deposit trace element geochemistry
Main ore zones contain elevated abundances of Sb > Fe > As ± Pb ± Zn ± Cu ± U ± Ba. Lead, zinc, copper, uranium, and barium are present as minor constituents of ore minerals in local zones in some deposits. Sericitic alteration assemblages contain elevated abundances of iron and arsenic.

Ore and gangue mineralogy and zonation
Minerals listed in decreasing order of abundance. Potentially acid-generating minerals underlined. Quartz, stibnite, <u>pyrite</u>, calcite, native antimony, <u>arsenopyrite</u>, <u>pyrrhotite</u>, <u>berthierite</u>, <u>sphalerite</u>, <u>tetrahedrite</u>, lead sulfosalts, barite, fluorite, <u>chalcopyrite</u>, hematite. Veins are typically zoned from outer quartz-dominated margins to stibnite-dominated cores. At Lake George, high sulfidation assemblages (stibnite + pyrite) in the eastern part of the vein are laterally zoned to low sulfidation assemblages (native antimony + pyrrhotite) in its western part.

Mineral characteristics
Stibnite grains range from less than 1 mm to as much as approximately 50 cm long. Grain habits range from anhedral to euhedral. Sheared and kink-banded fabrics are common. Vug fillings locally are present within the deposits. Accessory sulfide minerals are typically less than 1 mm in diameter.

Secondary mineralogy
Minerals formed by supergene oxidation include: valentinite (orthorhombic Sb_2O_3), senarmontite (cubic Sb_2O_3), cervantite (Sb_2O_4), kermesite (Sb_2S_2O), and stibioconite ($(Ca,Sb)_2Sb_2O_6(O,OH)$), and limonite. None of these minerals are readily soluble.

Topography, physiography
Topography and physiography vary widely and cannot be generalized.

Hydrology
Rock cut by vein-filled or replacement-deposit-related faults may have enhanced permeability. Otherwise, local hydrology is not significantly influenced by features associated with these deposits.

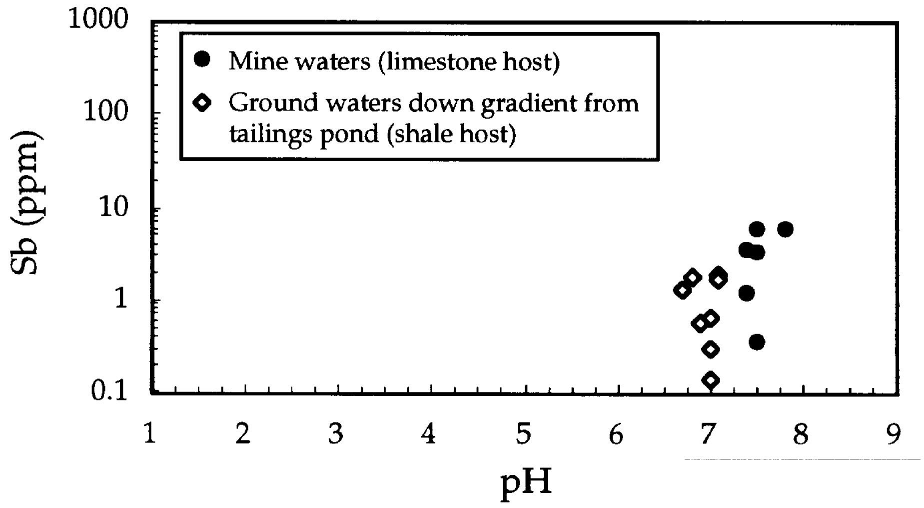

Figure 1. Plot of pH versus dissolved antimony in mine and ground water down gradient from a tailings pond. Data from Shvartseva (1972) and Woessner and Shapley (1984).

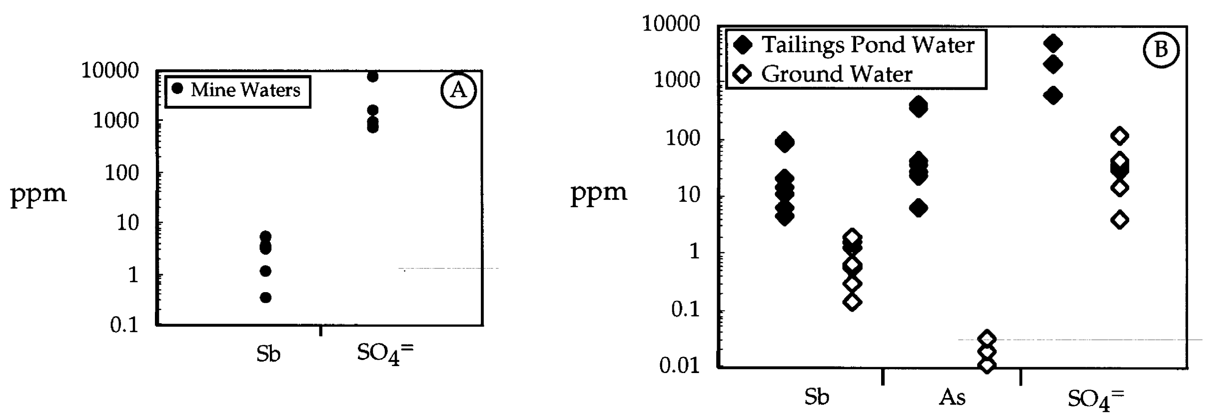

Figure 2. Plot of antimony, arsenic, and sulfate concentration ranges associated with stibnite-quartz deposits. *A*, mine water data, Kadamzhay deposit, Russia (Shvartseva, 1972); *B*, tailings pond and ground water data (within 50 m, down gradient, of tailings pond), Thompson Falls deposit, Mont. (Woessner and Shapley, 1984).

Mining and milling methods

These deposits have been exploited by a combination of underground and surface mining techniques. Ore is roasted or smelted to produce antimony metal or antimony trioxide (Sb_2O_3).

ENVIRONMENTAL SIGNATURES

Drainage signatures

Mine water draining limestone-hosted replacement ore (Kadamdzhay, Russia) is neutral (pH 7.4 to 7.8) and contains elevated dissolved metal abundances, including 0.4 to 5.7 mg/l antimony and 750 to 7637 mg/l sulfate (figs. 1 and 2). Stream water within 3 km of the deposit is also neutral (pH 7.0 to 7.1) and contains elevated dissolved metal abundances, including 0.06 to 0.24 mg/l antimony and 50 to 90 mg/l sulfate (Shvartseva, 1972). No data are available for shale-hosted vein deposits.

Metal mobility from solid mine wastes

Water from the tailings pond of shale-hosted vein ore waste (Thompson Falls, Mont.) has elevated dissolved metal concentrations, including 6 to 100 mg/l antimony, 6 to 380 mg/l arsenic, 0.05 to 3.4 mg/l cadmium, copper, iron, manganese, and zinc, and 570 to 4,800 mg/l sulfate (Woessner and Shapley, 1984); pH data for tailings-pond water are not available. Down-gradient ground water within 50 m of the tailings pond for shale-hosted vein ore waste is near neutral (pH 6.7 to 7.1) and contains elevated metal concentrations, including 0.14 to 1.9 mg/l antimony, 12 to 33 µg/l arsenic, and 4 to 125 mg/l sulfate (figs. 1 and 2).

Soil, sediment signatures prior to mining

Above the surface projection of mineralized veins in the vicinity of the Lake George (New Brunswick, Canada) deposit, soil samples (B horizon) contain a maximum of 565 ppm antimony. Background values are less than 2 ppm (Austria, 1971). Regional stream sediment data for the Lake George area indicate a general correlation between antimony and arsenic contents; maximum antimony abundances are 900 ppm, whereas maximum arsenic abundances are 170 ppm (Austria, 1971; Pronk, 1992). Antimony and arsenic concentrations are less than 20 ppm in stream sediment from sites upstream from the known extent of mineralized rock and from drainages in areas not known to contain mineralized rock.

Potential environmental concerns associated with mineral processing

Water associated with tailings ponds may contain high abundances of antimony, arsenic, and sulfate.

Smelter signatures

No data.

Climate effects on environmental signatures

No generalizations can be made concerning the relationship between climate and environmental signatures because of the limited amount of environmental data available for this deposit type. However, in most cases the intensity of environmental impact associated with sulfide-mineral-bearing mineral deposits is greater in wet climates than in dry climates. Acidity and total metal concentrations in mine drainage in arid environments are several orders of magnitude greater than in more temperate climates because of the concentrating effects of mine effluent evaporation and the resulting "storage" of metals and acidity in highly soluble metal-sulfate-salt minerals. However, minimal surface water flow in these areas inhibits generation of significant volumes of highly acidic, metal-enriched drainage. Concentrated release of these stored contaminants to local watersheds may be initiated by precipitation following a dry spell.

Geoenvironmental geophysics

Metal-bearing ground water plumes may be traceable using geoelectric methods, including the ground slingram. Plumes associated with stibnite-quartz deposits may contain elevated sulfate ion contents which renders them electrically conductive. Slingrams such as the Geonics EM-31 or EM-34 give readings of greater than about 25 mS/m within about 5 m of metal-charged plumes. In ideal circumstances, contaminant plumes can be rapidly outlined by sequential traverses across their edges.

Comments

The stibnite-quartz geoenvironmental model is probably generally applicable to ore deposit models 27d, 27e, and 36c. The acid-buffering capacity of igneous rocks associated with some of these deposits is probably not significantly different from that of shale-hosted stibnite-quartz deposits. Key differences between stibnite-quartz veins and those of models 27d, 27e, and 36c that may significantly affect associated environmental impact include: (1) the presence of minor cinnabar in the latter, (2) the presence of siderite in deposits of the Model 36c type, and (3) specific mineral-processing and mining techniques applied to each of the different deposit types.

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