COPPER-GOLD-SILVER DEPOSITS TRANSITIONAL BETWEEN SUBVOLCANIC PORPHYRY AND EPITHERMAL ENVIRONMENTS

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INTRODUCTION

The many and varied types of intrusion-related mineral deposits in circum-Pacific volcanic arcs, including gold-rich porphyry and related epithermal types, have been discussed by Berger and Henley (1989), Sillitoe (1989, 1990, 1991a, b and in press), Hedenquist *et al.* (1990) and Sillitoe and Camus (1991). The similarity in geological environments of the many described porphyry copper, copper-gold, copper-molybdenum and epithermal precious metal deposits with those in the Canadian Cordillera is evident, but the scarcity of documented acid-sulphate high-sulphidation, advanced argillic-type epithermal deposits and mineralization in British Columbia is surprising. This lack of deposits is probably only apparent and not a geologic reality. It appears to be largely due to a lack of recognition and study of acid-sulphate-type deposits and their environments except for rare cases, for example, Clapp (1915), Bradford (1985) and Diakow *et al.* (1991).

A new project has been initiated to study the interrelationships of subvolcanic porphyry copper deposits and genetically related epithermal mineralization in British Columbia. Of particular interest are deposits with hydrothermal alteration of the kaolinite-alunite-quartz-pyrite-bearing **acid-sulphate** type (Hayba *et al.* 1985, Heald *et al.* 1987), also known as **high sulphidation** (Hedenquist, 1987) or a special case of **advanced argillic** (Meyer and Hemley, 1967). Similar mineralization and alteration suites have been described as: alunite-kaolinite (pyrophyllite), enargite-gold, enargite massive sulphide, high sulphur, Nansatu-type, epithermal quartz-alunite, alunitic quartzite (Russian terminology), volcanic-hosted copper-arsenic-antimony, Roseki clay or acidic zone (Japanese terminology) and hotspring gold-silver.

BACKGROUND

The spatial proximity of magmatic hydrothermal and some epithermal mineralization has been postulated in a number of geologic models (Sillitoe, 1983, 1988, 1989, 1991a; Mutschler *et al.*, 1985; Bonham, 1986, 1988; Panteleyev, 1986). This re-emphasizes Lindgren's concepts of a continuum in ore-forming hydrothermal environments in volcanic settings, from hydrothermal systems dominated by magmatic fluids at depth, to largely geothermal meteoric-groundwater systems near the surface. As stated by Henley (1991):

- "magmatic vapour from crystallizing plutons is critical to [mineralization in] the epithermal environment much as described for porphyry copper-molybdenum deposits."
- "in volcanic terranes the distinction of epithermal from porphyry-type environments of mineralization becomes largely one of convenience for exploration than one of reality." and ". . . a practical understanding of the relationship between magmatism and structural evolution is critical to the future of [epithermal] exploration . . .".

Some epithermal deposits are positioned above or marginal to subvolcanic intrusion-related porphyry-type mineralization. Although the relationship between porphyry copper deposits and adularia-sericite-type epithermal deposits is considered by some to be speculative, the genetic connection with acid-sulphate-type deposits is well established (Henley and Ellis, 1983; Henley, 1991; Sillitoe, 1991a, b). According to Sillitoe (1989, 1991a), the latter typically occur above porphyry copper mineralization, albeit they are laterally offset in some districts by structural channeling.

Acid-sulphate alteration with associated copper-gold-silver mineralization is characterized by zoned hydrothermal mineral assemblages containing abundant silica as quartz, chalcedony and opaline silica (cristobalite), kaolin (including kaolinite, dickite and halloysite) pyrophyllite, and alunite/natroalunite. Locally, white mica (sericite/illite), mixed-layer clays, andalusite, and rarely diaspore, corundum and dumortierite are present, commonly in zonal arrangement. In some deposits late-stage barite, gypsum, anhydrite, jarosite and native sulphur are common as well as minor boehmite, phillipsite, tourmaline and accessory topaz, rutile and zunyite. The principal ore minerals, in addition to abundant pyrite and/or hematite, are gold, electrum, chalcopyrite, copper sulphosalts (enargite – famatinite/luzonite), tetrahedrite/tennantite, bornite, chalcocite and covellite. Elevated values of gold, silver, arsenic and antimony are common in copper ores.

The advanced argillic alteration with its siliceous and aluminous mineral assemblages, commonly with the sulphate minerals alunite, gypsum and jarosite and rarely native sulphur, is a product of strongly oxidized, sulphur-rich, acidic hydrothermal fluids. It generally occurs at late stages of mineralization during declining hydrothermal activity. The acid-sulphate, advanced argillic alteration originates in three ways (Hayba *et al.*, 1985; Rye *et al.* 1989, Sillitoe, in press): from magmatic-hydrothermal fluids in which magmatic volatiles are evolved at depth from crystallizing magma and interact with surrounding groundwater as described by Henley and McNabb (1978) - the porphyry environment; near surface where steam-heated fluids occur above the water table due to vapour separation (boiling) caused by depressurization of ascending hydrothermal fluids – the epithermal environment; and by oxidation of sulphides in the supergene environment.

INTRUSION-RELATED EPITHERMAL PRECIOUS METAL DEPOSITS IN BRITISH COLUMBIA

This new project proposes to examine, describe and study prospective environments for these deposits in British Columbia. MINFILE has five listings for enargite-bearing deposits; three of these in the Taku-Sutlahine River area are related zones within a large hydrothermal alteration system at the Thorn and adjoining properties. Pyrophyllite has been documented at four locations (MacLean, 1988). These and other deposits mentioned in various reports, mainly company reports, are listed in Table 2-1-1.

TABLE 2-1-1
BRITISH COLUMBIA DEPOSITS WITH ACID-SULPHATE, ADVANCED ARGILLIC ALTERATION CONTAINING KAOLINITE±PYROPHYLLITE±ALUNITE AND/OR ENARGITE*

Location/Property Name	MINFILE	Published References
Sutlahine River area		
1. *THORN, DAISY, INK, Camp Creek	104K 031, 116	
2. *KAY, LIN, LIN 1-8	104K 030	
Iskut River Area		
3. *Johnny Mountain/ REG	104B 107	
4. Treaty Glacier	104B 078	Alldrick and Britton, 1991; J.F.H. Thompson, personal communication, 1991
Toodoggone River area		Diakow *et al.*, 1991
5. AL, Alberts Hump, Bonanza	94E 078, 79, 85, 91, 99	
6. Brenda (Jan alunite)	94E 107	
7. SHAS (Shasta)	94E 050	
8. Silver Pond	94E 069	
Central B.C.		
9. Equity Silver mine	93L 001	Cyr *et al.*, 1984; Wojdak and Sinclair, 1984; 'deep acid-sulphate' – Sillitoe, 1991a
Taseko River/Mt. McClure area		Bradford, 1985
10. Empress	92O 033	Company reports, Westpine Metals Ltd.
11. *Taylor-Windfall	92O 028	
Vancouver Island		
12. Expo (Hushamu, Mt. MacIntosh, HEP, Pemberton Hills)	92L 185, 240, 78, 308	Company reports, Moraga Resources Ltd., BHP-Utah Mines Ltd.; P.G. Dasler, personal communication, 1991
13. Red Dog	92L 200	Company reports, Moraga Resources Ltd., Crew Natural Resources Ltd.
14. Wanokana	92L 272	Company reports, Acheron Resources Ltd., P.G. Dasler, personal communication, 1991
15. Island Copper mine	92L 138, 158, 273	Cargill *et al.*, 1976; Perello, 1987; Company reports
16. Kyuquot Sound (Easy Inlet)	92L 072, 117	Clapp, 1915; MacLean, 1988
Southern B.C.		
17. Riverside	92INW087	MacLean, 1988
18. Pyro	92HSE131	MacLean, 1988

Note: * denotes occurrences containing enargite. Deposits with MINFILE numbers are summarized in MINFILE from various published and unpublished sources — mainly company reports and assessment reports filed with the Ministry.

During the summer of 1991, the Thorn property and a number of northern Vancouver Island occurrences considered to be the highest priorities were briefly examined. The presence of widespread enargite in quartz veins is confirmed at the Thorn property within a large area of pyritic, intensely leached, limonitic (jarositic), sericite alteration. On northern Vancouver Island silica-clay 'caps' and pyrophyllite-bearing breccias form extensive alteration zones in Bonanza Group volcanic rocks. More detailed work in these and other areas is planned for 1992.

SUMMARY

Zones of acid-sulphate high-sulphidation, advanced argillic alteration can host or overlie major precious metal and copper deposits. The discovery of even one major deposit in this environment can be a major economic bonanza. For example, at El Indio, Chile in 1975, the recognized economic potential of veins and breccias led to the discovery of ore reserves containing 140 tonnes of gold, 771 tonnes of silver and 0.4 million tonnes of copper in a 150 by 500-metre area (Jannas *et al.*, 1990). In addition, acid-sulphate advanced argillic alteration zones are near-surface features that can mark buried bulk-mineable porphyry copper-gold deposits such as the Island Copper orebody (Cargill *et al.*, 1976; Perello, 1987) or enargite-type copper-gold-silver deposits such as the Lepanto deposit in the Philippines and the related, newly discovered, Lepanto Far Southeast deposit with combined metal content of 526 tonnes gold and 3.45 million tonnes copper (Sillitoe, 1991a).

The target areas for this study are both areas of past exploration or newly discovered areas of interest in which hydrothermal clay-silica zones of acid-sulphate advanced argillic alteration have not been recognized or evaluated. The relationships of intrusive rocks, hydrothermally altered zones, structural controls for ore and mineralization might best be studied at a regional or district scale. As stated by Sillitoe 1991, page 202, in a summary of intrusion-related gold deposits: "An appreciation of the variety of gold deposit types in intrusion-centered systems, the geological parameters that controlled them, their mutual interrelationships and the resultant metal zoning patterns provide a cogent framework for gold exploration in volcano-plutonic arcs." With regard to recent discoveries in long-active mining districts, he further states: " No less than 25 of the 33 newly discovered [post-1979] deposits . . . are located in old mining districts. Furthermore, given that districts possess radii as great as 8 km, individual exploration targets can be large."

An invitation is extended to readers with personal knowledge of acid-sulphate, high-sulphidation, advanced argillic deposits in British Columbia to share information with the writer in order to inventory the deposits and identify the favourable geological environments.

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