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TOURMALINE FROM ANDEAN PORPHYRY COPPER DEPOSITS AND ITS SIGNIFICANCE IN THE EXPLORATION OF ANDEAN MINERALIZATION

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INTRODUCTION

In the field of economic geology, resistate indicator minerals are in general non-ore minerals which were deposited during the mineralizaton event and may carry geochemical signatures diagnostic of their origin. Ideally, these signatures should survive weathering, alteration, metamorphism and dispersal processes and thus constitute the basis for ore genesis interpretation and geochemical exploration.

Several minerals have been investigated as "pathfinders" or mineralization indicators including biotite, magnetite, pyrite, feldspar, muscovite, apatite and rutile.

This presentation describes the importance of another, and commonly overlooked gangue mineral -tourmaline, and explores the use of this resistate mineral as an exploration guide. Emphasis of the presentation will be on Andean porphyry copper deposits, however current research on other types of Andean mineralization will also be presented.

TOURMALINE AS A RESISTATE MINERAL

Tourmaline is a complex boro-silicate mineral that is the chief repository of boron in a variety of rock types and metallic deposits. Popularly know as a semi-precious gemstone and mineral collectors showpiece, due to its attractive colors, crystal form, durability and workability, the petrologic significance of tourmaline in its diverse environments of crystallization has received little attention. During the last twenty years however, studies on tourmaline from a wide variety of geologic settings have shown that useful information may be gained from the careful study of this mineral (see Henry and Dutrow 1996 for review). Tourmaline has also been observed to be associated with diverse types of ore deposits and Boyle (1974) proposed its use in mineral exploration. Similar contributions studying a variety of styles of mineralization include (Power, 1968; Ethier and Campbell, 1977; Birk, 1980; Taylor and Slack, 1984; Smith et al., 1987 and King 1988, 1990).

Tourmaline possesses several fundamental characteristics that confer its use for geochemical studies and exploration, including;

1) tourmaline has a complex chemical structure which can accommodate a wide spectrum of major elements. This is reflected in the large number of naturally-occurring (11 IMA approved) species and (5 approved) synthetic species.

2) the "loose" crystal structure of tourmaline allows minor, trace, and rare earth elements present in the environment of crystallization to be adsorbed and/or substituted into the crystal lattice. A multitude of these elements, in various concentrations have been reported in the literature (see Henry and Dutrow 1996; King 1990 for reviews). The assumption that tourmaline is an effective trace element scavenger is substantiated by the number of these different elements found in tourmaline.

3) tourmaline is characterized with a robustness that typically survives weathering and most alteration events.

In summary, tourmaline associated with ore deposits will scavenge a wide assortment of elements from its environment of crystallization and will retain these elements during subsequent alteration, metamorphism and weathering. Tourmaline composition has been shown to reflect the primary chemical and isotopic features of the ambient mineralizing conditions at the time of crystallization (King, 1990).

TOURMALINE ASSOCIATED WITH PORPHYRY-COPPER DEPOSITS

PETROGRAPHY

Tourmaline present in Chilean porphyry copper deposits generally occurs as a trace constituent in veins and altered wallrocks, but may comprise as much as 80% were it occurs as the matrix in breccia pipes. Texturally, the tourmaline occurs as scattered isolated needles, as radial groups of crystals (starburts), as massive granular aggregates and as felted aggregates of fine-grained fibrous needles. (Photo 1).

In hand specimens the color of the tourmaline is matte black however in thin section the coloration varies widely from light to dark brown, blue and green. Some crystals display color zonation which may be either pronounced core-rim relationships or patchy irregular zonation (Photo 2).

CHEMISTRY

Analytical results for tourmaline from the El Salvador and El Teniente deposits display wide compositional variations in FeO (1.2-9.4), Al_2O_3 (27.1-35.7) and TiO_2 (0.02-0.7); moderate variations in MgO (6.3-8.8) and SiO_2 (35.1-36.8); and smaller variations in Na_2O (1.5-2.8). Amounts of K_2O (0.02-0.06), CaO (0.01-0.7) and MnO (0.00-0.07) are systematically low.

Tourmaline from Andean porphyry copper deposits have characteristic major and trace element compositions, the majority plotting in a cluster along the schorl-dravite solid solution series, with a tendency for Mg-rich members (dravite) to dominate (Figure 1).

Most of the tourmaline compositions fall between the proton- and alkali-deficient exchange vectors, which account for the increase of Al content in the Y-site and decrease of X and OH occupancies at the expense of the schorl/dravite end member. X-site cation totals (Na+Ca+K) vary from 0.69 to 0.84, indicating the presence of vacancies in the X-site.

DISCUSSION

A more detailed analytical study at the El Salvador deposit reveals that tourmaline compositions cluster on the Al-Fe-Mg diagram (Figure 2), even though the locations of the collected samples (and the type of host rocks) varies widely. These locations include very deep (below the Inca Adit), middle portions (main ore zones) and near-surface to surface areas. These latter samples are hosted in rocks displaying various intensities of alteration including supergene and gossans.

Although the tourmaline samples occur with such minerals as kaolinite, montmorillonite, alunite, and turquoise, the tourmalines still retain their primary chemical composition, even where many of the original components of the rocks or veins have been altered. This resistance to intense alteration is a characteristic feature of tourmaline which makes it so amiable as a resistate phase.

Figure 2 also compares tourmaline compositions from within the zone of mineralization and tourmaline collected on the fringe/barren portion of the El Salvador deposit. A notable feature is the distinct differences in composition, where the tourmaline outside the zone of mineralizaton are more Fe-rich members of the schorl-dravite solid solution series. The compositions are marked by elevated FeO (9.4 - 11.1 wt.%), TiO2 (0.5 - 0.9) and low MgO (4.4 - 5.0). The tourmalines are also slightly more enriched in Mn.

EXPLORATION APPLICATIONS

Deep weathering, concealing overburden and transported material are fundamental exploration problems in many countries. In addition, in the copperrich region of northern Chile, the arid to semi-arid climate has impeded the development of soil and stream sediments. Except for a small percentage of rock outcrops, most of the region is covered by an extensive apron of talus. In all these regions, alternative exploration techniques (soils, stream sediment, talus) play a greater role in the search for mineralization.

On the basis of the well known chemical and mechanical stability of tourmaline, the potential exists for the use of the tourmaline mineral composition in mineral exploration in the supergene environment of the Chilean Andes. Tourmaline associated with Andean porphyry copper deposits are characterized by Mg>Fe and based on preliminary data, also have distinctive trace element compositions with identified anomalous concentrations of Co, Cr, Cu, Ni, Sr, V and Zn. These factors may be used to distinguish these Mg-rich tourmalines from the black Fe-rich schorls typical of most felsic plutonic rocks and thus serve to discriminate between granitic and regional metamorphic sources.

Reconnaissance regional exploration programs should take into account anomalous concentrations of tourmaline in talus, stream sediments, soils or altered rock horizons and should consider tourmaline compositions as a prospecting guide.

It is important to note that care should be used in using only the major element composition of tourmaline i.e. Fe vs. Mg as the sole discriminating factor. In areas devoid of mineralization, Mg-rich or intermediate Mg/Fe compositions could be found which in these cases reflects the bulk chemistry of the host rocks rather than the chemistry of the mineralizing hydrothermal fluids. If an exploration program anticipates using tourmaline chemistry, a careful evaluation of the geology and chemistry of the terrain should be considered. In conjunction with this evaluation, other discriminating factors such as the trace element signature of the tourmaline should be used.

Work is currently in progress to characterize the composition of tourmaline from various other types of Andean mineralization including epithermal Au. The ultimate goal is to formulate discriminants to distinguish betwee tourmaline from various forms of mineralization and more importantly, to distinguish between tourmalines from mineralized and barren zones.

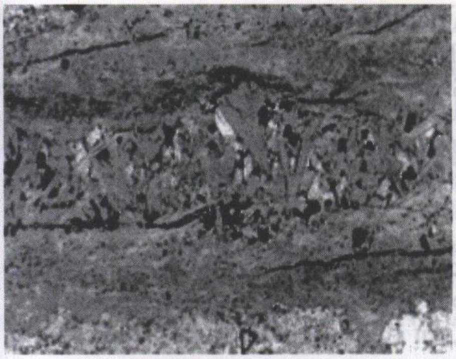

Photo1: Veinlet of interlocking tourmaline needles, with quartz and chalcopyrite in altered porphyry. Note vein selvage of fine tourmaline and K-feldspar. El Salvador, Inca Adit level. ppl, Field of view 2.5 mm.

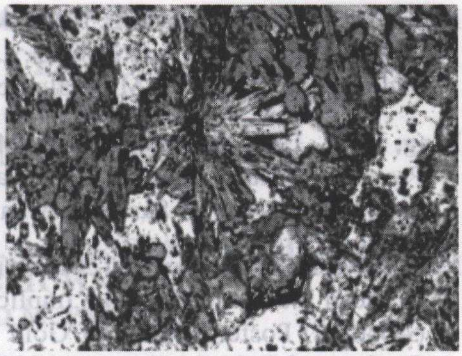

Photo 2: To9urmaline starburst with quartz, anhydrite and sulfides Note: patchy zonation in some of the needles. El Teniente, ppl, Field of view 2.5 mm.

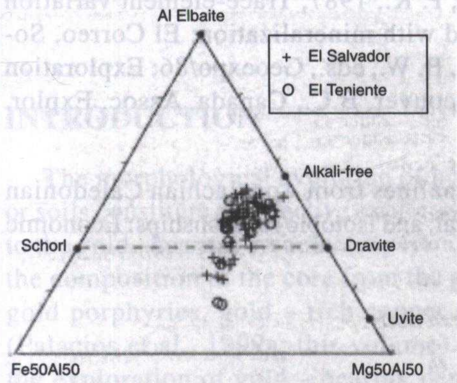

Figure 1: Ternary cation plot of microprobe analysis from the El Salvador and El Teniente porphyry copper deposits.

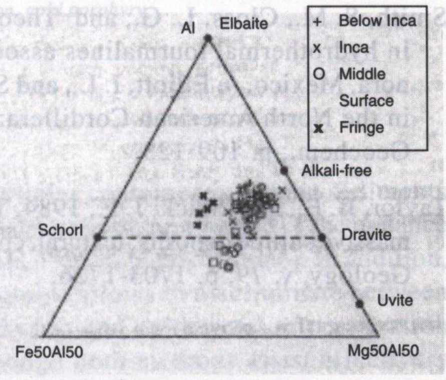

Figure 2: Ternary cation plot of microprobe analysis from various location in the El Salvador porphyry copper deposit.

REFERENCES

Birk, R. H., 1980, The petrology, petrography, and geochemistry of the Black Jack breccia pipe, Silver Star Plutonic Complex, Skamania County, Washington: Unpub. M.Sc. thesis, Western Washington University, 107 p.

Boyle, R. W., 1974, Elemental associations in mineral deposits and indicator elements of interest in geochemical prospecting (revised): Geological Survey of Canada, v. Paper 74-75, p. 40p.

Brown and Ayuso

Ethier, V. G., and Campbell, F. A., 1977, Tourmaline concentrations in Proterozoic sediments of the southern Cordillera of Canada and their economic significance: Canadian Journal of Earth Sciences, v. 14, p. 2348-2363.

Henry, D. J., and Dutrow, B. L., 1996, Metamorphic Tourmaline and its Petrologic Applications, *in* Anovitz, E. S. G. a. L. M., ed., Boron Mineralogy, Petrology and Geochemistry, 33, Mineralogical Society of America, p. 503-557.

King, R. W., 1990, Tourmaline from Mesothermal gold deposits of the Superior Province, Canada: Textural, chemical and isotopic relationships: Unpub. Ph.D. thesis, University of Saskatchewan, 228 p.

King, R.W., 1988, Geochemical characteristics of tourmaline from Superior Province Archean lode gold deposits: implications fro source regions and processes. (Abstract) Poster Volume of Gold ´88, an Internationla Symposium on the Geology pf Gold: Melbourne, 1988

Power, G. M., 1968, Chemical variation in tourmalines from south-west England: Mineral. Mag., v. 36, p. 1078-1089.

Smith, S. M., Closs, L. G., and Theobald, P. K., 1987, Trace-element variation in hydrothermal tourmalines associated with mineralization: El Correo, Sonora, Mexico, *in* Elliott, I. L., and Smec, B. W., eds., Geoexpo/86; Exploration in the North American Cordillera: Vancouver, B.C., Canada, Assoc. Explor. Geochem., p. 109-125.

Taylor, B. E., and Slack, J. F., 1984, Tourmalines from Appalachian Caledonian massive sulfide deposits: textural, chemical, and isotopic relationships: Economic Geology, v. 79, p. 1703-1726.