Volatile Element Haloes of Volcanogenic Massive Sulfide Deposits of the Bathurst Mining Camp, New Brunswick, Canada: Implications of Mineral Micro-Chemical Vectors by Laser Ablation ICP-MS Systematics in VMS Exploration

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Volatile elements, by their ubiquitous nature and relative mobility, have the potential to define geochemical anomalies that are larger than the volcanogenic massive sulfide (VMS) deposit footprint from which they formed. We introduce an innovative approach using in situ LA-ICP-MS techniques to establish variation in the volatile element contents of silicate and sulfide minerals of the Middle Ordovician polymetallic Zn-Pb-Cu-Ag VMS deposits of the Bathurst Mining Camp (BMC), Canada. This technique allows measurement of a wide range of volatile trace elements with high-spatial resolution sampling, low detection limits, and cost efficiency in surveying large number of samples. Volatile elements of interest as VMS vectoring tools include As, Bi, Cd, Hg, In, Sb, and Tl.

The felsic, mafic volcanic, and sedimentary host rocks of the BMC show mineralogical and chemical zonation related to VMS deposit formation. Hydrothermal mineral assemblages can be categorized based on the mineralogical and chemical variations from the core to the margins of the footwall hydrothermal fluid upflow zones and partially in the overlying hanging wall of some deposits. Phyllosilicates, including chlorite and white mica, are the predominant constituents of the hydrothermal alteration assemblages. The proportion of chlorite increases toward the ore horizon, with distinct occurrence of Fe-rich chlorite varieties in the immediate footwall below the massive sulfide lenses. White mica is more widespread in distal footwall and hanging wall. Similarly, disseminated and vein-type sulfides (in particular, pyrite) occur in wide dispersion around the deposits (up to several hundred meters).

LA-ICP-MS spot analyses of phyllosilicates and sulfide samples from the BMC demonstrate significant contents of volatile elements. Pyrite is the most abundant sulfide mineral throughout the BMC VMS and enclosing host rocks. Most forms of pyrite are arsenian type with As contents up to 7.3 wt %, with elevated Sb (up to 2910 ppm), Tl (up to 4110 ppm), and Hg (up to 220 ppm). In addition, phyllosilicates can accommodate minor amounts of volatile elements in their structure via lattice-bound substitution. White mica typically contains As (up to 1.01 wt %), Sb (up to 4750 ppm), Tl (up to 698 ppm), In (up to 563 ppm), Hg (up to 67 ppm), Cd (up to 83 ppm), and Bi (up to 185 ppm). In comparison to white mica, chlorite is preferentially enriched in Cd (0.07–420 ppm) and Bi (0.02–185). Integrated LA-ICP-MS data of phyllosilicate and sulfides show systematic variation with increasing proximity to the ore horizons. In the footwall of the deposits, all of the volatile elements (As, Sb, Tl, Bi, and to a lesser extent Cd, In, and Hg) increase toward the ore horizons. Likewise, volatile element contents in the proximal hanging-wall units show the same increasing patterns. Together, phyllosilicates and sulfides serve as the main dispersal vectors for volatile elements in VMS deposits of the BMC. The result of this study led to three mineral micro-chemical vectors, including pyrite, phyllosilicates (chlorite and white mica together), and white mica. This new approach may be applicable in other VMS districts, and may complement other geochemical and geophysical exploration techniques.