The Discovery of Halogens in the Ores at Broken Hill, NSW: Economic Implications of Sulfide Melting

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A suite of primary lead bromine-substituted chlorides and bromine-iodine substituted oxy-hydroxychlorides have been identified within the ores of Broken Hill. These halogens substituted into sulfide ores at peak metamorphic conditions, and subsequently exsolved upon cooling. They provide a direct view of the chemical evolution of the Broken Hill partially melted ore system. The presence of halogens and low melting point chalcophile elements (LMCEs) in these ores suggest that they were introduced together and are a protolith feature. Partial melting, melt residue fractionation, enrichment and subsequent mobilization are predicted. The suite of lead halides represent a bulk composition or final fractionate of a sulfide melt preserved in the post-metamorphic ore deposit at Broken Hill.

The halogens have lowered the melting point of the ores at Broken Hill, allowing exsolution of lead halide exsolution lamellae and halide-bearing compounds down to very low temperatures. This is supported by melting of halogen-bearing Broken Hill galena at 500°C (at 5 kb), which is at least 600°C below its pure melting point. Halogens allowed melting to occur at relatively low temperatures and allowed fractionation to very low temperatures. Did this allow the formation of Thackaringa-type carbonate-hosted melts of the Consols and Junction mine lodes? Halogens are also found in the Thackaringa-type deposits. Geochemical and isotopic links are made between the Broken Hill ore deposit and the Thackaringa-type deposits through mobilization of LMCEs and halogens, via F_4 fault conduits.

The economic implications for partial melting of both styles of mineralization are profound. The LMCEs are modelled as concentrated into depositional sites following differentiation of polymetallic melts, e.g., dropper orebodies of Broken Hill ore deposits, during a separate mineralizing event. The strongest evidence for isolated concentrations is in the form of sulfosalts and metal alloys, e.g., freibergite, arsenopyrite, native silver, silver-antimony alloys (e.g., dyscrasite) and other LMCEs. The definition of a spatially separate vertical fractionation sequence envisaged in the Broken Hill Block, intimately linked to Broken Hill-type mineralization, which is host to differentiation of Thackaringa-type melts, may have considerable exploration potential.

Indeed, the partial melting of sulfides in medium- to high-grade metamorphic terranes is considered to have a critical effect on the concentration of precious metals and halogens in such deposits. If the deposit has undergone melting, these precious metals and halogens may have been concentrated in small areas of high-grade ore in preference to being widely disseminated. Understanding the spatial and structural mode of occurrence of droppers in terms of the melt model in Broken Hill-type mineralization and Thackaringa-type veins may be critical in terms of economic significance. Through examination of the surface expressions above droppers and Thackaringa-type veins at Broken Hill, this research may lead to practical issues of improved exploration concepts, discovery, mine geology, and recovery. In doing so, the LMCEs + halogens (especially iodine) of the regolith (especially the A and B horizon soil components) above potentially buried Broken Hill-type ore deposits and the spatially separate Thackaringa-type veins in the Broken Hill Block should be measured carefully.