The behaviour of semi-metals (Se, Te, Bi) in magmatic-hydrothermal systems and their role in precious metal transport

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Semi-metals bismuth (Bi), tellurium (Te) and selenium (Se) are critical for green technology and are potential co-products of porphyry copper deposits. LA-ICP-MS analysis was performed on sulphides from two porphyry copper deposits – Muratdere, a Cu-Mo (Au) deposit in Turkey enriched in Se, and Skouries, a Cu-Au (PGE) deposit in Greece enriched in Te. Sulphides from both deposits have variable Te and Bi contents, while Se concentrations are consistant within sulphide generations. LA-ICP-MS analysis reveals that Se is preferentially incorporated into galena, with galenas from Muratdere containing an average of 309 ppm Se, and those from Skouries containing an average of 3.9 wt% Se (from EPMA). Pyrite and sphalerite in assemblages containing galena are Se depleted in comparison to those in other assemblages, and galena-clausthalite (Pb-S-Se) solid solutions are observed. Molybdenite also has relatively high Se concentrations (50 – 266 ppm), as does chalcopyrite (182-373 ppm), while pyrite shows the largest variability in semi-metal content in both deposits (Se between 26 – 349 ppm; Te between 0.1 - 15 ppm; and and Bi between 0.1 – 11 ppm).

SEM-EDS and EPMA analysis of vein samples from Skouries has identified the platinum group minerals (PGM) sopcheite ($Ag_4Pd_3Te_4$), sobolevskite (PdBi), kotulskite (Pd(Te,Bi)) and merenskyite ((Pd, Pt)(Te, $Bi)_2$), as well as hessite (Ag_2Te), sylvanite ($(Au,Ag)_2Te_4$), empressite (AgTe) and volynskite ($AgBiTe_2$). These PGM and Ag-Au minerals are found as blebs within euhedral hydrothermal quartz crystals. This, combined with the low concentrations of Te and Bi in sulphides, suggests they were transported as a melt and precipitated due to a drop in temperature rather than being transported solely as ligands within the fluid.

Fluid inclusion studies have shown the main mineralising fluids in Skouries to have temperatures of >550 ^oC. As the Pd-Bi-Te system is molten above 489^oC Bi-Te melts may act as a collector mechanism for PGEs and other precious metals in high temperature hydrothermal fluids. This mechanism would allow the formation of PGE-enriched porphyries without Pt and Pd sulphide saturation.