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Investigation of trace ore elements in melt inclusions using ToF-SIMS

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Time of flight secondary ion mass spectrometry (ToF-SIMS) is a powerful tool for analyzing concentrations of elements and isotopes in very small areas and/or in very low concentrations that are not achieved by conventional mineralogical techniques such as electron microprobe or SEM. ToF-SIMS yields both molecular and elemental information, which has led to many studies, for example, on the analysis of polymers and organic films; however, we have applied it successfully to mineralogical solids. Ions are sputtered onto a solid surface and the secondary ions are selected according to their velocity of passage through a mass spectrometer and their m/z ratios. Areas as small as 0.1μm with detection limits in the parts per billion range can be analyzed. A current limitation to achieving quantitative analyses is the need for standards having vanishingly low concentrations of the elements of concern and preferably in the same matrix as the material being analyzed. We are currently working with others to develop such standards.

We have used ToF-SIMS to detect ultra trace metals in melt inclusions in phenocrysts of volcanic rocks on the modern seafloor of the Manus basin off the east coast of Papua New Guinea where there are active high temperature hydrothermal vents ("black smokers") and large sulfide deposits of Fe, Ba, Cu, Zn, Pb, Ag and Au. We have begun similar studies at hydrothermal vent sites on the Mid-Atlantic Ridge in the vicinity of

the Azores and on volcanogenic massive sulfide ore deposits of Ordovician age at Bathurst, New Brunswick, Canada and of Devonian-Carboniferous age in the Iberian Pyrite Belt. Our previous studies have discovered large and well preserved melt inclusions primarily in plagioclase but also in pyroxene and olivine in rocks ranging from basalt to rhyolite composition. Many of the vapor cavities of the melt inclusions as well as, in the modern samples, small vesicles contain minute precipitates of the ore elements and Cl. This discovery lends credence to the idea that magmatic fluids, as represented by the CO_2-H_2O fluids and metallic precipitates in the vapor cavities of melt inclusions and in vesicles, are important to the formation of base and precious metal massive sulfide deposits in volcanic rocks. We have obtained semi-quantitative analyses of the major elements in these precipitates by means of careful electron microprobe and SEM analyses but Ag, although detected, and particularly Au have been elusive. ToF-SIMS has enabled us to image Ag and Au as well as PGE in these precipitates but for now, lacking standards, we cannot determine their concentrations which are likely to be at high ppb levels. We have also detected many of these same elements as well as As, Cu and Ni in the glass of melt inclusions from the Azores area.