Applications of triple quadrupole ICP-MS (ICP-MS/MS, or ICP-MS QQQ) in economic geology

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Triple quadrupole ICP-MS (Inductively Coupled Plasma – Mass Spectrometry) is the latest generation quadrupole ICP-MS. The front quadrupole set and the reaction cell before the traditional quadruple set make it possible to minimize isotope interferences that are not separable before, e.g., $^{87}\text{Rb}^+$ vs $^{87}\text{Sr}^+$, and $^{32}\text{S}^+$ vs $^{16}\text{O}^{16}\text{O}^+$. Coupled with a laser ablation system, it has several new applications in economic geology research and mineral deposit exploration, including in-situ Rb-Sr dating, measurement of low concentration sulfur, in-situ sulfur isotope analysis, and molybdenite Re-Os dating.

In-situ Rb-Sr dating methodology is being developed in several labs. At Colorado School of Mines, with an Agilent 8900 ICP-MS/MS, a Resolution-SE 193nm laser system, $\text{O}_2$ cell gas, Mica-Mg-NP nano-pellet standard, laser downhole fractionation corrected using an averaging method, and machine drift with an exponential model, we achieve ~2% relative uncertainty at two sigma level. This is demonstrated by the dating of a muscovite. Our result is $304 \pm 6\text{Ma} \ (\text{MSWD} = 1.3)$, which is statistically indistinguishable from the Ar-Ar ages of $305 \pm 3$ and $308 \pm 3\text{Ma}$ and Re-Os ages of $306 \pm 3$ and $306 \pm 2\text{Ma}$ of molybdenite of the same paragenesis stage [1]. For low concentrations of sulfur, using the MS/MS mode, $\text{O}_2$ cell gas, BAM-S005B external standard, 50-100µm spot, 5 Hz and 3-4J/cm$^2$ laser, the detection limit (DL) is reduced to 3-10 ppm, significantly lower than the ~200 ppm DL at single quadrupole mode. This capacity is applied on hydrothermal calcite around a porphyry-skarn deposit and the S content shows a trend, adding another distal vector for exploration of skarns [2] and porphyry deposits hosted in carbonates. Sulfur isotope analysis using LA-ICP-MS/MS is at an early stage, with an uncertainty of ~1‰ (2SD).
