Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.36637

Efficient in situ Sr isotope analysis of apatite via LA-MC-ICP-MS

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Apatite is a resistant accessory mineral with $^{87}Sr/^{86}Sr$ signatures used as key tracers of magmatic evolution and crustal differentiation, providing an essential tool for petrogenetic studies and multidisciplinary applications. The potential for apatite to exhibit complex internal zonation or occur as small inclusions necessitates Sr isotopic measurements with high spatial resolution. While laser ablation multi-collector inductively coupled plasma mass spectrometry (LA-MC-ICP-MS) has emerged as the preferred technique for such in-situ measurements, achieving accurate results remains challenging due to complex spectral interferences. Existing data reduction strategies are often time-consuming, requiring external solution-based measurements. Furthermore, the availability of suitable apatite reference materials is limited, with a lack of reported $^{87}Sr/^{86}Sr$ values for several widely distributed examples.

This study aims to establish an efficient analytical framework by expanding the suite of well-characterised natural apatite reference materials and optimising data reduction procedures for best practice *in situ* LA-MC-ICP-MS analysis of apatite. We systematically explore interference correction efficiency and data quality (precision and accuracy) across both spot and raster sampling modes with mask sizes ranging from 14 to 100 µm. A diverse range of reference materials spanning a wide range of Sr and REE concentrations, including glass and apatite reference materials, was utilised to evaluate matrix effects and optimise analytical conditions. We report enhanced-precision LA-MC-ICP-MS $^{87}Sr/^{86}Sr$ values for several common apatite reference materials, including 401, 815, Emerald Lake and Phalaborwa, and provide further detailed characterisation of established Sr isotope apatite reference materials including Durango, Mud Tank, MAD1, MAD2, McClure Mountain and Otter Lake. The automated workflow demonstrates robust accuracy in correcting for interferences while significantly reducing data processing complexity compared to traditional offline stripping methods.

The refined high-spatial-resolution protocols are successfully applied to a case study of apatite inclusions in clinopyroxene megacrysts from Stromboli Volcano, Italy. The results demonstrate the ability of the approach to resolve subtle isotopic signatures within magmatic plumbing systems, providing a versatile tool for the broader geochemical community.