Laser Ablation ICP-MS Analyses of Geological Materials

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Abstract
Laser ablation ICP-MS (LA-ICP-MS) is a powerful quantitative micro-analytical tool for many solid samples. Geological materials are especially suited for LA-ICP-MS given the importance of detailed resolution of trace elements. Trace element information recorded in minerals can often unravel geological events that are often indecipherable based on major element information. Information such as rare earth element zoning recorded during mineral growth can lead to interpretation about the geological conditions during such mineral growth. The combination of LA-ICP-MS and detailed isotopic dating provide further strengthening of any geological interpretation.

Using a 266 nm laser ablation system, detailed trace element information from a variety of geological materials is obtained for both interpretive and fundamental research. Advances in laser ablation standards, data collection, data processing and analytical flexibility now allows a greater range of samples to be analyzed with greater certainty. Using automated spot analyses of mineral grains, trace element maps are generated, providing information on trace elemental zoning, inclusion density and chemical behavior during mineral growth. Information about standardization, parameter optimization and fundamental ablation characteristics will be presented.

Elemental Fractionation and Wavelength Issues
Much has been said about the performance of different wavelengths used for laser ablation. Two important considerations of selecting a laser ablation system are the performance regarding elemental fractionation and the ablation performance in the desired matrices. It has been said that 266 nm does not ablate calcite, quartz and fluorite. Here we present data collected on gem quality calcite with a high energy 266 nm system. Also shown are pictures of craters in high purity quartz. Elemental fractionation is often measured by the stability of elemental ratios during a long ablation. In both the calcite and NIST612 the CETAC LSX-500 demonstrates performance superior to previous 266 nm systems. The data collected on calcite and NIST612 were run at 250 µm, 10 Hz.

Geological Laser Ablation Standards
• Carbonate Materials (calcite, coral, etc.)
  • The US Geological Survey MACS-1 is a carbonate standard designed for the purpose of quantitative trace element work on carbonate minerals
  • A flexible precipitation recipe allows homogeneous powders to be produced for a variety of matrices and doped elements
• Phosphate Materials (apatite, bone, teeth, etc.)
  • The USGS MAPS-1 is a phosphate matrix, trace element doped precipitated powder
• Sulfide Materials
  • THE USGS MASS-1 is sulfide matrix, trace element doped precipitated powder, especially useful for volatile and toxic elements (see Wilson, Ridley and Koenig, JAAS 2002, 17, 406-409)

Conclusions
• Laser ablation ICP-MS is a powerful tool for elemental fingerprinting and mapping of virtually any solid material
• High energy (> 9 mJ) 266 nm is suitable for virtually any geological material, including the allegedly difficult materials such as quartz, calcite and fluorite
• Trace element mapping that is impossible or impractical by other techniques is a powerful strength of LA-ICP-MS
• New laser ablation standards allow quantitative analyses on a wider range of sample types
• New understanding of the fundamentals of the ablation process and new laser technology will continue to improve the performance of laser ablation systems in the future

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