Recently, ALS has partnered with CODES Analytical Laboratories at the University of Tasmania to offer Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) to extend the methods of mineral characterization to include trace-element point analyses. Developments in LA-ICP-MS technology have enabled routine determination of the trace-element concentrations in small volumes of in situ material. This can include parts of individual minerals, such as the core, rim or zoned features in mineral grain. The composition of minerals is a function of their formation conditions, which in turn can be used to infer information about the fluid or magma from which they crystallized. Research into the chemistry of minerals in ore and associated alteration systems suggests that spatial changes in mineral composition may make an effective exploration tool. This is of interest to explorers, who are commonly, dealing with exploration settings in which part or even the entire mineralisation system may be covered by post mineralisation lithologies or unconsolidated cover. The ability to discriminate between prospective and less prospective systems can help prioritise areas for further exploration and reduce the size of exploration target areas (Cooke et al., 2020). The chemistry of some alteration minerals can also indicate the distance they formed from a mineralising centre, making mineral chemistry as an effective vectoring tool in both porphyry systems (Cooke et al., 2014; Wilkinson et al., 2017; Cooke et al., 2020; Uribe-Mogollon, and Maher, 2020), and also in VMS systems (Hannington et al., 2003).
How does LA-ICP-MS work?

During LA-ICP-MS analyses, a laser is used to ablate a small pit on the surface of the mineral or material to be measured. The ablated material forms an aerosol of condensed particles which is transported by a gas stream, usually He, to the ICP instrument. At the ICP the particles are broken down into ions. These ions are then introduced to the mass spectrometer where they are separated into isotopes, and sequentially counted by a detector. Concentration is determined by calibrating detector counts with elements of known concentration in the sample and within bracketing reference material. The reference materials are also used periodically during the analysis sequences to correct for any instrument drift over time.

The spot size of the laser can be varied from 20 to 80 microns in order to select the part of the mineral of interest. Most minerals are large enough to permit multiple analysis points within the mineral grain to allow internal variation to be quantified.

From 20 to 40 element are routinely determined during each spot analysis, depending on the application. Specific element lists can be provided on request. The preparation of samples for analyses can be either mineral separates mounted in an epoxy resin button or 25mm round mounts made from rock samples for in situ mineral analyses. Thin sections are not recommended for analyses by this method due to the laser drilling through the sample into the glass slide. Analyses are charged per spot with sample preparation as a separate cost. Please refer to the ALS fee schedule for the current cost of LA-ICP-MS analyses.

An example of LA-ICP-MS output for an analysis of epidote shown graphically. The point where the laser is turned on and the ablated material hits the mass spectrometer is where the signal increases at approximately 30 seconds. The analytical response in the grey-shaded zone shows the portion of the analyses that is used to determine the concentration of the elements in the sample. The analytical response in the blue-shaded zone is used to assess the background signal when the laser is off.
Applications of trace-element mineral chemistry to exploration

In a single mineral type, measurable trace element variation has been observed between the distal and proximal parts of the alteration halo in fertile mineralising systems. Such studies are dominantly available for porphyry systems (Cooke et al., 2014; Wilkinson et al., 2017; Uribe-Mogollon and Haher., 2020) but similar changes in mineral chemistry would be expected in other hydrothermal ore systems where alteration cells exceed the visible alteration distribution (e.g., using pyrite chemistry for exploration for SEDEX deposits; Mukherjee and Large, 2019) or where similar alteration systems are associated with both fertile and infertile systems.

One example from Cooke et al. (2014) describes the changes in epidote chemistry with distance from a porphyry deposit and how these changes can be used as a vectoring tool outside the pyrite halo. The importance of this new tool is that the pyrite halo around a porphyry system is easily identified using traditional geophysical and geochemical exploration tools but the more distal “green alteration” zone has been much less useful as a regional exploration tool (Cooke et al., 2014). The ability to identify if epidote is part of a distal alteration assemblage around a fertile porphyry system and in which direction the porphyry is expected, allows for more wide spaced sampling at early stages of exploration. This is particularly important where large parts of a porphyry system may be hidden under post-mineralisation cover and exposed portions of the system can be used to vector towards exploration targets.

Uribe-Mogollon and Maher (2020) have similarly identified variations in white mica associated with early phyllic alteration from mineralised and unmineralised porphyry systems. One tool used to quantify changes in trace-element composition of the white mica was LA-ICP-MS. The authors were able to characterise the trace-element changes in the white micas with fertility which could be used during exploration to discriminate between porphyry systems. Other mineral chemistry changes that have been identified in porphyry systems include zircon (Ballard et al., 2002), apatite (Bouzari et al., 2016), plagioclase (Williamson, et al., 2016), and magnetite (Dupuis and Beaudoin, 2011).

ALS and its partners offer a comprehensive range of methods to assist explorers and miners characterise minerals. Services include SEM-MLA (Scanning Electron Microscope-Mineral Liberation Analyser), QEMSCAN and many other quantitative and semi-quantitative mineralogy solutions within the ALS family. Information about all the services available can be found on the company’s web page or obtained from ALS client service teams.
References and Further Reading


ALS provides a wide range of specialised testing services covering all stages of your project’s life cycle.

Please visit alsglobal.com for more information on our services and specialties.

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