



## Chemistry at the mine site accelerates resource characterization

### The challenge

Modern mining increasingly depends on high-sensitivity analytical tools to detect trace elemental signatures. Such results help locate valuable ore pockets and characterize mineral composition and morphology for optimal processing. Traditionally, such analyses could only be performed by laboratory-based instruments, like Inductively Coupled Plasma Mass Spectrometry (ICP-MS) or Electron Probe Microanalysis (EPMA). These high-performance instruments must operate in controlled facilities far from the mine site, and they require highly trained experts to prepare samples, maintain complex systems, and interpret the results. As a result, mines follow a slow analytical cadence, involving shipping samples to centralized labs in monthly batches and reviewing results three to six weeks later.

This multi-week delay in analytical results impacts the efficiency of mining operations. Decisions about where to drill, which ore zones to target, or how to adjust blends are always weeks behind real-time conditions.

Techniques like X-ray Fluorescence (XRF) can be used at field sites for preliminary evaluation of elemental composition, however, they are not well-suited for trace elemental detection at low-ppm levels. Many rare earth elements are especially challenging due to the overlapping spectral lines.

In addition to bulk elemental analysis, elemental mapping is important for resource characterization. The distribution of valuable elements and their mineral hosts is a critical part of predicting ore grade recovery. Elemental maps can also reveal phases carrying impurities or penalty elements.

**Until now, no analytical technique could provide trace-level elemental analyses and elemental mapping in a compact package suitable for mine sites.**



Figure 1: Image of the EXUM™ MASSBOX™ LALI-TOF-MS instrument with dimensions of 24" x 30" x 27". Because it does not require gas supplies, ancillary equipment, and isn't sensitive to vibrations, it can be deployed to the field.

## The MASSBOX LALI-TOF-MS as the solution

The MASSBOX's Laser Ablation Laser Ionization Time of Flight Mass Spectrometry (LALI-TOF-MS) addresses many challenges associated with other analytical techniques to offer rapid, high-sensitivity chemical characterization at the point of need. The ionization source, LALI, uses two lasers to first ablate, or release, material from a solid sample's surface and then ionize neutral particles present in the ablated material. The laser ablation process allows direct analysis of solid materials, from ground rock samples to cores, without the complicated sample preparation procedures of other techniques that require liquid sample introduction.

The ionization laser targets the neutral particles created by ablation, which are more representative of the sample's

constituents than plasma-generated ions. Overall, LALI results in more reliable elemental verification and reduces sample matrix effects. After ionization, the TOF mass analyzer creates a full mass spectrum at each laser spot. Based on the naturally occurring isotope patterns, the software verifies each detected element.

Because of the MASSBOX LALI-TOF-MS's compact, desktop package and robust design, it brings geochemical characterization out of the laboratory environment. Instead of waiting weeks for results from centralized labs, field offices can make quicker informed decisions about exploration strategies and processing facilities can gain in-plant analytical insights about the material quality.

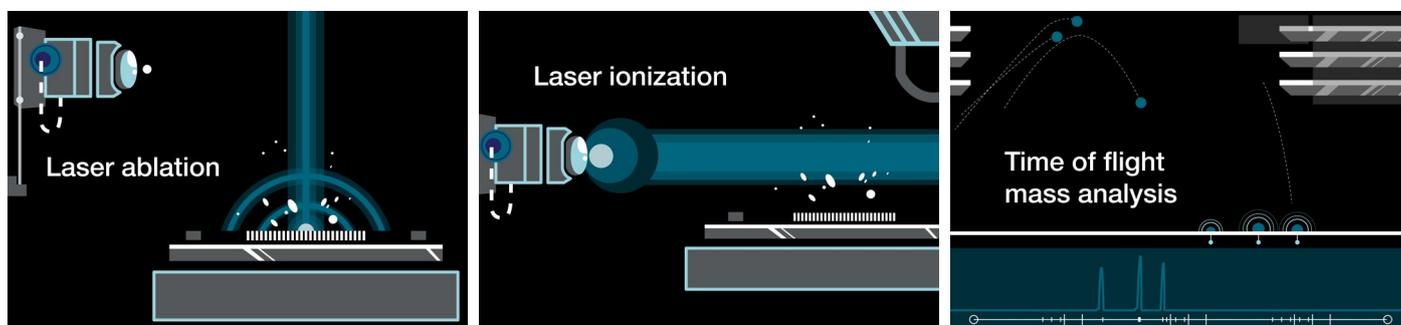


Figure 2: A) Ablation laser fires perpendicular to the sample's surface. The laser spot size is adjustable from 5-150 microns; B) Secondary laser performs multiphoton ionization of neutral particles created by ablation process; C) Ions are separated by Time-of-Flight mass spectrometry and detected with a multichannel plate (MCP)

## Core evaluation

This exploration study focuses on determining:

- The potential to extract lithium
- The mineralogy of composite grains, highlighted in Figure 3

## Thin section core plug

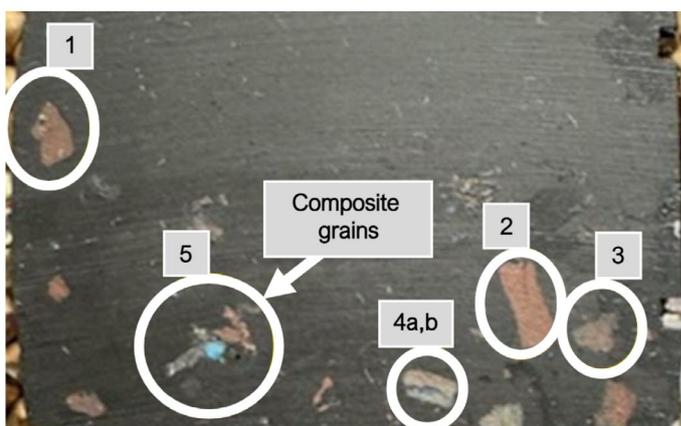


Figure 3: Image of a thin section core plug with 5 areas of interest (#1-5) highlighted. This study investigated the mineralogy and potential to extract lithium from the composite grains shown in Area #5

## Elemental mapping

In each analytical session, the MASSBOX LALI-TOF-MS can analyze an area up to 90 mm by 90 mm. The user adjusts the ablation laser spot size, from 5-150 microns, which determines the elemental map's spatial resolution. Each laser spot contains a full mass spectrum of data, and the resulting map reveals the variation of any element of interest. Figure 3 shows a subset

of maps acquired across the composite grains in Area #5. On each map, the color scale indicates the relative concentration. Brighter blues are higher concentrations, and darker blues are lower. Results reveal groupings of various elements (e.g., Al, K, Na, and Ba) used for mineral identification.

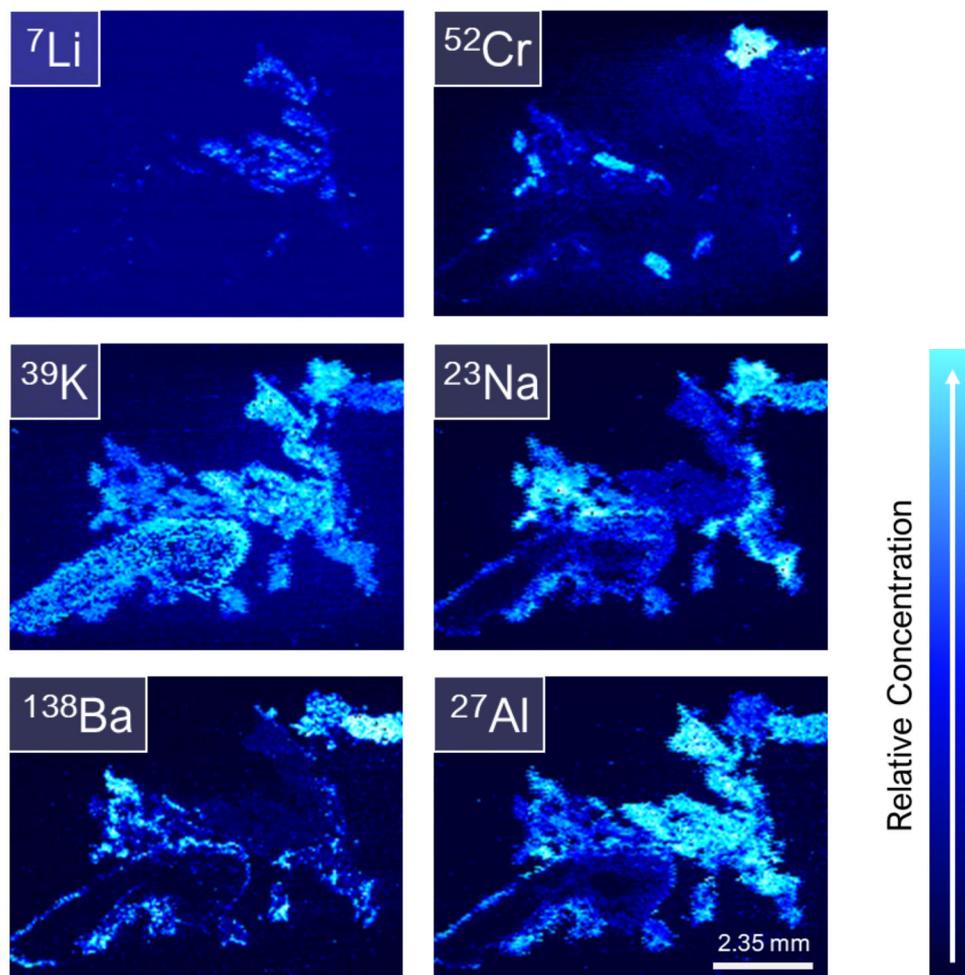


Figure 4: Mapping results acquired by the MASSBOX LALI-TOF-MS on a thin section core plug. The 9.4-mm-by-7.35-mm maps have spatial resolutions of 50 microns. The maps show the distributions of lithium (Li), chromium (Cr), potassium (K), sodium (Na), barium (Ba), and aluminum (Al). Each elemental map is relative to itself. In each map, brighter blues represent relatively higher concentrations, and darker blues are lower.

## Trace lithium detection

Rapid elemental mapping allows geoscientists to make more informed decisions on exploration potential, mineral zoning, and process optimization. The MASSBOX LALI-TOF-MS acquires results like those shown in Figure 4 in less than 30 minutes.

In addition to determining the mineralogy of the composite grains, the elemental maps presented in Figure 4 identify trace amounts of lithium (Li). The exploration company was especially interested in potentially extracting Li from this reservoir rock. The elemental mapping results show trace Li in distinct grains with relatively high K and Al. These elemental signatures help determine the mineral hosts of valuable elements like Li.

Scanning electron microscopy with energy dispersive x-ray spectroscopy (SEM-EDX) is commonly used for elemental mapping and automated mineralogy identification. Li is a challenging element to reliably measure with either SEM-EDX or XRF. Addressing these limitations, LALI-TOF-MS quantifies Li in low-ppm levels.

Determining if Li is present and how it is distributed within the grains enables informed extraction strategies and accurate resource estimation.

### Rare earth element quantification

From smartphones to electric motors, Rare Earth Elements (REEs) are essential to consumer and industrial technologies, and demand for them continues to increase. Because REEs are not typically found in concentrated, economically viable mineral forms, it is critical to detect them at trace (ppm) levels. Most of the geochemical analyses required during the resource characterization and evaluation phase of mining REE deposits is performed by techniques like ICP-MS at centralized laboratories. Traditional ICP-MS involves digesting solid material with acid for the most accurate elemental analyses.

To simplify the sample preparation process, some users combine mass spectrometry techniques with laser ablation instruments (LA-ICP-MS). Due to the complexity of each part of the combined laser ablation and spectroscopy system, there are still numerous challenges in data collection and processing. As such, LA-ICP-MS is not well suited for field deployment.

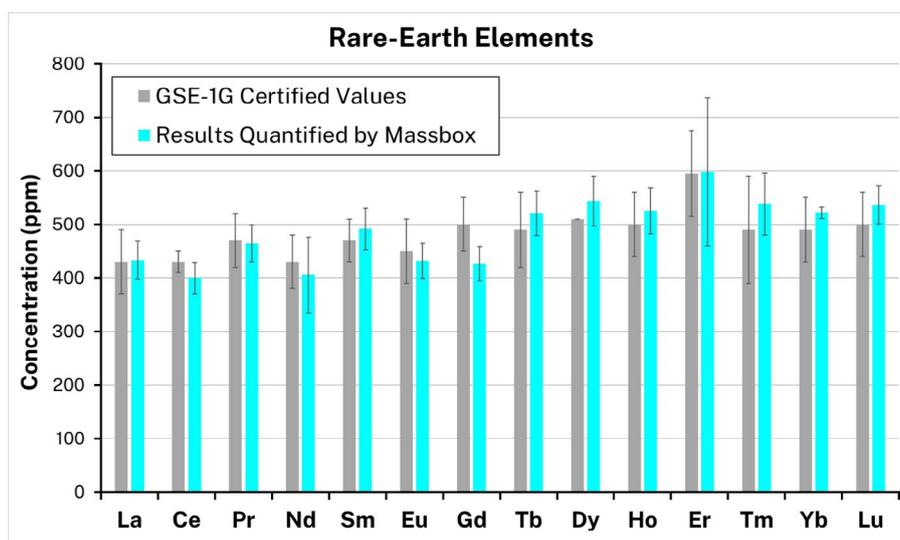


Figure 5: Comparison of the MASSBOX LALI-TOF-MS's results quantified across the average of three raster areas (blue) compared to the GSE-1G certified results (gray), demonstrating 6% average accuracy. On Massbox's results, error bars depict the standard deviation from triplicate raster areas. On the certified values, the error bars show a confidence interval for 95% uncertainty.

Figure 5 demonstrates the MASSBOX LALI-TOF-MS's ability to accurately quantify 14 REEs directly from a glass reference material, GSE-1G. Using a similar black glass reference material as a calibrant, the MASSBOX LALI-TOF-MS quantified the

concentrations within 6% accuracy compared to the certified values. Figure 5 compares results acquired by the MASSBOX LALI-TOF-MS (in blue) with the reference material's certified values (in gray).

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