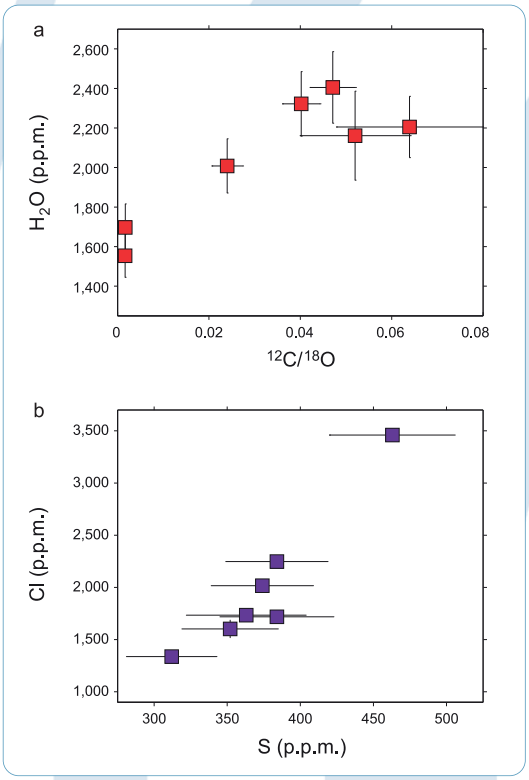
Applications of the CAMECA **IMS 7f-GEO** Ion Microprobe to **Cosmochemistry**

High Precision Measurement of Volatile Trace Elements

Lunar Apatite with Terrestrial Volatile Abundances

The Moon is thought to be depleted relative to the Earth in volatile elements such as H, Cl and the alkalis. Determination of volatile contents in lunar samples is important for understanding lunar origin and evolution. This study reports quantitative Secondary Ion Mass Spectrometry (SIMS) measurements of late-stage apatite from lunar basalt 14053 using the **IMS 7f-GEO**. The key result of this study is the observation that H, Cl and S contents of apatite from the lunar basalt are essentially indistinguishable from apatites grown from terrestrial magmas. One possible implication is that portions of the lunar mantle or crust are more volatile-rich than previously thought.

The **IMS 7f-GEO** is well suited for measurement of volatile species (C, H, F, S and Cl) in mineral samples. High quality data and low detection limits are obtained using spot analysis mode due to its high-density Cs+ primary beam, optical and electronic gating to eliminate contribution from crater edges, and high mass resolving power capabilities for eliminating mass interferences (e.g.$^{16}O^{1}H^{-}$ / $^{17}O^{-}$, $^{32}S^{-}$/ $^{31}P^{1}H^{-}$ and $^{35}Cl^{-}$ / $^{19}F^{16}O^{-}$).



Plots of H^2O versus C (a) and Cl versus S (b), for SIMS analyses of 14053 apatite. All concentrations are reported by weight, with hydrogen reported as H_2O and sulfur reported as S.

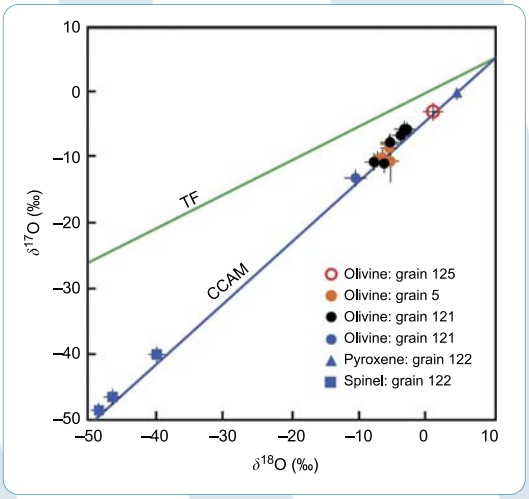
Data collected on IMS 7f-Geo at Caltech (USA). From J. W. Boyce et al., NATURE 466, 466-469 (2010).

Oxygen Three-Isotope Analysis

Evidence for the Extraterrestrial Origin of the Rock Containing a Natural Quasicrystal

The discovery of a natural quasicrystal, icosahedrite ($Al_{63}Cu_{24}Fe_{13}$), accompanied by khatyrkite ($CuAl_2$) and cupalite (CuAl) in the Khatyrka meteorite has posed a mystery as to what extraterrestrial processes led to the formation and preservation of these metal alloys in the oldest rocks (~4.5 billion years) of the solar system. In this study, the extraterrestrial origin is inferred from the $^{18}O/^{16}O$ and $^{17}O/^{16}O$ isotopic data obtained on different grains of the Khatyrka meteorite using the **IMS 7f-GEO**.

High precision isotope measurements are performed using the **IMS 7f-GEO**'s specific detection system with two low-noise Faraday cups and one discrete-dynode Electron multiplier. In this study, secondary ions were collected by peak-jumping into either a Faraday cup (^{16}O-) or Electron multiplier (^{17}O- and ^{18}O-) at a mass resolving power of ~6,500, which easily resolves the ^{16}OH- interference on ^{17}O-. A measurement precision of ~1-1.3 ‰ (1σ) was achieved for both $\delta^{17}O$ and $\delta^{18}O$.



Oxygen 3-isotope composition, to discriminate terrestrial (TF = terrestrial fractionation) and extraterrestrial (CCAM = carbonaceous chondrite anhydrous minerals) sources. The plot displays data for olivine , pyroxene, and spinel coexisting with a natural quasicrystal in the Khatyrka meteorite. Terrestrial minerals fall along the TF line (green line) with a slope of ~0.5; the oxygen isotope compositions measured for these samples lie along the CCAM line with a slope of ~1.

Data collected on IMS 7f-Geo Caltech (US). From L. S. Hollister et al., NATURE Communications 5, 4040 (2014).

CAMECA SCIENCE & METROLOGY SOLUTIONS
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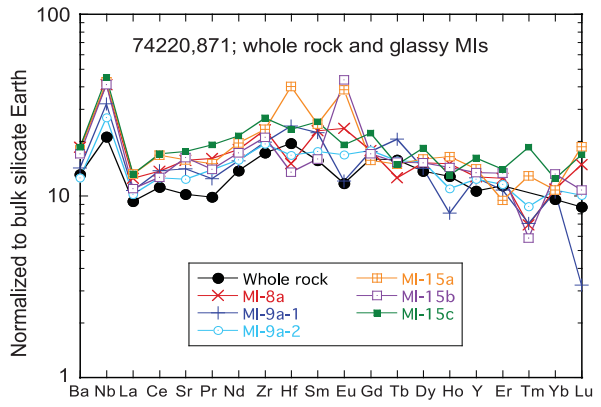
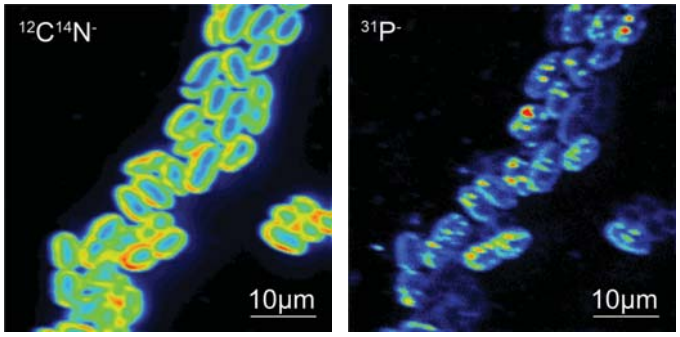
The IMS 7f-GEO is a compact, monocollection SIMS specifically designed for Geoscience laboratories. Delivering high precision and high throughput stable isotope ratio measurements, Rare Earth Element analysis, and trace element mapping down to micron scale resolution, it covers a wide range of applications in geo and cosmochemistry as well as microbiology.

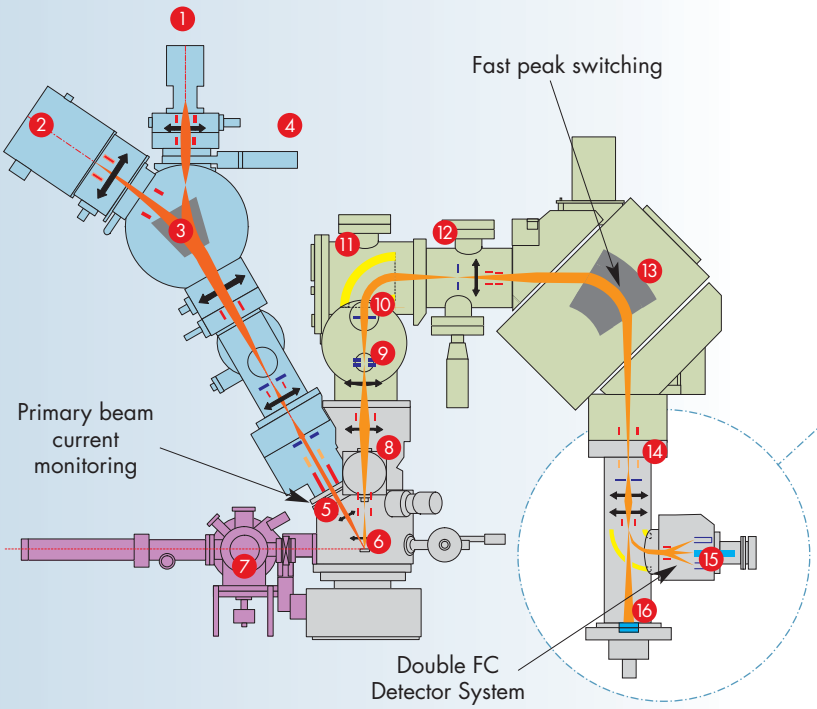


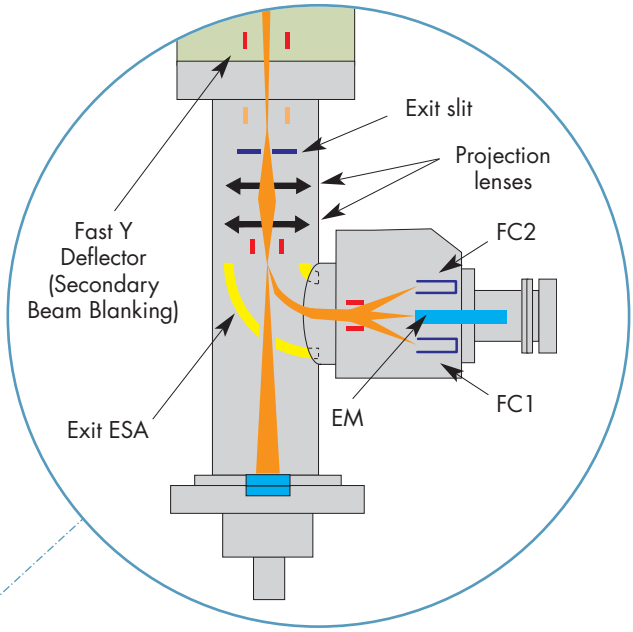
Trace element concentrations in olivine-hosted basaltic melt inclusions (MI) in a lunar sample obtained using energy-filtering technique.
Data from: Y. Chen et al, Earth and Planetary Science Letters 427 (2015) 37



Scanning ion imaging analyses of cynobacteria on a rinsed ITO/glass mount. Left: CN^- indicating protein. Right: P^- from phosphate. Elemental & isotopic mapping with high lateral resolution (~1µm).
Courtesy of C. Jones and M. Liberton, Washington Univ. in St. Louis, USA

A unique detection system combining one double Faraday cup detector system and one Electron Multiplier.





1 Microbeam Cesium ion source
2 Duoplasmatron ion source
3 Primary Beam Mass Filter (PBMF)
4 Cesium source isolation option
5 Primary Faraday cup
Motor driven primary column aperture
6 Sample (-10kV to +10kV) (Z axis in option)
7 UHV airlock system (Sample storage chamber in option)
8 Normal incidence Electron Gun (NEG)
9 Motor driven contrast aperture and entrance slit
10 Motor driven field aperture
11 Electrostatic Analyzer (ESA)
12 Motor driven energy slit
13 Fast laminated magnet
14 Motor driven exit slit
15 Electron Multiplier and double FC detectors
16 Ion image detector

For more information please visit www.cameca.com/products/sims/ims7f-geo

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