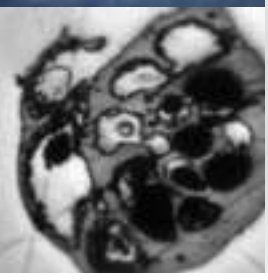
IMS 1300-HR3

Ultra High Sensitivity Secondary Ion Mass Spectrometer

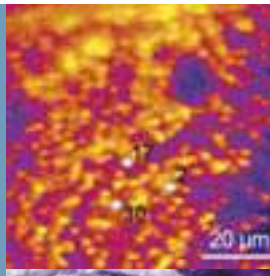


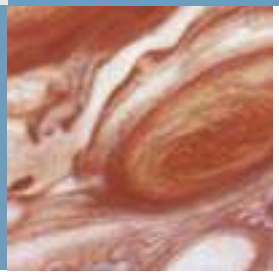
STABLE ISOTOPES

GEOCHRONOLOGY

TRACE ELEMENTS

ENVIRONMENTAL STUDIES





CAMECA® / AMETEK®

SCIENCE & METROLOGY SOLUTIONS

The most powerful Large Geometry SIMS instrument

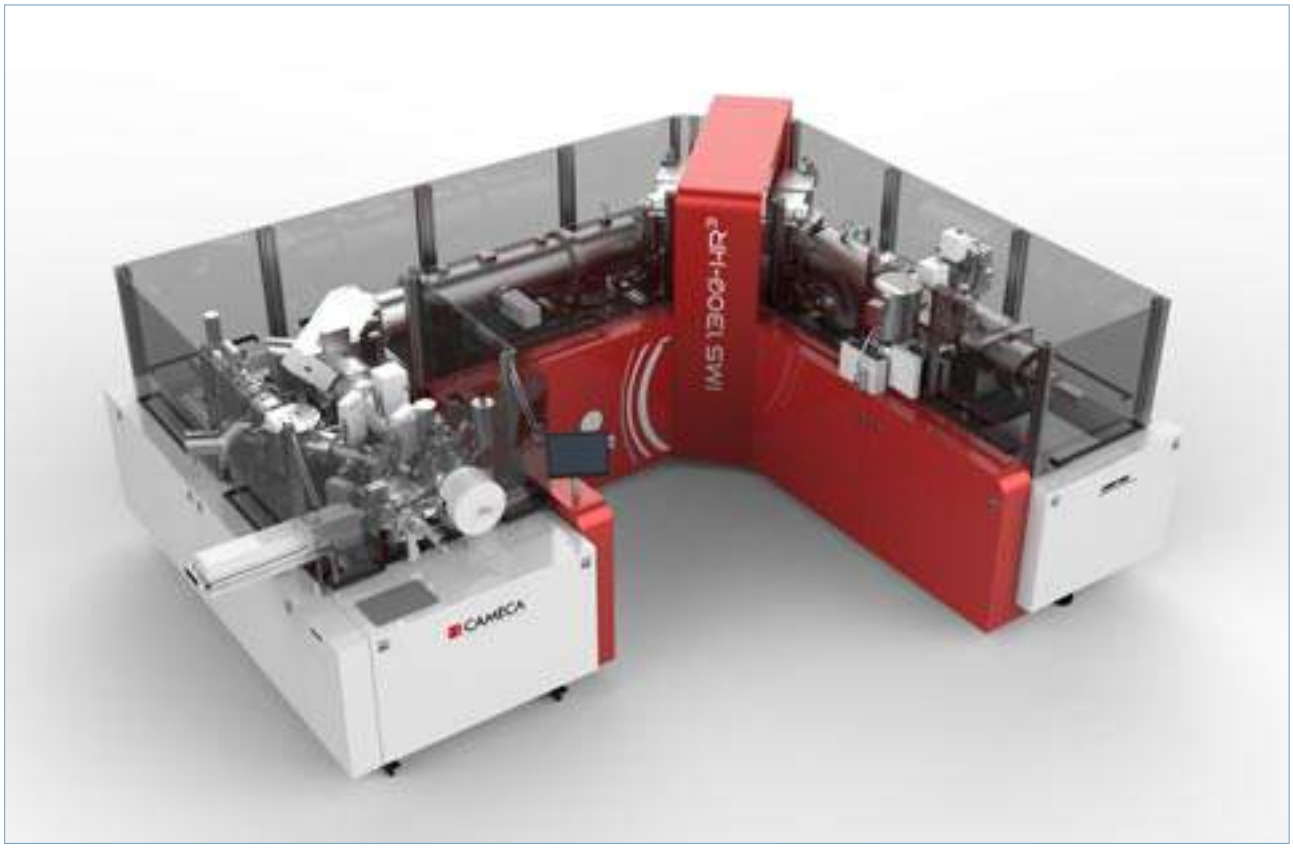
The IMS 1300-HR³ multicollection Large Geometry Secondary Ion Mass Spectrometer (LG-SIMS) delivers unequalled analytical performance, opening up the path to a large range of applications in geology, cosmochemistry and environmental sciences...

Successor of the internationally acclaimed IMS 1280-HR, CAMECA's IMS 1300-HR³ Secondary Ion Mass Spectrometer delivers unequalled analytical performance for a wide range of applications : tracking geological processes using stable isotopes, dating minerals, determining the content of trace elements, screening and analyzing large numbers of particles...

The IMS 1300-HR³ model combines the well-proven features of the former IMS 1280-HR with new developments that offer a unique combination of High Reproducibility at High spatial Resolution and High mass Resolution.

High density cesium or oxygen primary ion beam bombardment combined with optimized transmission allow high precision stable isotope studies and analysis of trace elements at high sensitivity (mandatory for Pb analyses in Zircon). The multicollector system ensures excellent reproducibility for stable isotope ratio measurements (C, O, S, Li, B, Mg...) and significantly increases the throughput of the instrument by reducing the total acquisition time.

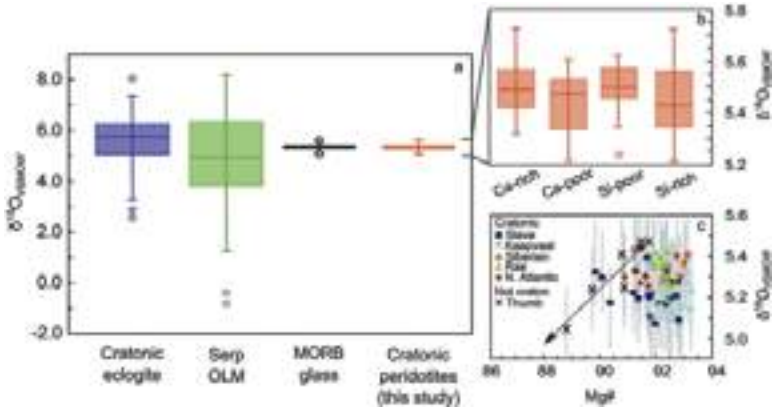
The IMS 1300-HR³ ion microprobe provides both microscope and microprobe imaging. Thanks to these superior imaging capabilities, the instrument is capable of mapping the distribution of major, minor and trace elements or isotopes at sub-micron lateral resolution.



EXCELLENT REPRODUCIBILITY FOR STABLE ISOTOPE RATIO MEASUREMENTS

High-precision $\delta^{18}O$ measurements of olivine from peridotite xenoliths in kimberlites from worldwide Archean cratons.

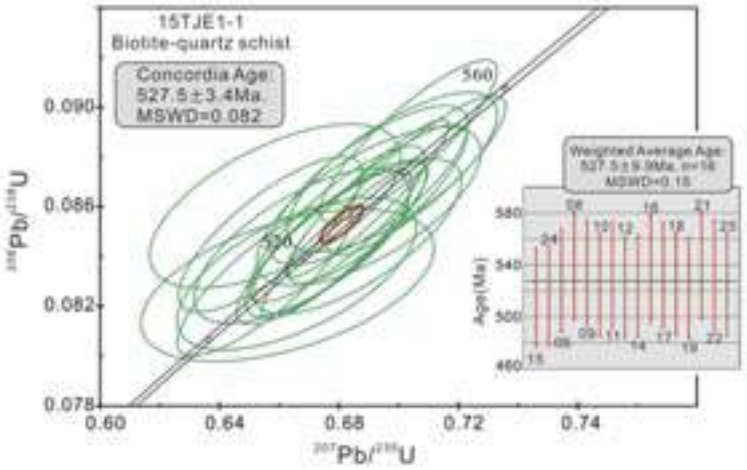
Data from M.E. Regier et al., An oxygen isotope test for the origin of Archean mantle roots, Geochemical Perspective Letters 9, 6-10, (2018).



FINE SCALE, EXTREME PRECISION U-Th-Pb DATING

Concordia plot and weighted average plot for zircon U-Pb ages from biotite-quartz schist.

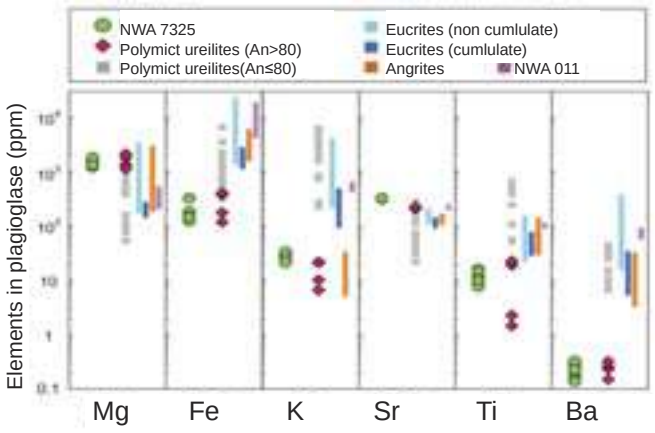
Data from Z.-Q. Li et al., Earth's youngest banded iron formation implies ferruginous conditions in the Early Cambrian ocean, Scientific Reports 8:9970 (2018).



ANALYSIS OF TRACE ELEMENTS WITH OPTIMUM SENSITIVITY

Selected trace element concentrations in plagioclase in NWA 7325, polymict ureilites, and basaltic achondrites.

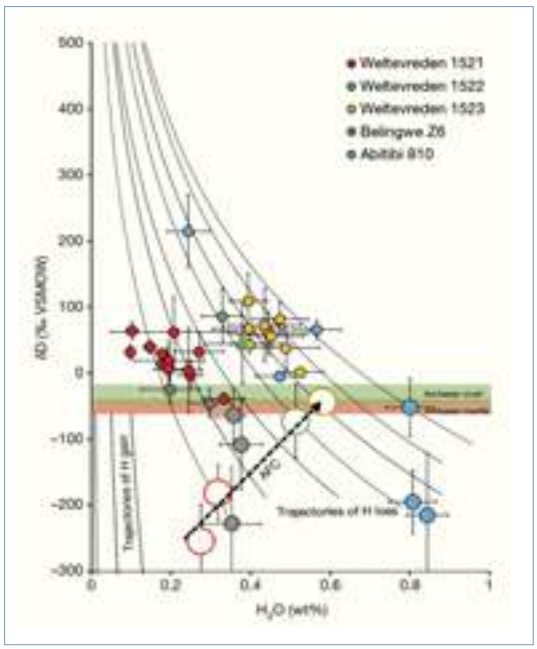
Data from C.A. Goodrich et al., Petrogenesis and Provenance of Ungrouped Achondrite Northwest Africa 7325 from Petrology, Trace Elements, Oxygen, Chromium and Titanium Isotopes, and Mid-IR Spectroscopy, Geochim Cosmochim Acta 203: 381–403 (2017).



Stable isotopes

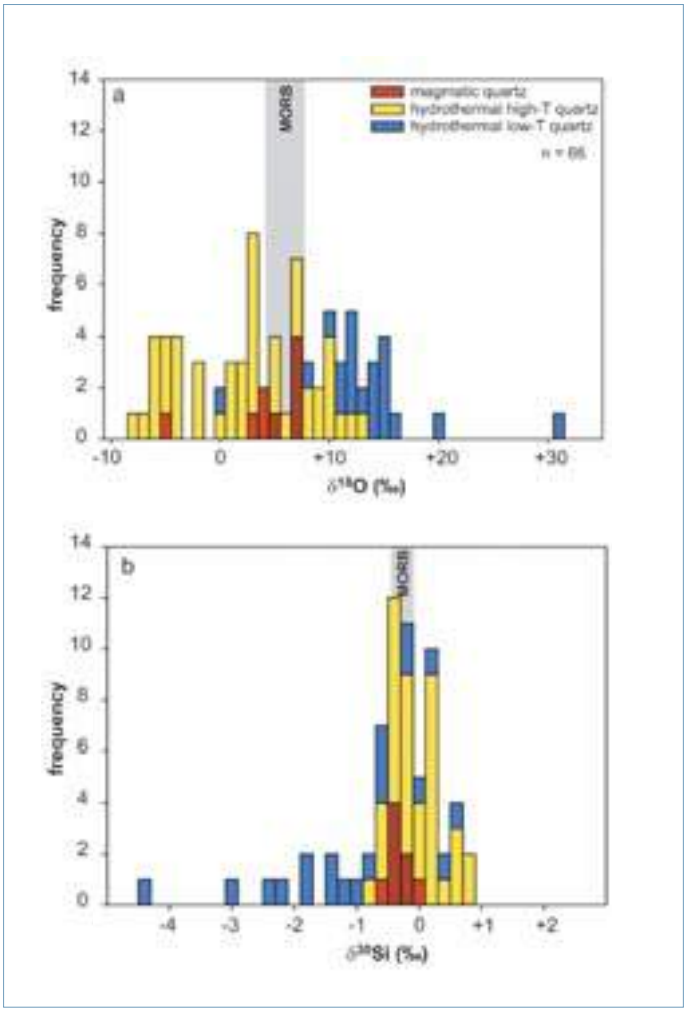
The CAMECA IMS 1300-HR³ is designed to achieve excellent precision and reproducibility on stable isotope ratio measurements.

- High mass resolving power to remove mass interferences ($^{2}D/^{1}H_2$, $^{17}O/^{16}O^{1}H$, $^{33}S/^{32}S^{1}H$...)
- Simultaneous detection of several isotopes using the multicollector system
- Low noise, stable detectors
- Two ion sources: Cs and O for negative and positive secondary ion emission
- Ultra-high vacuum (UHV) in the analysis chamber for precise isotopic characterization of atmospheric species (H, C, N, O)
- Efficient charge compensation on electrically insulating samples (using the Normal-incidence Electron Gun)
- Precise control of the instrumental mass fractionation variability using automatic centering routines.



H_2O contents and H isotope compositions of melt inclusions. SIMS measurements (small symbols) and model (large symbols).

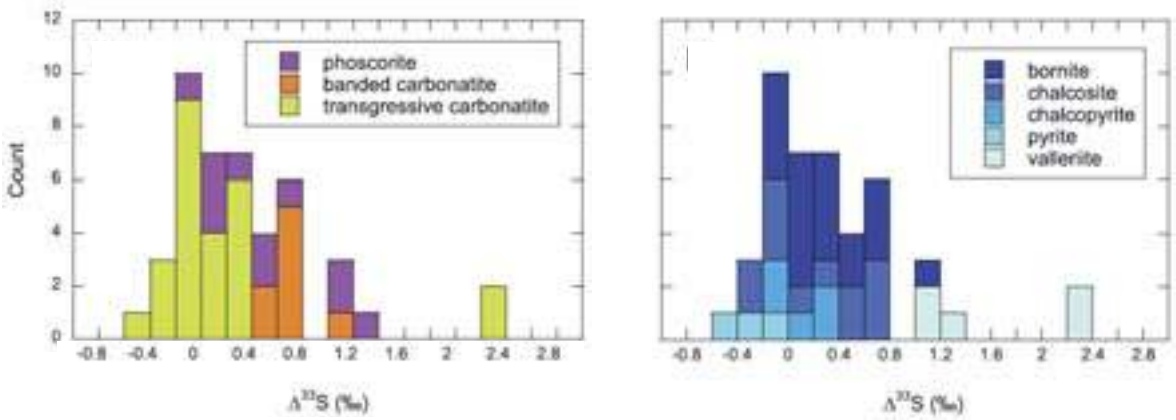
Data from A. Sobolev et al., Deep hydrous mantle reservoir provides evidence for crustal recycling before 3.3 billion years ago, Nature 571, 555 (2019).



(a) $\delta^{18}O$ and (b) $\delta^{30}Si$ variations in magmatic quartz, hydrothermal high-temperature quartz, low-temperature quartz, and other silica polymorphs.

Data from B.I. Kleine et al., Silicon and oxygen isotopes unravel quartz formation processes in the Icelandic crust, Geochem. Persp. Let. 7, 5-11 (2018).

Geochemistry



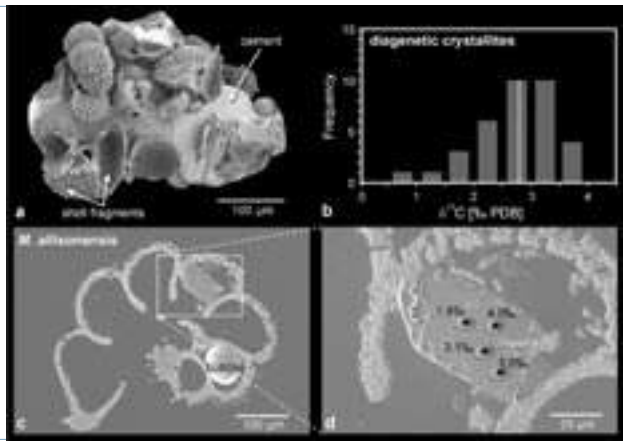
Histograms of SIMS $\Delta^{33}S$ data grouped by type of host rock and sulphide minerals.

Data from R. Bolhar et al., Atmospheric S and lithospheric Pb in sulphides from the 2.06 Ga Phalaborwa phoscorite-carbonatite Complex, South Africa, Earth and Planetary Science Letters 530, 115939 (2020).

Paleoclimate studies

SIMS in situ measurements of $\delta^{13}C$ in minute (7 µm) domains of planktic foraminifer shells.

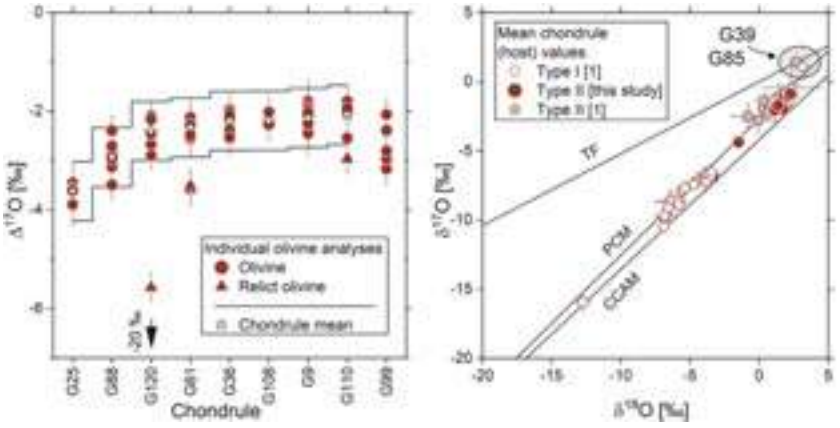
Data from R. Kozdon et al., Diagenetic Attenuation of Carbon Isotope Excursion Recorded by Planktic Foraminifers During the Paleocene-Eocene Thermal Maximum, Paleoceanography and Paleoclimatology 33, 367–380 (2018).



Cosmochemistry

Oxygen isotope ratios in olivine and mean values for chondrules in Acfer 094.

Data from A.T. Hertwig et al., The ^{26}Al-^{26}Mg systematics of FeO-rich chondrules from Acfer 094: Two chondrule generations distinct in age and oxygen isotope ratios, Geochim. Cosmochim. Acta 253, 111-126 (2019).



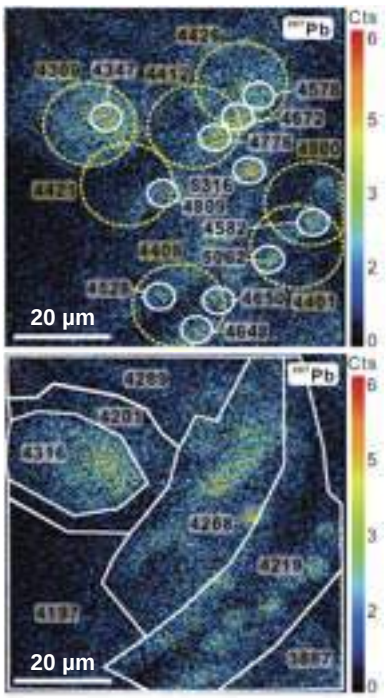
Geochronology

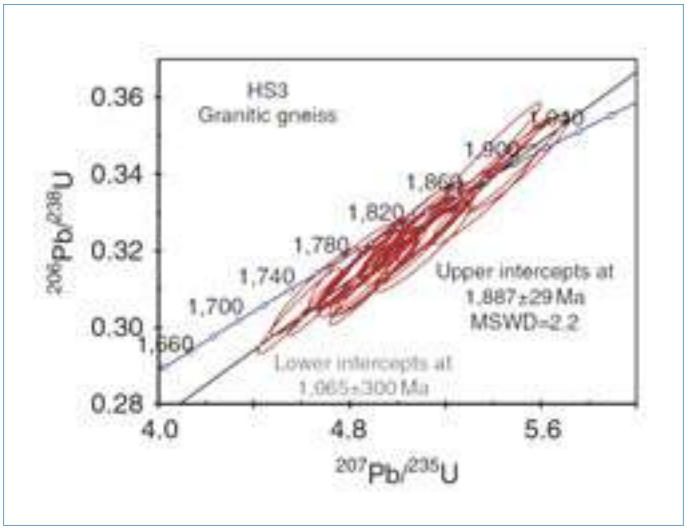
Several key instrumental features of the IMS 1300-HR³ make it the best suited tool for U-Pb dating.

- High mass resolution for peak separation between Pb isotopes and HfSi molecular ions
- High transmission for analysis of low lead concentration
- Oxygen flooding technique for improved sensitivity and highly reproducible analytical conditions
- Small spot size with high beam density for better lateral resolution
- Outstanding ion image capabilities for Pb and U mapping in zircon grains (inhomogeneity, zonation)
- Powerful Geochronology data reduction software

Scanning ion images showing distribution of ^{207}Pb isotope and calculated $^{207}Pb/^{206}Pb$ ages for detrital zircon grain from the Jack Hills (Western Australia).

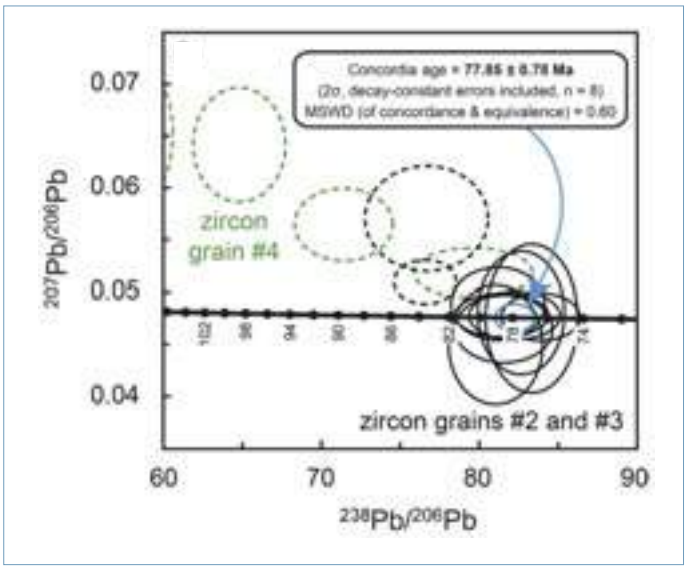
Data from R. Ge et al., A 4463 Ma apparent zircon age from the Jack Hills (Western Australia) resulting from ancient Pb mobilization, Geology 46 (4): 303–306 (2018).





U-Pb concordia diagram of granitic gneiss.

Data from B. Wan et al., Paleoproterozoic high-pressure metamorphism in the northern North China Craton and implications for the Nuna supercontinent, Nature Communications 6:8344 (2015).



Tera-Wasserburg U-Pb concordia diagram for shocked zircon.

Data from G.G. Kenny et al., A new U-Pb age for shock-recrystallised zircon from the Lappajärvi impact crater, Finland, and implications for the accurate dating of impact events, Geochimica et Cosmochimica Acta 245, 479–494 (2019).

Trace elements

Providing optimum sensitivity at high mass resolution, the IMS 1300-HR³ analyzes traces at ppm concentration levels or below.

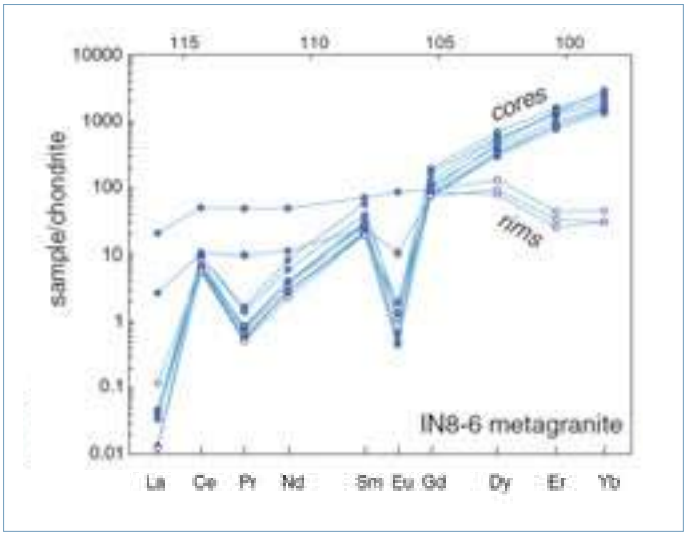
When analyzing trace elements, one has to deal with several molecular interferences of extremely close masses which must be eliminated using high mass resolution and/or energy filtering methods. High-brightness oxygen and cesium ion sources are also essential in order to obtain the highest sensitivity. The IMS 1300-HR³ has been designed to meet all these requirements.

Rare Earth Elements

The interpretation of Pb-U ages remains ambiguous, particularly in metamorphic rocks where the goal is to accurately relate pressure-temperature (P-T) evolution to geochronology.

One approach to relate zircon growth to P-T evolution paths is to study the trace element composition of the zircon grains themselves, as well as of other potentially key metamorphic minerals.

Thanks to its high density oxygen primary beam and to its large energy band-pass, which allows discrimination of monoatomic against molecular species (energy filtering technique), the IMS 1300-HR³ is able to easily obtain µm-scale elemental information for a large mass range.

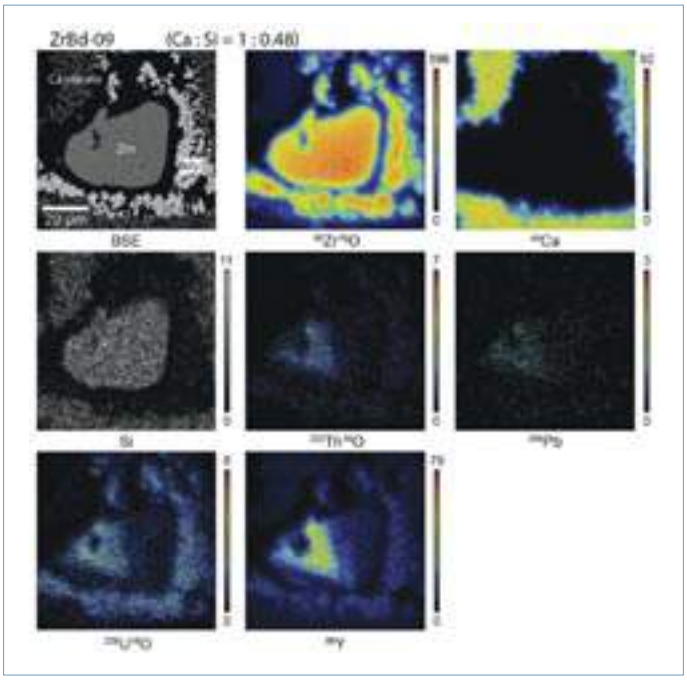


Chondrite-normalized abundances of REE in high-K metagranite.

Data from M.J. Whitehouse et al., Behaviour of radiogenic Pb in zircon during ultrahigh-temperature metamorphism: an ion imaging and ion tomography case study from the Kerala Khondalite Belt, southern India, Contrib Mineral Petrol 168:1042 (2014).

Trace element ion imaging

Ion imaging of trace and major species in zircon or other matrices permits detailed insights of elemental and isotopic distributions at a fine scale and is therefore of great interest for a large range of geological or environmental applications. The IMS 1300-HR³ offers outstanding ion imaging capabilities with µm to sub-µm lateral resolution using both oxygen and cesium sources.



SIMS ion imaging (with BSE image) of reacted zircon grains.

Data from A. Lewerentz et al., Baddeleyite formation in zircon by Ca-bearing fluids in silica-saturated systems in nature and experiment: resetting of the U–Pb geochronometer, Contributions to Mineralogy and Petrology 174:64 (2019).

Nuclear Particles

Unique analytical sensitivity combined with a dedicated particle measurement software have established CAMECA's Large-Geometry SIMS as the reference technique for isotopic uranium particle analysis.

A unique sensitivity for small particle analysis

The IMS 1300-HR³ features numerous instrumental advantages that make it the best choice for small particle analysis:

- Removal of background interferences with minimal loss of transmission
- Parallel detection of all U isotopes thus shortening the acquisition times and reducing measurement uncertainties. In multicollection, a maximum number of ions are collected, and thus the smallest particles can be analyzed (down to sub-µm size range)
- Ion imaging capabilities for localizing U particles within a sample matrix, also in multicollection mode
- High density O^- / O_2^+ source providing the best lateral resolution for optimized particle separation
- Sample stage with excellent position repeatability for easy and precise navigation over particles of interest.

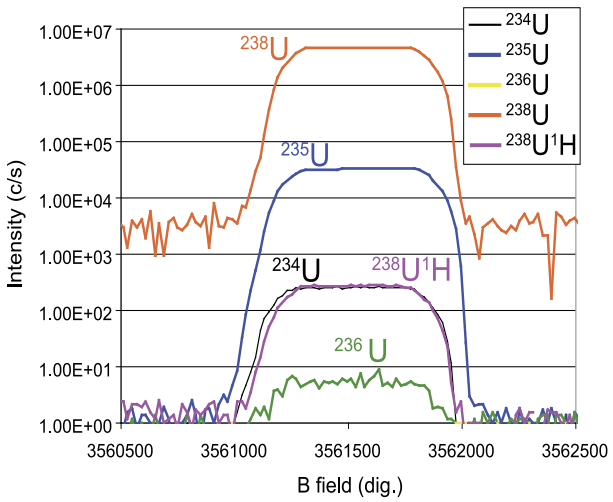
CRM U100

Isotope	^{234}U	^{235}U	^{236}U	^{238}U
Mean	0.0678	10.1954	0.0380	89.6988
SD	0.0004	0.0061	0.0002	0.0062
RSD%	0.54	**0.06**	0.59	0.01

High precision uranium abundance measurements on U100 particles thanks to optimized analytical protocol:
• dynamic multicollecton protocol,
• automated adjustment of EM detectors high voltage,
• pixel dead time correction of the ion images.
51 measurements performed over a period of 3 months.

Data from P.M.L. Hedberg et al., Latest improvements in isotopic uranium particle analysis by large geometry-secondary ion mass spectrometry for nuclear safeguards purposes, Journal of Vacuum Science & Technology B, 36, 03F108 (2018).

Uranium isotope mass spectrum in multicollection mode (Uraninite sample).



Uranium isotopes can be measured simultaneously on the IMS 1300-HR³ multicollector system for optimized precision and throughput.

The “APM-SIMS”method

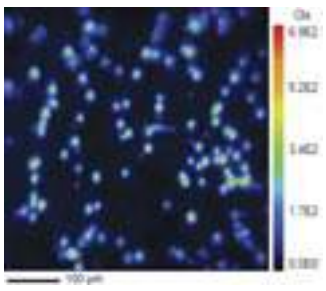
Fast screening of millions of particles, automated particle detection and isotopic characterization is made possible by CAMECA’s Automated Particle Measurement (APM) software.

Dedicated software

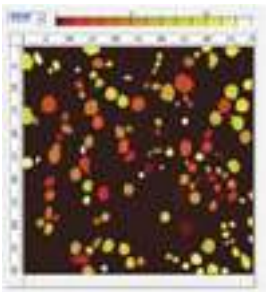
The IMS 1300-HR³ can be equipped with Automated Particle Measurement (APM) which performs fast screening of the sample to determine the location and enrichment of uranium particles. The selected particles are then re-analyzed using microbeam conditions in order to obtain their precise isotopic composition.

Combined with APM, the IMS 1300-HR³ greatly improves the overall performance and throughput of isotopic analyses of uranium particles for nuclear safeguards purposes. It is the only method that can provide both exact particle locations within a sample matrix, along with the precise isotopic composition.

The APM SIMS method can also be applied to cosmochemistry, environmental studies, cell and microbiology, or any application that requires capability for the location and isotopic measurement of micron to sub-micron sized particles/areas.



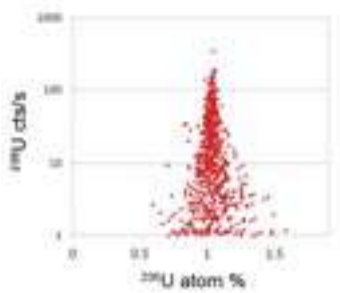
SIMS scanning ion image of $^{235}U + ^{238}U$ over a field of 500 x 500 µm².



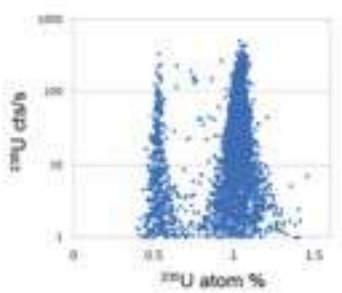
APM screening results: identification of particles, both large & small, with optimum separation of closely situated particles.

Fast and efficient particle screening thanks to the SIMS ion imaging capabilities and APM image processing algorithm.

APM provides a first assessment of the isotopic composition for every particle located on the sample.



Sample containing 1% enriched uranium particles amongst an environmental matrix. 1000 particles identified over the central area of the sample (ø 10 mm).



Sample containing 0.5% depleted and 1% enriched uranium particles. 6653 particles identified over the central area of the sample (ø 16 mm).

Data from P. Peres et al., Nuclear safeguards applications using LG-SIMS with automated screening capabilities, Surf. Interface Anal. 45: 561-565 (2013).

State-of-the-art LG-SIMS design

High brightness ion sources

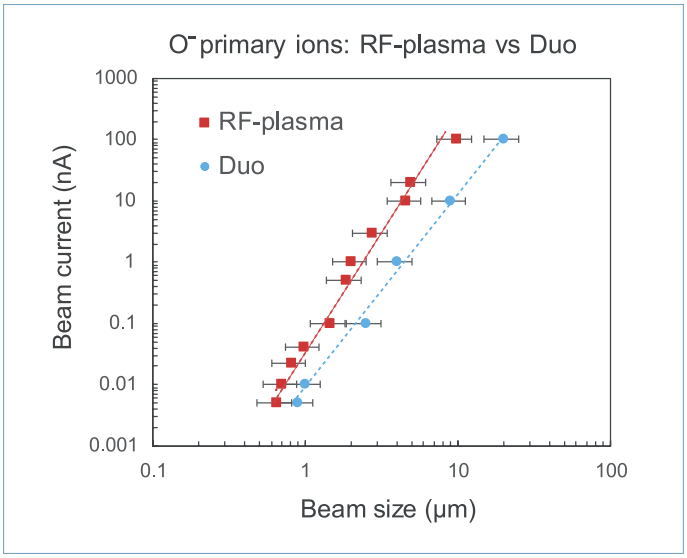
The IMS 1300-HR³ is equipped with two ion sources (oxygen, cesium) which enhance the secondary ion emission of electropositive or electronegative species, respectively. The high brightness Cs microbeam and RF-plasma oxygen ion sources offer high beam density for large as well as for small beam size, optimized beam current stability and long lifetime. These features bring major analytical benefits, such as high spatial resolution, excellent data reproducibility and enhanced productivity.

Automated sample introduction

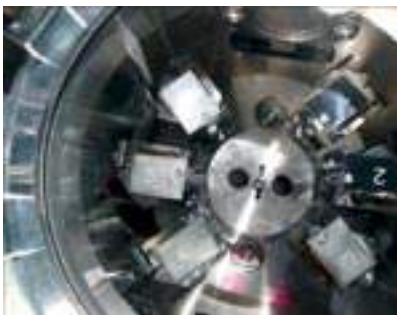
The IMS 1300-HR³ is equipped with the field-proven CAMECA IMS motorized storage chamber. Holder exchange between storage and analysis chambers is fully automated and computer-controlled. Multiple sample mounts can be analyzed in chained or remote mode, greatly improving ease-of-use and productivity. Sample Z-positioning is fully automated and can be performed at the beginning of every analysis in chained and unattended mode. It ensures a constant distance between the sample surface and the extraction plate which is mandatory for high precision measurements.

High resolution UV-light optical system

The resolution of the sample surface optical image is optimized thanks to the UV light microscope (developed by University of Wisconsin). It includes dedicated software for sample imaging, which greatly enhances the accuracy of positioning, ensuring easy and efficient sample navigation and instrument operation.



Comparison of primary beam current vs beam size for RF-plasma and Duo ion sources in O- mode. RF-plasma source provides significantly higher beam density.



The automated storage chamber ensures unprecedented sample throughput, in particular for applications requiring good vacuum quality. It can accomodate up to six sample holders with motorized holder exchange and provides sample outgassing capabilities.

Sample surface optical image obtained with the UV-light microscope on a Ta/Si grid test sample.

N.T. Kita et al., UV-light microscope improvements in optical imaging for a secondary ion mass spectrometer, J. Anal. At. Spectrom. 30, 1207 (2015).

Optimized mass spectrometer

The IMS 1300-HR³ is based on a double focusing mass spectrometer with a large radius magnetic sector. The secondary ion optics has been optimized to perform analyses with both high mass resolution and high sensitivity. The instrumental mass fractionation variability is minimized using automatic beam centering routines. The Normal-incidence Electron Gun provides efficient charge compensation when analyzing insulating samples. This ensures excellent signal stability, which is mandatory for high reproducibility conditions.

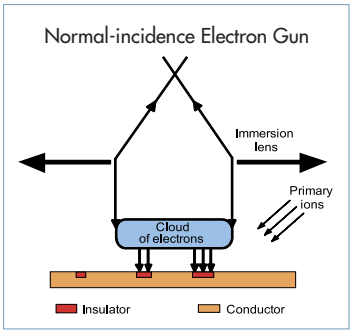
Versatile multicollector system

The IMS 1300-HR³ is equipped with a multicollection detector system for isotope measurements. This field-proven system consists of five moveable collector units. Each unit contains a collection slit adjustable in width for adjusting the mass resolution and either an Electron Multiplier (EM) or a Faraday Cup (FC). Two additional FCs are fitted onto the two extreme collector units, making a total of seven detectors. The large mass range capability, ranging from Li to U isotopes, makes it a powerful parallel detection system that provides optimized analysis throughput and increased precision, as isotopes are measured simultaneously.

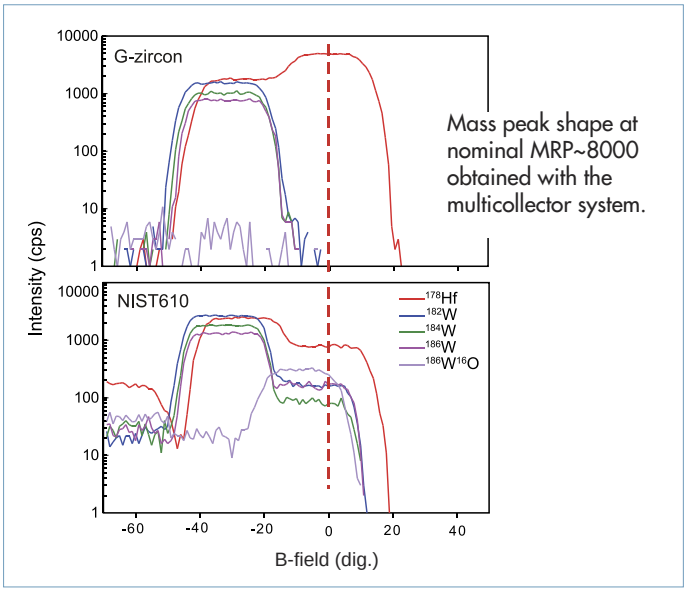
State-of-the-art detectors

Mono- and multicollection EMs are based on discrete dynode design, which ensures negligible background and enhanced detector yield stability. For FCs, the CAMECA electrometry system guarantees low noise and very stable baseline. Different preamplifier boards are available including a 10^{12} Ω resistor board for measuring low signal intensities.

The IMS 1300-HR³ detector system ensures high precision for a large range of applications including isotope ratio measurements at fine scale.

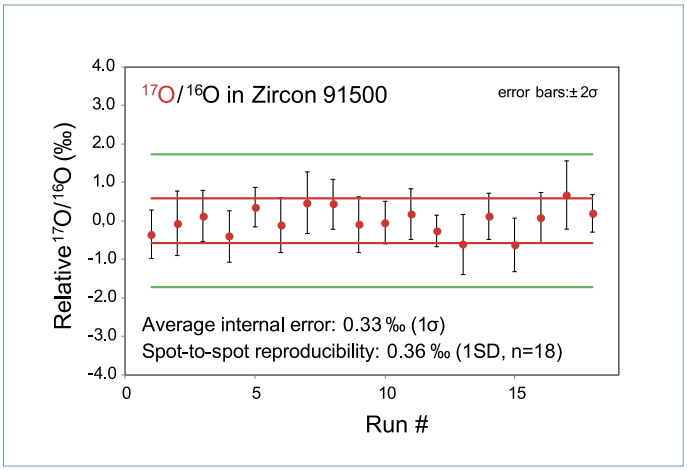


The NEG produces an electron beam perpendicular to the sample surface. In negative ion extraction mode, the electrons emitted by the NEG produce a cloud of electrons with very low energy (few eV) near the sample surface, which results in charge "self-compensation", routinely used for high precision measurements in insulating samples.



Mass peak shape at nominal MRP~8000 obtained with the multicollector system.

The NMR magnet control ensures improved long-term magnetic stability in multicollection mode.



FC detector with 10^{12} Ω resistor electrometry:
Excellent $^{17}O/^{16}O$ precision, ^{17}O signal ~ 4.7×10^5 c/s on FC 10^{12} Ω.
Multicollection 3-isotopes FC/FC/FC mode, mass resolution ~7 000 on ^{17}O.
Fully automated analysis session. 20 cycles x 4 sec integration time, ~4 min/spot.
Red lines: expected dispersion (-2σ,+2σ) for FC 10^{12} Ω.
Green lines: expected dispersion (-2σ,+2σ)
if ^{17}O had been detected on FC 10^{11} Ω.

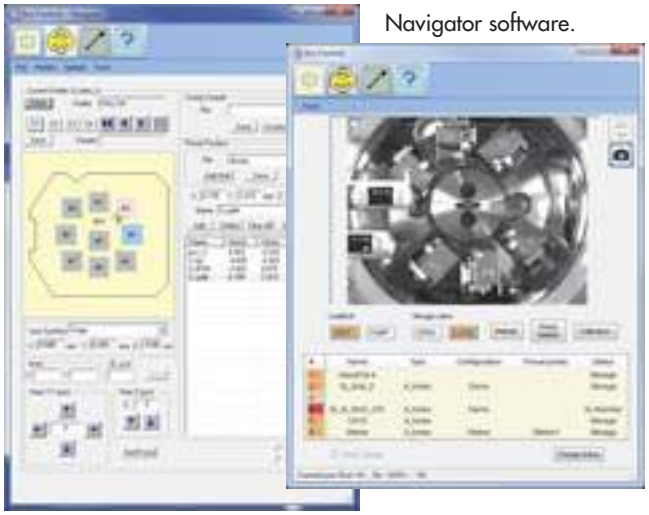
A fully automated and user-friendly instrument

The IMS 1300-HR³'s software package has been developed to meet the specific needs in all fields of geology and geochemistry. It guarantees both ease of use and high analysis throughput.

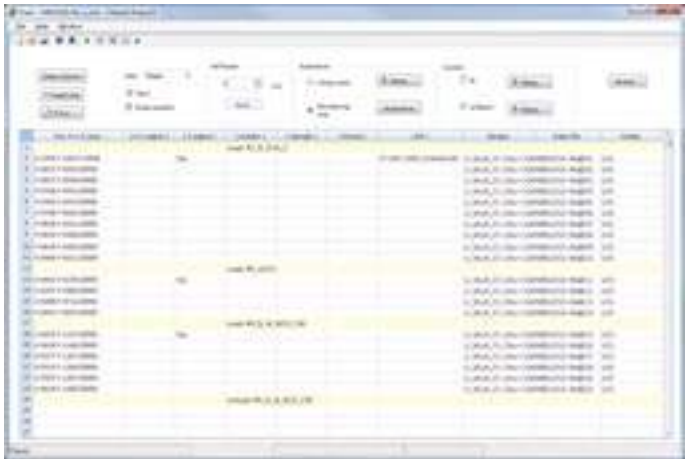
Easy instrument setup

- Complete instrument set-up can be saved to or restored from files.
- The Optical Imager software for sample imaging ensures easy and efficient sample navigation and improves the accuracy of positioning.
- Dedicated to the control of the sample stage, the Navigator software includes save/recall of preset positions and automated storage chamber functions.
- The Point Logger software allows fast and easy analysis area selection using an imported image (SEM or other).
- Analysis recipes can be defined for different types of analyses, and centering and adjustment routines can be performed automatically during acquisition for enhanced data reproducibility.
- A spreadsheet window provides real time data reduction during acquisition.
- The ChainPlus software allows the operator to easily define a chain analysis sequence. The set of analyses is then performed in automated mode on one or multiple mounts.

Optical Imager software with mutliple functionalities: AutoExposure, Frames average, Difference function…



Navigator software.



ChainPlus software: analysis of multiple sample mounts in chained mode, manual position snapping or import from Navigator, X-Y adjust & Z adjust functions, easy copy/paste of multiple lines, flexible Autoname options...

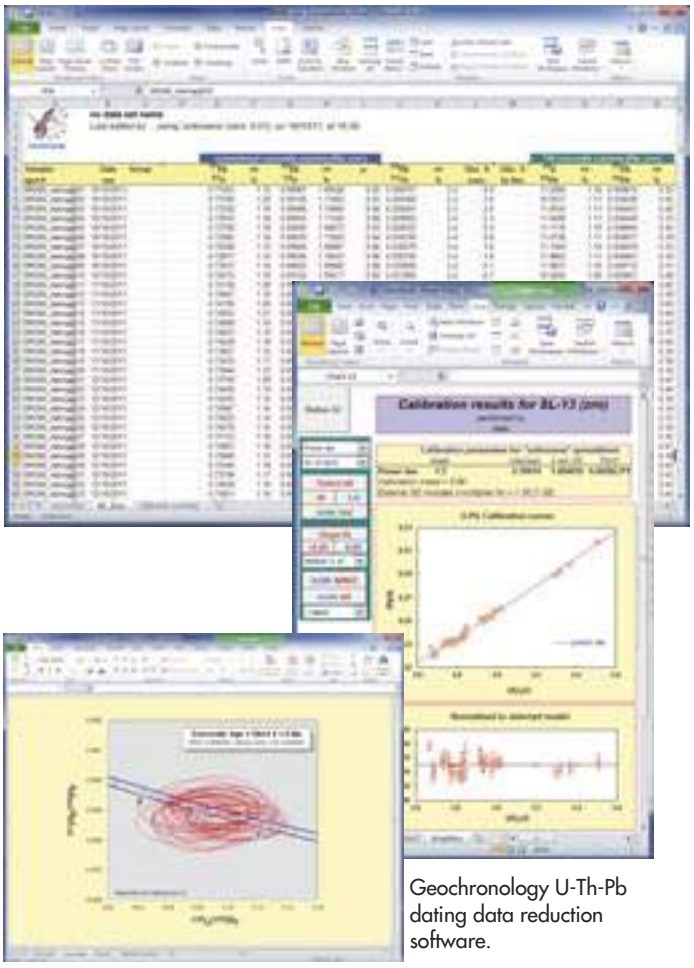
Dedicated programs for data & image processing

Geochronology

Developed at NORDSIM by Dr Martin Whitehouse, Geochronology is a powerful data reduction software package for processing U-Th-Pb dating results.

It offers outstanding features for accurate and highly productive data processing:

- Direct import of SIMS files in Excel
- Fast and easy processing of large volumes of data
- Multiple types of calibration including Pb/U vs. UO_2/U using power law parameters
- Common lead correction methods
- Age table display
- Export for Concordia diagram plotting.



Geochronology U-Th-Pb dating data reduction software.

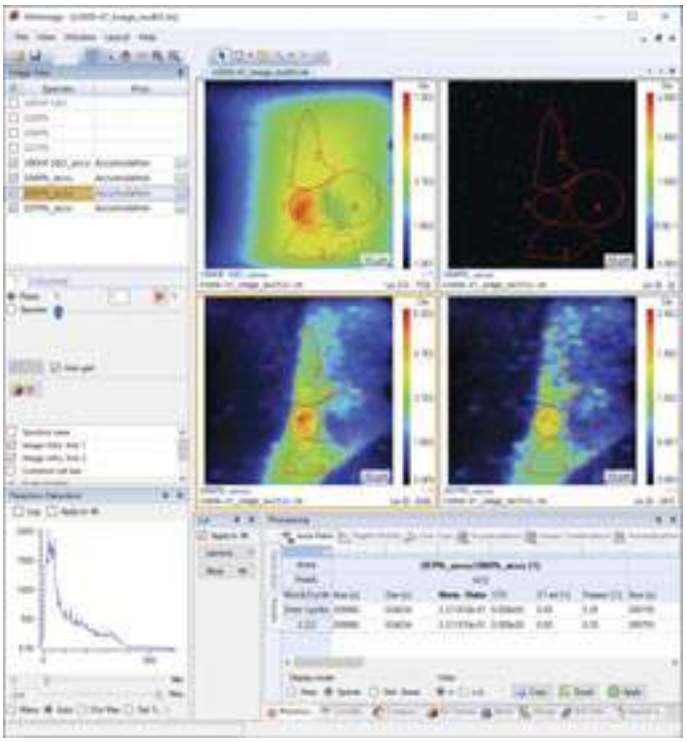
WinCurve

Specifically developed for CAMECA Magnetic Sector SIMS instruments, WinCurve offers high volume data processing capabilities (depth profiling, mass spectra...), tools for real-time visualization of SIMS data, together with easy report creation functionalities. Data can be processed directly from the IMS 1300-HR³ instrument control, but also on a stand-alone computer or lap-top.

WinImage

Specifically developed for CAMECA Magnetic Sector SIMS instruments, Winimage offers powerful image visualization, processing and analysis, as well as export functions in a user-friendly environment.

WinImage software.



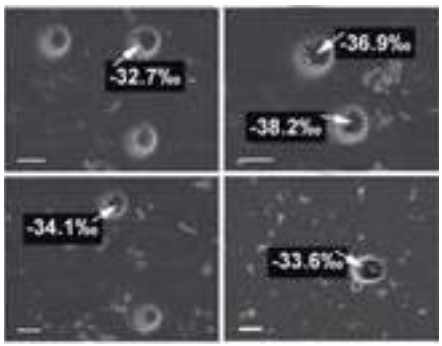
WinImage offers dedicated functions for isotope ratio computation from regions of interest (ROI), defined within a set of isotope mapped images, along with dozens of powerful SIMS image processing functions (includes a set of Aphelion™ imaging libraries).

A universal SIMS instrument

Combining High Reproducibility at High spatial Resolution and High mass Resolution, the IMS 1300-HR³ excels in all types of analyses.

Flexible spot analysis mode

Isotope ratio measurements are typically performed in spot analysis mode. The primary column of the IMS 1300-HR³ forms an ion probe at the sample surface with a probe size adjustable from tenths to tens of microns. Flat bottom craters are obtained with either a static shaped beam or a rastered Gaussian probe.



Spot analyses using small beam size: SIMS craters on microfossil samples analyzed for $\delta^{13}C$. All scale bars: 10 µm.

Data from J.W. Schopf et al., SIMS analyses of the oldest known assemblage of microfossils document their taxon-correlated carbon isotope compositions, PNAS 115, 53-58 (2018).

Unique 2D & 3D imaging capabilities

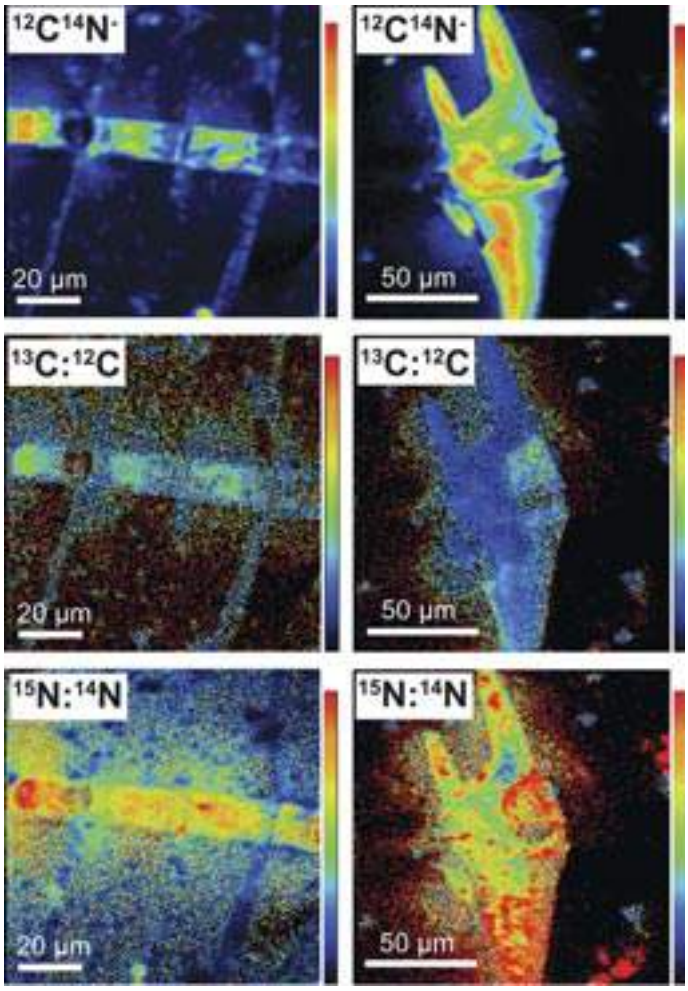
The CAMECA IMS 1300-HR³ is capable of both microprobe and microscope ion imaging.

In microprobe mode, a focused primary ion beam is scanned over the sample surface and secondary ions are sequentially collected for every pixel to form scanning ion images. In multicollection mode, up to five images can be recorded simultaneously for high precision quantitative analysis. The microprobe mode ensures high analytical sensitivity for mapping over large to very small areas, with down to sub-micron lateral resolution. Successive 2D images can be recorded as a function of depth, thus allowing 3D imaging and analysis.

In addition, the unique ion microscope design of the IMS 1300-HR³ is extremely useful for day-to-day instrument tuning and for easy location of analytical areas. It also allows for spatial selection of secondary ions from the center of the analysis crater (optical gating), which minimizes crater edge effects and improves depth profiling capabilities.

Powerful depth profiling

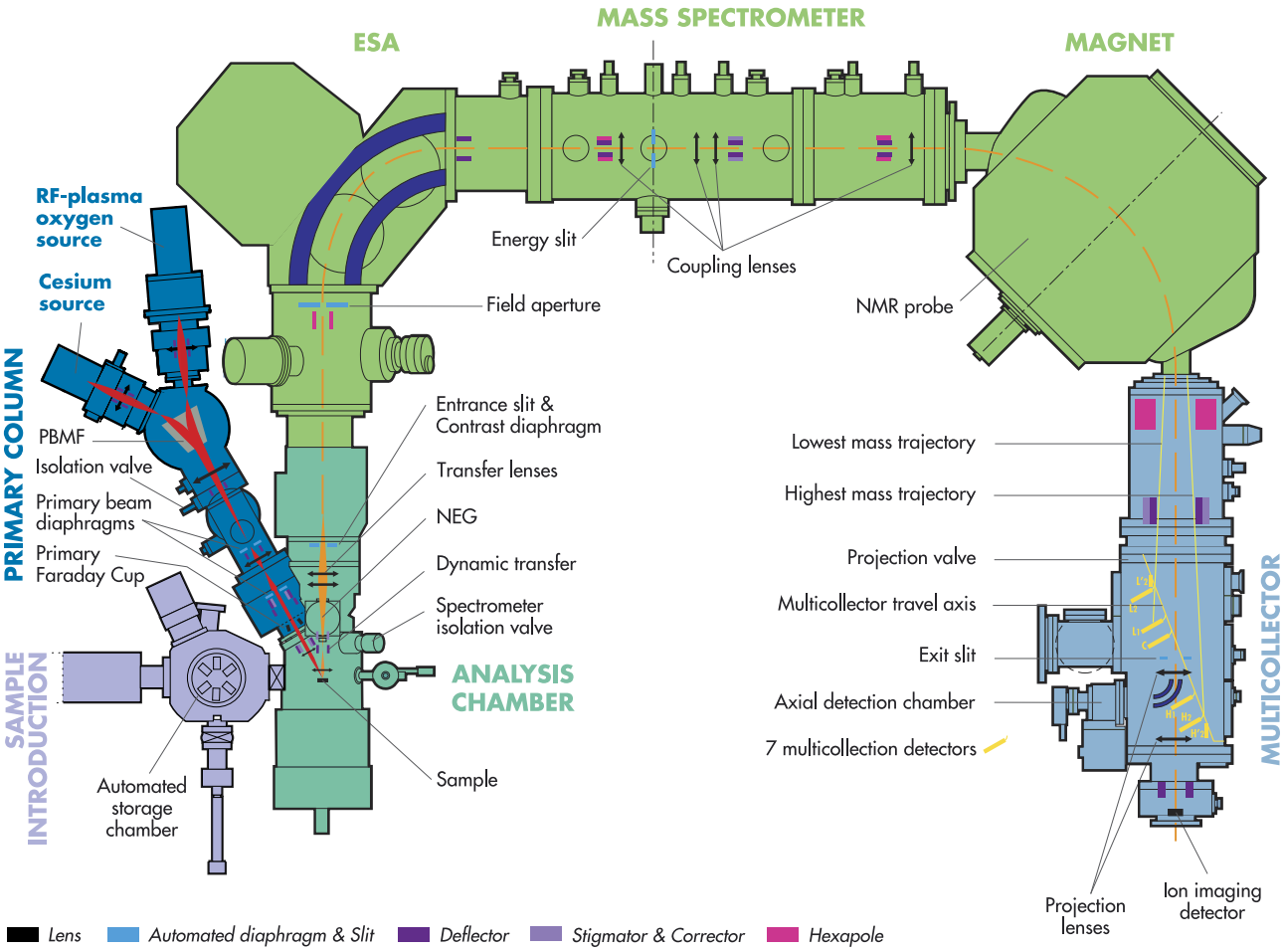
The high brightness of the O and Cs sources combined with high transmission and optical gating capabilities offer true state-of-the-art dynamic SIMS: depth profiling analysis with high depth resolution, excellent sensitivity and dynamic range.



SIMS images of stable isotopes measured within phytoplankton.

Data from M. Olofsson et al., Nitrate and ammonium fluxes to diatoms and dinoflagellates at a single cell level in mixed field communities in the sea, Scientific Reports 9:1424 (2019).

Synoptic of the IMS 1300-HR³



IMS 1300-HR³

KLEORA

The specialized LG-SIMS for World-leading Research in Geochronology

Based on the IMS 1300-HR³, KLEORA delivers superior SIMS analytical performance in a high throughput, easy-to-use platform, covering the entire range of geochronological applications from precise age determination of zircon to dating of other U-rich minerals such as apatite, rutile, baddeleyite, and more.

KLEORA can be upgraded at any time to a full IMS 1300-HR³.

Standard configuration:	IMS 1300-HR³	KLEORA
RF-plasma O source	•	•
Cs microbeam source	•	
Auto-Z motion	•	•
Auto storage chamber	•	•
High resolution UV- light microscope	•	•
Oxygen flooding	•	•
Normal-incidence Electron Gun	•	
Multicollector system	•	
NMR control	•	
Geochronology software	•	•

IMS 1300-HR^3

Large Geometry Ion Microprobe for Path-breaking Advances in Geoscience

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