Dating Volcanism on the Moon with LG-SIMS

U-Pb Analysis of Chang'E 5 Returned Samples

Crater-counting chronology has been widely used to date terrains on the Moon. The radiochronology analyses of samples returned by the Apollo and Luna missions allowed scientists to anchor the chronology with absolute ages. In particular, they revealed a basaltic magmatism that occurred between 4.4 Ga and 2.9 – 2.8 Ga. But while crater-counting chronology suggested a more extended volcanism period (up to 1.2 Ga), no samples were returned to confirm those ages.

The Chinese sample-return mission Chang'E 5 landed specifically on young mare basalt units previously dated by crater-counting chronology at 1.2 to 2.1 Ga. These returned samples offer a unique opportunity to provide precise age through radioisotopic dating in order to extend the calibration of the Moon crater-counting chronology, achieving a better understanding of the timing and mechanism of late mare volcanism on the Moon.

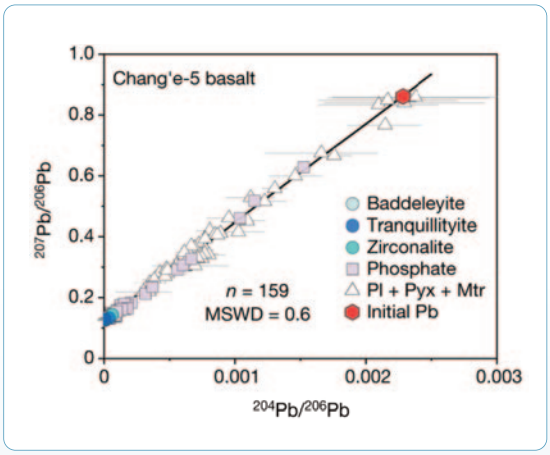
U-Pb (Uranium-Lead) dating requires in-situ isotopic analyses of individual mineral grains of micrometric size, for which Large-Geometry Secondary Ion Mass Spectrometry (LG-SIMS) is particularly suited. Indeed, LG-SIMS can achieve the necessary isotopic ratio accuracy and deliver fine-scale analyses, thus providing precise isochrons of the crystallization ages of lunar basalts. Over 150 grains were analyzed by Electron Probe Microanalysis (EPMA) for their elemental composition before U-Pb dating by LG-SIMS. The obtained isochrons reveal a crystallization age of 2.030 ± 0.004 Ga for those young lunar basalts (Figure 1), bringing conclusive evidence that volcanism on the Moon existed until at least 2 Ga.

While previously analyzed samples from the Apollo and Luna missions provided calibration points in the extreme ranges (0 – 0.8 Ga and 3.2 – 4.0 Ga), the new LG-SIMS radio-isotopic data obtained from Chang'E 5 samples fills an important gap in the middle range of the chronology (Figure 2). Precise and accurate age determination by LG-SIMS is key to this study, and once more contributes to shedding light on the evolution of the solar system.

Data collected on CAMECA SXFive-FE EPMA and IMS 1280-HR LG-SIMS at IGGCAS Beijing, China.

From Li, QL et al. Two-billion-year-old volcanism on the Moon from Chang'e-5 basalts. Nature 600, 54–58 (2021).

Figure 1: Pb–Pb isochron showing the mixing line between the Y intercept as radiogenic $^{207}Pb/^{206}Pb$ and the initial Pb compositions.



The black line is the best-fitted isochron with an intercept of 0.12510 ± 0.00028 giving an age of 2.030 ± 0.004 Ga.

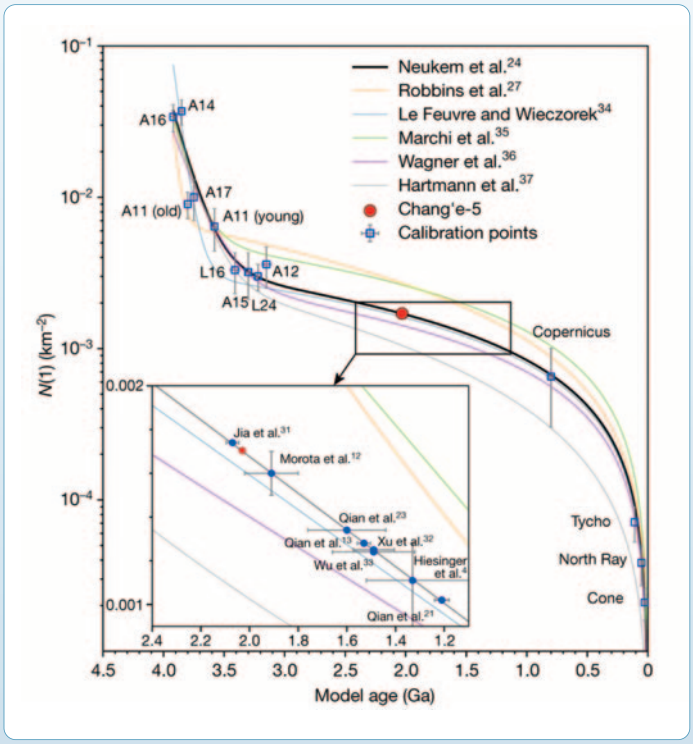
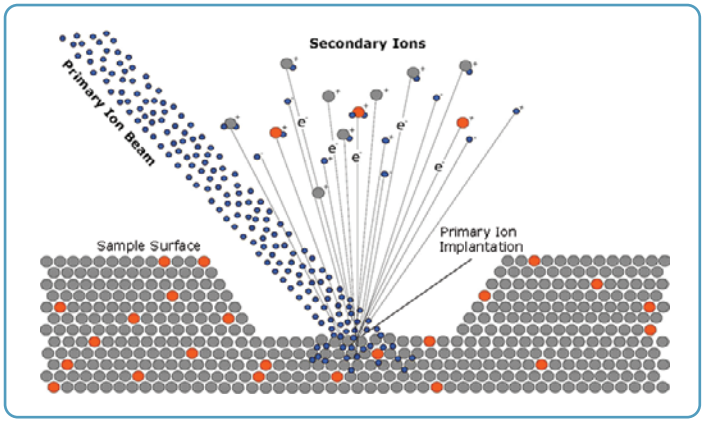


Figure 2: Critical reference point of the radio-isotope age of Chang'E-5 basalts (red point). The different lines represent different models of the crater-counting chronology. The blue squares are the calibration points established from Apollo and Luna samples.

The Technique Behind



Dynamic SIMS

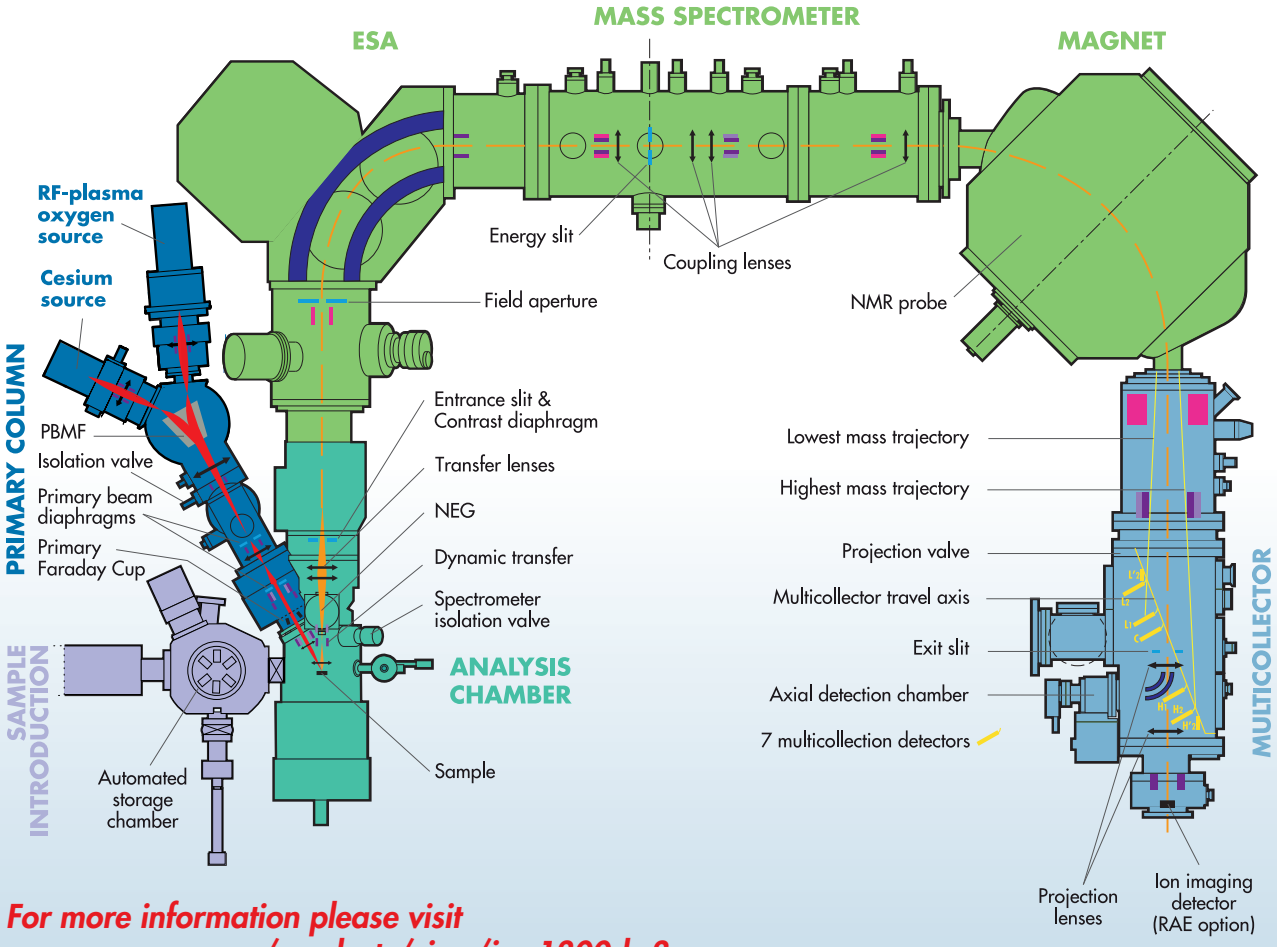
When a solid sample is sputtered by primary ions of few keV energy, a fraction of the particles emitted from the target is ionized. Secondary Ion Mass Spectrometry consists of analyzing these secondary ions with a mass spectrometer.

The SIMS technique is "destructive" by its nature (sputtering of material). It can be applied to any type of flat, solid material that can be kept under vacuum.

In dynamic SIMS, bulk composition and in-depth distribution of trace elements are investigated with a depth resolution ranging from sub-nm to tens of nm. SIMS is recognized as the most sensitive elemental and isotopic surface analysis technique.

CAMECA IMS 1300-HR³

The latest generation multicollection Large-Geometry SIMS is equipped with a high-brightness RF-plasma oxygen ion source in addition to the cesium microbeam source. It also includes an automated storage chamber for analysis of multiple mounts in chained mode.



For more information please visit
www.cameca.com/products/sims/ims1300-hr3

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