Using composition to assess pairing relationships among lunaites

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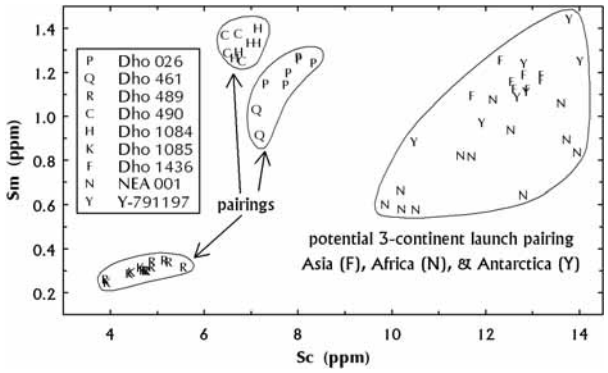
More than 120 named lunar meteorite stones have been recognized since 1982. Three quarters of them have been announced in the last 5 years as collectors scour the world's deserts for new meteorites. A first-order question with each new find is "Is this stone paired with another?," i.e., is it another piece of an already known meteorite that fragmented during of after it encountered Earth's atmosphere. For lunar (and Martian) meteorites, a second first-order question is "Is this stone launch paired with another?," i.e., did a single impact on the Moon launch multiple stones that made the Moon-Earth trip. Launch-paired meteoroids can land on different continents.

For lunar meteorites, bulk-composition data are powerful for establishing or rejecting potential pairings because compositions of lunar meteorites are far more variable than are those of meteorites from any other parent body. For example, among lunar meteorites Sc concentrations range from 4 ppm (feldspathic) to 94 ppm (basaltic) and incompatible elements vary over factors of several hundred (e.g., 0.2–75 ppm Sm).



We divide samples of 0.1–0.3 g into (typically) 4–10 subsamples which we subject to instrumental neutron activation analysis for trace elements. Most lunar meteorites are breccias, and subsample data often reflect variation in plagioclase to pyroxene + olivine. Useful elements are Fe, Na, Sc, Cr, Sm, Eu, and Th. Stones with overlapping compositional ranges are candidates for further tests based on petrography and cosmic-ray exposure data. For example, Dhofar 1436 (Oman), Northeast Africa 001 (Sudan), and Yamato 791197 (Antarctica) are potential launch pairs on the basis of composition (figure).

Laser ablation MC ICP-MS U-Pb zircon dating using multiple channeltron ion counting detection

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Since the introduction of laser ablation (LA) ICP-MS, the goal of the Earth science community has been to achieve figures of merit (e.g. spatial resolution, precision) comparable to those of already established *in situ* isotopic techniques, such as are the secondary ion mass spectrometry or TIMS combined with micro-sampling. Precision and accuracy of laser ablation ICP-MS U-Pb dating of accessory minerals is largely limited by uncontrolled elemental fractionation of Pb and U during laser ablation and also by variable mass discrimination of the ICP-MS instruments. The use of short laser wavelength, homogeneous laser beam, ablation in He, improved sampling strategies, and recently also the implementation of short-pulsed (fs) lasers have all contributed to reduction of laser-induced Pb/U fractionation. The effect of Pb/U fractionation on the precision of U-Pb age data can be further reduced by using shorter analysis/ablation time. Combination of short ablation with ability to detect small isotopic signals should also result in significant improvements of spatial resolution of the analysis.

We report results of U-Pb dating of different zircon reference samples by laser ablation (213nm Nd:YAG) multiple ion counting ICP-MS (Thermo Finnigan Neptune). The array of eight channeltrons allows for simultaneous detection of ^{202,204}Hg, ^{203,205}Tl, ^{204,206,207,208}Pb ion signals and one of the ^{235,238}U isotopes. Detection of all isotopes required for U-Pb dating and monitoring the instrument mass bias in electron multipliers, rather than in a mixed faraday - multiplier detector array, eliminates potential difficulties with detector cross-calibration due variable response of faradays and electron multipliers and slow decay of faraday resistors. This method is limited by maximum ion beam intensity that can be reliably detected by the channeltrons (ca. 200 Kcps) and by reproducibility of channeltron cross-calibration (ca. 0.5-1 ‰). Precision of measured Pb/U ratios in zircon after 20 seconds of ablation is better that 5 permil (2 sigma), resulting in routinely achieved precision of U-Pb ages obtained by external calibration of ~1 percent or better. In addition, the short ablation required to achieve such precision results in spatial resolution that is superior to comparable U-Pb zircon analyses by single collector ICP-MS.