

DEVELOPMENT OF U-PB SIMS ANALYSIS OF APATITE IN ORDINARY CHONDRITES

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Introduction: Chronological constraints on the evolution of ordinary chondrite parent bodies are primarily derived from bulk U-Pb analyses of phosphates, such as apatite and whitlockite. Bulk analyses require a significant portion of a meteorite to be crushed before apatite grains can be separated out and analyzed for their ages; therefore, only ~10 H chondrites have been analyzed for their ages using bulk techniques [e.g., 1], despite these samples being crucial for our understanding of chondrite parent bodies [e.g., 2]. We seek to significantly increase the number of U-Pb age constraints for ordinary chondrites by further developing *in situ* U-Pb techniques for analyzing individual phosphate grains within polished slices of meteorites. Although *in situ* analysis is associated with larger analytical uncertainties (>10 Ma) than the bulk methods (± 0.1 Ma), it allows for preservation of the petrographic context of each grain. *In situ* U-Pb analyses have been performed for dating terrestrial apatites by laser ablation ICP-MS [e.g., 3, 4] and SIMS [e.g., 5, 6], but only a few *in situ* analyses of chondrite apatite have been reported so far [7]. Here, we present our current ion microprobe analysis protocol, preliminary results, and plans for the future method development.

Samples: A suite of terrestrial apatite standards from McClure Mountain (MMAP, ~524 Ma, [4]), Durango (DUR, ~32 Ma, [4]) and Madagascar apatite (MAD, ~487 Ma, [4]) were mounted in epoxy alongside the apatite samples separated from LL5/6 Cherokee Springs (~4540 Ma, [8]). The samples were cleaned with soapy DI water and methanol and oven dried prior to gold coating.

SIMS Technique: *In situ* analyses of U-Pb systematics were carried out using the Cameca IMS-1290 ion microprobe at UCLA. The primary O₂⁻ beam (~3 nA) produced by a Hyperion-II RF oxygen ion source [9] rastered over the sample surface (25×25 μm²) for 90 s to clean the analysis area before data collection. Data acquisition was done using a smaller 15×15 μm² raster square. The mass resolving power was set to ~7500 (10% peak height) to resolve interferences from REE oxides. Secondary ⁴⁰Ca₂P¹⁶O₄⁺, ²⁰⁴Pb⁺, ²⁰⁶Pb⁺, ²⁰⁷Pb⁺, ²⁰⁸Pb⁺, ²³²Th⁺, ²³⁸U⁺, ²³⁸U¹⁶O⁺, and ²³⁸U¹⁶O₂⁺ ions were collected over 20 cycles using the axial electron multiplier in mono-collection mode, and the total analysis time for one measurement was ~50 min. Before each analysis, magnetic field centering was performed by referencing all the Pb peaks to ⁴⁰Ca₂P¹⁶O₄⁺ and U-related peaks to ²³²Th⁺.

Data analyses: After correcting for the deadtime in the counting system, raw isotope ratios were determined by dividing the mean count rates of the respective isotopes. At this point, uncertainties in the ratios are estimated based on counting statistics. For the terrestrial standards, we apply a ²⁰⁷Pb-based common lead correction scheme. MMAP analyses were used to calibrate the relative sensitivity factor (RSF) of Pb/U using raw UO⁺/U⁺. Due to the preliminary nature of error analysis, we report an unweighted mean of the ²⁰⁶Pb/²³⁸U dates of a sample; the spread in dates is shown as 1SD.

Results: Our *in situ* U-Pb analyses of terrestrial apatite yield dates consistent with those determined from the bulk and LA ICP-MS measurements. Using MMAP as our calibration standard, we obtain 508 Ma \pm 15 Ma (n=23) and 32 Ma \pm 3 Ma (n=3) for Madagascar apatite and Durango apatite, respectively; within uncertainties, these values are consistent with 486.58 \pm 0.85 Ma (ID-TIMS U-Pb, 95% conf, [4]) and 32.2 \pm 5.3 Ma (LA ICP-MS, concordia age, 2s, [4]). Apatite analyses of LL5/6 Cherokee Springs are uncorrected for non-radiogenic lead, because of unknown isotopic composition of the common lead component. ²⁰⁶Pb/²³⁸U dates of 9 analyses range from ~3-5 Ga, which is consistent with the distribution derived from bulk U-Pb analyses [8].

Discussion: SIMS U-Pb ages of apatite in chondrites can be improved by (1) identifying terrestrial standards that cover a broader range in UO⁺/U⁺ for a more accurate RSF calibration; (2) constraining the common Pb for each sample, possibly by analyzing appropriate minerals in each sample; (3) reducing surface contamination, which may be more difficult with thin sections compared to mineral separates. Although uncertainties in SIMS U-Pb ages are significantly larger than for bulk analyses, this technique deserves more attention as it has the potential to provide constraints on samples that may be out of reach for bulk analyses due to low quantities of material (e.g., from sample return missions).

Acknowledgments: We thank M. A. Coble (Stanford) and G. H. Edwards (UCSC) for providing the apatite grains for this study.

References:

- [1] Gopel C. et al. (1994) *Earth and Planetary Science Letters* 121, 153–171. [2] Tieloff M. et al. (2003) *Nature* 422, 502–506. [3] Chew, D.M. et al. (2011) *Chemical Geology* 280, 200–216. [4] Thomson S.N. et al. (2012) *G³* 13, Q0AA21. [5] Sano, Y. et al. (1999) *Chemical Geology* 153, 249–258. [6] Terada, K. & Sano, Y. (2003) *Applied Surface Science* 203–204, 810–813. [7] Terada, K. & Sano, Y. (2002) *Geophysical Research Letters* 29. [8] Edwards G., et al., *in preparation*. [9] Liu M.-C. et al. (2018) *International Journal of Mass Spectrometry* 424, 1–9.