# Over 500 million years of lunar impact history quantified by laser microprobe $^{40}Ar/^{39}Ar$ dating of two Apollo 17 breccias

Cameron M. Mercer,[1] Kelsey E. Young,[1] John R. Weirich,[2] Kip V. Hodges,[1] Bradley L. Jolliff,[3] Jo-Anne Wartho,[1] Matthijs van Soest[1]

[1] *School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287, USA*
[2] *Centre for Planetary and Space Exploration, Department of Earth Sciences, University of Western Ontario, London, ON, N6A 5B7, Canada*
[3] *Department of Earth and Planetary Sciences and McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130, USA*
cameron.m.mercer@asu.edu

**Abstract**. Quantitative constraints on the timing of major lunar impact events are based primarily on the isotope geochronology of impact melt breccias. However, interpreting the results of such studies can often be difficult[1,2,3,4] since the provenance regions of returned samples may have experienced multiple impact events throughout lunar history. Though each of those events may have produced impact melt or resulted in the partial or complete resetting of isotopic chronometers in pre-existing rocks, there is no guarantee that any individual sample will record all the geochemical and geological evidence for polyphase impact. We demonstrate this with new laser microprobe $^{40}Ar/^{39}Ar$ data for two Apollo 17 impact melt breccias. While sample 77115,121 preserves evidence for only a single melt-forming event at 3.851 ± 0.015 Ga (all age uncertainties reported here are 2SE), data from the polymict breccia 73217,83 document at least three impact melt-forming events at 3.8097 ± 0.0095 Ga, 3.676 ± 0.013 Ga, and ≤ 3.283 ± 0.023 Ga. Analyses of lithic and mineral clasts in both samples yielded uniformly older apparent ages than their host melts. Notably, published zircon and phosphate U/Pb data[5] indicate the existence of even older ca. 4.34 Ga and ca. 3.93 Ga melt products in 73217. The presence of 3.85-3.81 Ga melt components in both samples supports emerging interpretations that most Apollo 17 impact breccia samples are derived from Imbrium, rather than Serenitatis, ejecta[6]. In addition, the maximum age of the youngest melt component (ca. 3.28 Ga) in 73217,83 is consistent with the finding that a significant ca. 3.3 Ga impact event affected the Apollo 16 landing site[7], perhaps indicating a regional event that affected both locations. Finally, our results support the possibility that multiple impactors contributed to the highly-siderophile-element signature that dominates Apollo 17 impact melts[8]. Evidence for marked inter- and intra-sample variability in the preserved impact record of the Moon has important implications for the design of future human and robotic exploration missions in the inner Solar System. If establishing a robust impact chronology is a primary goal of such missions, then either the return of a large number of samples will be necessary, or the development of appropriate technologies for in situ geochronology will be required to high-grade samples for detailed analysis on Earth.

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