Refining Models of the Lunar Bombardment History Using the Laser Microprobe $^{40}Ar/^{39}Ar$ Method

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The precise early bombardment history of the Moon remains one of the most poorly understood aspects of lunar science. Quantitative constraints are largely derived from returned samples and lunar meteorites through isotopic chronometry of impact melt breccias. Because many of the available breccias were collected from ejecta deposits that can be traced to major basin-forming impact craters (e.g., Serenetatis, Nectaris, or Imbrium), researchers often assume that the dates of melt domains in these breccias represent the ages of those major impacts. However, orbital images of the lunar surface clearly indicate that even very small impacts can produce locally significant amounts of impact melt. Uncertainties regarding the local *vs.* distant origin of dated melts can be reduced through a better undrestanding of their cooling histories: melt deposits from large, distal impacts should cool much more slowly than melt deposits from small, locally significant impacts. Laser ablation microprobe (LAMP) $^{40}Ar/^{39}Ar$ geochronology and thermochronology – combined with careful mapping of the distribution of ^{40}Ar in ancient plagioclase xenocrysts within melt domains – provide valuable insights regarding the broader significance of isotopic dates obtained for specific lunar melt breccias.

A study of Apollo 15 melt breccia sample 15455 is illustrative. The melt domain in this sample contains abundant, isolated xenocrysts of pre-4.3 Ga plagioclases, ranging in size up to a few hundred µm. Twelve LAMP $^{40}Ar/^{39}Ar$ dates of the melt in 15455 yielded an inverse-variance weighted mean apparent age of 3.7801 ± 0.0047 (2σ) Ga for for the dominant melt component in this rock. LAMP dates for eight fragmented plagioclase xenocrysts ranged from 4.265 ± 0.025 Ga to 3.799 ± 0.030 Ga, implying derivation from larger crystals that were partially reset by heating in the melt but subsequently fragmented during breccia sheet emplacement. The largest unfragmented, completely reset xenocryst studied thus far (*ca.* 400 µm) would have required no more than 900 s of entrainment in a typical lunar impact melt for resetting. On-going LAMP studies of larger xenocrysts are aimed at constraining the maximum size that shows complete resettting and thus the maximum duration of cooling of the enclosing melt to ambient temperatures.