A record of basin-forming impact from Pb clusters in lunar zircon

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Lunar zircon grains provide constraints on the early evolution of the Earth-Moon system, including a lower limit on the age of the Moon, and the initiation, duration, and spatial extent of lunar magmatism. While zircon dating remains one of the most robust tools for lunar geochronology, debate persists regarding the prevalence and length scales of impact-induced Pb-mobility in the lunar zircon population as a whole [1]. Our work applies atom probe tomography (APT) and secondary ion mass spectrometry (SIMS) to the study of zircon 17B-4, a zircon grain within the matrix of lunar sample 73235. The $^{40}Ar/^{39}Ar$ plateau age of the breccia matrix (3946 ± 95 Ma, recalculated from [2]) has been interpreted to reflect the timing of the Serenitatis basin-forming impact. SIMS U-Pb analyses on 17B-4 yield $^{207}Pb/^{206}Pb$ ages between 4338 ± 12 and 4392 ± 12 Ma (2σ); the oldest and most concordant U-Pb analysis (4392 ± 12 Ma, 99% concordant) is interpreted to reflect primary crystallization. APT data sets contain a small number of Pb-rich clusters, between 5-10 nm in diameter. The $^{207}Pb/^{206}Pb$ ratio within individual clusters are statistically identical, with a combined ratio of 1.42 ± 0.07. Using a simple clustering model, this places Pb cluster formation at 3850 +150/-170 Ma (2σ), overlapping the $^{40}Ar/^{39}Ar$ age for the host breccia and linking cluster formation to the Serenitatis impact event. The multi-scale characterization of zircon 17B-4 provides a high degree of confidence that the $^{207}Pb/^{206}Pb$ age of 4392 ± 12 Ma records primary crystallization, making 17B-4 one of the oldest reliably dated lunar zircons. APT data document the first known occurrence of nanoscale Pb clustering in lunar zircon, and the first ever correlation of Pb clustering to impact processes.

[1] Cavosie et al., (2015) Geology, 999-1002.

[2] Turner et al., (1975) Proc. 6th L.S.C., 1509-1538.