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Investigating a potential 4.33 Ga large impact event on the Moon with high-precision lunar zircon ages and geochemistry.

MELANIE BARBONI[1], DAWID SZYMANOWSKI[2], BLAIR SCHOENE[3] AND KEVIN D MCKEEGAN[4]

[1]Arizona State University
[2]ETH Zurich
[3]Princeton University
[4]University of California, Los Angeles

Presenting Author: mbarboni@mainex1.asu.edu

The Moon holds a very important place in Planetary Science, providing unique insights on the origin and dynamic evolution of our planetary system. However, most available lunar rocks are breccia, which obscure our ability to decipher between endogenous and exogenous processes (i.e. preserved early magmatism or overprint by secondary impact heating). Apollo zircons offer an alternative to whole-rock studies, as both age and chemical information can be obtained on single crystals. U-Pb analysis of > 500 Apollo zircons from the 14, 15, and 17 landing sites show ages ranging from ~4.4 to ~3.9 Ga with a shared pronounced peak at ~4.33 Ga, hinting at what could be a major (potentially global) magmatic event occurring in the early history of the Moon. However, that peak has so far been identified only by secondary ion mass spectrometry (SIMS) which is generally unable to assess concordance in U/Pb* (i.e., Pb-loss) at a precision better than ~1 to 2% and $^{207}Pb/^{206}Pb$ ages at the level of a few permil. Here we present high-precision U-Pb isotope dilution – thermal ionization mass spectrometry (ID-TIMS) geochronology on a suite of zircons previously dated at 4.33 Ga by SIMS to test if this peak indeed represents a single magmatic event, or multiple sub-events that could not be resolved by the SIMS U-Pb precision. Our results show zircon crystallization ranging over 5 Ma (4.334-4.339 Ga), which could either indicate one large impact that produced a long-lived melt sheet or multiple smaller impact occurring close in time. Coupling those ages with zircon trace elements (recording the melt evolution) and comparing our results to large terrestrial impact melt sheets allow us to test those hypotheses and shed light on this crucial time in the Solar System evolution.