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Geochemistry and U-Pb chronology of impact glass spherules from Apollo 11 soil 10084

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Lunar impact glasses found in the regolith provide constraints on the compositional diversity of source terrains and the timing of impact events. Here we present major element, trace element and U-Pb isotopic data for impact spherules from Apollo 11 soil 10084 to evaluate source lithologies, age distributions, and implications for lunar regolith evolution.

A total of 223 glass spherules from the 25-250 μm fraction were characterized by electron microprobe, LA-ICP-MS, and SIMS [1]. Based on CaO/Al_2O_3 and MgO/Al_2O_3 ratios [2], the spherules were classified as impact glasses, comprising ~86% mare and~14% with highlands compositions. The compositions of most mare glasses can be explained by mixing between basaltic, feldspathic, and KREEP-rich endmembers, indicating melting of a heterogeneous regolith [3] and excavation of lithologies not represented by the returned samples, including low-Ti (TiO_2=2.5-6.0 wt%) basaltic material. Highlands-type glasses are consistent with melts of impactites such as granulitic breccias variably mixed with mare material.

U-Pb ages for Apollo 11 impact glasses range from <10 to 4300 Ma and define several populations, with most ages <1 Ga. A dominant peak is observed at ~580-600 Ma and subordinate peaks at ~40-50 Ma, ~230-250 Ma, and ~2.0 Ga. Combined impact-glass ages from three landing sites distributed across different regions on the Moon (Apollo 11, Chang'e-5 and Apollo 14; [4,5]) yield 22 statistically distinct age populations. The bead size-age relationship is characterized by a decreasing abundance of larger spherules with increasing age, such that older populations are dominated by smaller beads. This pattern indicates progressive comminution and remelting of older glasses during regolith evolution. These results suggest that the apparent "young spike" during the last ~500 Ma in lunar impact glass ages reflects a combination of recent small- to moderate-sized impacts at a constant rate and strong preservation bias of older glasses (i.e., older beads are preferentially fragmented, remelted, and destroyed over time).

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