PETROLOGIC EVALUATION OF PRE-CATAclySM IMPACTS ON THE MOON.
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Introduction: Intriguing indications of a thermal event in the lunar crust at ~4.2-4.3 Ga has been apparent since the mid-1970's, based on the $^{40}$Ar-$^{39}$Ar [1] and Rb-Sr isotopic systematics [2] of some highlands breccias. Although the geochronological significance of some of these data has been questioned [3,4], the recent demonstration of a 4.2 Ga crystallization age in a lunar melt rock linked to a basin-scale impact event [5] supports the idea that the late heavy bombardment was more extended and more complex than implied by the classical ‘Terminal Cataclysm’ concept. Here we consider some of the petrological characteristics of lunar samples that record isotopic evidence for impacts at ~4.2-4.3 Ga with the aim of evaluating the ‘pre-cataclysm’ impact history of the Moon.

Samples characteristics: Petrologic and isotopic characteristics of lunar melt rock and breccias are consistent with a number of large (basin scale?) impact events during the period 3.8-4.0 Ga. The exact number of these events, and their geological relationships to specific basins, has not been firmly established, but resolvable differences in $^{40}$Ar-$^{39}$Ar and Rb-Sr isochron ages among petrologically and geochemically distinct groups of lunar melt rocks [6,7,8] are consistent with multiple events of sufficient size to produce thick melt sheets.

In contrast, aside from the notable exception of sample 67955, which is now interpreted as a brecciated and moderately annealed melt rock [5], the record of 4.2-4.3 Ga impact events comes predominantly from metamorphic granulites, fine-grained to glassy-matrix clasts and fragments, and small volumes of deformed zircons. Petrological characteristics of these samples suggest either lower-PT regimes, smaller craters, or preferential sampling of distal, near-surface environments compared to those that formed the 3.9 Ga crystalline melt rocks.

Implications: While we now have definitive evidence for basin-forming impacts on the Moon prior to 3.9 Ga, the sample-based record of older events seems to reflect predominantly smaller craters or relatively shallow depths of emplacement. At first glance, this seems inconsistent with models invoking extensive early gardening of the megaregolith [9] but additional discussion is warranted. Although the endmember ‘Terminal Cataclysm’ concept in which all lunar basins formed between 3.8-4.0 Ga [10] is no longer tenable, the impact history of the Moon and its implications for planetary dynamics remains only dimly perceived.