THE UTILITY OF LUNAR METEORITES TO INVESTIGATING LUNAR BOMBARDMENT HISTORY.

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Introduction: The stochastic nature of lunar meteorite launch events implies that lunar meteorites represent a more complete sample of the lunar surface than do the Apollo and Luna samples [3-6]. More than 100 impact melt clasts from feldspathic regolith breccias MAC 88105, QUE 93069, DaG 262, DaG 400, Dhofar (Dho) 025, Dhofar 303, Dho 910, Dho 911, NWA 482, Kalahari 008, and Yamato (Y) 86032; Th-enriched feldspathic meteorites Calcalong Creek and Sayh al Uhaymir (SaU) 169; and basaltic meteorite Kalahari 009 have been investigated and dated [7-15]. Here we report new results from Dhofar 911, a shocked impact-melt breccia that previously gave enigmatic results, and an impact lithology in Dhofar 961, which has a composition closely resembling the South Pole-Aitken basin floor. These data are used to examine the impact histories of regions of the moon that have yet to be sampled by humans or robots, determine whether impact-melt clasts in these meteorites are indicators of the global lunar bombardment record, and to search for evidence of ancient impact events in these areas.

Sample Descriptions and New Results. Dhofar 911 (194 g) is a crystalline impact-melt breccia, part of a group of more than fifteen other Dhofar stones having distinctively high MgO/FeO and the lowest concentrations of both siderophile and incompatible elements among feldspathic lunar meteorites [16, 17]. We investigated three aliquots from the crystalline groundmass. Dhofar 961 is an impact melt breccia with abundant mineral fragments and lithic clasts set within a fine-grained impact melt matrix [6, 18-20]. We investigated a split of Dhofar 961 consisting of a large clast of a high-Th impact-melt lithology. We employed analysis techniques detailed more fully in [21] including identifying impact-melt clasts in thick sections using textural criteria, using electron microprobe data to determine the bulk composition of each clast, and conducting ^{40}Ar-^{39}Ar stepped-release experiments.

For Dhofar 961, we achieved >30 heating steps on five splits of the IM lithology. The degassing steps don't form extensive plateaus, but do reveal well-constrained isochrons showing ages around 3.8 Ga, which is only slightly younger than the U-Pb ages reported for phosphates in this meteorite by [20]. U-Pb ages are commonly slightly older than their Ar-Ar counterparts, having a higher closure temperature and being less susceptible to low-temperature losses. Additionally, this particular IMB lithology was not sampled by [20], so it is possible that this IMB could be recording the youngest age for the meteorite. For Dhofar 911, we achieved very high-resolution step-heating profiles of >50 steps each. These data are still being interpreted, but show potential multidomain behavior in diffusion plots that will yield insight into the thermal history of this sample.

The Utility of Meteorites: Some workers [22-24] have argued that some or all the Th-rich impact melt rocks in the Apollo collection are products of a single impact event, the Imbrium basin-forming impact, and therefore, no cataclysm was required to explain the Apollo impact melt distribution. It is still a matter of debate whether this hypothesis can accommodate the multiple groups of impact melt that are resolvable from each other in age and in trace-element composition. Impact-melt clasts in lunar meteorites show that surface breccias provide a relatively representative sample of the upper lunar surface in the area where they formed [4]. The impact-melt ages within them therefore record of the impact history of that region between the time of the last major resurfacing (or gardening) event and the time of breccia closure, perhaps with a statistically small number of older samples entrained in the upper regolith. Because the samples come from the uppermost surface, we can correlate composition of the clasts with lunar terrains from remote sensing data [20, 25] to conclude that the age distribution of clasts in the feldspathic meteorites reflects the impact history of the FHT from ~4 Ga to the closure age of the meteorites. It is well worth noting that the study of impact-melt clasts as representative lunar surface samples was first suggested in the context of the Antarctic collection [3]. The Antarctic lunar meteorites continue to be a crucial source of material that contributes to these efforts, being widely available to all interested researchers.

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