GEOCHEMISTRY AND ^{40}AR-^{39}AR GEOCHRONOLOGY OF IMPACT-MELT CLASTS IN LUNAR METEORITES DAR AL GANI 262 AND CALCALONG CREEK.

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Introduction: We are continuing our study of impact-melt clasts in lunar meteorites [1, 2]. The dissimilarity of DaG262 and Calcalong Creek impact-melt clasts to Apollo mafic, KREEPy impact melts (Fig. 1) makes them excellent candidates for age dating in order to further constrain lunar bombardment history.

Meteorites: DaG 262 [3] is a well-consolidated breccia, consisting of a fine-grained matrix with abundant clasts of granular anorthosite and crystalline impact melt clasts, melt veins and metal grains. Calcalong Creek [4] is a polymict breccia containing sub-mm clasts of both highlands and mare affinity welded by a glassy, vesicular matrix. It is unusual among lunar meteorite breccias in having a high concentration of Th (~4 ppm) and other incompatible elements, largely carried in the meteorite matrix, indicating a possible affinity with the Procellarum KREEP terrane (PKT).

Geochemistry: We identified 14 large (>100 µm) impact-melt clasts in DaG 262 and 12 in Calcalong Creek using the petrographic microscope. These clasts are fully crystalline, generally microporphyritic or quench-textured, and do not contain large mineral inclusions. Major-element chemistry of each clast was obtained using defocused-beam analyses (DBA) with a Cameca SX-50 electron microprobe at the University of Arizona (15kv and 20nA) (the DBA technique yields Al values that may be systematically low by a few percent, but this does not affect comparison among grossly similar clasts analyzed using the same conditions, as is the case here).

Impact-melt clasts in DaG 262 have compositions similar to other lunar meteorite feldspathic breccia clasts and to the bulk meteorites themselves (Fig. 1), indicating their origin in feldspathic terrane far from the PKT or mare regions. The Calcalong Creek clasts ranged to higher K and lower Al abundances than those in feldspathic meteorites and Apollo 16 breccias (Fig. 1), though they still do not have compositions similar to KREEPy, mafic impact-melt rocks in the Apollo collection. These results are similar to clasts studied in [4], where the KREEP component in bulk INAA measurements was not observed in most clasts. However, the trend of the Calcalong Creek clasts away from typical feldspathic lunar meteorites may indicate a contribution from PKT material to the target material incorporated into these impact melts.

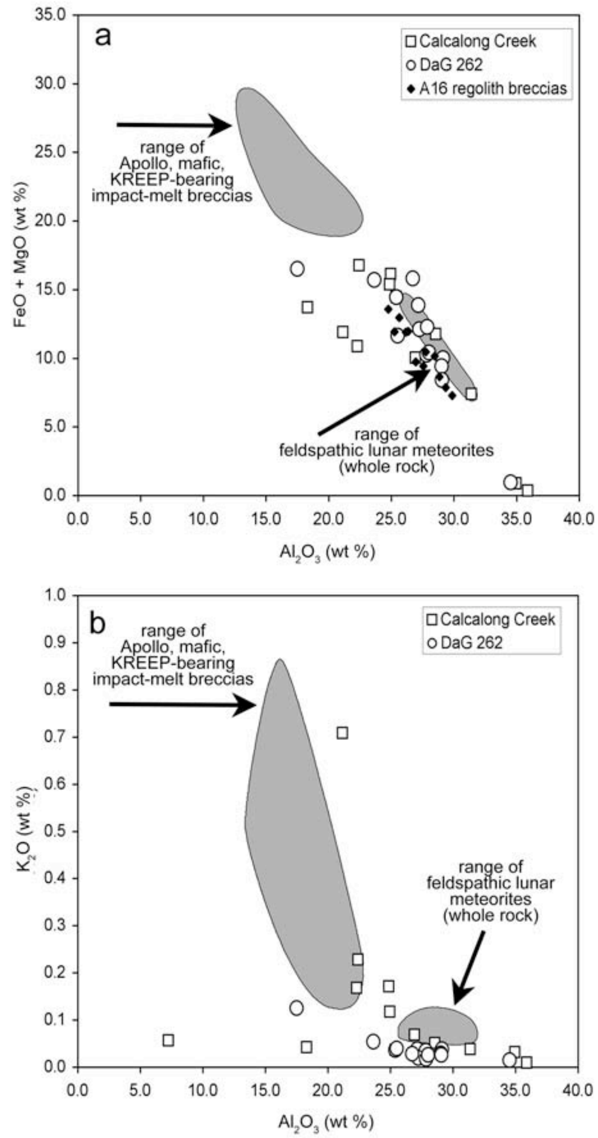

Fig.1. a) FeO+MgO (wt.%) and b) K_2O (wt.%) vs Al_2O_3 (wt.%) in DaG 262 and Calcalong Creek impact-melt clasts. Also shown are Apollo 16 bulk regolith breccias [5] and fields for bulk feldspathic lunar meteorites and Apollo mafic impact-melt breccias [6].

Geochronology: Impact melt clasts were extracted from 100-µm thick sections using a microcorer and irradiated for 500 hours at the Ford reactor. Unfortunately, we were not able to extract the highest-K_2O clast in either meteorite for ^{40}Ar-^{39}Ar analyses. Laser step-heat experiments were conducted in the University of Arizona noble gas lab using a continuous Ar-ion laser heating system. Heating steps were determined by varying the laser amperage. Due to the small size and low K content (Fig. 1), few heating steps could be performed on each sample. The lowest-power step in most samples produced a large plug of hydrocarbons, presumably from epoxy clinging to the microcores. Because hydrocarbon interference is partially resolved from ^{39}Ar by the VG5400 mass spectrometer, we were able to identify, and correct, for the interference by routinely monitoring three locations in the mass 39 region. A well-defined contribution from HCl at masses 36 and 38 was also subtracted. All data were also corrected for blanks, reactor-induced interferences, decay time, and cosmic-ray spallation.

A trapped argon component was evident in almost every sample. Initial ^{40}Ar/^{36}Ar ratios were determined using the Isoplot package for Excel, assuming 0.95 for error correlations between ratios. Two DaG 262 samples yielded well-defined isochrons with initial ^{40}Ar/^{36}Ar ratios of 2.31 ± 0.10 and 2.65 ± 0.17. One Calcalong Creek sample had a well-defined isochron with an initial ^{40}Ar/^{36}Ar ratio of 3.67 ± 0.39. These trapped argon ratios indicate that the breccia components were exposed to the lunar surface within the last 1.5-2 Ga [7]. Other noble gases in Calcalong Creek indicate its total exposure for up to several hundred million years [4]; its trapped argon component indicates that this exposure time predated DaG 262. In cases where isochrons could not be determined, a trapped component was assumed (2.0 ± 0.5 for DaG 262 and 3.0 ± 1.0 for Calcalong Creek) with a relatively large uncertainty, leading to large uncertainties in the derived ages.

Plateau ages are shown in Table 1, though these data must be considered preliminary at this time. None of the data reflect impact events older than 3.9 Ga, consistent with the lunar cataclysm hypothesis [8, 9]. However, the lunar meteorite impact-melt clast age distribution (Fig. 2) peaks 400-800 Myr after the nearside basin ages of 3.9 Ga. Neither the smooth-decline or terminal cataclysm hypotheses, by themselves, explain this distribution. Small clasts in the meteorites are probably sampling later, local impacts whereas hand samples favor chunks from the largest nearby impact. More analyses of impact melt clasts in soil samples identified using the same criteria as in the meteorites may be able to clarify this discrepancy. It is interesting to note, nevertheless, that evidence may exist for several impact events on the Earth around 3.2-3.5 Ga [10].

References: [1] Cohen et al. (2000) *Science* **290**, 1754. [2] Cohen et al. (2002), *LPSC 33,* abstract #1252. [3] Bischoff et al. (1998) *MAPS* **33**, 1243. [4] Hill and Boynton (2003) *MAPS* **38**, 595. [5] McKay et al. (1986) *JGR* **91**, D277. [6] Korotev et al. (2003) *GCA* **67**, 4895. [7] Eugster et al. (2001) *MAPS* **36**, 1097. [8] Ryder (1990) *Eos* **71**, 313. [9] Hartmann et al. (2000), in *Origin of the Earth and Moon*, 493. [10] Byerly et al. (2002) *Science* **297**, 1325. [11] Fernandes et al. (2000) *MAPS* **35**, 1355. [12] Daubar et al. (2002) *MAPS* **37**, 1797. [13] Fernandes et al. (2004), *LPSC 35,* abstract #1514.

Table 1: DaG 262 & Calcalong Creek clast ages

Sample	Weight (μg)	^{40}Ar/^{36}Ar initial	Plateau age (Ma)
		Dar al Gani 262	
262AA	30	2.0 ± 0.5[1]	2152 ± 910
262BB	20	no ^{36}Ar	3341 ± 420
262LL	84	2.31 ± 0.10	3355 ± 190
262OO	193	2.65 ± 0.17	3100 ± 68
262PP	56	1.81 ± 0.55	2898 ± 420
262SS	97	2.0 ± 0.5[1]	3308 ± 520
		Calcalong Creek	
CC07	22	3.67 ± 0.39	1031 ± 450
CC08	8	3.0 ± 1.0[1]	2035 ± 1100
CC11	16	3.0 ± 1.0[1]	983 ± 1300
CC17	21	3.0 ± 1.0[1]	1324 ± 1000
CC19	28	3.0 ± 1.0[1]	3833 ± 1500
CC20	26	3.0 ± 1.0[1]	2942 ± 900

[1]assumed rather than defined by isochron

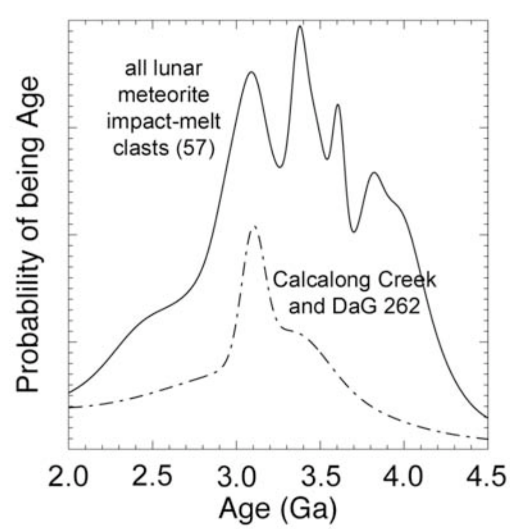

Fig. 2. Ideogram of impact-melt clast ages from DaG 262 and Calcalong Creek (this work; lower dashed line) and from all feldspathic lunar meteorites (including DaG 262 and Calcalong Creek; [1, 2, 11-13]; upper solid line). Units on y-axis are arbitrary.