AGES OF IMPACT-MELT CLASTS IN APOLLO 16 BRECCIAS. B.A. Cohen[1], S.J. Symes[2], T.D. Swindle[3], J. Weirich[3], and C. Isachsen[3], [1]Institute of Meteoritics, University of New Mexico, Albuquerque NM 87131 (bcohen@unm.edu); [2]University of Tennessee-Chattanooga, Chattanooga TN 37403; [3]University of Arizona, Tucson AZ 85721.

Introduction: The preponderance of 3.9 Ga lunar impact-melt rock ages and the dearth of older samples of unequivocal impact origin, from either the Apollo collection or lunar meteorites, suggest an extraordinary bombardment event in the Earth-Moon system at ~3.9 Ga. Impact-melt rocks that form the basis of the cataclysm hypothesis are predominantly mafic, KREEP-rich samples, affording enough radiogenic elements to be feasibly dated, but possibly dominated by the large volume of melt created in the stratigraphically young, nearside basins. In contrast, Apollo 16 feldspathic breccias [1] lack KREEPy impact-melt clasts, suggesting that these rocks were lithified and closed to new input before the exposure and dissemination of KREEP material. High amounts of trapped ^{40}Ar and excess fission Xe present in many Apollo 16 feldspathic breccias indicates that they acquired their noble gases, including solar wind exposure, very early in lunar history. These breccias lack mature regolith components such as agglutinates, indicating that following exposure, the breccia components were shielded for some time. These characteristics make the Apollo 16 breccias attractive targets for searching for evidence of impact events that may pre-date formation of the large, nearside basins.

Chemistry: 66075 is a feldspathic fragmental breccia and 60016 and 66035 are feldspathic regolith breccias. All are subcompact with low shock and rare occurrences of agglutinates and glass spheres. We obtained 100-μm thick sections of each breccia to conduct petrologic, geochemical, and geochronological studies on crystalline lunar spherules (CLS) and impact-melt fragments. We previously [2] reported on the petrology and chemistry of 18 large (>100 μm) melt fragments (mf) and two glass fragments (g) in the three thick sections. The melt fragments are fully crystalline and generally microporphyritic.

Fig. 1 shows that about half the impact-melt clasts have lower Ti contents than the average Apollo 16 soil (indicated with an asterisk). Their normative compositions are ≥80% plagioclase by volume. These clasts may indeed be derived from the pre-Imbrium feldspathic highlands of the Moon. The other clasts have similar compositions to A16 breccia bulk compositions, where admixture of a less aluminous component, such as basalt [3], is implied. Diversity in the clasts' Mg' (molar Mg/(Mg+Fe)) suggest that these breccia clasts sample multiple impact events.

Geochronology: We extracted the clasts from the rock matrix using a Medenbach microcorer. Microcore characteristics are listed in Table 1. We irradiated the samples at the Ford reactor at the University of Michigan, producing a J-factor of 0.0389. We conducted laser step-heat experiments in the University of Arizona noble gas lab using a continuous Ar-ion laser heating system, determining heating steps by varying the laser amperage. Due to the small size and low K content, few heating steps could be performed on each sample. Data were corrected for system blanks, contribution from HCl at masses 36 and 38, reactor-induced interferences, decay time, and cosmic-ray spallation.

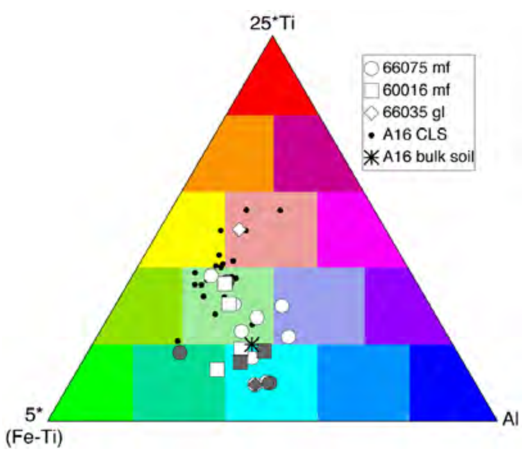
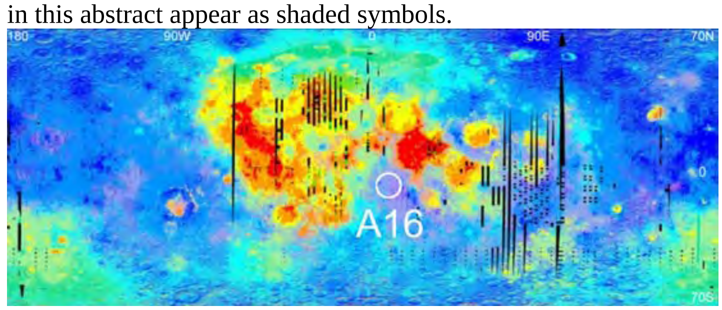


Fig. 1. Major-element chemistry of A16 impact-melt and glass fragments, A16 crystalline lunar spherules (see also Symes et al., this volume), and the average A16 soil compared with global lunar surface compositions (after [4]). Samples with ages reported in this abstract appear as shaded symbols.



Results: As of November 2006, we have dated five impact-melt samples and one glass sample (Table 1). Initial $^{40}Ar/^{36}Ar$ ratios were determined using the IDL routine *fitexy*. Two 66075 samples yielded well-defined isochron intercepts indicating initial $^{40}Ar/^{36}Ar$ ratios of 10 ± 1 and 12 ± 1; two 66016 samples had slightly higher initial $^{40}Ar/^{36}Ar$ ratios. These trapped argon ratios indicate that the breccia components were exposed at the lunar surface ~3.5-4 Gyr ago [5]. The intercept-determined initial ratios were subtracted from each sample in order to obtain a step-heat plateau.

Plateau and isochron ages are shown in Table 1, though these data must be considered preliminary at this time. Possibly surprisingly, none of the data reflect impact events older than 3.9 Ga, consistent with the lunar cataclysm hypothesis. In fact, four impact-melt clasts and the glass sample appear to fall within a narrow age window, within uncertainties, of ~3.83 ± 0.07 Ga. This is consistent with the inferred age of formation of the Imbrium basin (3.85 Ga), an event sometimes credited with creating all the 3.9-Ga, KREEP-rich impact melt rocks whose ages define the lunar cataclysm [6].

One possible interpretation of our data so far is that these impact-melt clasts were created by a large impact event into the feldspathic crust at 3.83 Ga. To create feldspathic impact–melt samples, this event must have either been distant from the PKT or created non-KREEPy impact melt products from the upper (feldspathic) target layers that were thrown out early in the process. The breccias themselves may also have been lithified by heat provided by shock or emplacement of hot material from Imbrium or another nearside basin-forming event, even though they did not incorporate KREEPy material. The Apollo 16 unconsolidated regolith contains impact-melt samples from numerous events with ages 3.75-3.96 Ga [7, 8], indicating the influence of these large impact events at the Apollo 16 site. Alternatively, the breccias may have been previously lithified and closed to new input, but experienced subsequent metamorphic heating at ~3.83 Ga that reset the Ar ages of the components within the breccias. In this interpretation, it is difficult to explain the older age of 99mf10, though we note this older age is very preliminary. A third interpretation is that these breccias were formed elsewhere on the lunar surface and distributed to the Apollo 16 site by a later impact event, though the similarity between the bulk composition of the breccias and the A16 unconsolidated soil make this unlikely. We are collecting more data to help evaluate these scenarios.

References: [1] McKay, D.S., *et al.* (1986) *JGR* 91, D277. [2] Cohen, B.A., *et al.* (2006) *LPSC* 36, #1231. [3] Korotev, R.L., *et al.* (1997) *GCA* 61, 2989. [4] Zellner, N.E.B., *et al.* (2002) *JGR* E107, 12. [5] Eugster, O., *et al.* (2001) *MAPS* 36, 1097. [6] Haskin, L.A., *et al.* (1998) *MAPS* 33, 959. [7] Korotev, R.L. (1997) *Meteoritics* 32, 447. [8] Norman, M.D., *et al.* (2006) *GCA* doi:10.1016/j.gca.2006.05.021.

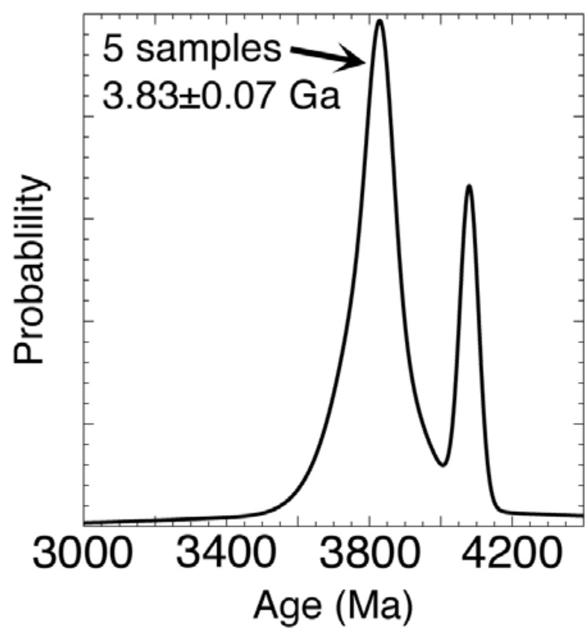


Figure 2. Ideogram of impact-melt and glass sample ages reported in this abstract.

Table 1. Sample characteristics and ages. *Two subsamples of the same impact-melt clast.

Breccia	Sample	Mass	Description	K_2O (wt.%)	$40/36_i$	Isochron Age (Ma)	Plateau Age (Ma)	Plateau steps	$\%^{39}Ar$
66035,48	48g2	121	glass	0.05	241 ± 3	0 ± 245	3956 ± 579	6	75
66075,99	99mf4	43	poikilitic	0.20	10 ± 1	3732 ± 49	3832 ± 34	4	94
66075,99	99mf8	22	microporhyritic	0.63	-117 ± 228	3835 ± 436	3764 ± 101	7	100
66075,99	99mf10	22	microporhyritic	0.06	12 ± 1	3946 ± 20	4080 ± 26	9	100
60016,270	270mf3A	102	microporhyritic	0.18	19 ± 27	3796 ± 137	3808 ± 67	9	77
60016,270	270mf3B	109	microporhyritic	0.18	157 ± 38	3691 ± 417	3874 ± 106	3	100