INAA OF GLASS SPHERES FROM ANCIENT APOLLO 16 REGOLITH BRECCIAS.

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Introduction. We are developing techniques for analyzing individual lunar glasses for minor and trace elements by means of INAA with procedures similar to those currently being developed for interplanetary dust particles [1,2]. It should be possible to analyze very small glasses (i.e., as small as 10-20 um) with these techniques, which would be advantageous because many lunar glasses are found in these small size ranges. In addition, the nondestructive nature of INAA permits further studies of the glasses, including scanning electron microscopy studies of surface morphologies and electron microprobe major element analysis. As discussed by [3,4], trace element data for lunar glasses, and for volcanic glasses in particular, would be of great importance in understanding the sources of the glasses and the systematics of lunar volcanism. Trace element data would also be useful in determining the origins of glasses with unusual major element compositions.

Glasses for this study were chosen from ancient Apollo 16 regolith breccias 60016,165 and 66075,16. These breccias are of interest because they are thought to be on the order of 4 Gy old [5] and contain a few glasses with mare affinities [6]; trace element data for such glasses would help define early mare volcanism. The ancient Apollo 16 regolith breccias also contain ultra Mg' glasses (i.e., glasses with atomic Mg/Mg+Fe > 0.90), which are of uncertain origin and possibly even komatiitic [6]. Six spheres were picked from the 150-250 um sieve fractions of freeze-thaw disaggregated breccias 60016,165 and 66075,16, three spheres from each sample. Spheres were the only type of glass chosen in order to rule out the possibility of confusion with mineral or lithic fragments during sample selection. The chosen spheres are typical in appearance of those present in the samples: two (60016,165-3 and 66075,16-1) are greenish/translucent, and the rest are dark gray to black.

Techniques. The procedures were similar to those used for individual cosmic dust grains [1,2], even though the lunar glasses were about 1000X larger. Samples and glass standards were weighed individually on a Cahn microbalance and sealed in fused silica containers (1 cm long by 0.5 mm inner diameter); these containers were then sealed together in a larger quartz tube. This large tube was irradiated for 153 hours at a flux of 4×10^{14} n/cm^2s in the Missouri University Research Reactor. Samples were counted for 12 hours each, 10-13 days after the end of the irradiation, too late for short lived Na and K to be observed. Count rates were more than adequate, ranging from 400 to 1400 counts per second. Abundances were obtained by comparison with glass standards WU-A and WU-B (Lindstrom and Korotev, unpublished) and fused standard basalt BHVO-1, except for Ir and Br, which were estimated using published cross sections.

Results. Because of the small sizes of the samples, measured weights (Table 1) are somewhat uncertain. If the weights are incorrect, absolute abundances of elements given in Table 1 and discussed below would also be incorrect, but relative abundances of elements within each sample would still be correct. In order to verify the weights and absolute abundances shown, we plan to do major element electron microprobe analysis of the glasses for comparison of Ca and Fe.

All six glasses are of highland composition, demonstrated by high CaO and low FeO contents (Table 1). The glass compositions are all distinctly different from those of the breccias in which they were found: compared to 60016 and 66075 bulk compositions [5], the glasses are lower in CaO and higher in FeO. Glass 66075,16-1 has a relatively flat REE pattern and even lower incompatible trace element abundances than those of the bulk breccias or most Apollo 16 soils; its composition is similar to that of the highly feldspathic Group 3 melt rocks of [7]. Compositions of four of the glasses (60016,165-5 and -7; 66075,16-3 and -5) are very much alike and appear to contain a sizeable KREEP component, as shown in the cluster of REE patterns in Fig. 1. These four glasses have compositions that seem to be intermediate between those of Apollo 16 impact melt Groups 1 and 2 of [7], also known as POIK and VHA. One glass (60016,165-3) is quite KREEP-rich, more so than any of the groups defined by [7], but similar to the mafic fragment-laden impact melt clasts found in North Ray Crater breccia 67975 [8].

Feldspathic glass 66075,16-1 is the only one with a composition resembling any Apollo 16 soil; it is similar to North Ray Crater bulk soil compositions and may have formed locally. The rest of the glasses are more KREEP-rich than the bulk breccias or any local soils, so they could not have formed by impact into local regolith materials. The compositional similarities between the glasses and some Apollo 16 impact melt

INAA OF APOLLO 16 GLASS SPHERES

Wentworth et al.

rocks suggest a common origin, probably by large-scale impact(s), into the same source area. If the inferred ancient ages of the Apollo 16 regolith breccias are correct [5], it is important to determine the compositions of these ancient impact glasses, because of their proximity in time to the large basin-forming events. It is likely that the basin-forming events created impact spherules and it may be possible, by analyzing a population of ancient impact glass spherules, to establish correlations with the major impacts and, consequently, to more tightly define the average composition of the target materials at the basin. Whether the spheres analyzed here were formed in these large impacts remains to be determined, but at least they seem to be approximately the right age, and are mostly different in composition from the local regolith.

References: [1] Zolensky et al. (1989) This volume. [2] Lindstrom et al. (1989) This volume. [3] Hughes et al. (1988) Geochim. Cosmochim. Acta 52, pp. 2379-2391. [4] Simon et al. (1989) Proc. Lunar Planet. Sci. Conf. 19th (in press). [5] McKay et al. (1986) Proc. Lunar Planet. Sci. Conf. 16th, pp. D277-D303. [6] Wentworth and McKay (1988) Proc. Lunar Planet. Sci. Conf. 18th, pp. 67-77. [7] McKinley et al. (1984) Proc. Lunar Planet. Sci. Conf. 14th, pp. B513-B524. [8] Lindstrom (1984) Proc. Lunar Planet. Sci. Conf. 15th, pp. C50-C62.

TABLE 1: INAA abundances for glasses in regolith breccias 60016 and 66075.

	-1-	-2-	-3-	-4-	-5-	-6-
	66075,16-1	60016,165-3	60016,165-5	66075,16-3	66075,16-5	60016,165-7
	8.60 ug.	12.0 ug.	6.60 ug.	8.50 ug.	12.0 ug.	8.60 ug.
CaO	13.3 ± 0.9	13.8 ± 1.1	10.7 ± 1.1	10.6 ± 0.8	13.5 ± 1.1	11.7 ± 0.9
FeO	6.53 ± 0.08	6.39 ± 0.08	7.14 ± 0.09	6.13 ± 0.08	6.57 ± 0.08	7.78 ± 0.10
Sc	9.28 ± 0.12	21.02 ± 0.26	13.09 ± 0.16	15.84 ± 0.20	15.47 ± 0.19	20.17 ± 0.25
Cr	841. ± 12.	1275. ± 19.	1301. ± 19.	1630. ± 24.	1223. ± 18.	1544. ± 23.
Co	6.60 ± 0.11	31.0 ± 0.4	26.9 ± 0.4	32.5 ± 0.4	28.5 ± 0.4	16.65 ± 0.23
Ni	80. ± 10.	657. ± 16.	478. ± 15.	667. ± 25.	547. ± 15.	360. ± 16.
Rb	<1.9	1.74 ± 0.25	1.6 ± 0.7	15.9 ± 1.5	<1.0	<0.49
Cs	——	<0.15	——	0.44 ± 0.08	<0.20	<0.25
Sr	171. ± 19.	170. ± 17.	189. ± 22.	185. ± 22.	189. ± 18.	191. ± 23.
Ba	73. ± 9.	728. ± 17.	430. ± 17.	552. ± 18.	509. ± 16.	495. ± 18.
La	6.7 ± 0.4	82.4 ± 1.9	43.2 ± 1.1	58.3 ± 1.6	58.0 ± 2.1	46.2 ± 1.6
Ce	19.3 ± 0.4	213. ± 3.	111.8 ± 1.8	148.7 ± 2.3	144.7 ± 2.3	117.2 ± 1.9
Nd	12.6 ± 2.2	123. ± 4.	65. ± 3.	91. ± 4.	89. ± 3.	73. ± 4.
Sm	2.97 ± 0.10	29.9 ± 0.9	16.2 ± 0.5	21.9 ± 0.6	22.0 ± 0.7	17.2 ± 0.5
Eu	1.17 ± 0.09	2.05 ± 0.12	1.88 ± 0.14	2.02 ± 0.14	1.91 ± 0.12	2.09 ± 0.13
Tb	0.64 ± 0.04	6.74 ± 0.12	3.64 ± 0.08	4.71 ± 0.09	4.91 ± 0.09	3.92 ± 0.08
Yb	2.46 ± 0.13	27.5 ± 0.6	13.4 ± 0.3	17.7 ± 0.4	19.4 ± 0.5	14.9 ± 0.4
Lu	0.419 ± 0.021	3.81 ± 0.08	1.88 ± 0.04	2.50 ± 0.06	2.53 ± 0.06	2.15 ± 0.05
Zr	112. ± 23.	860. ± 40.	630. ± 40.	850. ± 40.	700. ± 40.	690. ± 40.
Hf	2.30 ± 0.07	21.4 ± 0.3	14.64 ± 0.25	19.9 ± 0.3	17.20 ± 0.28	15.59 ± 0.26
Ta	0.47 ± 0.06	3.18 ± 0.22	1.92 ± 0.15	2.48 ± 0.18	2.30 ± 0.17	2.75 ± 0.21
U	<0.22	3.67 ± 0.25	1.19 ± 0.16	1.66 ± 0.18	1.21 ± 0.20	2.15 ± 0.22
Th	0.83 ± 0.04	14.90 ± 0.28	7.12 ± 0.20	9.14 ± 0.21	12.60 ± 0.20	7.29 ± 0.13
Se	——	12.9 ± 2.9	6.6 ± 1.9	6.6 ± 1.9	6.4 ± 1.6	7.4 ± 1.9
Sb	0.14 ± 0.04	——	<0.13	——	<0.22	<0.14
Ir	——	0.038 ± 0.010	<0.021	0.094 ± 0.020	<0.017	0.015 ± 0.007
Ag	<0.9	<0.5	<0.8	<0.7	<0.6	<0.6
Zn	6.0 ± 1.4	109. ± 3.	17.3 ± 2.6	26.1 ± 2.0	37.6 ± 2.7	38. ± 3.
Br	<15.	<6.	<13.	<10.	<20.	<18.

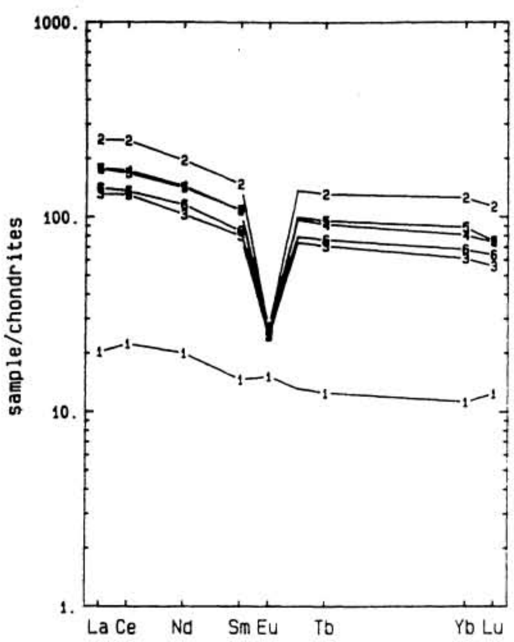

FIGURE 1: Chondrite-normalized REE abundances. Numbers 1-6 correspond to column headings in Table 1.