APOLLO 16 IMPACT MELT BRECCIAS 3. HOW MANY MELTING EVENTS?;

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Crystalline impact melt breccias are the most common rock type returned from the lunar highlands [1]. Previous studies have concluded that three [2,3] or four [4] distinct melt compositions occur at the Apollo 16 site. Results obtained in companion abstracts [IMB1,IMB2] allow reevaluation of the number of different melting events represented by the Apollo 16 melt breccias.

Melt Group 1. One of the melt groups identified by previous studies is that known as "group 1" [2,4], "poikilitic-textured low-Al_2O_3 LKFM" [3], or "Apollo 16 KREEP" (basalt) [5]. Such rocks are the least feldspathic (i.e., <20 % Al_2O_3 and >12 μg/g Sc) and the most ITE-rich (>16 μg/g Sm) of the Apollo 16 impact melt breccias. Fourteen samples of group-1 impact melt rocks were encountered in the present study (Table 1 and Fig. 1; the mean composition of several clasts from regolith breccia 60016 is also included here [6]). Several of these (60315, 62235, 65015) are "type specimens" of group-1 melt [2,3]. Ryder and Seymour [7] argue that because the compositional spread among the "poikilitic" (group-1) rocks is large compared to that of the dimict-breccia melts [IMB2], the group-1 samples must derive from several different melting events. However, this argument alone is not sufficient because *intrasample* variation in the group-1 rocks, particularly for the ITEs like Sm, is significantly larger than that for the dimict breccia melts [IMB1, Table 1]. (Note in Fig. 1 of [IMB1] that the scatter is worse among the 20-40 mg subsamples of the group-1 rocks than among the 100 and 170 mg subsamples.) Perhaps there is some factor associated with development of the poikilitic texture that leads to nonuniformity of composition on the size scale of the samples studied here. {Also, Ryder and Seymour [7, Fig. 1] (also [4]) implicitly compare *absolute* differences in concentrations. For elements such as Sm or, to a lesser extent, Sc, which are carried in large part by minor phases (phosphates and ilmenite, respectively), we would expect the absolute variation to increase as the concentration of the phase increases. The *relative* differences among the subsamples of group-1 rocks are not particularly large compared to those of the more Sc-poor, ITE-poor melts [IMB1].}

The data obtained here show one apparent dichotomy not previously noted in the group-1 melts. Most samples with >0.575 % Na_2O have greater Na/Sm and Cs/Sm ratios than those with <0.575 % Na_2O (Fig. 1). Samples 60525 and 60526 (symbols b and c) cannot unambiguously assigned to either subgroup, which suggests that the apparent dichotomy may be an artifact of the limited number of samples. Fig. 1 shows that the low-Na subgroup also tends to have higher Ca concentrations. I cannot find any factor in the published petrographic data for the samples which corroborates this geochemical dichotomy.

Melt Group 2. Group-2 melt rocks ("VHA basalt" [5,4], "low-An[orthite] anorthositic gabbro" [3]) are taken to be those melt breccias with approximately 20-25 % Al_2O_3 [2,4]. This corresponds roughly to samples with 6-12 μg/g Sc and 4-14 μg/g Sm [IMB1, Fig. 1]. Within this composition range, only samples with the composition of the dimict breccia melt form a tight cluster [2,4,7,IMB2]. If the tightness of the dimict breccia cluster is used as a standard, then it is likely that each of the remaining 17 samples in this composition range represents a different melting event. Samples that plot near each other on the Sc-Sm plots [IMB1] can usually be separated when other element concentrations or ratios are considered. The Cr/Sc ratio is one useful discriminator. For example, samples 61549 (A) and 64506 (E), which have similar Sc and Sm concentrations [IMB1], have considerably different Cr concentrations (Fig. 2). The radial trends in Fig. 2 result from constancy of ratios among pyroxene, spinel, and ilmenite for some groups of samples coupled with variation in the proportion of feldspar [IMB1,IMB2]. Note that spinel-rich sample 62295 [8] (symbol n) has a higher Cr/Sc ratio than the dimict breccia melt. Sample 61549 (A) has a similarly high Cr/Sc ratio and similar Sc and Sm concentrations to 62295, however the two samples have vastly different Cs/Sm ratios (Fig. 3).

Melt Group 3. Type specimens of melt group 3 are 68415 and 68416 [2]. These are feldspathic samples (27-30 % Al_2O_3) with low concentrations of ITEs. Intrasample compositional variability for 68415 and 68416 are small [IMB1, Fig. 1b, symbols x and y]. None of the other samples analyzed here is sufficiently similar in composition to 68415/6 to warrant inclusion in group 3. Although sample 65758 appears to plot in the same region of the Sc-Sm plot [IMB1, Fig. 1a, symbol P], it has only half the concentration of Sm and other ITEs. (The difference is particularly evident on logarithmic plots.) Sample 64817 also appears similar on the Sc-Sm plots [IMB1, symbol M], but has a distinctly greater Cs/Sm ratio (Fig. 3).

Melt Group 4. McKinley et al. [4] identify a highly feldspathic (30-32 % Al_2O_3) melt group. Compositional (particularly INAA) data are scarce for samples identified as group-4 melts so it is not clear which, if any, of the samples analyzed here correspond to this composition. Among the feldspathic (low-Sc) samples, the only compositional cluster occurs for samples 68526, 68845, and 68846 [IMB1, Fig. 1a, symbols W, X, and Z]. As these were all collected in the same vicinity, it is likely that they are all samples of the same melt. Cs concentrations, however, are highly variable among the subsamples, particularly for 68845 (X, Fig. 3). Concentrations of siderophile elements for these 3 samples are low (Ni: 20-30 μg/g). This contrasts with similarly feldspathic sample 61548 (J) which has 1300 μg/g Ni. The Ir/Au ratio of 61548 is more nearly chondritic (0.75X) than that of the dimict breccia melt [IMB2]; the large meteoritic component probably accounts for the high Cr/Sc ratio of this sample (Fig. 2).

Outliers. Several relatively mafic samples lie outside the range of groups 1 and 2. These include 62245 (B), 64515 (F), 61568 (k), 68525 (z), 64507 (*) and 64815 (t and #). These samples are of particular interest because they most likely to represent melt from large, distant craters or local craters buried beneath the present surface debris. The Sc-rich samples 64507 and 64815, for example, are more typical of Apollo 15 impact melt rocks. Crystallization ages are not available for any of these samples [8].

Conclusions. The data and discussion presented here support the conclusion of Ryder and Seymour [7] that the Apollo 16 impact melt breccias derive from a large number of impact events and that few "groups" exist. This suggests that the "group-1" and "group-2" samples cannot all be products of basin formation [e.g., 8], but that some are produced during formation of smaller (10 km?, 100 km?) craters. "Group-1" melts may derive from one or two large impact events and the compositional variations result from different cooling rates, location in the melt regime, or subsequent reworking. Some (or all) of the more feldspathic melts may be anorthositic surface material remelted with older, more mafic melts.

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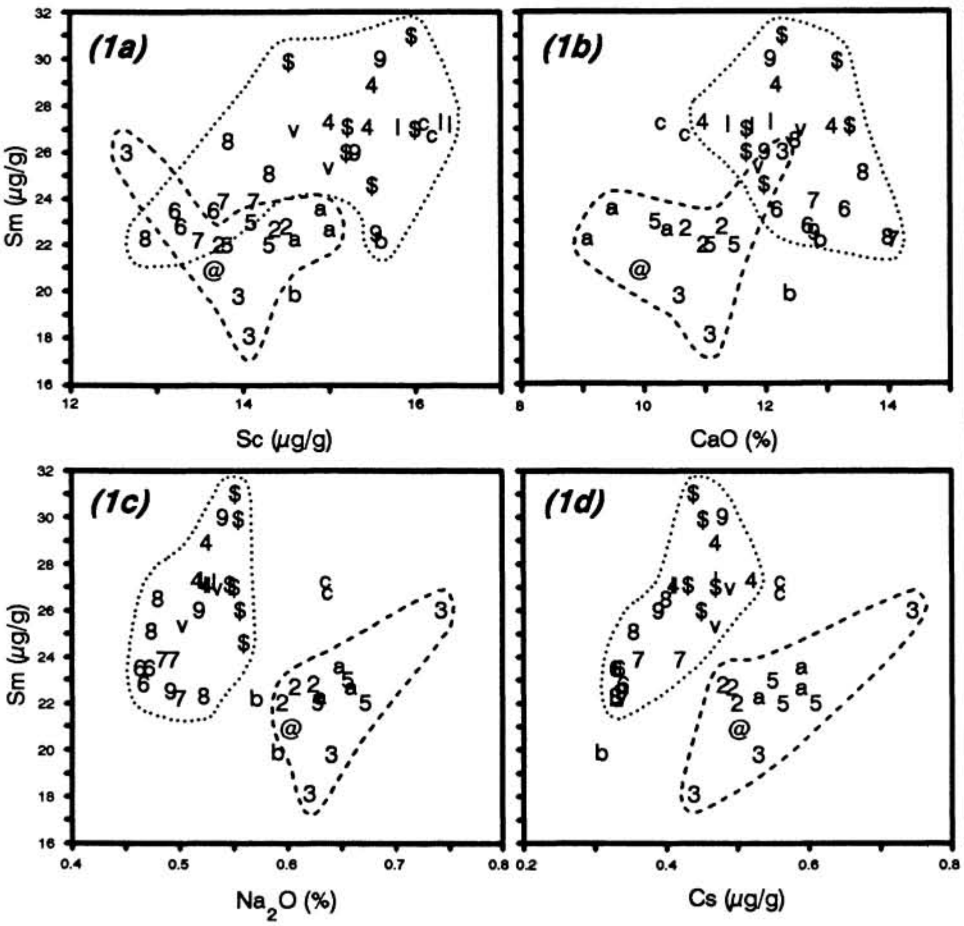

Table 1

Apollo 16 Group 1 Impact Melt

low Na ······	
9	*61247*
I	*62235*
4	*64575*
$	*65015*
v	*65357*
6	*65358*
7	*65778*
8	*65905*
high Na - - - -	
@	*60016 (clasts)*
a	*60315*
3	*63558*
5	*64816*
2	*69945*
others	
b	*60525*
c	*60526*

Fig. 1. Variation of some elements with Sm in samples of Apollo 16 group 1 impact melt breccias.

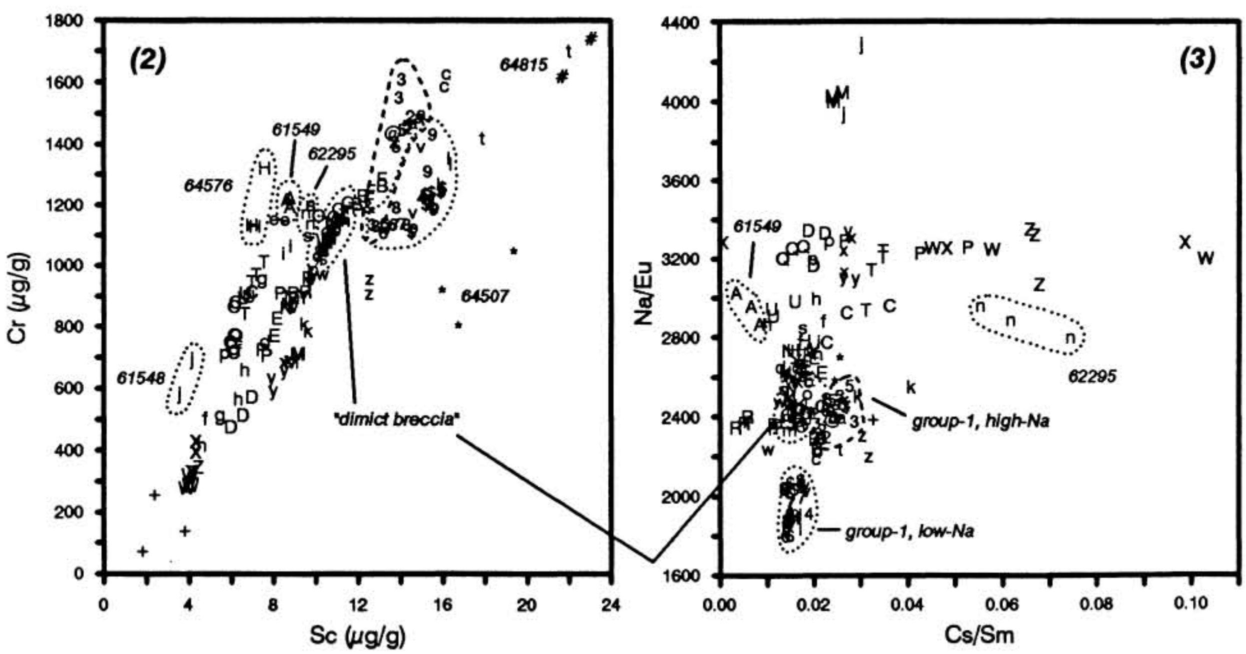

Fig. 2. Variation of Cr and Sc in Apollo 16 impact melt breccias. See [IMR1] for sample number key.

Fig. 3. Variation of Na/Eu ratios and Cs/Sm ratios in Apollo 16 impact melt breccias.