SIDEROPHILE AND VOLATILE ELEMENTS IN APOLLO 17 IMPACT MELT ROCKS: Odette B. James, 959 National Center, US Geological Survey, Reston, VA 22092

Introduction: Most Apollo 17 impact melt rocks fall into two groups. One ("poikilitic") consists of rocks from boulders at Stations 6 and 7 and Boulder 2 at Station 2. These are clast poor and have fine- to medium-grained poikilitic melt-derived groundmasses of similar compositions and roughly constant ratios of siderophile elements. The second group ("aphanitic") consists of rocks from Station 3 and Boulder 1 at Station 2. Most are clast rich and heterogeneous in texture, clast population, and siderophile-element ratios. They have very fine grained melt-derived groundmasses with higher Al_2O_3 and lower TiO_2 contents than those in the poikilitic rocks. The poikilitic rocks are thought to be melt generated in the Serenitatis impact [1-3]. Some authors [4-6] have proposed that the aphanitic rocks represent a different facies of Serenitatis melt, whereas others [3,7] have suggested that some aphanitic rocks are melt formed in a different impact. Some of the evidence for the latter view is based on the assumption that siderophile elements in an impact melt are almost entirely derived from the impacting body, so that variation of siderophile-element ratios indicates genesis in different impacts. To reevaluate the relations among the melt rocks and the hypothesis that siderophile-element ratios are diagnostic of specific impacts, I am reexamining previously published radiochemical neutron activation analysis data for siderophile and volatile elements in these rocks.

Method: Most of the data used thus far in this study are from the laboratory headed by Edward Anders [7-12], so that interlaboratory bias is minimized. In this work, the most useful plots are normalized abundance patterns like those used for rare-earth elements. Two different normalizing compositions are used herein. For comparisons with meteorites, the data are normalized to the composition of C1 chondrites [13]. For comparisons with lunar rocks, the data are normalized to the composition of one type of aphanitic melt rock (average 73215 black aphanite). The relative abundance patterns fall into numerous groups, and only those judged to be the most important are discussed herein.

Geochemical behavior of elements: In the relative abundance patterns (Fig. 1), the elements Ir-Tl are arranged, from left to right, roughly in order of increasing volatility. The elements Ir-Pd ("siderophiles") are primarily siderophile, but Ni can also be chalcophile and lithophile. The elements Sb-Tl ("volatiles") are primarily chalcophile, except that Sb and Ge can also be siderophile, Br is lithophile, and Zn, Cd and Tl can also be lithophile. The elements Rb-U ("lithophiles") are lithophile.

Endogenous lunar rocks: To determine the composition of meteoritic components in the melt rocks, it is necessary to know the composition of endogenous lunar components. Many Apollo 17 endogenous rocks show similar relative abundance patterns (Fig. 1a): the increasingly refractory siderophiles are increasingly depleted relative to chondrites; and the volatiles are less depleted and show patterns with pronounced "humps" and "troughs." KREEP basalt shows a distinctive peak at Sb-Ge.

Aphanitic melt rocks: Black aphanites from 73215 and 73255 show patterns (Fig. 1b) of siderophile and volatile elements that are little fractionated relative to C1 chondrites, whereas most other aphanites show more complex patterns. Most samples from Boulder 1 at Station 2 show one of two patterns (Figs. 1c,d). The patterns differ for the siderophile elements and Ge: Group I (Fig. 1c) has high Ir; and Group II (Fig. 1d) has low Au and high Ge. Both patterns are similar for most volatile elements and are typified by "troughs" at Bi, Te and Tl and "humps" at Zn-Cd and Br.

Poikilitic melt rocks: Typical relative abundance patterns for these rocks are shown in Fig. 1e. The volatiles are like those in Group I and II aphanites, but the siderophiles are like those in 73215-73255 black aphanites.

Granulitic breccias: Granulitic breccias are the most abundant siderophile-element-rich clasts in the Apollo 17 impact melt rocks; they are especially abundant in the aphanitic melt rocks. Many of the granulitic breccias fall into three groups. In Groups A and B (Fig. 1f), the siderophile-element patterns suggest that the samples in each group contain metals of the same bulk composition but that the amount of metal varies considerably; in Group B, relative abundances of Ir and Re are similar, and in Group A, Ir is enriched. Group C (Fig. 1g) consists of samples that have similar patterns for most volatile elements.

Discussion: The endogenous lunar rocks considered herein (Fig. 1a) show elemental abundances that are fractionated relative to chondrites. The most striking features of the volatile-element patterns are relative enrichments in Ag, Br, Zn, and Cd and relative depletions in Te, Bi, and Tl; Ge and Sb enrichment of the KREEP basalt is noteworthy.

The 73215-55 black aphanites are clast-poor, rapidly crystallized variants of aphanitic melt rock. Because the elemental abundances in these rocks are little fractionated relative to chondrites (Fig. 1b), both the siderophiles and volatiles in these rocks may be largely derived from the impacting body. The relative abundances of the elements Ir-Sb are identical with those in EH chondrites (Fig. 1h); thus, the impacting body (probably the Serenitatis projectile) may have been a variant of enstatite chondrite.

The Boulder 1 aphanites are much richer in unmelted clasts than the 73215-55 black aphanites, suggesting that contamination by clasts is the reason for the variable relative abundance patterns in these rocks (Fig. 1c,d). The patterns for the Group I aphanites from Boulder 1 (Fig. 1c) suggest that these samples contain large amounts of high-Ir (Group A) granulitic breccia and small amounts of KREEP basalt. A quantitative test of this hypothesis is shown in Fig. 1i. The components used are: 3% 72275 KREEP basalt; 76% metal-poor granulitic breccia, in which volatile- and lithophile-element abundances are the average shown in Fig. 1g and siderophile-element abundances are 30% of those in 72235,37 (see Fig. 1f); and 21% metal-rich black aphanite (average of 73215-55 black aphanite, with siderophile-element abundances doubled). Using these components, the average siderophile- and volatile-element composition of the Group I aphanites is closely approximated, but a good match was not possible without varying the metal content of the melt and granulitic-breccia lithologies. The lithophile elements could not be matched without an additional component (probably lunar granite, a common clast type in these rocks). The Group II aphanites from Boulder 1 (Fig. 1d) appear to show contamination by the KREEP basalt that is a common clast type in this boulder, in that they have very low Bi and Tl contents and relatively high Ge, Br, Zn and Cd contents. Calculations like those done for the Group I aphanites show, however, that adding KREEP basalt alone will not duplicate the Group II siderophile-element patterns; a good match also requires changing the granulitic-breccia component to one having a composition like that of 77135,50 (see Fig. 1g), but only 80% of the siderophiles.

The relative abundance patterns for poikilitic melt rocks indicate that there is no more variability between these rocks and the aphanitic melt rocks than there is within the group of aphanites as a whole. In fact, aphanitic melt rock 72215,40 (Fig. 1c) is virtually identical in all elements, except Ir, to poikilitic rock 76015 (Fig. 1e). The flat siderophile-element patterns in the

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poikilitic rocks suggest that the metals in these rocks have the same composition as those in the black aphanites.

Conclusions: This study suggests that siderophile-element compositions of analyzed melt-rock samples do not always relate to the composition of the impacting body in a simple way, and the assumption that data such as Ir-Au ratios alone are diagnostic of the impacting body is probably not correct. The variations in siderophile-element ratios in the aphanitic melt rocks from Boulder 1 at Station 2 can probably be explained by variations in content of clasts in the analyzed samples. The similarity of volatile-element patterns in endogenous rocks, Type C granulitic breccias and Types I and II aphanitic melt rocks suggest that the volatiles in all these rocks are dominated by a similar endogenous component. Noteworthy is the fact that rocks showing similar volatile-element patterns can show different siderophile-element patterns, and vice versa, suggesting decoupling of the siderophile and volatile components. The data for all the aphanitic and poikilitic melt rocks show no persuasive evidence for more than one impact, and all could have formed in a single impact.

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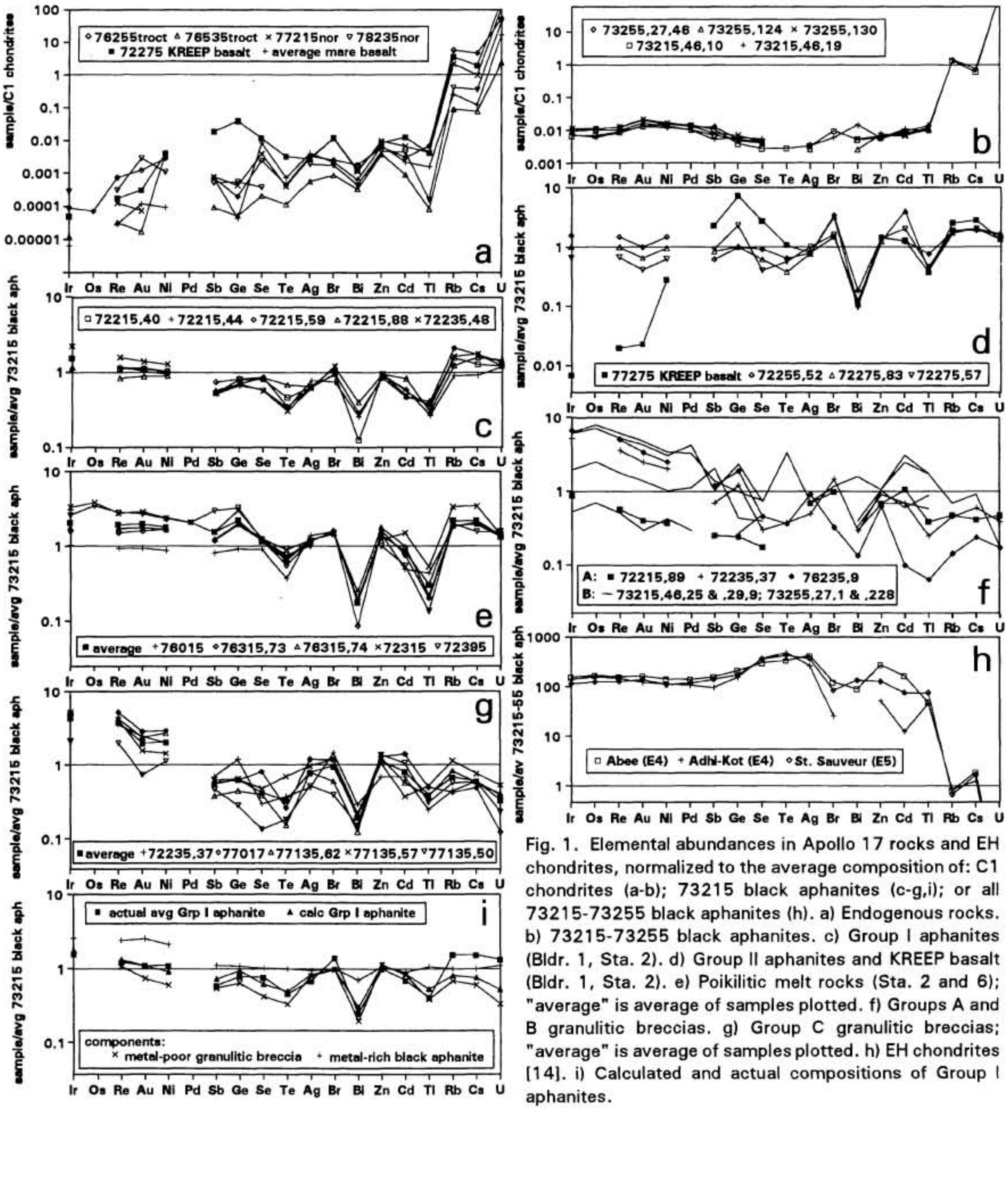

Fig. 1. Elemental abundances in Apollo 17 rocks and EH chondrites, normalized to the average composition of: C1 chondrites (a-b); 73215 black aphanites (c-g,i); or all 73215-73255 black aphanites (h). a) Endogenous rocks. b) 73215-73255 black aphanites. c) Group I aphanites (Bldr. 1, Sta. 2). d) Group II aphanites and KREEP basalt (Bldr. 1, Sta. 2). e) Poikilitic melt rocks (Sta. 2 and 6); "average" is average of samples plotted. f) Groups A and B granulitic breccias. g) Group C granulitic breccias; "average" is average of samples plotted. h) EH chondrites [14]. i) Calculated and actual compositions of Group I aphanites.