THE RECOGNITION OF MONOMICT & POLYMICT CLASTS FROM APOLLO 17 BRECCIAS
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In our never-ending quest for knowledge regarding lunar genesis and evolution, it is essential that the maximum amount of information be extracted from the existing sample collection. Inherent in this endeavor are breccia "pull-aparts" which allow the examination of clasts or "rocklets" of hitherto unsampled lithologies (e.g., lunar granite, spinel troctolites, etc.[1-2]). Furthermore, breccia pull-aparts have allowed a significant increase in the data base for Apollo 14 high-alumina and VHk basalts (e.g., [3-5]) and without these types of studies, the recognition of mare volcanism at > 4 Ga [6-7] would not have been made. Therefore, the study of breccias and their contained clasts has greatly expanded our knowledge of lunar processes, composition, and evolution.

We have re-examined three Apollo 17 breccias (73215, 73216, 77035), from which 13 clasts were extracted. Preliminary analyses, including mineral compositions, were reported at LPSC XXI and XXII [8-10]. Problems were encountered, not least of which was the welded nature of the breccias (especially 77035), making pure clast extraction difficult. Previously, we identified 1 spinel troctolite (73215,579), 1 troctolite (77035,206), 4 anorthosites (73216,66; 73216,70; 77035,229; 77035,230), 3 impact melts (73216,67; 73216,68; 77035,227), 2 dunites (73215,580; 77035,226), 2 norites (73216,69; 77035,228). It was noted that several INAA analyses did not correspond to material observed in the thin sections, in that most of the thin section was comprised of breccia matrix. In order to overcome this, thin sections have been made of the samples used for INAA. It is these results which are presented here.

PETROGRAPHY - Thin sections were made from all but two of the INAA samples (77035,206 - a "troctolite": 77035,227 - an impact melt). The original "thick" sections of these samples demonstrated the presence of breccia matrix in the troctolite and relict plagioclase (up to 0.45 mm) and pigeonite (up to 0.14 mm) clasts in the impact melt. The thin sections of these two samples clearly indicate a polymict nature for both. Spinel troctolite 73215,579 (PM = 7001) contains spinel, but it is found in light and dark breccia matrix and is polymict. Anorthosite 73216,66 (PM = 7002) is comprised of many small chips up to 1 mm long of predominantly plagioclase, but cpx grains also. Smaller lower-Ca pyroxenes (0.2 mm) are interstitial to the plagioclase grains. Intercumulus igneous textures are present, but several chips appear to be heavily crystallized (i.e., many triple junctions). Also present are six chips of breccia matrix, which clearly demonstrate a polymict nature. Anorthosite 73216,70 (PM = 7005) is comprised of many large (1 mm) plagioclase laths with intercumulus ortho- and clinopyroxenes (up to 0.3 mm). Several appear to contain extremely fine exsolution lamellae. No adhering breccia matrix was noted and the sample appears monomict. Anorthosite 77035,229 (PM = 7003) is made up of plagioclase (up to 0.3 mm) grains forming triple junctions, but still exhibiting twin lamellae. Olivine is the predominant mafic mineral, but does not form triple junctions. There is very little granulation, and no adhering breccia matrix or any other lithology was noted. This sample appears monomict. Anorthosite 77035,230 (PM = 7004) is comprised of strained plagioclase (up to 0.5 mm), maskelynite, and glass. Minor mafic minerals (0.3 mm) of olivine and clinopyroxene (possibly containing relict exsolution lamellae) are also present. The shattered nature, coupled with the abundant glass, suggests this sample is polymict, and may be an impact melt. Impact melts 73216,67 (PM = 7002) and 73216,68 (PM = 7003) are both plagioclase-rich, containing blocky plagioclase clasts (0,002) and a variolitic texture (7,003). There is a far greater range in grain size in 7,002 (< 0.005 mm to 0.2 mm) than in 7,003 (< 0.05 to 0.1 mm). In fact, 7,002 has a similar texture to the "norite" 73216,69 (7,004), although this latter sample does also contain recrystallized plagioclase grains. All are undoubtedly polymict. "Norite" 77035,228 (PM = 7002) has the texture of glassy breccia matrix or impact melt. It is comprised mainly of black glass, containing small (up to 0.1 mm) pyroxene and olivine grains, as well as 0.2 mm masses of recrystallized plagioclase. This sample appears to be polymict and may be an impact melt. Dunite 73215,580 (PM = 7002) is comprised of many small (max. = 0.2 mm) grains, principally olivine, but also plagioclase, FeNi metal, and possibly chromite. It is impossible to say whether this sample is texturally monomict or polymict. Dunite 77035,226 (PM = 7001) is made up of 6 olivine grains, 4 of which exhibit some strain features (i.e., strained extinction). No other minerals of lithologies were noted and it is likely that this sample is monomict.

WHOLE-ROCK CHEMISTRY - has been determined for all 13 of the clasts. On the basis of new petrographic data, we have classified all glassy samples as impact melts (Fig. 1). These are generally all LREE-enriched with a negative Eu anomaly (except for 77035,228), which parallels the Apollo 17 KREEP and Apollo 16 LKFM REE profiles, but below the urKREEP composition of [11] and QMD composition of [12]. The remaining polymict samples exhibit LREE-enriched profiles and either positive or negative Eu anomalies of varying magnitude (Fig. 2). Of these, only 77035,207 and 73216,67 contain detectable Ir (37 and 5 ppb, respectively), but all contain detectable Au (4-11 ppb). However, 3 of these (73215,579; 73216,66; 77035,206) are relatively feldspathic (28.1 wt%, 28.2, and 23.9 wt% Al2O3, respectively) and should contain strong positive Eu anomalies. We have identified three texturally monomict samples - two anorthosites and a dunite (Fig. 3). These have low
POLYMICT SAMPLES

REEs abundances and non-KREEPy REE profiles - dunite 77035,226 is LREE-depleted.

DISCUSSION - (a) Polymict Samples: The general similarity of the impact melt REE profiles with LKFM & Apollo 17 KREEP indicates the incorporation of such a component(s) into all samples, except possibly 77035,228 which still maintains a slight positive Eu anomaly. The variable Eu anomalies of the remaining polymict samples (Fig. 2) is surprising - the most feldspathic sample (73216,66 - 28.2 wt% Al2O3) contains a negative Eu anomaly. This demonstrates the incorporation of a REE-rich component containing a strongly negative Eu anomaly (e.g., Apollo 17 KREEP). Mixing of 10-20% of Apollo 17 KREEP with 73215,579 will overprint a positive Eu anomaly with a negative one. Thin section 73216,7001.66 is comprised of anorthositic fragments, but also contains 6 chips of breccia matrix. Sample 73215,580 is dominated by olivine (Al2O3 = 12.12 wt%) - it is difficult to judge the amount of contaminant as the negative Eu anomaly is inherent in this sample. Detectable Ir & Au suggests the presence of a meteoritic component in these polymict samples.

(b) Monomict Samples: 77035,229 is suspect due to its recrystallized texture. However, it does exhibit a non-KREEPy REE profile & a relatively large positive Eu anomaly (Fig. 3), and it does not contain adhering breccia matrix or other lunar lithologies. The monomict samples all contain detectable Au, and 73216,70 contains 15 ppb Ir & 11 ppb Au. This is surprising, considering the igneous texture and the lack of any adhering breccia matrix. Were these elements added via a vapor phase as a meteorite disintegrated on impact? The texture of 73216,70 demonstrates that this sample is monomict, as does textural and whole-rock chemical evidence from the other two proposed monomict samples, even though siderophile elements are detected. The whole-rock MG# (~88) for dunite 77035,226 is supported by the Fo content of the olivines (max Fo = 88). Core-to-rim variation in the olivine composition (Fo 88-72) suggests that this "dunite" was derived from a near-surface intrusion which cooled relatively quickly. Using an olivine/liquid Fe/Mg Kd of 0.3, the parental magma would have had a MG# of ~70 at the beginning of crystallization. However, the calculation of an equilibrium liquid REE profile for this dunite (assuming 100% olivine & using the Kds of [13]) yields a highly LREE-enriched profile, with La abundances at 40,000 x chondritic levels (Fig. 4). Clearly, either the Kds are not applicable, or we have not accounted for a component in this sample. Equilibrium liquid REE profiles also have been calculated for the 2 monomict anorthosites - 73216,70; 77035,229. Modes were calculated by iterating the proportions of the observed mineral compositions until the major-element composition of the whole-rock analysis was matched. The Kds of McKay et al. ([14] - pigeonite), McKay et al. ([15] - clinopyroxene), and Pinney and Morrison ([16] - plagioclase) were used. The equilibrium liquid REE profiles thus calculated are similar to the urKREEP composition of Neal and Taylor [11] and the QMD of Jolliff [12].

CONCLUSIONS - Polymict highlands clasts & impact melts from Apollo 17 breccias demonstrate that a LKFM component is present in the regolith at this site and/or Apollo 17 KREEP is more widespread than originally thought. The monomict samples present a number of problems. Although texturally monomict, siderophiles are detected, especially in 73216,70. Equilibrium liquid REE profiles suggest crystallization from KREEPy melts, yet the mineralogy is somewhat primitive - e.g., the dunite 77035,226 would have crystallized from a melt of MG# 70. The elevated LREE abundances of the equilibrium liquids may be generated by a primitive magma assimilating urKREEP, or by metasomatism of the samples after crystallization. Distinguishing between these processes cannot be undertaken on the basis of this small data base.