$^{187}Os/^{188}Os$ and Highly Siderophile Element Characteristics of Apollo 16 and 17 Impact-melt Breccias. M. G. Galenas, J. G. Liu and R. J. Walker. Department of Geology, University of Maryland, College Park, MD 20742 (gobyliu@umd.edu).

Introduction: Although only small proportions of impactor materials are normally incorporated into impact-generated melts, likely impactor materials, such as chondrites and iron meteorites, are typically enriched in highly siderophile elements [1, 2] (HSE: here including Re, Os, Ir, Ru, Pt, and Pd) compared to planetary crusts, such as the lunar crust [3]. The relative abundances of the HSE in impact melt breccias that are highly leveraged towards the impactor composition, can therefore, be used to fingerprint the nature of impactors responsible for basin-forming events on the Moon [e.g., 4, 5]. Comparisons to various meteoritic materials are commonly made by determining the relative abundances of HSE using $^{187}Os/^{188}Os$ (a proxy for long-term Re/Os) and slopes of linear trends generated from plots of Ir versus other HSE. The goal of this study is to present results for Apollo 16 and 17 impact melt breccias and use the data to constrain the chemical nature of impactors that contributed to basin forming events near these landing sites.

Samples: Lunar impact melt breccias from Apollo17 (73235, 72435, and 76035), and 16 (67095) landing sites are the target of this study. Sample 73235 is an aphanitic melt breccia collected from the regolith at Station 3 at the base of South Massif of the Apollo 17 landing site. In contrast, sample 72435 is a poikilitic rock that was chipped from a large melt-rock boulder at Station 2. Sample 76035 is also a poikilitic breccia that was collected near a boulder at Station 6. Sample 67095 is a basaltic impact melt rock that was collected from the rim of the North Ray Crater at the Apollo 16 landing site. This sample contains substantial metal globules, and metal and troilite crystals, which are rich in HSE. Sizable (50-250µm) metal and troilite grains were separated for study using a laser ablation ICP-MS technique and will be digested individually for analyses of Os isotopes and HSE abundances.

Analytical Methods: Analytical procedures followed those reported in Puchtel et al. [5]. Each breccia specimen (1-2 g) was gently broken up with an alumina mortar and pestle and separated into approximately ten ~30-300 mg sub-samples. Any granulitic (for Apollo 17 rocks) or exterior material was removed using a dry-cut saw blade. Each sub-sample was then spiked and digested using 3ml of concentrated HNO_3 and 2ml of concentrated HCl in sealed Pyrex Carius tubes at 270^{o}C for at least 72 hours. Osmium was separated from the rest of the HSE by solvent extraction and analyzed using by negative thermal ionization mass spectrometry. The rest of the HSE were separated and purified by anion exchange chromatography and analyzed using a *Nu-Plasma* MC-ICP-MS. Average blanks (pg) were: Re 1.9, Os, 0.9, Ir 0.5, Ru 7.2, Pt 7.0, and Pd 14. The blanks constituted generally less than 0.5 % for Os and Ir, 2.0 % for Ru, Pt and Pd, but as much as 10 % for Re.

Results: The average $^{187}Os/^{188}Os$ of nine sub-samples of aphanite 73235 is 0.1309±10 ($2\sigma_{mean}$), which is slightly higher than that of 11 sub-samples of aphanites 73215 and 73255 examined previously (0.1295±4 [5]). In contrast, this ratio, is somewhat lower than averages for various poikilitic samples examined here and previously: 0.1322±5 for 72435 (n=9), 0.1329±3 for 76035 (n=4), and 0.1324±7 for 72395 and 76215 (n=22) [5]). In contrast to Apollo 17 impact melt rocks, 10 sub-samples of Apollo 16 sample 67095 yield a substantially higher $^{187}Os/^{188}Os$ of 0.1349±7, which is comparable to that of a poikilitic Apollo 16 breccia 60315 reported by [6].

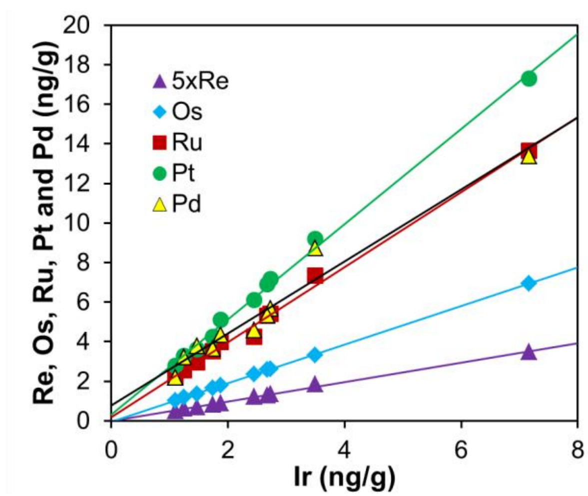

Fig. 1. Plot of Ir vs. Re, Os, Ru, Pt, and Pd for sub-samples of Apollo 16 basaltic melt breccia 67095.

The sub-samples of Apollo 17 breccias show a relatively large range of Ir contents (e.g., 1.0 to 3.9 ng/g for 73235, 1.5 to 12.3 ng/g for 72435, and 5.6 to 13.9 ng/g for 76035). Subsamples of Apollo 16 impact melt rock 67095 show a similar range with Ir contents ranging from 1.1 to 7.2 ng/g. Iridium is generally well correlated with other HSE in sub-samples (e.g., 67095; **Fig. 1**). Regressions of HSE vs. Ir were conducted using ISOPLOT [7]. Ru-Ir and Pd-Ir regressions show some scatter not visibly associated with sample petrology. The y-intercepts for the Apollo 16 and 17 breccias are statistically indistinguishable from zero consistent with target material being relatively free of HSE. Thus, the slopes of regression lines between Ir and HSE most likely represent the relative abundances present in the dominant HSE-rich impactors [e.g., 4, 5]. The two Apollo 17 poikilitic samples show similar raised Ru/Ir and Pd/Ir in comparison with major chondrite groups as previously measured poikilitic rocks [5, 6] (**Fig. 2**), while the aphanitic sample 73235 has slightly lower but still suprachondritic Ru/Ir ratios. Pd/Ir ratios overlap with the majority of chondrites, due to the relatively large uncertainties. The Apollo 16 basaltic melt breccia 67095 has suprachondritic Ru/Ir and Pd/Ir ratios that are comparable to the three Apollo 17 samples, as well as those of the Apollo 16 poikilitic breccia 60315 reported by [6].

Discussion: Our new HSE results, combined with results from [5], show that the Apollo 17 poikilitic breccias from three geographically separate stations appear to have a single dominant impactor signature. Of greatest note is that the new aphanitic sample 73235 differs from the previous results on the Apollo 17 aphanitic breccias 73215 and 73255 [5]. Those samples exhibited relative HSE abundances and $^{187}Os/^{188}Os$ within the range of ordinary chondrites. The new aphanite has only slightly lower Ru/Ir and $^{187}Os/^{188}Os$ than the poikilitic Apollo 17 samples (**Fig. 2**). By and large, the results for sample 72325 suggest that some aphanitic impact melt breccias have a similar signature to that of the poikilitc rocks. This, in turn, suggests that these two types of Apollo 17 breccia samples may have been generated by the same impact, most likely the Serenitatis impactor.

Compared to the poikilitic Apollo 17 breccias, the higher $^{187}Os/^{188}Os$ ratios of the Apollo 16 basaltic melt breccias 67095 and poikilitic melt breccia 60315 [6], appear to indicate a different type of impactor with a higher Re/Os, for at least some Apollo 16 melt breccias. Alternately, the different isotopic composition may reflect some unidentified fractionation process that affected the relative abundances of the HSE during formation of the melt breccias.

Assuming that the Earth received similar meteoritic material as the Moon during their histories of late accretion, the high Ru/Ir and Pd/Ir ratios, as well as $^{187}Os/^{188}Os$ (the value in Fig. 2 may be underestimated [8]), of the primitive (upper) mantle can potentially be accounted for by calling on impactors with HSE characteristics that are similar to, but not represented in the chondritic suite sampled by Earth today.

References: [1] Horan M.F. et al. (2003) *Chem. Geol.* 196, 5-20. [2] Fischer-Godde M. et al. (2010) *GCA* 74, 356-379. [3] Day J.M.D. et al. (2010) *EPSL* 289, 595-605. [4] Norman M.D. et al. (2002) *EPSL* 202, 217-228. [5] Puchtel I.S. et al. (2008) *GCA* 72, 3022-3042. [6] Fischer-Godde M. et al. (2010) *LPSC XXXXI.* 2262. [7] Ludwig K.R. (2003) *Berkeley Geochron*. Center Spec. Pub No. 4. [8] Walker R.J. *Chemie der Erde* 69, 101-125. [9] Meisel T. et al. (2001) *GCA* 65, 1311-1323. [10] Becker H. et al. (2006) *GCA* 70, 4528-4550.

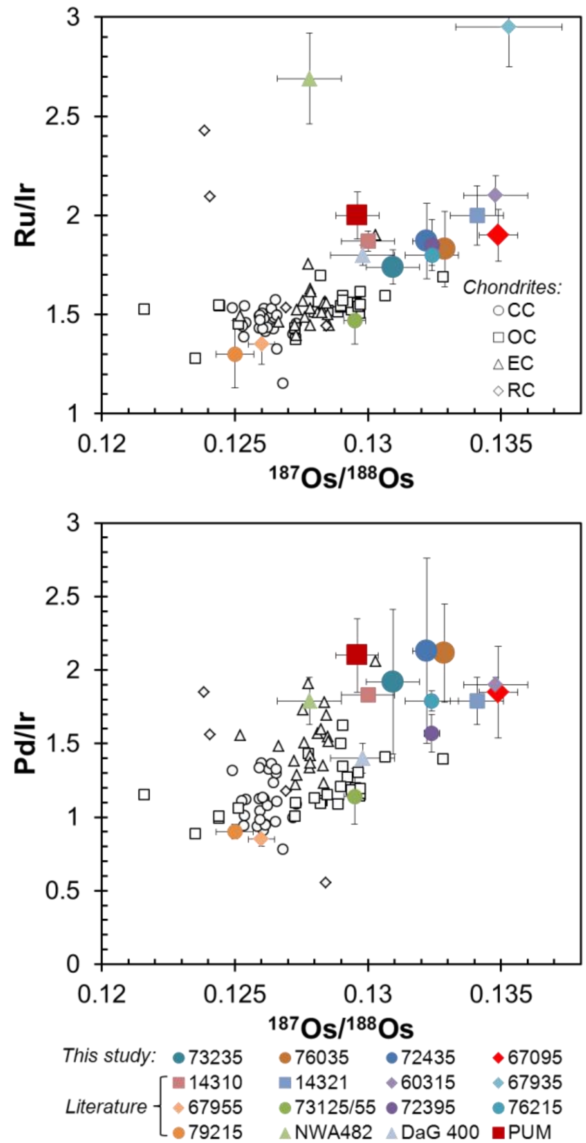

Fig. 2. $^{187}Os/^{188}Os$ vs. Ru/Ir (upper panel) and Pd/Ir (lower panel) for lunar impact melt breccias from this study (Apollo 16 and 17) and literature [5,6] in comparison with chondrites [1, 2] and the estimate of the primitive upper mantle (PUM) [9, 10].