IMPACTOR POPULATIONS STRIKING THE MOON DETERMINED FROM MELT COAT AND REGOLITH METEORITE COMPOSITIONS. E. Carrie McIntosh[1], James M.D. Day[1] and Yang Liu[2], [1]Scripps Institution of Oceanography, University of California San Diego, La Jolla CA 92093-0244, USA; e-mail: ecmcinto@ucsd.edu, [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA.

Introduction: Impacts can generate melt rocks and breccias that can potentially reveal the composition of the impactors themselves. One method that has been utilized to determine the composition of the impactors striking the Moon has been to use $^{187}Os/^{188}Os$ ratios and highly siderophile element (HSE: Re, Os, Ir, Ru, Pt, Rh, Pd, Au) abundances in impact melt breccias [1-7]. An outstanding concern is whether fractionation processes in melt sheets and multiple impact events affect HSE compositions in impact melt breccias and other impact melt rocks [8]. We have examined this question utilizing impact melt coats (IMC) (*Fig. 1*) and lunar anorthositic regolith breccia meteorites. IMC are small-scale features found as glassy exteriors on some Apollo rocks when melts were rapidly quenched [9]. As quenched materials, they can provide insight into the extent of HSE fractionation that might occur during impact processes. Lunar anorthositic regolith breccia meteorites allow study of parts of the Moon that were not sampled during the Apollo missions [10-12] and represent materials formed after multiple impact events.

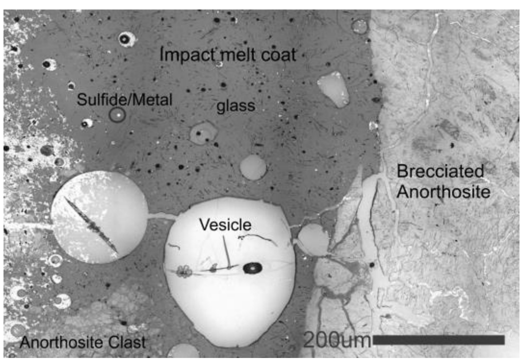

Figure 1: *Reflected light image of impact melt coating in abrupt contact with interior cataclastic anorthosite in 60015,116. Major components are labelled.*

Methods: Polished sections of 60015(,116), 60015(,805), 65325(,18), and 65035(,176) were analyzed for HSE abundances using a *New Wave* UP-213nm laser ablation system coupled to a *ThermoScientific* iCAPq inductively coupled plasma mass spectrometer (ICP-MS). Chips of IMC 65035,192, 65325,24, and 60015,791, and a mixture of powders and fragments of regolith breccia meteorites Miller Range (MIL) 090034,22, MIL 090036,14, MIL 090070,16, MIL 090075,15, and MacAlpine Hills (MAC) 88105,180 were analyzed for Re-Os and highly siderophile element abundances using described methods [13]. We measured bulk rock powders and chips of the anorthositic regolith breccia meteorites in order to examine the variation between homogenous powders and fragments. IMC were measured for Rb-Sr isotope systematics using methods in [14].

Results: *IMC Rubidium-strontium isotope systematics:* Impact melt coats have higher $^{87}Sr/^{86}Sr$ ratios (0.701013 to 0.704414) than those of FAN samples (0.699230 to 0.699537) (*Fig. 2*).

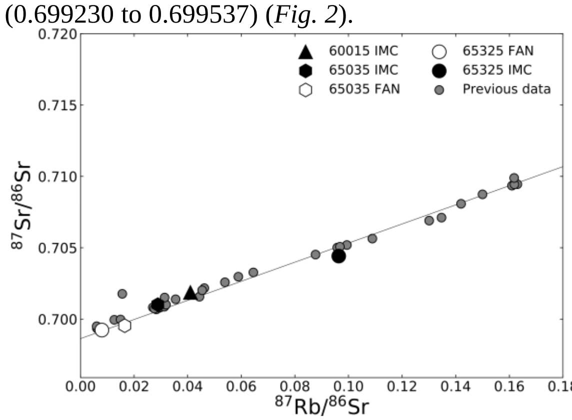

Figure 2: *Plot of $^{87}Rb/^{86}Sr$ versus $^{87}Sr/^{86}Sr$ for impact melt coats with a 4.03 Ga isochron line with a y-intercept of 0.699 and previously analyzed impact melt rocks [15,16].*

Metal and Schreibersite HSE compositions: FeNi metals and schreibersite in 60015 have relatively flat HSE patterns at ~1-10 × CI chondrite abundances, with the exception of a single metal grain with low Pd (~4 × CI), but high Pt, Ru, Ir, Os, and Re (~100 × CI) (*Fig. 3*). One analysis of 65325 metal has Re exceeding 1000 × CI chondrite whereas some metals and schreibersite in 65035 show fractionations of the HSE, in particular elevated Pd and Ru in some fractions.

HSE and $^{187}Os/^{188}Os$ Systematics: The majority of IMC and anorthositic regolith breccias fall within the lower range defined by impact melt breccias in Ru/Ir and $^{187}Os/^{188}Os$ compositional space (*Fig. 4*). However, some analyses of IMC show distinct differences from previously measured impact melt breccias [1,2]. For example, one fragment of MIL 090075 displays a high Ru/Ir ratio of ~4.7 with a lower $^{187}Os/^{188}Os$ ratio of 0.1230. Another fragment has a lower Ru/Ir ratio of ~0.53 and a $^{187}Os/^{188}Os$ ratio of 0.1164. Similarly, MIL 090070 displays consistently low Ru/Ir ratios and can contain low $^{187}Os/^{188}Os$ (0.1177). The variations in the anorthositic regolith breccia meteorites reflect nugget heterogeneity in the samples due to uneven distribution and fractionation of the HSE. Likewise, IMC can exhibit low Ru/Ir (0.67) and $^{187}Os/^{188}Os$ ratios (0.1189) reflecting similar heterogeneities.

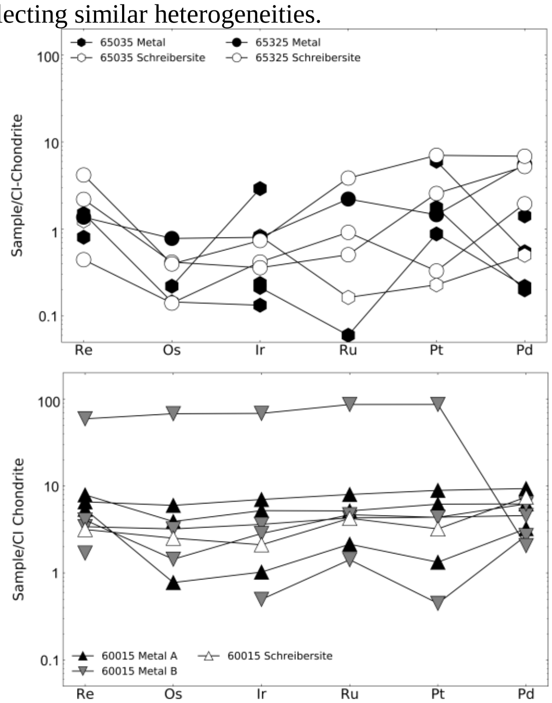

Figure 3: *Metal and schreibersite compositions within Apollo 16 IMC measured in situ using LA-ICP-MS. CI chondrite normalization from [17].*

Discussion: IMC have compositions close to ordinary and enstatite chondrite compositions, while anorthositic regolith breccia meteorites have compositions similar to that of a carbonaceous chondrite impactor population (*Figure 4*). There is significant heterogeneity within IMC due to the heterogeneous distribution of metal-schreibersite-troilite segregations. These segregations lead to significant HSE fractionation that occur at small scales even within IMC, as shown by LA-ICP-MS data. Our analyzed IMC and anorthositic regolith breccia meteorites show a broader range of highly siderophile elements than previous analyzed impact melt breccias [2,3] and indicate that significant HSE fractionation can occur through both sulfide-metal fractionation and multiple impact events in melt-rocks.

We find that analyses of sample powders are more homogenous than for fragments in anorthositic regolith breccia meteorites. By measuring fragments more variably fractionated HSE compositions can be accessed. These points raise concerns as to whether impact melt breccias are affected by the same fractionation issues, and thus if their compositions faithfully record the compositions of impactors, or not.

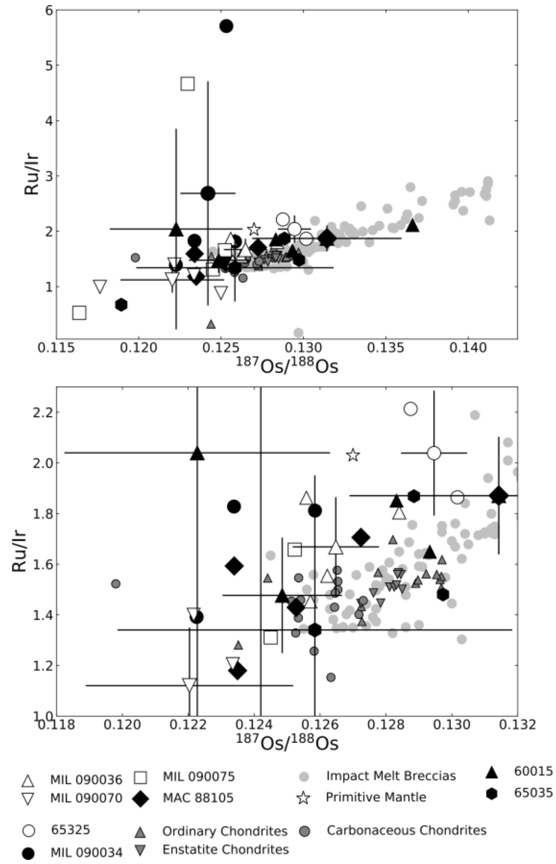

Figure 4: *Plot of Ru/Ir versus $^{187}Os/^{188}Os$ for IMC, lunar regolith breccia meteorites, impact melt breccias, and chondrites. Averages with 2σ error are shown for data collected in this study. Impact melt breccias data in gray circles are from [1,2]. Chondrite data are from [17].*

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