FURTHER STUDY OF $^{187}Os/^{188}Os$ AND HIGHLY SIDEROPHILE ELEMENT SYSTEMATICS OF LUNAR IMPACT MELT ROCKS. I.S. Puchtel[1], R.J. Walker[1], D.A. Kring[2], and O.B. James[3], [1]Department of Geology, University of Maryland, College Park, MD 20742 (ipuchtel@geol.umd.edu), [2]Lunar & Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77059, [3]U.S. Geological Survey, 926A National Center, Reston, VA 20192.

Introduction: Lunar impact melt rocks may provide the only direct chemical link to the material of the late accretionary period [1]. The $^{187}Os/^{188}Os$ ratios, coupled with ratios of other highly siderophile elements (HSE: Ru, Rh, Pd, Re, Os, Ir, Pt, Au) in impact melt breccias can be diagnostic for identifying the nature of the impactors. We have continued study of the chemical nature of late accreted materials to the Earth-Moon system by examining the HSE contained in lunar impact-melt rocks. Previously, we reported results for Apollo 14 and 17 impact melt rocks [2,3]. This year we report new results for additional Apollo 17 poikilitic (76215) and aphanitic (76215, 76255) impact melt rocks, with an emphasis on deciphering why fractions of previous aphanitic rocks provided complex results. We also report initial results for the lunar meteorite NWA482. The HSE in the Apollo 17 rocks were likely added at ~3.9 Ga from the impactor that formed the Serenitatis basin. The origin of NWA482 has been debated. It has a possible melt age of ~3.75 Ga. It has been speculated that it originated from the far side of the Moon [4] due to the lack of KREEP component.

Samples: Both poikilitic and aphanitic melt rocks were collected from the Apollo 17 site. Poikilitic melt rocks were found primarily at Stations 6 & 7 (North Massif) and HSE data for these rocks have been previously reported [5]. The impact melt breccia 76215 is unique in containing metal globules, and metal and troilite crystals, rich in HSE. These were also studied using a laser ablation ICP-MS technique [6] before we digested the subsamples for the bulk analysis. Aphanitic melt rocks were found primarily at Stations 2 & 3 (South Massif). They vary widely in clast population, although on average they are richer in clasts than the poikilitic melt rocks. NWA482 is a crystalline impact melt breccia with highlands affinities [4]. The recrystallized matrix and the clast population are both highly anorthositic. The latter include plagioclase crystals and lithic anorthosites and troctolites.

Analytical Methods: Analytical details were similar to those reported previously. Un-ground 50-300 mg subsamples of each rock were digested in Pyrex Carius tubes at 270°C for 96h. Substantially improved blanks averaged (pg): Ru 0.7, Pd 19, Re 0.9, Os 0.3, Ir 0.3, and Pt 52. The accuracy of all new concentration data is ±0.5% or better. The same spikes and analytical techniques were used for generating the HSE database for chondrites [7,8] to which the lunar data are compared. The accuracy of the analytical procedures were assessed by comparing the results for the peridotite standards UB-N and GP-13 from this study with results obtained in other laboratories, which show a good agreement.

Results: The $^{187}Os/^{188}Os$ ratios of the new suite of seven aphanitic subsamples (73215, 73255) average 0.1293±5, and four NWA482 subsamples average 0.1283±10. Nine poikilitic subsamples 76215 average 0.1321±10 ($2\sigma_{mean}$). There are, thus, resolvable differences in average $^{187}Os/^{188}Os$ ratios between the aphanitic rocks and NWA482, on the one hand, and the 76215 poikilitic rock, on the other. The NWA482 subsamples show a limited range of Ir concentrations (5.0 to 6.7 ppb). The range of Ir concentrations in the new set of aphanitic melt rock subsamples (3.5 to 6.1 ppb) is similar to that in the set analyzed previously. The 76215 subsamples show the largest range of HSE abundances (Ir: 1.6 to 66 ppb, Fig. 1) due to the presence of metal particles.

Discussion: Iridium is well correlated with all HSE in subsamples of 76215 (Fig. 1) and NWA482. In contrast with our previous analyses of Apollo 17 aphanitic melt rock subsamples, our new set also shows a good correlation between Ir and all other HSE measured. This could be due to improvements in technique for HSE measurement, different sample preparation strategy (chips were not ground before digestion), or combination of both. Such good correlations for all lunar melt rocks indicate that the studied subsamples may represent simple two-component mixtures of indigenous and impactor endmembers.

In our previous reports we attempted to establish the nature of the impactor for each set of subsamples by subtracting concentrations of the indigenous component (extrapolated from linear correlations of Ir vs. HSE) from the measured concentrations. In the case of Os isotopes, indigenous Re does not appear to be a factor for any of the samples examined, based on a lack of correlation between isotopic compositions and concentration, so isotopic ratios are averaged to obtain the isotopic composition of the impactor. Previous work, however, has suggested that indigenous Ru and Pd may be significant for some samples. It has been shown that the slopes of meteorite-crustal mixing trends determined by linear regression of the data (e.g., Ir vs. Ru or Pd), are insensitive to the presence of a moderate amount of an indigenous component and can be used to define the ratio present in the impactor [9]. Modeling with synthetic datasets shows that this is true for the ranges of concentrations of HSE present in the lunar melt rocks examined here. For example, slopes are little affected with as much as 3 ppb Ru or Pd of an indigenous component. Thus, all element ratios presented here are based on linear regressions of the data using the program ISOPLOT [10]. In Fig. 2, average $^{187}Os/^{188}Os$ ratios in all five lunar melt-rock suites are plotted against slope-derived Ru/Ir and Pd/Ir ratios. The errors plotted are 2σ uncertainties of the regressions. Also plotted are the range of isotopic compositions and elemental ratios for the three chondrite groups [7,8] and estimates for Earth's primitive upper mantle (PUM) [11,12]. The aphanitic rocks and NWA482 (Fig. 2) are most similar to enstatite and ordinary chondrites. The other three lunar samples plot above the high end of the ranges defined by chondrites.

Three possible interpretations are considered. First, although the slope-based estimates are presumably not significantly affected by indigenous components, it is possible that we are still underestimating the effects of the lunar target rocks. Second, it is also possible that some unidentified fractionation process affected Ru, Pd, and Re/Os during creation of the melt rocks. Finally, the divergence in the $^{187}Os/^{188}Os$, Ru/Ir and Pd/Ir ratios of some lunar impact melt rocks from known chondrite groups may indicate that the impactors were not chemically identical to any known chondrite group. Recent attempts to better constrain the composition of the Earth's PUM suggest that it too may have "suprachondritic" Ru/Ir and Pd/Ir, similar to 76215 and 14231. The $^{187}Os/^{188}Os$ of the PUM was reported as a minimum value [11], so the HSE characteristics of the PUM and some lunar impact melt rocks may ultimately be shown to be a good match.

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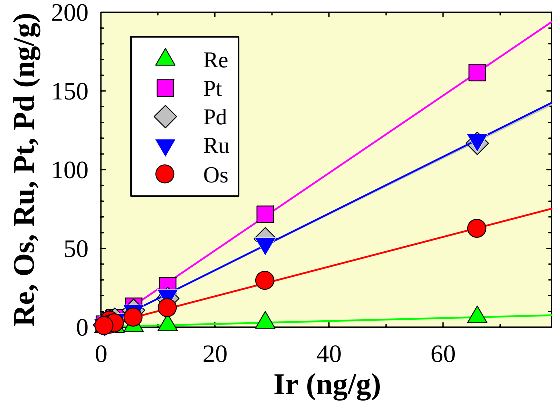

Figure 1. Plot of Ir *vs.* Re, Os, Ru, Pt, and Pd for pieces of Apollo 17 poikilitic melt rock 76215.

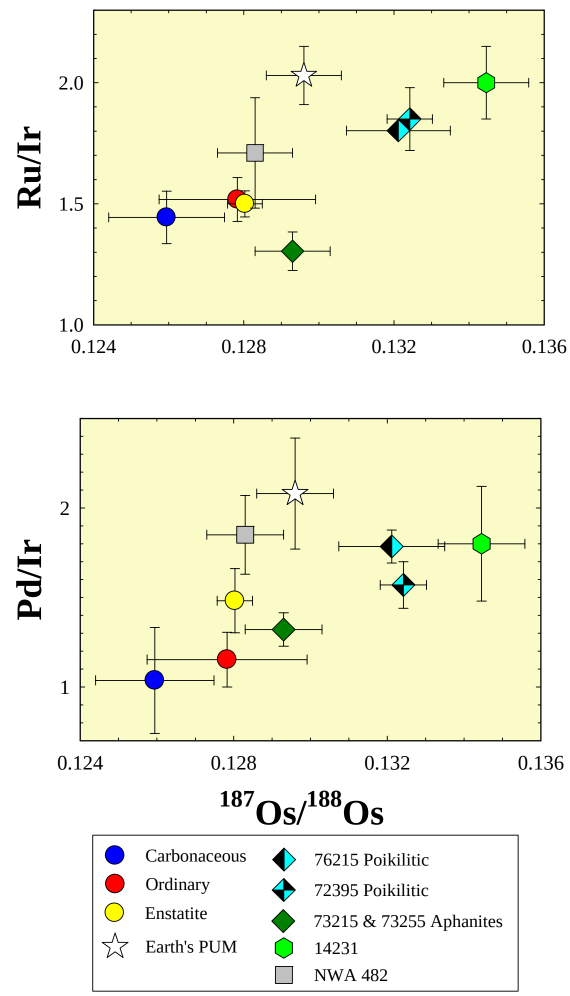

Figure 2. Plot of $^{187}Os/^{188}Os$ *vs.* Ru/Ir and Pd/r ratios. All elemental ratios for lunar melt rocks were determined via the linear regression of Ir *vs.* HSE correlations.