FURTHER STUDY OF $^{187}Os/^{188}Os$ AND HIGHLY SIDEROPHILE ELEMENT SYSTEMATICS OF APOLLO 14 & 17 IMPACT MELT ROCKS. I.S. Puchtel[1], R.J. Walker[1] and O.B. James[2], [1]Department of Geology, University of Maryland, College Park, MD 20742 (ipuchtel@geol.umd.edu), [2]Emeritus, U.S. Geological Survey, 926A National Center, Reston, VA 20192.

Introduction: We have continued study of the chemical nature of late accreted materials to the Earth-Moon system by examining the highly siderophile elements (HSE: Ru, Pd, Re, Os, Ir, Pt) contained in lunar impact-melt rocks. The HSE contained in melt rocks were largely added to the Moon during the period of time from the origin of the lunar highlands crust (4.4-4.5 Ga) to the end of the late bombardment period (~3.9 Ga). These materials provide the only direct chemical link to the late accretionary period. The $^{187}Os/^{188}Os$ ratios, coupled with ratios of other HSE, can be diagnostic for identifying the nature of the impactor. A critical issue, however, will be deconvolving the exogenous from indigenous components.

Last year we reported initial results for Apollo 17 aphanitic melt rocks 73215 and 73255 [1]. Herein we report results for additional chunks of these rocks, and we also report results for Apollo 17 poikilitic melt rock 72395 (previously analyzed by Norman et al. [2]) and initial results for microbreccia (melt rock) subsamples from Apollo 14 breccia 14321. The HSE in the Apollo 17 rocks were likely added at ~3.9 Ga from the impactor that formed the Serenitatis basin. The Apollo 14 breccia may contain impact melt produced during formation of the Imbrium basin. As in the case of the Apollo 17 melt rocks, formation of the impact melts in 14321 has been dated at ~3.9 Ga [3].

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 [2]. They have a coarser grained melt fraction than the aphanitic rocks. The melt fractions of both types of rock are similar in major- and minor-element compositions. Aphanitic melt rocks were found primarily at Stations 2 & 3 (South Massif). They have a very fine-grained melt fraction, thus they crystallized rapidly. They vary widely in clast population, although on average they are richer in clasts than the poikilitic melt rocks. Breccia 14321 consists of clasts of dark microbreccias (impact-melt rocks), igneous basalts, vitrophyric impact melts, and pristine rocks, all in a light-colored matrix of finely comminuted basalt. The 14321 subsamples we analyzed consisted of dark microbreccia (impact melt) containing sparse light clasts.

Analytical Methods: Analytical details were similar to those reported earlier [4], with some modifications. Subsamples of 50-100 mg from each rock were digested in Pyrex Carius Tubes at 270°C for 72-96 h. Blanks averaged (pg): Ru 1.6, Pd 24, Re 1.5, Os 2.8, Ir 0.6, and Pt 76. The accuracy of all new concentration data is $\pm$0.5 relative % or better.

Results: The average $^{187}Os/^{188}Os$ of the samples we analyzed are as follows: in twenty A17 aphanitic subsamples, 0.1299±5 (2σ $stdev_{mean}$); in thirteen A17 poikilitic subsamples, 0.1324±3; and in six 14321 subsamples, 0.1341±10. There are, thus, resolvable differences in average $^{187}Os/^{188}Os$ between the three groups of samples. These differences could reflect differences in impactor compositions, in contributions of indigenous components, or a combination of both factors. The concentrations of the HSE (Fig. 1) are generally similar to those measured previously for aphanites 73215 and 73255 by RNAA [5-6] and for poikilitic melt rocks by ICP-MS [2].

Discussion: Removal of the effects of indigenous contributions from the HSE of impact-melt rocks is critical to accurately fingerprinting the HSE of the impactors. In the A17 poikilitic rocks and 14321 subsamples, Ir shows good linear correlations with all other HSE, consistent with two-component mixing of a single indigenous component and a single meteoritic component. The data of Norman et al. for A17 poikilitic melt rocks [2] indicate similar two-component mixing. That study differed from ours in that it examined larger, homogenized samples of a variety of poikilitic rocks. Here, we examine small subsamples from a single poikilitic rock. For two-component mixes, indigenous concentrations of HSE can be estimated from the intercepts of the linear trends of HSE vs. Ir, assuming near-zero Ir in the indigenous component.

In the A17 aphanitic rocks, there are good linear correlations between Ir and Re, Os, and Ru, and, to a lesser extent, Pt (Fig. 1). There is no statistically significant correlation of Ir with Pd, however. This difference between the aphanitic rocks and poikilitic rocks is striking and difficult to explain. Volatility of Pd is an unlikely explanation, because Au/Ir is constant in the aphanites [7-9]: Au is more volatile than Pd, thus should show the effects of volatility if Pd has been affected by this process. Perhaps the much greater scatter of Pd vs. Ir results from heterogeneity of either the impactor or the indigenous component.

Regressions of the linear correlations vs. Ir indicate resolvable indigenous Ru in the aphanitic rocks, with an intercept of 2.01±0.72 ng/g, and resolvable indigenous Pd in the poikilitic melt rock, with an intercept of 2.86±0.94 ng/g. The regressions suggest modest indigenous Re in both types of A17 melt rock, but the present results are not statistically well resolved. The pristine lunar rocks closest in composition to the A17 melt rocks, the Mg-suite noritic rocks and gabbros, contain the following concentrations of indigenous siderophiles (RNAA data, in ng/g [10-13]): Re, 0.0085; Os, 0.095; Ir, 0.064; and Pd, 1.2. Thus we would expect small indigenous concentrations of these elements in the melt rocks, and additional efforts to characterize the indigenous component are important. Determination of indigenous Re is particularly important because corrections for this element would lead to lower estimates of $^{187}Os/^{188}Os$ for the impactors. Without correction, the average $^{187}Os/^{188}Os$ of only the A17 aphanitic rocks overlaps with that in ordinary and enstatite chondrites, and both the A17 poikilitic melt rock and the 14321 microbreccia are more radiogenic than any chondrite group [14].

The new results for poikilitic rock 72395 are generally similar to the results of [2], but the slopes of Ir vs. other HSE differ between the two data sets. It will be important to assess whether these differences are analytical or reflect real differences in indigenous or impactor characteristics among different poikilitic rocks.

When corrected for indigenous Ru, values of Ru/Ir for the A17 aphanites plot in the middle of the chondritic range. Uncorrected Ru/Ir values for A17 poikilitic rock 72395 and the 14321 microbreccias plot beyond the highest end of the range for ordinary and enstatite chondrites [15]. Corrected Pd/Ir for the A17 poikilitic melt rocks and uncorrected Pd/Ir for the 14321 subsamples are most similar to the Pd/Ir of enstatite chondrites [15].

References: [1] Puchtel I.S. et al. (2005) *LPS XXXVI*, 1707. [2] Norman M. et al. (2002) *EPSL* 202, 217 [3] York D. et al. (1972) *PLSC*3, 1613. [4] Cook et al. (2004) *GCA* 68, 1413. [5] James O.B. et al. (1975) *Proc. LSC*6, 547. [6] Morgan J.W. & Petrie R.K. (1979) *PLPSC*10, 789. [7] James O.B. (1994) *LPSXXV*, 617. [8] James O.B. (1995) *LPSXXVI*, 671. [9] James O.B. (1996) *LPSXXVII*, 603. [10] Gros et al. (1976) *PLSC*7, 2403. [11] Higuchi & Morgan (1975) *PLSC*6, 1625. [12] Ebihara et al. (1991) *PLPSC*22, 418. [13] Morgan et al. (1975) *Moon* 14, 373. [14] Walker R.J. et al. (2002) *GCA* 66, 4187. [15] Horan M.F. et al. (2003) *Chem. Geol.* 196, 5.

This work was supported by NASA grant NNG04GJ49A (RJW), and order W-10,252 (OBJ).

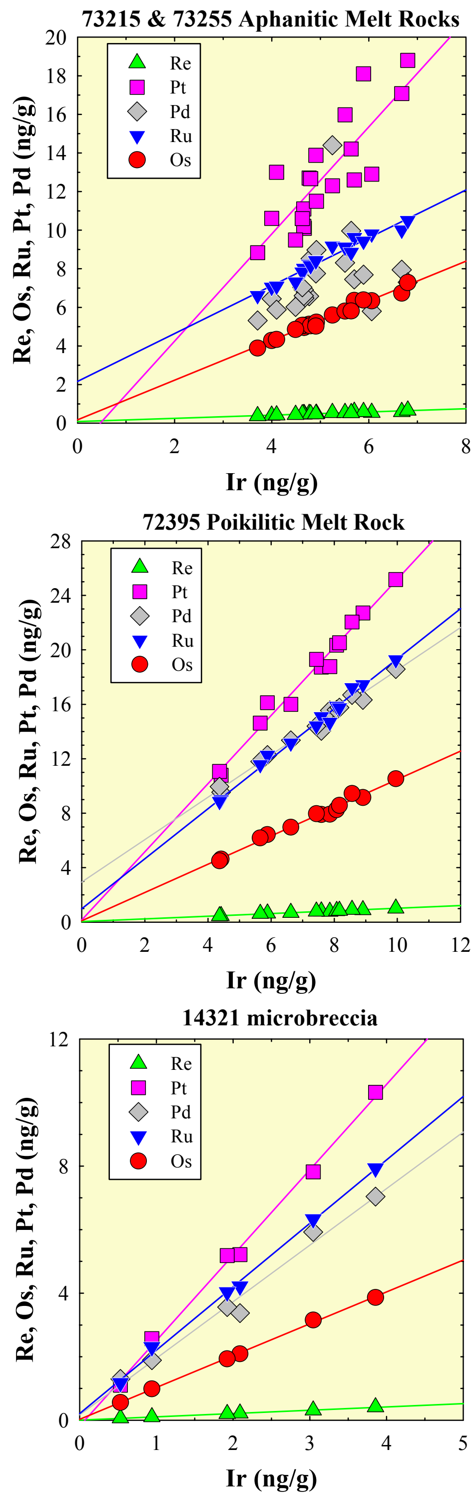

Figure 1. Iridium vs. Re, Os, Ru, Pt, and Pd (ng/g), for A17 aphanites (top), A17 poikilitic rock 72395 (center) and A14 14321 microbreccia (bottom). Linear regressions for each element are shown.