$^{187}Os/^{188}Os$ AND HIGHLY SIDEROPHILE ELEMENT SYSTEMATICS OF APOLLO 17 APHANITIC MELT ROCKS.

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Introduction: Generally chondritic relative abundances and high absolute abundances of the highly siderophile elements (HSE: Ru, Rh, Pd, Re, Os, Ir, Pt, Au) in Earth's upper mantle provide strong evidence that these elements were added to the Earth following the last major interaction between its metallic core and silicate fraction. So called "late accretion" may have added materials comprising as much as 0.8% of the total mass of the Earth and possibly a similar proportion of mass to the Moon [1,2]. We have begun to study the chemical nature of late accreted materials to the Earth-Moon system by examining the HSE 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 (ca. 3.9 Ga). These materials provide the only direct chemical link to the late accretionary period. The chemical fingerprints of the HSE in late accreted materials may enable us to ascertain under what conditions and where in the solar system the late accreted materials formed. The $^{187}Os/^{188}Os$ ratios (reflecting long-term Re/Os), 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.

Herein we examine the Os isotopic and HSE systematics of Apollo 17 aphanitic melt rocks 73215 and 73255. The HSE in these rocks were likely added at ~3.9 Ga from the impactor that formed the Serenitatis basin.

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 [3]. They have a coarser grained melt fraction than the aphanitic rocks of this study. The melt fractions of both types of rock are similar in major- and minor-element composition, except that the melt fraction in the poikilitic rocks is slightly richer in Ti. Argon-argon ages for poikilitic and aphanitic rocks are nearly identical, at 3.89 Ga and 3.87 Ga, respectively [4]. Aphanitic melt rocks were found primarily at Stations 2 & 3 (South Massif). They have a very fine-grained melt fraction, thus crystallized rapidly. They vary widely in clast population, though on average they are richer in clasts than the poikilitic melt rocks. The Station 3 aphanitic melt rocks that we have analyzed are poorer in clasts than those at Station 2. Most workers interpret the poikilitic melt rocks as Serenitatis melt [4], but there is uncertainty about the aphanitic melt rocks because of the slight differences in age and composition between the two types of melt rock.

Analytical Methods: Approximately 100 mg of relatively clast-free subsample of each rock, 3 mL of *aqua regia,* and appropriate amounts of Re-Os and HSE spikes were sealed in 10 mL quartz Carius tubes and equilibrated at 270°C for 96 h. Osmium was extracted from the sample solution and purified by solvent extraction. Ruthenium, Pd, Re, Ir, and Pt were purified using anion exchange chromatography. Blanks for Ru, Pd, Re, Os, Ir, and Pt averaged 4.3, 11, 1.6, 1.4, 1.8 and 27 pg, respectively, and were insignificant, except for Re, for which the blank comprised as much as 25% of some samples. Osmium measurements were accomplished by NTIMS. The measurements of all other elements were done by static ICP-MS (*Nu Plasma*) using a triple electron multiplier configuration. Fractionation was monitored and corrected by interspersal of samples with standards. The precision of all concentration data (except for Re) is ± 1 relative % or better.

Results: The $^{187}Os/^{188}Os$ ratios of the entire suite of subsamples average 0.1300 ± 0.0014 (2σ). There is no discernable difference in average $^{187}Os/^{188}Os$ ratios between 73215 and 73255 (Table 1). Because of the relatively large blank contributions to Re, thus relatively large error for this element, concentrations of Re were also calculated from the Re/Os ratio required to evolve from a chondritic initial $^{187}Os/^{188}Os$, at the time of formation at 3.9 Ga, to the present isotopic composition. The calculated Re concentrations range from 0.37 to 0.66 ng/g. Concentrations of Ru, Os, Ir, and Pt each vary by about a factor of 2 (Table 1). Palladium concentrations are more variable, ranging from 5.3 to 14 ng/g.

Duplicate analyses of two splits of sample 73215_c4 (one coarsely crushed and the other finely ground) varied by no more than 10% for each element. Duplicate analyses of two splits of sample 73215_d1 (one coarsely crushed and the other finely ground) varied by as much as 40%, with the finely ground split having higher concentrations of all elements except Pd. The concentrations of all HSE are generally similar to those measured previously for aphanitic melt rocks by RNAA [5,6] and for poikilitic melt rocks by ICP-MS [3] .

Discussion: All but one of the subsamples have $^{187}Os/^{188}Os$ ratios that overlap the range of ordinary and enstatite chondrites. Only a duplicate of sample 73215_d1 has an Os isotopic composition that overlaps with those of carbonaceous chondrites.

Iridium is well correlated with Re, Os, Ru, and, to a lesser extent, Pt (Fig. 1). Linear correlations of Os, Re, and Pt with Ir extrapolate to near zero at zero Ir. If we assume that the indigenous lunar component contains negligible Ir, then concentrations of Re, Os, and Pt are also very low in the indigenous component. Hence, the ^{187}Os/^{188}Os appears to be determined almost entirely by the meteoritic component and is strong evidence that the impactor had a Re/Os similar to that in ordinary and enstatite chondrites, *not* carbonaceous chondrites [7]. The linear correlation of Ru with Ir, however, has an intercept at zero Ir appreciably above zero Ru, indicating a substantial indigenous component, ~2 ng/g. Palladium concentrations are more variable and do not show a good correlation with Ir. Our results do not yet allow good constraints on Pd/Ir, which, unfortunately, is one of the most diagnostic parameters for constraining the nature of the impactor [8].

Previous evaluation of RNAA data for siderophile elements in 73215 and 73255 has indicated that the siderophile component in the melt fractions of these aphanitic melt rocks, as well as in most poikilitic melt rocks, closely matches that in EH chondrites [9-11]. Precise analyses of HSE in poikilitic melt rocks by ICP-MS [3] have confirmed this conclusion. The data we report herein are also consistent with an enstatite-chondrite meteoritic component in the aphanitic melt rocks.

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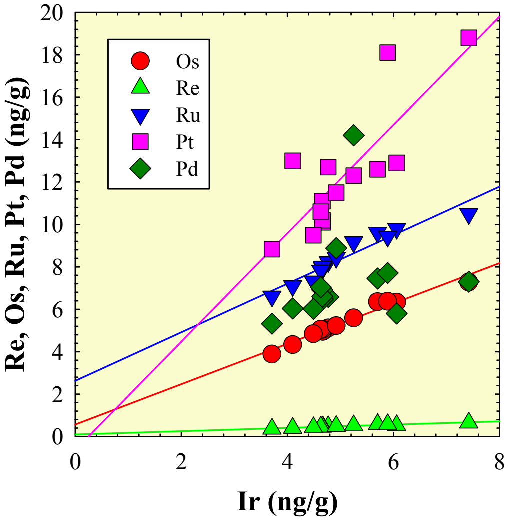

Figure 1. Plot of Ir vs. Re, Os, Ru, Pt, and Pd (in ng/g).

Table 1. ^{187}Os/^{188}Os and HSE concentration data for Apollo 17 aphanitic melt rocks. All concentrations are in ng/g.

Sample	**Wt. (g)**	**Re**	**Re^***	**Os**	**Ir**	**Ru**	**Pt**	**Pd**	**^{187}Os/^{188}Os**
73215_c1	0.12	0.617	0.484	5.120	4.77	8.23	12.7	6.58	0.13064±14
73215_c2	0.11	0.471	0.467	4.959	4.67	7.93	10.1	6.48	0.13060±12
73215_c3	0.05	0.581	0.533	5.596	5.25	9.17	12.3	14.2	0.13090±20
73215_c4	0.10	0.473	0.474	4.962	4.66	7.99	10.2	6.91	0.13090±11
Duplicate	0.09	0.562	0.463	5.059	4.66	8.02	11.1	6.60	0.12966±10
73215_d1	0.08	0.468	0.469	5.060	4.63	7.83	10.6	7.04	0.13007±11
Duplicate	0.05	0.833	0.532	6.334	6.06	9.80	12.9	5.80	0.12726±22
73215_d4	0.10	0.489	0.409	4.335	4.10	7.10	13.0	6.04	0.13060±22
73215_d5	0.09	0.537	0.368	3.886	3.71	6.61	8.83	5.32	0.13072±13
73255_a	0.09	0.608	0.590	6.356	5.70	9.62	12.6	7.45	0.13007±15
73255_b1	0.10	0.463	0.435	4.848	4.49	7.32	9.49	6.02	0.12906±17
73255_c1	0.13	0.592	0.583	6.378	5.89	9.43	18.1	7.71	0.12960±16
73255_c2	0.11	0.527	0.499	5.226	4.92	8.44	11.5	8.88	0.13093±20
73255_c3	0.11	0.674	0.657	7.284	7.42	10.5	18.8	7.30	0.12925±13

Re^* - calculated as discussed in text.