Highly Siderophile Element Abundances and ^{187}Os/^{188}Os in Lunar Impact Melt Rocks: Implications for Late Accretion Processes in the Earth-Moon System.

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Introduction: Ancient lunar impact melt rocks have revealed details about the composition of impacting bodies during the Hadean history of the Earth-Moon system [1]. The application of improved analytical techniques can provide new insights on the origin of the excess abundance of highly siderophile elements (HSE: Re, Os, Ir, Ru, Pt, Rh, Pd, Au) in the Earth's mantle [2-8,13], and maybe even its volatile element budget. The current data base for ^{187}Os/^{188}Os data and HSE abundances on lunar impact melt rocks is rather limited. The goal of the present work is to increase the data base and to include lithologies and locales for which no comprehensive data set has been available. Lunar impact melt rocks from Apollo 14 (14310), 16 (60315, 67935, 67955), 17 (79215), and the lunar meteorite DaG400 have been studied and will be compared and discussed along with previous HSE data. Evaluating mixing between putative impactor compositions and indigenous or multiple meteoritic components in the target rock requires analysis of multiple aliquots of a single rock sample.

Analytical techniques: The samples were crushed into coarse grained chips using a ceramic mortar. Of gram size impact melt rock samples about 10 subsample aliquots weighting ~100 mg (40 mg aliquots for DaG400) were digested in reverse aqua regia using a HP asher at 320°C [9]. The HSE were purified by chemical separation using cation exchange resin and a 0.5 M HCl-60% acetone solution as the eluting solvent [7]. Abundances of Re, Os, Ir, Ru, Pt and Pd were determined by isotope dilution using a mixed ^{185}Re-^{190}Os spike, and a mixed ^{191}Ir-^{99}Ru-^{194}Pt-^{105}Pd spike. The monoisotopic elements Rh and Au were quantified by standardization using the abundance of ^{193}Ir from the sample as internal standard [9]. Osmium isotopic compositions were measured by N-TIMS (Triton) and all other HSE by sector-field ICP-MS (Element XR) at FU Berlin. Accuracy and reproducibility of the method were tested by repeated analysis of the Smithsonian Allende reference powder and the UB-N peridotite reference powder [7,13], and by comparison with the results obtained by other studies [3,9,10,11].

Results: The HSE concentration data from different subsamples of a given impact melt are generally well correlated. For the refractory HSE (Re, Os, Ir, Ru, Pt, Rh) only few exceptions from these correlations are observed for some subsamples. Correlations involving the moderately volatile siderophiles Pd and Au are less well defined and show more scatter for some samples. In the case of DaG400 Re and Au abundances are affected by terrestrial weathering and hence yield no meaningful correlations.

Slope derived HSE/Ir ratios represent the high HSE end-member composition [12] and yield suprachondritic ^{187}Os/^{188}Os, Ru/Ir, Pt/Ir, Rh/Ir, Pd/Ir and Au/Ir ratios for poikilitic impact melt rock 60315 and even more pronounced suprachondritic ratios for basaltic impact melt rock 67935. Slightly suprachondritic Ru/Ir, Pt/Ir, Rh/Ir and Pd/Ir are observed for basaltic impact melt 14310. The lunar meteorite DaG400 shows slightly suprachondritic Ru/Ir while other HSE ratios are in the range of chondritic meteorites. The granulitic impact melts 67955 and 79215 are characterized by ^{187}Os/^{188}Os and HSE ratios similar (but not identical) to CI chondrites. Because of the limited spread in absolute concentrations HSE ratios of the granulitic impactites were calculated as averages over the sample splits.

Discussion: Our new HSE data on lunar impact melt rocks in conjunction with previous high precision data [2,3] show that suprachondritic HSE ratios are observed for many lunar impactites. HSE compositions calculated from linear regressions and ^{187}Os/^{188}Os of 14310, 60315 and DaG400 are comparable to the compositions of Apollo 17 poikilitic impact melts [2,3] and indicate that HSE ratios of impactors at different sites show similarities (Fig. 1). Apollo 16 sample 67935 shows by far the highest suprachondritic ratios reported so far. Ratio vs. element plots reveal that the most suprachondritic HSE ratios observed for subsamples of 60315 and 67935 coincide with the highest concentrations.

Osmium isotopic compositions and HSE abundance systematics outlined in Figs. 1 and 2 most probably reflect mixing relationships between the low HSE lunar target rocks and at least three different types of high HSE meteoritic end-member compositions. The first end-member composition is mirrored by the granulitic impactites and is characterized by ^{187}Os/^{188}Os and HSE ratios similar to CI and carbonaceous chondrites. The second meteoritic end-member is represented by suprachondritic ^{187}Os/^{188}Os and HSE ratios like Ru/Ir and Pd/Ir at its lower end overlapping with ordinary and enstatite chondrite-like compositions. The third component is characterized by abundance systematics of 67935 and shows pronounced suprachondritic compositions plotting substantially above the range observed for chondrites.

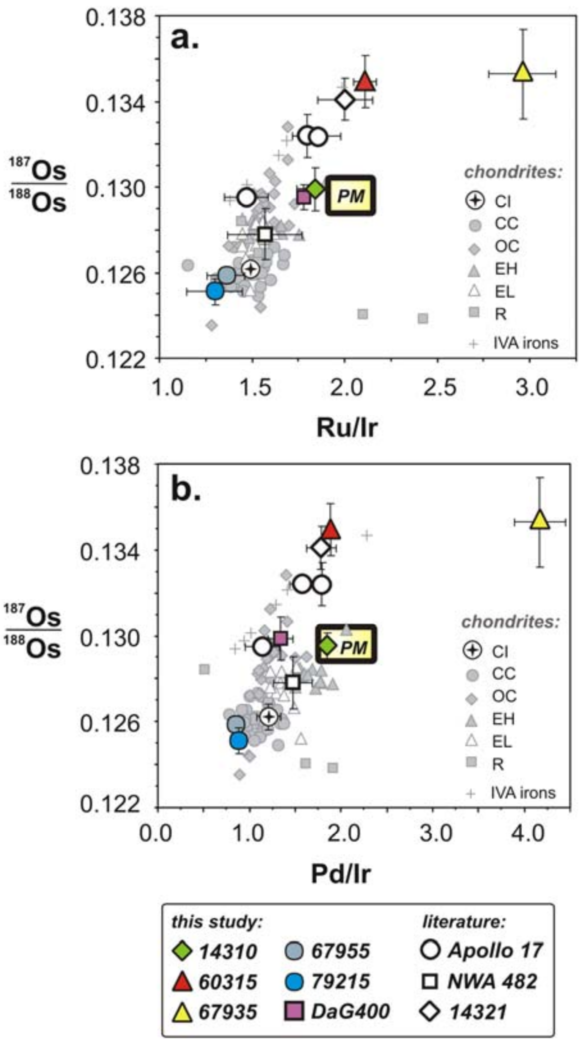

Figure 1. ^{187}Os/^{188}Os vs. Ru/Ir (a) and Pd/Ir (b) for lunar impact melt rocks from this study (colored symbols) and literature [3] (white symbols) in comparison to chondrites and the primitive mantle (PM) model composition [4-8].

HSE concentration data from subsamples of samples from different landing sites are well correlated (Fig. 2, including data from [2,3]). Assuming that similar meteoritic material has been delivered to Earth and Moon during their late accretionary history, the excess HSE abundances of the Earth´s mantle and suprachondritic Pd/Ir and Ru/Ir inferred for the primitive mantle can be explained by binary mixing of two different meteoritic end-members recorded in lunar impact melt rocks, one similar to chondrites, the other similar in composition to the meteoritic component in 67935 (Fig. 1).

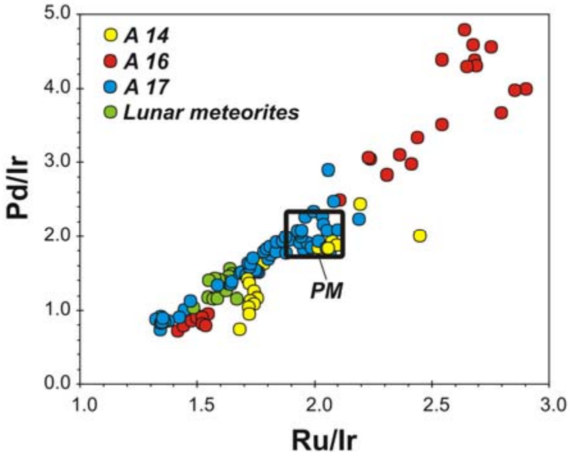

Figure 2. Pd/Ir vs. Ru/Ir for subsamples of lunar impact melt rocks from this study and [2,3]. Data from different landing sites display a well defined linear correlation passing through the HSE composition inferred for Earth´s primitive mantle (PM) [6].

References:

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