**CHARACTERIZING THE DOMINANT IMPACTOR SIGNATURE OF APOLLO 17 IMPACT MELT ROCKS AND METALS.**

M. Sharp[1], I. Gerasimenko[1], L. Loudin[1], O. B. James[2], I. S. Puchtel[1] and R. J. Walker[1]. [1]Department of Geology, University of Maryland, College Park, MD 20742 (mgalenas@umd.edu), [2]Emeritus U.S.Geological Survey, Reston, VA 20192

**Introduction:** Highly siderophile elements (HSE: including Re, Os, Ir, Ru, Pt, and Pd) from meteoritic impactors are incorporated into lunar impact melt breccias during impacts. The relative abundances of HSE in impact melt rocks can potentially be used to fingerprint impactors, as a consequence of the four to five orders of magnitude higher concentrations of HSE in impactors with chondritic bulk compositions, in comparison to lunar target rocks [1-2]. In particular, slopes derived from linear regressions of, e.g., Ir *vs*. other HSE concentrations, or $^{187}Os/^{188}Os$, for multiple pieces of an individual breccia, can be used to determine the HSE ratios of the impactors [3-5]. The HSE ratios can be diagnostic with regard to the broad category of impactor, given the variance of these ratios among primitive and differentiated meteorites.

The Apollo 17 impact melt breccias were collected proximal to the Serenitatis basin. The origin of the melt has generally been assumed to be Serenitatis, however, Imbrium has also recently been suggested [6-7]. Apollo 17 breccias are divided into two petrographically and chemically distinct groups: poikilitic and aphanitic. These rocks are broadly similar but differ in both texture and composition. The main HSE carrier in both types of rock are small metal globules that are thought to exsolve from the melt or condensed from the vapor state [3]. Most metal globules are microscopic and heterogeneously distributed, however some are sufficiently large to be extracted and individually analyzed for HSE.

Prior work on Apollo 17 poikilitic melt rocks 76215 and 72395 showed that their HSE ratios were indistinguishable from each other, and that they also had suprachondritic $^{187}Os/^{188}Os$, Ru/Ir, and Pd/Ir [8]. Aphanitic melt rocks 73215 and 73255 were chemically and isotopically indistinguishable from each other, but characterized by lower average $^{187}Os/^{188}Os$, Pd/Ir and Ru/Ir, compared to the poikilitic melt rocks [8]. Overall, their HSE characteristics are consistent with ordinary chondrites.

**Samples:** Seven samples from three stations were analyzed for this study. Samples 72355, 72435, 72535, 76035, 76055, and 76135 are poikilitic, while 73235 is aphanitic. Four metal grains (~1 to 6 mg) were removed from sample 76135 and analyzed separately.

**Analytical Methods:** Multiple 40-100 mg chunks of samples were comminuted with an alumina mortar and pestle. Exterior surfaces of some samples exhibited micrometeorite pits and exposure patina. These surfaces were removed with a dry-cut diamond saw blade. Total analytical blanks were measured for each sample set. Osmium was analyzed by negative thermal ionization mass spectrometry using a *VG Sector 54* in electron multiplier mode. A *Nu Plasma* inductively-coupled plasma mass spectrometer with triple electron multipliers was used to analyze Re, Ir, Ru, Pt, and Pd. The overall precisions for HSE concentrations are estimated to be 0.5% for Os, 2% for Re, Ir, and Ru, 5% for Pt, and 2.5% for Pd.

**Results:** With the exception of poikilitic sample 76055, the HSE ratios of all the samples, including the aphanite 73235, overlap with those of Apollo 17 poikilitic rocks reported by Puchtel et al. (2008). We interpret these ratios as reflecting the dominant HSE signature of the Apollo 17 site, therefore, possibly the Serenitatis impactor. This signature is characterized by Ru/Ir and Pd/Ir ratios that are elevated with respect to the averages of enstatite, ordinary, and carbonaceous chondrites, although there is minor overlap with some chondrites at the extreme ranges of their fields (Fig. 1). The Os/Ir and Re/Ir ratios overlap with the four major types of chondrites. The dominant signature is also characterized by a $^{187}Os/^{188}Os$ ratio that averages $0.1321\pm5$ ($2\sigma$), indicating a higher long-term Re/Os ratio than is typical for chondrites.

Sample 72535 is typical of the dominant signature. Chondrite normalized HSE patterns for sub-samples of this rock (Fig. 2a) most closely resemble those of EH-chondrites, especially with respect to elevated Ru/Ir, and Pd/Ir ratios. However, EH chondrites do not have $^{187}Os/^{188}Os$ ratios as high as this rock.

With the exception of the metal with the lowest HSE concentrations, metal separates from 76135 are characterized by similar, albeit more fractionated HSE patterns, compared to the dominant signature (Fig. 2b). The metal globule with the lowest HSE concentrations is characterized by having a significantly lower Pd/Pt ratio than the other metals. The $^{187}Os/^{188}Os$ ratios of all of the metal grains overlap with the dominant signature.

In contrast to other samples, the HSE patterns of 76055 subsamples are characterized by Ru/Ir, Pt/Ir, and Pd/Ir ratios that are lower than the rest of the poikilitic suite (Fig. 2c). Two subsamples are characterized by an EH-like pattern, however, most subsamples are dominated by mostly flat patterns, with modest depletions in Pd. Sample 76055 also has a much lower $^{187}Os/^{188}Os$ ratio of $0.1279\pm10$ ($2\sigma$).

**Discussion:** The combined data from [3,4] and this study show that Apollo 17 aphanitic and poikilitic impact melt rocks largely share a single dominant impactor signature. If the HSE signature of this component was not modified by impact processes, it represents a meteoritic composition that is not present in our collections of bulk chondrites. The impactor responsible for the impact melt rocks has higher Ru/Ir, Pd/Ir, and $^{187}Os/^{188}Os$ ratios than is typical of the major groups of chondrites.

The dominant signature most closely resembles EH chondrites, potentially indicating that the impactor may have undergone a similar nebular fractionation history as recorded by the EH parent body (albeit with a higher Re/Os ratio). High Pd/Ir ratios in EH chondrites have been attributed to high temperature fractionation via removal of refractory elements before the condensation of moderately volatile elements [2]. Yet, the high Re/Os is difficult to achieve by high temperature fractionation, except under highly oxidizing conditions.

Other options to create the HSE charactereistics of the dominant signature include: fractionation during the impact process, averaging of multiple impact signatures, or a reflection of one or more iron meteorite impactors with fractionated signatures [e.g., 9].

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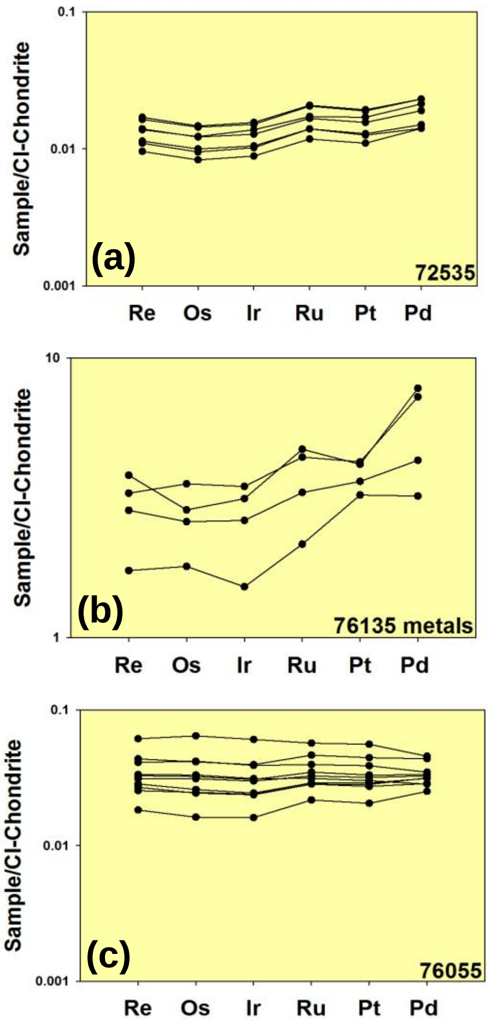


**Figure 2.** HSE patterns for: **a)** 72535, **b)** 76135 metal separates, and **c)** 76055.

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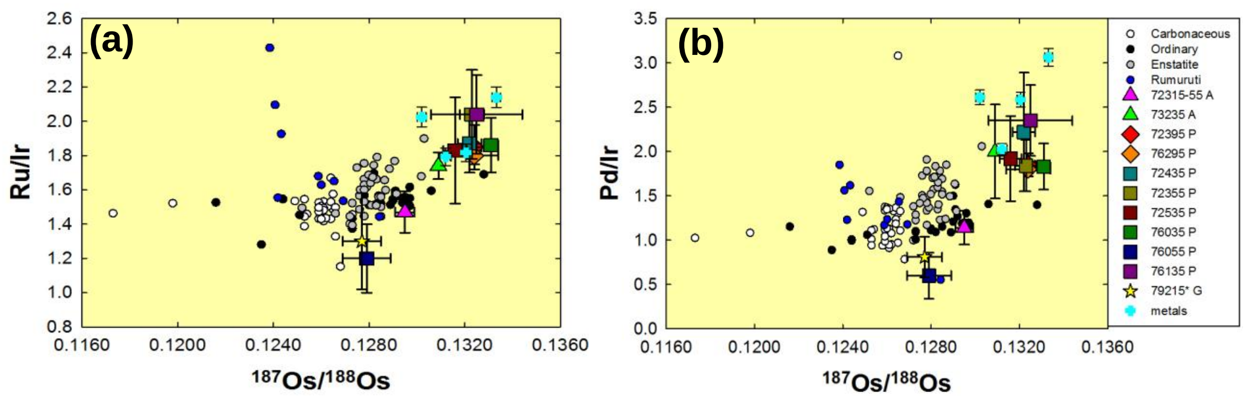


**Figure 1**. **a)** Plot of $^{187}Os/^{188}Os$ *vs.* Ru/Ir. **b)** Plot of $^{187}Os/^{188}Os$ *vs.* Pd/Ir. On each diagram, bulk chondrite data from [2,9-11] are also plotted for comparison. Error bars in y-axis represent uncertainty from linear regressions. Error bars in x-axis reflect the absolute range of $^{187}Os/^{188}Os$ ratios for each sample.