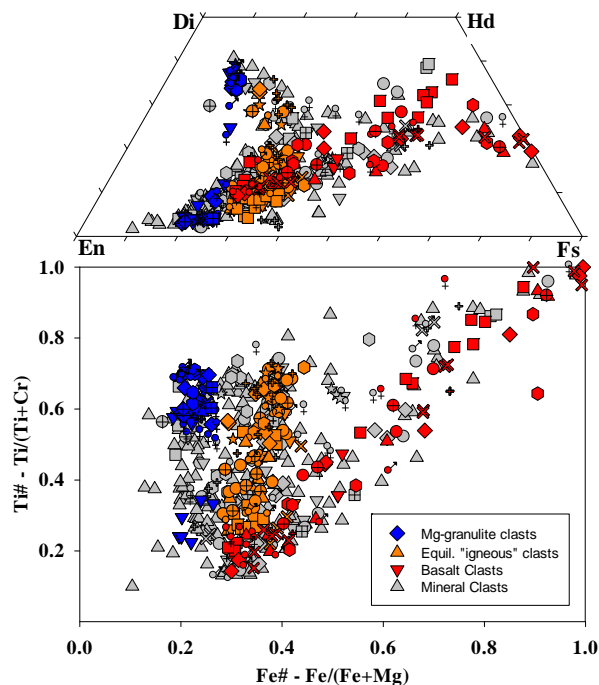


**LUNAR METEORITES SAYH AL UHAYMIR 449 AND DHOFAR 925, 960, AND 961: WINDOWS INTO SOUTH POLE AITKEN BASIN?** R. A. Zeigler<sup>1</sup>, B. L. Jolliff, and R. L. Korotev<sup>2</sup>. <sup>1</sup>NASA - JSC, KT, 2101 NASA Pkwy, Houston TX 77058 ([ryan.a.zeigler@nasa.gov](mailto:ryan.a.zeigler@nasa.gov)). <sup>2</sup>Washington University in St. Louis, CB 1169, 1 Brookings Dr., St. Louis, MO 63130.

**Introduction:** In 2003, three lunar meteorites were collected in close proximity to each other in the Dhofar region of Oman: Dhofar 925 (49 g), Dhofar 960 (35 g), and Dhofar 961 (22 g) [1-2]. In 2006, lunar meteorite Sayh al Uhaymir (SaU) 449 (16.5 g) was found about 100 km to the NE [3]. Despite significant differences in the bulk composition of Dhofar 961 relative to Dhofar 925/960 and SaU 449 (which are identical to each other), these four meteorites are postulated to be paired based on their find locations [1-2], bulk composition [4-5], and detailed petrographic analysis [6]. Hereafter, they will collectively be referred to as the Dhofar 961 clan. Comparison of meteorite and component bulk compositions to Lunar Prospector 5-degree gamma-ray data [7] suggest the most likely provenance of this meteorite group is within the South Pole-Aitken Basin [6,8]. As the oldest, largest, and deepest recognizable basin on the Moon, the composition of the material within the SPA basin is of particular importance to lunar science. Here we review and expand upon the geochemistry and petrography of the Dhofar 961 clan and assess the likelihood that these meteorites come from within the SPA basin based on their bulk compositions and the compositions and characteristics of the major lithologic components found within the breccia.

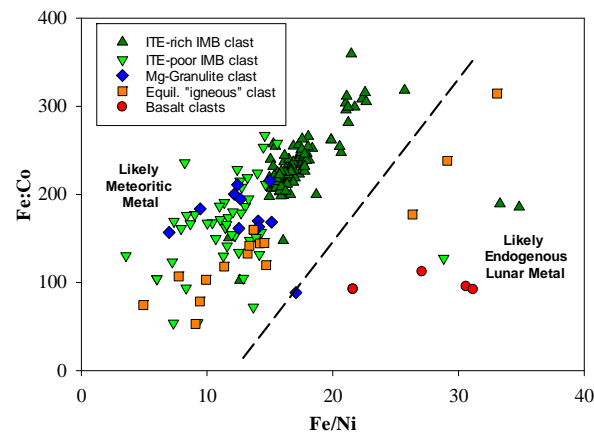
**Petrography:** The different stones within the Dhofar 961 clan are clast-rich glassy matrix regolith breccias containing large impact-melt breccia (IMB) clasts. These IMB clasts typically compose >50% (by mode) of the stones. There is a compositional dichotomy in the IMB clasts found in the different stones, with the Dhofar 961 IMB clasts being more mafic (~14 wt% FeO), more ferroan (mg' of 56-60), and more incompatible trace-element (ITE) rich (~0.3 wt% K<sub>2</sub>O; ~0.6 wt% P<sub>2</sub>O<sub>5</sub>) than the IMB clasts seen in the other stones (~8 wt% FeO, mg' of 64-70, <0.1 wt% K<sub>2</sub>O, P<sub>2</sub>O<sub>5</sub>). In addition to the large IMB clasts, there are also significant numbers of basalt clasts, magnesian granulite clasts, and equilibrated "igneous" clasts found throughout the Dhofar 961 clan [for details on 961 clan petrography see 6,8,9]. Looking at the major element composition and non-quadrilateral systematics of the pyroxene grains in these three groups (Fig. 1), the basaltic pyroxene compositions following a normal igneous differentiation trend and match what is seen in the Apollo basalts. The pyroxene compositions in the magnesian granulites and equilibrated igneous clasts have compositions akin to what is observed in Apollo IMB and granulite clasts. Although the basalt clasts are unambiguously igneous in origin, recent high resolution imaging (and correspond



**Figure 1:** Pyroxene compositions in the Dhofar 961 clan.

ing electron probe analyses) have shown that small metal grains (typically <5  $\mu\text{m}$ ) are present in a small number of magnesian granulite and equilibrated "igneous" lithic clasts (conflicting with previous reports [6]). Moreover, the compositions of most of these metal grains are consistent with a meteoritic origin (Fig. 2).

**Discussion:** Given the areal extent of the SPA basin (5.3% of the lunar surface), the total number of lunar meteorites to date (84), and the likely number of source



**Figure 2:** Metal compositions in Dhofar 961 clan lithic clasts. Most of the observed metal grains are consistent with a meteoritic origin based on their Fe:Ni:Co ratios.

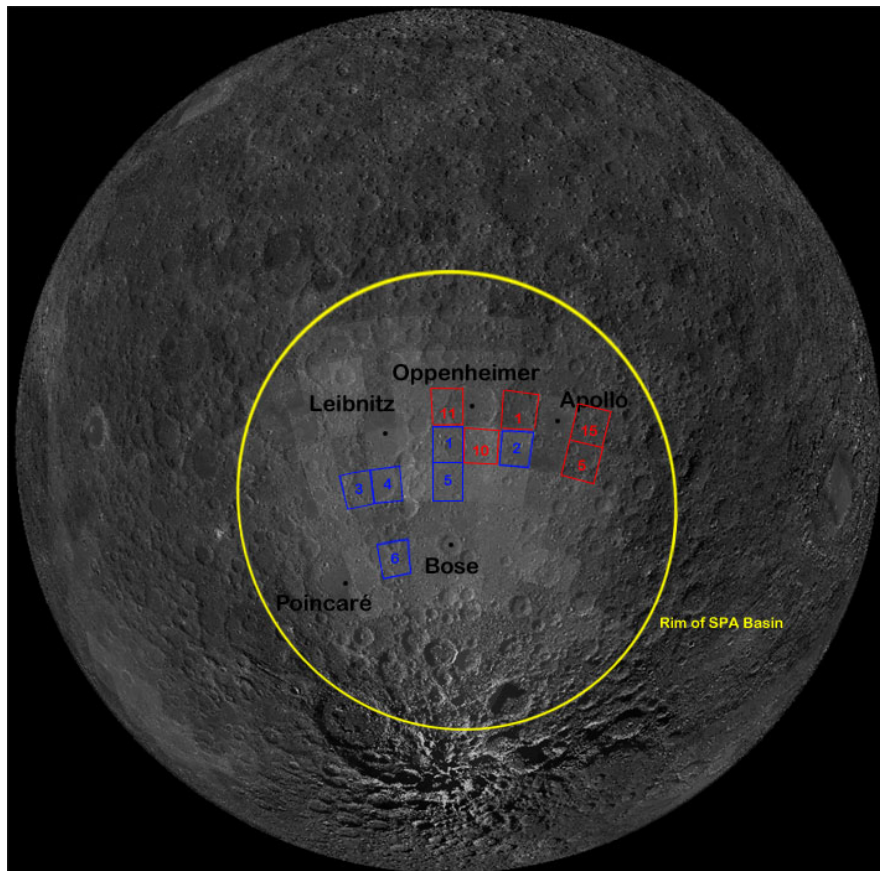
craters represented by these meteorites (minimum of 35), there is a >85% chance that at least one lunar meteorite is from the SPA basin [4]. Of the known lunar meteorites, the composition of the Dhofar 961 clan, particularly the bulk composition of the Dhofar 961 stone, is the best match for compositions observed within the SPA Basin (e.g., moderately high concentrations of FeO and a modest Th enrichment [4]). Moreover, by comparing the bulk composition of the Dhofar 961 stone to the average composition of the lunar surface as measured by the Lunar Prospector gamma-ray spectrometer (LP-GRS) for Si, Ti, Al, Fe, Mg, Ca, K, Th, and U, the six best compositional matches (and 14 of the top 25) are within the SPA Basin [7]. Additionally, a similar comparison of the bulk composition of the Dhofar 925/960 and SaU 449 stones, which is considerable less mafic and ITE-rich than Dhofar 961, shows that approximately 1/3 of the high quality matches on the lunar surface are within the SPA Basin (Fig. 3). Because the composition of 925/960/449 is less unique than 961, many more places on the Moon are a good match.

A fair question to ask is whether trying to match the

composition of a 120 g lunar meteorite with a 5° swath of the Moon (~350 km<sup>2</sup>) is valid. Given that the Dhofar 961 clan is a regolith breccia, it is at least plausible, since it represents the average composition of the upper few meters of the lunar surface (the same approximate depth that the LP-GRS samples). Also, given the well mixed composition of the lunar surface due to innumerable impacts, the lunar surface can be fairly uniform in composition over distances of at least 10s of km, as indicated by the composition of Apollo 16 soils, and sometimes much greater distances as indicated by remote sensing data of light plains deposits such as the Cayley Plains. If we examine the major components with the Dhofar 961 clan, many of them are indicative of, or at least consistent with, a SPA Basin origin. The ITE-rich IMB composition that dominates the Dhofar 961 stone in particular is an excellent match for the SPA Basin, as it contains the largest continuous area of nonmare moderately mafic, moderately ITE-rich material on the Moon. Also, the ITE-ratios in Dhofar 961 do not match those seen in typical KREEP materials [4,6], presumably ruling out a PKT origin. The presence of

low-Ti and VLT basalt clasts within the Dhofar 961 clan is also consistent, as there are numerous mare and cryptomare deposits within the SPA Basin. Finally, the equilibrated “igneous” clasts and magnesian granulite clasts are also consistent with a SPA Basin origin. Both are relatively coarse grained, largely clast free, and contain meteoritic metal, suggesting an origin within a basin melt sheet (not thrown out of one). There are numerous ancient impact basins within the SPA Basin that could be their source.

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**Figure 3:** Wide-Angle Camera Mosaic of the South Polar Region of the Moon, overlain with the 5° LP-GRS data. Best compositional matches between LP-GRS data and 961 (in red) and 925/960/449 (in blue) are shown.