

NEW GEOCHEMICAL CONSTRAINTS ON PAIRING OF THE DHOFAR 961 CLAN OF LUNAR METEORITES.

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Compositionally and petrologically, Dhofar 961, a glassy-matrix regolith breccia, is unique among lunar meteorites (Fig. 1) and distinct from any Apollo sample. In a recent paper [1], we make two observations. (1) If the ~65 known lunar meteorites represent even as few as only 30 source craters on the Moon, then there is still an 80% chance that at least one is from the South Pole-Aitken basin. (2) Among lunar meteorites, Dhofar 961 is the most likely SPA candidate on the basis of its mineralogy and unusual composition [1,2].

Dhofar stones 925 (49 g), 960 (35 g), and 961 (22 g) were reportedly found together at a point distant from other lunar meteorite stones and have been regarded as mutually paired on the basis of field location, texture, clast population, and mineral chemistry [3–5]. Our compositional data for 9 small samples (239 mg total mass) of Dhofar 961 scatter greatly ([1], Fig. 2). Nevertheless, our 2 samples of Dhofar 925 are substantially more feldspathic and poorer in incompatible elements than all but one of the Dhofar 961 samples. This difference led us to question whether the two stones were actually paired [1]. To confuse the issue further, Dhofar 925 is compositionally indistinguishable from and texturally similar to SaU 449, reportedly found 212 km away.

We have subsequently obtained new bulk compositional data on a small sample (16 mg) from a different slice of Dhofar 961 as well as data for 6 samples (138 mg total mass) of previously unanalyzed Dhofar 960. The Dhofar 960 samples mostly overlap the fields of

Dhofar 925 and SaU 449 (Figs. 1,2). The new sample of Dhofar 961 lies outside the compositional range of the first 9 samples but is clearly more similar to the other Dhofar 961 samples than it is to samples of the other 3 stones (Fig. 2).

In a companion abstract we report on the petrography of the four stones [6]. On the basis of that work and the new compositional data we conclude that Dhofar 925, 960, and 961 are all stones from a common fall and together they represent a regolith consisting of a variety lithologies of widely varying composition, a regolith that is heterogeneous at millimeter to centimeter scale. The differences in composition between Dhofar 961 and the other stones occurs because Dhofar 961 contains a high (~50%) proportion of an IMB (impact-melt breccia) that is both mafic and moderately rich in incompatible elements. This component is uncommon in Dhofar 925, Dhofar 960, and SaU 449. The large degree of scatter among the Dhofar 961 samples (Fig. 2) is caused by the large compositional diversity and coarse grain size of the clastic components – basalt, magnesian granulites, anorthositic granulites, and at least two kinds of impact-melt breccia [6].

The mafic IMB component of Dhofar 961 is only moderately rich in incompatible elements compared to otherwise similar breccias in the Apollo collection and does not contain a high-Sm KREEP norite component ([1], Fig. 2b). This characteristic argues that Dhofar 961 is not from the Procellarum KREEP Terrane [1].

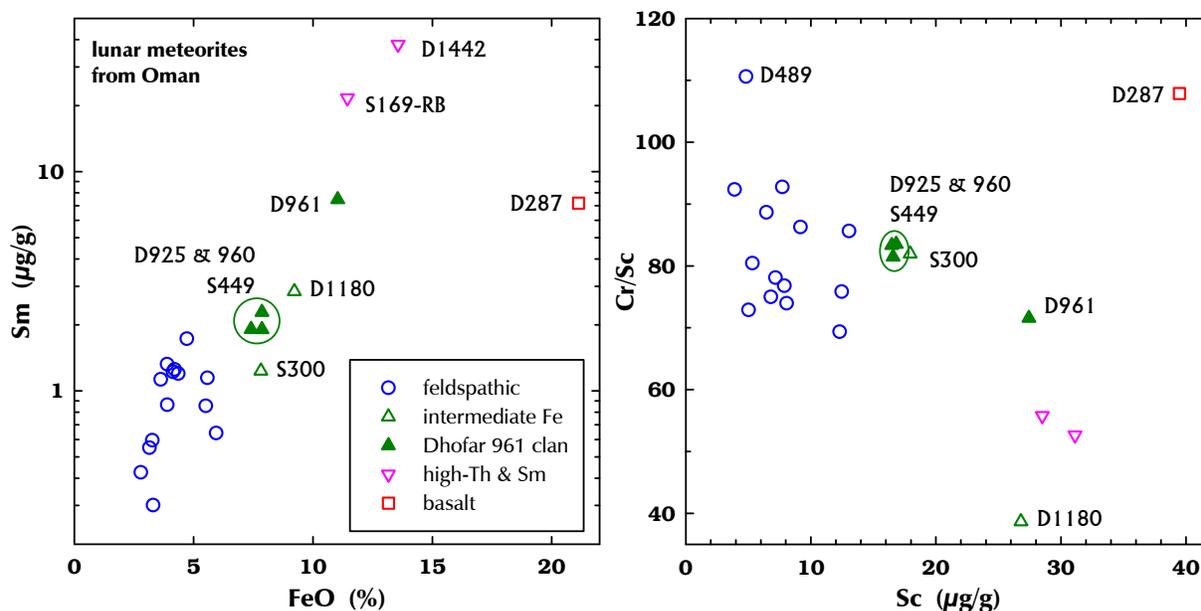


Figure 1. Dhofar 961 is compositionally unique among lunar meteorites from Oman. Points represent mass-weighted means of all analyzed samples. D = Dhofar, S = Sayh al Uhaymir 169 (SaU). All data from this lab.

Dhofar 961 is rich in FeNi metal. We previously noted that the metal is nonchondritic in composition but consistent with an iron meteorite ([1], Fig. 3). The other three meteorites also contain metal, but overall, Ir/Ni is more consistent with a chondritic source (Fig. 3). This difference is not an argument against pairing. Siderophile elements in Dhofar 925/960 derive mainly from chondritic micrometeorites because the meteorite is a regolith breccia whereas siderophile elements in Dhofar 961 are dominated by nonchondritic metal in the mafic IMB clasts in the regolith breccia. A similar situation occurs in the Apollo 16 regolith [7].

Because of the great separation distance (212 km), SaU 449 cannot be terrestrially paired with the Dhofar stones if the stones fell where they are reported to have been found [1]. A coincidence seems to be required. Either two separate impacts delivered rocks of similar texture and similarly unusual composition or SaU 449 is a launch pair of the Dhofar meteorite and both meteorites happened to fall in Oman.

Even if the Dhofar 961 clan of meteorites is not from SPA, they are important in tying the occurrence of a diverse suite of lithologies to a single location on the Moon.

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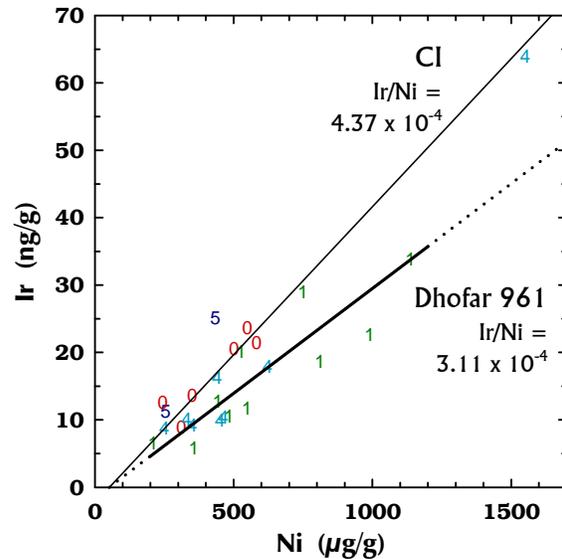


Figure 3. Variation in Ni and Ir concentrations in Dhofar 961 samples requires a metal component with an Ir/Ni ratio about 70% that of the CI ratio. The line is an error-weighted least squares fit to the data. Dhofar 925, 960, and SaU 449 largely plot along the chondritic line, which is defined by the intercept of the Dhofar 961 line and CI chondrites [9].

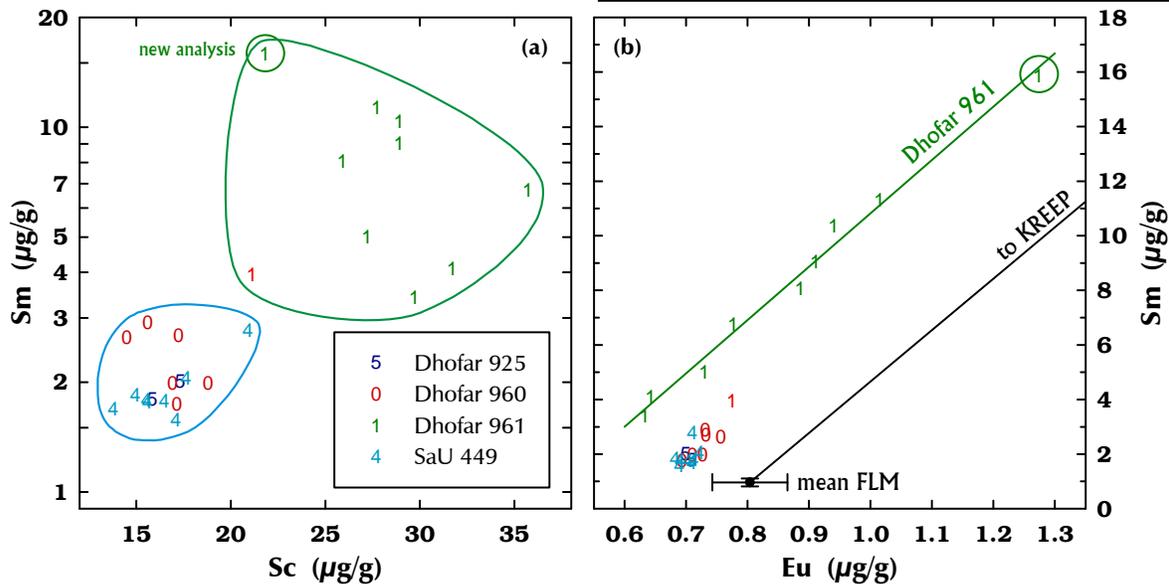


Figure 2. (a) Data for the circled sample of Dhofar 961 and all data for Dhofar 960 are new since [1]. Points represent samples of 16–31 mg in mass. (b) Nine of the ten Dhofar 961 samples lie along a mixing line distinct from mixtures of KREEP [8] and typical material of the Feldspathic Highlands Terrane, represented here by the mean of 33 feldspathic lunar meteorites (error bars represent 95% confidence limits). One of the Dhofar 961 samples (red 1) is similar to Dhofar 925 and 960. The others are dominated by an impact-melt breccia that is both moderately mafic and moderately rich in incompatible elements. Nonmare Apollo samples tend to plot along the FLM-KREEP line because their REE compositions are dominated by anorthosite (Eu) and KREEP (trivalent REE and Eu) [1]. The offset of the lines indicates that the carrier of REE in the mafic impact-melt breccia component of Dhofar 961 is different from the KREEP component of Apollo samples.