BULK-COMPOSITIONAL STUDY OF THREE DHOFAR LUNAR METEORITES: ENIGMATIC SIDEROPHILE ELEMENT RESULTS FOR DHOFAR 026.

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We report some of the first bulk analysis data for three new lunar meteorites found in Oman, during December, 1999 and January, 2000. The analyzed samples are: 1) Dhofar 025, a 104 mg aliquot from a larger powder from the Vernadsky Institute; 2) Dhofar 026, a 57 mg chip (post-pulverization mass), also from the Vernadsky Institute; and 3) Dhofar 081, a 421 mg chip, donated by the Institut für Mineralogie (Berlin). A combination of INAA and fused-bead electron-probe analysis has been employed. Because our study only commenced a short time ago, some of our data (Table 1) are still preliminary.

In general, our data for diagnostic parameters such as Fe/Mn confirm the lunar provenance of all three meteorites. An admittedly imprecise analysis by Greshake et al. [1] indicated that Dhofar 081 has an uncommonly low Fe/Mn ratio, by lunar standards. Our data confirm an extraordinarily low Fe/Mn (63); literature data for 16 other lunar meteorites average 72.1± 4.3 (1σ). Nonetheless, all other signs clearly indicate that Dhofar 081 is an anorthositic breccia of lunar highland origin.

The petrology of Dhofar 025 and 026, as well as additional bulk-chemical data, are presented in companion abstracts [2-4]. Dhofar 025 is compositionally a typical (e.g., Sm- and Th-poor) lunar meteoritic regolith breccia [4]. Dhofar 026 is dominated by a single textural domain, its poikilitic impact-melt-produced groundmass [2]. However, an intriguing feature of this impact melt breccia is the survival of scattered igneous-textured spherules, typically ~100 µm across. As illustrated in Fig. 1 (transmitted light), the rock appears texturally heterogeneous on scales of mm to cm.

Greshake et al. [1] have classified Dhofar 081 as a fragmental breccia. This choice seems correct. However, this sample's complex and unusual texture is difficult to pigeonhole. Its texture is completely unlike that of Dhofar 026. Dhofar 081 (Fig. 2) contains a great variety of small lithic clasts (mostly fine-grained impact-melt breccia) set in a groundmass remarkably rich in swirly glass (schlieren), often brownish in color. No obvious regolith components (glass spherules, intact agglutinates) are discernible. Noble gas contents [1] are low, but virtually the same as in MAC88105, which is by all accounts a regolith (albeit, immature regolith) breccia. In any case, Dhofar 081 appears to be another thoroughly polymict lunar meteorite, which is probably at least roughly representative of the composition of its highland source region.

All three Dhofar lunar meteorites have probably been compositionally altered to some degree during their residence in the desert. This alteration is most obvious in Dhofar 025, where the Sr content is more than 10 times higher than the typical concentration in unweathered but otherwise similar lunar highland regolith samples. Lesser, but still significant Sr contamination is also present in Dhofar 026 and 081. Our (preliminary) results for Ba in Dhofar 026 and especially Dhofar 025 also indicate contamination. However, the preservation of troilite and FeNi metal in Dhofar 026 appears good [3], so we can reasonably suppose that most elements, including siderophile elements, have not been radically altered.

Dhofar 081 is easily the most pure-anorthositic

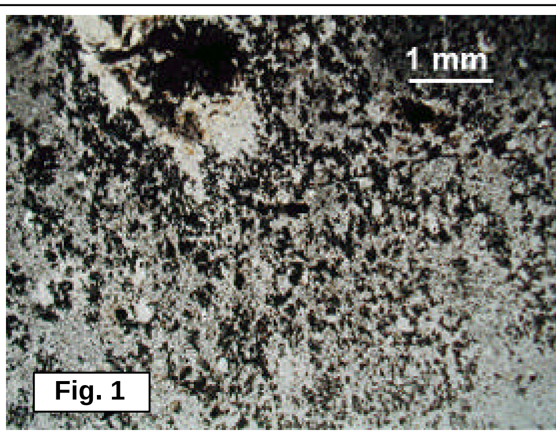


Fig. 1

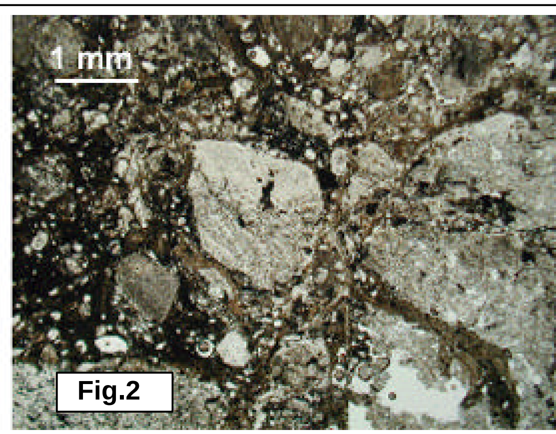
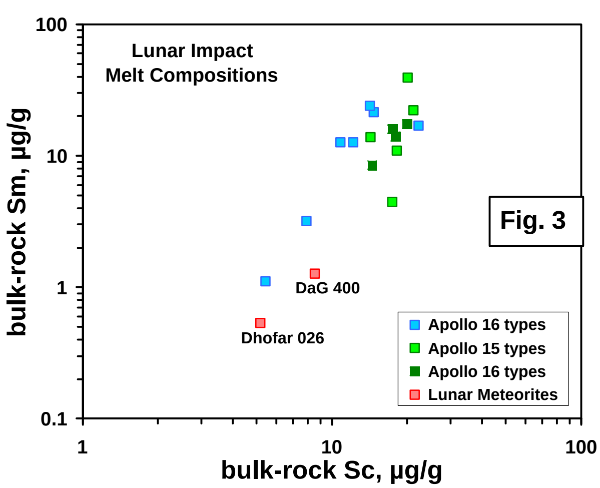


Fig.2

lunar meteorite. As noted by Greshake et al. [1], Dhofar 081 resembles MAC88105; so, conceivably the two are launch-crater paired. We confirm that Dhofar 081 and MAC88105 [5] have similarly low *mg* (63 mol%). Also, both have uncommonly low Ni/Ir (only 0.7X chondritic in Dhofar 081). This ratio is usually greater than chondritic in other lunar meteorites and thoroughly polymict Apollo 16 highland samples. This is still only weak circumstantial evidence, but careful study of the cosmic-ray exposure history of Dhofar 081 is clearly warranted. Our analysis has not confirmed the remarkably high Na content nor the low Ca/Al ratio found in the initial [1] admittedly imprecise analysis.

A remarkable feature of our analysis of Dhofar 026 is that the most "noble" siderophile elements, Os and Ir, are at approximately 1X CI-chondritic levels. Not included in Table 1 are Re and Ru, but we have determined them semi-quantitatively, and they, too, are at approximately 1C CI. Yet Ni and Au, two similarly siderophile elements, are at only 0.02-0.03× CI. These results are enigmatic. The data of [4], derived from a much larger sample (~1 g), are similar for Ni and Au, but unexceptional for Ir. The Ru-Re-Os-Ir enrichment is not easily explained as artificial contamination. Why should these elements be in roughly chondritic proportion, if they came from an artificial source (jewelry?, a Pt crucible?)? If the contamination source was another handled meteorite, why should Ni/Ir and Au/Ir be so extremely fractionated? It seems at least conceivable that this petrologically weird and heterogeneous impact-melt breccia is also inhomogeneous with respect to siderophile-rich nuggets. We plan further analysis, hopefully with a larger sample.

As an impact-melt breccia, Dhofar 026 resembles Dar al Gani 400 [6,7] (which, however, has a much higher *mg* than Dhofar 026), inasmuch as both have remarkably low incompatible element contents in comparison to Apollo impact melt breccias (Fig. 3).



This difference even appears significant if the comparison is made to similarly Sc-poor melt rocks of Apollo 16 groups 3 and 4 (Apollo melt rock data are from [8-10].)

References: [1] Greshake A. et al. (2001) *MaPS*, in press. [2] Taylor L. A. et al. (2001) This volume. [3] Cohen B. A. et al. (2001) This volume. [4] Tayor L. A. et al. (2001) This volume. [5] Lindstrom M. M. et al. (1991) *GCA 55*, 2999. [6] Zipfel J. et al. (1998) *MaPS 33*, A171. [7] Bukovanska M. et al. (1999) *MaPS 34*, A21. [8] Lindstrom M. M. et al. (1990) *PLPSC 20*, 77. [9] Korotev R. L. (1994) *GCA 58*, 3931. [10] Ryder G. (1992) p. 49 in *Workshop on Geology of the Apollo 17 Landing Site*, LPI Tech. Rpt. # 92-09.

Table 1. Bulk compositions of Dhofar meteorites.

		Dhofar	Dhofar	Dhofar
		25	26	81
Na	mg/g	2.53	2.50	2.27
Mg	mg/g	39	39	17
Al	mg/g	142	141	160
Si	mg/g	210	210	210
K	mg/g	0.44	*0.38*	0.17
Ca	mg/g	115	121	120
Sc	μg/g	10.3	9.1	5.4
Ti	mg/g	1.7	1.7	0.9
Cr	mg/g	0.81	0.83	0.41
Mn	mg/g	0.57	0.53	0.36
Fe	mg/g	38	38	22.8
Co	μg/g	17	18	9.8
Ni	μg/g	*110*	*170*	*85*
Ga	μg/g	3.1	3.7	2.4
Sr	μg/g	1900	*200*	240
Ba	μg/g	130	56	*19*
La	μg/g	3.0	3.1	1.43
Ce	μg/g	7.8	*8.7*	*3.4*
Nd	μg/g	*5*	*5.6*	1.9
Sm	μg/g	1.4	1.5	0.63
Eu	μg/g	0.9	0.9	0.7
Tb	μg/g	0.32	0.37	0.15
Ho	μg/g	0.44	0.41	0.18
Yb	μg/g	1.20	1.1	0.51
Lu	μg/g	0.18	0.17	0.073
Hf	μg/g	0.94	0.97	0.44
Ta	μg/g	<0.3	<0.4	<0.1
Re	ng/g	<20	*40*	<10
Os	ng/g	<300	*560*	<300
Ir	ng/g	*6*	510	5
Au	ng/g	5.1	4.4	5.2
Th	μg/g	*0.5*	*0.5*	0.20
U	μg/g	*0.2*	*0.2*	0.07