PETROGRAPHY AND GEOCHEMISTRY OF DHOFAR 733 – AN UNUSUALLY SODIC, FELDSPATHIC LUNAR METEORITE.

A. B. Foreman, R. L. Korotev, B. L. Jolliff, and R. A. Zeigler, Department of Earth and Planetary Sciences, Washington University, Campus Box 1169, Saint Louis, MO 63130; Andrewforeman@levee.wustl.edu

Introduction: Dhofar 733 is a 98-g lunar meteorite collected in the Dhofar region of Oman in 2002 [1]. In the initial description [1], Dhofar 733 is described as an anorthositic granulitic breccia, one that is probably not paired with any other lunar meteorite on the basis of its unique texture and isolation from other lunar meteorites (the next closest lunar meteorite was found 22 km away). The brownish gray stone does not have a fusion crust and is "moderately weathered." Terrestrial alteration minerals include gypsum, smectite, and Fe hydroxides [1].

Methods: We obtained from a meteorite dealer a 32-mg sample of Dhofar 733 (0.1× the mass we would have preferred, but we have not been able to obtain more). We divided the sample into two splits for INAA (instrumental neutron activation analysis, Table 1).

The compositions of both splits are similar (e.g., 3.28 and 3.25% FeO). After INAA, we fused one split into a glass bead and determined major-element concentrations by EPMA (electron probe microanalysis, Table 1). We prepared a polished thick section of the other split and determined mineral compositions via EPMA (Table 2). Plagioclase was analyzed with a 10–20-µm beam whereas mafic minerals were analyzed with a 1-µm beam.

Results: With 29.5% Al_2O_3, Dhofar 733 is one of the most feldspathic of all lunar meteorites [3,4]. Our sample of Dhofar 733 contains a plagioclase matrix (87% normatively, 84% modally) with interstitial granoblastic grains of olivine (10 vol% both by norm and mode). Poikiloblastic low and high-Ca pyroxene (2.5% norm (vol%), 1.5% modal) and minor amounts (0.15%) of the accessory minerals armalcolite, chromite, rutile, ilmenite, and Ca phosphate (Fig. 1). Olivine textures are commonly anhedral and equant, with boundaries forming smooth curves approaching 120° triple junctions, consistent with the classification of feldspathic granulitic impactites [4–7] (Fig. 1). The plagioclase has a relatively sodic (for the Moon) average composition of An_{93}, with a small amount of compositional zoning observed ($An_{91–96}$). The olivine ($Fo_{70–77}$) and orthopyroxene (Wo_4En_{78}) are both magnesian and relatively well equilibrated. Alteration comprises some 4 vol.% of the section

Table 1. Bulk composition of Dhofar 733.

SiO_2	44.3	Sc	3.89	Eu	1.63
TiO_2	0.27	Co	9.9	Tb	0.109
Al_2O_3	29.5	Ni	35	Yb	0.360
Cr_2O_3	0.05	Sr	410	Lu	0.050
FeO	3.27	Zr	10	Hf	0.34
MnO	0.05	Ba	90	Ta	0.060
MgO	5.37	La	1.58	Ir	1.3
CaO	16.2	Ce	3.66	Au	5.0
Na_2O	0.70	Nd	2.3	Th	0.104
K_2O	0.04	Sm	0.580	U	0.14
P_2O_5	0.02	Oxides in wt%, others in µg/g, except Au and Ir in ng/g.			
sum	99.77				

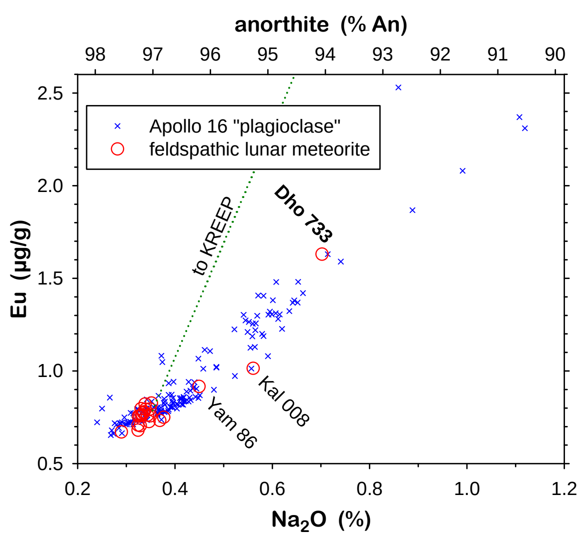

Figure 2. In plagioclase-rich rocks from the lunar highlands, the concentration of Eu (and Sr) increases with albite content of the plagioclase. The "anorthite" axis is based on plagioclase stoichiometry assuming pure plagioclase.

Compositionally, Dhofar 733 is unusual among feldspathic lunar meteorites, as well as Apollo samples, in being magnesian (bulk molar Mg/[Mg + Fe] = 74%) and having high (again, by lunar highlands standards) concentrations of Na and Eu (Fig. 2). Some samples from Apollo 16 (mainly from North Ray Crater) are similarly sodic, but have ferroan-anorthositic suite affinities [8]. The whole-rock Na_2O concentration of Dhofar 733 requires plagioclase with a mean composition of An_{94} (Fig. 2), similar to the average plagioclase composition obtained via EPMA, An_{93}. Thus, the plagioclase in Dhofar 733 is about twice as sodic, on average, as that in most feldspathic lunar meteorites ($An_{96–97}$) and the Eu concentration is also about twice as great (Fig. 2).

Discussion: Dhofar 733 must have formed at depths well below the regolith in order to account for the low concentrations of siderophile and incompatible elements [3], the high degree of equilibration witnessed among mineral phases, and the granulitic textures. These textures are characteristic of post-formation high-temperature metamorphism [4–7]. It has been noted by [4] that homogeneity of mineral compositions within feldspathic granulitic impactites is typically on the scale of a few millimeters. Though our subsample is only 2.5 mm in length (Fig. 1 a, b), the mineral composition variations closely follow the variability of compositions within the type specimens [1].

Dhofar 733 does not derive from alkali anorthosites such as those of the Apollo 12 and 14 sites. Alkali anorthosites crystallized from a liquid rich in incompatible elements [9] and are products of the Procellarum KREEP Terrane. Dhofar 733 is a product of the Feldspathic Highlands Terrane. Like Dhofar 489 et al. [3,10], it derives from a magnesian (troctolitic) anorthosite, but one more sodic than any observed before. If our sample is representative of the meteorite, then Dhofar 733, a meteorite from some unknown location in the feldspathic highlands, provides another constraint for models of formation of the feldspathic crust of the Moon.

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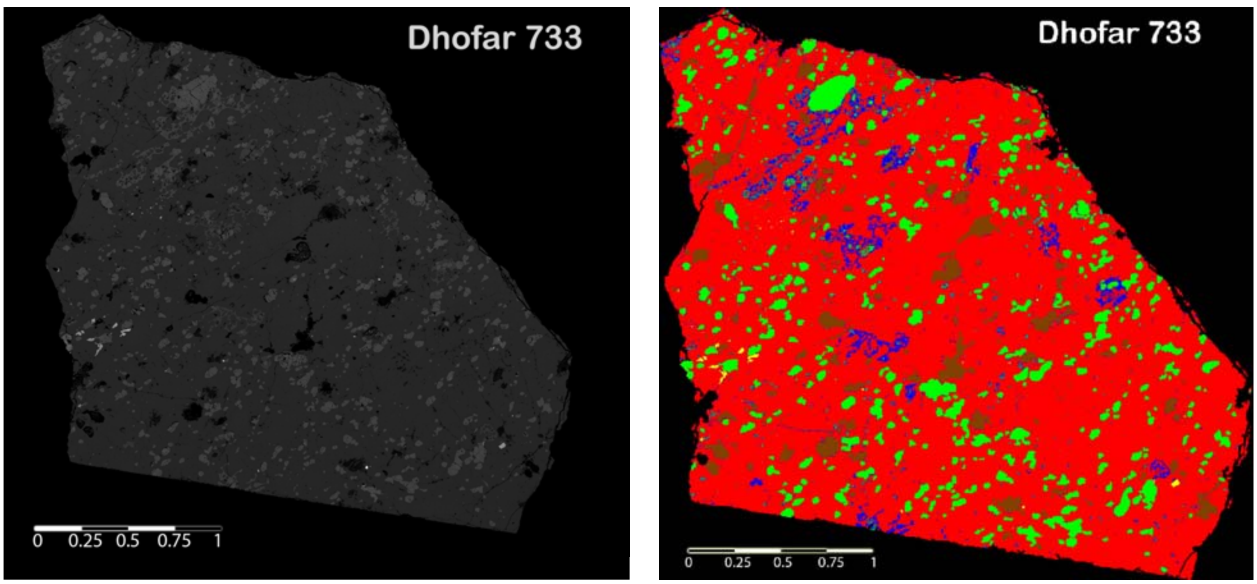

Figure 1. (a) Back-scattered electron (BSE) mosaic of Dhofar 733. Scale in mm. (b) False-color image of Dhofar 733. Red = Plagioclase/Maskelynite, Green = Olivine, Blue = Pyroxenes, Yellow = Oxides, Brown = Fractures. Scale in mm.

Table 2. Average compositions (weight %) of mineral assemblages in Dhofar 733.

	Olivine	Plagioclase (An_{91-93})	Plagioclase (An_{94-96})	Armalcolite	Chromite	Ilmenite	Pyroxene	Rutile
# of analyses	7	6	4	2	3	2	3	1
SiO_2	38.65	45.14	44.79	0.03	<0.02	<0.02	54.61	<0.02
TiO_2	0.05	0.06	0.07	71.17	5.50	57.13	0.89	96.82
Al_2O_3	0.07	35.51	36.14	1.93	13.78	0.20	1.14	0.11
Cr_2O_3	0.07	<0.02	0.02	1.23	43.67	0.88	0.47	0.17
FeO	23.03	0.15	0.20	14.58	26.18	31.52	13.68	0.17
MnO	0.24	0.05	<0.03	0.07	0.28	0.32	0.29	<0.04
MgO	37.56	0.08	0.10	7.87	7.20	8.36	26.62	<0.01
CaO	0.23	18.82	19.31	0.37	0.51	0.31	2.15	0.48
Na_2O	<0.02	0.89	0.58	<0.02	<0.02	<0.02	0.05	<0.02
K_2O	<0.01	0.04	0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Total	99.90	100.73	101.25	97.24	97.11	98.70	99.90	97.75