TRACE ELEMENT CHEMISTRY OF LUNAR HIGHLAND METEORITES FROM OMAN.

Mikhail A. Nazarov[1], Svetlana I. Demidova[1], and Lawrence A. Taylor[2]; [1]Vernadsky Institute of Geochemistry and Analytical Chemistry, Moscow 117975, Russia (nazarov@geokhi.ru); [2]Planetary Geosciences Institute, University of Tennessee, Knoxville TN 37996, USA (lataylor@utk.edu).

Introduction: During the last few years, numerous lunar meteorites have been discovered in the Dhofar region of Oman. All of them are lunar highland breccias, except for Dhofar 287A, which is a mare basalt. In this paper, we present the first trace-element chemistry of these new lunar highland meteorites: Dhofar 280, 301-310. Mineralogy and petrology of these meteorites have been reported in [1,2,3].

Results: Meteorites Dh 025, 301, 304, and 308 were found relatively close together. For purposes of discussion, this group will be designated as Dh 025, because this is the largest stone in this group. Meteorites Dh 302, 303, 305, 306, 307, 309, and 310 were collected near to Dh 081 and Dh 280 in another area. Dh 280 is the largest meteorite in this group, hence, the designation as Dh 280 for this meteorite group. Representative 10-20 mg chips of each meteorite were analyzed for trace elements by INAA. Characteristic trace-element relationships are shown on Figs 1-5, as compared to those of other lunar meteorites and lunar rocks.

Lithologic Compositions: Similar to other lunar meteorites, the Dhofar finds are depleted in incompatible elements and show a strong positive correlation on an Sm-Sc plot (Fig. 1). The trend is aligned in the general direction of the Luna 20 highland soil and lies within the noritic anorthosite field [4]. Obviously, lunar meteorites do not contain the MIMB (mafic-impact-melt breccia) component [4], which is of major significance in Apollo 16 soils. They do not show any evidence for contamination by KREEP and mare basalt material. However, the Dh 025 and the Dh 280 families are very different within the range of lunar meteorite compositions. Whereas the Dh 025 meteorites are highest in Sm and Sc, the Dh 280 group is lowest in these elements. Because Sc is present mainly in pyroxene, the Sc- and Sm-depleted finds should be enriched in anorthositic and/or troctolitic lithologies, and they are. On the MG# versus Sc plot (Fig. 2), the Dh 025 group appears to indicate the highest pyroxene (Sc) enrichment among lunar meteorites, whereas the low-Sc Dh 280 group shows a large scatter. Individual meteorites Dh 280 and 081 are lowest in MG# and highest in feldspar [2], e.g., highest in the FAN component. Conversely, Dh 303, 306, 307, 309, and 310 form a very compact group of rocks lowest in Sc and highest in MG#. This group is enriched in troctolitic lithologies [3]. Breccias Dh 302 and 305 are intermediate in composition.

Pairing: Terrestrial residence time is a common first approach to estimating pairings of meteorites. Lacking such data, we have taken another approach. Within a particular climatic terrain on Earth, it is to be expected that meteorites with different degrees of weathering would have different terrestrial ages. That is, their pairings would be highly improbable. Not unexpectedly, hot-desert weathering of meteorites is substantially different from that in the Antarctic. The weathering additions of Ba and Sr to the hot-desert meteorites is a ‘signature’ of this environment, but more importantly, can be used to estimate the degree of weathering that a given meteorite has experienced. Enrichment in Ba and Sr is evidenced by the common presence of secondary barite and celestite mineralization in these meteorites.

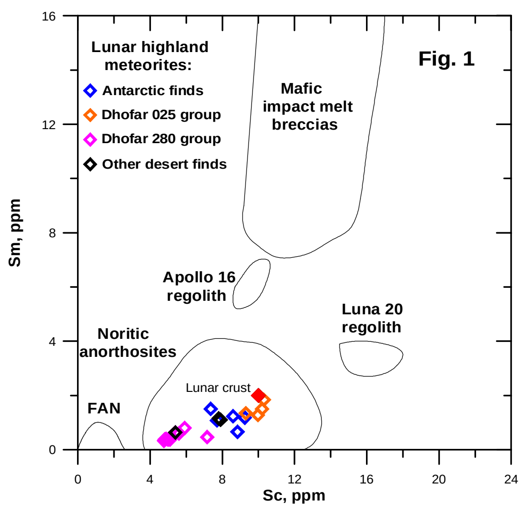
Based on this Ba-Sr-weathering axiom, it is strongly suggested that the Dh 025 meteorites, which are similar to each other and richest in Ba and Sr, possibly represent a single and most-ancient fall. In the Dh 280 group, Dh 081 and 280 are lowest in Ba and Sr and reside in the field of Antarctic lunar meteorites. Other members of this group have distinctly higher Ba and Sr. This suggests that the Dh 280 family consists clearly of at least two different falls: (1) a recent Dh 081/280 fall, and (2) an older fall, including the other family members. Furthermore, this separation is supported by geochemical differences among the Dh 280 meteorites (Fig. 2), which suggest that Dh 302 and 305, indeed, could be the result of different events. In support of this, Dh-305 appears to be the most-weathered meteorite in the population (Fig. 3). Thus, by this Ba-Sr signature, it would appear that there must be at least 2, perhaps 4, independent lunar meteorite falls in the Dh-280 area.

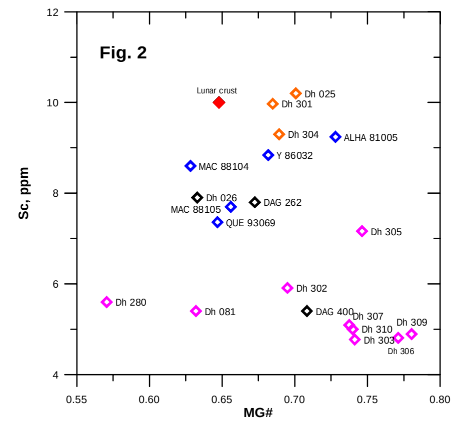
Siderophile-element paradox. All lunar meteorites are enriched in siderophile elements (Ir, Ni, Co), which are positively correlated. Ratios of Ir/Ni are approximately cosmic, but Co/Ni values are generally higher, possibly indicating a presence of 10-12 ppm of indigenous Co. The siderophile excess in the lunar meteorites is thought to indicate a contamination of lunar rocks with extra-lunar cosmic material [e.g., 5]. Interestingly, however, that the extraneous siderophiles positively correlate with the indigenous incompatible elements such as La, Sm, Hf, Th (Fig. 4). Similar relationships are reported to exist in the lunar FAN suite [6], as shown in Fig. 5. For example, the Sm/Ni values in lunar highland meteorites are close to and on an extention of the FAN values.

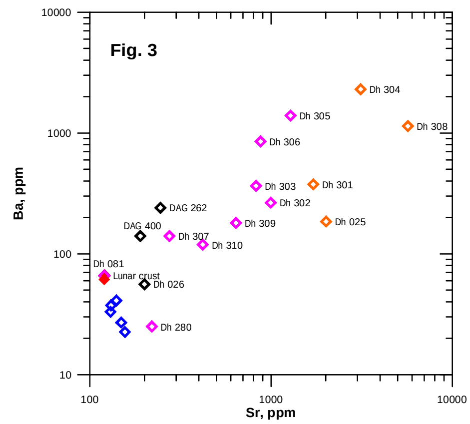
There are two possible explanations for this apparent paradox: 1) The situation producing these relationships was caused by impact mixing. This suggests that lunar meteorites were contaminated by ejecta material enriched in both cosmic siderophiles and lunar incompatible elements. In this case, however, FANs could be considered as impact-produced rocks resulted from impact mixing. 2) The elemental abundances resulted from incompatible behavior of the siderophiles during crystallization of the feldspatic rocks. This would suggests that the extraneous siderophiles were incorporated into the outer portion of the Moon *before* FAN formation, then involved in magmatic fractionation as lunar elements. This suggests, also, that the lunar meteorites contain only ancient extraneous component, i.e., they were not contaminated by cosmic material during the heavy bombardment or later.

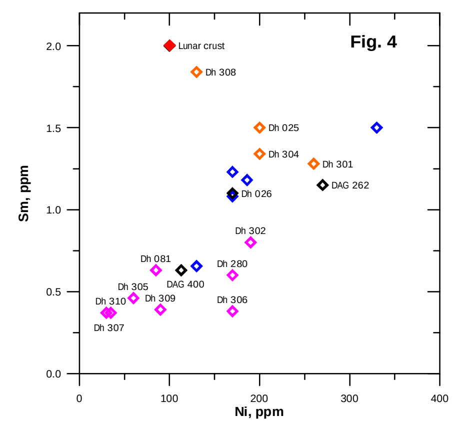
References: [1] Nazarov M.A. et al., (2002) *LPSC*, **33**, #1293; [2] Cahill J.T. et al. (2002) *LPSC*, **33**; [3] Demidova S.I. et al. (2003) *LPSC*, **34**, This volume; [4] Korotev R.L. (1997) *MAPS*, **32**, *447-478;* [5] Palme H et al. (1991) *GCA*, **55**, 3105-3122; [6] Nazarov M.A. (1984) *LPS*, **XV**, 591-592; [7] Bishoff A. et al. (1998) *MAPS*, **33**, 1243-1257; [8] Zipfel J. et al. (1998) *MAPS*, **33**, A171; [9] Taylor S.R. (1982) *Planetary Science - A lunar perspective*. LPI

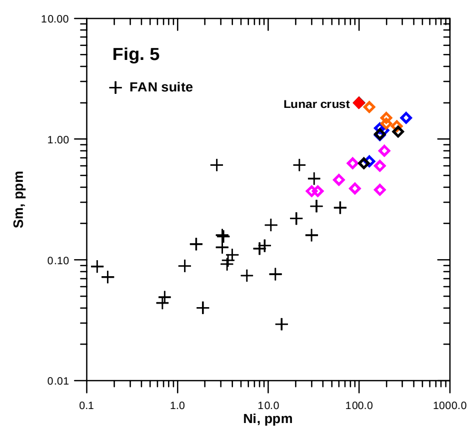
Acknowledgements: This study was supported by RFBR (grant 02-05-64981).











Figs 1-5. Data source: Dhofar lunar meteorites are from our lab; other lunar meteorites are from [5,7,8]; the lunar crust composition is from [9]; the FAN suite is from Warren et al. publications; the fields on Fig. 1 are from [4]