TRACE ELEMENT CHEMISTRY OF A SILICON-BEARING ASSOCIATION IN THE DHOFAR 280 LUNAR METEORITE. M. O. Anosova[1], M. A. Nazarov[1], S. I. Demidova[1], Yu. A. Kostitsyn[1], Th. Ntaflos[2], and F. Brandstaetter[3] [1]Vernadsky Institute of Geochemistry and Analytical Chemistry, Moscow 119991, Kosygin St., 19, Russia, e-mail: anosova@geokhi.ru [2]Department für Lithosphärenforschung, Universität Wien, Althanstrasse 14, 1090 Wien, Austria; [3]Naturhistorisches Museum, Burgring 7, 1010 Wien, Austria.

Introduction: Dhofar 280 is a lunar impact melt breccia of anorthositic composition [1]. The rock contains rare Fe-silicides [2] and native silicon associated with a SiO_2-rich melt [3]. Here we report on a trace element study of the unusual association.

Methods: A laser ablation system UP-213 (New Wave) attached to inductively coupled plasma-mass spectrometer Element-XR was used to measure Al, P, Ca, V, Fe, Ga, Ge, Rb, Sr, Zr, Nb, Sb, La, Ce, Nd, Sm, Eu, Gd, Tb, Yb, Lu, W, Pb, Th, and U. Laser pulse frequency of 4 Hz and beam diameter of 30 µm were used for the analyses. Data reduction was performed with Glitter software program [5]. Analyses were calibrated against the NIST 612 external standard. No internal standard was used and the trace element chemistry is considered here in terms of element ratios. We performed one analysis of a silicon (Si^o)-bearing inclusion (Fig. 1), 7 analyses of the SiO_2-rich melt containing rare inclusions of Fe-silicides and native silicon, and 12 analyses of the Dho 280 impact melt matrix. The analyzed spots are too big and include therefore different components but they are sufficient to show some specific trace element characteristics of the unusual lunar assemblage.

Results: The obtained data demonstrate that the Si^o -rich inclusion is strongly enriched in P, Ga, W, Pb and U relatively to the Dho 280 matrix (Fig. 2). The SiO_2-rich melt exhibits similar but less prominent enrichments. Th/U ratio of both Si-rich constituents is significantly lower (0.18 and 2.3) than that of lunar rocks (3.8). Other measured elements, except for Sm, Eu, Yb, and Lu, are 1.5-3 times higher than those in the Dho 280 matrix. Sm, Eu, Yb and Lu are certainly depleted in the Si^o -rich inclusion relatively to the matrix. (Fig. 2). The SiO_2-rich melt does not show these depletions although Eu is distinctly low in the element pattern. The chondrite - and La - normalized REE patterns of both Si-rich constituents reveal however a positive Eu anomaly that is typical for lunar highland rocks (Fig. 3). Nevertheless, there are also distinct Sm, Yb and Lu depletions in the pattern of the Si^o-bearing object. Ge, Rb, and Sb contents are below detection limits in the Dho 280 matrix but the elements are certainly detectable in the Si^o -rich inclusion and the SiO_2-rich melt. Ge(ppm)/Al(wt%) is 4.3 in the Si^o -rich inclusion. This value is extremely high for lunar rocks. The Rb/Al ratio of the inclusion is not too high but Rb/La (3.2) of the object is very high and comparable with that of lunar granites. When normalized to Al, both refractory (e.g., REEs, Th, Zr etc.) and volatile (e.g., P, Ga, Pb etc.) elements show positively correlated different trends (Fig. 4, 5).

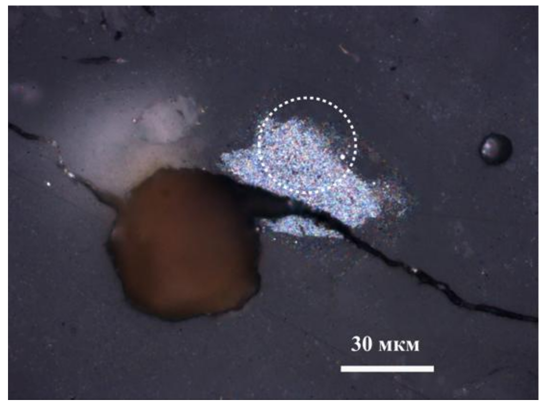

Fig.1. The analyzed Si^o-rich inclusion. The circle shows the area of the analysis by LA-ICP-MS. Reflected light.

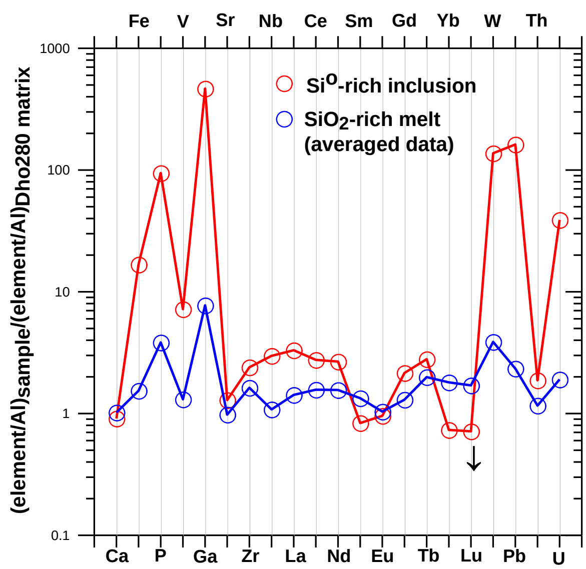

Fig. 2. Al- and Dho 280 matrix-normalized element contents of the Si-rich constituents.

Discussion: The study demonstrates that the Si^o -rich inclusion and the SiO2-rich melt are strongly enriched in volatile elements and elements which can be easily reduced. Some of the elements can be present in Fe-silicides as cations, e.g. U, W, whereas Ge and

Pb can replace Si in both metallic silicon and Fe-silicides. Refractory lithophiles are only slightly higher in the Si-rich constituents compared to the Dho 280 matrix and can be present also in Fe-silicides. The prominent Sm, Eu, and Yb depletions (Fig. 2, 3) in the Si^{o} -rich inclusion relatively to the Dho 280 matrix can be due to the extremely reducing conditions. In contrast to other REEs, the elements can be in 2+ state and could be extracted into the adjacent silicate melt. However it is not the case for Lu that is always exists as Lu^{3+}. Therefore, the depletions in heavy REEs could be also the result of local partial melting.

The Ge enrichment of the association could be related to contamination of an iron meteorite projectile that is indicated by enhanced Ni content of Fe-silicides [3]. The same is possible for P, Pb and Sb at least partly. However a significant portion of Ga should be of lunar origin. The Ga/Ge ratio (10-15) of the silicon-bearing association is much higher than that of CI (~0.3) and most abundant iron meteorites (<0.3). Rb should be also derived from a lunar source because Rb is extremely poor in iron meteorites.

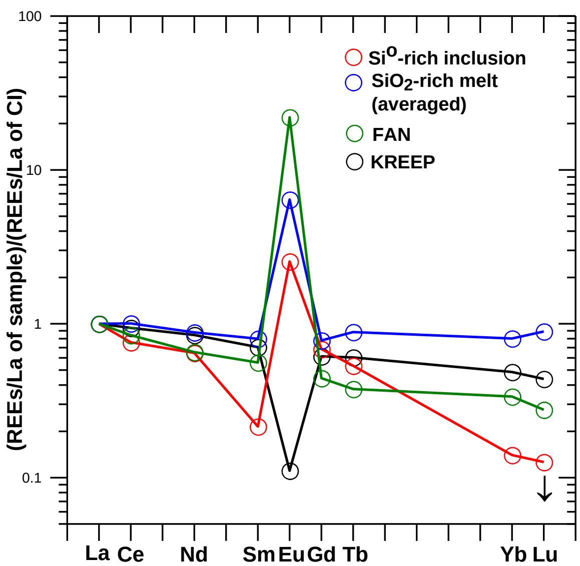

Fig. 3. REE element patterns of the Si-rich constituents, FAN and KREEP rocks.

Element relationships (Fig. 4, 5) indicate that the Si-rich constituents cannot be related with known lunar rocks by processes of magmatic fractionation or mechanical mixing. The volatile element enrichment could be originated in lava fountains similar to that of orange and green glasses [e.g.,4]. Alternatively, the volatile metals could be condensed from an impact-generated vapor. The last case is much more probable because the Si-rich assemblage includes both lunar (e.g., Rb, Ga) and meteorite (e.g., Ge, Ni) volatiles. The occurrence of such an association in an impact melt breccia strongly supports an impact origin of the volatiles as reduced condensates of a silicate vapor [3].

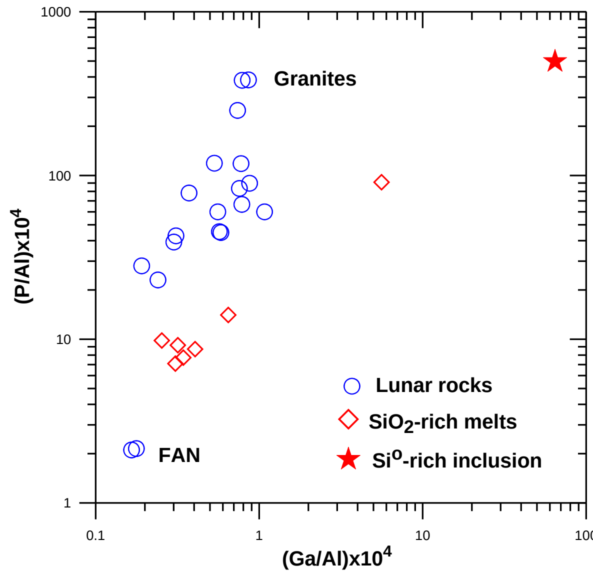

Fig. 4. P/Al vs. Ga/Al in the Si^{o}-bearing association and lunar rocks.

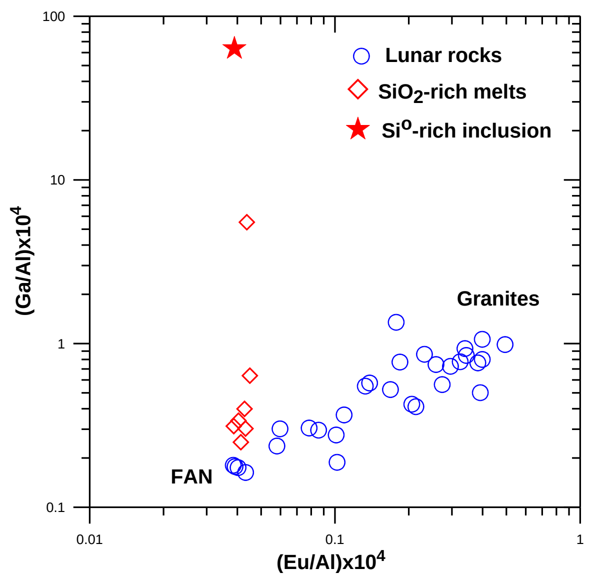

Fig. 5. Ga/Al vs Eu/Al in the Si^{o}-bearing association and lunar rocks.

References: [1] Demidova S.I. et al. (2007) *Petrology*, 469-472. [2] Anand M. et al. (2004) *PNAS* 101, 6847-6851. [3] Nazarov M.A. et al. (2012) *this volume.* [4] Chou C.-L. et al. (1975) *PLSC 6th*, 1701-1727. [5] van Achterberg E. et al. (1999) *Proc. 9th Goldschmidt Conf*, 305.