DEEP-SEATED CRUSTAL MATERIAL IN DHOFAR LUNAR METEORITES: EVIDENCE FROM PYROXENE CHEMISTRY.
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Introduction: Very rare fragments of spinel cataclasites were found in lunar breccias 15445, 72435 and 73263 collected by Apollo 15 and 17 missions [e.g.,1,2]. The rocks consist of Al-rich orthopyroxene, Mg, Al-rich spinel, plagioclase and olivine. Based on experimental data and thermodynamic analysis, the spinel cataclasites were interpreted as deep-seated lunar crustal rocks which equilibrated at depths of more than 12 km or even in the uppermost lunar mantle [3,4,5]. A spinel cataclasite clast has been recently documented in the lunar meteorite Dhofar 310 [6]. It suggests that lunar meteorites could contain a certain portion of deep-seated lunar crustal material. The goal of this study was to search for such components in lunar meteorites collected in the Dhofar region of Oman.

Approach: Al-rich orthopyroxene is a characteristic phase of spinel cataclasites. Therefore, a high-pressure component can be documented by the presence of Al-rich orthopyroxene fragments in lunar breccias. However, enrichment in Al in orthopyroxenes could be related also to disequilibrium during fast crystallization from a melt and not exclusively to high-pressure equilibria. It has been noted, however, that high-Al orthopyroxene of lunar spinel cataclasites is very poor in Ca [2] that should be enhanced similar to Al in quickly crystallized pyroxenes. Taking into account the Al enrichment and the Ca depletion, we searched for orthopyroxenes derived from spinel cataclasites in our database on mineral chemistry of Dhofar lunar highland meteorites. About 1000 EMP analyses of low-Ca pyroxene (CaO <5 wt%) from Dho 025, 301-307, 309-311, 730, 731, 733, 925, 950, 960 and 961 were used.

Results: Al-rich, Ca-poor orthopyroxenes were found in Dho 303, 306, 307, 310, 925 and 950. In their Al and Ca contents, the grains are not distinguishable from those of spinel cataclasites from lunar samples and Dho 310 but they differ strongly from usual orthopyroxenes analyzed in lunar meteorites (Fig. 1). All meteorites, except Dho 925, are highland impact melt breccias. They are troctolitic anorthositic in composition and are probably paired [7]. Dho 925 is a mixed meteorite, which contains highland, VLT, KREEPy and granitic lithologies [8]. Only one grain of Al-rich orthopyroxene was found in this meteorite. The Al-rich pyroxene is most abundant in Dho 950 in which a small intergrowth of Al-rich orthopyroxene (3.2 wt% Al_2O_3; 0.27 wt% CaO; MG# 90) and spinel (Cr/Cr+Al=0.1(at.) MG# 77) was also found. Compared to the Dho 310 cataclasite [6], the assemblage is poorer in Al and richer in Cr. The richest in Al (up to 9.6 wt% Al_2O_3) and largest orthopyroxenes (up to 80 μm) were recognized also in Dho 950.

A prominent characteristic of the Al-rich, Ca-poor orthopyroxenes is their high MG# (Fig. 2). All pyroxenes have practically the same MG# of about 90. As compared to common orthopyroxenes, Al-rich enstatites appear to be poorer in Cr (Fig. 3). Chromium and Al correlate positively in all orthopyroxenes but the Al-Cr trend of Al-rich enstatites has a steeper slope. In contrast, Ti and Al do not show a significant correlation in Al-rich enstatites (Fig. 4). However, it appears that the Al-rich enstatites are not systematically poorer in Ti relatively to common orthopyroxenes. The Fe/Mn ratio is the same in both types of orthopyroxenes (Fig. 5). The best fit line: FeO (wt%) = 53.92±0.77*MnO (wt%) – 0.12±0.24 defines an average Fe/Mn ratio for the lunar orthopyroxene population.

Discussion: The study shows that Al-rich, Ca-poor orthopyroxenes are present in lunar highland meteorites. In composition, the grains are very similar to those of lunar spinel cataclasites and, therefore, could be derived from the same or a similar high-pressure lithology. The deep-seated origin of the grains is supported by their rarity and their restricted MG# range indicating that they come from an equilibrated, very slowly cooled lithological unit.

Depth estimates cannot be done based on Al content in the enstatites because the Al concentrations are dependent not only on T, P parameters but they are sensitive also to the composition of co-existing phases [5]. Even if all necessary parameters are known, only a minimum depth can be obtained [5]. However, the big range of Al content in the enstatites suggests that they probably represent a variety of high-pressure lithologies.

The distinctly low Ca content in Al-rich enstatite should reflect a Ca-poor precursor. In fact, the enstatite compositions are buffered by forsterite and spinel [4,5], which are Ca-poor phases. Apparently, Ca-rich pyroxene should be absent in the parent environment. If so, the lower lunar crust should be strongly depleted in Ca-rich pyroxenes as compared to the upper crust. The troctolitic composition of lunar meteorites, in which Al-rich enstatite is most common, suggests that troctolitic lithologies should dominate the lower lunar crust. In spite of the possible compositional differences, the similar Fe/Mn ratio of all orthopyroxenes means that the lower and upper crustal units were formed under similar redox conditions.

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References: [1] Bence A. E. et al. (1974) *PLSC 5th*, 785-827. [2] Warner R. D. et al. (1978) *PLPSC 9th,* 941-958. [3] Bence A. E. et al. (1978) *LPS IX*, 67-69. [4] Herzberg C. T. (1978) *PLPSC 9th*, 319-336. [5] Herzberg C. T. and Baker M. B. (1980) *Proc. Conf. Lunar Highlands Crust,* 113-132. [6] Demidova S. I. et al. (2003) *MAPS*, 38, A30. [7] Nazarov M. A. et al., (2004) *LPSC XXXV*, #1233. [8] Demidova S. I. et al. (2005) this volume.