SECONDARY ALTERATION OF A PYROXENITE FROM THE DHOFAR 1302 HOWARDITE: A POSSIBLE RECORD OF WATER METASOMATISM. C. Lorenz[1], F. Brandstäetter[2], N. A. Starkey[3], I. A. Franchi[3], [1]Vernadsky Institute of Geochemistry and Analytical Chemistry RAS, Kosygin St. 19, 119991, Moscow, Russia, c-lorenz@yandex.ru, [2]Naturhistorisches Museum, Postfach 417, A-1014 Vienna, Austria, franz.brandstaetter@nhm-wien.ac.at, [3]Planetary & Space Sciences, Open University, Milton Keynes, UK.

Introduction: Traces of metasomatism are rare in the HED achondrites because of the initial deficit of volatiles of the HED parent body and their rapid loss into space during magmatic and impact processes. Only a few signs of post-magmatic mass transfer are known in the HED meteorites. The secondary alteration of the pyroxenite fragment from the Dho 1302 howardite described here could be a result of water metasomatism on the HED parent body. Preliminary NanoSIMS study of the oxygen isotopic composition of the fragment indicates an indigenous nature for the secondary alterations.

Results: A fragment of pyroxenite ~15 mm^2 in size was found in the Dho 1302 howardite. The pyroxenite is composed of coarse-grained pyroxene $En_{76}Wo_{1.1}$ (Fe/Mn=30) with minor 15-60 µm subhedral chromite inclusions. Rare thin chromite veinlets of the same composition and chains of tiny chromite inclusions were also observed.

The pyroxenite fragment is fractured. The pyroxene is zoned from En_{76} to En_{72} toward the closed subparallel fractures (Fig. 1).

The pyroxene is crossed by olivine veins 5-50 µm width and up to 500 µm in length. The thick veins are linear; the narrow ones are curved and have apophyses. The contact between the olivine and the host pyroxene is irregular (Fig. 2). The polished surface of the olivine is finely fractured and has small holes in contrast to the surface of the host pyroxene. The veins consist of homogeneous olivine Fo_{68} (Fe/Mn=60), locally enriched in P_2O_5 up to 0.5 wt%. The host pyroxene is zoned toward the thick olivine veins, from En_{76} to En_{72} over a width of ~50 µm. The pyroxene zoning observed along the closed fractures has a similar compositional range to that observed along the olivine veins. Most probably these veins are traces of olivine veins located below or above the surface of the section.

Some of the veins inherit fractures that have crossed large chromite grains and have displaced their fragments along the fractures. Other veins occasionally contain isolated small chromite grains similar in composition to the large chromite grains, and both populations of chromites probably have similar origin.

The oxygen isotopic compositions of the host pyroxene and the olivine veins were analyzed in a gold-coated thick section of Dho 1302 by NanoSIMS following the methods of [1]. Four analyses of the olivine yielded an average $\delta^{18}O$ value of 3.1 ± 1.0 (2σ)‰. A fifth analysis had much lower $\delta^{18}O$ = 0.3‰. The reason for this anomalous value is unclear but may have been related to the fractured surface in the vicinity of the measurement. The $\Delta^{17}O$ of the olivine is -0.6 ± 1.0‰. The pyroxene isotopic data are not fully calibrated yet but the $\delta^{18}O$ is similar to that of the olivine and the $\Delta^{17}O$ = -0.14 ± 2.1‰.

Discussion: The pyroxenite fragment has a chemical [2] and isotopic [3] composition in the HED range. The fragment is similar to diogenites and was possibly formed on the HED parent body.

The high-Mg olivine veins are unique and have not been previously observed in HED pyroxenes. Among the Dho 1302 material, the veins occur only in the pyroxenite fragment and therefore originated before the mixing of the howardite components. The veins' olivine (Fo_{68}) has Fe/Mn ratio of 60, which strongly differs from the Fe/Mn ratio of HED olivines of the same composition (~40-45, [2]) and from the host pyroxene, and therefore cannot have co-genetic origin with the host pyroxene.

Ultramafic melts are known on the Earth and have been proposed to occur on other bodies of the Solar system [4]. However, pure olivine melts are not previously known. The olivine melt can not be formed on the HED parent body by an indigenous differentiation of chondrite melt or as the product of indigenous remelting of cumulative rock. Moreover, the olivine with Fe/Mn=60 is not consistent with magmatic origin of the veins from a HED-related source. The olivine veins probably can't be formed by an impact melting based on their clear monomineral composition and the oxygen isotopic composition which does not indicate an exotic origin of the vein-forming material or admixture of a non-HED component during the impact event.

The zoning in FeO, observed before in the pyroxenes of the eucrites and howardites [5-7], is proposed to be a result of the transfer of FeO during high-temperature non-aqueous metasomatism in the late magmatic or post-magmatic evolution of their parent igneous rocks.

The range of FeO content of the zoned pyroxene and between the host pyroxene and the olivine veins in the Dho 1302 pyroxenite fragment is narrower compared to that of altered pyroxenes from the HED meteorites [5-7]. If the olivine veins in the Dho 1302 pyroxenite fragment have metasomatic origin, then the process was different from that mentioned in [5-7]. The metasomatic agent must have brought FeO and removed SiO_2 and MnO for the transformation of pyroxene (En_{76}, Fe/Mn=30) to the more Fe-rich olivine (Fo_{68}) with a much higher Fe/Mn ratio (60). We propose that the olivine veins observed in the pyroxenite fragment of Dho 1302 could be a result of mobilization of SiO_2 from the pyroxene by the water-bearing fluid.

Hydrothermal experiments indicate high volatility of SiO_2 in water-rich vapor [8]. Synthesis of forsterite and talc in the closed-system reaction of enstatite and H_2O demands relatively low temperature and water pressure ranges [9] which seem to be appropriate for a large asteroid. The SiO_2 mobilized by the proposed hydrous metasomatism could be redeposited as quartz veins as described for the Serra de Magé eucrite [10].

Since the oxygen isotopic composition is consistent with the HED origin of the veins' olivine, the source of the water-bearing metasomatic fluid is unlikely to have been exogenous, such as carbonaceous chondrite or cometary ice containing H_2O enriched in $^{17,18}O$ [11]. Instead, water or water-bearing material had to have been captured by the HED parent body during accretion and then isotopically equilibrated with the host rock or melt. A problem is how the water could be stored in the hot interior of the HED parent body up to at least the crystallization of the host pyroxene of the studied fragment. A small amount of water (<<1 mol%) could be dissolved in a mafic silicate melt under the lithostatic pressure estimated for Vesta. Another scenario is that the heating and melting of the HED parent body interior was irregular. If some blocks of primitive composition were heated later than others, they could release the volatile components at a time when the other blocks were completely molten, underwent differentiation and the host pyroxenite was formed. This scenario seems less plausible due to general isotopic homogeneity of the HED meteorites [1]. The uniqueness of the secondary alteration described here among the HED meteorites appears to be evidence for degassing of the interior of the HED parent body before the crystallization of diogenites and eucrites and supports the idea about nearly complete melting of the HED parent body [1].

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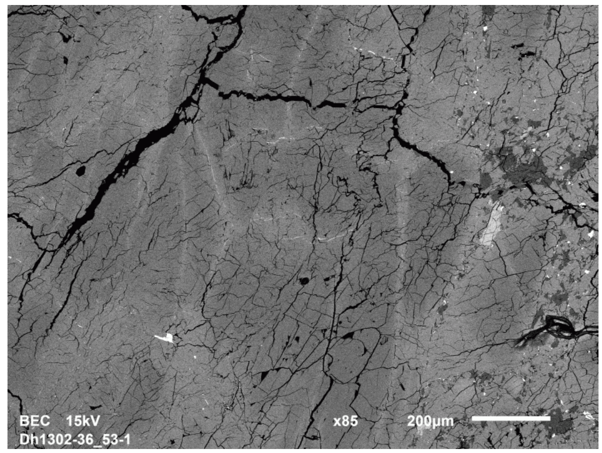

Fig. 1. BSE image of pyroxene zoning along closed fractures in the pyroxenite fragment of Dhofar 1302.

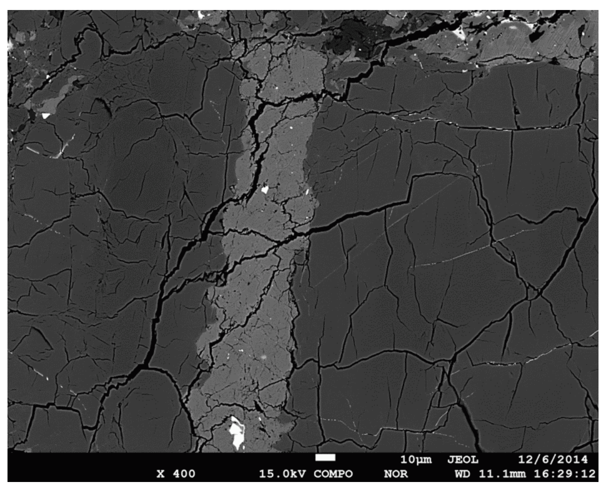

Fig. 2. BSE image of olivine vein in the pyroxenite fragment of Dhofar 1302.