OCCURRENCE AND IMPLICATIONS OF SECONDARY OLIVINE VEINLETS IN LUNAR HIGHLAND BRECCIA NORTHWEST AFRICA 11273

X. Zeng[1], S. Li[1], K. Joy[2], X. Li[1], Y. Li[1], R. Li[1], and S. Wang[1] [1]Institute of Geochemistry, Chinese Academy of Sciences, Guiyang, China; [2]School of Earth and Environmental Sciences, University of Manchester, Manchester, UK

Introduction: During the past few decades, secondary olivine veinlets (i.e., the olivine veinlets crossing cut pyroxene grains) have been discovered in a series of HED meteorites [e.g., 1–3]. Similar secondary olivine veinlets have also been observed in a few lunar basaltic samples, e.g., Apollo 14 mare basalts 14072 [4]. Warren et al. (2018) suggested that the olivine veinlets in Apollo basalt 14072 are likely deposited by a water-bearing fluid. However, the formation mechanism of lunar olivine veinlets and their geological records on the Moon are still poorly understood. Recently, five olivine veinle-bearing clasts have been recognized in Northwest Africa (NWA) 11273. This finding could help expand our understanding of the secondary olivine veinlets from a new geographic region on the Moon.

Sample and Methods: Polished thick sections of NWA 11273 have been characterized by a suite of different analytical techniques, including FE-SEM, EMPA, Raman spectrometer, and STEM. Bulk major and trace elements compositon of this meteorite were measured using ICP-OES and ICP–MS, respectively.

Results and Discussion:

Petrography and mineralogy of olivine veinlet-bearing clasts. In NWA 11273, we have recognized the secondary olivine veinlets cutting across pyroxene grains in five lithic clasts (i.e., clasts V1–V5; see Fig. 1). These olivine veinlets exhibit similar mineralogy mainly composed of olivine with a few accessory mineral grains of chromite, pyroxene, and plagioclase. Compared with other olivine grains ($Fa_{54.3–83.1}$) in lithic clasts and matrix of NWA 11273, the olivine veinlets in clasts V1–V5 are relatively fayalitic ($Fo_{41.4–51.9}$).

Bulk-rock meteorite composition. NWA 11273 has high bulk Al_2O_3 of 25.1 wt% and relatively low incompatible trace elements (e.g., Sm = 0.49 ppm and Th = 0.17 ppm). Such geochemical composition indicates that NWA 11273 is most likely ejected from the lunar FHT [5].

Origin and geological records of olivine veinlets on the Moon. Multiple formation mechanisms have been proposed to account for veinlets in HED meteorites and lunar mare basalts [1, 2, 3, 6]. In the case of secondary olivine veinlets in NWA 11273. Our studies shown that the fluid deposition processes seems the most plausible mechanism for interpreting the formation of secondary olivine veinlets in NWA 11273. Specifically, the fluid agent (water-bearing?) could transport the olivine/Ca-plagioclase cations (e.g., Fe^{2+}, Mg^{2+}, Si^{4+}, Ca^{2+}, and Al^{3+}) and then direct deposited the secondary minerals by the following reactions:

$$Fe^{2+}{}_{(aq)} + Mg^{2+}{}_{(aq)} + SiO_{2(aq)} \rightarrow (Fe, Mg)_2SiO_{2(s)}$$

$$Ca^{2+}{}_{(aq)} + 2Al^{3+}{}_{(aq)} + 2SiO_{2(aq)} + 4H_2O_{(aq,g)} \rightarrow CaAl_2Si_2O_{8(s)} + 4H_{2(g)}$$

Where aq = aqueous (water-bearing), g = gas, and s = solid. The specific details and mineral chemistry of products are controlled by temperature, fluid partial pressure, oxygen fugacity etc.

The studied secondary olivine veinlets in NWA 11273 may be evidence of fluid deposition at or close to the lunar surface. On the basis of the currently available data, we propose that such fluid was likely S,P-poor and was from an endogenic origin on the Moon.

Further works: To better understand the formation mechanism of secondary olivine veinlets on the Moon, more olivine veinlet-bearing lunar clasts are need to be examined and comparative studies of olivine veinlets between lunar samples (such as those that will be collected by the upcoming Chang'e-5 mission) and HED meteorites are also necessary. In addition, the systematic studies of *in situ* oxygen isotope and trace elements, in the future, would allow for greater revealing the geological records of such secondary olivine veinlets in lunar samples.

References: [1] Barrat J. A. et al. (2011) *Geochimica et Cosmochimica Acta* 75, 3839–3852. [2] Roszjar J. et al. (2011) *Meteoritics & Planetary Science* 46, 1754-1773. [3] Warren P. H. et al. (2014) *Geochimica et Cosmochimica Acta* 141, 199–227. [4] Warren P. H. et al. (2018) *LPSC* abstrct #2747. [5] Korotev R. L. (2005) *Chemie der Erde*, 65, 297–346. [6] Pang R. L. et al. (2017) *Geochimica et Cosmochimica Acta* 141:199–227.

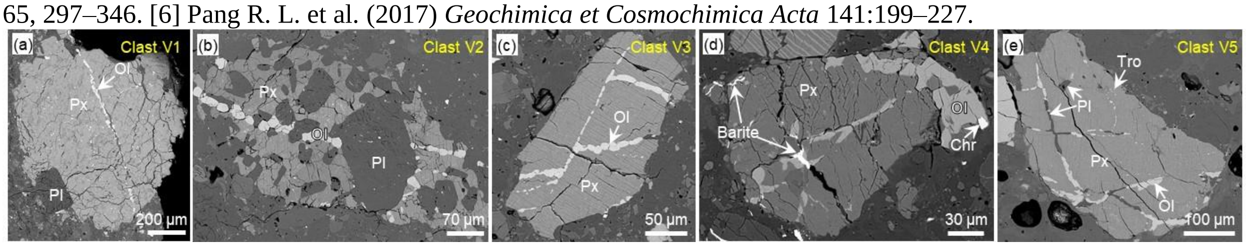

Figure 1. Back-scattered electron (BSE) images of the olivine veinlets bearing lithic clasts in NWA 11273. The mineral phases are labeled: Px = pyroxene, Ol = olivine, Pl = plagioclase, Chr = chromite, Tro = troilite.