

The petrological and mineralogical descriptions of nakhlites NWA 6148 and NWA 10153

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We conducted a petrological and mineralogical study of nakhlites NWA 6148 and NWA 10153 to clarify an aqueous alteration in the nakhlites complex. NWA 6148 is suggested to have derived from the deeper part of the nakhlite complex [1]. NWA 10153 was hardly investigated and its position in the nakhlites complex is unknown. For the petrological and mineralogical descriptions, microtextural observations by an FE-SEM and chemical composition analysis by an EMPA were conducted. We used a FIB system to prepare the foils of alteration textures found in the samples. The chemical species of iron, oxygen, carbon, and sulfur in the foils were analyzed by XANES. The microtextures, chemical compositions, and crystal structures of minerals in the foils were analyzed using an FE-STEM-EDS.

NWA 6148 consists mainly of olivine, low-Ca pyroxene, plagioclase, K-feldspar, pyrrhotite, and Fe-Ti oxides. Plagioclase, K-feldspar, pyrrhotite, and Fe-Ti oxides occur in a mesostasis. NWA 6148 has a higher fraction of a mesostasis (55.2 vol.%) than other nakhlites (7–24 vol.%) [2]. The low-Ca pyroxene has normal compositional zoning. The Ca content increases toward the rim in some pyroxene grains. Alteration texture is not found in NWA 6148. NWA 10153 also has a high fraction of a mesostasis (36.3 vol.%), and its major constituents are low-Ca pyroxene, plagioclase, K-feldspar, pyrite, and Fe-Ti oxides. Only a small amount of olivine occurs as small grains (< 100 μm) in the mesostasis. Alteration textures are found between low-Ca pyroxene grains and/or plagioclase grains. The alteration textures can be divided into four types: i) Fe-rich, ii) Si-Fe-rich, iii) Fe-S-rich, and iv) Carbonate-rich types. Based on Fe L-edge XANES, Fe^{3+} is dominant in the Fe-rich portion. Considering the SAED pattern and chemical compositions, the Fe-rich portion consists mainly of goethite. The absorption peaks both of Fe^{2+} and Fe^{3+} are observed in the Si-Fe rich portion. The Si-Fe-rich portion seems to consist mainly of smectite. Fe^{3+} is dominant and SO_4^{2-} is included in the Fe-S rich portion. Considering the SAED pattern and chemical compositions, the Fe-S rich portion consists mainly of Na/K-jarosite.

Cohen et al. (2017) [3] suggest that the nakhlite complex formed through several lava flows. The high proportions of mesostasis in NWA 6148 and NWA 10153 mean low crystallization degrees, suggesting that both of them were originated from lava flows that rapidly cooled and solidified near a surface. The Ca zoning in a pyroxene grain is observed in other nakhlites NWA 5790 and MIL 03346 along with NWA 6148 [1, 2]. The petrological similarities indicate that NWA 6148 and NWA 5790 might have formed by the same lava flow. However, more detailed investigations are necessary for the conclusion, because the proportion of a mesostasis in NWA 6148 (55.2 vol.%) is higher than NWA 5790 (36.3 \pm 3 Vol.%) [2]. NWA 6148 seems to be escaped from an aqueous alteration.

By contrast, NWA 10153 includes goethite, smectite, and carbonates as alteration minerals. Considering the formation conditions of the alteration mineral assemblage, two different aqueous alteration events likely occurred. In the first event, a hot neutral-basic fluid containing carbon dioxide gas formed smectite and carbonates. In the second event, a weak acidic fluid dissolved pyrite, which made the fluid to become

more acidic. Jarosite formed under very low-pH. With increasing the pH again due to the reaction between the surrounding minerals and the strongly acidic fluid, goethite precipitated from the fluid finally.

References:

[1] Jambon et al. (2016) *Geochimica et Cosmochimica Acta* 190, 191–212.

[2] Mikouchi et al. (2006) 37thLPSC, abstract no.1865.

[3] Cohen et al. (2017) *Nature Communications* 8, 1–8.

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