NWA 10659: A CLAY-RICH NAKHLITE PAIR OF NWA 10153

Conference or Workshop Item

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L. J. Hicks[1], J. C. Bridges[1], R. C. Greenwood[2] and I. A. Franchi[2]. [1]Space Research Centre, Dept. of Physics & Astronomy, University of Leicster, LE1 7RH, UK. Email: ljh47@le.ac.uk. [2]Planetary and Space Sciences, The Open University, MK7 6AA, UK.

Introduction: Newly discovered nakhlite NWA 10659 is a pair with NWA 10153 [1]. We have studied NWA 10659, comparing to the other nine nakhlites including its meteorite pair [1-5] to characterise the origin of the nakhlite hydrothermal system.

Methods: We used SEM-EDX to image polished sections and mineral analyses, and FEG-STEM analysis of FIB extractions to investigate the presence of any crystalline clay material. Oxygen isotope measurements were performed in duplicate by laser fluorination [6] on a ~100 mg powdered sample washed in EATG.

Results: Similar to its pair, NWA 10659 consists of compositionally zoned tabular pyroxenes (~65%), up to 1.5 mm in length, and larger grains of Fo_{22-37} olivine (~5%). There is also an interstitial mesostasis (~30%) consisting of orthoclase feldspar and albite, plus phosphate grains and Ti-rich magnetite.

NWA 10659 also contains an Fe-rich clay in fracture veins within the olivine and mesostasis. The clay (Fig. 1a) is similar to the poorly crystalline gel present in other nakhlites [2,4]. The average wt% composition in the olivine fractures is SiO_2 57.1, Al_2O_3 0.0, FeO 38.3, MgO 3.2, CaO 1.5 (Mg# =14; Fe/Si wt =0.9), and in the mesostasis SiO_2 57.3, Al_2O_3 3.8, FeO 32.0, MgO 2.9, CaO 3.1, K_2O 0.9 (Mg# =13; Fe/Si wt =1.1). This is consistent with the alteration in NWA 10153: SiO_2 53.4, Al_2O_3 2.0, FeO 39.9, MgO 2.5, CaO 1.2, Na_2O 0.5, K_2O 0.5 (Mg# =10; Fe/Si wt =1.2), normalized 100 wt% anhydrous [5]. No carbonates or salts have been observed in NWA 10659, distinguishing it from Lafayette, Governador Valadares and Nakhla [2].

The O-isotopic composition of NWA 10659 is: $\delta^{17}O$ 2.99‰; $\delta^{18}O$ 5.14‰; $\Delta^{17}O$ 0.32‰. NWA 10659 appears to be distinct from the O-isotopic composition of its pair NWA 10153, which has $\delta^{17}O$ 2.713‰; $\delta^{18}O$ 4.663‰; $\Delta^{17}O$ 0.251‰ [1]. The greater $\delta^{18}O$ may be a reflection of high martian clay abundance in NWA 10659.

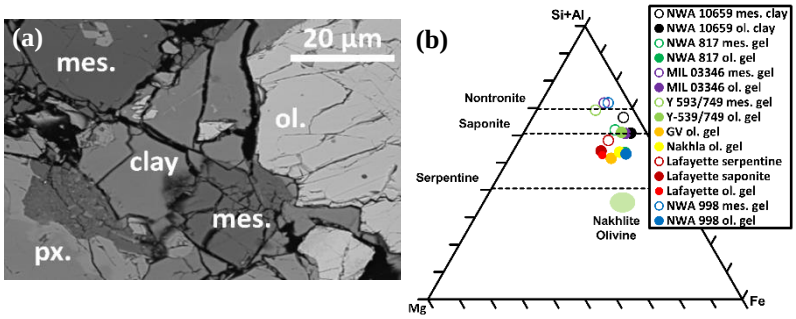

Fig. 1. (a) BSE image of Fe-rich clay in NWA 10659, within a fracture between olivine (ol), pyroxene (px), and mesostasis (mes). (b) Ternary plot showing average atomic proportions of Si+Al, Fe, and Mg, for saponite, serpentine and silicate gel found in the nakhlites [4], and the clay in NWA 10659. This includes clay in olivine fractures (circles) and mesostasis fractures (rings). The green ellipse shows the range of nakhlite olivine compositions.

Discussion: The veins in NWA 10659 are considered martian due to their similarities with veins in the other nakhlites and the lack of any petrographic evidence that the fusion crust has been cross-cut by them.

With Fo_{22-37} olivine, a mesostasis abundance of 30%, and compositionally zoned pyroxene grains; NWA 10659 originated in the upper regions of the nakhlite pile, corresponding to burial depths of 1-7 m [7,8,9]. The Mg# values and Fe/Si ratios closely resemble those of MIL 03346 silicate gel [4], also from the upper regions of the nakhlite pile. The clay is similar to the chemical composition of the saponite, serpentine and silicate gel identified in other nakhlites [4] (Fig. 1b), including the variation between the material in olivine fractures and mesostasis fractures. Like the nakhlites reported in [4], in NWA 10659 the Al_2O_3 content is higher in the mesostasis fractures than in the olivine fractures. The composition of the olivine minerals varies relatively little between the individual nakhlite samples (Fig. 1b), but variations in the alteration material indicate a change in the hydrothermal fluid, with decreasing Mg# from the lower to the upper regions of the nakhlite pile. The lack of carbonates observed in NWA 10659 suggests the hydrothermal fluid was no longer saturated in HCO_3^- at the further extremes of the hydrothermal system. The NWA 10659 clays are also consistent with the cooling of a fluid towards the top of the nakhlite pile, partially dissolving olivine in particular, and also mesostasis, in a rapidly cooled hydrothermal event [2,3].

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