MODAL MINERALOGY AND CHEMISTRY OF NAKHLITE NORTHWEST AFRICA (NWA) 5790: HOW IT STACKS UP WITH THE REST OF THE NAKHLITES

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Introduction: The group of martian meteorites known as the nakhlites currently consists of eight meteorites (each individual meteorite often being made up of multiple paired stones). The nakhlites are thought to represent a coherent clinopyroxenite thick flow, dike or sill intrusion that was emplaced at or near the martian surface and subsequently disrupted by impact [1]. The nakhlite group as a whole shows internal variation between samples consistent with different formation depths within the nakhlite stack [2, 3]. The meteorites also show variation within individual paired samples [1].

The nakhlite Northwest Africa (NWA) 5790 was found in Mauritania in 2009. It is likely paired with NWA 6148, which was also found that year in Mauritania. [4] reported that the mineralogy of this meteorite is consistent with the rest of the nakhlites; it is a clinopyroxenite and modal analyses of their samples showed it consisting of 51% pyroxene (augite), 9% olivine with accessory titanomagnetite (<1%). In the description of the meteorite by [4], mesostasis makes up the other 40% of the sample. This complicated nakhlite mesostasis is composed of feldspars, silica, merrilite, apatite, olivine, pyroxene, oxides and glass. Olivines and pyroxenes retain contain primary zoning.

Methods: In this study, three sections of NWA 5790 were obtained from the Monnig Collection at Texas Christian University. Modal mineralogy was calculated from all three sections using mineral mapping techniques on the FEI NanoSEM at the Smithsonian Institution (Fig. 1, 2), which is equipped with a Thermo-Scientific NSS energy dispersive (e.d.s) X-ray analytical system. The Smithsonian SEM system is currently being fitted with a silicon drift detector which will enable us to obtain mineral maps and backscattered images of these three large (approximately 1.5 x 2 cm) thin sections samples very quickly (within hours as opposed to almost a week of mapping time each). Refined modal mineralogy will be obtained from each of these three sections using both the X-ray based mapping method and the backscattered electron imaging method utilized the Miller Range (MIL) meteorites described by [5].

Electron microprobe analyses of NWA 5790 sections were also acquired using the JEOL 8900R instrument at the Smithsonian.

Results: *Modal mineralogy* calculated using the mineral mapping method for NWA 5790 differs slightly from that of [4]. The sections obtained from the Monnig Collection, which are serial sections, contain 56±2% augite crystals, ~2±.04% olivine, and <1% large titanomagnetite crystals; the remainder consists of mesostasis (42±0.1%).

Mineral Chemistry: Microprobe analyses of olivines and pyroxenes in NWA 5790 from this study agree well with those of [4]. Olivine rims were shown to vary from Fa_{65-73}, while cores vary from Fa_{78-90}. Pyroxene rims showed variation of $Fs_{28}Wo_{30-40}$ while pyroxene cores vary from $Fs_{40-50}Wo_{38-42}$. Al_2O_3 values ranged from 0.9-1.2 wt. % in the cores of pyroxenes.

Discussion: *Modal mineralogy*: The variation in modal mineralogy that exists between different sections of this meteorite is not surprising. Large variations exist between individual members of the Miller Range (03346 and the '09 trio) pairing group as well [5-7]. These results agree with previous work [4] showing that NWA 5790 contains the most abundant percentage of mesostasis in the nakhlite group. Our measurements extend that high abundance by another 2-3%. The absence of aqueous olivine alteration in NWA 5790 is unique among nakhlites.

How NWA 5790 stacks up: The mineral compositions of pyroxene cores show agreement with the other nakhlites [8], while the rims seem to coincide most closely with Y000593, though more analyses are likely required in order to determine whether Wo values in rims trend toward Fs as in Y000593 or toward Hd as in MIL 03346 (Fig. 3). [9] proposed a stacking order for the nakhlites based on Al_2O_3 values in the cores of pyroxenes. When viewed in this respect, NWA 5790 would appear to have been the most exterior sample in the stacking series (Fig. 3). [4] suggested that high mesostasis abundance should indicate that the NWA 5790 meteorite represents the chilled top of the nakhlite stack. Based on the mineral chemistry and the modal mineralogy (particularly the high abundance of mesostasis), we agree that NWA 5790 would likely have formed at the edges of the nakhlite igneous body, but whether or not that was at the top of the pile or the bottom is yet to be determined. Solidification fronts proceeded from both the top and the bottom of the nakhlite igneous body, as cooling progressed toward the center, as discussed by [10], althought the rate of heat loss is expected to be greatest from the upper zone.

References: [1] Friedman Lentz R. C. et al. (1999) *Meteoritics and Planetary Science, 34,* 919–932. [2] Mikouchi T. et al. (1996) *27th LPSC,* Abstract #2363. [3] McCubbin F. et al. (2013) *Geochimica et Cosmochimica Acta, 73,* 4907–4917. [4] Jambon A. et al. (2010) *41st LPSC*, Abstract #5696. [5] Corrigan C. M. et al. (2011) *42nd LPSC,* Abstract #2657. [6] Hallis L. J. and Taylor G. J. (2011) *Meteoritics and Planetary Science, 46*, 1787-1803. [7] Udry A. et al. (2012) *Meteoritics and Planetary Science 47,* 1575–1589. [8] Treiman A. (2005) *Chemie der Erde 65*, 203-270. [9] McKay G. et al. (2006) *37th LPSC* Abstract #2435. [10] Marsh B. D. (1996) *Mineralogical Mag. 60*, 5-40.

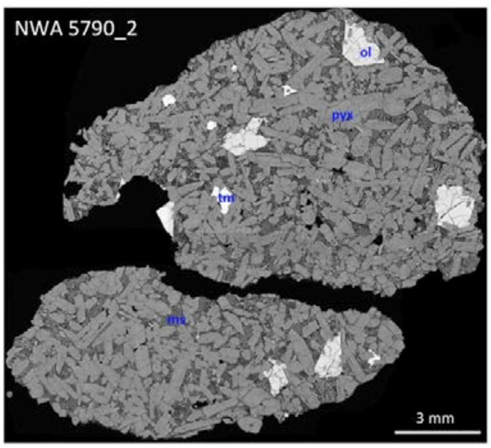

Figure 1: Backscattered electron image of NWA 5790_2 showing (from brightest to darkest) titanomagnetite, olivine, clinopyroxene and mesostasis.

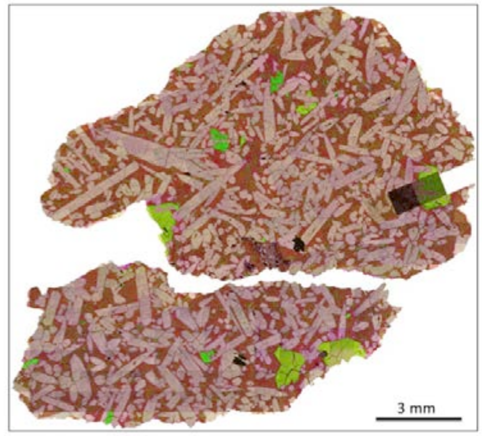

Figure 2: Mineral map of NWA 5790_1. Red = mesostasis, pink = pyroxene, yellow-green = olivine and bright green = titanomagnetite.

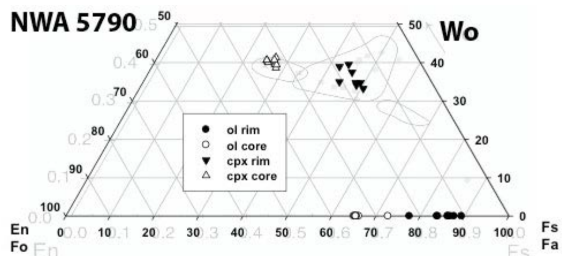

Figure 3: Pyroxene and olivine compositions. Underlying figure from [4, fig. 3].

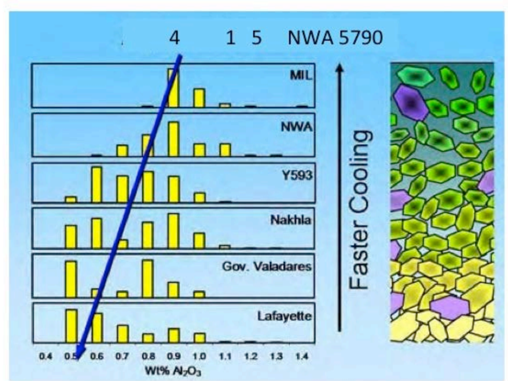

Figure 4: Trend line (arrow) showing increasing depth in nakhlite stack with decreasing Al_2O_3 in pyroxenes. NWA 5790 is represented by numbers in white box at top - number of analyses with x wt. % Al_2O_3 (Adapted from [9]).