MINERALOGY AND PETROLOGY OF NEW ANTARCTIC NAKHLITE MIL 03346. G. McKay[1] and C. Schwandt[2], [1]Code KR, NASA Johnson Space Center, Houston, TX 77058, USA, Gordon.McKay@jsc.nasa.gov, [2]Lockheed Martin, 2400 NASA Parkway, Houston, TX 77058, USA.

Introduction: Among the ~1300 meteorites returned from Antarctica by the 2003-2004 ANSMET expedition was a 715g nakhlite, MIL 03346, recovered from the Miller Range. Samples of this meteorite were distributed to investigators on December 16, 2004. We were allocated PTS MIL 03346,63,100. This abstract is our preliminary report on the mineralogy and petrology of this important new sample.

Petrography: Like other nakhlites, MIL is an olivine-bearing clinopyroxene cumulate with a dark-colored, fine-grained intercumulus mesostasis. The *clinopyroxene* grains are subhedral to euhedral prisms, and often appear elongated. Optical photomicrographs of MIL 03346 can be seen in the on-line JSC Antarctic Meteorite Newsletter at: http://www-curator.jsc.nasa.gov/antmet/amn/amnaug04/petdes2.htm.

To obtain modal abundances, we used the ratio ([Fe+Mg+Ca] / Si) and the Ti concentration obtained from whole-section elemental maps to classify each pixel as olivine, pyroxene, mesostasis, or Ti-magnetite. The resulting phase map is shown in Fig. 1, and the ensuing mode is given in the caption.

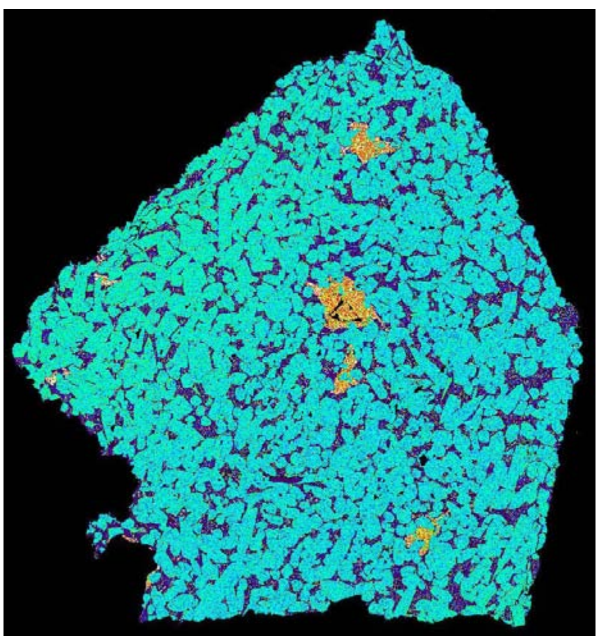

Figure 1. Phase map of MIL 03346, 100. Phases, with modal proportions (vol.%) are: clinopyroxene (light blue, 79.8%), olivine (orange, 4.6%), and mesostasis (dark blue, 15.7%). Ti-magnetite, a component of the mesostasis, constitutes 0.9% of the sample. This sample is 1.6 cm wide. There is a suggestion that the elongate pyroxene crystals are aligned vertically in this image.

Olivine is subhedral to anhedral, and often partially encloses clinopyroxene. Olivine rims occasionally have skeletal overgrowths into the mesostasis (Fig. 2). (Overgrowths are also common on pyroxene, but at a much smaller scale.) Two olivine grains exceed all but the largest pyroxene grains in size, but there are also a few smaller interstitial grains.

The *mesostasis* is partially crystallized to very fine-grained skeletal olivine, pyroxene, and Ti-magnetite (Figs. 2, 3). Feldspar may also be present, although we have yet to confirm its identity. Sulfide and phosphate are also present, but the latter is too small to analyze.

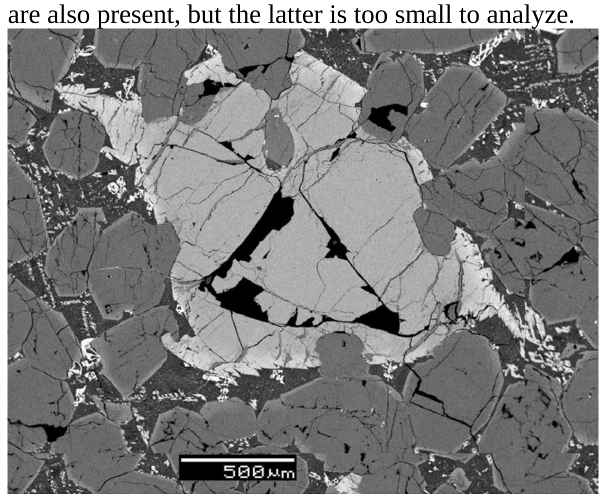

Figure 2. BSE image of central region Fig. 1. Olivine is light gray, pyroxene is medium gray. Mesostasis contains skeletal Ti-magnetite (white), olivine (light gray), and pyroxene (medium gray) in a matrix of feldspar and/or feldspathic glass and silica.

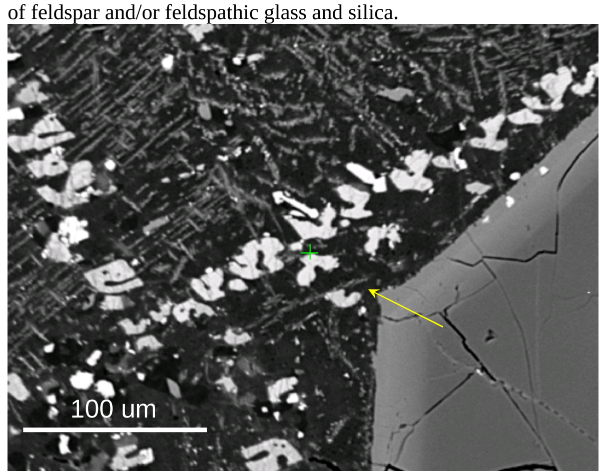

Figure 3. Pyroxene rim and mesostasis region. Bright skeletal phase is Ti-magnetite with fine ilmenite exsolution lamellae. Note strongly zoning in pyroxene rim, and discrete rim of ferro-hedenbergite extending upwards and right of arrowhead. Arrow indicates microprobe traverse discussed below.

Alteration: Olivine, mesostasis, and occasionally pyroxene are cut by veins of an alteration material similar to that reported by [1, 2]. This material can be seen filling olivine fractures in Fig. 2, and appears as a red stain in transmitted light. [1] showed that alteration was pre-terrestrial in Nakhla. It may also be in MIL, but this should be confirmed using fusion crust stratigraphy. In addition, we observed an Fe-rich mineral that occurs as isolated grains and superficially resembles the porous oxide reported in Nakhla by [1].

Mineral Chemistry: *Pyroxene* -- MIL pyroxene compositions are shown in Fig. 4. Core compositions cluster around $Wo_{39}En_{37}$. As the rims are approached, compositions begin to evolve towards higher Fe/Mg and slightly lower Wo contents. Then, at the very outer edge of the rims when they rims reach compositions of about $Wo_{34}En_{14}$, the trend abruptly changes direction towards Hd (Fig. 4). This outer Hd-rich zone can be clearly seen in Fig. 3.

Fig. 4a compares MIL and Nakhla pyroxenes. Several workers have noted that the core compositions of all nakhlites are nearly identical [e.g., 3,4,5]. MIL is no exception (Fig. 4). Moreover, the compositions during initial stages of Fe enrichment are also very similar among nakhlites [e.g., 4,5]. However, pyroxene rims in MIL are zoned to more extreme compositions than those in any other nakhlite (e.g. 4, 5). While MIL most closely resembles NWA 817, the latter lacks the extreme Hd-rich rims. Moreover, we have not yet observed any Fe-rich low Ca pyroxenes such as those observed in the extreme rims [4] and groundmass [4, 5] of NWA. We don't yet know if they are absent entirely or merely present at such fine grain-size that special care will be required to analyze them.

Fig. 4b shows major element variation along the single ~35µm profile in Fig. 3. Variation of Fe/Fe+Mg and minor elements along this profile is shown in Fig. 5. It is remarkable that this short traverse displays nearly the entire compositional variation we see among hundreds of MIL pyroxenes we have analyzed!

Olivine: Large olivine grains have homogeneous cores of Fa_{56-57}. However, in contrast to pyroxene, they display broad zoning profiles, extending 100s of um. As with pyroxene, olivine zoning in MIL appears to be more extreme than any other nakhlite. Olivines ranging from Fa_{59}-$_{86}$ have been reported in NWA [4], the sample most closely resembling MIL, while we have observed olivines in MIL ranging from Fa_{56-91}.

Ti-Magnetite is Cr-free, like that in NWA [4], but is richer in Ti (up to 19% TiO2). We intend to use mineral compositions to estimate fO_2 for MIL.

Discussion: The nakhlites display a continuum of textures and zoning patterns, especially in olivine and pyroxene [e.g., 3, 4, 5]. Lafayette has the most homogeneous olivines and the least Fe-enriched pyroxenes. Heretofore, NWA 817 had the most zoned olivines and the most Fe-enriched pyroxenes [4, 5]. Now it appears that MIL is the new nakhlite champ of extreme zoning. To the extent that degree of zoning indicates cooling rate (and burial depth, e.g., 3,5), MIL appears to be the fastest-cooled and thus the shallowest nakhlite.

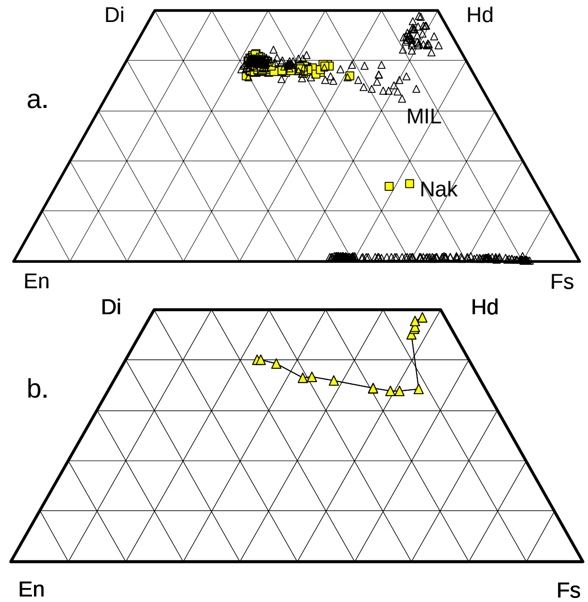

Figure 4a. Pyroxene and olivine compositions in MIL 03346 (open triangles) and Nakhla (yellow squares). b. Compositional profile along the traverse indicated in Fig. 3. This single 35 µm traverse exhibits the complete range of zoning seen in all MIL pyroxenes!

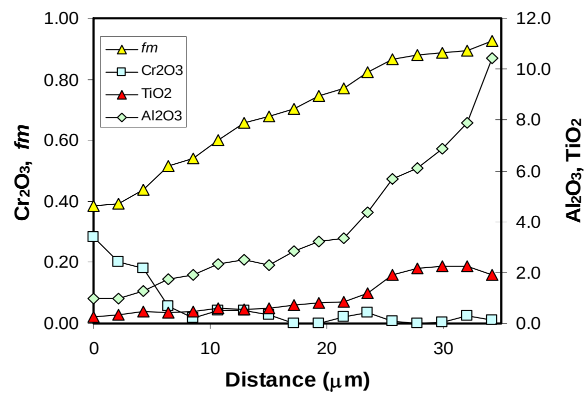

Figure 5. Variation of minor elements and *fm* (Fe/Fe+Mg) along traverse in Fig. 3. Note that the Cr content drops to essentially zero within 10 µm of the beginning of Fe enrichment. Non-quadrilateral components are low in the cores, but can become very significant in the rims where Al_2O_3 can approach 10 wt%.

References: [1] Trieman *et al.* (1993) *Meteoritics* 28, 86. [2] Gillet *et al.* (2002) *EPSL* 203, 431. [3] Harvey & McSween (1992) *GCA* 56, 1655. [4] Sautter *et al.* (2002) *EPSL* 195, 223. [5] Mikouchi *et al.* (2003) Antarctic. Met. Res. 16, 34.