PETROLOGY AND MELT COMPOSITIONS IN NAKHLITE MIL-03346: SIGNIFICANCE OF DATA FROM NATURAL SAMPLE AND FROM EXPERIMENTALLY FUSED GROUNDMASS AND M.I.'s.

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Abstract: Textural and compositional analyses of Mil-03348 phenocrysts and refuse groundmass indicate magmatic conditions and enviironment of crystallization for this new nakhlite.

Introduction: The SNC meteorites are an important source of information about the petrological and volcanological history of Mars. It is probably significant, that essentially all of the meteorite samples we have from Mars are of the SNC group. Although most of the SNC meteorites have been extensively studied (1) in attempts to determine as much as possible about their age, origin, and petrogenetic history, many unanswered questions remain. [1] Under what conditions of pressure and oxidation state did the different samples crystallize, [2] What are the parent melts for the different SNC samples, and can the be related by differentiation processes. [3] Can we identify evidence of volatile abundance and degassing having occurred in the SNC magmas? Finding the MIL 03346 Nakhlite offers an opportunity to attempt to resolve the question of the Nakhlite parent melt and crystallization conditions for this sample beyond what has been done to date (2, 8 and 9).

Methods: A PTS of Mil-03346 has been studied analytically and texturally using EMPA and petrographic techniques. Approximately 1mm^3 chips of the sample are also being used in experiments to reconstitute the phenocryst-melt equilibria in the sample at various pressures, temperatures and fO2's. The experiments are being done at pressures of a few 10's of MPa to 160 MPa using graphite powders in a sealed Pt container together with the oxidized natural sample to generate a G-CO assemblage which fixes the fO2 at values from WI to QFM.

Results: The Mil-03346 Nakhlite, like other members of this group consists of Ca-rich pyroxene ($En_{38}Fs_{21}Wo_{41}$ cores with thin rims that reach $En_{9}Fs_{44}Wo_{47}$) and olivine phenocrysts ($Fo_{43.5}$ cores with 70 micron thick normally zoned rims) in a dark fine-grained groundmass that contains fayalitic olivine, Fe-rich Ca-pyroxene, Ti-magntite, cristobalite, and apatite in order of decreasing abundance. Phenocrysts make up 65v% of Mil-03346,105 and the groundmass 35v%. Olivine phenocrysts are sparse; only one large (1.7mm) crystal occurs in this section (Fig. 1). No Low-Ca pyroxene phenocrysts have been identified, but a 50 micron crystal ($En_{55}Fs_{44}Wo_{1}$) is the largest daughter crystal in an olivine-hosted melt inclusion. (This inclusion also contains relatively large pigeonite crystals, Ca-Px, and a sulfide bleb). Both the olivine and Ca-Px phenocrysts have large cores that are unzoned within analytical error. The Olivine has a normally-zoned, 150 um-thick rim adjacent to the groundmass; Cpx generally has a <30um rim zoned to higher Al_2O_3 (6 wt%) and FeO. Where the Olivine contacts or partially grew around Cpx crystals the zoning is absent.

Three experiments have been done at temperatures of 1140, 1135 and 1120^{o}C using previous experiments on ALH77005 (7) as a guide. The tube failed in the first 80 MPa experiment generating an fO_2 just below IW; the other two at 160 MPa produced excellent textured samples with re-homogenized matrix glass and melt inclusions.

Discussion: The textures in the Mil-03346 sample suggest the possibility of relatively slow phenocryst growth at some depth in Mars, and the likelihood of crystal-melt segregation. On the other hand, the olivine appears to have partially grown around some of the smaller Cpx phenocrysts, (Fig. 1) indicating co-crystallization of these two phases. The homogenous core compositions of the natural Olv and Cpx phenocrysts, which represent ~60v% of the Mil-03346 sample, indicate that the parent magma underwent little compositional change during their formation. Thus, the olivine and Cpx represent a small degree of crystallization of the parent magma, otherwise more zoning would be expected. Mil-03346 must have formed by a process such as crystal settling. The close correspondence between the rehomogenized groundmass composition and the melt trapped as a M.I. in a Cpx core (Table 1) confirm the small change in the melt present during crystallization of the Cpx phenocrysts. Just as the cores of the phenocrysts in this Nakhlite indicate very slow crystal growth in a large pool of melt, the rims indicate a sharp change in the cooling rate, and a relatively closed, small-volume, melt system. The thin normally zoned rims on the Cpx, particularly the rapid increase in Al and Ti, illustrate this rapid growth. The somewhat thicker rims on Olivine adjacent to groundmass compared to Cpx-groundmass are consistent with this interpretation. The high rate of cooling continued as the groundmass crystallized to form a network of rod-like to acicular and hopper-chaped crystals of fayalite, titaniferous magnetite, Ca-Px, cristobalite and apatite. The texture and the composition of the interstitial groundmass areas suggest this melt may have developed immiscible silicate melts (now glasses). A general lack of sulfide blebs in the groundmass compared to melt inclusions suggests the development of a gas phase during groundmass crystallization.

The presence of fayalitic olivine, titaniferrous magnetite, and cristobalite in the groundmass indicate that the fO_2 in the magma during crystallization was close to the QFM oxygen buffer. SIMS analysis of the REE in the Ca-Px cores will determine whether the entire crystallization sequence was at this same oxidation state.

References: (1) Johnson et al., 1991, GCA, 55,349-366; Longhi, J., 1991 PLSC21, 695-709; McSween H.Y. Jr. 1994, Meteroitics, 29,757-779 (2) Harvey, R.P., and McSween, H.Y., 1992a, GCA, **56**,1655-63. (3) Hale et al., 1997, (5) McSween and Jarosewich, 1983, (6) Harvey and McSween, 1992b, EPSL, 111,757-779. (7) Calvin, C and Rutherford, M.J., 2003, LPSC XXXV, # 1284. (8) Mikouchi, T. et al., 2000, Meteorites and Planetary Sci. 35, 937-942. (9) Borg, L.E., et al., 2002, GCA, 61,4915-4931.

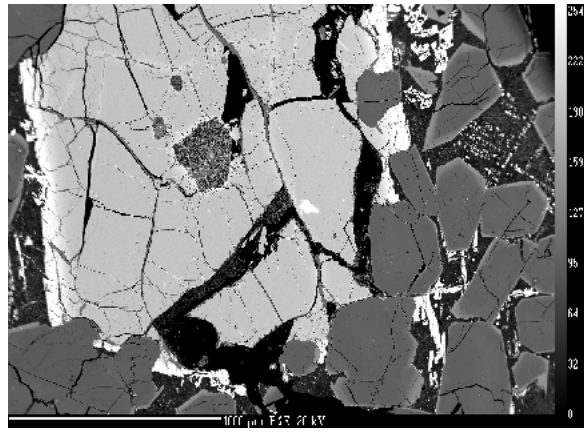

Figure 1a. (above) BSE image of the olivine and surrounding Cpx phenocrysts in Mil 03346. Scale bar is 500 um. Fig. 1b (below) shows groundmass at left of large Olivine. Bar is 200 um.

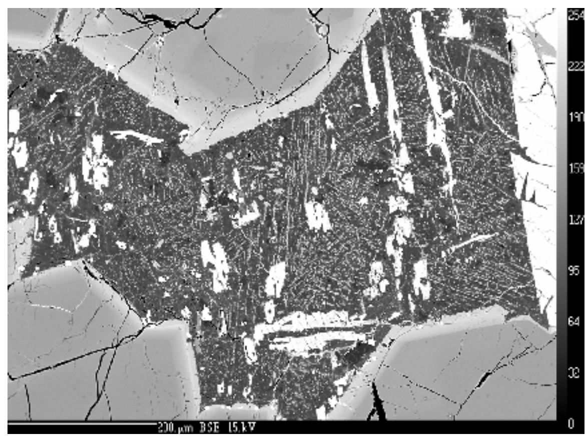

Table 1: SNC parental magma compositions (wt %)

	A* Chassig. [1]	Shergotty [2]	E79001 gm [3]	Nakhla NK3 [4]	Gov. Vald. GV1 [5]	Mil- 03346 Matrix [6]	Mil-03346 Fused M.I. in Cpx [7]
SiO_2	50.33	50.8	50.67	45.8	46.7	49.34	49.50
TiO_2	1.75	1.0	0.86	3.1	4.2	1.35	1.55
Al_2O_3	8.16	8.0	7.10	7.2	8.1	9.20	9.80
FeO*	19.87	19.8	18.67	26.2	23.3	22.90	24.50
MgO	7.39	7.7	12.22	5.7	5.1	3.51	2.25
CaO	8.95	9.7	8.74	10.4	9.7	9.35	8.70
Na_2O	1.71	1.5	1.07	0.8	2.1	2.58	2.35
K_2O	0.43	0.2	0.07	1.4	1.2	0.73	0.78
P_2O_5	0.50	0.9	n.d.	n.d.	n.d.	0.60	0.64
MnO	0.52	0.5	0.52	n.d.	n.d.	0.44	0.46

Compositions [1] Chassigny from (1); [2] Shergotty from (3); [3] EETA79001 groundmass composition from (5); [4 and 5] Nakhla NK3 and Govenor Valderas from (6); [6 & 7] Mil-03346 Nakhlite (this study) heated to 1140°C at pressure to refuse matrix and melt inclusions.