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PETROLOGY AND GEOCHEMISTRY OF NAKHLITE MIL 03346: A NEW MARTIAN METEORITE FROM ANTARCTICA

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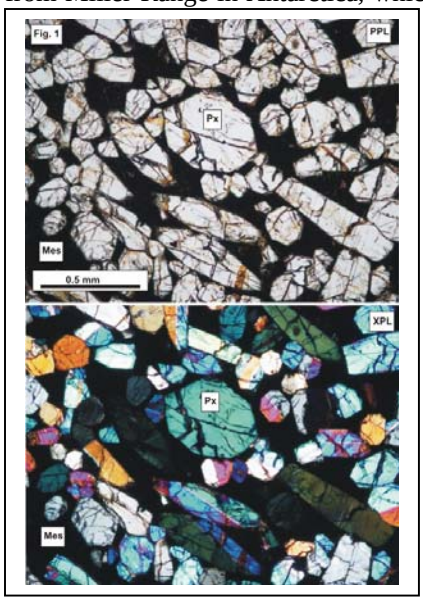
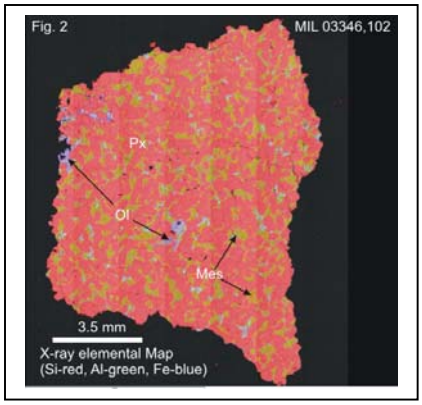
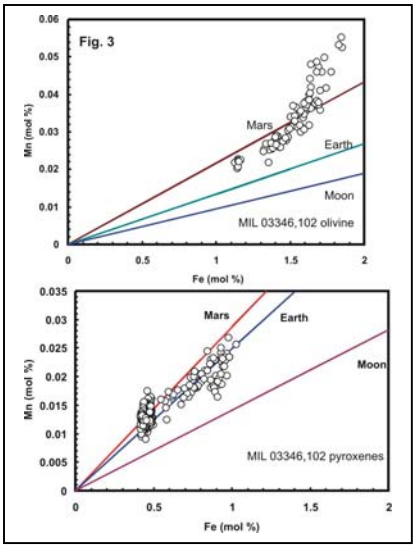
MIL 03346 is a newly discovered meteorite from Miller Range in Antarctica, which belongs to the nakhlite group of Martian meteorites [1]. It is an unbrecciated, medium-grained olivine-bearing clinopyroxenite with a cumulate texture, similar to the 6 other previously known nakhlites. This is only the 2nd nakhlite in Antarctic collections, the other being Yamato 000593 and its pairs. The Meteorite Working Group (MWG) allocated us two polished sections (MIL 03346,102 & MIL 03346,116), and 1 g rock chip (MIL 03346,37) for carrying out petrological and geochemical investigations.

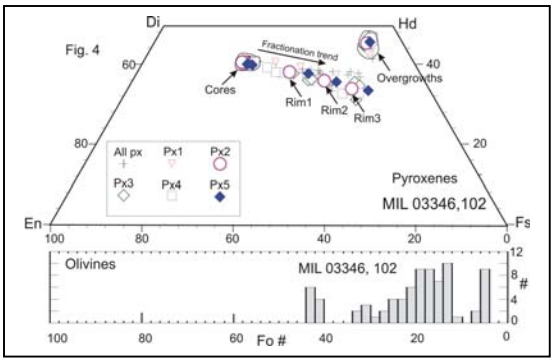


Petrography and Mineral Chemistry: The rock displays a cumulate texture (Fig. 1) consisting predominantly of zoned euhedral clinopyroxene (0.5-1 mm long) and glassy mesostasis, with rare olivine grains (up to 1 mm, Fig. 2). Accessory minerals mostly occur in the mesostasis, and include Ti-magnetite, fayalite, a sulphide phase, and free silica. Shock effects are evident in the form of extensive cracks and shock induced twinning in some pyroxenes. The mineralogy, Fe to Mn ratios in pyroxene and olivine (Fig. 3, after [2]) and bulk-rock composition (Table 1) confirm the Martian origin. In textural appearance, this rocks appears most similar to the nakhlite, NWA 817 [3].



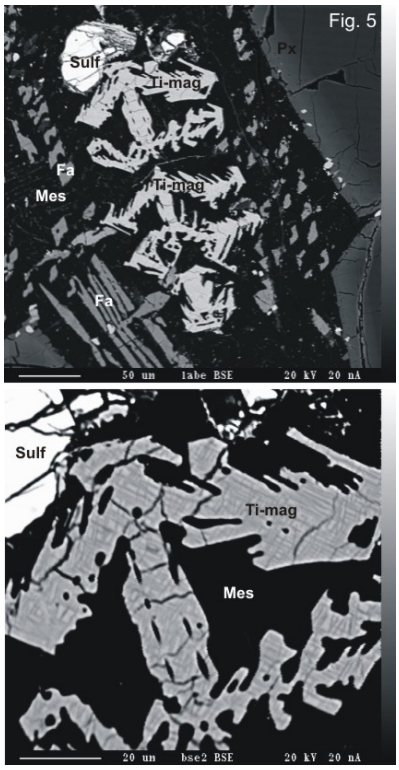


The modal mineralogy of MIL 03346 is dominated by cumulus pyroxenes (~70%) followed by glassy mesostasis (~25%). Olivine is only present in minor amounts and no crystalline plagioclase was observed in our sample. However, the composition of the glassy mesostasis is most closely



matched by a Na-K-rich-feldspar. The majority of the pyroxene grains show extensive zoning from core to the rim. The outer 10-20 μm zones of pyroxene grains display several generations of growth (sometimes up to 4), clearly evident in back scatter electron images. The cores of pyroxene crystals are remarkably homogeneous in composition at $Wo_{41}En_{38}Fs_{21}$ (Fig. 4). Different generations of rim growth can be demarcated based on Wo-En-Fs contents. In general, there is a gradual decrease in Wo and En contents from core to rim except in the outermost growth zone (overgrowth), which is marked by an increase in Wo content (Fig. 4). Olivine grains are also zoned in terms of Fe-Mg and vary from Fo_{44} in the core to Fo_{13} in the rim regions. This is the highest forsterite content measured in any nakhlite olivine. A secondary alteration phase has also been identified in the cracks of the olivine grains, chemical com-

position of which closely matches those of 'iddingsite-smectite' mineral assemblage reported from Nakhla, Lafayette and other nakhlites. Fayalitic grains (Fo_{5-12}) are abundant in the mesostasis areas but because of their skeletal growth and spongy texture, reliable compositions were difficult to measure. The CaO and MnO contents in olivines vary from 0.1 to 0.6 wt% and 0.8 to 1.9 wt%, respectively. Feldspathic-glass compositions in the mesostasis are $Ab_{71-62}Or_{7-14}$. MIL 03346 also contains pure silica pods (~5 μm in size) distributed throughout the mesostasis. Opaque minerals are abundant and Ti-magnetite is most common (as euhedral and skeletal grains; Fig. 5), with significant proportions of Fe^{3+}. Close inspection reveals submicron level exsolution, probably of ilmenite, in the Ti-magnetite grains but the composition of the exsolved phase could not be determined.



Bulk-rock Major- and Trace-element chemistry: The major- and trace-element composition of MIL 03346 was determined using an Axial Varian Vista Pro ICP-AES (Table 1). Major elements were determined following a lithium metaborate fusion of 20 mg powdered rock sample in a Pt crucible and re-dissolution in dilute nitric acid. Primary calibrations were against international Certified Reference Materials (CRM). Other CRMs were used as a check, where samples fell outside the primary calibration range. A sample of Nakhla (BM 1913, 25) was also analyzed in the same batch for comparison purposes. Trace-element concentrations were determined on a 100 mg powdered rock sample by ICP-AES after digestion by hydrofluoric and perchloric acids and re-dissolution in dilute nitric acid. The instrument was calibrated with synthetic standards, and a number of CRMs were also prepared to check data quality and to correct for any matrix effects. The same instrumental analytical conditions were used as for the major elements analysis. In terms of major and trace elements (9.3 wt% MgO, 3.6 wt% Al_2O_3, 46 ppm Sc), MIL 03346 is a nakhlite, most similar to NWA 817.

Table 1: Major and trace-elements in MIL 03346,37 and Nakhla

wt %	MIL 03 346,37	Nakhla (BM 1913,25)
SiO_2	49.2	48.8
TiO_2	0.07	0.34
Al_2O_3	3.59	2.09
FeO	19.23	21.71
MnO	0.45	0.52
MgO	9.33	11.43
CaO	15	14.36
Na_2O	1.01	0.58
K_2O	0.29	0.16
P_2O_5	0.22	0.12
Total	**98.34**	**100.08**
Mg #	46.3	48.3
ppm		
Zn	65	40
Sc	46	37
V	184	142
Co	25	31
Cr	1300	1765
Cu	13	9
Ni	60	47
Sr	106	51
Y	7	3
Ba	53	28

Summary: MIL 03346 is a new member of the nakhlite group of Martian meteorites. Texturally, this rock appears to be slightly different from other nakhlites because it lacks plagioclase crystals in the mesostasis. This is probably a result of rapid cooling of the MIL 03346 parental magma upon extrusion, preventing crystallization of plagioclase crystals. Remarkable skeletal Ti-magnetite and fayalite grains in the mesostasis areas of this rock also support this interpretation. However, the occurrence and preservation of up to 4 distinct growth zones on cumulus pyroxenes indicates that the parental magma was subjected to complex magma chamber processes before erupting on the Martian surface, similar to those inferred for other nakhlites. The similarity in chemical composition but slightly more fractionated nature and faster cooling history than other nakhlites suggest that MIL 03346 might have been derived from the upper levels of the lava flow sequence on the Martian surface and thus the geochemical signature of this meteorite may provide complementary information about petrogenesis of the nakhlite group of martian meteorites.

References: [1] Ant. Met. News Lett. (2004), 27(2); [2] Papike et al. (2003) Am. Min., 88, 469-472; [3] Sautter et al. (2002) EPSL, 195, 223-238.