**SHOCK-ENHANCED AQUEOUS ALTERATION OF THE NAKHLITE MILLER RANGE 03346.**

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**Introduction:** The nakhlites are igneous rocks composed principally of clinopyroxene (augite) and olivine phenocysts, between which is a glass- or feldspar-rich mesostasis. These meteorites sample a stack of Amazonian (1.3-1.4 Ga) lava flows [1], most of which have evidence for mild aqueous alteration [2,3]. As these alteration products have been dated to 633 ± 23 Ma [4], the liquid water must have interacted with the lavas long after magmatic activity, although the driver of fluid/rock interaction remains unknown. During a microtextural study of Miller Range (MIL) 03346 we found that augite grains in discrete regions of the meteorite have been heavily deformed, and the associated mesostasis has been pervasively aqueously altered. Here we explore the nature and significance of this apparent link between deformation and water-rock interaction.

**Methods:** This study used one polished thin section: MIL 03346,118. After polishing in colloidal silica, Electron Backscatter Diffraction (EBSD) maps were acquired in variable pressure mode on a Zeiss Sigma variable pressure scanning electron microscope (VP-SEM) operated at an accelerating voltage of 20 kV. The thin section was tilted to 70° and large area EBSD maps were collected across a 1 $cm^2$ area at a step size of 4 µm/pixel. Backscattered SEM images and quantitative X-ray analyses were also obtained using the Zeiss Sigma VP-SEM.

**Results:** The modal mineralogy of MIL 03346 is 67.7 % augite, 31.5 % mesostasis, 0.8 % olivine [5,6]. The olivine phenocrysts contain veins of iddingsite (average chemical composition 46 wt. % $SiO_2$, 33 wt. % FeO, 3 wt. % MgO). EBSD misorientation maps show that regions of the thin section have evidence for considerable deformation and brecciation. The deformation is focused in discrete 2 mm wide bands that are typified by 2-10° of crystal plastic deformation and mechanical twinning within individual augite phenocrysts. The mesostasis in these regions contains grains of hematite together with patches or concentric layers of two very fine-grained materials: (i) a Fe-Mg silicate that is very similar in chemical composition to the olivine-hosted iddingsite (46 wt. % $SiO_2$, 30 wt. % FeO, 3 wt. % MgO, 3 wt. % $Al_2O_3$), and (ii) a Fe-oxide/hydroxide (54 wt. % FeO, 20 wt. % $SiO_2$, 3 wt. % $SO_3$). In areas of the thin section between deformation bands the augite grains are free of crystal plastic deformation, and the mesostasis contain glass with crystals fayalite, titanomagnetite, cristobalite, sulphides and apatite [5].

**Discussion:** The bands of deformed augite in MIL 03346 are analogous to areas of shock-produced cataclasis that occur in the nakhlite Northwest Africa (NWA) 998 [7], and to 'granular zones' that have been described from Nakhla [8]. Mechanical twins that occur within MIL 03346 augite have also been interpreted as products of mild shock deformation [e.g., 9]. The hematite, Fe-Mg silicate and Fe-oxide/hydroxide in the MIL 03346 deformation bands is interpreted to have formed principally by aqueous alteration of mesostasis glass, fayalite and titanomagnetite. The intimate association between shock-deformed augite and aqueously altered mesostasis indicates that: (i) ingress of liquid water postdated impact shock, and (ii) interaction of water with the mesostasis was facilitated by prior deformation – for example through the formation of a high density of fractures that enabled fluid ingress.

A key question arising from this work is whether the water that was responsible for alteration was sourced from the crust/atmosphere of Mars, in common with fluids that altered MIL 03346 olivine to iddingsite [10], or was terrestrial in origin (i.e., Antarctic meltwater). A martian origin for the alteration products would be consistent with the similarity in chemical composition between olivine-hosted iddingsite and Fe-Mg silicate in the mesostasis, whereas a terrestrial origin is supported by evidence for Antarctic weathering of MIL 03346 and its paired meteorites [11]. Work to discriminate between these two possibilities is ongoing.

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