IMPLICATIONS OF SHOCK-FACILITATED ALTERATION ON MARS FROM EBSD AND EDS ANALYSIS OF THE NAKHLITES.

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Introduction: The nakhlites are a subgroup of Martian meteorites that provide unique information about Mars' history. These meteorites have a basaltic chemistry, with a mineralogy mainly comprising various proportions of clinopyroxene (augite), and olivine within a fine grained mesostasis [1]. Recent work on two of the nakhlites (Miller Range (MIL) 03346 and Lafayette) proposed that they record two impact events [2], despite the moderate-low levels of shock metamorphism observed (5-12 GPa, ~5 – 40 K above ambient) [1,3,4]. The initial impact is proposed to have driven martian water-rock interactions, represented by alteration products including iddingsite. Aqueous alteration occurred 633 ± 23 Ma ago, ~700 Ma after the nakhlite's magmatic origin. Such a young age significantly postdates areas on the martian surface observed to contain hydrous weathering products (dated ~3.7 Ga from crater counting statistics) [5-7]. Understanding how aqueous fluids were generated close to the surface of Mars and independently of freely available flowing surface water is vital for future missions to the red planet. Here we have expanded the study of Daly et al. [2] to further investigate shock-driven aqueous alteration on Mars via the nakhlite meteorites.

Methods: Thick sections of nakhlite specimens Yamato (Y)-000593 (106-A, 127-A), Y-000749 (64-A, 72-A), Y-000802 (36-A), Governador Valadares (BM1975, M16, P8469), Nakhla, MIL 090032 (108), Northwest Africa (NWA) 11013 (UG-1), and NWA 998 (T1, UG-1), were used so as to capture the diversity of the nakhlites. These samples were prepared for EBSD analysis by mechanical and chemical polishing prior to coating with carbon. Data were collected using a Zeiss Sigma variable pressure field-emission SEM (VP-FEGSEM) with a NordlysMax2 EBSD detector and indexed using AZtec analysis software v3.3 from Oxford instruments at the University of Glasgow. Large area EBSD maps were collected under high vacuum, 20 keV, 4-8 nA beam current, tilted at 70°. The stepsizes used ranged from 2.4 µm (NWA 11013) to 5 µm (Y-000802). Data were noise reduced using Oxford Instruments HKL Channel 5 software employing a wildspike followed by a 6 point nearest neighbor zero solution reduction. Energy dispersive X-ray spectroscopy (EDS) of 'iddingsite' used the same Zeiss Sigma VP-FEGSEM and an Oxford Instruments 80-mm^2 X-Max silicon drift EDS under high vacuum. X-ray measurements were rastered over an ~9 µm^2 area for 60 s. Spectra were processed using Oxford Instruments INCA software and quantified using the following standards: Na and Al (jadeite), Mg (periclase), Ca (wollastonite), Si (diopside), P (apatite), S (pyrite), Ti (rutile), Cr (chromite), Mn (rhodonite), Ni (nickel), and Fe (almandine).

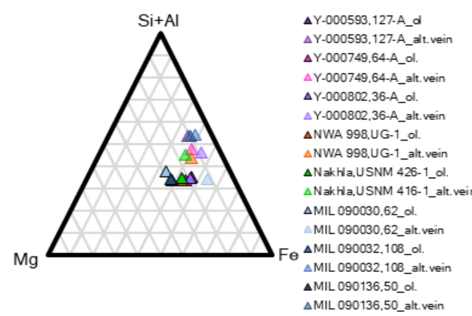

Figure 1: EDS analyses of iddingsite veins (at. %) and host olivine phenocrysts.

Results and implications: EDS analyses of alteration products of nakhlite olivine phenocrysts show a trend in the alteration assemblages (Fig 1). All measured veins show higher Fe and Si + Al concentrations relative to the host olivine. Shock deformation, interpreted as regions with increased EBSD grain relative orientation distribution (GROD) angles (Fig. 2), increases around areas with a greater abundance of mesostasis (orange regions Fig. 2). Mechanical twinning is also present in many of these highly deformed areas (Fig. 2). Observed alteration within the mesostasis appears to be related to shock deformation of the larger olivine crystals. However, iddingsite alteration**.**

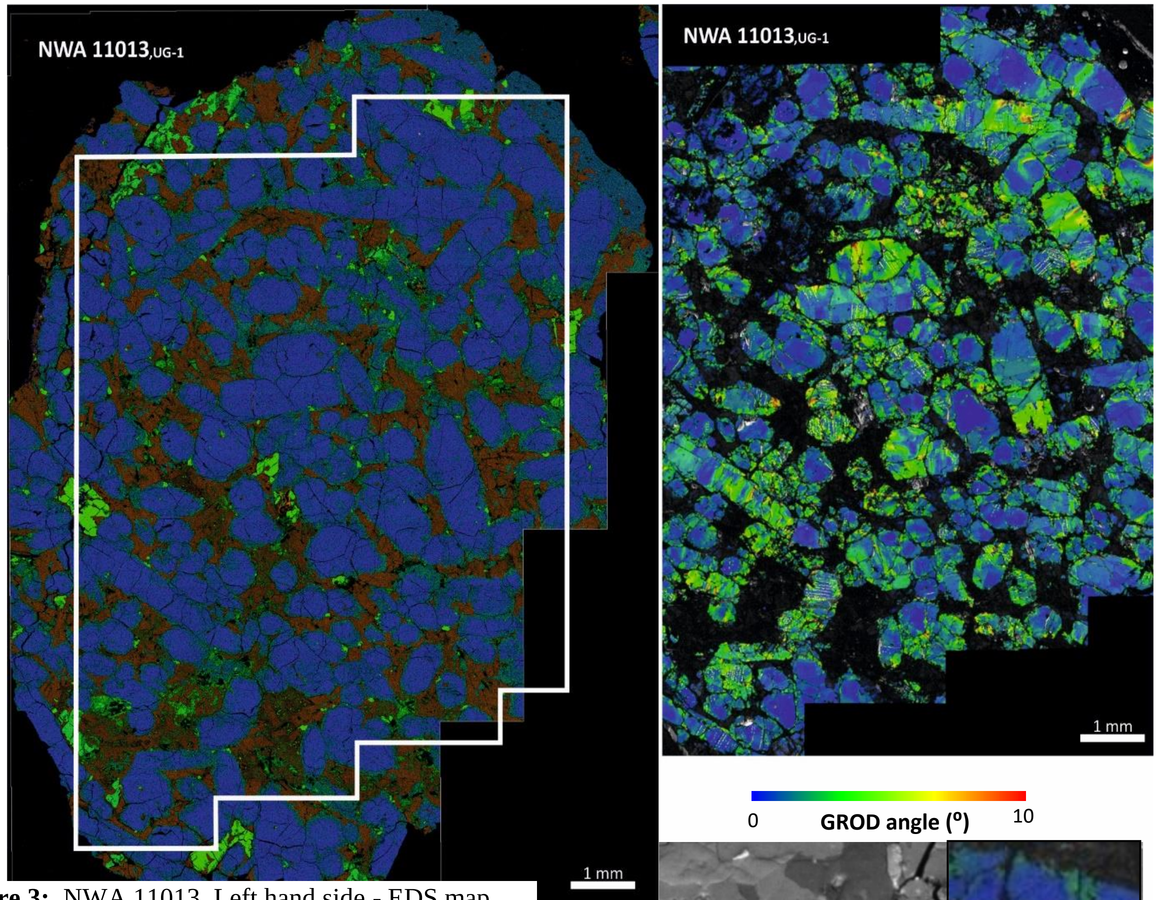

Figure 3: NWA 11013. Left hand side - EDS map (Al-orange, Fe-green, Mg-blue). Colours were chosen to highlight the main phases: olivine (green), augite (blue) and mesostasis (brown/orange). Right hand side - grain relative orientation distribution map (GROD) of part of the EDS mapped region (outlined in white). Green =, yellow and red areas are the most highly deformed.

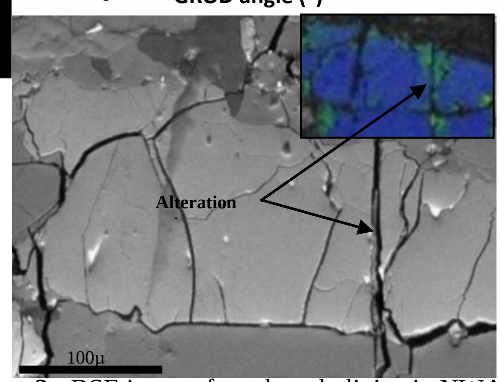

Figure 2: BSE insert of an altered olivine in NWA 998. Insert: GROD map of the same olivine crystal showing many of the alteration veins correspond to areas of higher deformation.

veins present within shocked and unshocked olivine crystals show low to no deformation (Fig. 3). This observation agrees with previous results from MIL 03346 and Lafayette [2].

The degree of deformation within the studied nakhlites varies, with the Yamato samples being least deformed and NWA 11013 being most highly shocked (Fig. 2). However, the correlation between areas with deformed minerals and the distribution of alteration mineral assemblages agrees with previous results (Fig. 3) [2].

Results relating to the exact relationship between deformation and the distribution of aqueous alteration mineral assemblages investigation will be presented at the meeting

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