CRYSTALLOGRAPHIC DEFORMATION WITHIN THE NAKHLITES: IMPLICATIONS FOR EMPLACEMENT AND EJECTION. S. Griffin[1], L. Daly[1,2,3], M. R. Lee[1], L.V. Forman[2], S. Piazolo[4], P. W. Trimby[5], P. Chung[1], B. E. Cohen[1,6], R. Baumgartner[7], G. K. Benedix[2,8,9]. [1]School of Geographical and Earth Sciences, University of Glasgow, U.K. E-mail: Sammy.Griffin@glasgow.ac.uk, [2]Space Science and Technology Centre, School of Earth and Planetary Sciences, Curtin University, Australia. [3]Australian Centre for Microscopy and Microanalysis, The University of Sydney, Australia. [4]School of Earth and Environment, University of Leeds, Leeds, UK. [5]Oxford Instruments Nanoanalysis, High Wycombe, UK. [6]School of GeoSciences, University of Edinburgh, U.K. [7]Australian Centre for Astrobiology, University of New South Wales, Australia. [8]Department of Earth and Planetary Sciences, Western Australia Museum, Australia. [9]Planetary Institute, Tuson, USA.

Introduction: The nakhlites are the least shocked group of Martian meteorites currently available for study on Earth [1] despite evidence for exposure to at least two separate shock deformation events [2]. Comprised of high-Ca clinopyroxene (augite) and olivine (forsterite) crystals with regions of fine-grained mesostasis [3], the nakhlites represent several distinct magmatic events from the same volcanic edifice [4,5]. Both major phases within the nakhlites exhibit low water content and higher δD values compared to terrestrial rocks of similar chemical compositions [5], yet the nakhlites contain evidence of alteration from martian fluids [1,3]. This alteration postdated one shock event but predated impact-ejection [2]. However, the relatively low water content of the nakhlites could reflect degassing processes from a melt of similar water content to the Earth's shallow mantle [6].

Peak shock pressures within the nakhlites range between 5-20 GPa and have produced localised regions associated with high fracture densities and mechanical twins [7]. The way that shock deformation is expressed across the different nakhlite specimens has left distinct regions within each of the nakhlites that exhibit very low levels of crystallographic deformation. These lower deformation regions, which retain petrological emplacement textures, represent the nakhlite emplacement environment. Therefore, by analysing the slip systems present in these low shock deformation regions we can further constrain the parameters of deformation being enacted on the nakhlites pre-shock and ejection from Mars.

Crystallographic slip systems are predominantly constrained by water content, temperature, stress, and strain [8]. However, the activation conditions for specific slip systems can also be influenced by pressure, prior deformation history, the mechanism of deformation, geometry, pressure, presence of melt, and mineral composition [8-13]. In the case of forsterite and augite, considered in this study, forsterite is known to have a lower deformation threshold than augite [14,15] and has better defined deformation slip systems, constraints, and parameters informed by Terrestrial experimental mantle pressure and temperature conditions [8-13]. Here we investigate the crystallographic deformation of the nakhlites using observed slip systems from high and low deformation regions across the nakhlite group to determine whether we can identify different emplacement environments within the nakhlites, the influence of shock on the expression of inherent crystallographic emplacement deformation within a given sample with the aim of further constraining the nakhlite source environment on Mars.

Methods: 21 sections representing 16 of the 20 known nakhlite stones were carbon coated and prepared for EBSD analysis following standard mechanical and chemical polishing procedures. Large area maps (LAM) ranging from 7.6 – 209.6 mm^2 in area were collected by SEM at a tilt of 70°, under high vacuum, 4-8 nA beam current, 20 KeV, with a 120 µm aperture. Analysis step sizes ranged from 0.4 – 15 µm. The EBSD scans were collected using several instruments; 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 (ISSAC imaging centre, University of Glasgow), Carl Zeiss IVO SEM using a HKL NordlysNano high Sensitivity EBSD detector (Geochemical Analysis Unit (GAU), Macquarie University), a Hitachi SU70 FEGSEM equipped with a Symmetry CMOS detector and indexed using Aztec analysis software v3.4 (Oxford Instruments Nanoanalysis HQ, High Wycombe), and a Tescan MIRA3 VP-FESEM with Symmetry EBSD detector and Aztec EDS/EBSD acquisition system (John de Laeter Centre, Curtin University). All acquired data was processed at the University of Glasgow using Oxford Instruments HKL Channel 5 software using the phases augite and forsterite. Noise reduction procedures of a wildspike followed by 8-6 iterative nearest neighbour zero solution reduction were applied prior to removing twin boundaries and manually selecting regions of high and low regions within each sample.

Results and implications: We observe areas of high deformation that are associated with regions of more abundant mesostasis across the entire nakhlite group. The high deformation regions have more mechanical twins (Fig. 1), which we attribute to shock deformation. We also observe a change in the expression of major slip systems between the regions of high and low deformation for both forsterite and augite phases across the entire nakhlite suite. We interpret these differences in slip-system expression as an indicator of the different external deformation conditions related to the one or more shock events experienced by the nakhlites. In the high deformation regions we observe a general trend towards {hk0}[001] deformation in forsterite and a more equal distribution in the ratio between (100)[001] and (001)[100] in augite indicating a strong stress-strain control on deformation (Fig. 1). Within the lower deformation regions, we observe different augite-forsterite slip-system combinations indicating varying stress-strain, water content, and temperature conditions indicating several different emplacement environments for the nakhlite group.

The constraints related to the formation of different slip-systems within the lower deformation regions (*i.e.* emplacement), the trends between the higher deformation and lower deformation crystallographic slip systems (*i.e*. influence of shock deformation), and implications for the nakhlite source environment on Mars will be discussed at the meeting.

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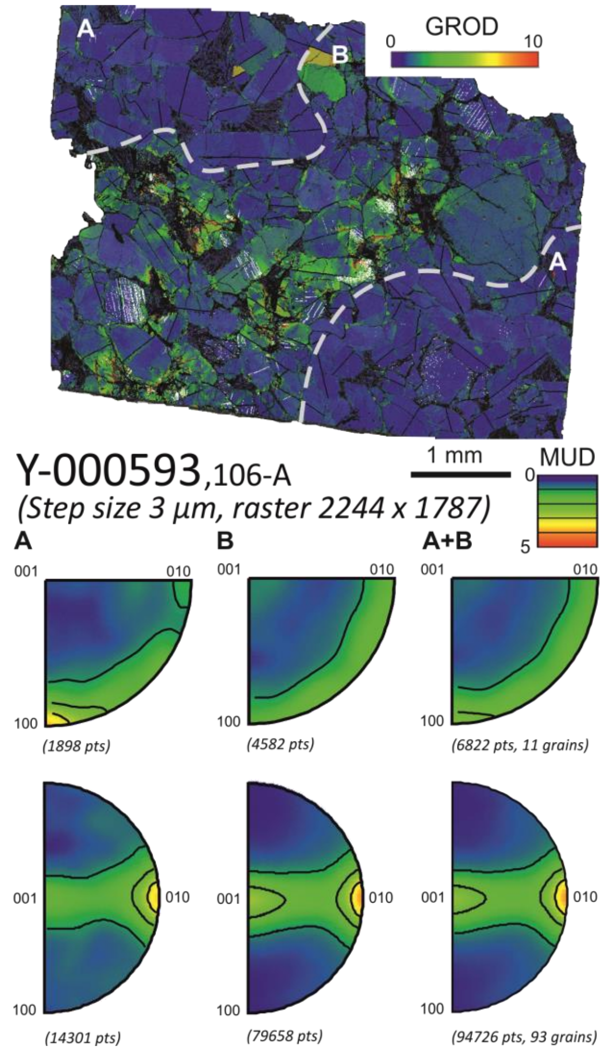

Figure 1: Grain relative orientation distribution (GROD) map of meteorite Yamato 000593 (section 106-A) showing simple twinning (black lines) and mechanical twinning (white lines). Regions A and B (separated by the grey dashed lines) represent the areas of low and high deformation within the sample, respectively. Below the GROD map we show the corresponding slip systems, disorientation 2-10°, cluster 3°, halfwidth 15°, for forsterite (top, unit cell b>c>a) and augite (bottom; unit cell a>b>c) for regions A (low deformation) B (high deformation) and A+B (combined whole section slip systems).