WHAT CAN CRYSTALLOGRAPHIC ORIENTATION TELL US ABOUT NAKHLITE FORMATION? S. Griffin[1], L. Daly[1-3], S. Piazolo[5], L.V. Forman[4,6], M. R. Lee[1], B. E. Cohen[7], P. W. Trimby[8], R. Baumgartner[9,10], G. K. Benedix[4,6,11], and B. Hoefnagels. [1]School of Geographical and Earth Sciences, University of Glasgow, UK. E-mail: Sammy.Griffin@glasgow.ac.uk, [2]Australian Centre for Microscopy and Microanalysis, University of Sydney, Australia. [3]Department of Materials, University of Oxford, UK. [4]Space Science and Technology Centre, School of Earth and Planetary Sciences, Curtin University, Australia. [5]School of Earth and Environment, University of Leeds, UK. [6]Department of Earth and Planetary Sciences, Western Australia Museum, Australia. [7]School of GeoSciences, University of Edinburgh, UK. [8]Oxford Instruments Nano analysis, High Wycombe, UK. [9]School of Biological, Earth and Environmental Sciences, The University of New South Wales, Kensington, NSW, Australia. [10]CSIRO Mineral Resources, Australian Resources Research Centre, Kensington, WA, Australia. [11]Planetary Institute, USA.

Introduction: The nakhlites currently represent the largest number of meteorite stones from a single location on Mars [1]. These volcanic rocks, indicate several distinct magmatic events (confirmed by discrete $^{40}Ar/^{39}Ar$ geochronological ages) sourced from a geochemically related magmatic source [2-4]. However, the style of distinct nakhlite magmatic events (intrusive, extrusive, or a mix), their emplacement relationship to one another, and the location of the nakhlite source crater on Mars remain poorly understood. The combination of multiple meteorite specimens and the identification of several magmatic events makes the nakhlites an ideal group to physically investigate magmatic processes on Mars here on Earth using established petrological techniques.

Augite (high Ca-clinopyroxene) is the dominant phase in all nakhlites (modal abundance ranging between 55–76%) [4], and cumulate textures have been a dominant descriptor for most samples across the nakhlite group [4]. Previous analyses of augite crystal preferred orientation (CPO) from several nakhlite samples indicate that the dominant formation mechanism is one of a single plane of strain as is typically observed on Earth in both intrusive and low energy extrusive settings [6]. Such deformation mechanisms have also been observed in lower gravitational Lunar surficial flows [7].

Here, microstructural properties of the dominant phase, augite, were assessed from 16 nakhlites to better understand the physical processes recorded within the suite of meteorites, and thus Amazonian volcanism on Mars.

Methods: Twenty-one sections representing 16 of the currently identified nakhlite stones were prepared for EBSD analysis following standard mechanical and chemical polishing procedures [5,8] and were carbon coated with a thickness of 7 µm. EBSD maps 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 using comparable settings; Zeiss Sigma variable pressure field-emission SEM (VP-FEGSEM) with a NordlysMax^2 EBSD detector and indexed using AZtec analysis software v3.3 from Oxford instruments (ISSAC imaging centre, University of Glasgow), Tescan MIRA3 VP-FESEM with Symmetry EBSD detector and Aztec EDS/EBSD acquisition system (John de Laeter Centre, Curtin University, Carl Zeiss IVO SEM using a HKL NordlysNano high Sensitivity EBSD detector (Geochemical Analysis Unit (GAU), Macquarie University), and a Hitachi SU70 FEGSEM equipped with a Symmetry CMOS detector and indexed using Aztec analysis software v3.4 (Oxford Instruments Nanoanalysis HQ, High Wycombe). All acquired data were processed initially using Oxford Instruments HKL Channel 5 updated with AZtecCrystal. Wildspike removal and noise reduction using an iterative 6-point nearest neighbour analysis. Twin boundaries were subsequently exempted for grain boundary determination, and .ctf files were also imported into MTEX for further quantitative analysis.

Results and Implications:

Assessment of augite CPO within the different analysed nakhlites, four of which are shown in Figure 1, reveals several distinct misorientation patterns within the group. Intercrystalline misorientation confirms a low intensity girdle feature for all analysed samples (Fig. 1c). The 2–10° intracrystalline misorientation patterns plotted in the crystal reference frame (Fig. 1b) show (100)[001] and (001)[100] to be the dominant distortion with some also exhibiting distortion related to {110}<001> or {110}$^1/_2$<110> (*e.g.*, Y 000749, Fig. 1b). In Figure 1a (intracrystalline misorientations plotted in the section reference frame) both pure compaction (distortion in plane, typical of cumulate formation *e.g.*, NWA 11013) and shear processes (distortion forming a point maxima, typical of flow *e.g.*, Y 000802) are observed. The combination of the different types of CPO misorientations across the nakhlite suite indicate emplacement mechanisms that cannot be explained purely by cumulate formation processes.

Acknowledgments: For providing the samples used in this study we thank the NHM London, Japanese

Antarctic Meteorite Research Centre (NIPR), Smithsonian, NASA Meteorite Working Group, Macovich Collection, The Museum of Western Australia, Centre Européen de Recherche et d'Enseignemet de Géosciences de l'Environment (CEREGE), and the Institute of Meteoritics University of New Mexico.

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Figure 1. Orientation plots for four of the sixteen analysed nakhlites: Yamato (Y) 000802 (lower shock), Northwest Africa (NWA) 11013 (higher shock), Caleta el Cobre 022 (weakest texture), and Y 000749 (highest texture) for the analysed suite. A) 2–10° misorientation in the sample reference frame, where a girdle indicates a single plane of strain and point represents two plains of strain. B) 2–10° misorientation in the crystallographic reference frame indicating patterns related to crystallographic slip. C) [001] pole figure from the reduced one point per grain (oppg) dataset with MTEX calculated textures indices – M-Index, J-Index, and Eigenvalue (PGR, LS-Index, and BA-Index).