NAKHLITE METEORITE PETROFABRICS REVEALED BY ELECTRON BACKSCATTER DIFFRACTION. S. Griffin[1], L. Daly[1,4], M. R. Lee[1], S. Piazolo[2], P. W. Trimby[3], L.V. Forman[4], P. Chung[1], B. E. Cohen[1], R. Baumgartner[5], G.K. Benedix[4]. [1]School of Geographical and Earth Sciences, University of Glasgow, Glasgow G12 8QQ U.K. E-mail: s.griffin.3@research.gla.ac.uk, [2]School of Earth and Environment, University of Leeds, Leeds, LS2 9JT, UK. [3]Oxford Instruments Nanoanalysis, High Wycombe, HP12 3SE, UK. [4]Space Science and Technology Centre, School of Earth and Planetary Sciences, Curtin University, GPO Box U1987, Perth, WA, 6845, Australia. [5]Australian Centre for Astrobiology, University of New South Wales, Sydney, NSW, Australia.

Introduction: Textural information, such as petrofabric, provide important evidence about the physical properties of crystallisation and deformation within rocks [1-5]. The nakhlite meteorites are a subgroup of basaltic igneous rocks from Mars [6]. These meteorites are porphyritic and rich in euhedral augite phenocrysts with small amounts of olivine phenocrysts and interstitial fine-grained mesostasis [6]. Their crystallisation ages span nearly 100 Ma (~1.4-1.3 Ga) and cover at least 4 temporally distinct magmatic events [7], yet have the same (~11 Ma) cosmogenic exposure age [7,8]. This particular subgroup is the least shocked of the known Martian meteorites [6,9].

Previous studies of the textures within the nakhlite meteorites have been limited to hand specimen [10,11] or 2 dimensional (2D) studies of thin sections using image processing software. [9,12-13]. However, the crystallographic orientation of elongate euhedral augite phenocrysts correlates with their grain shape in 3 dimensions (3D). Here we take advantage of this feature to present a quantitative description of the 3D textures of 10 different nakhlites using electron backscatter diffraction (EBSD) expanding upon our previous work [14].

Methods: A combination of premade and newly made sections were selected for EBSD analysis. Samples were picked to capture the diversity within the nakhlites, taking into account recovery location, known age, and modal mineralogy. All samples were cut at random with no regard for any petrofabric. Samples were mechanically and chemically polished, as well as carbon coated (with the exception of Lafayette and Miller Range (MIL) 03346) prior to EBSD analysis using standard EBSD preparation methods. EBSD data for Northwest Africa (NWA) 998 (UG-1 and T1), NWA 11013, Governador Valadares (BM 1975,M16), Yamato (Y)-000593, Y-000749 and Y-000802 were collected using a Zeiss Sigma variable pressure field emission gun scanning electron microscope (VP-FEGSEM) with a NordlysMax^2 EBSD detector and indexed using AZtec analysis software v3.3 from Oxford instruments at the ISAAC imaging facility, University of Glasgow; EBSD data for meteorites Nakhla, Governador Valadares, Lafayette, and MIL 03346 were collected using a Carl Zeiss IVO SEM at the Geochemical Analysis Unit (GAU; Macquarie University) using a HKL NordlysNano high sensitivity EBSD detector; and EBSD data for NWA 817 was collected using a Hitachi SU70 FEGSEM equipped with a Symmetry CMOS detector and indexed using AZtec analysis software v3.4 at Oxford Instruments Nanoanalysis HQ in High Wycombe. The SEMs were run under high vacuum (except MIL 03346 and Lafayette which were run at low vacuum ~ 49 Pa), 20 keV, 4-8 nA beam current and tilted at 70°. Large area EBSD maps were collected using a 3.3 μm step size (2.5 μm NWA 11013, and 0.4 μm for NWA 817) The data were noise reduced using Oxford Instruments HKL Channel 5 software using a wildspike followed by a 6 point nearest neighbor zero solution reduction. This reduced data then underwent a further one point per grain reduction to remove any bias from fractured grains and grains less than the map step size prior to being plotted on the stereonet.

Results: All meteorite samples exhibit a girdle feature along the augite <c> axis (long axis; Figure 1). This foliation becomes more visually distinct in samples where larger areas were mapped, with lower and more consistent experimental densities (MUD) values observed between different meteorite samples. The girdle feature is also consistent between different analysed samples of the same meteorite specimen (e.g. NWA 998 and Governador Valadares; Figure 1). Different slip systems are also present within the nakhlite olivine and augite phenocrysts [15] (this meeting).

Discussion: The most recent in depth study of the nakhlites reported that no distinctive textures were discernable [16], which contrasts with earlier studies in which textural features such as foliations and lineations were identified [9-11,13]. Our 3D study using EBSD shows that there is in fact a foliation present with a preferred alignment along the augite <c> axis evidenced by a girdle feature present within all 10 of the nakhlites. The size of the sampled area is important for being able to discern representative textural features. Large area EBSD mapping of samples enables the thin section scale crystallization related igneous textures to be discerned from the microscale. With the larger the area providing a better interpretation of the textures present. These textures can be linked to magmatic processes such as flow or gravity settling of the nakhlite parent lavas. Further EBSD work using samples cut perpendicular to the petrofabric will need to be done to distinguish between these two possibilities. How these textures inform our understanding of the nakhlite magmatic environment is ongoing work and will be discussed at the meeting.

Acknowledgements: We thank the Natural History Museum London, the Japanese Antarctic Meteorite Research Centre, Smithsonian Museum, NASA Meteorite Working Group, Macovich Collection, and The Museum of Western Australia for providing samples. S.G. would also like to thank PSI and the Pierazzo award as well as the UofG Early Career Mobility Scheme to L.D. for support in attending LPSC 2019.

References: [1] Baschou, J. et al. (2005).*Jour. Volc. & Geotherm. Res., 145,*1-2, 119-135. [2] Bhattacharyya, D. (1966). *Tectonophys., 3,* 1, 29-33. [3] Boiron, T. et al. (2013). *Geophys. J. Int., 193,* 2, 29-33. [4] Cashman, K.V. and Marsch, B.D. (1988) *Cont. Min. and Pet., 99,* 292-305. [5] Prior D. J. et al. (1999) *Amer. Mineralogist, 84,* 1741–1759. [6] Trieman A. H. (2005) *Chemie der Erde – Geochem., 65,* 203-270. [7] Cohen et al. (2017) *Nat. Comm., 640* (8), 1-9. [8] Nyquist, L.E. et al. (2001). *Chronology and evolution of Mars,* 105-164. [9] Berkley et al. (1980) *LPS XXI,* 1089-1102. [10] Imae et al. (2003) *Antarc. Met. Res., 16,* 13-33. [11] Bunch, T., and Reid, A.M. (1975). *Meteoritics & Plantetary Science, 10,* 4,303-315. [12] Irving et al. (2002) *MetSoc.,* Abstract: #A70. [13] Jambon et al. (2016) *Geochem. et Cosmochim., 190,* 191-212. [14] Daly, L. et. al. *in prep.* [15] Griffin, S. et al. (This meeting) *LPSC L.* [16] Udry and Day (2018) *Geochim. et Cosmochim., 238,* 292-315.

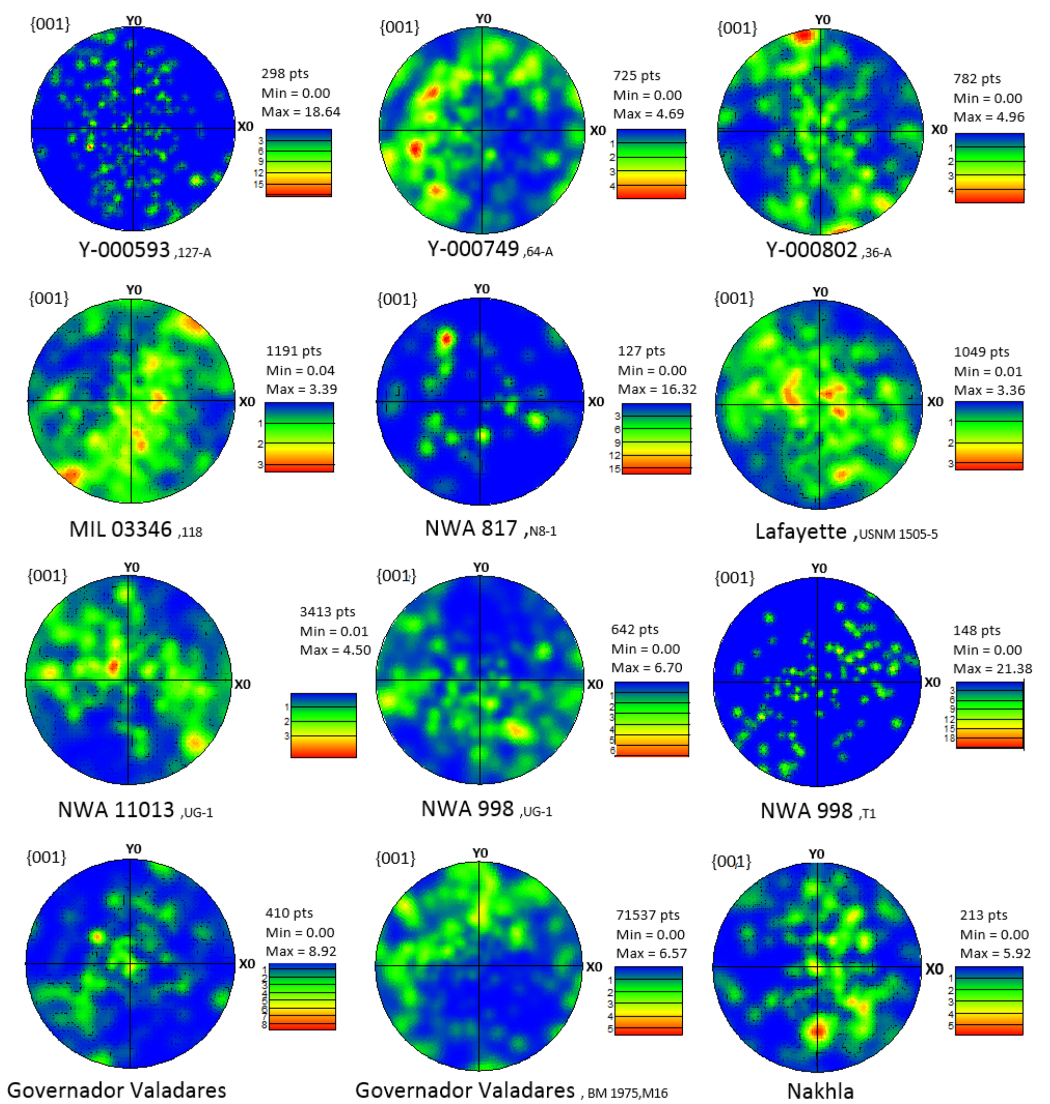

Figure 1: Lower hemisphere stereographic projection of the <c> axis of augite crystals (one point per grain, cluster size 5°, half width 5°) from large area EBSD maps. A girdle feature can be seen within the <c> axis of each nakhlite meteorite. This girdle feature becomes more prominent with increasing grain count.