THE YAMATO NAKHLITES: A CASE STUDY FOR THREE DIMENSIONAL ANALYSIS

S. Griffin[1], L. Daly[1], M. R. Lee[1] and B. E. Cohen[1], [1]School of Geographical and Earth Sciences, University of Glasgow, Glasgow, G12 8QQ, UK (s.griffin.3@research.gla.ac.uk).

Introduction: The Yamato nakhlites are basaltic igneous rocks that were impact-ejected from Mars. They comprise three separate stones, Y-000593, Y-000749, and Y-000802, that were recovered from the Yamato Mountains, Antarctica by the 41st Japanese Antarctic Reseach Expedition (JARE) in 2000 [1,2]. Previous petrographic studies of thin sections (which provide 2-D views of rock structure), and geochemical analyses, have suggested that the three Yamato nakhlites are paired. However, $^{40}Ar/^{39}Ar$ geochronology of Y-000593 and Y-000749 [3] have indicated a crystallisation age discrepancy of 69 ± 15 Ma (2σ), which is inconsistent with pairing. There is currently no published age for Y-000802. Here we have used electron backscatter diffraction (EBSD) to obtain new 3-D information on igneous and impact-generated fabrics of the Yamato nakhlites, and to identify and characterise similarities and differences between the three stones that may in turn elucidate their original petrologic relationships.

Methods: We studied three thin sections (Y-000593,127-A, Y-000749,64-A, Y-000802,36-A) that were cut without considering the orientation of any petrofabric that may or may not have been present. These samples were mechanically and chemically polished using standard EBSD preparation methods then carbon coated for analysis [4]. EBSD data were collected at the University of Glasgow using a Zeiss Sigma variable pressure field emission gun scanning electron microscope (VP-FEGSEM) equipped with a NordlysMax^2 EBSD detector. Kikuchi patterns were indexed using the AZtec v3.3 software package from Oxford instruments following the settings and processing described in [5].

Results: Augite crystals in all three stones are aligned with their [001] axes roughly parallel [6]. Such alignment is commonplace in pyroxene-rich terrestrial lava flows [7]. Deformation observed within the Yamato stones is linked to weak amounts of shock. This shock deformation is represented by different combinations of slip systems within constituent olivine and clinopyroxene crystals (Figure 1). Of the three stones, Y-000802 differs the most in its type of shock deformation microstructures. The significance of these slip system differences was tested by analysing multiple thin sections of two other nakhlites: Northwest Africa (NWA) 998 and Governador Valadares. Results show that slip systems remain the same between different thin sections of each nakhlite [5].

Implications: In providing 3-D information on mineral microstructures from 2-D thin sections, our EBSD results have revealed important new differences between the Yamato nakhlites. The differences observed between the three sections in olivine and clinopyroxene slip systems indicates that they were deformed at contrasting pressures and temperatures [5]. Such heterogeneity in intensity and style of shock deformation is typical of terrestrial impact structures [8] and so should also be expected for the nakhlite source crater.

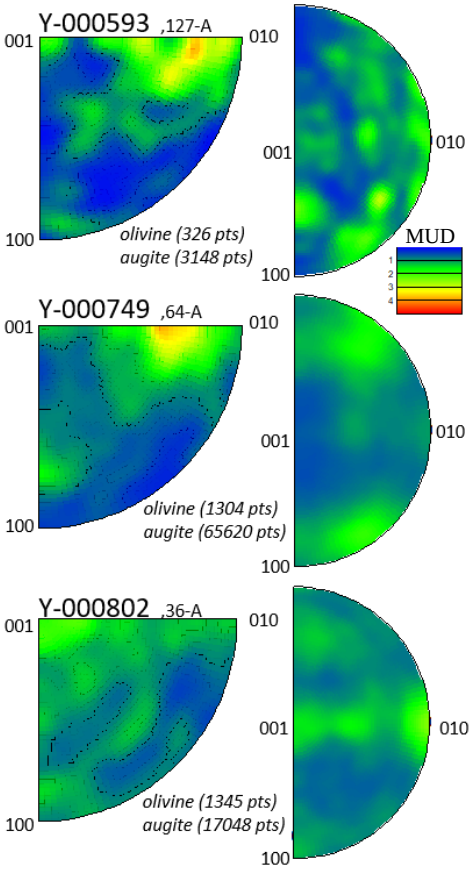

Figure 1: slip systems, olivine (left) and augite (right), of the Yamato nakhlite stones. CS crystal coordinate roatation axis, upper hemisphere equal area projection, cluster size 0°, half width 10°.

Conclusion: 3D analysis by EBSD has revealed new petrofabric and textural features within the Yamato nakhlites. We are able to discern petrofabric orientation regardless of the sample's cut orientation and observe features that would otherwise be unobservable using standard 2D analysis .

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Acknowledgements: We thank the Japanese Antarctic Meteorite Research Centre for the loan of the samples.