CRYSTALLISATION AND ALTERATION OF THE YAMATO NAKHLITES

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Introduction: Published geochemical and petrographic studies of the three Yamato nakhlites, Y-000593, Y-000749, and Y-000802, have lead to the interpretation that they are paired, consistent with their recovery from the same ice sheet [1,2]. However, ^{40}Ar/^{39}Ar geochronology of the Y-000593 and Y-000749 stones has indicated a crystallisation age discrepancy of 69 ± 15 Ma (2σ) [3] (there are currently no published crystallisation age data for Y-000802). Here we combine new large area mapping electron dispersive X-ray spectroscopy (LAM-EDS) by scanning electron microscopy (SEM) with wavelength dispersive X-ray spectroscopy (WDS) and published geochemical data to investigate the geological histories and genetic relationships of the Yamato nakhlite stones. We assess how Y-00802 relates to the other Yamato nakhlites and how each stone relates to the nakhlite source volcano on Mars.

Methods: Geochemical data for all three Yamato nakhlites were compiled and interrogated from the published literature e.g. [4,5]. LAM-EDS, LAM-electron backscatter diffraction (EBSD), and LAM-SEM images were collected at the University of Glasgow using a Zeiss Sigma variable pressure field emission gun SEM (VP-FEGSEM) equipped with a NordlysMax^2 EBSD detector; Kikuchi patterns were indexed using Oxford Instruments AZtec analysis software. Quantitative chemical analyses of the alteration assemblages in these meteorites is being collected using WDS on the same Zeiss Sigma VP-FEGSEM.

Results: Here we consider rare earth element (REE) data for Y-000593 and Y-000749 only as no REE data have been published for Y-000802. The geochemical data from the Yamato stones sit within the overall pattern of the nakhlite group. However, geochemical differences between Y-000593 and Y-000749 exceed analytical uncertainties; for example, there is a 25% difference in La/Yb between the stones, and there are also differences in Zr/Nb, La/Ba and La/Nb values. LAM-EBSD mapping reveals differences in mineral distribution and grain size (Y-000593: 52.6% augite, 12.3% olivine, 33.4% mesostasis; Y-000749: 44.7% augite, 3.54% olivine, 51.2% mesostasis; Y-000802: 61.3% augite, 6.8% olivine, 30.7% mesostasis; Figure 1).

Implications: Y-000593 and Y-000749 show similar petrology and major element geochemistry [1, 2, 5]. Modelling suggests two different scenarios for the Yamato stones; either that the geochemical differences can be explained by subtle difference in soure melting, or that the differences are caused by fractional crystalisation. Using La/Yb REE ratio we see a fractional crystallisation difference that is substantially greater than what would be expected from the modal mineralogy of the two stones. Other REE geochemical modelling related to the mantle source of the Yamato stones reveals that the samples likely derived from a similar - and related - but not identical mantle source. Studies of multiple flows from the same terrestrial volcano show similar geochemical characteristics to those observed in Y-000593 and Y-000749 [6].

Conclusions: Our modelling of published Yamato nakhlite geochemical data show the two stones to have similar geochemistry, but with subtle variations in REE and some other trace elements. These geochemical differences between Y-000593 and Y-000749 can be explained by minor differences in source melting or crystal fractionation, which is consistent with these stones representing different eruptions from the same source volcano.

References: [1] Imae N. et al. (2005) *Meteoritics and Planetary Science* 40:1581–1598. [2] Misawa K. et al. (2003) *Antarctic Meteorite Research* 16:1–12. [3] Cohen B. E et al.. (2017) *Nature Communications* 640:1–9. [4] Bridges, J. C. and Warren C. D. (2006) *Journal of the Geological Society* 163:229-251. [5] Udry, A. and Day, J. M. D. (2018) *Geochimica et Comochimica Acta* 238:292-315. [6] Fenton et al. (2004) *The Journal of Geology* 112:91-110.

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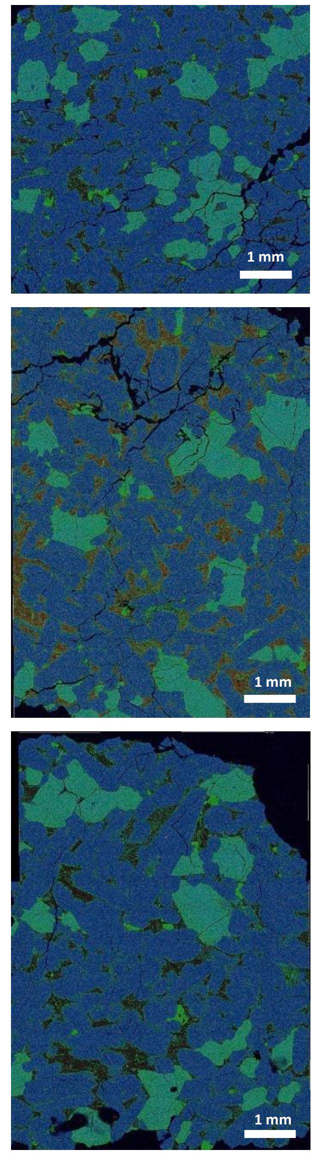

Figure 1: The Yamato nakhlites: Y-000579 (top), Y-000749 (middle), Y-000802 (bottom). False coloured EDS maps Al (orange), Mg (blue), Fe (green). Note the differences in grain size and mineral abundances..