# OLIVINE ALTERATION IN SHERGOTTITE NORTHWEST AFRICA 10416.

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**Introduction:** Secondary alteration phases in martian meteorites allow us to study martian hydrous processes and potential habitability, but first, it is crucial to discover the origin of any secondary alteration phases, martian or terrestrial. Here we report on the petrology and alteration history of the olivine-phyric shergottite, Northwest Africa (NWA) 10416, paying particular attention to the origin of the extensive aqueous alteration products identified in this meteorite.

**Methods:** A thin section was characterised using a FEI Quanta 650 FEG-SEM. A JEOL JXA-8200 Electron Microprobe was also used for EPMA-WDS analysis at the University of Nottingham. Wafers suitable for Transmission Electron Microscopy (TEM) were extracted using Focused Ion Beam (FIB) Milling on a FEI Quanta 200 3D Dual FIB-SEM and TEM was performed using a JEOL 2100+ at the University of Nottingham. Fe-K X-ray Absorption Spectroscopy (XAS) was carried out using the 2.5µm I-18 microfocus spectroscopy beamline at the *Diamond* synchrotron, UK. Oxygen isotopic analysis of NWA 10416 was performed using the infrared laser-assisted fluorination system at the Open University [1].

**Olivine:** Occurs in two forms, the ~1 mm, megacrysts bearing a distinctive zoned colouration, and smaller, ~400 µm, groundmass grains. The megacrysts display amber-coloured cores, brown mantle zones and clear rims (Fig. 1). We identified a gradual compositional trend across the grains that is consistent with relict igneous zonation, showing amber-coloured Mg-rich cores and clear rims of almost equal MgO and FeO content, $Fo_{52}$. Notably, the groundmass olivine shows no signs of zonation and has a large compositional range, $Fo_{39-58}$, which overlaps with the megacryst clear rims. EPMA-WDS analysis reveals that only the groundmass grains and megacryst clear rims are stoichiometric olivine, the coloured zones of olivine have low WDS totals, consistent with alteration and partial replacement.

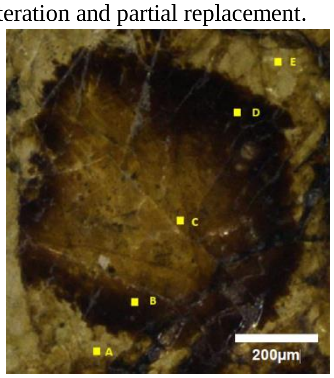


**Figure 1** - *Optical image of olivine megacryst, labelled A to E are the locations corresponding to XAS data in Figure 2.*

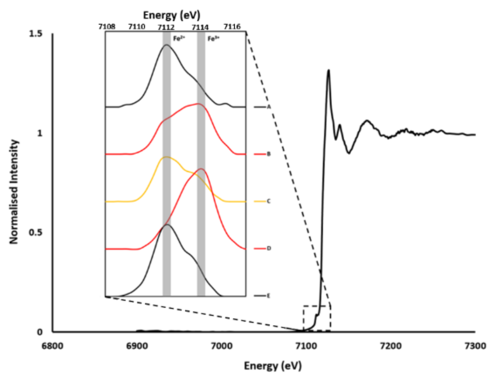


**Figure 2** - *XAS data of Fe K XANES region. Lines A to E correspond to XAS sites shown in Figure 1.*

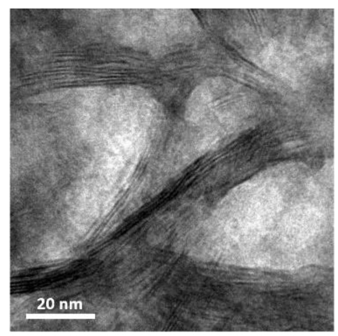


**Figure 3** - *HRTEM image of alteration features seen in a shock-melt olivine grain. Image taken at ×150k magnification.*

**X-ray Absorption Spectroscopy**: was performed across a megacryst (Fig. 1) in order to gather information about the oxidation state of the different coloured zones. The results (Fig. 2) revealed that the coloured olivine has an increase in ferric iron compared to the clear rim (clear rim, $Fe^{3+}/\Sigma Fe = 0.03$; brown mantle zone, $Fe^{3+}/\Sigma Fe = 0.77$; amber core, $Fe^{3+}/\Sigma Fe = 0.24$).

**TEM Analysis:** A TEM wafer was taken from an olivine within a shock-melt vein in order to investigate the origin of the alteration. The hypothesis being that if fluid alteration features overprint the shock features then it is more probable that the water-rock interaction took place after the shock event and most likely on Earth. During analysis we did identify sporadic curved *d*-spacings (Fig. 3), characteristic of a flexible phyllosilicate structure, that were unaffected by any type of shock feature. The d-spacings were of a trioctahedral nature and were measured as 0.95 nm, consistent with dehydrated saponite. This presence of clay features, without disturbance by any shock features, suggests that the fluid alteration postdates the shock event and is therefore terrestrial in origin.

**Oxygen Isotope Analysis:** Bulk meteorite is $\delta^{17}O = +2.98$ ‰, $\delta^{18}O = +5.13$ ‰, and $\Delta^{17}O = +0.309$ ‰; and amber-coloured relict olivine, $\delta^{17}O = +2.68$ ‰, $\delta^{18}O = +4.63$ ‰, and $\Delta^{17}O = +0.272$ ‰. The bulk material essentially plots on the Martian Fractionation Line (=0.307 ‰) [2]. Amber-coloured olivine, average $\Delta^{17}O = 0.271 \pm 0.002$ ($2\sigma$) ‰, lies slightly closer to the TFL, consistent with some terrestrial fluid contamination from the NWA desert find locality.

**Discussion:** Mg-olivine is more susceptible to alteration than its Fe counterpart under oxidizing conditions [3,4] like those shown through our XAS analysis, when exposed to low T fluids. This could explain why the alteration is only within the Mg-rich megracryst cores. Shock effects caused veins and fracturing of the compositionally zoned olivines, and finally, during its time in NW Africa, groundwater exploited the fractures and altered the olivine in a way that was controlled by the pre-existing, igneous compositional zonation.

**References:** [1] Greenwood R. C. (2017) *Chemie der Erde - Geochemistry*, 77(1): 1-43. [2] Franchi I. A. et al. (1999) *Meteoritics & Planetary Science,* 34: 657-661. [3] Hausrath E. M. and Brantley S. L. (2010) *Journal of Geophysical Research, 115,* 2156–2202. [4] Wogelius R. A. and Walther J. (1992) *Chemical Geology,* 97(1-2): 101-112.