CRYSTALLINE CLAYS IN AN INTRIGUING OVOID STRUCTURE IN NAKHLA.

E. Chatzitheodoridis[1], S. Haigh[2] and I. Lyon[3]
[1]National Technical University of Athens, School of Mining and Metallurgical Engineering, Department of Geological Sciences, Room 2.10, 9 Heroon Polytechneiou str., GR-15780 Zografou, Athens, Greece eliasch@metal.ntua.gr. [2]School of Materials, University of Manchester, Manchester M13 9PL UK. sarah.haigh@manchester.ac.uk. [3]School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Manchester, M13 9PL, UK. Ian.Lyon@manchester.ac.uk

Introduction: An ovoid structure was found in a thin section of the Nakhla meteorite (BM1911,369) during a visible light microscopy survey (figure 1).

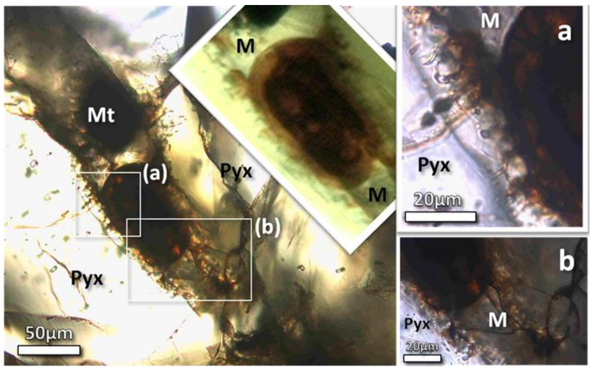

Figure 1. Transmitted light optical image of the ovoid structure demonstrating its reddish-orange colour (slightly magnified in the inset). Areas (a) and (b) are shown on the right magnified to enhance some details (see text). The non-transparent phase is Ti-magnetite (Mt), while the structure sits between the two large pyroxene crystals (Pyx) and the amorphous mesostasis phase (M).

The thin section containing the structure was originally prepared using non-polar solvents and polished with Al_2O_3 in order to reduce contamination and dissolution of soluble materials. The shape and certain structural details (figure 2) were suggestive of a possible biological origin and so a detailed study using Raman spectroscopy, TOF-SIMS, AFM, X-Ray tomography, EFTEM and HRTEM was carried out to try and elucidate its origin.

The ovoid sits solidly within a narrow mesostasis area composed of amorphous material and between two pyroxene crystals. Its size, structure and relationship to surrounding minerals dictate that it originated on Mars within the rock that went to make up the Nakhla meteorite and not through subsequent alteration whilst on Earth.

The structure is composed of several highly distinct concentric zones with an internal void. Within the void space are two masses referred to as 'islands' that are chemically and structurally similar to the walls. A symmetrical fissure cuts through the wall of the ovoid. The fissure is now blocked by a filamentous deposit that also covers the internal walls of the ovoid and the outer boundary of the islands.

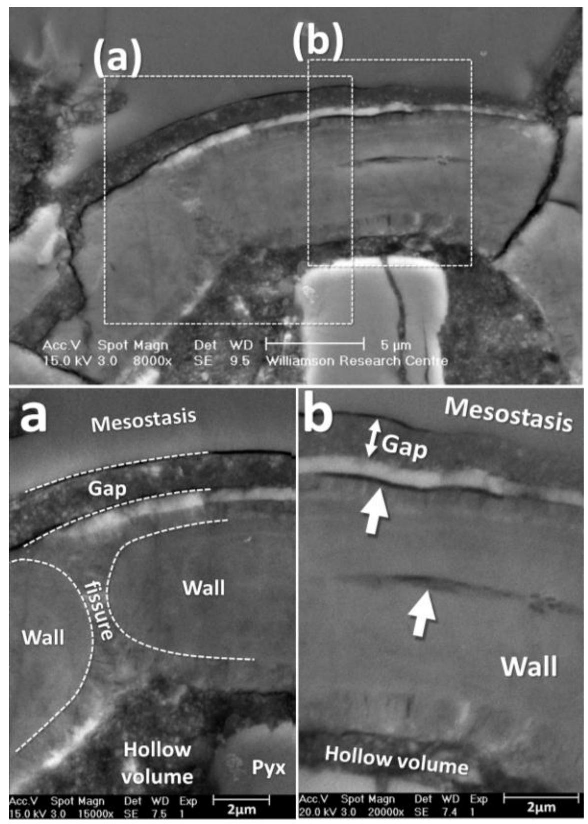

Figure 2. BSE SEM images of the area of the ovoid structure, which clearly demonstrate the presence of a highly symmetrical fissure. Frame (a) depicts the fissure, the gap between the mesostasis and the wall of the ovoid, as well as the hollow volume of the structure. Frame (b) shows details of the ovoid walls with arrows indicating gaps probably opened due to mechanical stress.

An electron transparent section was removed by Ga^+ ion beam milling a cross section of one of the walls of the ovoid.

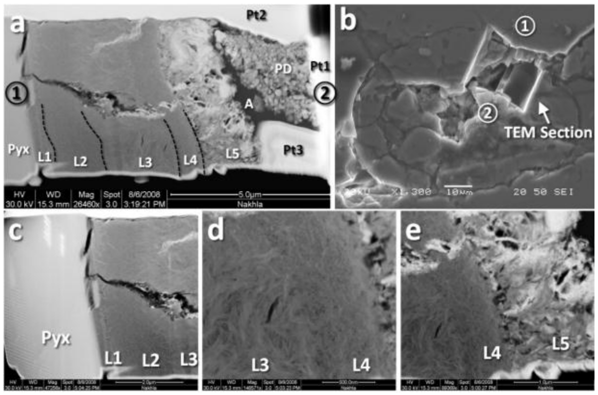

Figure 3. BSE SEM images showing the TEM slice (a) removed from the wall of the ovoid structure using focussed ion beam (FIB) milling. (b) Secondary electron (SEM) image of the FIB pit (section ①-②). Images (c), (d) and (e) are magnified images of the film, showing the boundaries between the different phases and layers, starting from pyroxene (Pyx) on the left, through layers L1, L2, L3, L4 and L5. The bright region on the right hand side of (a) is the platinum metal capping layer (Pt1). Further Pt layers on either edge of the slice (Pt2 and Pt3) provide stability to the thin section and are added during FIB sample preparation. The region of polishing debris (PD) is a result of previous SEM sample preparation. Black or very dark parts of these images (a),(c),(d),(e) represent vacuum or regions of low atomic mass, such as the araldite epoxy glue (A) used for the preparation of the thin section.

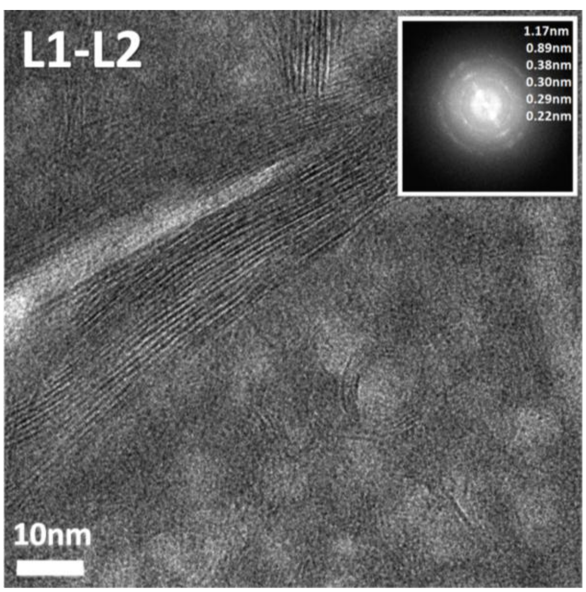

Figure 4. HRTEM image of an area at the interface between layers L1 and L2. Lattice planes are visible both in large crystallites and in the less ordered region where they are highly curved, producing spherical features of less than 10nm diameter. Inset is the Fast Fourier Transform (FFT) of the image demonstrating that the planes visible in the image correspond to planes with separations of 1.17, 0.89, 0.38, 0.30, 0.29 and 0.22nm.

The wall of the ovoid structure is divided into 5 areas based upon crystallinity and morphology. These are labeled L1-L5 in figure 3 and some extra detail of the interface between L1 and L2 is shown in figure 4. Details of other layers and HRTEM imaging will be detailed during presentation.

The layers L1-L5 show varying degrees of crystallinity with nanocrystalline sheet silicates mixed with amorphous materials in L1-L4 and iron-rich phases in L5. Stoichiometry suggests a trioctohedral clay, interpreted as an iron-rich saponite. This is the first time that crystalline clay is reported for Nahkla.

Several inorganic scenarios could be invoked to explain the origin and formation of the ovoid, these include the complete replacement of a pre-existing mineral phase through alteration or deposition of a transported phase in a hollow amygdaloid. There are difficulties however with each of these possible scenarios which will be discussed in presentation. An alternative hypothesis is that the pre-existing structure was of biological origin as suggested by its morphology. Replacement and fossilization of soft tissues by clays is well known [1] and terrestrial analogues of known biological origin are documented [2,3]. A biological origin for other structures in Nakhla, ALH84001 and Tissant have been advanced [4-7] and whilst there is no conclusive evidence at present that the ovoid structure in Nakhla reported here is of biological origin, it strongly resembles terrestrial analogues of known biological origin.

References:

[1] Orofino V. et al. (2010), *Icarus*, 208, 202-206.

[2] Gorlenko V. M. et al. (2000) *Orig Life Evol Biosph*, 30, 567-577. [3] Thomas-Keprta K. L. et al. (1998) *Geology*, 26, 1031-1034. [4] Gibson E.K. et al. (2001) *Precambrian Res*, 106, 15-34. [5] McKay D. S. et al. (1999), *LPS XXX*, Abstract #1816. [6] Wallis J. et al. (2012) *J Cosmology*, 18, 8500-8505. [7] Miyake N. et al. (2012) *EPSC Abstracts*, 7, EPSC2012-906.

Acknowledgements. The authors acknowledge support from STFC and thank D. Blagburn, M. Lee, D Plant, P Wincott for technical support and the acquision of some preliminary data that led to the work reported here.