COATED SILICA NANOPARTICLES IN NAKHLA IDDINGSITE VEINS: IMPLICATIONS FOR WATER-ROCK INTERACTION WITHIN THE MARTIAN CRUST.

M. R. Lee[1], I. MacLaren[2], A. Kovacs[3], T. Tomkinson[1,4], D. F. Mark[4], L. J. Hallis[1] & C. L. Smith[5]. [1]School of Geographical & Earth Sciences, University of Glasgow, G12 8QQ, UK Martin.Lee@Glasgow.ac.uk. [2]School of Physics & Astronomy, University of Glasgow, G12 8QQ, UK [3]Ernst Ruska-Centrum für Mikroskopie und Spektroskopie mit Elektronen, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany. [4]Scottish Universities Environmental Research Center, East Kilbride, UK [5]Natural History Museum, London, SW7 5BD, UK

Introduction: Nakhla is a martian olivine-bearing clinopyroxenite fall that contains 0.11-0.13 wt. % water [1, 2]. Most of this water is contained within olivine-hosted veins of 'iddingsite', whose principal constituent is a Mg- and Fe-bearing hydrous silicate [3]. Since the discovery of iddingsite in 1975 [4], the Mg-Fe silicate has proven difficult to identify, largely owing to its very fine grain size. Findings from examination of this material by transmission electron microscopy (TEM) are contradictory, and include: smectite [3]; smectite plus hematite, goethite, quartz, cristobalite, tridymite and amorphous silica [5]; amorphous gel [6]. We have sought to resolve this debate by high-resolution electron imaging and spectroscopy of Nakhla iddingsite veins.

Methods: Using a FEI Duomill focused ion beam instrument, an electron transparent foil was cut from a vein in a polished thin section prepared from Nakhla BM1913,25. The foil was milled initially to ~100 nm and then further thinned to ~50 nm by argon ion milling using a Fischione Nanomill operated at 500 eV. (Scanning) TEM was performed using a JEOL ARM200F including electron energy loss spectroscopy (EELS) with a Gatan GIF Quantum. EELS was used to map chemical compositions and Fe valence states at nanometre resolution.

Results and discussion: We focused on an iddingsite vein containing a central band of Mg-Fe silicate that is flanked by siderite, itself partially altered to goethite. The Mg-Fe silicate yields diffraction rings with d-spacings of 0.254 and 0.154 nm, and dark-field TEM imaging using the 0.254 nm ring demonstrates that it is formed by scattering from numerous ~2-5 nm sized crystals. STEM imaging and EELS mapping shows a structure of globular nanoparticles embedded in a matrix; most of the nanoparticles are 3-5 nm in diameter, although a small proportion are larger, up to 30 nm. The nanoparticles are almost pure silica, and the O- Mg- and Fe^{3+}-rich composition of their matrix is consistent with a ferrihydrite/goethite coating, probably intergrown with smectite. Our discovery of embedded silica nanoparticles agrees well with previous mineral identifications by Thomas-Keptra et al. [5]. Nakhla vein formation started by dissolution of olivine [7], and the challenge now is to determine why this reaction produced nanoparticles, and the implications of their discovery for understanding water-rock interaction within crust of Mars.

References: [1] Karlsson H. R. et al., 1992. *Science* 255:1409–1411. [2] Leshin L. A. et al. 1996. *Geochmica et Cosmochimica Acta* 60:2635-2650. [3] Gooding J. L. et al. 1991. *Meteoritics* 26:135–143. [4] Ashworth J. R. and Hutchison R. 1975. *Nature* 256:714–715. [5] Thomas-Keptra, K. L. et al. 2000. Abstract #1690. 31st Lunar & Planetary Science Conference. [6] Changela H. G. and Bridges J. C. 2011. *Meteoritics & Planetary Science* 45:1847–1867. [7] Lee M. R. et al. 2013. *Meteoritics & Planetary Science* 48:224–240.