ORIGINS AND DELIVERY OF VOLATILE ELEMENTS IN TERRESTRIAL PLANETS: INSIGHT FROM THE COMPOSITION AND FUNCTIONAL CHEMISTRY OF ORGANIC MATTER IN METEORITES. P. Haenecour[1], T. J. Zega[1,2], J. Y. Howe[3], M. Bose[4] and P. Wallace[1]. [1]Lunar and Planetary Laboratory, The University of Arizona, Tucson, AZ, USA. [2]Dept. of Materials Science and Engineering The University of Arizona, Tucson, AZ, USA. [3]Hitachi High-Technologies America Inc., Clarksburg, USA. [4]School of Earth and Space Exploration, Arizona State University, Tempe, AZ, USA. (pierre@lpl.arizona.edu).

Introduction: It is believed that chondrites were a major sources of volatiles for terrestrial planets, including the Earth. The volatile component consist of water and organics. Chondrites can contain up to 6 wt% C, much of which occurs in the insoluble organic matter (IOM) fraction [1]. Meteoritic IOM often exhibits isotopic anomalies in N and/or H. However, the elemental composition and functional chemistry of the organic carriers of these isotopic anomalies is still poorly constrained. Here, we report electron energy-loss spectrometry (EELS) analyses of D-rich carbon nanoglobules identified in the meteorite CM2.6 Queen Alexandra Range (QUE) 97990 meteorite.

Experimental Methods: D-rich hotspots were identified by NanoSIMS 50L raster ion imaging of ^{1}H, ^{2}H, ^{12}C and ^{16}O isotopes in multicollection mode of matrix areas in a thin-section of QUE 97990. We then selected several hotspots for further characterization with transmission electron microscopy (TEM). We extracted three hotspots located in two NanoSIMS images (3Aa1 and 3Aa11) using the Helios Focused-Ion Beam SEM at the University of Arizona (UA). Subsequently, the FIB section was analyzed using the newly installed 60-200 keV Hitachi HF5000 TEM/STEM at UA. All our STEM/TEM data were acquired at 60 kV to avoid sample damage.

Results and Discussion: QUE 97990 is one of the least altered CM chondrites [2] and it is more D-rich than most CMs (bulk δD of IOM residue = 1218 ± 5 ‰) [3]. We identified numerous D-rich hotspots (D/H ratio up to 6.25×10^{-4}) in fine-grained matrix areas of QUE 97990. The three hotspots extracted for TEM study have D/H ratios between 4.04 – 6.25×10^{-4}. TEM images of the cross-section of these hotspots show that one is filled with an aggregate of nanoglobule-like objects, possibly hollow, that are surrounded and intimely associated with fine-grained fibrous silicates. The two other hotspots do not show any C-rich material but show the presence of phyllosilicates, suggesting that these phyllosilicates are the carriers of these D enrichments. We obtained detailed EELS spectal imaging of two carbon nanogubles adjacent to a hotspot and their energy-loss near-edge structure (ELNES) for C, K are consistent with the presence of aromatic functional groups (sharp rise from edge onset to a peak at 285 eV, the π* peak). Our observation of aqueous alteration in the area of the hotspot associated with the D-rich isotopic and aromatic C compositions of the IOM is inconsistent with a previous observation of a decrease in the fraction of aromatic nanoglobules with increasing degree of aqueous alteration [4]. The spectrum also indicates the presence of S, N, and O in these nanoglobules but they are heterogeneously distributed (Fig.1); e.g., area #1 does not contain detectable amount of S and has significantly less N. The N/C and O/C elemental ratios of these two hotspots are similar to nanoglobules in other CM chondrites [5], but significantly higher than the N/C ratios of bulk IOM residues (typically lower than 0.05 [1]). EELS analysis of additional hotspots within QUE 97990 and other CM and CR chondrites, which we plan to do prior to the meeting, will better constrain the carriers and distribution of volatiles in meteoritic organics; thus allowing us to better understand the delivery of volatile elements to terrestrial planets.

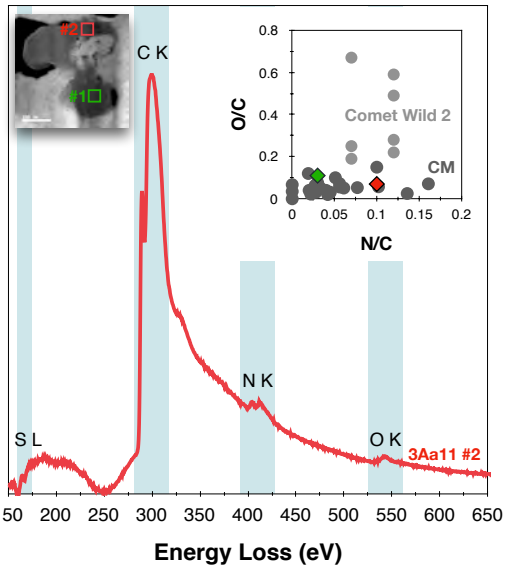

Fig. 1. EELS spectrum of an small area in the C nanoglobule adjacent to hotspot 3Aa11. Comparison (inset) with other nanoglubes in CM chondrites [5] and organics from Comet Wild 2 samples [6].

References: [1] Alexander et al. (2017) *Chem. Erde* 77, 2, pp 227-256. [2] Rubin A. E. et al. (2007) *GCA* 71, 2361. [3] Alexander et al. (2010) *GCA* 74, 4417. [4] De Gregorio, B.T. et al. (2013*) MAPS* 48: 904. [5] Garvie & Buseck (2006) *MAPS* 41, 633–642. [6] Cody et al. (2008) *MAPS* 43, 353–365.

Acknowledgment: This work is supported by NASA Grant NNX15AD94G for the NExSS "Earths in Other Solar Systems" (EOS) program.