

## ELECTRON ENERGY-LOSS SPECTROSCOPY OF DEUTERIUM-RICH ORGANIC MATTER IN THE CM CHONDRITE QUEEN ALEXANDRA RANGE 97990.

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**Introduction:** The dominant organic component in meteorites is composed of material that is insoluble in polar solvents and de-mineralizing acids [1]. Such insoluble organic matter (IOM) typically occurs either as discrete domains (e.g., nanoglobules) or as  $\mu\text{m}$ -sized diffuse material [2-5] and often exhibits large enrichments in D and  $^{15}\text{N}$ . It has been hypothesized that such enrichments reflect the preservation of molecules originally formed in cold molecular clouds and/or at the cold edge of the solar protoplanetary disk [6-8]. However, the origin of IOM and its associated isotopic anomalies remain unclear. To probe the nature of primitive IOM and further constrain the origin(s) of isotopic anomalies and their carriers, we are performing *in-situ* correlated electron energy-loss spectroscopy (EELS) analysis of  $^{15}\text{N}$ - and D-rich organic matter in several meteorites of different petrologic types [9]. Few studies [e.g., 2, 3, 5] have thus far investigated *in-situ* the functional chemistry of their carrier phases, and the possible effect of aqueous alteration on their isotopic composition and functional chemistry. Here, we report on initial results on two D-rich hotspots identified in the CM chondrite, Queen Alexandra Range 97990 (QUE 97990).

**Sample and Experimental Methods:** D-rich hotspots were identified by raster ion imaging of  $^1\text{H}$ ,  $^2\text{H}$ ,  $^{12}\text{C}$  and  $^{16}\text{O}$  isotopes in multicollection mode of matrix areas in a thin-section of QUE97990 using the NanoSIMS 50L at ASU. We then selected several hotspots for further characterization with transmission electron microscopy (TEM). We extracted two hotspots located in the same NanoSIMS image (3Aa1) using the FEI Helios Focused-Ion Beam SEM at the University of Arizona following the procedure described in [10]. Subsequently, the FIB section was analyzed using the newly installed 200 keV Hitachi HF5000 TEM/STEM at the University of Arizona. We first acquired images (SE, bright-field and dark-field) of the FIB section and the two hotspot regions under low-dose conditions to avoid sample damage due to electron irradiation. EELS spectra were acquired using DualEELS in STEM mode to simultaneously acquire the C K core-loss edge and low-loss region, including the zero-loss and plasmon peaks, on a small side portion of one of the two hotspots to avoid beam damage to the overall hotspot.

**Results and Discussion:** QUE97990 (CM2.6) is one of the least altered CM chondrites [11] and it is more D-rich than most CMs (bulk  $\delta\text{D}$  of IOM residue =  $1218 \pm 5$  ‰) [12]. We identified numerous D-rich hotspots ( $\delta\text{D}$  = 234 to 4,111‰) in fine-grained matrix areas of QUE 97990. The two hotspots extracted for TEM study have  $\delta\text{D}$  values of  $4,054 \pm 115$  ‰ and  $4,111 \pm 155$  ‰, respectively. TEM images of the cross-section of the two hotspots show that they both have a micropore structure filled with carbonaceous matter. In particular, one hotspot is filled with an aggregate of nanoglobule-like objects, possibly hollow, that are surrounded and intimately associated with fine-grained fibrous silicates. However, despite its significant degree of aqueous alteration, the IOM in both hotspots still preserve D-enrichments. The EELS spectrum of a small portion of one of the nanoglobules show a C K edge with an energy-loss near-edge structure (ELNES) consistent with the presence of aromatic functional groups, i.e., a sharp rise from edge onset to a peak at 285 eV (the  $\pi^*$  peak) followed by a delayed maximum beginning at 290 eV (the  $\sigma^*$  peak). The spectrum also indicates the presence of oxygen in the nanoglobules with a peak at 532 eV. This observation is in good agreement with previous studies that showed that many nanoglobules are composed of structurally disordered organic matter [4,13]. 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]. Analysis of additional hotspots within QUE 97990 and other CM and CR chondrites will reveal whether aqueous alteration effects the isotopic composition and functional chemistry of IOM in different petrologic type meteorites.

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