CORRELATED ANALYTICAL STUDIES OF ORGANIC MATERIAL FROM THE TAGISH LAKE CARBONACEOUS CHONDRITE. T. J. Zega[1], R. M. Stroud[1], L. R. Nittler[2], H. Busemann[2], C. M. O'D. Alexander[2] [1]Naval Research Laboratory, Code 6360, 4555 Overlook Ave. SW, Washington, D.C. 20375, [2]Carnegie Institution of Washington, 5241 Broad Branch Rd., NW, Washington, DC 20015-1305 (zega@nrl.navy.mil).

Introduction: The Tagish Lake meteorite is among the most primitive carbonaceous chondrites available for study [1]. Measurements suggest that approximately 2 to 3 wt% of the C that it contains occurs in organic form [1,2], and determining its character is important for understanding the primitive organic chemistry of the early solar system.

Recent measurements show that fragments of matrix from Tagish Lake contain large enrichments of ^{15}N and deuterium (D) relative to terrestrial isotopic ratios [3-6], which may indicate a presolar origin. Organic compounds are suggested as the carrier of the anomalous ^{15}N and D [3-6]. However, the form and distribution of the putative organic material as well as its relationships to other mineral phases in the host meteorite are unknown. Here we report on correlated secondary-ion mass spectrometry (SIMS), focused-ion-beam / scanning-electron microscopy (FIB-SEM), and transmission-electron-microscopy (TEM) studies to determine the carrier(s) of the isotopically anomalous ^{15}N and D in Tagish Lake.

Methods: Matrix material from the Tagish Lake CC was pressed into Au and analyzed with SIMS [3,6]. Regions containing anomalous enrichments ("hotspots") of ^{15}N and D were selected for higher-resolution investigation. We developed a technique to extract, in situ, electron-transparent sections of these regions using an FEI Nova 600 FIB-SEM (see the companion abstract, Zega and Stroud, 2006, this meeting) equipped with an Ascend Extreme Access lift-out tool. We analyzed the sections using a 200 keV JEOL 2200FS transmission electron microscope (TEM) equipped with an energy-dispersive spectrometer (EDS), in-column energy filter, and bright- and dark-field detectors.

Results and Discussion: SIMS (Cameca ims-6f) and NanoSIMS (Cameca NanoSIMS 50) mapping of the Tagish Lake CC reveal a region of matrix enriched in D and ^{15}N (Fig. 1a,b). We used the FIB-SEM to create an electron-transparent section that transects both of these hotspots, and we lifted the section out for TEM analysis. The secondary electron image reveals that the section is held securely between the prongs of the microtweezer and shows that the matrix material is sandwiched between the Pt and Au (Fig. 1c).

The high-angle annular dark-field (HAADF) image mosaic shows that the thickness of the matrix fragment varies across the field of view (Fig. 2), reflecting the topology of the grain as mounted on the Au stub for the SIMS analysis. The isotopically anomalous regions occur at both ends of the section (^{15}N occurs on the left; D on the right), and the HAADF image shows that they contain bright and dark contrast, indicating material with high and low atomic number, respectively (Fig. 3). EDS analysis shows that the region rich in ^{15}N contains Fe, Si, C, and O with lesser amounts of Mg, Al, and Ni. In comparison, EDS analysis of the D-rich region indicates that it contains Fe, Si, Mg, and O, but is relatively poor in C.

Discussion: The extracted sample is held securely between a pair of microtweezers that we patterned in the FIB microscope. Once inside the TEM, the electron beam propagates directly through the section. The C-K_α peak observed in the X-ray spectra from this sample is therefore not contamination from a support film or other material (see discussion in the companion abstract). Our results suggest that the ^{15}N-rich region contains abundant C- and silicate-bearing material, whereas the D-rich region contains material rich in silicates but poor in C.

Aliphatic hydrocarbons were indicated as the major carrier of the largest D anomalies in IDPs [7], whereas D-enriched material in Tagish Lake was shown to be exclusively aromatic [8]. It is likely that the C we measure is from an organic compound(s) and thus a major carrier of the anomalies that we observe. However, it is not yet clear whether such C occurs in aliphatic or aromatic structures. Nevertheless, the EDS data indicate that silicates also occur in these isotopically anomalous regions, suggesting that they are spatially associated with the organic material or that they too could be carriers. Sheet silicates, which contain H in hydroxyl groups, are abundant in Tagish Lake [9], and have been shown to contain C in the CCs [10] are the most likely candidate silicates. High-resolution imaging and spectroscopy, which we plan to do, will help test such speculation.

Acknowledgements: TJZ gratefully acknowledges support from the NRL-NRC postdoctoral fellowship program. Research supported in part by NASA.

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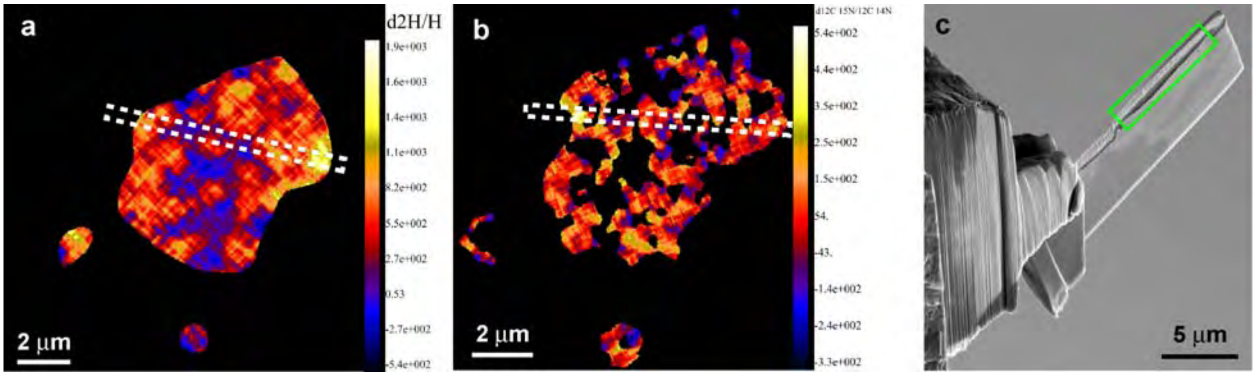

Figure 1 Images of isotopically anomalous matrix from Tagish Lake. **(a)** ims-6f SIMS map showing distribution of D. **(b)** NanoSIMS map showing distribution of ^{15}N. Scale bars on right are in ‰. Dashed boxes show the location of the FIB section. **(c)** Secondary electron image (oblique view) of the microtweezer and electron-transparent section.

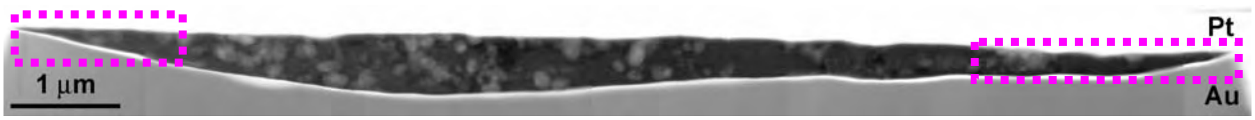

Figure 2 TEM-HAADF mosaic of the matrix fragment from Tagish Lake. Images were acquired from the region delineated by the green box shown in Fig. 1c.

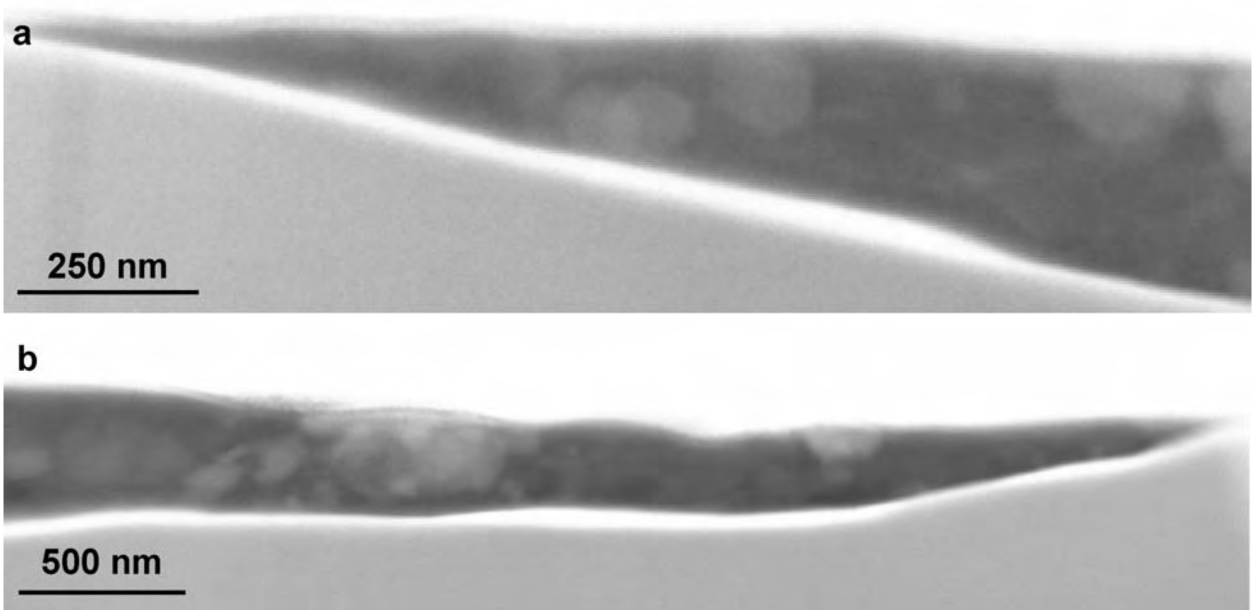

Figure 3 HAADF images of the **(a)** ^{15}N- and **(b)** D-rich regions acquired from the left and right sides of the section (pink boxes in Fig. 2).