EVIDENCE FOR TERRESTRIAL ORGANIC CONTAMINATION OF THE TAGISH LAKE METEORITE. S. Wirick[1], G. J. Flynn[2], L. P. Keller,[3] and C. Jacobsen[1], [1]Dept. of Physics, SUNY-Stony Brook, Stony Brook NY 11974 (swirick@bnl.gov), [2]Dept. of Physics, SUNY-Plattsburgh, 101 Broad St., Plattsburgh, NY 12901 (george.flynn@plattsburgh.edu), [3]NASA Johnson Space Center, NASA Route 1, Houston, TX, 77058.

Introduction: The Tagish Lake meteorite is a rare discovery in the meteorite world. Tentatively classified as an ungrouped type 2 carbonaceous chondrite, it is the first known CI2 meteorite [1, 2, 3]. Tagish Lake is the first meteorite to exhibit a reflectance spectrum showing the red color characteristic of the D- and P-type asteroids that populate the outer main-belt [2], although many interplanetary dust particles collected from the Earth's stratosphere exhibit a similar spectrum [4].

Several large pieces of the Tagish Lake meteorite were recovered on Jan. 18, 2000. We obtained two samples of the Tagish Lake meteorite, both collected on April 24, 2000, designated MG02 and MG03, from A. Hildebrand (Univ. of Calgary) and P. Brown (Univ. of Western Ontario). Smaller fragments collected in May 2000 were purchased from the The Meteorite Market (samples designeated "MM"). We have reported preliminary results from infrared and X-ray Absorption Near-edge Structure (XANES) spectroscopy on the MM samples [5]. We report evidence to suggest that there was terrestrial contamination of the meteorite, even in fragments in contact with the lake ice for only a few months .

Instrumentation: Using the scanning transmission microscope (STXM) at the X1A beamline at the National Synchrotron Light Source (NSLS) [6] at Brookhaven National Laboratory, absorption images and XANES spectra were collected on both crushed and microtomed samples of the Tagish Lake meteorite. Microtomed samples were prepared by embedding a small chip of the meteorite in molten elemental sulfur and slicing ~80 nm thick sections. The crushed samples were prepared by placing a small piece of the meteorite between 2 clean glass slides and crushing it. The larger pieces were tapped off of the glass slide and the finer pieces remaining on the slide were suspended onto the surface of a drop of deionized water. Floating particles were then collected using a silicon monoxide backed copper TEM grid. This technique selects for particles less than about 3 μm in size. With both of these sample preparation techniques we have never seen evidence of organic contamination of the samples.

Results: The Tagish Lake Meteorite is known to be composed of 2 different rock types, one rich in carbonates, the other containing only low concentrations of carbonates [1]. For the crushed samples we selected for areas in the rocks containing little carbonate. Figure 1 displays both an image and spectrum from a crushed fragment of the MM sample. The solid graph line is a carbon XANES spectrum collected from dried bacteria, the red dashed line spectrum is from an area of the MM sample indicated in the image by the arrow.

In XANES spectroscopy the energy of each absorption is determined by the functional group while the intensity of that absorption is determined by the absorption coefficient and concentration of that functional group. The three carbon bond functional groups of this MM sample area match the carbon bond functional groups of the dried bacteria in both absorption energy and relative absorption intensities. Figure 2 shows similar results but this data is from MG02.

Four crushed samples were prepared from both the MM samples and the two MG samples. In virtually all of the MM samples, spectra matching the bacteria spectrum in Fig. 1 were found. The pieces where the spectra were obtained were in the 1-3 micron range. Of the four samples prepared from the MG pieces, only one showed any evidence for bacteria-like material, and the area where the spectrum was obtained is small, approximately 1 μm in size.

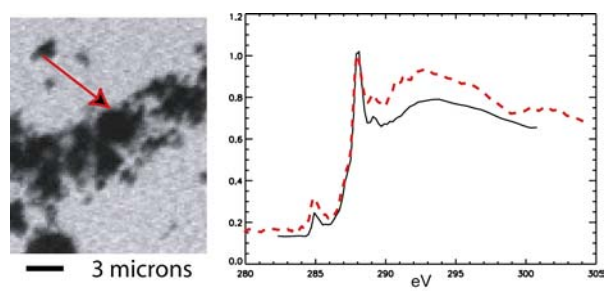

Figure 1. X-ray absorption image at 288.5 eV and C-XANES spectra from the MM Tagish Lake Meteorite fragment (red) and dried bacteria (black).

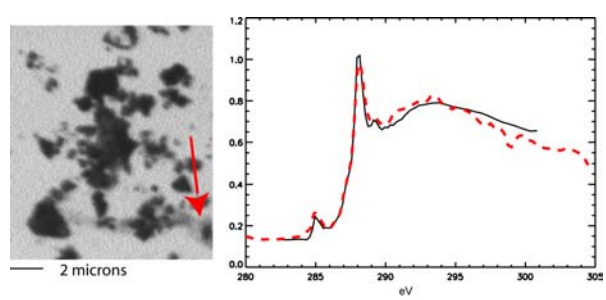

Figure.2. X-ray absorption image at 288.5eV and C-XANES spectra from the MG02 Tagish Lake meteorite fragment (red) and dried bacteria (black).

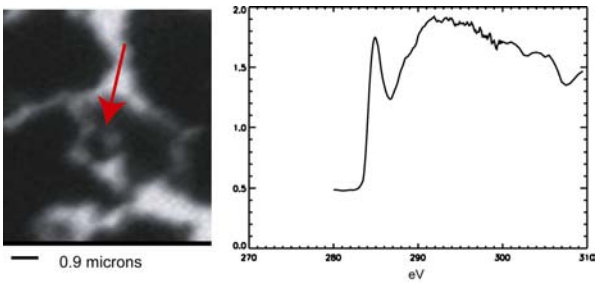

Figure 3. X-ray absorption image taken at 288.5 eV and carbon XANES spectrum from the MGXX Tagish Lake meteorite sample.

It is interesting to note in Figure 2 a streak of material that extends from the dark particle indicated by the arrow across the image to the left. Spectra collected from this area are the same as the area indicated by the arrow. If we assume this is a bacterial cell, it looks as though the cell has lysed.

Several microtome sections were also prepared from each sample. In this case areas containing carbonates were used. In the microtome sections from the MM sample there was again evidence for bacterial-like material. None of the microtome sections from the MG samples showed evidence for bacterial-like material.

The XANES spectrum of a carbon compound found in MG samples, but not seen in any of the MM samples, is shown in Fig. 3. This spectrum shows a substantial amount of C=C bonds, located near 285 eV from either a benzene like ring structure or a C=C bond on a chain structure similar to a diene. The spectrum is similar to standard amorphous carbon spectra but is missing a 286 eV feature found in the amorphous carbon spectra.

Discussion: Natural organic matter is ubiquitous on this planet especially in aquatic systems. The Tagish Lake Meteorite contains carbonates and clay minerals, both of which are known for their affinity for organic matter [7, 8]. It is no great surprise than that the MM samples show evidence of terrestrial contamination. These samples were collected from the land adjacent to Tagish Lake, and had several months to interact with ice and snow melts. The Tagish Lake Meteorite has a porosity of approximately 40% [3]. Over several months, water is likely to have permeated our samples which ranged in size from 1 to 4 mm, and could have carried with it organic matter. Although several of the fragments from the MG samples were larger than the fragments of the MM samples, we selected only pieces in the same size range for comparative reasons. We see evidence for bacterial-like compounds in the MG samples as well. The one bacteria-like particle is significantly smaller than the organic matter we find in the MM samples, suggesting a much younger growth stage in the MG samples. Bacteria are extremely opportunistic. Given a liquid water environment and perhaps a source of food [from the meteorite itself], a short-lived bacterial culture could have developed around fragments of Tagish Lake meteorite.

We found a carbon compound in MG samples that we don't see in the MM sample. Oxygen XANES measurements on this C-rich spot show that this is not just elemental carbon, but it contains oxygen and probably CH, CH_2, CH_3 as well.

It is important to note that identifying material using C-XANES is limited. Though the spectra shown in Fig. 1 and Fig. 2 match spectra obtained from dried bacteria, this only indicates these compounds both contain the same C-bonds in roughly the same proportions, but they are not necessarily the same material. Though we are not aware of other compounds with spectra that match the dried bacteria, other compounds not in our reference data may have the same spectrum.

Conclusions: If we assume that the spectra we have obtained from the Tagish Lake meteorite are indicative of bacterial matter, then it appears the Tagish Lake Meteorite was rather quickly contaminated with terrestrial organics. Short term contamination was reported by Roy [9] who cultured bacteria from several meteorite falls, and contamination on a longer time scale has been reported in the Tatahouine meteorite [10]. Falling in an aquatic environment was not the best place to minimize terrestrial organic contamination. A thorough analysis of organic matter contained in the ice surrounding the Tagish Lake meteorite is needed. Interpretation organic analyses on the Tagish Lake meteorite should be guided by the possibility that samples may contain terrestrial contamination.

References: [1] Zolensky, M. E., et al (2002) *Meteoritic and Planetary Sci,* **37**, 737-761. [2] Hiroi T., et al. (2003) *Science*, **293**, 2234-2236. [3] Brown P. G., et al (2001) *Science*, **290**, 320-325. [4] Bradley, J. P.; Kelller, L. P.; Brownlee, D. E.; Thomas, K. L. (1996) *Meteoritics and Planetary Science*, **31**, 394-402. [5] Flynn, G. J. et al. (2001) *32nd Annual Lunar and Planetary Science Conference*, Lunar & Planetary Institute, Houston, Texas, Abstract No. 1593. [6] Jacobsen, C. et al (2000) *J. of Microscopy*, **197**, 173-184. [7] Becker, L. et al (1997) *Geochimica et Cosmochimica Acta*, **61**, 475-481. [8] Scheafer, T. et al (2003) *J. de Physique* **104**, 409-412. [9] Roy, S. K. (1935) *Field Museum, Geology*, **Series 4**, 179-98. [10] Gillet, P.; Barrat, J. A.; Heulin, T.; Achouak, W.; Lesourd, M.; Guyot, F.; Benzerara, K. (2000) *Earth and Planetary Science Letters*, **175**, 161-167.