Organics in the Murchison Meteorite Using Carbon XANES Spectroscopy. S. Wirick[1], G. J. Flynn[2], C. Jacobsen[1] , and L.P. Keller[3] , [1]Physics Depart., SUNY, StonyBrook, NY 11974, [2] Depart. Of Physics, SUNY, Plattsburgh, NY 12901, [3] NASA Johnson Space Center, Houston, TX 77058

Introduction: The Murchison meteorite is a carbonaceous chondrite recovered in Australia in 1969. There have been a number of studies reporting organics in this meteorite ranging from simple amino acids [1], aldehydes and ketones [2], sugars [3], carboxylic acids [4] and aromatic hydrocarbons [5]. The techniques involved in these analyses require a substantial amount of work and in some cases the mixing of the meteoritic organic with other organic compounds in either an extraction process or in the analytical procedure. We report here a very simple technique to characterize the organics in the Murchison meteorite.

Technique: Several small pieces, approximately 800 microns in size, of the Murchison meteorite were crushed between two, clean, glass slides. The part of the meteorite that remained on the glass slide after tapping was suspended in 600 µl of sterilized water (Sigma no. W3500). A copper TEM grid, backed with silicon monoxide was used to collect material from the surface and near surface of the water droplet. Any soluble material formed a thin film on the gird substrate and the rest of the particles were randomly distributed over the whole of the TEM grid. This technique selects for particles less then ~3 microns in size with most of the particles in the sub-micron size range. It biases against large crystals, which our prior analyses show to contain little or no detectable organic matter. Thus, we concentrate the organic matter in a process that subjects the sample only to gentle crushing and water. The Scanning Transmission X-ray Microscope [STXM] located at beamline X1A1 at the National Synchrotron Light Source was used to collect absorption images and carbon X-Ray Absorption Near Edge Structure [XANES] spectroscopy [6].

Results.: Spectra collected fell into 3 major categories; water soluble organics, water insoluble organics and water insoluble inorganic carbon. Only a representative group of spectra are reported here. Figure 1 shows three spectra from the water soluble organic group in the Murchison meteorite and three standard spectra that exhibit similar features. The first spectrum (a.) is also similar to spectra we have seen in the Tagish Lake meteorite [7]; the standard spectra (b.) that plots nearly exactly to this spectrum is from a phospholipid. The second spectrum (c.) in figure 1. resembles that of a monosaccharide, the standard spectrum (d.) is from glucose. Sugars have been reported in Murchison by others [3]. The third spectrum (e.) is similar to bacterial protein. We have also seen this in the Tagish Lake meteorite. The standard spectrum (f.) is from Bacillus subtilis.

Figure 2 shows three spectra of water-insoluble material from Murchison. Spectrum (b.) is that of organic-rich acid insoluble residue from Murchison, not from the crushed meteorite. The other 2 spectra (a. and c.) are from the crushed sample.

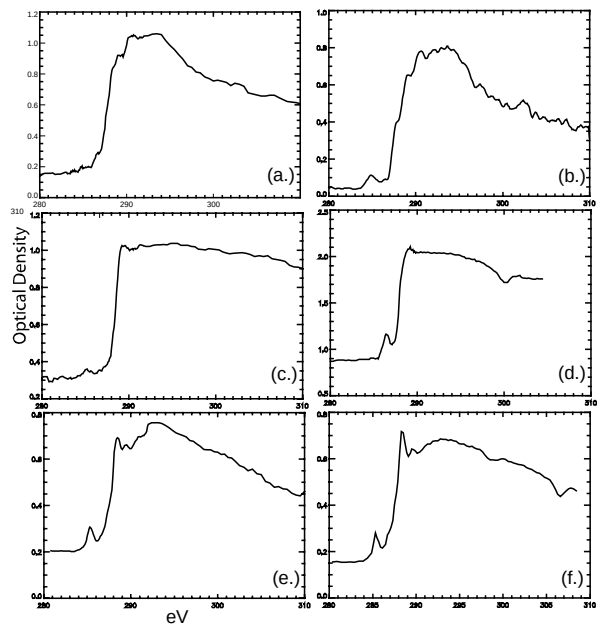

Fig.1. Carbon XANES of water soluble or partially soluble compounds

The majority of the particles in our samples fell into this category and were all submicron in size. Spectrum (a.) is very similar to the acid insoluble organic spectrum with the key difference being increased absorption in the 287-305 eV range when compared to the acid insoluble spectrum. This implies that the indigenous water insoluble organic in Murchison contains more C=O bonds and also more aliphatic carbon chains then the acid insoluble material. Spectrum (c.) is from particles in the sample that ranged in size around 100-400nm. Because of the large peak at 285 eV, this compound contains significant quantities of C=C in either a ring or chain structure. We have observed similar carbon rich particles in this size range in the Tagish Lake meteorite but there are significant differences. The shoulder on the 285eV peak suggests substitution of either N or O in a carbon ring structure, peak at 288.5 eV to a carbonyl or

carboxyl bond and the peaks at 290.2 to a carbonate or a polymethylene oxide bond.

Spectrum (b.) in figure 3 is a pure carbonate spectrum from a calcite standard and the spectrum from Murchison (a.) is also a pure carbonate. The differences in the spectra are due to different cations in the molecules. There were very few of these pure carbonate particles and they were less then 300 nm in size. The second spectrum is a carbonate closely associated with an organic compound.

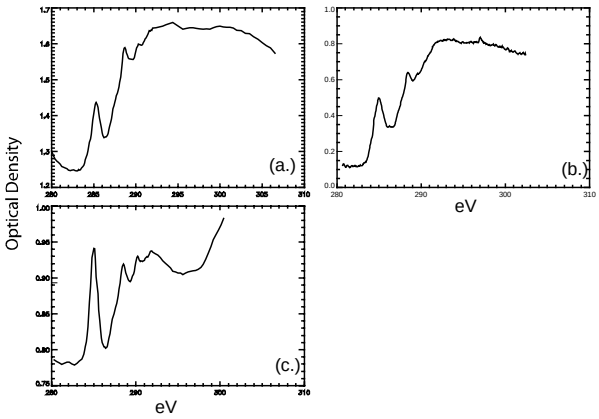

Fig. 2 Carbon XANES spectrum b. acid insoluble organic extracted from Murchison, spectra a. and c. organics from crushed Murchison.

Discussion: The Murchison meteorite has approximately 2% carbon by weigh. By size fractionating the sample we select for carbonaceous compounds and it was a simple task to find carbon in every sample we prepared. This suggests that most of the carbonaceous matter in the Murchison meteorite is on the micron to submicron size scale or is easily crushed to this size scale. The water soluble components are easily detected because they form a thin film on the TEM grid. The phospholipid like molecules we found [fatty acids] are likely part of the group of the dicarboxylic acids found by others [4]. The monosaccharide like compounds we observed are very similar to a simple sugar. The bacterial protein we found suggests that our sample of Murchison is contaminated with terrestrial organics. The sugar that we see may also be of terrestrial origin. The water insoluble organic material we analyzed has more C=O bonds and perhaps more aliphatic chains suggesting that either the acid extraction process may alter some of the insoluble organic in Murchison or the organic we observed was a mix [mixed on the size scale of less then 50 nm] of acid insoluble plus water insoluble organics. The small carbon rich particles we observed in our samples are similar to particles in the Tagish Lake meteorite except that the Murchison globules have well defined peaks at 288.5 eV [C=O] and 290.2 eV that we do not see in the Tagish globules. With the technique we use to select for small particles we have not seen carbonate in other meteorites, [we have observed carbonates in microtomed sections]. Much of the carbonate that we have observed is closely associated with an organic compound. We have observed this as well with carbonates from ALH84001 and the Tagish Lake meteorite. The spatial resolution of the STXM we used in this study is 50 nm , therefore, the organic matter and the carbonates are a mix of particles smaller then 50 nm.

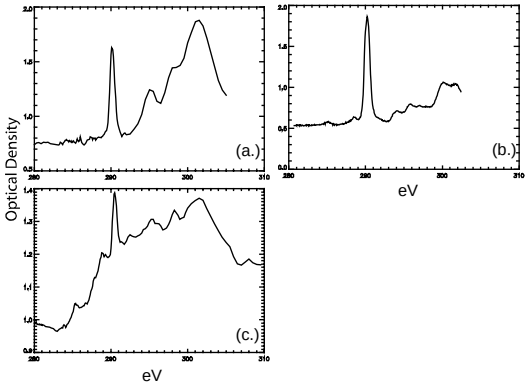

Fig. 3 Carbon XANES spectra of the insoluble inorganic carbon from crushed Murchison.

Conclusions: We report here a simple method for analyzing some carbonaceous compounds, both organic and inorganic, in meteorites. It is clear from the soluble organics we found that our sample is contaminated with terrestrial organics. This result only strengthens the need for sample return missions where specimens collected will be isolated from terrestrial organics. Also important to note is that we did not observe any graphitic carbon and very little amorphous carbon both of which are easily detected by STXM. We also did not find any compounds that matched spectra from the acid insoluble organic extracted from the Murchison meteorite suggesting that the acid extraction method may alter the insoluble organic material in Murchison.

References: [1] Pizzarello, S. and Huang, Y. (2005) Geochimca et Cosmochimica, 69, 599-605, [2] Jungclaus, G. A. et al (1976) Meteoritics, 11, 231-237, [3] Cooper, G. et al (2001), Letters to Nature, 414, 879-882, [4] Yuen, G. and Kvenvolden, K. (1973), Nature, 246, 301-303 [5] Bernatowicz, T. et al , (1996), Astrophysical Journal, 472,760-782, [6] Jacobsen, C., et al (1998) Nature Structural Biology, 5, 650-653, [7] Wirick, S., et al (2005), Lunar & Planet. Sci XXXVI, no 1662