A POST ACCRETIONARY ORIGIN FOR METEORITIC AND COMETARY ORGANIC SOLIDS? G. D. Cody[1], Emily Heying[1], and C. M. O'D. Alexander[2], [1]Geophysical Laboratory, Carnegie Institution of Washington (g.cody@gl.ciw.edu). [2]Department of Terrestrial Magnetism, Carnegie Instituution of Washington (alexande@dtm.ciw.edu).

Introduction: The insoluble organic matter (IOM) contained with in all chondritic meteorites constitutes a significant reservoir of extraterrestrial organic matter that in some cases may be as high as 3.5 wt. % [1]. Whereas considerable effort has been made to develop a molecular understanding of meteoritic IOM, there remains considerable uncertainty regarding its origins, i.e., was IOM formed prior to the origin of the solar system, as consequence of nebular processes, or as consequence of post accretionary processing.

Notwithstanding this uncertainty, recent studies have shown that IOM carries in its molecular structure a rich history of parent body chemical evolution, e.g., chemical oxidation [2]. More recently it has been shown that chondritic IOM precisely records the integrated thermal history associated with parent body metamorphism [3]. A significant conclusion of this later study is that primitive IOM (as occurs in type 1 & 2 chondrites) is clearly not formed through hot processes and IOM that occurs in type 3 chondrites is derived directly from heating of primitive IOM.

With the successful capture of cometary organic matter from the Stardust mission the opportunity to analyze and compare organic solids from a comet with organic matter of primitive meteorites was finally possible. In these first analyses, it became evident that the cometary organic particles exhibit a wide range in their respective molecular structures and elemental chemistry [4,5]. One subset of particles, the oxygen rich particles, exhibit what appears to be a clear chemical connection with primitive IOM (e.g., that present in Murchison CM2). A comparision of C-XANES spectra of two oxygen rich particles with that of Murchison is shown in Figure 1. Wild 2 particle A exhibits a simple (in terms of diversity of organic functional groups) absorption spectrum revealing a predominance of alcohol moieties; Wild 2 particle B, with slightly lower O/C exhibits a more complex spectrum with significant peaks at 285 and 286.5 eV. The peak at 286.5 eV has been shown to be directly related to the degradation of sugars, e.g., polysaccharides [6]. The peak at 285 eV can be attributed to either olefinic or aromatic carbon. In comparision, Murchison's IOM exhibits considerably greater intensity at 285 eV (consistent with the high aromatic carbon content [2]), but also exhibits intensity at 286.5 eV.

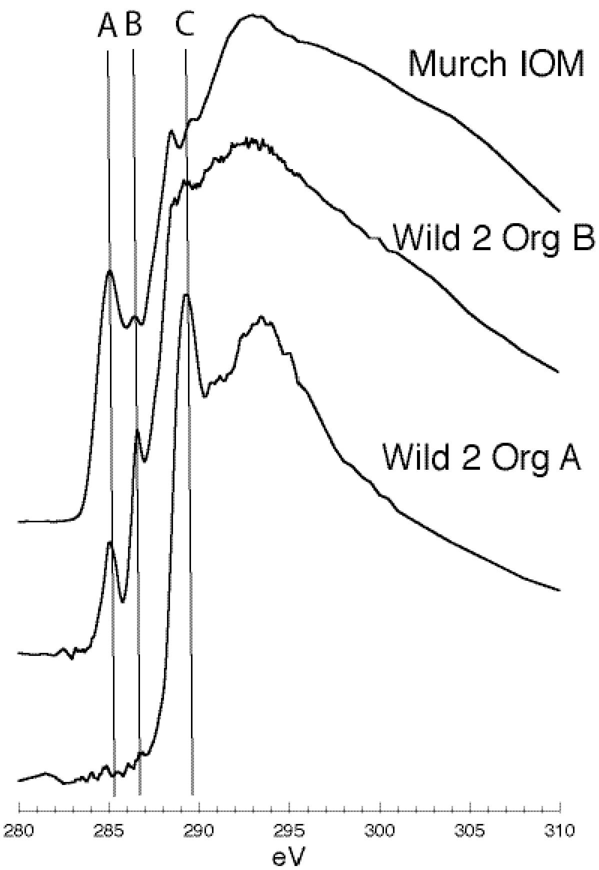

Figure 1: C-XANES spectra of IOM from Murchision (CM2) and two organic particles extracted from Stardust aerogel collectors. Particle Wild 2 Org A is characterized by having a large atomic O/C and a C-XANES spectrum dominated C-OH absorption at 289.5 eV (peak C). Particle Wild 2 Org B has a lower O/C and in addition to C-OH, peaks at 285 and 286.5 eV (A & B) are clearly evident corresponding to aromatic/olefinic and vinyl keto moieties.

Any chemical pathway connecting the most oxygen rich cometary organic matter to the molecular matter that is chondritic IOM requires the formation of considerable sp2 bonded carbon (e.g. peak A, Fig 1) at the expense of oxygen bearing sp3 carbon (e.g. peak C, Fig. 1). Such a transformation would have to occur at very low temperatures, for even type 2 chondritic IOM never experienced sustained temperatures in excess of 100 °C. The apparent trend in chemical evolution observed in Fig 1 is potentially informative. In particular, the growth of the peak at 286.5 eV (Peak B, Fig 1) is consistent with the transformation of complex sugar-like molecules into unsaturated keto bearing structures through the elimination of OH.

Recently we have obtained independent evidence for a sugar-like precursor for Murchison IOM via the application of a sophisticated multi-dimensional Solid State NMR experiment which reveals much greater detail about local electronic environments than that obtained by conventional 1D SS NMR. Specifically, we observe that up to 25 % of the carbon in IOM exists in furan moieties. Furans, e.g. furfuryl aldehyde, are readily produced through the dehydration of sugars.

The most likely route to the synthesis of sugars, abiologically, is through the formose condensation of formaldehyde that yields a complex array of molecules and organic solids. Experiments were performed to test whether formose solids could be transformed into an organic solid similar to IOM.

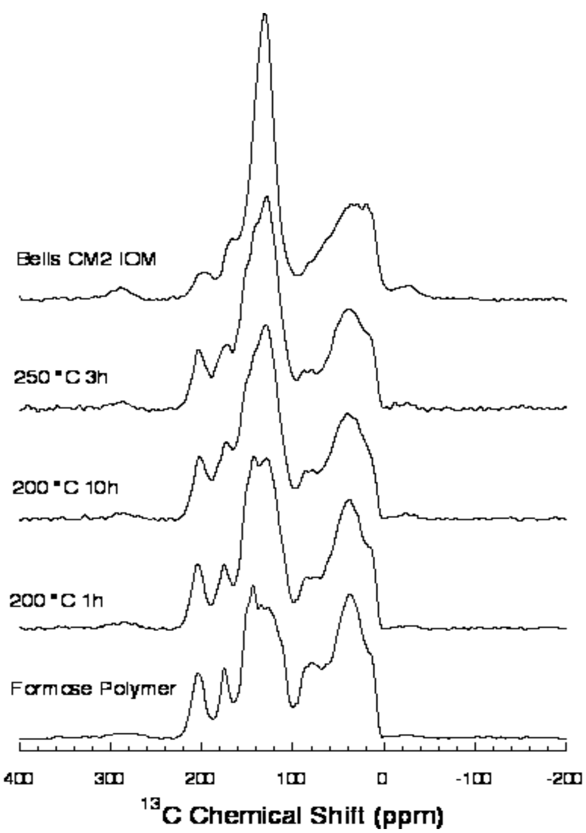

Figure 2: SS NMR spectra of formose rxn polymer and its degradation products upon hydrothermal alteration, compared with the NMR spectrum of IOM isolated from Bells a CM2.

In Fig 2 we present SS NMR spectra of the formose rxn organic solids (bottom). Following hydrothermal treatment, this polymer transforms into an insoluble organic solid that bears considerable chemical similarity to primitive IOM in type 1 & 2 chondrites. The transformation reactions connecting formose polymer to IOM are straight forward lending credibility to the hypothesis that chondritic IOM and cometary organic solids are ultimatley derived from formose sugars.

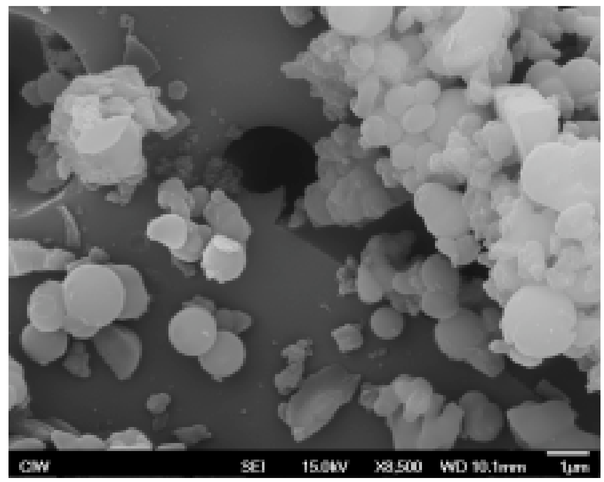

Figure 3: SEM image of Formose polymer hydrothermaly processed to 250 °C high-lighting the presence of abundant micron and sub-micron organic spheres.

Finally, SEM imaging of the formose polymer reveals that it consists of micron and sub-micron sized spheres, a striking feature that has been observed previously in formose solid products [7]. Superficially such spheres are very similar in size to organic nanoglobules common in chondritic meteorites [8,9]; thus, organic nanoglobules may also be a signature of a formose precursor to IOM.

Taken together these data lend strong support to the idea that meoritic IOM and cometary organic solids are ultimately derived from formaldehyde, one of the most common molecules in the galaxy. If such solids can only form under aqueous conditions (presumably a requirement for the spherical particles), then these results may point to a post accretionary origin for IOM and may place constraints on the water(ice)-rock ratio at the point of accretion.

References: [1] Cronin et al. (1988) Meteorites andd the Earrly Solar System p. 819. [2] Cody and Alexander (2005) GCA, 69, 1085. [3] Cody et al. (2008) EPSL, 272, 446. [4] Sandford et al. (2006) Science 314,1720. [5] Cody et al. (2008) MAPS, 43, 353. [6] Cody et al. (in press) J. Elect. Spect. Rel. Phenom. [7] Weber (2005) OLEB, 35, 523. [8] Nakamura et al. (2002) Ant. Met. 27. [9] Garvie and Buseck (2003) LPSC 35, 1789. **Acknowledgement**: NASA Origins of the Solar System Program and NASA Astrobiology.: