

**ORGANIC CONSTITUENTS IN CARBONACEOUS CHONDRITES; EVIDENCE FOR PRESERVATION OF PRISTINE PARTICLES OF MIXED ORIGINS.** L. Remusat<sup>1</sup>, Y. Guan<sup>1</sup> and J. M. Eiler<sup>1</sup>, <sup>1</sup> GPS Division, Caltech, 1200 E. California Blvd, Pasadena, CA 91125, USA (remusat@gps.caltech.edu).

**Introduction:** Carbonaceous chondrites are primitive meteorites that have sampled the oldest condensates of the solar system. They have accreted components of various origins: CAIs (also known as refractory inclusions), chondrules, ice, noble gases and organics. Radioactive decay of short lived radionuclides quickly heated these parent bodies and drove thermal metamorphism and aqueous alteration of their various constituents. Despite this post-accretionary modification, at least some components of the organic matter in the carbonaceous chondrites have retained distinctive isotopic and molecular properties that plausibly relate to their pre-accretionary origins in the early solar nebula or in the molecular cloud that gave birth to it [1, 2]. The processes that gave rise to early solar-system organics and the extent to which these compounds were modified by parent body processes are still a matter of debate [3], and this work provides new insight into those questions.

One way to address these questions is to study the relationships between the organic constituents of the carbonaceous chondrites and their surrounding inorganic matrix, *in situ*. Our goal is to assess how the organic matter was accreted on the parent body of the carbonaceous chondrites and what alterations it has undergone during the 4.5 billion years evolution of the parent bodies. Moreover we want to shed light on the potential of the minerals that are associated with the organics to induce catalytic processes for organic synthesis or isotopic exchange which could alter the original isotopic signatures.

Preliminary work on the most hydrated carbonaceous chondrites (CI) confirmed previous observations that organic matter occurs mainly as individual particles randomly distributed in the matrix within clay minerals [4]. No specific association with any inorganic component was observed, ruling out the hypothesis that the main fraction of the organic matter could be synthesized by catalytic reactions on grain surfaces. The present contribution reports new observations performed on CM, CV and CR chondrites along with the study of the isotopic processes that occurred on the parent body of these meteorites.

**Experimental:** We have used the Cameca NanoSIMS 50L installed at Caltech to image matrix fragments of Orgueil (CI), Tagish Lake (CI), Murchison (CM), Cold Bokkeveld (CM), Allende (CV) and Renazzo (CR) carbonaceous chondrites. A focused Cs<sup>+</sup> primary beam was used to generate ion images of H,

D, <sup>12</sup>C, <sup>18</sup>O, <sup>26</sup>CN, <sup>28</sup>Si and <sup>32</sup>S. We were then able to determine both elemental and isotopic compositions of organic particles with a spatial resolution between 200 and 300 nm. To avoid any contamination from epoxy or deformation of small, soft materials during polishing, fragments of matrix material were pressed into clean indium foils. No chemical treatment was applied to the sample before image acquisition. A standard terrestrial charcoal was used to correct the composition of the organic material. O, Si and S images are used to map inorganic material whereas the other species give the composition of the organic material in the matrix.

**Results:** All the chondrites observed exhibit a random distribution of C-rich particles with an average size around 1 micron. Allende contains fewer particles per unit area, perhaps expected given its relatively lower bulk content of organic matter. No specific association is observed between carbon and either sulfides or oxides. This should be the result of the accretion of small organic particles with inorganic material to form the parent bodies.

When the chemical and isotopic compositions of all the particles identified in the CI, CM and CR chondrites are compared, one observes compositional trends that reflect mixing between an organic constituent and the inorganic matrix (fig 1A). The organic end member seems to have a similar H/C ratio in all the chondrites studied. Thus, the elemental compositions of the organic particles in all examined samples are broadly similar to one another. Nevertheless, the D/H ratio of some of the organic particles are extremely high (fig 1B), leading to D-rich 'hot spots' in ion images [5]. Not all the C-rich particles are D-rich hot spots, but the D-rich hot spots always cover an entire C-rich particle. It must be noted that Allende does not exhibit any D-rich hot spots.

In detail, the D/H images show that D enrichments, when present, are closely spatially correlated with the C-rich particle. Moreover, profiles through D-rich particles (fig 2) of C/H and D/H ratios clearly indicate that there is no significant self diffusion of D from the D-rich organic particle to the D-depleted (but generally hydrogen rich) inorganic matrix. Since equilibrium should result in organic matter being depleted in D compared to clay minerals, the isotopic signature of the organic matter is protected from alteration that can occur during hydrothermalism on the parent body.

**Discussion:** Based on these observations, it appears that the hydrated carbonaceous chondrites con-

tain two kinds of particulate organic matter. One kind is extremely enriched in D, forming the D-rich hot spots previously reported by Busemann et al. [5]. The second sub-set has D/H ratios in the range of the bulk isotopic ratios determined in IOM of carbonaceous chondrites [3]. The thermally processed Allende only exhibits D-poor organic particles.

It has been proposed that extreme D-enrichment in some chondritic carbonaceous materials is hosted by organic radicals [6,7]. These moieties are suggested to have accumulated D from an ionized hydrogen gas in the early stage of the solar nebula. The occurrence of radicals is likely the result of intense UV-irradiation, in an interstellar-like environment. Thus, the D-rich hot spots could be organic particles that have been subjected to intense irradiations in the outer regions of the solar nebula and then mixed with other organic particles that were protected from UV radiation by dense gas. This conclusion is consistent with mixing processes that are supposed to have occurred in the proto-solar nebula and that have resulted in the association of high temperature (CAI) and low temperature (OM) material in the carbonaceous chondrites parent bodies.

The lack of D-rich hot spots in Allende may be the result of either the sampling of organic particles from the neutral gas phase or the thermal process to which the organic matter was exposed on the parent body or before accretion. Indeed, it has been shown that the organic moieties that constitute the D-rich reservoir in the hot spots are destroyed by high temperatures [7].

The lack of significant exchange between organic particles and adjacent D-poor hydrous silicates and oxides presents an intriguing problem. In terrestrial sediments, organic matter undergoes isotopic exchange in timescales of hundreds of thousands years. In the case of carbonaceous chondrites, organics have been in contact with adjacent hydrous phases for 4.5 Gy and no significant exchange of D across the particle/matrix interface is observed. A careful look at the inorganic material surrounding the organic particles does not reveal any structure that could shield them from isotopic exchange, leading to the conclusion that the preservation process is only due to the exchange rate of the organic matter constituting the particles. Despite hydrothermal activity on the parent body that has induced partial oxidation of the IOM [8], the organic particles seem to have preserved their pristine isotopic signature.

**References:** [1] Pizzarello S. et al. (2006) in *Meteorites and the Early Solar System II* 625-651; [2] Remusat L. et al. (2006) *EPSL* 243, 15-25; [3] Alexander C. M. O'D et al. (2007) *GCA* 71, 4380-4403; [4] Remusat L. et al. (2008) *LPS XXXIX*, Abstract #2477; [5] Busemann et al (2006) *Science* 312, 727-730; [6] Gourier et al. (2008) *GCA* 72,

1914-1923; [7] Remusat L. et al (2008) *LPS XXXIX*, Abstract #1399; [8] Cody G. D. and Alexander C. M. O'D. (2005) *GCA* 69, 1085-1097.

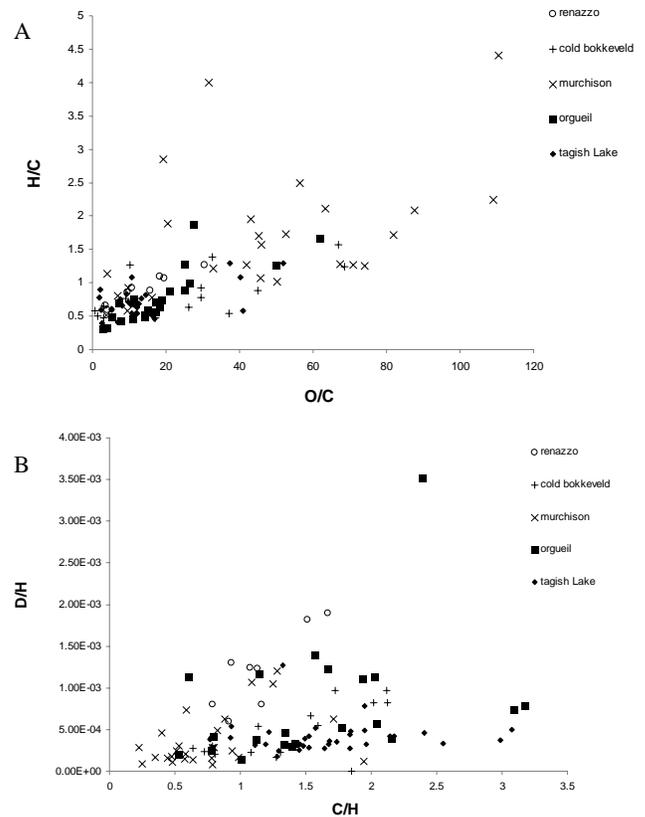


Figure 1: Isotopic and elemental compositions of the C-rich particles observed in this study in CI, CM and CR chondrites.

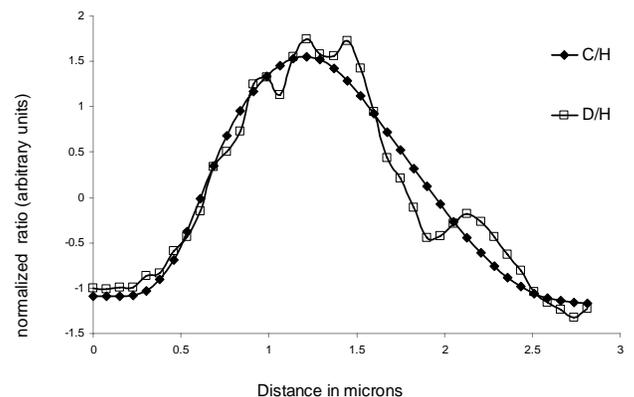


Figure 2: D/H and C/H profiles through a D- and C-rich particle in Murchison.