NANOSIMS MAPPING OF ORGANIC MATTER IN ORGUEIL AND TAGISH LAKE CARBONACEOUS CHONDRITES: NEW DATA ON THE RELATIONSHIPS WITH THE MINERAL MATRIX. L. Remusat, Y. Guan and J. M. Eiler, GPS division, Caltech, Pasadena, California, USA (remusat@gps.caltech.edu).

Introduction: Carbonaceous chondrites have been extensively studied for their content in primitive condensates, noble gases and organic matter [1]. They are widely considered to be the most primitive objects available in the solar system, along with IDPs and comets, and thus likely record the chemical and isotopic compositions of components present in the early solar system.

Both insoluble and soluble organic matter in carbonaceous chondrites has received great interest because such meteorites may be related to the building blocks of the Earth and other planets, and because their organic constituents may have impacted the emergence and/or evolution of early life. The soluble components are a complex mixture of hydrocarbons, carboxylic acids and compounds of biological interest like amino acids [2]. Their isotopic composition and molecular distribution clearly distinguish them from their terrestrial counterparts. The insoluble fraction is less well known due to its refractory properties. Nevertheless it has distinctive isotopic and molecular properties [2] that can can be interpretated as signatures of abiotic synthesis in interstellar or nebular environements that could have occurred in the early solar system or in the molecular cloud that gave birth to the solar system. For instance, D-rich domains in insoluble organic matter have been suggested to be products of insterstellar synthesis reactions [3], or might instead reflect early solar-system process [4].

The association between organic compounds and minerals is still puzzling. However, understanding the detailed textural and compositional relationships among organics, D-rich domains and inorganic materials may provide important insight into the origin of chondritic organic matter and its subsequent evolution on the parent bodies. Some studies have focused on the distribution of the organics in the inorganic matrix. But the variations in isotopic or chemical compositions depending on the association with inorganic material are still unknown.

Previous fluorescence optical microscopy of Orgueil revealed that organic matter occurs as small circular particules (from hundreds nm to 2μm) randomly distributed in the matrix [5], though perhaps more closely associated with phyllosilicates then with other matrix components. More recently, Os labeling of organic matter has been used on various CI and CM carbonaceous chondrites to show that organic matter appears to be associated with clay minerals in the matrix [6]. This result suggests organics in these meteorites were produced or modified during the aqueous alteration on the parent body [7]. However, this study found no association between organics and other products of aqueous alteration, such as carbonates and magnetites, nor with other matrix components such as. Energy filtered transmission electron microscopy (EFTEM) of CM and CR chondrites [8, 9] has shown diverse nanometer scale features of organic constituents, which appear to be primarily associated with sulfides and phyllosilicates.

Experimental: We have used the Cameca NanoSIMS 50L to generate ion images of H, D, ^{12}C, ^{18}O, ^{26}CN and ^{30}Si in fragments of bulk matrix of Orgueil and Tagish Lake chondrites. The NanoSIMS combines high spatial resolution (around 100nm for the conditions used) and high mass resolution that permits precise determinations of both elemental and isotopic compositions. To avoid any contamination with epoxy or deformation of small, soft materials during polishing, samples were pressed into clean indium foils. Images were subsequently processed using l'image software (L. Nittler). The studied areas were also subsequently imaged on a LEO 1550VP FE SEM.

The goal of this study is to determine the distribution of organics in the matrix of these two primitive carbonaceous chondrites and to simultaneously study the relationships between D-rich domains and inorganic material.

Results: We observe that ^{12}C in ion images of matrix in both of the samples we examined commonly occurs as randomly distributed particules, each of which is typically several hundred nm to 1 μm in size (e.g., Fig. 1). This distribution closely resembles previous evidence from fluorescence microscopy for ~μm-scale domains of organics [5], suggesting that the ^{12}C hotspots we observe are small concentrations of organic matter. Nevertheless, some fraction of these ^{12}C concentrations we observe might instead be grains of carbonate, diamond, graphite or silicon carbide. We can attempt to distinguish among these possibilities by correlating ^{12}C concentrations to the simultaneously acquired ion images for H, ^{18}O and ^{30}Si (ie., association of H with a carbon rich domain is consistent with their attribution to organic matter). However, we must keep in mind that some ^{12}C rich domains may be physical mixtures of multipe phases that are not spatially resolved by NanoSIMS imaging. We continue to refine our understanding of this question through high-resolution SEM studies of domains that have already been ion imaged. Some associations are more obvious, like for example the occurrence of a oxide grain in fig.1, indicated by a bright area on the ^{18}O image in contrast to dark places on the other images. SEM confirms that is is an iron oxide grain.

As shown by fig.1, D-rich domains are observed in Orgueil matrix. SEM imaging indicate that the domain on fig. 1 is embedded in clay minerals. The highest D/H ratios we observe (max δD=19600‰) are comparable to those previously measured in D-rich hot spots in several IOMs from CR chondrites [3] and are several times higher than the D-rich hotspots previously detected in Orgueil IOM [10]. This difference suggests that the chemical treatments used by previous studies to recover the IOM from carbonaceous chondrite matrix lowers the D/H ratio of these hot spots (as one might expect from the stabilities of their constituents; [10]). This implies that accurate measurements of D/H ratios of refractory organics in such materials may require in-situ measurement of relatively un-processed materials, as we did in this study.

Discussion: Based on our initial observations, it seems that the distribution of organic compounds carbonaceous chondrites reflects mixing between carbonaceous dust and other constutients (e.g., silicate dust) in the solar nebula during the early stages of aggregation of meteorite parent bodies.

We observed no elongated carbonaceous structures that could be related to interpenetration of organic compounds between phyllosilicate layers (i.e, we see no carbonaceous 'veins'), and no carbonaceous coating of inorganic grains. This argues against synthesis through organic reactions on the catalytic surfaces of clay minerals or sulfides during aqueous alteration of parent bodies, as previously proposed. However, it might reflect the fact that our observations are at a too coarse scale to see very thin carbonaceous layers around grains, as reported for EFTEM studies [8,9].

Preliminary observations on Tagish Lake lead to the same conclusions.

References: [1] Scott E. R. D. and Krot A. N. *in Treatise in Geochemistry*, 143-200. [2] Pizzarello S. et al. (2006) *in Meteorites and the Early Solar System II*, 625-651. [3] Busemann H. et al. (2006) *Science, 312*, 727-730. [4] Remusat L. et al. (2008) *LPS XXXIX*. [5] Alpern B. and Benkheiri Y. (1973) *EPSL*, *19*, 422-428. [6] Pearson V.K. et al (2002) *Meteoritics & Planet. Sci.*, *37*, 1829-1833. [7] Bunch T. E. and Chang S. (1980), *GCA*, *44*, 1543-1577. [8] Brearley A. J. (2002) *LPS XXXIII*, Abstract #1388. [9] Abreu N. M. and Brearley A. J. (2006) *LPS XXXVII*, Abstract #2395. [10] Remusat L. et al (2008) *LPS XXXIX*.

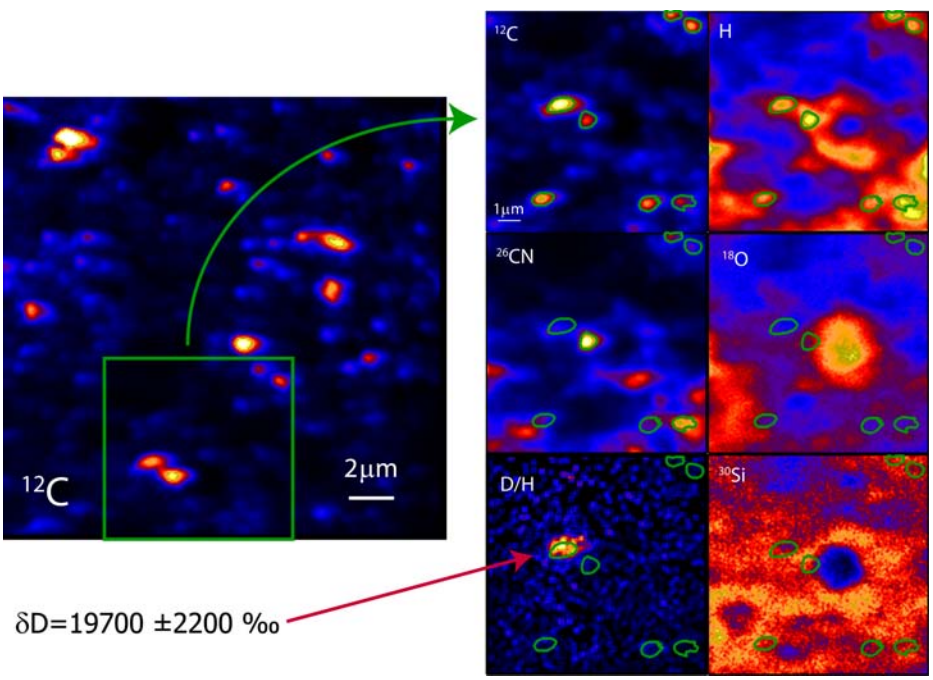

Figure 1: NanoSIMS images of Orgueil matrix. The left image is a 20×20 μm^2 ^{12}C image showing that carbon containing material is distributed as small spots in the matrix. A closer view reveals that the different species recorded have very different patterns. Carbon (green circles) is associated with H rich regions and seems mixed with Silicon. One D-rich hot spot was identified in this region, with a D/H ratio over 3 times higher than the highest D-rich hot spot detected in Orgueil IOM.