# Organics and iron speciation in CI chondrites : a combined STXM and TEM study

Le Guillou C.[1], Leroux H[1]., Bernard S.[2], Viennet J-C.[2], Marinova M.[1], Jacob D.[1], De La Pena F. [1], Brearley A.[3], El Kerni H.[3]
[1]*Unité Matériaux et transformation, Université de Lille, France*
[2]*IMPMC-MNHN, Sorbonne Université, Paris, France*
[3]*University of New Mexico, Albuquerque, USA*

In order to precisely comparing the mineralogy and the nature organic matter of known chondrites with Ryugu samples, we investigated 6 FIB sections of Orgueil and 2 sections of Ivuna CI chondrites. Orgueil insoluble organic matter (IOM) was also measured. We first performed Scanning Transmission X-ray Microscopy (STXM) at the Carbon and Iron edge, to determine the speciation of these elements. We are performing Transmission Electron Microscopy (TEM), with a special focus on the elemental composition of phyllosilicates and organic matter.

STXM delivers hyperspectral dataset that can be processed pixel by pixel using the python hyperspy library [www.hyperspy.org/]. For the Iron L-edge, we fit the background and an arctangente and quantify the $Fe3+/\Sigma Fe$ using previously established calibration (Bourdelle et al., 2013, Le Guillou et al., 2015). For the Carbon K-edge, we fit the background, normalize to the carbon amount and then fit gaussians at given positions to quantify some of the functional groups using previously established calibration (Le Guillou et al., 2018). Thanks to these procedures, we obtain quantitative maps and are able to describe the variablility and distribution at the scale of 10s of nanometer.

In Orgueil, Iron in phyllosilicates is oxidized, the $Fe3+/\Sigma fe$ varies between 65 and 80 %, with a dichotomy likely related to the fine grained/coarse-grained mixture of smectite and serpentine. Sulfides and oxides are also present.
Organics display three families of spectra (in addition to carbonates) :

- Organic particles, which are aromatic-rich and show important variability from one particle to the next. They contain some ketone and/or phenol groups. They are more aromatic than the IOM.
- diffuse organic, with is present all over the section, mixed at a fine scale with phyllosilicates. It is aliphatic and carboxylic rich. The carbon amount is lower than in particles. They are less aromatic than the IOM.
- Carboxylic-rich particles, preseent localy in some section, they show a carboxylic peak higher than the diffuse OM, and is often accompanied by a hydroxyl and/or a carbonate peak.

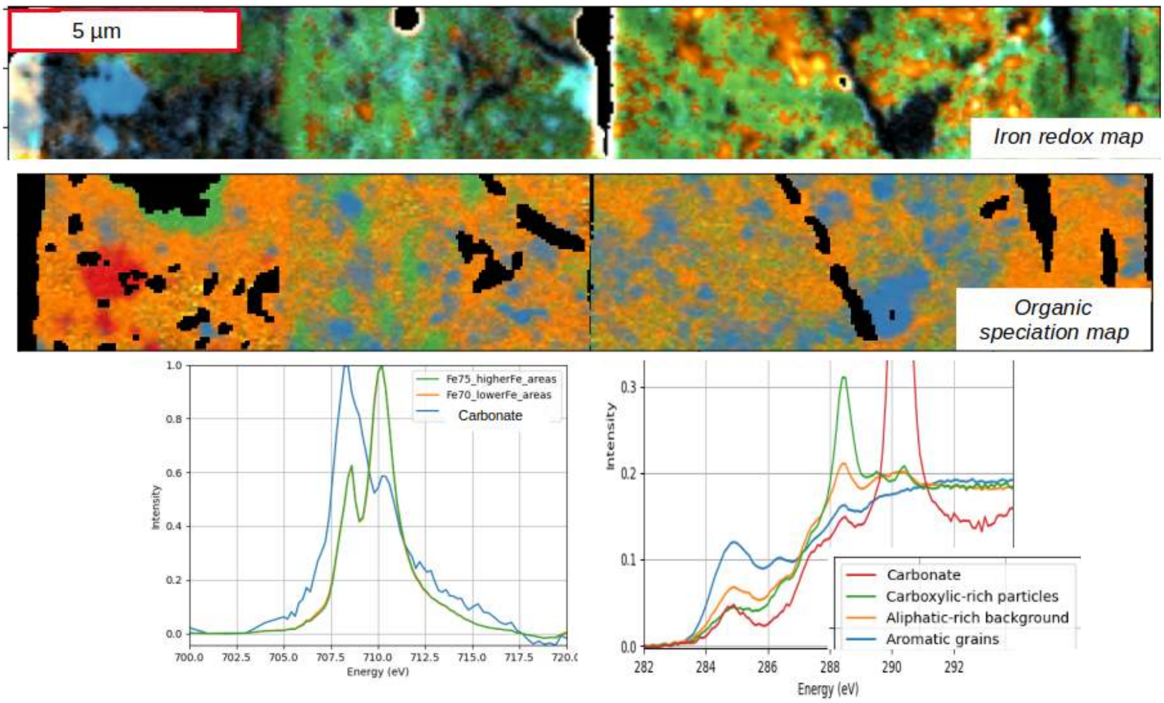


Figure 1. Maps based on liear combination fitting of individual components. On top, map based on the iron L-edge, showing different regions with both slight redox variation but also iron content variation. Below, map based on the carbon speciation showing indiviaula organic particles (blue) embedded in diffuse OM (orange) covering the entire section.

In order to describe the variability, we plotted histograms (Fig. 2).

The iron valency is heterogeneous from section to section, possibly depending on the ratio of coarse/fine grained phyllosilciates that are sampled each time. However, it could also be due to a more global variability of the sample at the micrometer scale. Several areas need therefore to be investigated to fully describe them.

Diffuse OM is very heterogeneous at the FIB section scale, with a tail extending toward aromatic particles. The latter are not really visible on the histograms because they are less abundant. There is also a little variability of the peak distribution, especially in one of the section (G2-2).

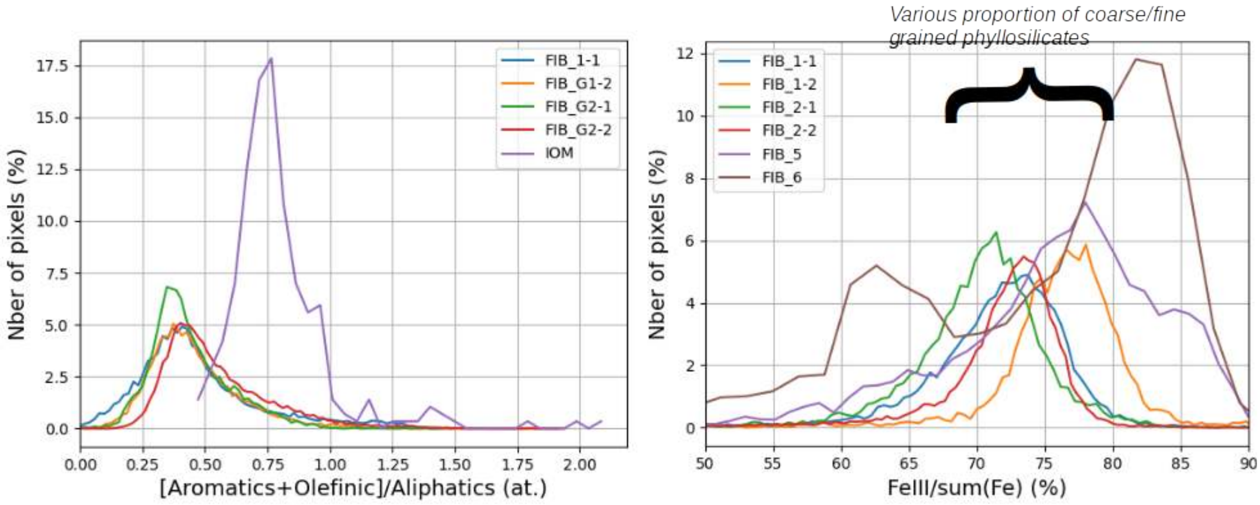


Figure 2. Histograms of quantified proxies at the carbon K-edge (left) and Iron L_edge (right). They allow to visualize the distribution of the composition within each FIB section, as well as the heterogeneity among different FIB sections.

Altogether, these data will help us understand the history of the CI parent body. Similar data obtained on Ryugu samples have been obtained and are presently being processed.