THE ORGANIC MATTER IN THE LESS METAMORPHIZED ENSTATITE CHONDRITE SAHARA 97096: ISOTOPIC COMPOSITION AND SPATIAL DISTRIBUTION. L. Piani[1], F. Robert[1], S. Derenne[2], A. Thomen[1], M. Bourot-Denise [1], S. Mostefaoui[1], Y. Marrocchi[1] and A. Meibom[1]. [1]LMCM, CNRS-MNHN, UMR7202, Case 52, 57 Rue Cuvier, 75005 Paris, France (contact : lpiani@mnhn.fr), [2]BioEMCo, CNRS-UPMC, UMR 7618, 4 place Jussieu, 75252 Paris, France.

Introduction With the aim to improve our knowledge on the Insoluble Organic Matter (IOM), which constituted the major part of the organic matter found in meteorites (i.e., ≥85%), we are engaged in a study of IOM in the most primitive known Enstatite chondrite: Sahara 97096. As Enstatite chondrites were formed in a highly reduced environment and at higher temperatures than the carbonaceous chondrites (e.g. [1, 2, 3]), the enstatite IOM constitutes a interesting comparative tool to test the homogeneity of the organic matter in the solar system and to constrain the processes which could affect the organic matter during the solar system evolution.

Previous results: The molecular structure and the hydrogen and nitrogen isotopic features were observed on the IOM isolated from Sahara 97096 following the classic acid treatments [5]. This IOM is more aromatic than those isolated from carbonaceous chondrites and is associated with graphite as revealed by Raman spectroscopy and High Resolution Transmission Electron Microscopy[4]. Electron Paramagnetic Resonance yielded no evidence for radical species in the Sahara 97096 IOM [4]. The mean hydrogen and nitrogen isotopic ratios (δD = +179 ± 12 ‰ and $\delta^{15}N$ = +11.2 ± 8.4 ‰, error bars given here and below at 2σ) obtained in the same analytical session ("peak switching") with the NanoSIMS, are in the range of values defined by the carbonaceous chondrite IOMs [6]. No deuterium-rich anomaly was detected. Based on previous studies [7, 8], this observation is consistent with the lack of radical species in the IOM and could be the consequence of a thermal event that took place after (parent body metamorphism) or before accretion. Contrary to the δD distribution, we observe $\delta^{15}N$-heterogeneity at the micrometer scale. In particular, some tiny areas (≤500nm) are highly enriched in ^{15}N (up to $\delta^{15}N$ = +2000 ‰) [4].

Complementary results: Two types of supplementary investigations are currently in progress: (i) NanoSIMS measurements to search for the carrier of the nitrogen isotopic heterogeneities, and (ii) transmission optical microscopy, scanning electron microscopy, Raman mapping and NanoSIMS imaging to study the distribution of the organic latter within the meteorite.

Through the first analytical session, we obtain images of the carbon and nitrogen isotopic ratios along with the silicon distribution. Because the ^{15}N-hotspots are infrequent in the Sahara 97096 IOM, images of a given region (20 x 20 μm^2, 256 x 256 pix) were repeatedly obtained up to 150 times (i.e. 150 cycles of ≈ 1 min with a primary current of 12 pA corresponding to a spot size of ≈ 400 nm) to probe a larger volume of IOM. Each cycle corresponds to the sputtering of few atomic layers. However the precise depth sputtered during one cycle was not determined accurately: it depends on the chemical and mineralogical nature of the sputtered surface and, as a consequence, the depth profile can be "bumpy" at the scale of 400 nm in a 20 x 20 μm^2 image.

One ^{15}N-poor "coldspot" was found ($\delta^{15}N$ = -245 ± 38 ‰) an observed to be spatially correlated with silicon enrichment. Additionally, Two different types of hotspots were observed in the NanoSIMS images: (1) moderately ^{15}N-rich type ($\delta^{15}N$ = 223 ± 27 ‰) spatially correlated with a silicon rich zone (one occurrence is shown as an example with grey arrow in Figures 1a and 1b) and present in the image during 80 cycles (2) highly ^{15}N-rich type ($\delta^{15}N$ = +829 ± 42 ‰ and $\delta^{15}N$ = +1658 ± 82 ‰) not spatially correlated with high silicon content (cf. two occurrences shown with white arrows in Figures 1a and 1b) and present during 15 cycles. It is important to note here that the values given for the latter two hotspots are underestimated because their sizes are smaller than the size of the primary beam (around 400 nm). As a comparison, the ^{15}N-hotspots found by [9] with the same type of NanoSIMS settings (images of 20 x 20 μm^2, 256 x 256 pix, primary beam of 19 pA and ≈ 1 min per cycles) in the IOM isolated from the carbonaceous chondrites Orgueil and Murchison exhibit lower $\delta^{15}N$ values (maximum +480‰) with a minimal thickness corresponding to 60 cycles.

The distinct features of the ^{15}N-hotspots of the carbonaceous chondrites and of the enstatite chondrite Sahara 97096 IOM suggest different evolution of the organic matter before its incorporation in their respective parent bodies. Nevertheless the molecular and bulk isotopic results obtained for the IOM of the enstatite chondrite Sahara 97096 supports the assumption of a common precursor for the organic matter of the different types of chondrites. Although this common precursor could have been modified by an interaction with a gas reservoir and/or heating events, important properties (molecular features, bulk isotopic ratios etc.) have been preserved.

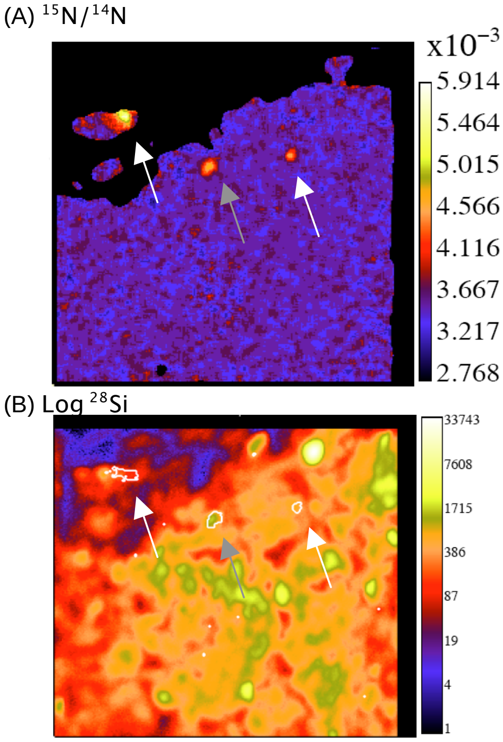

Figure 1: (A) Nitrogen isotopic distribution and (B) silicon distribution in the IOM of Sahara 97096 obtained by NanoSIMS imaging.

In a second approach, we studied the distribution of the organic matter within the meteorite. The main questions related to this second investigation are the following: Are molecular and isotopic differences related to the localization of the carbonaceous matter in the whole rock? Could we find evidences of any relationships between minerals and the carbonaceous matter? These issues were addressed through the study of a polished section of the Enstatite chondrite Sahara 97096. In order to avoid the problem of the H contamination introduced during polishing by the use of Epoxy and water, this section was cut and polished under alcohol with diamond paste without the use of Epoxy. In Sahara 97096, the organic matter is either mixed with silicates, sulfides and phosphides and located in 10 micro-metter sized matrix areas, mainly occurring around the chondrules (Figure 2A), or in aggregates within some metal-nodules(Figure 2B). The nitrogen and carbon isotopic ratios obtained by NanoSIMS imaging are undistinguishable between carbonaceous matter in the matrix areas or in the metal nodules, respectively. However the error bars of our results (+12 ± 24 ‰ for $\delta^{15}N$ and -2.4 ± 5 ‰ for $\delta^{13}C$ in metal nodules and +31 ± 120 ‰ for $\delta^{15}N$ and -17.9 ± 18 ‰ for $\delta^{13}C$ in the matrix) are still too large to distinguish a potential isotopic fractionation taking place during the reduction of the silicates by the carbonaceous matter. Nevertheless, the similarity in $\delta^{15}N$ and $\delta^{13}C$ of the IOM in the matrix or in the metal globule is a credible argument for a common origin. The on-going analyses with Scanning electron microscopy and Raman mapping will be discussed at the meeting.

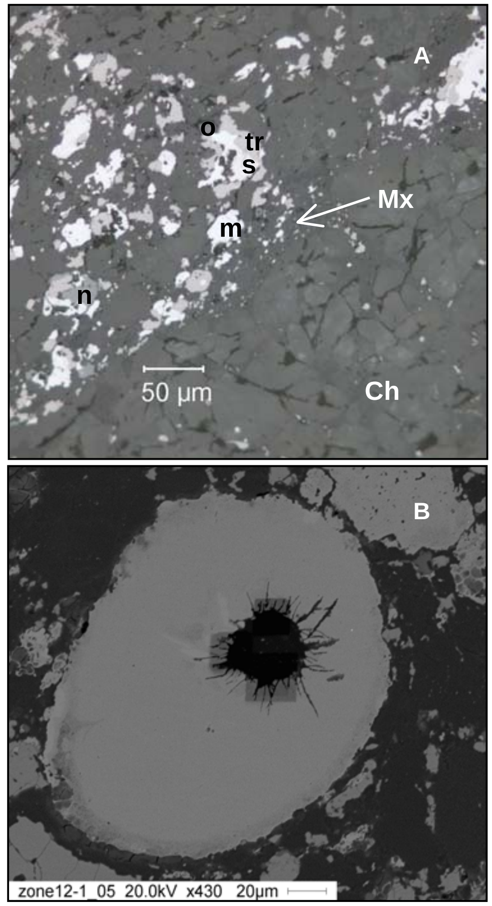

Figure 2: (A) Picture obtained with a Transmission optical microscope: a matrix area (Mx) localized around an enstatite chondrule (Ch); other minerals are troilite (tr), oldhamite (o), niningérite (n), schreibersite (s) and Fe-Ni metal (m) (B) BSE picture of a carbonaceous grain in a kamacite nodule. The 3 grey squares are the areas analysed with NanoSIMS. White features near the carbonaceous grain are Ni-rich perryite $(Ni,Fe)_8(Si,P)_3$.

References: [1] Hertogen et al., GCA, 1983, [2] Huss & Lewis, GCA, 1995, [3] Sears et al., GCA, 1982, [4] Piani et al., 72nd Annual Meteoritical Society Meeting, #5134, 2009, [5] Rémusat et al., EPSL, 2006, [6] Alexander et al, GCA, 2007, [7] Gourier et al, GCA, 2008, [8] Rémusat et al., ApJ (2009), [9] Thomen et al., 72nd Annual Meteoritical Society Meeting, #5284, 2009 and pers.comm.