

# INVESTIGATION OF ORGANIC MATTER IN CARBONACEOUS CHONDRITE LITHOLOGIES OF ALMAHATA SITTA.

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**Introduction:** The Almahata Sitta (AhS) meteorite is a brecciated, polymict ureilite that has originated from the near-earth asteroid 2008 TC3 which is classified as an F-type asteroid (a group in C complex) in spectroscopic taxonomy [1]. Carbonaceous chondritic lithologies AhS 671 and 91/91A have been characterized and contain phyllosilicates, bruennnerite, dolomite, magnetite, fayalite, ilmenite, phosphates, pyrrhotite, and pentlandite [2]. These lithologies are breccias and enclose fragments of ureilitic olivine and pyroxene [2]. Their bulk oxygen isotopic compositions are unique [2], but, interestingly, show relatively close  $\Delta^{17}\text{O}$  ( $\Delta^{17}\text{O}=1.6\text{--}1.8\text{‰}$ ) to that of the carbonaceous chondrite clast in the Zag meteorite ( $\Delta^{17}\text{O}=1.4\text{‰}$ ) [3] whose abundant organic matter we have been studying [4,5]. We report C-XANES, FTIR and NanoSIMS analyses of AhS 671 and 91A to elucidate the nature of their organic matter.

**Methods:** Approximately 1-mm subsamples from AhS 671 and 91A were separated for this study. An aliquot of each lithology was pressed between two KBr plates and IR absorption spectra were obtained using a Jasco FT/IR-6100+IRT-5200 at Yokohama National University. A 100 nm-thick section from each lithology was prepared using a focused ion beam (FIB, SMI-4050) at Kochi Institute for Core Sample Research, JAMSTEC. C, N, O-X-ray absorption near-edge structure (XANES) spectra of the sections were obtained using scanning transmission X-ray microscopes (STXM) on beamline 5.3.2.2 at the Advanced Light Source, Lawrence Berkeley National Laboratory, and BL4U at the UVSOR, Institute for Molecular Science. Subsequently, H, C and N isotope images were collected using a CAMECA NanoSIMS 50L ion microprobe at Kochi Institute for Core Sample Research, JAMSTEC.

**Results and Discussion:** Fig. 1 shows IR absorption spectra of AhS 671 and 91A. AhS 671 shows a broad band around  $3400\text{ cm}^{-1}$  with a peak at  $3675\text{ cm}^{-1}$  and a peak at  $1640\text{ cm}^{-1}$ . These are characteristic of phyllosilicate OH with some adsorbed/interlayer water. A Si-O band that has a peak center at  $1000\text{ cm}^{-1}$  is

consistent with phyllosilicates. A  $1440\text{ cm}^{-1}$  peak is assigned to carbonates. Phyllosilicates and carbonates were not observed in the subsample of AhS 91A, consistent with observed heterogeneity [2]. A features at around  $1000\text{ cm}^{-1}$  is most likely olivine possibly with some contribution of pyroxene. It is consistent with the samples being breccias that contain fragments of ureilitic olivine and pyroxene [2]. Organic features (aliphatic C-H) at around  $2900\text{ cm}^{-1}$  are barely visible.

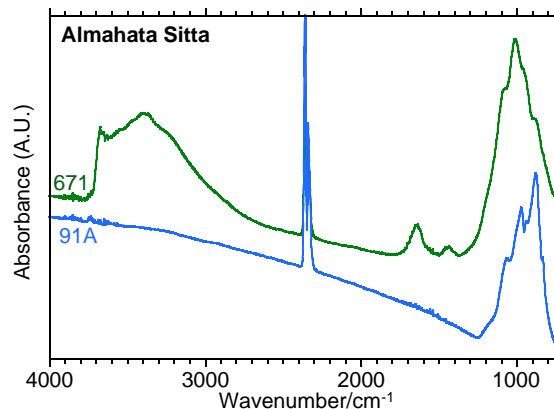


Fig. 1: FTIR spectra of Almahata Sitta 671 and 91A.

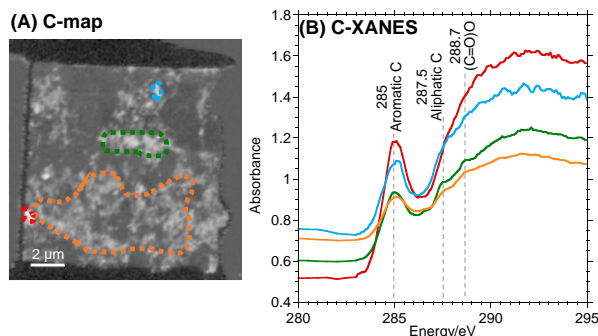


Fig 2: (A) STXM C-map of the FIB section of Almahata Sitta 671. (B) C-XANES spectra of the selected regions in the C-map.

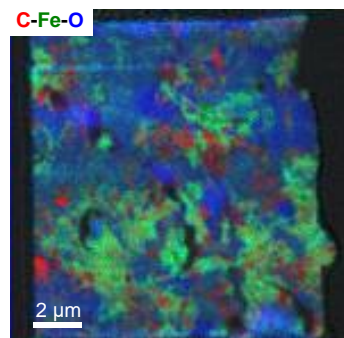


Fig. 3: STXM elemental map of the FIB section of Almahata Sitta 671. C in red, O in green, and Fe in blue.

STXM/C-XANES results are shown in Fig. 2. We only present the results for AhS 671 since the FIB section of 91A did not contain detectable carbon. The C-map of AhS 671 (Fig. 2A) shows that sub-micrometer organic matter is finely mixed with matrix. There is some sub-micrometer sized condensed organic matter (highlighted by red and blue in Fig. 2A). The C-map combined with Fe- and O-maps in RGB (Fig. 3) indicates that organic matter is scattered in Fe-rich regions (perhaps Fe-rich phyllosilicates?). C-XANES spectra of the organic-rich regions show large peaks at 285 eV assigned to aromatic carbon. The diffused organic regions (green and orange in Fig. 2) have small features at 297.5 eV and 288.7 eV that are assigned to aliphatic carbon and carboxyl/ester, respectively, but these feature are not observed in condensed organic matter (red and blue in Fig. 2). In N-XANES, a tiny peak at 401.3 eV, possibly assigned to N-C structure, is observed in the diffused organic regions. Although, organic matter in AS 671 is highly aromatic, there is no  $1s-\sigma^*$  exciton peak at 291.7 eV of graphene structures that is characteristic of thermally-metamorphosed meteorites [6]. Such characteristics are similar to the C-rich aggregate in the Zag clast [4]. The only difference of their organic matter is related to morphology; Zag organics form large (over 10  $\mu\text{m}$ ) aggregates while those in AhS 671 are smaller and mixed with the matrix at the submicron scale.

NanoSIMS isotope images are shown in Fig. 4.  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  in C-rich areas are homogeneous with averages of  $+3 \pm 3 \text{ ‰}$  and  $+234 \pm 32 \text{ ‰}$ , respectively. The  $\delta^{15}\text{N}$  value is close to the value of insoluble organic matter (IOM) of CR chondrites [7], and much less than the C-rich aggregate in the Zag clast [4]. The  $\delta\text{D}$  value in C-rich areas is  $+988 \pm 59 \text{ ‰}$ . It is similar to the value of IOM of CI and CM chondrites [7], but less than the value of CRs [7] and the C-rich aggregate in the Zag clast [4]. Downes and coworkers [8] reported C and N isotopic compositions ( $\delta^{13}\text{C}$  of  $-7.3$  to

$+0.4 \text{ ‰}$ ;  $\delta^{15}\text{N}$  of  $-53$  to  $-94 \text{ ‰}$ ) in ureilitic fragments of the Almahata Sitta. Our result for  $\delta^{13}\text{C}$  is broadly consistent but not for  $\delta^{15}\text{N}$ . The N isotopes of organic matter in AhS 671 shows an isotopically heavier component, which are consistent with different origins for organic matter in AhS 671 and the ureilitic fragments of the Almahata Sitta.

Considering the molecular structure and the nitrogen isotope composition, we hypothesize that the organic matter in AhS 671 experienced similar processes to the C-rich aggregate in the Zag clast, but originated from different organic precursors.

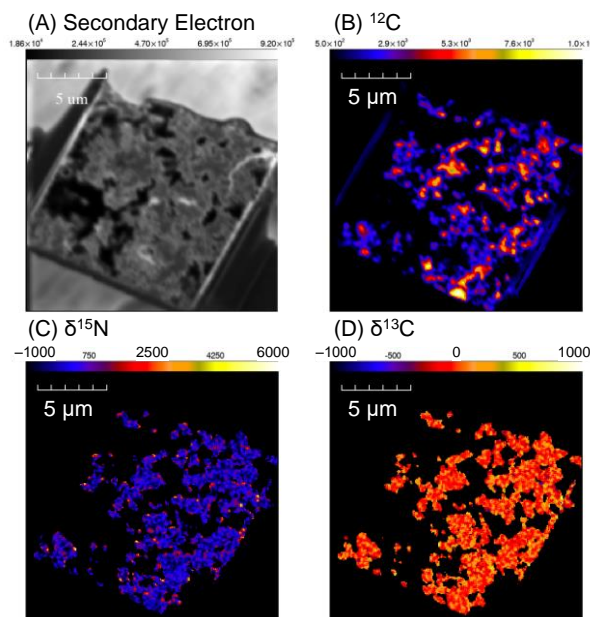


Fig. 4: NanoSIMS images. (A) Secondary electron image, (B)  $^{12}\text{C}$  image, (C)  $\delta^{15}\text{N}$  image, and (D)  $\delta^{13}\text{C}$  image.

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