ORGANIC AGGREGATES WITH δD AND δ15N ANOMALIES IN THE ZAG CLAST REVEALED BY STXM AND NANOSIMS.

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Introduction: Xenolithic clasts are often found in a wide variety of meteorite groups [e.g., 1]. Some ordinary chondrite clasts are interesting since these clasts might have originated from Ceres which shares crossing orbits with a possible ordinary chondrite parent body, Hebe [2]. The Zag meteorite contains a dark clast dominated by saponite, serpentine, carbonates, sulfides, magnetite, minor olivine and pyroxene, which is consistent with formation on a large, carbonaceous, aqueously active body, e.g., Ceres [3]. Abundant large C-rich grains up to 20 μm were found in the Zag clast as well [3]. Such large C-rich grains are unique among any other meteorites in our knowledge, and will provide important clues to decipher the origin of the clast and accretion history.

Methods: C-rich grains were selected in the Zag dark clast using SEM and approximately 100 nm-thick sections were prepared using a focused ion beam (FIB) at NASA-JSC. The sections were analyzed using the scanning transmission X-ray microscope (STXM) on beamline 5.3.2.2 at Advanced Light Source, LBNL, and BL-13A at the Photon Factory, KEK. Subsequently, the FIB section was analyzed for H, C and N isotopic compositions using a CAMECA NanoSIMS 50L ion microprobe at Kochi Institute for Core Sample Research, JAMSTEC.

Results and Discussion: The FIB section showed a large C-rich area over 10 μm width that corresponded to the C-rich grain (Fig. 1b). Carbon X-ray absorption near edge structure (XANES) of the C-rich grain showed a peak at 284.8 eV that is assigned to sp2 carbon (C=C) (Fig. 1c,d in Red). The surrounded matrix area showed a peak at 290.3 eV that is assigned to carbonates with smaller 284.8 eV peak. The C-XANES of the C-rich grain had no other functional groups (e.g., C=O) that are characteristic of primitive chondritic insoluble organic matter (IOM) (e.g., Murchison), nor 1s-σ* exciton at 291.7 eV of graphene structures that is characteristic of thermally metamorphosed meteorites (e.g., Allende IOM) [4]. No specific nitrogen features were observed in N-XANES. XANES results indicate that the C-rich grain may consist of a hydrogenated amorphous carbon-like structure.

The C-rich grain had large δD and δ15N anomaly, δD = 2,370 ± 74 ‰ and δ15N = 696 ± 100 ‰ in average. δ13C was −43 ± 20 ‰ that was broadly consistent with the values of CRs and Bells within the analytical error [5]. Two hot spots were observed; one is D- and 15N-rich (δD = 4,200 ± 550 ‰ and δ15N = 3,413 ± 1,070 ‰), and the other is D-rich (δD = 4,500 ± 900 ‰) with normal to moderate enrichment in 15N (724 ± 780 ‰) (Fig. 1e,f). The origin of the C-rich grain and isotope anomaly is puzzling since no molecular heterogeneity was observed between the hot spots and the average area. Some “aromatic” globules in chondrites reported by [6] show C-XANES spectra similar to the C-rich grains in the Zag clast. In their study however, no clear correlation between molecular structure and δ15N was observed; aromatic globules have similar or higher δ15N values than IOM-like globules [6]. If the C-rich grain is an assemblage of organic matter with different origins (with different δD and δ15N values), isotope heterogeneity might have survived the structural homogenization that possibly occurred during subsequent aqueous processing.