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Introduction: Zag and Monahans meteorites (H5) contains xenolithic dark clasts and halite (NaCl) crystals [e.g., 1]. The proposed source of the H chondrites is asteroid 6 Hebe [2]. The modern orbits of 1 Ceres and 6 Hebe essentially cross, with aphelion/perihelion of Ceres and Hebe of 2.99/2.55 and 2.91/1.94 AU, respectively [3]. Therefore, Ceres might be the source of the clasts and halite in Zag and Monahans meteorites [4]. Recent results from NASA’s Dawn mission shows that bright spots in Ceres’s crater may be hydrated magnesium sulfate with some water ice [5], and an average global surface contains ammoniated phyllosilicates that is likely outer Solar System origin [6].

One dark clast and all halite crystals in Zag and Monahans meteorites contain carbon-rich particles. We report organic analyses of these carbon-rich particles using carbon, nitrogen, and oxygen X-ray absorption near edge structure (C-, N-, and O-XANES), in order to constrain the origin of the clast and halite crystals.

Samples and Methods: C-rich spots were selected in the Zag dark clast using SEM and approximately 100 nm-thick sections were prepared using a focused ion beam (FIB) at JSC. C-rich residues were obtained after dissolving halite crystals in the Monahans meteorite. The residues were embedded in sulfur and ultramicrotomed with a diamond knife. The sections were analyzed using the scanning transmission X-ray microscope (STXM) on beamline 5.3.2.2 at the Advanced Light Source, Lawrence Berkeley National Laboratory, or BL-13A at the Photon Factory, KEK.

Results: Zag clast C-rich spots. Fig. 1 shows STXM carbon map of FIB sections of the Zag clast that contain micrometer-sized C-rich spots. C-XANES spectra were obtained from the C-rich spots and surrounding matrix of the clast (Figs. 2, 3). C-rich spots from FIB#2 show a peak at 284.8 eV that is assigned to aromatic/olefinic C=C. C-rich spots from FIB#1 show peaks at 286.3 eV that is assigned to aryl/vinyl-keto C=O, and 288.5 eV that is assigned to carboxyl/ester COOR, in addition to C=C peak. C-XANES of the matrix area shows 290.3 eV assigned to carbonates with some aromatic/olefinic C=C.

Fig. 1: STXM carbon map of the Zag clast FIB sections. C-rich areas are shown in light gray. C-XANES of selected areas are shown in Fig. 2, 3.

Fig. 2: C-XANES spectra of the Zag clast FIB#1. Corresponding C-map is shown in the left panel of Fig. 1.
C-XANES of Monahans residue type 2 shows some similarity to some of the comet 81P/Wild 2 particles [7], but type 1 does not resemble any extraterrestrial samples analyzed with C-XANES so far, to our knowledge.

The STXM-XANES analyses indicate that the Zag dark clast and the Monahans halite crystals contain comet-like organic matter as well as carbonaceous chondrite-like organics. If these clasts and halite crystallized from Ceres, it is consistent with the recent view of Ceres that it lies on a continuum in composition between asteroids and comets [5], also consistent with measured O and H isotopic composition of water from Zag and Monahans halite [11].

**Organic-rich residue from Monahans halite.** We obtained C-XANES spectra from several ultramicrotomed thin sections of the organic-rich residue from Monahans halite. Typical C-XANES spectra are shown in Fig. 4. The peak assignments are shown in Table 1. There were two types of spectra obtained from the Monahans residue. Type 1 shows large C=C with some aliphatic and COOR peaks. Type 2 shows a large COOR peak with C=C peak. Some analyzed areas also show carbonates.

**Discussion:** A large (>5 μm) carbon chunk in Zag clast FIB#1 shows similar C-XANES features with insoluble organic matter (IOM) in CI-CM-CR chondrites [8, 9]. A C-rich grain (<1μm) in FIB#1 and C-rich areas in FIB#2 have no organic features except C=C at ~285 eV. This characteristic is similar to some nanoglobules in carbonaceous chondrites [8] and coma particles from comet 81P/Wild 2 [10], but C-rich areas in FIB#2 are much larger than any nanoglobules.