COORDINATED NANOSIMS AND TEM ANALYSES OF C- AND N-ANOMALOUS PHASES IN THE CR3 CHONDRITE MET 00426. C. Floss[1], C. Le Guillou[2], F. J. Stadermann[1], and A. J. Brearley[2]. [1]Laboratory for Space Sciences and Physics Department, Washington University, St. Louis, MO 63130, USA (floss@wustl.edu). [2]Department of Earth and Planetary Sciences, MCS03-2040,1, University of New Mexico, Albuquerque, NM 87106, USA (corentin.san@gmail.com; brearley@unm.edu).

Introduction: MET 00426 is one of two known CR3 chondrites and has experienced significantly less aqueous alteration than other members of this group [1]; it also contains abundant presolar silicates [2], confirming its primitive nature. In addition, the matrix of this meteorite contains matter that is isotopically anomalous in C and/or N, either of interstellar or proto-solar nebular origin [3–6]. We are investigating the compositions, structures and petrographic associations of this material in order to help constrain its origin and to understand how it is affected by secondary processing.

Experimental: We initially carried out NanoSIMS C and N ion imaging searches in a thin section of MET 00426 to identify isotopically anomalous areas. Like other CR chondrites, MET 00426 contains abundant hotspots that are enriched in ^{15}N [4]. Grains that are isotopically anomalous in C are also present; these typically also show N isotopic anomalies [3]. We used focused ion beam (FIB) liftout to extract regions of interest and carried out TEM analysis of the sections. Following the TEM work, we made NanoSIMS measurements on the sections (C and N, except for one section, 5b-6, in which we measured C and O) to verify the anomalies in the original surface grains and to obtain data from the rest of the section for comparison with the TEM results.

Results and Discussion: We summarize here observations on six FIB sections cut through C- and/or N-anomalous regions in the MET 00426 matrix.

5b-6: Grain 5b-6c1 was identified earlier as a carbonaceous nanoglobule enriched in ^{13}C and ^{15}N [3]. TEM analysis of this grain shows that it consists of amorphous C (Fig. 1), confirming its identification as the first nanoglobule with a C isotopic anomaly. The grain is surrounded by Fe-rich amorphous silicates typical for this meteorite [1]. Several Mg-rich crystalline silicates also present in the section are depleted in oxygen compared to expectations from stoichiometric considerations, but have normal O isotopic compositions.

5b-9: This FIB section through two ^{15}N-rich hotspots shows that one is a nanoglobule connected to an area of isotopically normal C-rich matter by a thin vein of carbonaceous matter, while the other is a compact grain surrounded by amorphous Fe-rich silicates. Another large area of ^{15}N-rich amorphous C present in the subsurface of the section is associated with several large enstatite grains that show evidence of alteration in their rims.

1a-11: The ^{15}N-rich hotspot in this section is a composite grain consisting of a nanoglobule attached to an area of more compact amorphous carbon. Carbon isotopic imaging shows the presence of a likely mainstream SiC ($^{12}C/^{13}C = 38 \pm 4$) in the section.

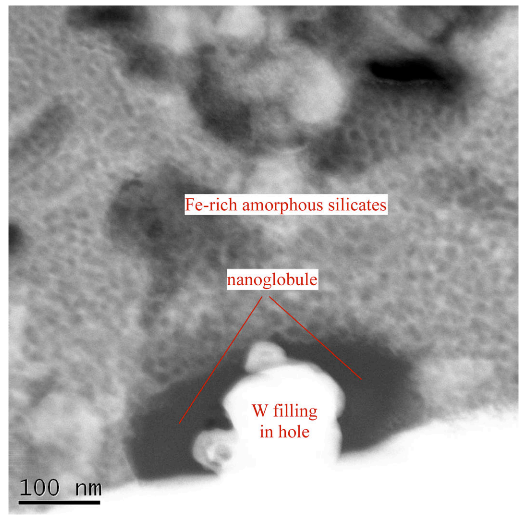

Figure 1. Dark field STEM image of amorphous ^{13}C-rich nanoglobule from FIB section 5b-6.

6d-2: This section was cut through an area anomalous in both C and N, and a grain with normal isotopic compositions. The normal grain consists of compact amorphous carbonaceous matter and is surrounded by phyllosilicates and amorphous silicates, as well as an enstatite grain. The anomalous area actually consists of two grains separated by a small amount of matrix material. The morphologies of these grains are unusual, with distinct blocky structures, but like other hotspots we examined are composed simply of amorphous carbonaceous matter. The grains are associated with a large Mg-rich pyroxene.

5a-8: This FIB section was cut through two large ^{15}N-rich regions and a mainstream SiC grain. Both N-anomalous areas consist of compact amorphous carbonaceous matter and extend as veins into the subsurface of the section. Isotopic imaging of the section shows that although both areas were originally ^{15}N-rich, only one of the regions now exhibits a ^{15}N enrichment; the other area is isotopically normal in N (Fig. 2). Energy-filtered TEM (EFTEM) images show that the ^{15}N-rich vein has higher N/C than other amorphous C in MET 00426, but there are no other obvious distinctions to account for the different isotopic compositions between the two areas.

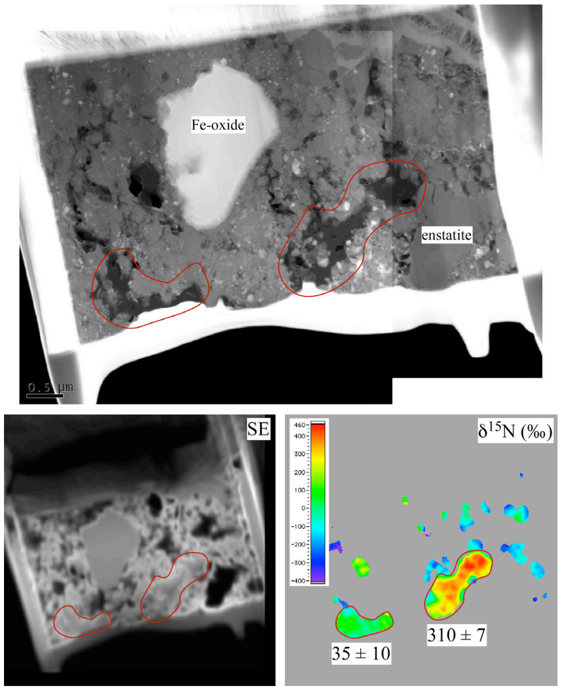

Figure 2. Dark field STEM (top) and NanoSIMS SE and false-color $\delta^{15}N$ (bottom) images of carbonaceous veins in FIB section 5a-8.

1a-17: This ^{15}N-rich grain consists of amorphous C with a nanoglobule morphology. Nitrogen isotopic imaging shows that large areas in the rest of the section are also enriched in ^{15}N. This section contains more phyllosilicates and fewer amorphous silicates than the others we studied, indicating localized, more extensive aqueous alteration. The ^{15}N enrichments are diffuse and the organics in which they are likely hosted occur mostly as cracks running along grain boundaries (Fig. 3), suggesting that ^{15}N has been redistributed from the original C-rich hosts to surrounding matrix through fluid action.

Summary and Conclusions: All areas with C and/or N isotopic anomalies that we examined in MET 00426 consist of amorphous carbonaceous matter, but morphologies are variable. Some grains are nanoglobules, while others have compact or blocky morphologies. Aggregates of isotopically anomalous grains are also present. There is no obvious correlation of the phases hosting the anomalies with petrographic association. Anomalous grains are found surrounded by amorphous and/or anhydrous crystalline silicates. There are also no clear compositional distinctions; for example, EFTEM images and EDX analyses show the presence of S in all grains. These observations are consistent with suggestions that isotopic fractionations may be inherited from precursor molecules [3] and with experimental work indicating that UV photolysis can easily convert icy interstellar analogs to complex organic compounds [7, 8]. Moreover, the association of diffuse ^{15}N enrichments with elevated abundances of phyllosilicates in one section studied here suggests that aqueous alteration has played a role in redistributing ^{15}N in MET 00426 and, by extension, probably also in other CR chondrites.

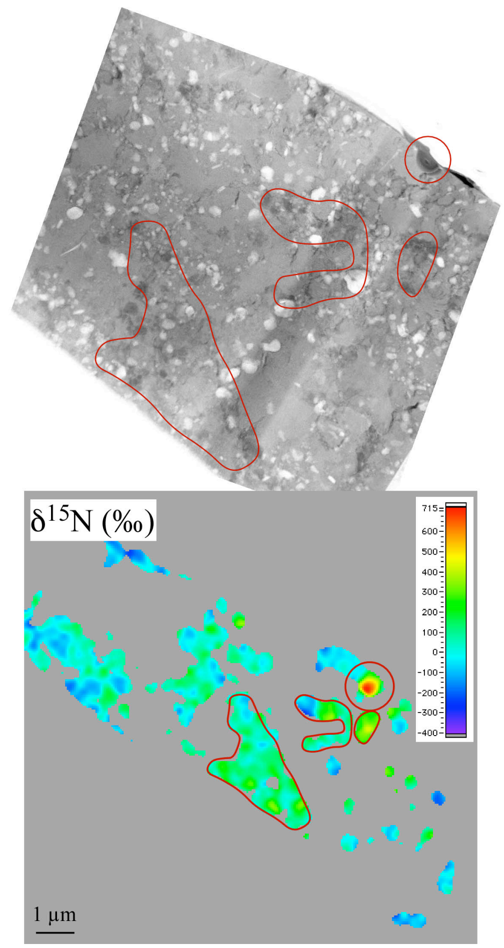

Figure 3. Dark field STEM (top) and NanoSIMS false-color $\delta^{15}N$ (bottom) images of FIB section 1a-17.

References: [1] Abreu N. and Brearley A. J. (2010) *GCA* **74**, 1146-1171. [2] Floss C. and Stadermann F. J. (2009) *GCA* **73**, 2415-2440. [3] Floss C. and Stadermann F. J. (2009) *ApJ* **697**, 1242-1255. [4] Floss C. and Stadermann F. J. (2009) *LPS XL*, #1083. [5] Remusat L. et al. (2010) ApJ **713**, 1048-1058. [6] Aléon J. (2010) ApJ **722**, 1342-1351. [7] Bernstein M. P. et al. (2002) *ApJ* **376**, 1115-1120. [8] Bernstein M. P. et al. (2003) *ApJ* **582**, L25-L29.

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