

**PARENT-BODY PROCESSING OF ORGANIC NANOGLOBULE AGGREGATES.** B. T. De Gregorio<sup>1</sup>, Z. Peeters<sup>2</sup>, R. M. Stroud<sup>1</sup>, L. R. Nittler<sup>2</sup>, and C. M. O'D. Alexander<sup>2</sup>, <sup>1</sup>Naval Research Laboratory (Code 6366, 4555 Overlook Ave. SW, Washington, DC 20375), <sup>2</sup>Department of Terrestrial Magnetism, Carnegie Institution of Washington (5241 Broad Branch Rd. NW, Washington, DC 20015).

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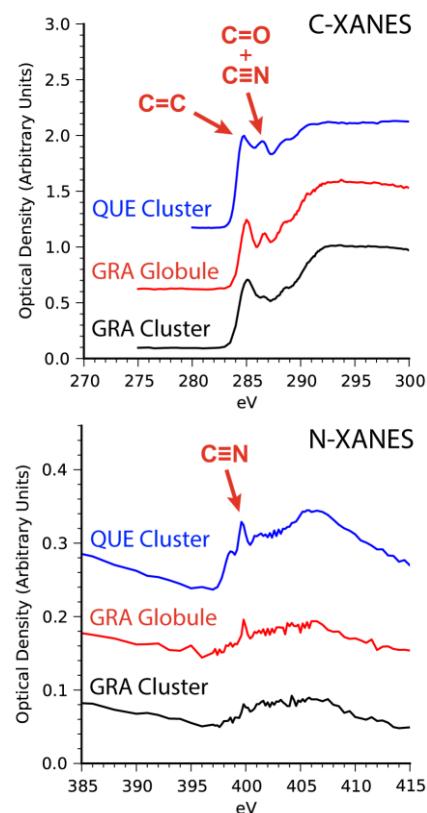
**Introduction:** Micrometer-sized organic nanoglobules are ubiquitous in primitive planetary materials [1-6]. However, the origins of these features are poorly constrained, with possible mechanisms ranging from interstellar ice chemistry to pre- or post-accretionary aqueous alteration. Although large surveys of nanoglobules in insoluble organic matter (IOM) in meteorite acid residues reveal important characteristics of their bulk population [3, 4, 6-8], *in situ* studies of nanoglobules in relation to surrounding mineral material [1, 2, 9, 12] are ultimately necessary to determine whether they formed in pre-accretionary and/or post-accretionary environments, and to reveal potential alteration histories. Here we describe several occurrences of nanoglobule clusters within primitive meteorite matrices and their implications.

**Materials and Methods:** This work is a continuation of a coordinated multi-technique *in situ* study of carbonaceous inclusions in the CR3 Queen Alexandra Range (QUE) 99177 and CR2 Graves Nunataks (GRA) 95229 meteorites [10-12]. Our general approach is to use secondary ion mass spectrometry (SIMS) and/or SEM-EDS mapping to identify carbonaceous inclusions a few  $\mu\text{m}$  in size and extract  $\sim 100$  nm thick lift-out sections containing these inclusions and surrounding matrix material with focused ion beam (FIB) methods. The FIB sections are first analyzed by X-ray absorption near-edge structure spectroscopy (XANES) at beam line 5.3.2.2 at the Advanced Light Source, Lawrence Berkeley National Laboratory, to determine the C and N functional group chemistry. Subsequently, the nanoscale morphology and organic-mineral spatial relationships are characterized with a JEOL 2200FS field-emission transmission electron microscope (TEM) at the Naval Research Laboratory, and, if possible the H and N isotopic composition are also measured with a Cameca NanoSIMS 50L ion microprobe at the Carnegie Institution of Washington. We have previously reported results for two sections from each meteorite [10-12]; here we report data for a third section from GRA 95229. Unfortunately, this section was lost before its isotopic composition could be measured.

**Previous Results:** Briefly, these sections contain large carbonaceous veins composed of “smooth”, dense organic matter, although some areas of “vesicular” organic matter are also present near the edges of the features (as defined in [5]). In one large carbonaceous vein from QUE 99177, internal curved and

spherical morphology suggests that the entire vein was originally a large collection of organic nanoglobules [11]. This vein and two found in GRA 95229 are enriched in D and/or  $^{15}\text{N}$ , indicating that the organic matter or its precursors originated in a cold molecular cloud or outer nebular environment [11, 12]. The common characteristic between all three large carbonaceous veins is abundant nitrile ( $\text{C}\equiv\text{N}$ ) functionality (Fig. 1), which has previously been implicated as a dominant carrier of extrasolar  $^{15}\text{N}$  [13, 14], but is not commonly seen in extracted IOM or isolated sub- $\mu\text{m}$  inclusions [12].

**Results – GRA 95229:** The latest FIB section from GRA 95229 also contains a small cluster of organic nanoglobules, many of which are deformed or smashed due to parent body compaction (Fig. 2). All



**Figure 1.** C- and N-XANES data from nanoglobule aggregates. Spectra of the large nanoglobule collection in QUE 99177 (described in [11]) are shown in blue. Spectra of the largest solid nanoglobule in GRA 95229 are shown in red, while the remaining vesicular nanoglobules are shown in black.

but the largest solid nanoglobule are composed of “vesicular” organic matter (Fig. 2C), similar to the description of nanoglobule aggregates in ultramicrotomed samples of the CM2 chondrite Bells [15]. Dessicated-looking vesicular nanoglobules were also observed in IOM from the heavily-altered CR1 chondrite GRO 95577 [6, 7]. The vesicular nanoglobule cluster appears to be depleted in nitrile functionality (Fig. 1) relative to the large, solid nanoglobule, which is also surrounded by a 30-50 nm rim of layered silicates that are compositionally identical to the surrounding matrix phyllosilicates (Fig. 2B). This rim likely formed during aqueous processing of the surrounding silicate matrix on the parent body.

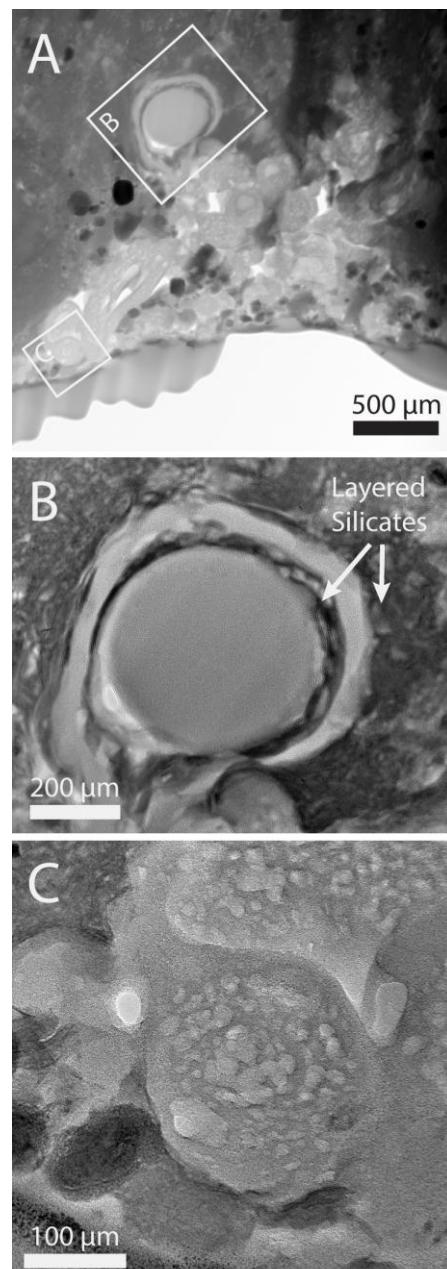
**Discussion:** Since QUE 99177 has experienced little aqueous processing relative to GRA 95229, we interpret the nanoglobule clusters in these two samples as representing distinct time points of a common aqueous processing pathway. In the GRA 95229 nanoglobule aggregate, hydrothermal fluids have processed and removed some of the organic matter, leaving behind copious vesicles. This is consistent with vesicular nanoglobules observed in other heavily aqueously processed chondrites [6, 7, 10]. Conversely, the nanoglobule-rich vein in QUE 99177 has not been significantly processed since it retains a large D and  $^{15}\text{N}$  isotopic excess relative to bulk organic matter in the meteorite.

Nitrile functional chemistry appears to have been depleted by hydrothermal processing of the vesicular nanoglobules in GRA 95229 (Fig. 1), yet it is retained in the large solid globule nearby (Fig 2B). It is possible that the layered silicates surrounding the solid nanoglobule protected it from further degradation. Nitrile functional groups are easily hydrolyzed in the presence of acidic or alkaline solutions, and might only be retained in large hydrophobic carbonaceous features or in those protected by nonporous rim materials. High levels of nitrile functionality may also be a chemical marker for primitive organic matter, independent of destructive isotopic measurements.

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**Figure 2:** (A) Bright-field STEM image of the nanoglobule aggregate in GRA 95229. (B) TEM image of the large solid nanoglobule shown in (A), surrounded by layered silicate material. (C) TEM image of a portion of the cluster containing nanoporous organic matter.