A SPACE ODDITY: A NANOSIMS STUDY OF A PRIMITIVE ULTRACARBONACEOUS CLAST AND FINE-GRAINED MATRIX IN THE LAPAZ ICEFIELD 02342 CR CHONDRITE. C.E. Moyano-Cambero[1,*], L.R. Nittler[2], J.M. Trigo-Rodríguez[1], C.M.O'D. Alexander[2], J. Davidson[2], and R.M. Stroud[3] [1]Meteorites, Minor Bodies and Planetary Sciences Group, Institute of Space Sciences (CSIC-IEEC). Campus UAB, Fac. Sciences, C5-p2, 08193 Bellaterra (Barcelona), Spain. [2]Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington DC 20015, USA. [3]Naval Research Laboratory Code 6366, 4555 Overlook Ave. SW, Washington, DC 20375. [*]E-mail: moyano@ice.csic.es

Introduction: Renazzo-like carbonaceous chondrites (CRs) represent some of the most pristine extraterrestrial samples [1], occasionally containing abundant presolar grains and showing a complex diversity of organic compounds [2-7]. Indeed, CR chondrites can be considered primitive materials containing clues to the pathways of biogenic elements and their delivery to terrestrial planets [7]. CRs vary from petrologic type 1 to 3, showing a wide and variable degree of aqueous alteration [8]. Identifying the least altered CR chondrites is essential for better understanding the earliest stages of planet formation. Among other CR chondrites previously studied [9], we found LaPaz Icefield (LAP) 02342 to be a very promising candidate [8], due to its low degree of weathering and fracturing. Moreover, our prior Scanning Electron Microscope (SEM) work identified significant features in the matrix of LAP 02342 that suggested a pristine and highly unequilibrated nature for this meteorite [9], including an unusual C-rich clast. We report the results of a NanoSIMS H, C, N, and O isotopic survey of LAP 02342, focusing particularly on the C-rich clast, which may bear affinities to ultracarbonaceous micrometeorites collected in Antarctica [10, 11].

Experimental methods: We investigated a thin section of LAP 02342 provided by NASA's Johnson Space Center. Following thorough examination at the Institute of Space Sciences (CSIC-IEEC) by petrographic microscope, detailed backscattered electron imaging and elemental x-ray analyses were performed with a FEI Quanta 650 FEG SEM equipped with an Oxford silicon drift detector (SDD) [9]. Selected areas (Fig. 1) were then targeted for analysis with the Carnegie's Cameca NanoSIMS 50L ion microprobe. Analyzed areas were analyzed both before and after the SIMS measurements with a JEOL 6500F SEM also equipped with an Oxford SDD.

NanoSIMS measurements were carried out in automated imaging mode with a focused (~100 nm) Cs^+ primary ion beam and simultaneous collection of negative secondary ions. A total of ~30,000 μm^2 were mapped for C and O isotopes to search for presolar grains, 7,000 μm^2 to characterize H, C and N isotopes and an additional 8,000 μm^2 for just D/H ratios and elemental C. O isotopic ratios were standardized to the average values measured in each 10×10 μm image; terrestrial standards, purified meteoritic insoluble organic matter and epoxy in the thin section were used to quantify H, N, and C isotopes. Measured D/H ratios are lower limits due to the possibility of terrestrial contamination on the sample surface.

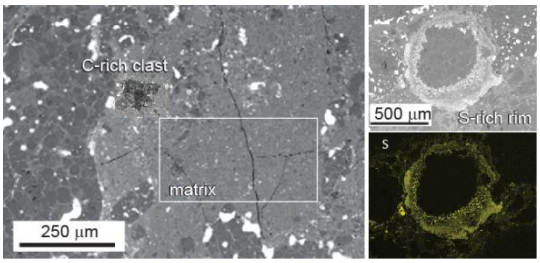

Figure 1: SEM images and sulfur x-ray map of LAP 02342 areas targeted for NanoSIMS analysis.

Results: Three areas of the LAP 02342 section were analyzed by NanoSIMS (Fig. 1): a ~100 μm diameter very C-rich clast (CRC) (Fig. 2) that appears to be in a fine-grained chondrule rim, nearby fine-grained matrix, and a highly altered S-rich chondrule rim [SRR, 9]. The CRC consists of ~70% fine-grained C by area, intermixed with inorganic materials.

O-isotope mapping identified 18 presolar O-rich grains (most likely silicates) with typical O-isotope ratios for presolar grains [4, 5]. Five presolar O-rich grains each were found in the matrix and SRR, giving an overall abundance for the two areas of ~30 ppm. In contrast, eight presolar grains were found within or very close to the CRC, giving a much higher overall presolar silicate abundance for that area of ~100 ppm. However, the presolar grain abundance may be as high as 400 ppm within the CRC itself depending on how it is calculated. In addition to presolar grains, some μm-sized grains at the edge of and/or within the CRC were also found to have isotopically anomalous O, with $\delta^{17}O \approx \delta^{18}O \approx 150–200‰$ (Fig. 2). The mineralogy of these grains has not yet been determined, but x-ray maps indicate that they are Na-rich. The ^{16}O-poor signature is reminiscent of materials found in the Acfer 094 meteorite and interplanetary dust particles that are postulated to reflect a water reservoir in the solar nebula [12, 13]. A few ^{13}C-rich presolar SiC grains

were also found in the matrix and SRR areas, giving an abundance of ~25–30 ppm, typical of primitive chondrites [14].

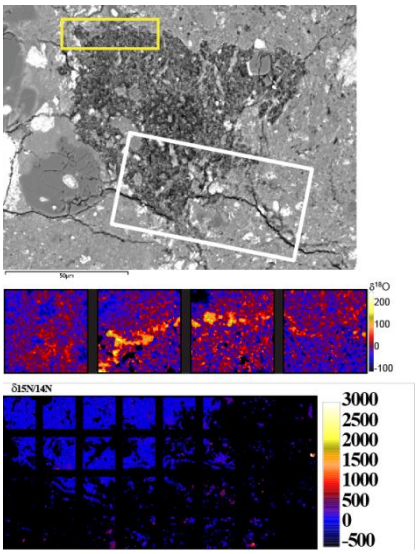

Figure 2: Top: SEM image of C-rich clast (CRC). Yellow box indicates location of middle panel, white box indicates bottom panel. Middle: δ^{18}O images showing anomalous ^{16}O-poor grains at upper border of CRC. Bottom: δ^{15}N image of CRC and neighboring matrix.

H, C and N isotope mapping revealed the LAP 02342 matrix and SRR to contain ubiquitous carbonaceous inclusions (0.1–1 μm) that are variably enriched in D and ^{15}N, similar to that seen in other CR chondrites [15, 16]. In contrast, most of the C within the CRC is isotopically normal with $\delta D \approx \delta^{15}N \approx 0$, though some localized regions of enhanced D and ^{15}N are seen (Figs. 2, 3).

Discussion: The presolar silicate abundance of LAP 02342 matrix and SRR (≈30 ppm) is lower than that (>100 ppm) of the most unaltered CRs [6, 17], implying that this meteorite has been somewhat more aqueously altered. The more extensive alteration experienced by the SRR is not reflected in the presolar grain abundances, but statistics are limited. The distributions of H and N isotopes in organic grains in LAP 02342 matrix (Fig. 3) are similar to those seen in other CRs [15, 17]. The distribution of δD values in the SRR is skewed to lower values than the matrix, most likely due to the more extensive alteration it has experienced [18]. It is not clear why this particular chondrule rim is so much more altered than even nearby materials, but it could be suggestive of a wet/ice accretion of this chondrule with a highly porous border. The abundant S, possibly initially present as sulfide, may also have played a role.

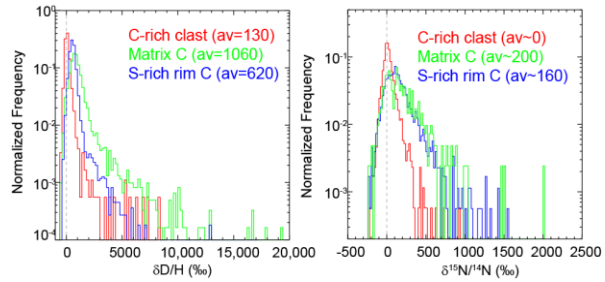

Figure 3: Histograms (normalized to total area under curves) of δD (left) and δ^{15}N (right) values for sub-μm C-rich regions of interest in analyzed areas of LAP 02342.

The C-rich clast is strikingly different from the matrix in terms of its C abundance, mostly normal H and N isotopes and higher presolar grain abundances. Moreover, it contains unusual Na-rich and ^{16}O-poor grains. In terms of size and composition, it bears some resemblance to ultracarbonaceous Antarctic micrometeorites (UCAMMs), commonly suspected to originate in comets. Although some UCAMMS are highly isotopically anomalous in H and N [10], others are not [19]. Our clast most likely existed as an isolated object in the solar nebula that accreted onto a chondrule rim before being incorporated into the LAP 02342 parent body and provides further evidence for the diversity of C-rich materials in the nebula, even within relatively restricted spatial regions. Further mineralogical and chemical characterization of this clast is needed to better understand its relationship to other primitive planetary materials.

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