ULTRACARBONACEOUS ANTARCTIC MICROMETEORITES: ORIGINS AND RELATIONSHIPS TO OTHER PRIMITIVE EXTRATERRESTRIAL MATERIALS. C. Floss[1], T. Noguchi[2], and T. Yada[3]. [1]Laboratory for Space Sciences and Physics Department, Washington University, St. Louis, MO 63130, USA. [2]Dept. of Materialogical and Biological Science, Ibaraki University, Mito, Ibaraki 310-8512, Japan. [3]Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science, Sagamihara, Kanagawa 252-5210, Japan. (contact email: floss@wustl.edu)

Introduction: Micrometeorites dominate the flux of extraterrestrial material accreting to the Earth [1] and have been collected from snow and ice in Antarctica and other polar regions [e.g., 2, 3]. Ultra-carbonaceous Antarctic micrometeorites (UCAMMs) are fine-grained, fluffy particles dominated by carbonaceous matter [4]. Hydrogen isotopic analyses of two UCAMMs showed extreme deuterium excesses over large areas (100s of μm^2) of the particles [5], suggesting links to other primitive materials with D anomalies, such as interplanetary dust particles (IDPs) and the insoluble organic matter (IOM) of some meteorites [6, 7].

TT54B397 is a UCAMM collected from blue ice at Tottuki Point in East Antarctica [3] and contains more than 90 vol.% carbonaceous matter. An early isotopic imaging survey of this micrometeorite showed the presence of two presolar silicate grains [8]. We have carried out additional isotopic measurements in order to constrain the origin of this UCAMM and its relationship to other primitive materials.

Experimental: TT54B397 was investigated by synchrotron X-ray diffraction and transmission electron microscopy in order to determine its mineralogy. Subsequently NanoSIMS raster ion imaging measurements for C and O ($^{12}C^-$, $^{13}C^-$, $^{16}O^-$, $^{17}O^-$, $^{18}O^-$), and C and N ($^{12}C^-$, $^{13}C^-$, $^{12}C^{14}N^-$, $^{12}C^{15}N^-$, $^{28}Si^-$) were carried out on several of the TEM slices. Carbon and N isotopic compositions were normalized to synthetic SiC and Si_3N_4 standards, respectively, while O isotopic compositions were normalized internally, assuming solar O values for the bulk micrometeorite.

Results: Synchrotron and TEM analyses show that the carbonaceous matter in TT54B397 is amorphous and forms a complex framework structure throughout the particle [4]. Low-Ca pyroxene, kamacite and taenite are present in the micrometeorite [8], as are GEMS (glass with embedded metal and sulfides) and enstatite platelets (Fig. 1).

Carbon and N isotopes were measured in four different slices of TT54B397 (13,200 and 8000 μm^2 measured, respectively). The isotopic compositions are normal in all slices, with no observable anomalous hotspots for either element. However, we did identify five O-anomalous presolar grains in several slices (~5200 μm^2 measured) of the micrometeorite (Fig. 2). Three grains have the ^{17}O enrichments and close-to-solar $^{18}O/^{16}O$ ratios of group 1 grains, which are thought to originate from low-mass red giant or AGB stars [9]. A fourth grain is enriched in ^{18}O and belongs to group 4, as do the two grains found by [8]; these grains likely have origins in supernovae. Finally, one grain is strongly ^{17}O-enriched with ~solar $^{18}O/^{16}O$ and can be considered an 'extreme group 1' grain (i.e., $^{17}O/^{16}O$ ratios > ~4 x 10^{-3}). Dredge-up in red giant or AGB stars cannot account for these grains and origins in binary star systems, in which the very high $^{17}O/^{16}O$ ratios expected from a nova explosion are diluted through mixing with material from a main sequence star [e.g., 10], have been suggested [9]. However, models with new reaction rates show large discrepancies with the grain data and require extensive mixing with solar system composition material in order to match the isotopic compositions of the grains [11]. Thus, the stellar origins of these 'extreme' group 1 grains remain ambiguous.

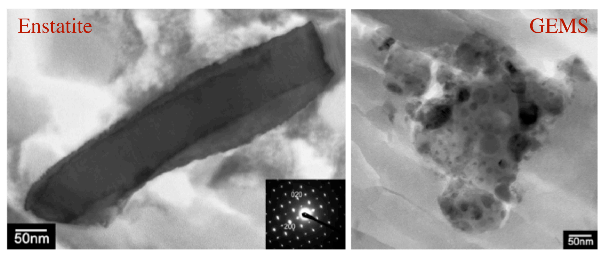

Figure 1. Enstatite platelet (left) and GEMS (right) in TT54B397.

Discussion: The presence of GEMS and enstatite whiskers in TT54B397, as well as several other micrometeorites [12], suggests a close link between these AMMs and anhydrous IDPs, and shows that fragile particles like these can reach the Earth's surface. TT54B397 has an O-anomalous presolar grain abundance of 135 ± 50 ppm, similar to the abundances seen in several primitive meteorites [e.g., 13, 14], although lower than in IDPs [15]. High presolar grain abundances are associated with N isotopic anomalies in some extraterrestrial samples, including IDPs, CR chondrites and at least one AMM [15-17]. The organic matter in these samples typically contains both H and N isotopic anomalies, although they are usually not spatially correlated [7, 15]. Enrichments in ^{15}N have been attributed to low-temperature reactions in the interstellar medium, largely because there is a lack of evidence for a nucleosynthetic origin and because of the association with D enrichments, which are also attributed to interstellar chemistry [e.g., 6].

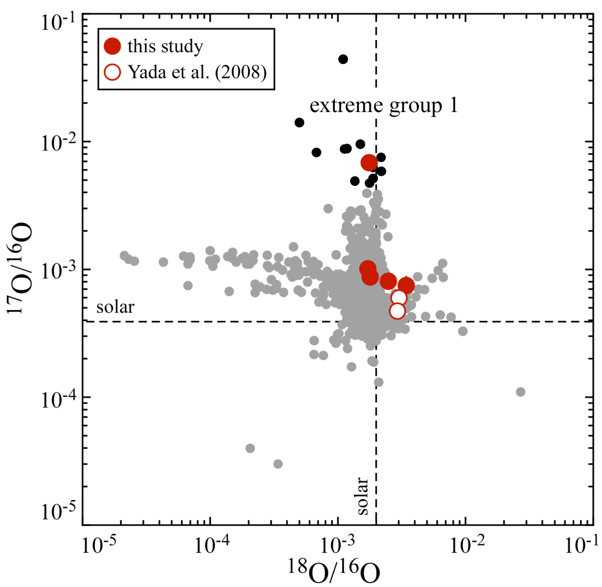

Figure 2. Oxygen three-isotope plot showing O-anomalous grains in TT54B397. Other data (black and grey) are from the presolar grain database (http://presolar.wustl.edu/~pgd).

TT54B397 contains high presolar grain abundances, but N isotopic compositions are normal in all the slices we analyzed, with an average $^{14}N/^{15}N$ ratio of 276 ± 4 (terrestrial $^{14}N/^{15}N$ = 272). Hydrogen isotopes have not been measured in this work, but the study of [5] shows the presence of large D enrichments in two UCAMMs; N isotopes were not measured in that study. Although D anomalies have commonly been attributed to low-temperature ion-molecule reactions in interstellar environments, [5] advocated a solar system origin for these UCAMMs, based on association of the carbonaceous matter with crystalline minerals that are unlikely to have been abundant in the interstellar medium. The D enrichments may have resulted from exchange with a local gaseous D-rich reservoir [e.g., 18].

Recent work on samples from the Genesis mission has shown that the sun is isotopically light in N compared to the Earth and other terrestrial planets [19]. Although an interstellar component enriched in ^{15}N may indeed be present in N-anomalous primitive extraterrestrial materials, it is unlikely that ^{15}N-rich interstellar matter alone can account for the lower-than-solar $^{14}N/^{15}N$ compositions of the inner planets. Large-scale N isotopic fractionations in the protosolar nebula, whether via ion-molecule reactions or some other chemical process [20], are probably required to account for the variations seen in the solar system.

Raman investigation of the UCAMMs of [5], showed that the carbonaceous matter in these micrometeorites is highly disordered, like that found in other primitive meteorites [21], indicating little thermal processing. The presence of abundant presolar grains in TT54B397 indicates that it is also quite primitive and has probably experienced little alteration. The lack of N isotopic anomalies in its carbonaceous matter is therefore unlikely to be due to secondary processing, and probably reflects formation from a N isotopic reservoir similar to that from which the terrestrial planets accreted. If all UCAMMs have a common origin, this isotopically normal (e.g., terrestrial) N composition, coupled with the presence of D enrichments, may further support a solar system, rather than interstellar, origin for the carbonaceous matter in these micrometeorites. In this regard, we note that crystalline silicates are also present in TT54B397. Moreover, if the difference in N isotopic compositions between the carbonaceous matter in TT54B397 and that of the CR chondrites and primitive IDPs is not due to alteration of a common precursor, the insoluble organic matter in primitive extraterrestrial samples must have formed in multiple reservoirs with distinct N isotopic compositions; these could include both interstellar and nebular sources. We plan to carry out additional isotopic measurements of both N and H on the remaining potted butt of TT54B397 in order to further constrain the origin of this micrometeorite.

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