PRESOLAR MATERIALS AND NITROGEN ISOTOPE ANOMALIES IN THE UNIQUE CARBONACEOUS CHONDRITE MILLER RANGE 07687. J. Davidson\textsuperscript{1,}, L. R. Nittler\textsuperscript{1}, C. M. O’D. Alexander\textsuperscript{1} and R. M. Stroud\textsuperscript{2}, \textsuperscript{1}Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015, \textsuperscript{2}Naval Research Laboratory Code 6366, 4555 Overlook Ave. SW, Washington, DC 20375. *E-mail: jdavidson@dtm.ciw.edu.

Introduction: Presolar grains are particularly abundant in pristine extraterrestrial materials such as interplanetary dust particles [e.g., 1,2] and in the matrices of the most primitive chondrites [e.g., 3–7]. They are sensitive indicators of nebular and parent-body processes. With the exception of nanodiamonds, whose origins are ambiguous, presolar silicates are the most abundant type of presolar grain and have been reported in high abundance in a number of primitive chondrites, including the CO3s Allan Hills (ALHA) 77307 [3] and Dominion Range (DOM) 08006 [4]. Here we report the results of a NanoSIMS ion imaging study of the Antarctic carbonaceous chondrite Miller Range (MIL) 07687, which was originally classified as a CO3 [8] but may be ungrouped [9]. High presolar silicate abundances (both O- and C-anomalous) indicate that this chondrite is of very low petrographic type, in agreement with petrographic observations [10].

Experimental: Areas of matrix in a thin section were identified in scanning electron microscope images and analyzed by isotopic imaging with a Cameca NanoSIMS 50L ion probe. A ~2 pA Cs\textsuperscript+ primary ion beam was used to image 10×10 µm\textsuperscript2 areas with a spatial resolution of ~150 nm. Two sets of measurements were performed: (i) to locate O- and C-anomalous presolar grains (\textsuperscript{16,17,18}O, \textsuperscript{12,13,14}C, \textsuperscript{28}Si, \textsuperscript{27}Al\textsuperscript{16}O and secondary electrons), and (ii) to characterize the N isotopic composition of carbonaceous material (\textsuperscript{16,17,18}O, \textsuperscript{12,13,14}C, \textsuperscript{15}N, \textsuperscript{12,13,14}C/\textsuperscript{15}N, \textsuperscript{28}Si and secondary electrons). It was possible to identify \textsuperscript{15}O-anomalous presolar grains in the second set of measurements – these grains were then re-analyzed for all three O-isotopes.

Petrographic Description: MIL 07687 is very terrestrially weathered: it possesses an oxidation rind, exhibits a polygonally fractured interior and exterior, the matrix contains abundant evaporite minerals, and chondrules appear to be rust colored [8]. MIL 07687 contains abundant small (<1 mm diameter) chondrules, chondrule fragments and mineral grains in an optically dark matrix [8]. Olivine is unequilibrated; compositions range from Fa\textsubscript{1} to Fa\textsubscript{90} [8]. MIL 07687 is unique in that it exhibits an unusual type of aqueous alteration that appears to be partial and localized, resulting in two apparent matrix lithologies (not to be confused with terrestrial alteration) [9]. The most altered matrix regions (either by parent body or terrestrial alteration) were avoided during analyses. On the basis of the Cr content of ferroan olivine [e.g., 11], MIL 07687 appears to have an estimated subtype of 3.00, similar to that of Acfer 094 (3.0), these results are presented in a companion abstract [10].

Results and Discussion: A fine-grained matrix area of ~14,500 µm\textsuperscript2 was analyzed for O-isotopes in two areas separated by several mm (Areas 4 and 5). Nineteen presolar O-anomalous and 16 presolar SiC grains were identified (Table 1). A further matrix area, A4 (N), of ~6,500 µm\textsuperscript2 (adjacent to Area 4) was analyzed for N isotopes (O-anomalous grains were also identified). Numerous regions with anomalous N-isotopic compositions were identified alongside a further 10 presolar O-anomalous and four SiC grains.

\textit{C-anomalous grains.} The diameters of the 20 presolar SiC grains range from ~200 to 460 nm. Other C-anomalies (not associated with Si) were also present.

\textit{O-anomalous grains.} The 29 identified O-anomalous grains have O-isotopic compositions (Fig. 1) similar to those previously reported [12]. They range in diameter from 260 to 470 nm. For the 19 grains identified in the first set of measurements it was possible to determine the silicate versus oxide nature of the grains based on their AlO/O ratios. Four appear to be Group 1 oxides and 15 are silicates (from Groups 1, 2 and 4), yielding a silicate/oxide ratio of ~5.

![Figure 1: O-isotopic ratios of presolar silicate and oxide grains from MIL 07687 (arrow indicates Group 4 grain from Fig. 2) compared to those of previously reported presolar O-anomalous grains [12]. Errors are 1σ.](image-url)
Presolar grain abundances. The abundances of presolar O-anomalous (i.e., silicate + oxide) and SiC grains were determined by dividing the total areas of the identified grains by the total areas of analyzed matrix (Table 1). The O-anomalous grain abundance from A4 (N) is corrected as only $^{16}$O and $^{17}$O O-isotopes were analyzed. Therefore, presolar grains in A4 (N) that exhibited $^{18}$O enrichments or depletions but had isotopically normal $^{17}$O could not be detected. Using results from the areas analyzed for all three O-isotopes, we calculated that these “missing” grains would account for $\sim$12% of all grains, and adjusted the A4 (N) abundance accordingly (from 126 to 141 ppm). In order to compare with previous data, our abundances are not corrected for the effects of beam broadening [e.g., 4]. Presolar O-anomalous grain abundances for MIL 07687 varied somewhat between areas (86, 140, 141 ppm), with an overall abundance of 124 ppm (Table 1) that is similar to, or slightly lower than, abundances determined for other primitive chondrites, such as CO3 ALHA 77307 (190 ppm [3]), the CR chondrites (75–220 ppm [3, 5, 13]), the ungrouped chondrites Acfer 094 (145–190 ppm [6, 14]) and Ningjiang (140 ppm [7]), but is significantly lower than that of DOM 08006 (338 ppm [4]).

Table 1. Abundances of presolar grains for the different areas of matrix analyzed in MIL 07687.

<table>
<thead>
<tr>
<th>Matrix area</th>
<th>Number of images</th>
<th>Total area</th>
<th># grains</th>
<th>Abundances (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area 4</td>
<td>69</td>
<td>6247</td>
<td>8 6</td>
<td>97 86</td>
</tr>
<tr>
<td>Area 5</td>
<td>91</td>
<td>8281</td>
<td>8 13</td>
<td>58 140</td>
</tr>
<tr>
<td>A4 (N)</td>
<td>71</td>
<td>6462</td>
<td>4 10</td>
<td>37 141</td>
</tr>
<tr>
<td>Total</td>
<td>231</td>
<td>20990</td>
<td>20 29</td>
<td>63 124</td>
</tr>
</tbody>
</table>

A presolar SiC abundance of 63±17 ppm (20 grains; errors based on counting statistics [15]) agrees with those reported in other primitive chondrites [16], including DOM 08006 (16 grains; 40±13 ppm [4]).

Presolar grain abundances were not corrected for the altered matrix regions where it is expected that presolar silicates will be progressively destroyed. As MIL 07687 is extremely terrestrially weathered, it is not possible to accurately determine which regions were altered in the parent body and which were altered terrestrial without further analysis. Regardless, we do not expect SiC abundances to be significantly affected as SiC grains are known to survive low-temperature parent body alteration and terrestrial weathering [16].

Isotopically anomalous matter. Abundant carbonaceous regions with anomalous N-isotopic compositions were seen with $\delta^{15}$N values of up to $\sim$2,000 ‰. One N-anomalous region (~700 nm in diameter; $\delta^{15}$N = 804±22 ‰) is adjacent to a Group 4 presolar silicate grain ($\delta^{17}$O = 773±120 ‰; $\delta^{18}$O = 754±54 ‰), and clearly warrants further investigation (Fig. 2).

Fig. 2. (a–c) NanoSIMS isotopic ratio maps and (d) a secondary electron image of a region containing a Group 4 presolar silicate (indicated by arrow in c and d) and an adjacent isotopically anomalous region in MIL 07687. All scale bars are 500 nm.

Summary: Although it is very terrestrially weathered, the high presolar grain abundances and the presence of $^{15}$N anomalous carbonaceous material in MIL 07687 indicate that it is a very primitive unequilibrated chondrite, in agreement with the Cr$_2$O$_3$ content of its ferroan olivine [10].

Acknowledgements: The authors thank K. Crispin for assistance with the FE-SEM. This work was funded by NASA grants NNX10AI63G and NNX11AB40G (PI: LRN), and NNX11AG67G (PI: CMODA).