**COMPLEMENTARY CARBON, NITROGEN AND OXYGEN ISOTOPIC IMAGING OF INTERPLANETARY DUST PARTICLES: PRESOLAR GRAINS AND AN INDICATION OF A CARBON ISOTOPIC ANOMALY.** C. Floss[1,2] and F. J. Stadermann[1,3]. [1]Laboratory for Space Sciences [2]Dept. of Earth and Planetary Sciences [3]Physics Dept., Washington University, St. Louis, MO 63130, USA.

**Introduction:** Interplanetary dust particles (IDPs) are composed of a variety of primitive materials and are the repositories of various isotopic anomalies. They are well known to exhibit enrichments of deuterium (D) and $^{15}$N [*e.g.*, 1-3], although the two types of isotopic anomalies do not appear to be directly correlated. The enrichments are generally thought to be carried by organic compounds [4-6], but C isotopic measurements of IDPs have thus far shown no clear evidence for anomalous C compositions [3,7,8]. Recently, silicate grains with extremely anomalous O isotopic compositions, indicating a presolar origin, have also been reported from IDPs [9,10].

We are carrying out complementary isotopic imaging measurements (*c.f.*, H, C, N, O) on a suite of IDPs using the NanoSIMS at Washington University. This work is part of a larger effort to survey the isotopic microdistributions of IDPs and Renazzo matrix, in order to compare and clarify the origins of such anomalies in both types of primitive materials [*e.g.*, 7,11,12]. Here we focus on the C, N and O isotopic systematics of two unusual IDPs.

**Experimental Procedures:** We have so far measured the C and N isotopes in 14 cluster and 11 non-cluster IDPs from collectors L2009, L2011 and L2036, and have measured the O isotopes in a subset of eight of these. The measurements are made in raster imaging mode, in which a $Cs^+$ beam is scanned over the sample surface and secondary ions are collected simultaneously at high mass resolution. Details of the measurement procedure for C and N imaging are given by [2,7]. The procedure for oxygen isotopic measurements is similar, with the measured species being $^{16}O^-$, $^{17}O^-$, $^{18}O^-$, $^{28}Si^-$ and $^{24}Mg^{16}O^-$. Particular care is taken to ensure complete separation of the $^{17}$O peak from the isobaric $^{16}$OH peak at high mass resolution. Results are calibrated to isotopic standards measured along with the samples. Each analysis consists of 15 to 40 scans, which, added together, constitute a single image measurement. Thus, observed isotopic anomalies can be verified through the different layers of the image.

**Results:** Nitrogen isotopic variations are generally similar to those previously observed [2,3,7]. Most IDPs have normal bulk N compositions but may contain discrete 'hotspots' that are enriched to varying degrees in $^{15}$N. Carbon isotopes are normal in all of the IDPs, with one exception discussed below. Oxygen isotopes are also normal in the bulk IDPs, but we report below the discovery of two sub-grains with significant $^{17}$O enrichments.

*IDP 'Kipling' (L2011-R12):* Last year we reported on the C and N isotopic compositions of this non-cluster IDP [7]. Carbon isotopic compositions are normal, but the bulk of the IDP is enriched in $^{15}$N, with an average $\delta^{15}$N value of +510‰. We also observed two hotspots in the center of the IDP with enriched $^{15}$N ($\delta^{15}$N = +1090‰ and +1250‰). We have now measured the O isotopes in this IDP and find a discrete sub-grain that is strongly enriched in $^{17}$O (Fig. 1). The grain, which is not associated with the $^{15}$N-rich hotspots, is about 350 by 500 nm$^2$ in size and has a $^{17}$O/$^{16}$O ratio of 0.00081 (solar value 0.00038 [13]) and normal $^{18}$O/$^{16}$O. Figure 1 compares the isotopic composition of this grain with those of similarly sized sub-regions from the rest of the IDP, clearly demonstrating its anomalous isotopic composition.

*IDP 'Benavente' (L2036-G16):* Like Kipling, the bulk N isotopic composition of this non-cluster IDP is enriched in $^{15}$N, although the degree of enrichment

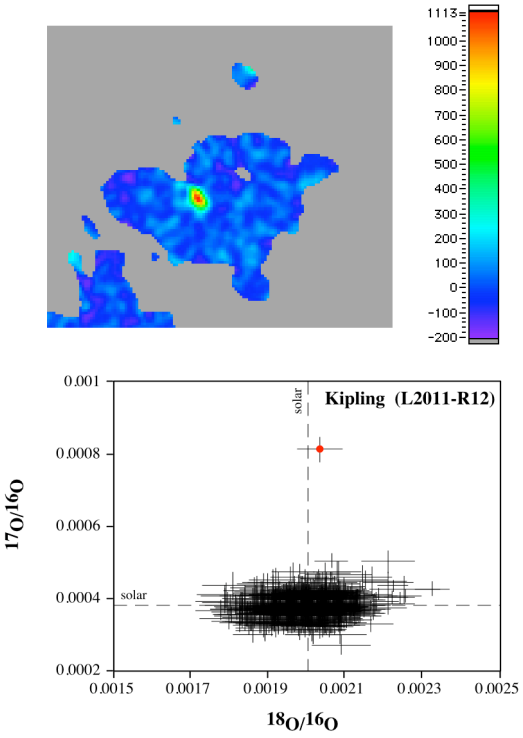


*Figure 1. Top: $\delta^{17}$O image of part of Kipling, showing the $^{17}$O-rich sub-grain. Field of view = 8 μm. Bottom: isotopic composition of the grain compared with similarly sized sub-regions of Kipling. Errors are 1σ.*

is less ($\delta^{15}N$ = +230‰). Benavente also contains a fairly large (0.6 x 1.8 μm$^2$) $^{15}N$-rich hotspot ($\delta^{15}N$ = +1280‰, similar to the most anomalous hotspot previously observed, see above and [7]). Of particular interest is that the same area appears to be depleted in $^{13}C$. This is illustrated in Fig. 2, which compares the C and N isotopic composition of the hotspot with the compositions of similarly sized regions from the rest of the IDP. The deviation from normal C is not large ($\delta^{13}C$ = –75‰), but two factors lead us to believe it is significant. First is the fact that the region is relatively large and is spatially associated with the N hotspot. Second, unlike other small C isotopic variations sometimes observed in IDPs, this anomaly is consistently present in all 20 layers of the image.

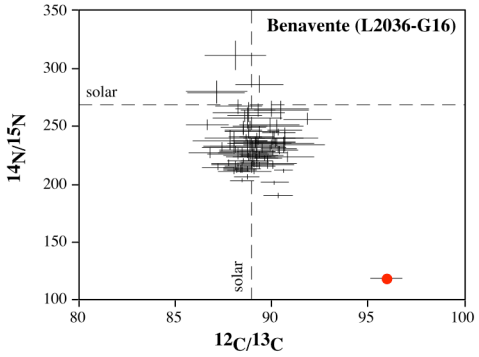


*Figure 2. Isotopic composition of hotspot compared with similarly-sized regions of Benavente. Errors are 1σ and for $^{14}N/^{15}N$ of the hotspot are smaller than the symbol. Note the unusually large spread of N isotopic compositions in the 'bulk' of the particle.*

Oxygen isotopic imaging shows that Benavente also contains a small (300 x 300 nm$^2$) grain with $^{17}O$ enrichment (Fig. 3). As in Kipling, this grain is not associated with the $^{15}N$-rich hotspot in this IDP. The grain has a $^{17}O/^{16}O$ ratio of 0.00093 and normal $^{18}O/^{16}O$, again clearly distinct from sub-regions of similar size in the surrounding IDP (Fig. 3).

**Discussion:** The two $^{17}O$-enriched grains are clearly presolar, with isotopic compositions similar to those of several presolar silicates reported by [10]. Elevated $^{17}O/^{16}O$ ratios and solar to moderately depleted $^{18}O/^{16}O$ ratios are characteristic of Group 1 presolar oxide grains [14] and are consistent with an origin in red giant and asymptotic giant branch stars.

McKeegan [15] noted possible depletions in $^{13}C$ in several IDPs (albeit with large errors), but this is the first indication of a C isotopic anomaly in an IDP in association with a $^{15}N$ enrichment. Although the $^{13}C$ depletion occurs in the same region of the IDP as the $^{15}N$ enrichment, there are minor differences in the detailed spatial distributions of the isotopic anomalies. This suggests that the anomalies may have been produced by different processes, and/or may be hosted by distinct carrier phases.

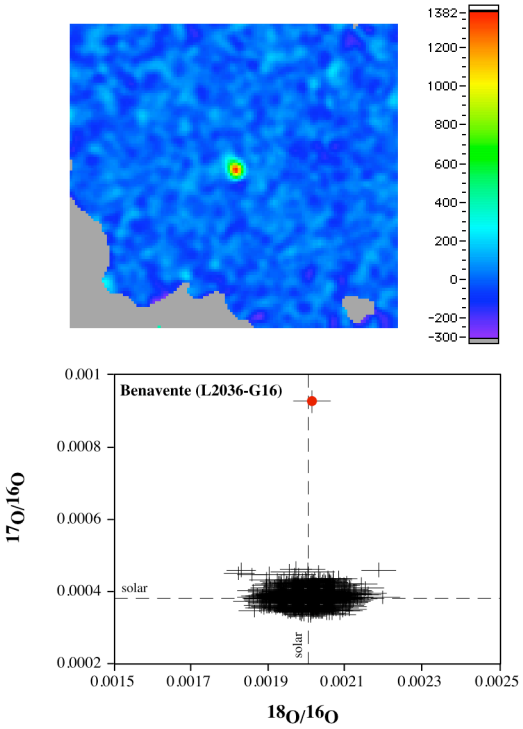


*Figure 3. Top: $\delta^{17}O$ image of part of Benavente, showing the $^{17}O$-rich sub-grain. Field of view = 9 μm. Bottom: isotopic composition of the grain compared with similarly sized sub-regions of Benavente. Errors are 1σ.*

Finally, we note that both of these presolar grains, as well as the $^{15}N$ hotspots, which are the largest observed to date in IDPs, have been found in particles that exhibit bulk enrichments of $^{15}N$. These IDPs may have experienced less secondary processing than others with normal bulk N isotopic compositions and, thus, have retained more primitive isotopic characteristics. The H isotopic composition of Kipling is D-enriched ($\delta D$ = +470 to +950 ‰), but not to the extreme levels observed in fragments of some IDPs [1]. Hydrogen isotopic measurements of Benavente are planned.

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