NANOSIMS MEASUREMENTS OF NITROGEN ISOTOPIC DISTRIBUTIONS IN IDPs AND RENAZZO: UNIFORM ^{15}N ENRICHMENT IN A CHONDRITIC IDP. 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) and primitive meteorites are well known to exhibit enrichments of deuterium and ^{15}N [1], although the two types of isotopic anomalies are generally not directly related. The carrier phases of these anomalies are poorly characterized. Organic compounds are clearly the source of many of the D and ^{15}N enrichments [2-4], but other carriers are also implicated [5-7]. Furthermore, it remains unclear whether or not the carriers are the same in both types of extraterrestrial materials. To address this question, we have been carrying out heating experiments on matrix material from Renazzo [8, 9], a CR chondrite which contains enrichments of both D and ^{15}N [10]. These experiments will later be extended to IDPs and other primitive meteorites.

As a part of this effort, we are also using the high spatial resolution of the new NanoSIMS at Washington University [11] to survey and compare the microdistributions of D, C and N isotopic compositions in various IDPs and fragments of Renazzo matrix material. Here we report the first results of this phase of our work.

Experimental Procedures: We measured the C and N isotopic compositions of 15 IDPs and five Renazzo matrix fragments. The IDPs come from stratospheric collectors L2009, L2011 and L2036. Most of the IDPs have previously been measured for H isotopes in our ims 3f ion microprobe using standard procedures [12], and have δD_{SMOW} values ranging between −512‰ and +3600‰ (unpubl. data). All samples are mounted on high-purity Au foil together with various isotopic standards.

The NanoSIMS measurements were made in a raster imaging mode in which a Cs^+ beam (~100 nm in diameter) is scanned over the sample surface. Details of the procedure are given by [13]. The acquired secondary ion images ranged in size from 5 x 5 μm^2 to 35 x 35 μm^2, depending on the size of the particle being analyzed. In each measurement five different species ($^{12}C^-$, $^{13}C^-$, $^{12}C^{14}N^-$, $^{12}C^{15}N^-$ and $^{28}Si^-$) were collected simultaneously at a mass resolution high enough to resolve interferences from neighboring peaks. Secondary electron images of the particles were also acquired during each analysis. Results are calibrated to isotopic standards measured along with the samples.

Each measurement was made as a series of 15 to 40 scans or layers which were subsequently added together to constitute a single image measurement. This procedure avoids potential data loss problems caused by the artificial limit of 2^{16} counts/pixel set by the counting system of the NanoSIMS [13]. It has the additional advantage that observed isotopic "hotspots" can be traced through the different layers to verify that their presence is not simply due to statistical variations.

Results and Discussion: Consistent with previous results [1, 10, 13] we find that both IDPs and Renazzo matrix fragments have essentially normal C isotopic compositions. Nitrogen isotopic compositions exhibit greater variability.

IDPs: Among the IDPs measured, several contain fragments or discrete sub-grains that are enriched in ^{15}N. The grains range in size from ≤ 0.5 μm to 3 μm and have δ^{15}N values between +230‰ and +600‰, similar to earlier results [1, 13]. One IDP (L2036-c17-E2), nicknamed Eucken, which contains the most deuterium-depleted H isotopic composition recorded to date (δD_{SMOW} = −512‰) unfortunately did not contain enough C or N to make meaningful isotopic measurements. The most interesting result from the N isotopic measurements on IDPs comes from a particle labeled Kipling (L2011-R12).

Kipling is a chondritic IDP, originally 12 μm in diameter. After crushing into the Au foil, its dimensions measured approximately 30 x 30 μm^2. In contrast to the very localized ^{15}N enrichments noted in some of the IDPs discussed here, Kipling is dominated by heavy N. Figure 1 shows the N isotopic composition of Kipling in terms of δ^{15}N. The particle appears non-contiguous in the image because some portions have either been sputtered away or have very low CN^- signals.

Much of the IDP is uniformly enriched in ^{15}N, shown by the green areas in Fig. 1. An overall average of these regions has a δ^{15}N value of +510‰. In contrast, the small region in the upper right portion of Fig. 1 shows two particles with normal N (average δ^{15}N = +23‰). These grains appear to be some type of contaminant in the original BSE image of the area. Finally, two discrete sub-grains in the center of Kipling have strongly enriched ^{15}N, with δ^{15}N values of +1090‰ and +1250‰, respectively. The "hotspots" can be traced through all 20 layers of the image. These are the highest ^{15}N enrichments observed in IDPs to date. Both sub-grains, and the whole IDP, have normal C isotopic compositions.
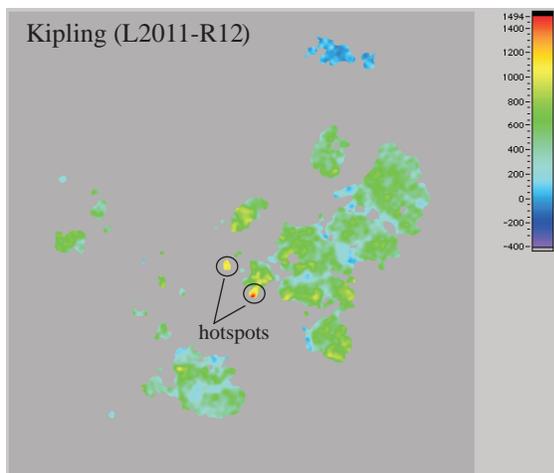
Figure 1. Image (35 x 35 μm^2) of $\delta^{15}N$ in Kipling.

Renazzo: We measured five fragments of matrix material from Renazzo for comparison with the IDP data. In most of the fragments, N appears to be concentrated in discrete regions or sub-grains, in contrast to C and Si abundances which are more uniform over the fragments' areas. Many of these N-rich regions have light enrichments of ^{15}N on the order of +100‰ to +400‰, consistent with previous results [10]. One fragment also contains a grain with a distinctly larger ^{15}N enrichment of +940‰, similar to the highest $\delta^{15}N$ value measured by [10]. Finally, one matrix fragment contains two distinct regions with different N isotopic compositions (Fig. 2). Areas shown in light green in Fig. 2 have high N abundances and normal N isotopic compositions (average $\delta^{15}N$ = +20‰). In contrast, a large region in the center of the fragment (darker green to yellow in Fig. 2) has lower N abundances and isotopically heavy N (average $\delta^{15}N$ = +230‰). Preliminary examination of the fragment suggests compositional differences between the two areas, but detailed study will be required to determine their exact nature.

Origin of N Anomalies: Deuterium enrichments in IDPs are generally attributed to low-temperature chemical processes occurring in the interstellar medium [14]. Similar processes have been invoked to account for the ^{15}N enrichments in IDPs and primitive meteorites [e.g., 1] although much smaller fractionation effects are expected. Indeed, a recent study by [15], investigating the possibility of producing N isotopic fractionations from ion-molecule reactions involving various N-bearing species in interstellar clouds found that fractionations are generally small and cannot account for ^{15}N enrichments on the order of 500‰ or more, such as those observed here in Kipling, and in other IDPs [13, 16]. Most recently, however, calculations of

gas-grain fractionations suggest that much higher ^{15}N enrichments may be obtained in dense molecular clouds where O/C-bearing molecules are removed from the gas [17]. Such a mechanism may account for the high $\delta^{15}N$ values observed in the Kipling "hotspots" (Fig. 1).

Conclusions: In contrast to most ^{15}N enrichments in IDPs which appear to occur as discrete "hotspots", we find that the IDP Kipling is dominated by heavy N. It also contains two sub-grains with the highest ^{15}N enrichments observed to date in an IDP. Renazzo matrix fragments appear to have smaller ^{15}N enrichments than those in IDPs, but they seem to be more consistently enriched. Different carrier phases or more extensive parent body processing in Renazzo than in the IDPs may account for the differences. We are presently investigating the phases associated with the N enrichments in both types of materials.

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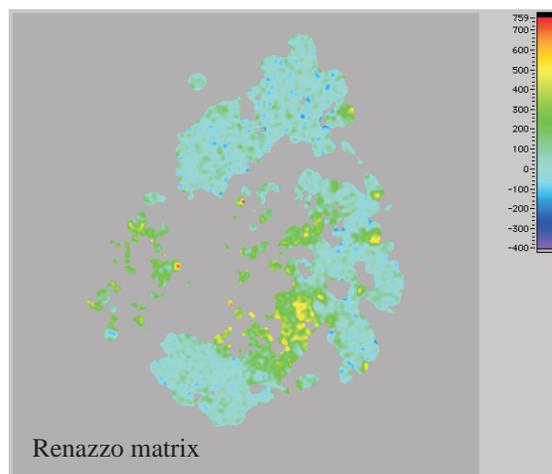

Figure 2. Image (25 x 25 μm^2) of $\delta^{15}N$ in Renazzo.