INTERSTELLAR COMPONENTS IN THE PRIMITIVE CR3 CHONDRITES QUE 99177 AND MET 00426. C. Floss and F. J. Stadermann. Laboratory for Space Sciences and Physics Dept., Washington University, St. Louis, MO 63130, USA. (Email: floss@wustl.edu; fjs@wustl.edu)

Introduction: Presolar material incorporated into primitive solar system bodies consists of both circumstellar stardust formed in the outflows of RG or AGB stars and the ejecta of supernovae [1], and interstellar material thought to form via low temperature ion-molecule reactions in cold molecular clouds [2]. Deuterium and N isotopic anomalies associated with the latter are common in interplanetary dust particles (IDPs) [3] and in various primitive meteorites, notably the CR chondrites [4]. Carbon isotopic anomalies are less common, but have also been observed [5, 6].

QUE 99177 and MET 00426 are CR3 chondrites that have experienced little aqueous alteration compared to other members of this meteorite group [7]. The carbonaceous matter in these meteorites exhibits a low degree of crystallinity and contains detectable amounts of N, indicating that this material has not experienced significant thermal processing [8]. Both also contain high abundances of O-anomalous and C-anomalous grains [9, 10], consistent with their primitive natures. Here we report on the N isotopic distributions of these two meteorites.

Experimental: N and C isotopes were measured together ($^{12}C^-$, $^{13}C^-$, $^{12}C^{14}N^-$, $^{12}C^{15}N^-$, $^{28}Si^-$) in matrix material from thin sections of QUE 99177 and MET 00426 using the NanoSIMS at Washington University. Individual areas of 10 x 10 μm^2 were mapped, with total analysis areas of 7300 μm^2 and 7100 μm^2 for QUE 99177 and MET 00426, respectively. Nitrogen isotopic compositions were normalized to a synthetic Si_3N_4 standard.

Results: Like other CR chondrites, both QUE 99177 and MET 00426 contain abundant N isotopic anomalies. As has been observed previously in IDPs and other primitive meteorites, the anomalies are present both as discrete localized hotspots and as larger, more diffuse regions. Average N isotopic compositions in 10 x 10 μm^2 areas of matrix material are enriched in ^{15}N, with $\delta^{15}N$ up to ~500 ‰; the mean N isotopic composition of all measured areas in QUE 99177 is somewhat more anomalous than that in MET 00426 ($^{14}N/^{15}N$ = 229 ± 16 vs. 248 ± 22). Individual ^{15}N-rich hotspots have $\delta^{15}N$ up to ~2500 ‰; some ^{15}N-depleted hotspots were also observed (Fig. 1). The average matrix area values are similar to those seen in isotopically primitive IDPs [3], but maximum ^{15}N enrichments in the hotspots are higher than in IDPs and are similar to those reported for insoluble organic matter from primitive meteorites [4]. The ^{15}N enrichments in QUE 99177 and MET 00426 are also higher than those observed in the CR chondrite Renazzo, which has hotspots with $\delta^{15}N$ up to ~800 ‰ and average matrix values on the order of 200 ‰ [11].

The N isotopic anomalies reported here are generally not accompanied by C isotopic anomalies. However, both QUE 99177 and MET 00426 do contain abundant C-anomalous phases [10]. While many of these are circumstellar SiC grains, both meteorites also contain high abundances (~120 ppm) of carbonaceous grains with anomalous C isotopic compositions that likely have an interstellar origin. Many of these grains have isotopically anomalous N, including a distinct subset with ^{15}N enrichments similar to those observed here [10].

Discussion: The N isotopic anomalies observed in QUE 99177 and MET 00426 are consistent with bulk N isotopic compositions of macromolecular organic matter from these meteorites, which exhibit ^{15}N enrichments on the order of 175–190 ‰ [12]. Less anomalous compositions are observed in Renazzo, but this may be due to the aqueous alteration experienced by this meteorite; laboratory alteration experiments have shown that labile ^{15}N-enriched organic matter is easily removed during aqueous processing [13].

We have not yet identified the nature of the N-anomalous hotspots from this study. However, based on the NanoSIMS ion images, at least some of them appear similar to organic nanoglobules recently identified in Tagish Lake and Bells [14, 15]. In addition, the first reported C-anomalous nanoglobule has been found in MET 00426 [10]. However, other N-anomalous areas in these meteorites have different characteristics: some have low C abundances and others are depleted in ^{15}N, unlike the nanoglobules reported by [14, 15].

Theoretical studies of low temperature interstellar chemistry show that ^{15}N enhancements can be produced through ion–molecule exchange reactions involving common N-bearing species in interstellar clouds. Early work suggested enrichments on the order of 250 ‰ [16], significantly less than the maximum enrichments observed in IDPs and primitive meteorites. However, more recent work focusing on NH_3 formation in dense molecular clouds [17] indicates that enrichments of more than 3000 ‰ are possible at very low temperatures (T < 10K). These values are sufficient to account for the ^{15}N-rich hotspots observed here and in the IOM from other meteorites [4].

The origin of interstellar carbonaceous matter with C isotopic anomalies is more complex. Gas-phase reactions are also expected to produce C isotopic fractionations, but different processes produce competing fractionations [18-20]. Indeed, the existence of multiple reaction pathways, which might cancel out any anomalies produced, has been suggested as one possible reason for the relative scarcity of C isotopic anomalies in primitive extraterrestrial materials [20, 21]. The fact that both ^{13}C-enriched and ^{13}C-depleted grains are found in QUE 99177 and MET 00426 indicates that a variety of reactions do contribute to the formation of interstellar carbonaceous matter. However, the high abundance of such grains in these meteorites suggests that secondary processes are responsible for the absence of these grains from other samples [10]. Finally, because ^{15}N-rich hotspots without associated C isotopic anomalies are common in QUE 99177 and MET 00426, as they are in other extraterrestrial materials, reactions that do not strongly fractionate ^{12}C from ^{13}C must also be important in low temperature interstellar chemistry. Indeed, there is evidence that fractionations for some carbon species are highly sensitive to the physical conditions present and that some reactions produce little isotopic fractionation [19].

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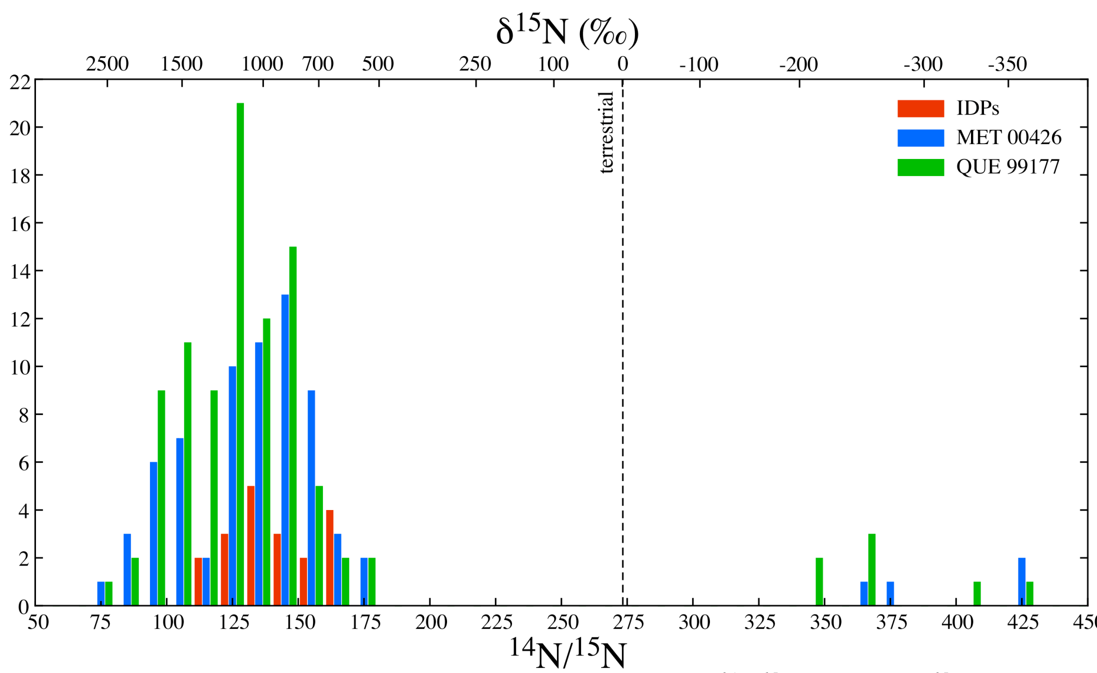

Figure 1. Distribution of N isotopic compositions (scale shows both $^{14}N/^{15}N$ ratios and $\delta^{15}N$) in isotopically anomalous hotspots of QUE 99177 and MET 00426. Also shown are data for primitive IDPs [3].