Nitrogen Sources In IAB/IIICD Iron Meteorites and Their Implications.

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Introduction: Nitrogen isotopic structures were studied by stepwise pyrolysis in IAB/IIICD iron meteorites. These two subgroups cannot be separated on the basis of our results. Isotopic data from one-step melting extractions do not yield unambiguous results because there are N components with distinct isotopic signatures heterogeneously distributed within a given meteorite. To explain the existence of these multiple N sources, models of incomplete homogenization of pre-accumulation signatures in several carriers and/or of diffusion-fractionated components need to be considered.

Experimental: We have analyzed replicate samples of eight IAB/IIICD iron meteorites for the N and Xe concentration and signature using techniques previously described.[1] In brief, these samples were treated with 1.0 N HCl and concentrated HF in sequential steps at room temperature in an ultrasonic bath, followed by cleaning steps in water, and then, in acetone/methanol. Samples were stored under ethanol until ready for loading. Two additional samples of Odessa were cleaned by mechanical means only and are compared with the acid-etched Odessa samples. Gases were released by pyrolysis at temperatures between 500ºC and 1600°C and analyzed by static mass spectrometry. A resistance quartz furnace was used in steps up to 1000°C and a radio frequency furnace fitted with a Mo crucible was used for steps up to 1600°C. There is sometimes significant gas release below 1200°C, but as we are primarily interested in the metal phase signature, we discuss only the high temperature results (1200°C-1550°C).

Results and Discussion: Replicate samples of the bulk metal phase for a given IAB/IIICD meteorite display variable N contents and isotopic signatures as shown in Figure 1. Acid has removed some of the inclusions, but Figure 1 shows that there are still multiple sources of N present, as this clean up removed only those inclusions in contact with the surface. Furthermore, some inclusions, such as graphites and nitrides, should be acid-resistant.

The Xe data can be used to trace the presence of inclusions like silicates. For a number of analyses, the Xe amounts compare to blanks of the extraction line. However, in one mechanically cleaned sample of Odessa, in one sample of Wichita County, Morasko, and Yardymly, and in both samples of Landes, we observe Xe components with ^{129}Xe excesses. Large ^{129}Xe/^{132}Xe ratios are observed in silicate inclusions of IAB irons [2, 3]. Using our data, we can place limits on the silicate inclusions present (% by wt) as follows: Landes #1, 1.5-4.3.; Landes #2, 1.2-3.4; Wichita County #1, 1.1-3.2; Odessa #3 (mechanically cleaned), 0.73-2.1, Morasko #2, 0.14-0.40 and Yardymly #2, 0.22-0.63. Both samples of Sardis contain significant amounts of Xe components without ^{129}Xe excess, indicative of some other inclusion, such as graphite.

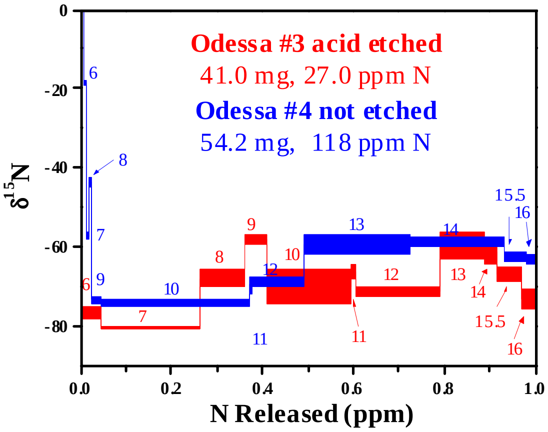

Figure 1 The stepwise pyrolysis of two samples of Odessa (IAB). The δ^{15}N data and release pattern indicate at least two components. Temp. in hundreds of °C.

The N concentration found in the bulk metal phase of IAB/IIICD iron meteorites is much higher than predicted by the solubility of N in Fe,Ni phases under a solar nebular environment [4], suggesting that a N carrier(s) imported the bulk of the N into the meteorite parent body. The data show a dependence of the δ^{15}N signature upon the N concentration (see Figure 2). This dependence suggests that there are at least two N sources, one of which is isotopically light and dominates the other(s).

A major carrier of the larger and isotopically lighter N component is probably the taenite phase. Nitrides could also be reasonable candidates for a major N source, as nitrides have been documented to be present in iron meteorites (roaldite [5, 6] and carlsbergite [7]). Nor does the presence of unidentified nitrides contradict the Xe measurements since small amounts of nitrides (10-100 ppm N) probably carry Xe concentrations below the detection limit.

To account for δ^{15}N dependence that is observed in Figure 2, at least one heavy N carrier is required. We are in the process of evaluating the contributions from spallation $^{15}N_c$ by measuring ^{21}Ne concentrations in aliquot samples, but it is clear that an additional heavy component is needed besides a contribution from spallation. Silicates are reported to have positive signatures in iron meteorites, but we place upper limits on their contribution based on the Xe data. One possible carrier for a heavier N might be graphite. Zipfel et al.[8] reported a range of graphite signatures from -20‰ to -48‰, which is consistent with the required signature of the smaller, isotopically heavier N source. We note that during the last pyrolysis step (1600°C) N might not be released from the graphite unless a source of oxygen is present during heating. In fact, the Mo crucible is being fluxed between samples with quartz pieces to reduce the N blank, so there may be some oxygen present in the system.

It is intriguing to speculate how the various N sources in IAB/IIICD iron meteorites might be related. One obvious scenario is that the N signatures observed in the different phases represent primary carrier signatures, having little to no exchange during parent body evolutionary processes. In this case a large-scale disequilibrium with respect to N signatures is indicated.

Another possible scenario would be the incorporation of a N-rich carrier(s) into the molten, and largely N-poor, metal pool on the parent body. If a system experienced diffusion-fractionation and partial retention, N-rich carrier(s) would become progressively heavier isotopically while the cooling metal incorporated the diffusionally fractionated, isotopically lighter gas. Model estimates for the change in the isotopic signature of a degassed N source relative to the signature formed from its lost gas are in keeping with the signatures seen in Figure 2.

Primary graphites and nitrides would be obvious choices for N-rich carriers, although there is no evidence that nitrides in IAB/IIICD iron meteorites have isotopic signatures which are distinct from that in the taenite phase. In fact, the N isotopic data for roaldite in Deport had essentially the same signature as the taenite.[6] This observation supported the assessment that roaldite is a secondary mineral, exsolved from metal.[6] On the other hand, graphites and their surrounding metal phases do have distinct N signatures in IAB/IIICD iron meteorites. The extreme range of N isotopic signatures found in El Taco [8] is consistent with a partially degassed, primary N source carrier.

Obviously, both of these scenarios are extreme end members for a spectrum of models addressing the N origin from carrier phase(s). Work is in progress to constrain the possibilities.

References: [1] Ponganis, K.V. and Marti, K., (1998) *Meteoritics & Planet. Sci.* **33**: A125. **[2]** Niemeyer, S., (1979) *Geochim. Cosmochim. Acta* **43**: 843-860. **[3]** Mathew, K.J. and Begemann, F., (1994) *LPS* **XXV**: 849-850. **[4]** Fegley, B., Jr., (1983) *LPS* **XIII**: 853-868. **[5]** Nielsen, H.P. and Buchwald, V.F., (1981) *LPS* **XII**: 1343-1348. **[6]** Sugiura, N., (1998) *Meteoritics & Planet. Sci.* **33**: 393-409. **[7]** Buchwald, V.F. and Scott, E.R.D., (1971) *Nature (Physical Science)* **233**: 113-114. **[8]** Zipfel, J., *et al.*, (1996) *LPS* **XXVII**:1501-1502.

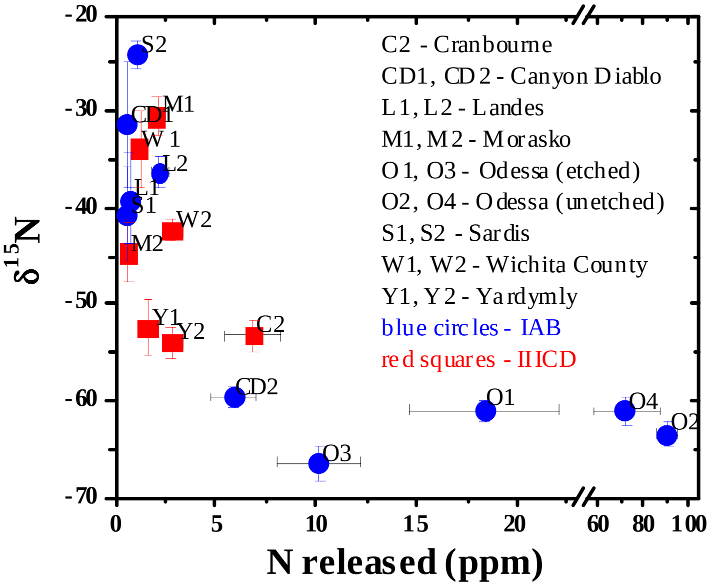

Figure 2. The weighted average of $\delta^{15}N$ for the pyrolysis steps from 1200°C to 1550°C versus the amount of N released in these steps for eight IAB/IIICD iron meteorites.