NEAR-EARTH ASTEROID ORIGIN FOR THE FARMINGTON METEORITE

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We report nitrogen and xenon isotopic signatures in separated metal and non-magnetic phases of a catastrophically degassed L5 chondrite and discuss implications for the collisional event and the impactor.

Introduction: Although the asteroid belt is considered the ultimate source of ordinary chondrites, extremely short CRE ages of chondrites are difficult to reconcile with delivery considerations from this source [1]. It had been noted that shocked L-chondrites with low ^{40}Ar ($<10^{-5}$ cm^{3}STP/g) concentrations and very low ^{4}He tend to have lower exposure ages and that none of these contain solar-type gases. The Farmington (L5) chondrite is known for its extremely short CRE age of 25-30 Ka [2,3]. The orbit of the Farmington parent was reconstructed by Levin et al. [4] as a small orbit of low inclination with perihelion ≥0.4 AU. These authors conclude that the extremely short CRE age implies that the parent object must have been in an Earth-crossing orbit. The records of radiogenic gases in Farmington show that its parent body was severely degassed in a recent collisional event ~500 Ma ago [5,6]. We investigate the nitrogen isotopic signatures for evidence of collisional perturbances, as two distinct nitrogen signatures in metal phases of the Portales Valley chondrite [7] suggested their use as tracers for possible impactors. The short CRE age of the Farmington meteorites does not require consideration of spallation $^{15}N_c$.

Results: The nitrogen signature (Figure 1) of the metal agrees with the uniform signature of metal ($\delta^{15}N$ = -6 ‰) in all L-chondrites studied in this laboratory [8]. We expect uniform signatures in the higher temperature steps (T > 1000°C) as the spallation $^{15}N_c$ component is negligible. However, Fig. 1 shows that contrary to the uniform signature (excepting the small 1200°C release) in the metal, the nonmagnetic separate shows the presence of two distinct components. While the nitrogen signature observed in the high-temperature (T > 1000°C) agree with signatures inferred for indigenous silicates in chondrites ($\delta^{15}N$ = +13 ±2 ‰), the signature in the 800°C and 1000°C steps reveal a major (~60%) distinct component, which may reveal a collisional perturbance. The inferred isotopic signature ($\delta^{15}N$ = -35‰) is novel for chondrites and possibly was associated with the impactor.

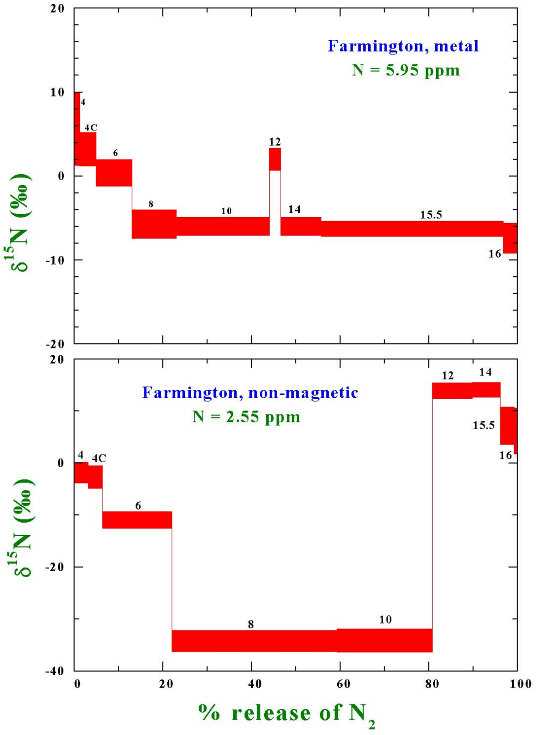

Figure 1. Stepwise release systematics of nitrogen inFarmington, from non-magnetic fraction (lower panel) and a metal separate (upper panel). The 1200° and 1400°C steps (lower panel) release chondritic silicate N, but the T < 1000°C steps release light N which is not known in chondrites.

To further assess signatures of incorporated gases, we use the Xe isotopic abundances in the same temperature fractions. First, as shown in Fig. 2, we observe large relative excesses of radiogenic $^{129}Xe_r$ in the nonmagnetic separate, in T >1000°C temperature steps, which otherwise show a trapped Xe component consistent with the OC-Xe signature [9]. This shows that radiogenic ^{129}Xe was retained in some minerals. However, the Xe isotopic signatures in the ≤1000°C temperature steps (~10% of Xe) show major deviations from the OC-Xe signature (Figure 2). The signature in the 600°C step indicates the presence of solar-type Xe, but the elemental abundances do not agree with solar abundances. This is the first observation of solar-type Xe in a meteorite with otherwise chondritic elemental abundances ($^{36}Ar/^{132}Xe$ ~ 180 and $^{84}Kr/^{132}Xe$ ~ 1.8). While the 600°C step also reveals a solar-type ^{129}Xe abundance, the 800°C step shows a ~18% excess (Fig. 2), representing radiogenic $^{129}Xe_r$ (as observed in T >1000°C $^{129}Xe_r$ (as observed in T >1000°C steps). We calculate that a mixture of 18% sample (T >1000°C) gases with 82% of a solar-type component can account for the isotopic signatures in the 800°C step. The 1000°C step (not shown) has a similar composition.

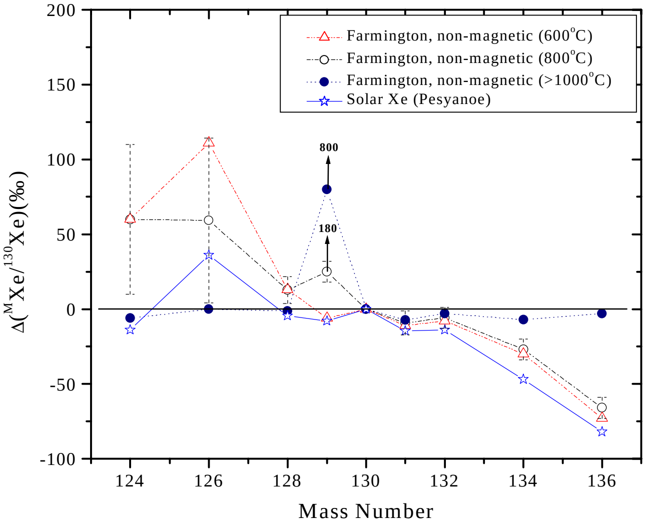

Figure 2. Xenon isotopic deviations from the OC compostion [9](in per mil) for the Farmington non-magnetic separate. Xe released in the 600° *and 800°C steps and as observed in the >1000°C steps are shown. Solar-type Xe data (spallation corrected) as reported in Pesyanoe [13] is shown for comprison.*

Conclusion: Late collisional events. The systematics of ^{40}Ar retention in shocked chondrites was studied by Turner [10] who also obtained an estimate of the energy deposition required to outgas shocked L-chondrites. His estimate of ~200 kJ/kg chondrite is in the range of the impact energies inferred from simulations of catastrophic disruption and gravitational reaccumulations of large asteroids, leading to the formation of families of large and small objects [11]. The origin of the nitrogen signature $\delta^{15}N$ = -35‰ and of solar-type Xe apparently relate to the reaccumulation and was either delivered by the impactor or imported from the regolith of the parent object. Wetherill [12] evaluated the dynamical origin of ordinary chondrites and calculated a ~90% probability that they derived from subsequent fragmentation of perturbed asteroid fragments, injected into the chaotic zone and perturbed into Earth-crossing orbits. Farmington was in a shielded location until its very recent collisional separation, ~25 Ka ago.

References: [1] Marti K. and Graf T. (1992) Annu. Rev. Earth Planet. Sci. 20, 221 [2] Anders E. (1962) Science 138, 431 [3] Patzer A. et al (1999) LPSC XXX, #1145 [4] Levin B. et al (1976) Icarus 28, 307 [5] Heymann D. (1967) GCA 29, 1203 [6] Bogard D.D. and Hirsch W. C. (1980) GCA 44, 1667 [7] Mathew K.J. et al (2001) Meteorit. Planet. Sci. 36, A126 [8] Mathew K.J. et al (2000) LPS XXXI, # 1169 [9] Lavielle B. and Marti K. (1992) JGR (Planets) 97, 20875 [10] Turner G. (1988) In *Meteorites and the Early Solar System*, pp. 276 [11] Michel P. et al (2001) Science 294, 1696 [12] Wetherill G.W. (1985) Meteoritics 20, 1 [13] Kim J.S. and Marti K. (1992) Proc. LPSC 22, 145-151.

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