HIGHLY ^{15}N-ENRICHED CHONDRITIC CLASTS IN THE CB/CH-LIKE ISHEYEVO METEORITE.
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Metal-rich (CB, CH, CB/CH-like) carbonaceous chondrites exhibit several anomalous characteristics not observed in other chondrite groups, including (*i*) a nearly complete absence of interchondrule fine-grained matrix, and (*ii*) the highest whole-rock enrichments in ^{15}N (δ^{15}N up to +1500‰) [e.g., 1, 2]. The fine-grained material occurs mainly as chondritic clasts, which represent foreign material having experienced some secondary processes on their initial parent body and subsequently incorporated into or accreted with the CH and CB high-temperature components [e.g., 1, 3].

In order to constrain the origin of the lithic clasts and to look for the pristine carrier of heavy nitrogen, we initiated a detailed study of the clasts in the CB/CH-like chondrite, Isheyevo. Based on petrography, chemical composition of altered minerals, the structural degree of the polyaromatic organic matter, and the oxygen isotopes of carbonates, we concluded that 1) the lithic clasts in Isheyevo are diverse and 2) they may originate from several parent bodies, some of them unsampled in our collections of cosmomaterials [3]. Three main groups of clasts were defined by [3]. Group I clasts have a mineralogy indicating of a high degree of aqueous alteration and they are the most common. Group II clasts contain variable abundances of anhydrous silicates; carbonates, magnetite and sulfide are rare. Group III clasts are characterized by the absence of magnetite and the presence of Fe,Ni-metal. They experienced thermal processing comparable to type 3.0 chondrites, as attested to by the structural order of aromatic organic matter. Groups I and II are characterized, with only a few exceptions, by a poorly ordered organic matter, comparable with CI and CM.

The present work is focused on the rare group II clasts. We report their petrographic characteristics, the O-isotopic composition of the anhydrous silicates, and their C- and N-isotopic compositions. Their origin and implication for the metal-rich chondrites are discussed.

Analytical procedures: *Petrography:* A systematic survey allowed us to identify 6 group II clasts with large anhydrous silicates. The clasts were mapped in Na, O, Mg, Al, Si, S, Ca, Mn, and Fe X-rays using a JEOL 5900LV SEM. The anhydrous silicates, micro-CAIs, and micro-chondrules were imaged by Back-Scattered Electrons (BSE) and their compositions were estimated from SEM X-ray. The opaque minerals were studied in reflected light and in BSE images.

Isotope measurements: Isotope measurements were carried with the University of Hawai'i Cameca ims 1280 microprobe. Analytical technique for oxygen isotope measurements is described by [4]. Isotope ratio maps for C and N were collected by scanning ion imaging. A Cs^+ primary beam of <10pA was rastered over areas of 50×50 µm^2. A mass resolving power of ~ 6000 was used and signals of $^{12}C^-$, $^{13}C^-$, $^{18}O^-$, $^{12}C^{14}N^-$, $^{12}C^{15}N^-$ and $^{28}Si^-$ were measured with the monocollector electron multiplier. A polished thin section of Orgueil (CI) was used as a standard, assuming bulk C and N values from [5]. The accuracy of the ratios inferred from image processing (L'image, L. Nittler) was checked by measuring the ratios in normal monocollection mode. Good agreement was obtained.

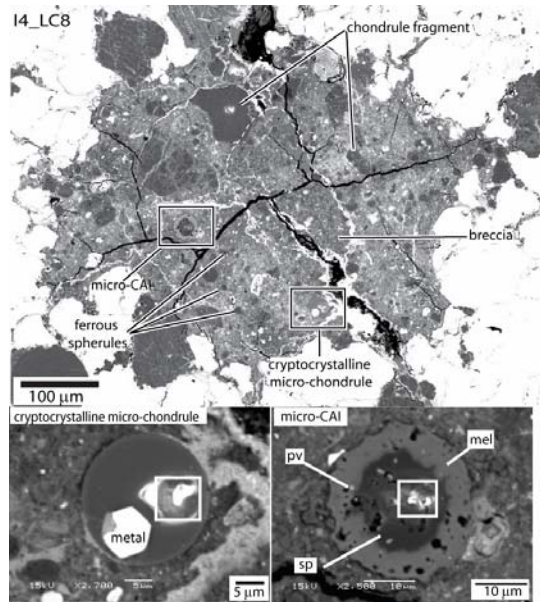

Fig. 1: BSE images of one of the lithic clasts. Numerous anhydrous silicates are present: fragments of chondrules, micro-chondrules and micro-CAI.

Results: The 6 group II clasts are characterized by a low abundance of opaque minerals (a few metal grains exhibiting some sulfidization and rare occurrence of magnetite) and a high abundance of crystalline silicates (Fig. 1). Some clasts show evidence of brecciation (Fig. 1). Preliminary mineralogical characterization by TEM, reported in [6], shows that the fine-grained materials in the clasts experienced parent body aqueous processing.

The anhydrous silicates, from ~1 to 50 µm in size, consist of olivine, low-Ca and high-Ca pyroxenes, rare fragments of albitic plagioclase, numerous cryptocrystalline micro-chondrules (<10 µm in size), a micro-CAI composed of spinel, perovskite and melilite (Fig. 1), and an AOA. Oxygen isotopic compositions of 22 crystalline silicates were measured. The silicates are distributed slightly above and below the TFL, along the

CCAM line. The micro-CAI and AOA are ^{16}O-rich (Fig. 2).

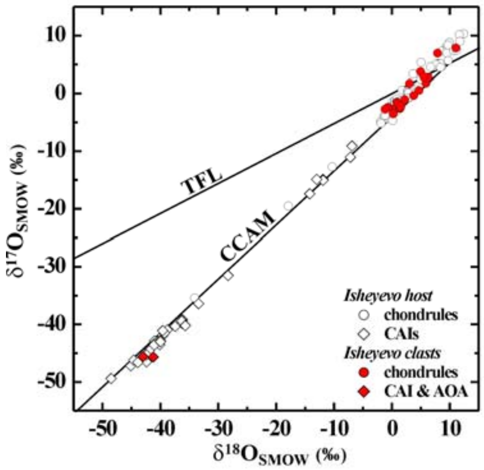

Fig. 2: O-isotopic composition of the chondrules and CAI from the lithic clasts and the host meteorite Isheyevo [7].

Scanning isotopic imaging of the fine-grained matrix has been done so far on 4 areas in 2 of the 6 group II clasts. Some ^{15}N-rich hotspots are visible in every studied area; the enrichment can be as high as $\delta^{15}N \sim +4000‰$. The most surprising finding is that the bulk of each group II clast is highly ^{15}N-rich, with $\delta^{15}N \sim +1000‰$ to +1300‰ (Fig. 3). The lithic clasts with a highly hydrated mineralogy are characterized by a lower ^{15}N enrichment with $\delta^{15}N \sim +300‰$ (group I on Fig. 3). The carbon appears to be isotopically normal (Fig. 3).

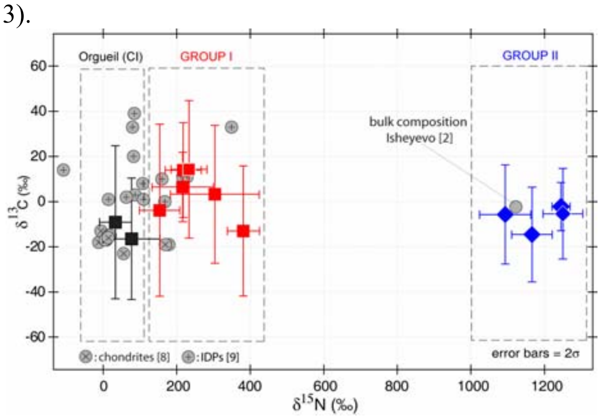

Fig. 3: Bulk N-, C-isotopic composition of the fine-grained matrix of some lithic clasts in Isheyevo compared to Orgueil.

Discussion: The bulk ^{15}N enrichment is different in clasts of groups I and II (Fig. 3), supporting our previous inference that they sampled different parent bodies [3]. Moreover, the group II clasts are characterized by the highest bulk ^{15}N enrichment ever measured in the fine-grained matrix of a cosmomaterial. Indeed, the CR chondrites, considered as the most primitive meteorites, have a bulk $\delta^{15}N$ value of ~ +200‰ [8]; IDPs have a bulk $\delta^{15}N$ value of ~ +300‰ [9]. The group II clasts are thus unique. Their nitrogen isotopic compositions are similar to the whole-rock Isheyevo sample [2]. Rough calculations based on our ion probe measurements indicate that group II clasts have ~3× higher nitrogen content than the group I clasts, which are at least 10× more abundant. Taken together, the clasts, which may provide only one third to one half of the nitrogen, cannot account for the composition of the Isheyevo whole rock. However, since chondritic lithic clasts are the only thermally unprocessed materials that accreted together with high-temperature components, the group II clasts probably are the surviving primordial carrier of the ^{15}N anomaly in Isheyevo. They may represent the remains of a body involved in the highly energetic event invoked for the origin of chondrules and metal grains (planetary scale collision) in CH and CB chondrites [10]. This event, as well as postaccretionary shock metamorphism, could have destroyed the original carrier and redistributed the ^{15}N-rich signature [11, 12], explaining the fact that most of the nitrogen in Isheyevo may currently sit in components other than the clasts.

The group II clasts are made of two main components: the ^{15}N-enriched fine-grained matrix and numerous anhydrous silicates. They may have been mixed together late in their histories. Indeed, the process leading to the extreme nitrogen isotopic fractionation has not yet been determined. However, similar ^{15}N-enrichments have been observed in comets [e.g., 13]. Moreover, some comets could have been trapped dynamically in the outer asteroid belt [14]. Once in the asteroid belt, some aqueous processing may have occurred on this cometary body, explaining the observed hydrated products [6]. The fine-grained matrix could then be a remnant of a cometary body. On the other hand, oxygen-isotope compositions and petrographic of the anhydrous silicates are similar to those of constituents in the Isheyevo host (Fig. 2), suggesting a genetic relationship. Finally, if one of these comets were the impactor that collided with the initial parent body of the CH chondrites to produce some of the chondrules and metal grains in CH and CB chondrites [10], then group II clasts could represent fragments of the impactor accreting products of the impact.

References: [1] Grossman et al. (1988) *EPSL* **91**, 33-54. [2] Ivanova et al. (2008) *MAPS* **43**, 915-940. [3] Bonal et al. GCA *submitted*. [4] Makide et al. (2009) *GCA* in press. [5] Kerridge et al. (1985) *GCA* **49,** 1707-1714. [6] Ishii et al. (2009) *this volume*. [7] Krot and Nagashima (2008) *MAPS* A81. [8] Alexander et al. (1998) *MAPS* **33**, 603-622. [9] Floss et al. (2006) *GCA* **70**, 2371-2399. [10] Krot et al (2005) *Nature* **436**, 989-992. [11] Suguira et al. (2000) *MAPS* **35**, 987-996. [12] Perron et al. (2008) *GCA* **72**, 959-977. [13] Bockelée-Morvan et al. (2008) *Ast. J.* **679**, L49-L52. [14] Levison et al. (2008) *ACM* #8156. Supported by NASA, NNX08AG58G (GRH), NNH06ZDA001N-COS (ANK).