

LITHIC CLASTS OF CB/CH-LIKE CARBONACEOUS CHONDRITE ISHEYEVO: DIVERSITY REVEALED BY MINERALOGY, STRUCTURE OF ORGANIC MATTER AND OXYGEN ISOTOPIIC COMPOSITION OF CARBONATES. L. Bonal^{1*}, G.R. Huss¹, A.N. Krot¹, K. Nagashima¹, ¹HIGP/SOEST, University of Hawai'i at Manoa, Honolulu, HI 96822, USA. *bonal@higp.hawaii.edu

The recently discovered metal-rich carbonaceous chondrite Isheyevu contains metal-rich and metal-poor lithologies that show mineralogical, chemical and isotopic similarities to both CH and CB chondrites [1]. Similarly to CH and CB chondrites, Isheyevu is characterized by the coexistence of mineralogically primitive high-temperature components (Fe-Ni metal grains, chondrules, refractory inclusions (CAIs and AOs)) and heavily hydrated, low-temperature, lithic clasts (LC). The LC experienced aqueous alteration in an asteroidal setting, but neither chondrules nor refractory inclusions in Isheyevu show evidence for *in situ* aqueous alteration. This indicates that LC are not genetically related to the high-temperature components in Isheyevu.

It has been recently suggested that some of the chondrules and metal grains in CH chondrites formed in a gas-melt plume produced during large scale asteroidal collision and that these components subsequently accreted together with the LC and nebular chondrules, metal grains and CAIs into the CH parent asteroid [2]. In this scenario, the LC experienced aqueous alteration on pre-existing parent body(ies) that could potentially be unsampled by known heavily hydrated chondrite groups (CM, CI, CR, Tagish Lake). In order to explore the origin and history of the LC from Isheyevu, in comparison to the CI and CM chondrite groups, we initiated detailed mineralogical (SEM), chemical (EPMA), structural (Raman) and isotopic (SIMS) studies.

LC in Isheyevu are characterized by a highly hydrated mineralogy (phyllosilicates, carbonates, magnetite). Nevertheless, preliminary results reported by [3] showed that they are not simply related to CI chondrites. Indeed, structural order of the organic matter (OM) and petrography of opaque minerals reveal different types of LC in Isheyevu [3]. Group 1 is characterized by (i) a structural order of the aromatic OM comparable with type 3.0 chondrites, (ii) the presence of metal and sulfide grains and (iii) the absence of magnetite. Group 1 LC may have suffered from a thermal event in addition to aqueous alteration. The other types of LC have a poorly-organized aromatic OM characteristic of CI/CM chondrites but a variable concentration of anhydrous silicates, defining the Group 2 (some olivine and pyroxene) and Group 3 (absence of anhydrous silicates). Here we report measurements of chemical composition of phyllosilicates and oxygen isotopic composition of carbonates in the Isheyevu LC.

Analytical procedures: Compositions of carbonates from 19 LC and phyllosilicates from 28 LC were deter-

mined with a Cameca SX-50 electron microprobe using fully focused beam, 15kV accelerating voltage and beam current of 20nA at University of Hawai'i. Natural minerals were used as standards. Phyllosilicates are fine-grained and intimately mixed with different phases on micron to submicron scale, so accurate microprobe analyses are difficult. Sulphur concentration was determined for phyllosilicates and analyses with a concentration higher than 2% were rejected.

The oxygen isotopic compositions of 8 carbonates grains (dolomite and magnesite) in 6 LC were analyzed *in situ* with the UH Cameca IMS1280 ion microprobe. A 1.8-1.2nA focused Cs⁺ primary ion beam was first rastered over a 25×25 μm² area for 250 seconds. The raster was then reduced to 10×10 μm² to collect the data. The normal-incidence electron gun was used for charge compensation. The secondary ion mass spectrometer was operated at -10keV with a 50eV energy window. ¹⁶O⁻ and ¹⁸O⁻ were measured on multicollector detectors L'2 and H1 (FC) and ¹⁷O⁻ with the monocollector electron multiplier (EM). The mass resolving power (m/Δm) for ¹⁶O and ¹⁸O was ~ 2500 and for ¹⁷O ~ 5500. Measured count rates were corrected for background (FC) and deadtime (EM). The contribution of ¹⁶OH on ¹⁷O was evaluated by high resolution mass spectra and a tail correction was done for each measurement. Carbonate mineral standards were used (calcite UWC1, dolomite 6220, 6250 and Ivigtut siderite, provided by N. Kita). Dolomite data were corrected for instrumental mass fractionation (IMF) by using the known δ¹⁸O value of dolomite standard; magnesite data were corrected by using the difference in IMF between dolomite and magnesite from [4]. The carbonates analyzed were all bigger than 20 μm² and each spot was checked by SEM to confirm that single carbonate phase was analyzed.

Results: *Chemical compositions of phyllosilicates and carbonates:* Electron microprobe analyses of the Isheyevu LC phyllosilicates are plotted in terms of wt% of Fe, Si+Al and Mg in Fig. 1. They mostly concentrate near the serpentine solid solution line with a high variability in Fe/Mg concentration. In CM chondrites, matrix phyllosilicates consist mainly of Fe-Mg serpentine, while in Orgueil serpentine and saponite are intergrown [5]. These observations imply that Isheyevu may be more closely related to CM than to CI chondrites. Phyllosilicates in the LC from the Group 1 appear to be depleted in Fe in comparison with the ones from Groups 2

and 3. Higher totals for some phyllosilicates of the Group 1 may suggest that they have suffered dehydration, as seen in metamorphosed CM chondrites.

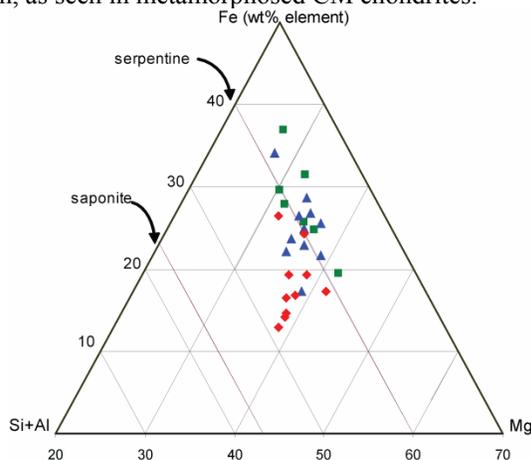


Fig. 1: Average electron microprobe analyses of phyllosilicates in terms of wt% of Fe, Si+Al and Mg. Also shown are the ideal Mg-Fe solid solution lines of serpentine and saponite (♦: Group 1; ■: Group 2; ▲: Group 3).

The carbonates in the Isheyevo LC are primarily dolomite and magnesite, with only a few calcite grains that may result from terrestrial weathering. In CI chondrites, the dominant carbonate is dolomite; magnesite is minor. In CM chondrites, the dominant carbonate is calcite. Carbonates in Isheyevo are homogeneous and “clean” crystals. In Murchison and Orgueil, they look corroded, fractured and often associated with other mineral phases. These differences may provide information about the conditions of aqueous alteration.

O-isotopic compositions of carbonates: The O-isotopic compositions of the Isheyevo carbonates are plotted in Fig. 2. The carbonates are from Group 3 LC, except for one carbonate from Group 1 (○ on the terrestrial fractionation line). The close similarity in $\Delta^{17}\text{O}$ from 2 spots in the same grain (■) and between 2 carbonate grains of the same LC (♦, ◆) allow us to be confident in our preliminary measurements.

Because of the general mineralogical and petrological similarities between Isheyevo LC and the aqueously altered carbonaceous chondrites (CI, CM, Tagish Lake), it is important to compare their O-isotope systematics. The reported ranges of $\Delta^{17}\text{O}$ values for carbonates in these meteorites are: Orgueil (CI), +0.42 to +0.51‰ [8]; Murchison (CM), -0.67 to -1.02‰ [6]; Tagish Lake, +1.42 to +1.98‰ [8]. In Isheyevo, $\Delta^{17}\text{O}$ in carbonates varies from LC to LC in the range -1.2 to +1.4‰. This range is as great as that covered by Orgueil, Murchison, and Tagish Lake combined. There is a resolvable difference between compositions of different LC. The observed ranges in O-isotopic compositions of the Isheyevo LC carbonates imply either that 1) Isheyevo LC

formed on different parent bodies that inherited distinct bulk (water ice + silicates) O-isotopic compositions from the solar nebula, or 2) they formed on a single parent body, with low and variable water/rock ratio, that experienced progressive aqueous alteration [e.g., 7]. For example, along the CM alteration sequence, $\delta^{18}\text{O}$ ranges from 20 to 35.7‰ and $\Delta^{17}\text{O}$ ranges from -0.7 to -2.7‰. Thus, while the oxygen data are consistent with the LC originating on different parent bodies, this is not required. The precision of our data does not allow us to determine from oxygen isotopes alone whether the LC with $\Delta^{17}\text{O} > 0$ are pieces of the CI chondrite or Tagish Lake parent bodies. LC with $\Delta^{17}\text{O} < 0$ have O-isotopic compositions similar to those of the Nogoya and Mighei CM chondrites [6]. But calcite is present in CM chondrites instead of the dolomite and magnesite found in Isheyevo, arguing against their origin on the same parent body.

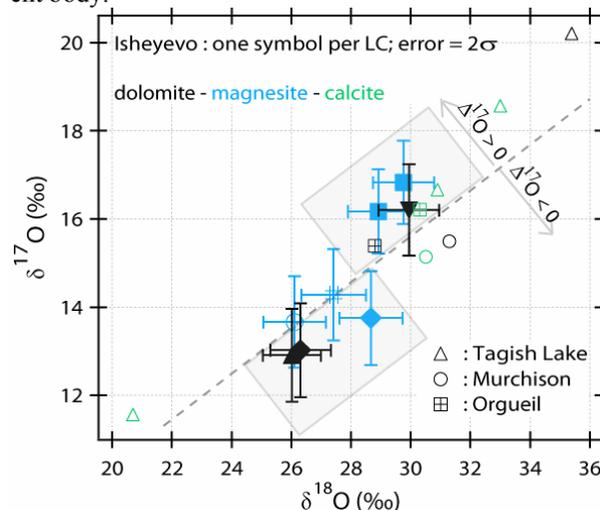


Fig. 2: Three-isotope plot of $\delta^{17}\text{O}$ vs. $\delta^{18}\text{O}$ relative to SMOW illustrating the isotopic variability of carbonates inside Isheyevo LC. The terrestrial fractionation line (TFL) is shown for reference. Data for carbonates from Tagish Lake, Murchison and Orgueil are from [6,8].

Conclusion: Mineralogy, petrology, mineral chemistry, Raman spectroscopy and oxygen isotopes have revealed a high diversity amongst the LC of Isheyevo. Although the LC broadly resemble aqueously altered carbonaceous chondrites, detailed comparisons show that they are distinct and not clearly affiliated with any of these meteorites. They probably represent distinct, previously unsampled parent bodies.

References: [1] Krot, A.N. et al. (2007) *Chem. Erde*, 67: 283. [2] Krot, A.N. et al. (2005) *Nature*, 436: 989. [3] Bonal, L. et al. (2007) *MAPS*, 42: #5287. [4] Leshin, L. A. et al. (1998) *GCA*, 62: 3. [5] Tomeoka, K. et al. (1988) *GCA*, 52: 1627. [6] Benedix, G.K. et al. (2003) *GCA*, 67: 1577. [7] Clayton, R.N. and Mayeda, T.K. (1999) *GCA*, 63: 2089 [8] Leshin, L.A. et al. (2001) *LPSC*, 30, #1843. Supported by NASA grant NNG05GG48G-GRH.