A divergent heritage for complex organics in Isheyevo lithic clasts - DTU Orbit (02/11/2019)

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Primitive meteorites are samples of asteroidal bodies that contain a high proportion of chemically complex organic matter (COM) including prebiotic molecules such as amino acids, which are thought to have been delivered to Earth via impacts during the early history of the Solar System. Thus, understanding the origin of COM, including their formation pathway(s) and environment(s), is critical to elucidate the origin of life on Earth as well as assessing the potential habitability of exoplanetary systems. The Isheyevo CH/CI carbonaceous chondrite contains chondritic lithic clasts with variable enrichments in $^{15}$N believed to be of outer Solar System origin. Using transmission electron microscopy (TEM-EELS) and in situ isotope analyses (SIMS and NanoSIMS), we report on the structure of the organic matter as well as the bulk H and N isotope composition of Isheyevo lithic clasts. These data are complemented by electron microprobe analyses of the clast mineral chemistry and bulk Mg and Cr isotopes obtained by inductively coupled plasma and thermal ionization mass spectrometry, respectively (MC-ICPMS and TIMS). Weakly hydrated (A) clasts largely consist of Mg-rich anhydrous silicates with local hydrated veins composed of phyllosilicates, magnetite and globular and diffuse organic matter. Extensively hydrated clasts (H) are thoroughly hydrated and contain Fe-sulfides, sometimes clustered with organic matter, as well as magnetite and carbonates embedded in a phyllosilicate matrix. The A-clasts are characterized by a more $^{15}$N-rich bulk nitrogen isotope composition ($\delta^{15}$N = 200–650‰) relative to H-clasts ($\delta^{15}$N = 50–180‰) and contain extremely $^{15}$N-rich domains with $\delta^{15}$N < 5000‰. The D/H ratios of the clasts are correlated with the degree of clast hydration and define two distinct populations, which we interpret as reflecting mixing between D-poor fluid(s) and distinct organic endmember components that are variably D-rich. High-resolution N isotope data of $^{15}$N-rich domains show that the lithic clast diffuse organic matter is typically more $^{15}$N-rich than globular organic matter. The combined H and N isotope data suggest that the organic precursors of the lithic clasts are defined by an extremely $^{15}$N-poor (similar to solar) and D-rich component for H-clasts, and a moderately $^{15}$N-rich and D-rich component for A-clasts. In contrast, the composition of the putative fluids is inferred to include D-poor but moderately to extremely $^{15}$N-rich H- and N-bearing components. The variable $^{15}$N enrichments in H- and A-clasts are associated with structural differences in the N bonding environments of their diffuse organic matter, which are dominated by amine groups in H-clasts and nitrile functional groups in A-clasts. We suggest that the isotopically divergent organic precursors in Isheyevo clasts may be similar to organic moieties in carbonaceous chondrites (CI, CM, CR) and thermally recalcitrant organic compounds in ordinary chondrites, respectively. The altering fluids, which are inferred to cause the $^{15}$N enrichments observed in the clasts, may be the result of accretion of variable abundances of NH$_3$ and HCN ices. Finally, using bulk Mg and Cr isotope composition of clasts, we speculate on the accretion regions of the various primitive chondrites and components and the origin of the Solar System’s N and H isotope variability.

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