Linking the formation pathways of organic matter in chondrites to their accretion regions

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The formation pathways of organic matter in chondrites are still poorly understood and could be related to some combination of inheritance from the molecular cloud, chemistry in the disk and Strecker synthesis on asteroids [1]. Some lithic clasts in Isheyevo (CB/CH chondrite) represent pristine chondritic materials with extreme ^{15}N-rich organic domains [2], for which an outer Solar System origin has been proposed, potentially akin to that of comets [3]. To better constrain the formation pathways and understand the origin of the N and H isotope variability in chondritic organic matter, we report on structural analyses by TEM-EELS of the Isheyevo lithic clast organic matter correlated to ^{15}N-rich domains identified by SIMS. Some of the least altered ^{15}N-rich clasts have distinct C=O (ketone/aldehyde- related) bonding environments in their organic matter with nitrile functional groups related to N-heterocycles. In contrast, the more hydrated clasts are highly aromatic with amine functional groups. Bulk D/H ratios from phyllosilicates plotted against relative water content show that the lithic clasts fall on distinct hydration lines that yield two different D-rich end members, which we infer represent different organic precursor molecules. We suggest that these precursors likely embody D-rich nanoglobules that contain aromatic or aldehyde/ketone-related functional groups. NanoSIMS analyses show that the ^{15}N-rich domains are dominated by diffuse organic matter unrelated to the nanoglobules, indicating that the organic precursors were altered by a ^{15}N-bearing fluid on the lithic clast parent body. Using radiative transfer models of the proto-planetary disk, we propose a scenario where the N- and H-isotope distribution in Solar System reservoirs is highly dependent on their accretion location with respect to H_2O, NH_3 and HCN and organic precursor ice stability regions.

[1] Ehrenfreund & Charnley (2000) *Ann. Rev. Astron. Astrophys.* **38**, 427-483; [2] Bonal et al. (2010) *GCA*, **74**, 6590–6609; [3] van Kooten *et al.* (2016) *PNAS*, in press.