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Isotopic and mineralogical constraints on the genesis of complex organic matter in dark clasts from the outer Solar System

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Chondrites are the relatively unaltered, left-over building blocks that formed our Solar System. Together, they are thought to represent materials from both the terrestrial planet region and beyond Jupiter's orbit (i.e., < 10 AU from the Sun) [1,2]. Considering that the protoplanetary disk was an order of magnitude larger, the meteorites in our collection represent a limited record of the potential reservoirs that contributed material to growing planets. Comets provide the main source of information about the outer Solar System (> 10 AU) and are relatively organic and volatile rich, making them a potent source of prebiotic molecules that are necessary for the emergence of life on Earth. No space mission has collected a sample from a comet's surface, limiting our understanding of these potential planetary building blocks. CR chondrites belong to a class of carbonaceous chondrites that may have sampled the same feeding zones as comets [2]. These chondrites contain dark clasts, namely inclusions that have a different origin than their host chondrite and for which some of them are inferred to have cometary origin [3,4]. Here, we investigate dark clasts within the CR chondrite NWA 14250. These clasts are predominantly made of CI-like matrix (and some containing few CM-like chondrules) that exhibits no volatile loss relative to CIs, whereas their bulk μ^{54}Fe, D/H ratios and δ^{15}N values point to an origin in the CR chondrite accretion region. Using H, N, C and O isotope data combined with HR nanoscale imaging and EDX mapping, we deduce an ISM origin for the organic matter that is closely related to primary sulfides. The most D-rich region within these clasts coincides with the presence of a presolar silicate, confirming an ISM origin. Finally, the high abundance of organics (organo-sulfide regions: 40-50 vol%) suggests that these clasts may be our closest link to comets yet.

[1] Kruijer et al. (2020) *Nat. Astron.* 4, 32-40; [2] van Kooten et al. (2016) *PNAS* 113, 2011-2016. [3] van Kooten et al. (2017) *GCA* 205, 119-148. [4] Nittler et al. (2019) *Nat. Astron.* 3, 659-666.