Very organic-rich bodies in the inner and outer solar system

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Although the solar C/Si atomic ratio of ~9.5 suggests abundant carbon-rich bodies, terrestrial planets and meteorites are rich in silicates and metals. Even carbonaceous chondrites with abundant insoluble organic matter (IOM) have C/Si < 0.8. Until recently, only dust of comets 1P/Halley (C/Si = 3.4-5.4) and 67P/C-G (C/Si = 4.3-6.9), and some anhydrous interplanetary dust particles (C/Si = 0.7-4.9) revealed more abundant organic matter (OM) than chondrites. The detection of ~8-14 wt% C in Ceres' surface materials with the Dawn spacecraft suggests 7-16 wt% and up to 30 vol% of IOM-like material in an ice-less interior with C/Si = 1.9-3.6 [1]. The similarity of near infrared spectra of Ceres with spectra of some large asteroids [2] suggests a half of the main asteroid belt mass consisted of very C-rich materials that are absent from the meteorite collection. Very C-rich asteroids could have formed at larger heliocentric distances than parent bodies of carbonaceous chondrites. According to the Grand Tack model, both C-type chondritic and very C-rich bodies could have migrated from the outer solar system at ~5-6 Ma after formation of CAIs. The migration implies abundant OM within icy moons (e.g. Europa, Enceladus, Triton) and trans-neptunian objects (TNOs) (Pluto, etc.). Interior models for Titan and Ganymede suggest ~20 wt% of OM [3]. Abundant OM within bodies with density of 1.5-2.5 g cm^{-3} advocates for relatively water-poor compositions, consistent with the detection of OM rather than water ice on Arrokoth [4] and some other TNO's. Abundant OM affected thermal and physical-chemical evolution of larger and tidally-forced bodies. Alteration of low- and high-molecular weight OM at variable T-P-fH_2-aH_2O conditions changed H/N/C/O ratios in IOM-like materials and led to formation of new compounds. Species released from altered OM (e.g. CH_4, N_2, NH_3/NH_4^+) affected interior, surface and atmospheric compositions. Organic-rich (oily) and hydrocarbon clathrate layers/lenses could have formed in addition to solid/liquid water layers and influenced thermal conductivity, viscosity, permeability and water-organic-rock interactions.

[1] Zolotov (2020) *Icarus* **335**, 113404. [2] Rivkin *et al*. (2019) *JGR-Planets* **124**, 1393–1409. [3] Néri *et al*. (2020) *EPSL* **530**, 115920. [4] Grundy *et al*. (2020) *Science*, 10.1126/science.aay3705.