

## Carbon chemistry of a Bennu sample

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The organic content of Bennu is important for understanding Solar System formation and astrobiology. Organic matter is present both as surviving primordial material, such as nanoglobules containing isotopic signatures indicative of formation in the molecular cloud or outer solar nebula, and as the product of aqueous alteration on Bennu's parent body [1]. The organic matter is divided into a soluble and insoluble component depending on whether solvents can easily remove it from the mineral matrix. Insoluble organic matter consists of a network of aromatic molecules connected via short-chain aliphatics [2]. Soluble organics contain a large diversity of individual molecules [3].

An electron-transparent sample (OREX-803030-100) was prepared using an FEI Helios G4 Focused Ion Beam (FIB) at the Lawrence Berkeley National Laboratory (LBNL). Scanning Transmission X-ray Microscopy (STXM) at the C-K edges was done at beamline 5.3.2.2 at the Advanced Light Source at LBNL. Transmission electron microscopy (TEM) of the FIB section reveals phyllosilicates, enstatite, forsterite, sulfides, magnetite, nanoglobules, and an amorphous Mg-phosphate that is likely an evaporite [4].

We observe that the abundance of CH<sub>x</sub> (aliphatic carbon) and C=C (primarily aromatic) varies significantly. One nanoglobule has a CH<sub>x</sub>/(CH<sub>x</sub>+C=C) optical density (OD) ratio of 0.3, whereas other regions can have a CH<sub>x</sub>/(CH<sub>x</sub>+C=C) OD ratio as high as 0.5. Most carbon contains both CH<sub>x</sub> and C=C bonds but some regions are substantially enriched in aliphatic carbon associated with phyllosilicates and not nanoglobules.

Carbonate is present almost everywhere in the section with a typical amplitude of 0.1 OD. However, in one region, the amplitude of the carbonate peak increases to 0.3 OD. CO<sub>3</sub> is poorly correlated with C=C and other organic species suggesting that CO<sub>3</sub> has a distinct chemistry and is unlikely to be dominated by organic carbonate. Instead, it may be a carbonate salt and therefore an evaporite. Carbonate is expected to be present in the late brine composition based on modeling of the evaporation process on Bennu [4].

Other oxygen-bearing functional groups provide additional insights into organic chemistry. C=O prefers aromatic carbon while COOH prefers aliphatic carbon. COOH is more acidic than C=O so it would appear that the aliphatic carbon has experienced a more acidic environment or reacted while aromatic species remained inert.

C=O is very strongly correlated to C=C and it may be that nearly all the C=O moieties are associated with aromatic carbon and/or the short aliphatic linkages associated with C=C carbon. We observe a multimodal correlation between C=O and CH<sub>x</sub> (aliphatic carbon), but a strikingly similar correlation between CH<sub>x</sub> and C=C. This suggests that C=O is only weakly associated with independent aliphatic carbon not associated with aromatic carbon. The aliphatic carbon is a very interesting target for further study, and more work will be needed to understand the chemistry using additional STXM, TEM, nanoscale infrared spectroscopy (nanoIR) and nanoscale secondary ion mass spectroscopy (nanoSIMS).

Aqueous alteration is known to preferentially destroy aliphatic moieties and oxidized carbon to create C=O [5]. Our data are consistent, at least in part, with aqueous alteration where aliphatic carbon has been oxidized to reduce the abundance of CH<sub>x</sub> groups and produce C=O groups associated with aromatic carbon or its aliphatic linkages. C=O in Ryugu samples is distributed across both aliphatic and aromatic species [6,7,8,9,10]. It is not clear currently whether we are seeing a fundamental difference between Bennu and Ryugu, or if it is simply a consequence of the specific chemistry present in this particular Bennu sample.

### References

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