CARBON AND NITROGEN ABUNDANCE, DISTRIBUTION, AND ISOTOPIC COMPOSITION IN SAMPLES OF ASTEROID (101955) BENNU.

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Introduction: Material from the B-type carbonaceous asteroid (101955) Bennu was returned on September 24, 2023, by NASA's OSIRIS-REx mission [1]. The mission brought back the largest sample of pristine primordial asteroidal material, largely free from the challenges of terrestrial contamination that are common in meteorite studies. The Bennu sample thus provides a unique source of material to investigate the abundance and isotopic signatures of C and N. The specific hypotheses tested by these analyses are whether Bennu contains macromolecular material and/or presolar grains similar to the populations found in CI and CM chondrites and recently returned samples from Ryugu [2].

Method: A sample of mixed fines and intermediates (OREX-803020-0) was sent, under nitrogen, to the Natural History Museum (NHM) in London as part of a general sample allocation from inside the Touch-And-Go Sample Acquisition Mechanism (TAGSAM) collector head. A sub-sample of around 5 mg was separated at the NHM for analysis at the Open University (OU). This sub-sample was further split at the OU into two sub-samples for analysis on the OU's Finesse system. These samples were OREX-803058-0 (1.427 mg) and OREX-803059-0 (1.170 mg).

The samples were analysed by stepped combustion-isotope ratio mass spectrometry to determine the abundance, distribution, and isotopic composition of C and N [3]. The C- and N-bearing components (as well as noble gases) were released by incremental heating under excess oxygen from 50˚C to 1400°C. The CO_2 and N_2 produced were cryogenically separated and purified prior to analysis in separate triple-collector noble gas-type mass spectrometers.

Results: The summed carbon and nitrogen data for the two samples of Bennu are compared with data acquired at the OU from carbon-rich carbonaceous chondrites and Ryugu, as well as reported analyses of Ryugu [4-7] and "quick-look" data acquired from Bennu material on the return capsule's avionics deck [8]. Overall, the Bennu samples contain around 4.4 wt. % C with $\delta^{13}C$ between +8 and +16 ‰ and 900 – 1200 ppm N with $\delta^{15}N$ between +44 and +72 ‰.

Discussion: From stepped combustion analysis of other carbonaceous chondrites [9] we know that carbon and nitrogen in these meteorites are a complex and heterogeneous mix of several components. The components combust across different temperature ranges, enabling their identification. The abundance and isotopic composition of the discrete components can be calculated by mixing calculations. The stepped combustion results indicate that around 70 % of the carbon and nitrogen in Bennu occurs as organic compounds with $\delta^{13}C$ between −10 and 0 ‰ and $\delta^{15}N$ between 0 and +60 ‰. There is a distinct maximum in carbon release at 650 °C from the abundant carbonates observed in Bennu samples [1]. The temperature implies that the carbonate is mostly calcite; it has a $\delta^{13}C$ of at least +80 ‰. There is a clear minimum in nitrogen isotopic composition at around 425 °C, with $\delta^{15}N$ dropping to +20 ‰ from +60 ‰, indicative of nanodiamonds mixed with organics. At temperatures above 700 °C, the remaining C and N is from combustion of graphite and presolar SiC.

Conclusions: A range of C- and N-bearing components are heterogeneously distributed in Bennu samples, similar to those in Ryugu samples and C-rich carbonaceous chondrites [4-9]. Bennu certainly contains macromolecular material and presolar grains, but the asteroid is not like a typical CI or CM meteorite. Our initial analyses suggest that it is richer in carbonates than CI and CMs. It seems to be closest in its chemistry to Tagish Lake, which has a similarly enhanced complement of carbonates.

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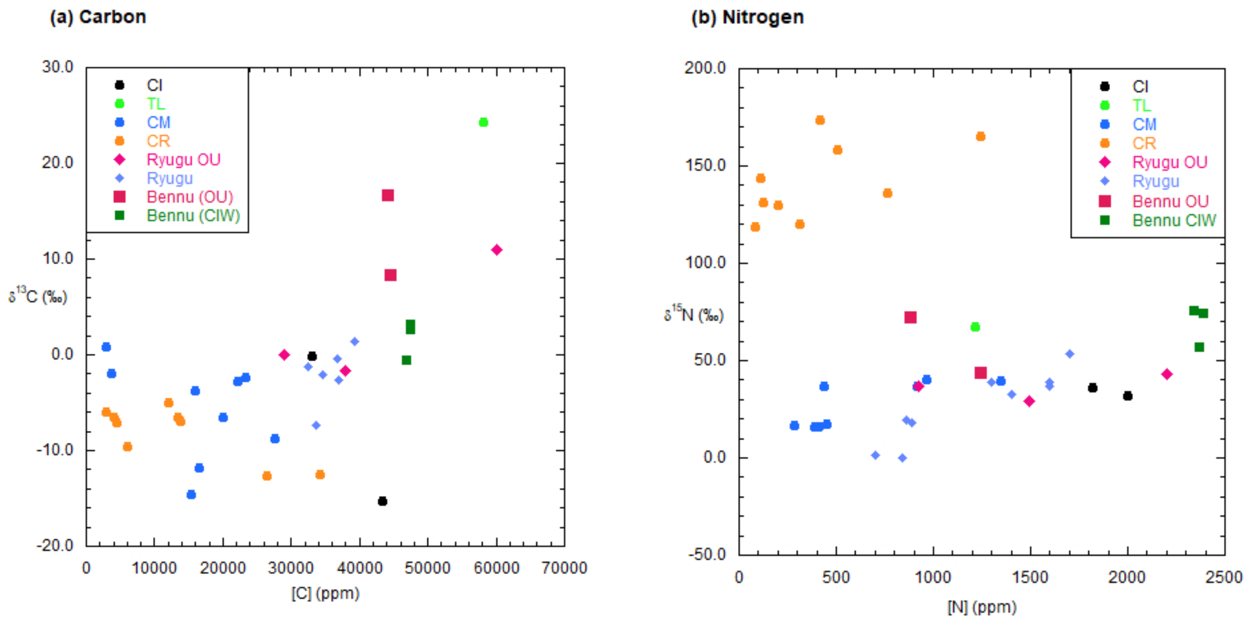

Figure: Summed abundance and isotopic composition of (a) carbon and (b) nitrogen obtained by stepped combustion of carbon-rich carbonaceous chondrites. Data were acquired at the Open University.