BULK OXYGEN ISOTOPE COMPOSITION OF AGGREGATE SAMPLES FROM ASTEROID BENNU RETURNED BY OSIRIS-REx.

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Introduction: On 24 September 2023, the OSIRIS-REx spacecraft delivered to Earth material collected from the surface of the B-type asteroid Bennu. During its ~2.5-year encounter with the asteroid, OSIRIS-REx made many important discoveries, including establishing its extremely primitive chemical composition, the presence of at least two lithologies, and evidence of fluid flow on its parent asteroid [1,2,3]. One of the driving hypotheses of the Sample Analysis Plan [4] is that Bennu's dominant lithologies are comparable to the most aqueously altered carbonaceous chondrites. Oxygen three-isotope analysis is a powerful tool for defining the relationship between different meteorite groups and can be used to understand the nature of the returned Bennu samples. The O isotope signatures reflect the materials that parent asteroids accreted from and the geological processes that operated during asteroidal evolution. Aggregate samples of particles (typically <500 µm) likely sampled many different larger stones and boulders, and their composition may therefore represent the average composition of Bennu. Fractionation of the sample, *e.g.* comparison of aliquots of finer material with coarser particles within the aggregate samples, offers the opportunity to identify different isotopic reservoirs within the returned material. The average O isotope composition will also provide a baseline from which to identify and characterize any exogenous clasts present in the sample.

Samples: Two samples were provided as part of the quick-look (QL) initial characterization, comprising ~5 mg of fines (approx. <100 µm) (OREX-501042-0) and ~3 mg of intermediate particles (~100-500 µm) (OREX-501047-0). Each sample was split (OREX-501066-0 and OREX-501067-0, respectively) to provide replicate analyses. The QL samples were not protected from air exposure once they were removed from the OSIRIS-REx cleanroom facility at NASA JSC.

Analytical methods: The O isotope composition of the samples was determined using the laser-assisted fluorination system at the Open University. An updated "single shot" method was employed, like that used for samples from Ryugu [5]. Samples are heated by a 10.6 µm CO_2 laser in the presence of BrF_5 to liberate O_2 gas that is purified and analysed on a Thermo MAT 253 dual inlet mass spectrometer. Typical 2σ precision is $\delta^{17}O = \pm0.05‰$; $\delta^{18}O = \pm0.10‰$; $\Delta^{17}O = \pm0.02‰$. A small blank correction was applied to the results (<3% of smallest sample).

Results: The weighted (by mass) average $\delta^{18}O$ of the four analyses was 20.9 ± 2.7‰ with a weighted average $\Delta^{17}O$ of 0.75 ± 0.17‰ (Fig. 1). The variation displayed by the samples is considerably greater than the typical analytical precision.

Discussion: The average O isotope composition of the aggregate samples from Bennu plots in the same region of oxygen three-isotope space as some of the most chemically primitive chondritic materials currently available (Fig. 1). This includes the CI and CY chondrites and samples from the asteroid Ryugu returned by the JAXA Hayabusa2 mission [5,6,7]. This result is consistent with preliminary observations of the mineralogy and chemistry of aggregate samples from Bennu, which show affinities to CI chondrites [*e.g.* 8,9]. The exact relationship to these chondrite groups remains to be confirmed, but the average $\Delta^{17}O$ value is slightly higher than any of these other groups of meteorites or returned samples reported to date. Indeed, the finest-grained aliquot analysed has a $\Delta^{17}O$ value beyond anything previously reported for bulk samples of materials present in this region of O isotope space. Further analyses are planned to confirm the magnitude of this variation and how this relates to variations in particle size. This will allow us to identify and characterise different O-isotopic reservoirs within the aggregate sample, and how they relate to known O isotope signatures. As primitive materials appear susceptible to alteration by atmospheric moisture, with the potential to modify O isotope signatures [5], further analyses will use samples not exposed to atmospheric moisture.

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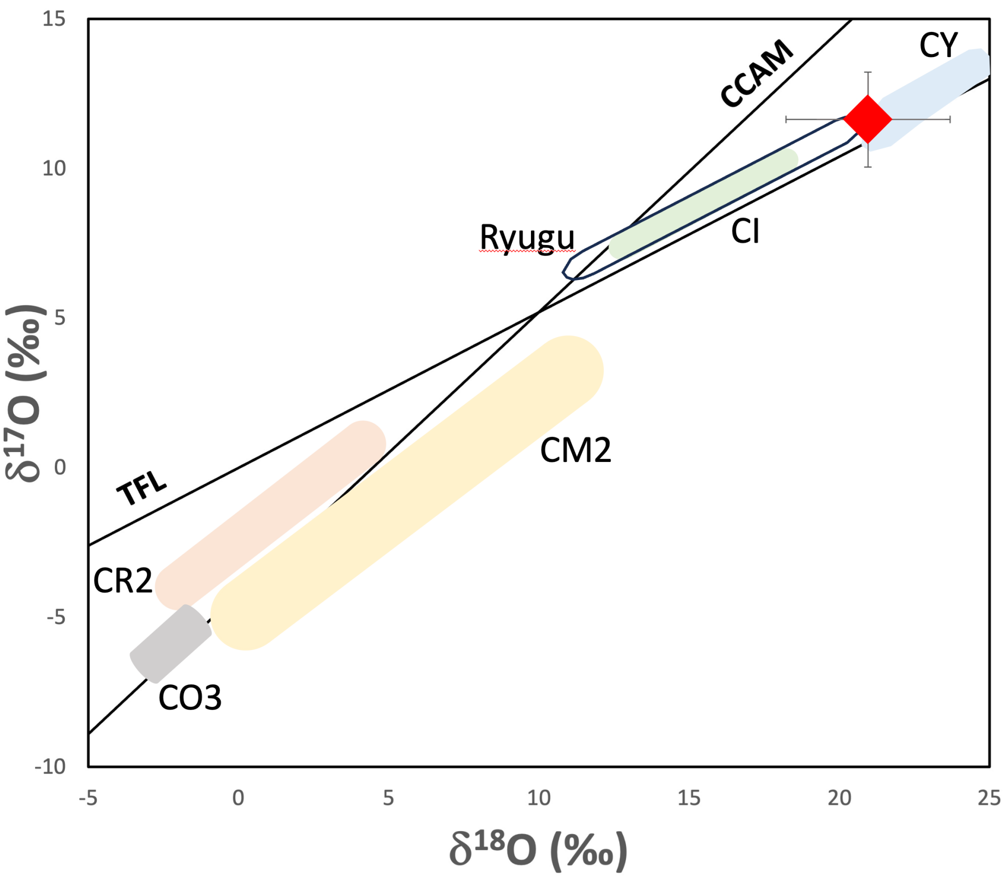

Figure 1. Oxygen isotope plot of weighted average of Bennu samples (red diamond) compared to the major primitive carbonaceous chondrite groups and asteroid Ryugu samples. Figure adapted from [5]. All data from OU lab except data for CYs and Ryugu that also include results from literature - see [5] for references to literature data.