

**XENON ISOTOPIC ANALYSIS OF INDIVIDUAL INTERMEDIATE PARTICLES FROM THE OSIRIS-REx SAMPLE OF ASTEROID BENNU.** S. A. Crowther<sup>1</sup>, J. D. Gilmour<sup>1</sup>, J. S. Cowpe<sup>1</sup>, L. Fawcett<sup>1</sup>, J. J. Barnes<sup>2</sup>, A. N. Nguyen<sup>3</sup>, H. C. Connolly Jr.<sup>2,4,5</sup> and D. S. Lauretta<sup>2</sup>; <sup>1</sup>Department of Earth and Environmental Sciences, The University of Manchester, Manchester, UK (sarah.crowther@manchester.ac.uk); <sup>2</sup>Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA; <sup>3</sup>ARES, NASA JSC, Houston, TX, USA; <sup>4</sup>Department of Geology, Rowan University, Glassboro, NJ, USA; <sup>5</sup>Department of Earth and Planetary Science, American Museum of Natural History, New York, NY, USA.

**Introduction:** The OSIRIS-REx mission sampled material from the B-type asteroid Bennu [1-3] and delivered the sample to Earth on 24 September 2023. Here we present initial xenon isotopic analysis of individual intermediate particles of Bennu material collected by the OSIRIS-REx mission.

Noble gases are key tracers of Solar System evolution. Xenon is particularly useful among the noble gases because its nine isotopes allow multiple contributing sources to be unambiguously identified. The sun [4, 5], asteroids (as measured in meteorites [6, 7]), and comets (measured in the coma of comet 67P [8]) have distinct xenon isotopic signatures reflecting different mixtures of nucleosynthetic components. In addition, <sup>129</sup>I, <sup>238</sup>U, and <sup>244</sup>Pu decay with different half-lives, producing characteristic xenon signatures. Exposure of samples containing light rare earth elements and barium to cosmic rays produces xenon from spallation and secondary neutron capture reaction.

Noble gas analyses help address several of the driving hypotheses of the mission [9]. Particle-by-particle analysis can elucidate the diversity of material present and reveal distinct noble gas compositions, including the potential to detect presolar or cometary noble gas signatures on a small scale. The isotopic signature provides a fingerprint that can be used to constrain the sources of volatiles in planetary reservoirs and combined with other information (e.g. mineralogy and petrology of the material analyses) contributes to our understanding of the initial constituents, formation, and history of Bennu and its parent asteroid.

**Samples:** We have been initially allocated sample OREX-803021-0, a ~0.5 mg aggregate of fine (<100 μm) and intermediate (100-500 μm) particles. This sample came from material inside the Touch-and-Go Sample Acquisition Mechanism (TAGSAM) [1]. Five individual particles have been separated from this aggregate for initial xenon isotopic analysis: OREX-803060-0, OREX-803061-0, OREX-803062-0, OREX-803063-0, and OREX-803064-0 (Fig. 1).

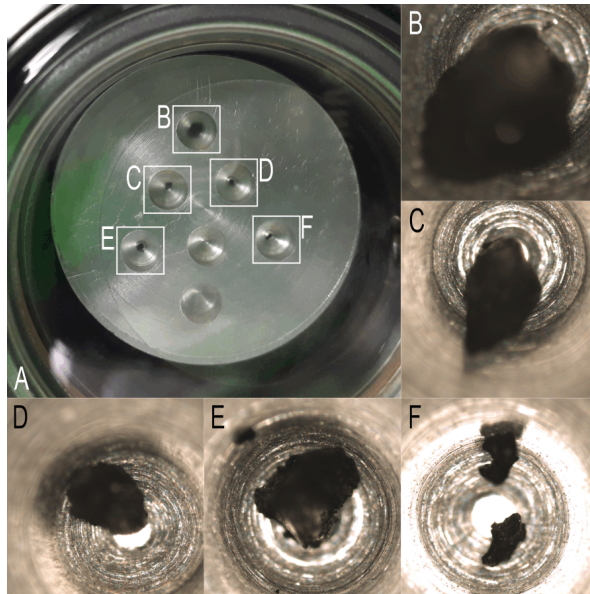
**Analytical methods:** The xenon isotopic analysis of the particles will be analysed using the RELAX mass spectrometer [10, 11]. Xenon will be extracted from the samples for isotopic analyses by heating with an infrared laser (JK Lasers JK50FL, λ = 1080 nm).

When samples are loaded into a noble gas mass spectrometer, the normal procedure involves evacuating the extraction line and sample port, and then baking them to temperatures ~160-180 °C. We have developed a protocol where we do not bake the sample port, so we can investigate any low temperature gases that might be lost from a sample during the baking [12]. After loading samples, both the extraction line and sample port are evacuated, the port is then isolated from the line, and only the extraction line is baked. The sample port is then pumped at room temperature for ~2 weeks to preserve low temperature components. This protocol has been applied to analyses of the Winchcombe (CM2) meteorite [12].

Our protocol [12] of not baking the sample port and instead pumping at room temperature is being applied to the Bennu samples. At the time of writing, the five OSIRIS-REx sub-samples are loaded in a RELAX sample port (Fig. 1) and are pumping at room temperature. Samples were handled in a nitrogen atmosphere and were not exposed to the Earth's atmosphere through the whole process of sample preparation (including documenting and imaging) and loading into the mass spectrometer.

**Discussion:** Exposure of volatile-rich carbonaceous chondrites to the terrestrial environment causes loss of important information about their composition and history [13]; returned samples such as the material delivered from asteroid Bennu by OSIRIS-REx can be protected and so enable a more accurate interpretation of the record inferred from carbonaceous meteorites.

One point of comparison for our data is provided by our analyses of the Winchcombe meteorite (~0.1-0.2 mg samples, two for naturally occurring xenon, three artificially neutron-irradiated to allow an I-Xe analysis) [12]. The xenon isotopic composition was dominated by Q-Xe [6] with variable contributions from solar wind [4, 5] and Xe-HL (a component enriched in heavy and light isotopes, identified in nanodiamonds [14]). Low temperature releases revealed excess <sup>129</sup>Xe (from the decay of <sup>129</sup>I, half-life 16.1 Ma [15]), which correlated with excesses in <sup>128</sup>Xe in neutron irradiated samples (artificial neutron irradiation converts <sup>127</sup>I to <sup>128</sup>Xe) and indicated a closure to xenon loss ~30 Myr after the start of the Solar System. Another is provided by our



**Fig. 1.** (A) RELAX sample holder inside the sample port, loaded with five OSIRIS-REx samples: (B) OREX-803064-0, (C) OREX-803062-0, (D) OREX-803060-0, (E) OREX-803061-0, and (F) OREX-803063-0. Sample OREX-803063-0 broke into two pieces on loading into the port. Scale: sample holes in the holder in (A) are 3 mm in diameter.

analyses of 0.6-11.5  $\mu\text{g}$  fragments from asteroid Ryugu (returned by JAXA's Hayabusa2 mission) [16], and our high-resolution step pyrolysis of particle A0105-03 (0.100 mg) [17], which showed individual heating steps can be modelled as mixtures of Q-Xe and solar wind, with variable contributions from Xe-HL. There was no evidence of fission-derived xenon or a cosmogenic component. Excess  $^{129}\text{Xe}$  was observed in most heating steps, paving the way for an I-Xe analysis.

The OSIRIS-REx samples present the exciting opportunity to further expand our understanding of how xenon isotopic signatures vary across and within primitive material, which samples the building blocks of terrestrial planets, and to explore the potential for an I-Xe analysis to constrain the timing of volatile loss on planetesimals.

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