INVESTIGATING BENNU'S VOLATILE ACCRETION HISTORY THROUGH STEP-HEATING N-Ne-Ar ANALYSES OF SINGLE AGGREGATE PARTICLES.

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Introduction: NASA's OSIRIS-REx spacecraft delivered a sample from the carbonaceous asteroid (101955) Bennu to Earth on September 24, 2023. Since Bennu presumably accreted in the outer protoplanetary disk, beyond Jupiter's orbit, the collected material is expected to be rich in highly volatile elements such as H, C, N, and noble gases [1]—similar to Ivuna-type (CI) carbonaceous chondrites [2] and material from asteroid (162173) Ryugu returned by JAXA's Hayabusa2 spacecraft [3,4]. This type of material may have contributed to the volatile inventory of Earth and the other terrestrial planets.

Bulk CI chondrites record a narrow range of $\delta^{15}N$ values (i.e., the permil difference from the atmospheric $^{15}N/^{14}N$ ratio), averaging between +42 and 49‰ [2]. In contrast, recent analyses at CRPG's noble gas facility revealed that two pelletized Ryugu samples have lower $\delta^{15}N$ values of +18.1 ± 0.9‰ and +19.5 ± 0.9‰ [3,4]. Together with the low measured N abundances, this observation suggests that Ryugu has lost a ^{15}N-rich, labile organic phase due to pervasive aqueous alteration. Subsequent high-resolution step-heating analyses of an additional Ryugu particle demonstrated that the $\delta^{15}N$ value varies significantly during successive extraction steps (between +1.0 ± 1.0‰ and 65.8 ± 1.1‰) [5]; the variable N isotopic composition points to the presence of several isotopically distinct N-carrier phases in CI-type material.

Here, we report preliminary N-Ne-Ar results obtained for individual particles from an aggregate Bennu sample using the Noblesse–HR (Nu Instruments) noble gas mass spectrometer at CRPG's noble gas facility. In a companion abstract, we will present the noble gas (He, Ne, Ar, Kr, Xe) characteristics of other aggregate particles determined with a HELIX MC *Plus* [6]. Whereas the abundance and isotopic composition of noble gases permit detection of various presolar phases and the so-called phase Q, as well as quantification of solar wind–derived and cosmogenic components, the abundance and isotopic composition of N are expected to provide further insights into the origin and evolution of N-bearing phases in carbonaceous asteroids.

Analytical Procedure: Aggregate sample OREX-800032-100 was shipped from the Natural History Museum (NHM, London) under nitrogen. Single particles were then handpicked in a cleanroom (ISO 6) at CRPG and weighed using a XPR2U microbalance from Mettler Toledo. Four particles, between 0.034 and 0.244 mg in mass, were placed into different pits of a laser chamber and imaged using a binocular microscope. During this entire procedure, the particles were exposed to air. The Zn-Se-windowed laser chamber was then connected to the purification line of the Noblesse–HR, pumped to ultrahigh vacuum, and baked out at 100 °C overnight. Each particle was heated using a CO_2 laser (MIR 10, Elemental Scientific) at increasing laser power, and the fraction of N and noble gases (Ne, Ar) extracted at each step was analyzed using the Noblesse–HR in multi-collection. For several heating steps, the amount of N introduced into the mass spectrometer had to be decreased through volume dilution in the volume-calibrated purification line to match the $^{14}N^{14}N$ signal of air standard measurements.

Preliminary results: Ne and Ar isotope ratios obtained over the course of 11 heating steps indicate that sample OREX-803035-0 (0.101 mg) does not contain a detectable amount of implanted, solar wind–derived noble gases. Instead, the isotopic compositions of Ne and Ar point to the presence of a presolar component (potentially carried by nanodiamonds) in addition to phase Q. A large amount of N with a $\delta^{15}N$ value of ~35‰ is released at very low laser power, and a small fraction of N with a $\delta^{15}N$ value of ~70‰ is released during melting. The 'bulk' $\delta^{15}N$ value is ~40‰, which is remarkably similar to the N isotopic composition of CI chondrites, but significantly enriched in ^{15}N compared to Ryugu samples. Step-heating analyses of (at least) three additional particles will allow us to assess the variability in both the abundances and isotopic compositions of N, Ne, and Ar in aggregates from Bennu, with crucial implications for our understanding of its volatile accretion history.

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