

NOBLE GASES IN SAMPLES RETURNED FROM ASTEROIDS RYUGU AND BENNU.

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Introduction: The asteroid sample return missions, JAXA's Hayabusa2 [1] and NASA's OSIRIS-REx [2], from C-rich asteroids Ryugu and Bennu offer unique opportunities to sample pristine early solar system material, unaffected by terrestrial weathering and contamination, and with a known geological context. The comparison with most primitive members of carbonaceous –and inner solar system ordinary and enstatite– chondrite classes allows us to (i) assess the variation (or the lack of thereof) of the distribution of the most volatile elements throughout the entire early solar system, (ii) determine the effects of parent body thermal and aqueous alteration, and (iii) learn about the dynamic evolution and history of the various parent bodies, as sampled by both return missions and meteorite delivery. Here we will present noble gas data obtained from newly received particles from Ryugu and Bennu.

Samples & Analysis: We received nine particles allocated by JAXA, with masses of 0.5-1.7 mg mass: four collected during Hayabusa2's first touchdown (chamber A) and five from a small artificial crater (chamber C). We received three particles from Bennu of 0.07, 0.89 and 0.94 mg mass (OREX-800032-102/3/4). All particles were processed, allocated, weighed, and transferred into our UHV sample chamber within pure N₂, to prevent any contact with air. We examined all He-Xe isotopes with our custom-built mass spectrometer "Albatros" ([3,4]). Gases were extracted individually from each particle by melting induced by a 1064 μm Nd:YAG IR laser in 2–4 heating steps. Large amounts of water and other reactive volatiles were released, consistent with the presence of abundant volatiles from both Ryugu and Bennu. Residues of Ryugu particles remaining after lasering, subsequently exposed to air, were additionally extracted in a crucible to verify complete gas extraction. Only the particle that still showed a "crystalline" structure after lasering contained detectable Ryugu noble gases, whereas all other particles turned immediately into glassy spheres by laser heating and lacked any gas.

Results & Discussion: Ryugu and Bennu matter contains noble gases similar to the most pristine, unheated aqueously altered meteorites, e.g., CM or CI chondrites [5,6]. Remarkably, all four chamber A samples that originated from Ryugu's surface show solar wind (SW) Ne (trapped $(^{20}\text{Ne}/^{22}\text{Ne})_{\text{tr}} \sim 12\text{--}13$), whereas all five chamber C samples do not ($(^{20}\text{Ne}/^{22}\text{Ne})_{\text{tr}} \sim 9.0\text{--}10.7$ consistent with the presence of non-solar trapped Ne components such as Q and HL). This demonstrates that JAXA's sampling strategy succeeded: Chamber C samples analyzed in this work originated from areas shielded from SW, slightly below the surface, that was sampled after the impactor excavated material. The three Bennu particles populate the same range as the Ryugu particles in Ne isotope space with one particle containing SW suggesting that it was part of the uppermost surface layer of Bennu during sampling, while Ne in the smallest sample can be explained best by mixing Ne from presolar diamonds and SiC or graphite, and that in the third one by mixing of, e.g., Q and HL. Using cosmic ray production rates given by [7] yields preliminary exposure ages for Ryugu particles in the same range as determined in [7]. There is, as expected, also no systematic difference between samples from chambers A and C because both sample sets were likely collected within the uppermost layer of Ryugu, which were not shielded from cosmic rays. The concentration of cosmogenic (cos) Ne in the Bennu particle, where Ne_{cos} was resolvable, is in the same range as found for Ryugu, suggesting roughly similar exposure time to cosmic rays for 5–8 Ma for all particles examined here.

The Xe isotopic compositions of all particles are consistent with those of phase Q, with small additions of Xe-HL from presolar diamonds and excess $^{129}\text{Xe}^*$ from short-lived ^{129}I decay. The comparably high $^{129}\text{Xe}^*/^{129}\text{Xe}_{\text{Q}}$ ratio is similar in all samples, suggesting similar initial I concentrations and closure to Xe loss –or the incorporation of a well-mixed Xe reservoir. The Bennu material was in brief contact with air in the capsule, after atmospheric entry and before storage in pure N₂ in a clean room. Both, the –most diagnostic– Xe isotopes and the Ar/Xe vs. Kr/Xe systematics prove that the noble gases are not affected by terrestrial contamination, in contrast to many CI, CY, and CM chondrites found on Earth [5,6], illustrating the importance of sample return. He-Xe concentrations in all particles unaffected by SW are comparable to but at the upper end of ranges reported [5-7]. In accordance with the strong aqueous alteration experienced on the parent bodies of Ryugu and Bennu [1,2], all samples lack the Ar-rich and water-susceptible noble gas components found in less aqueously altered CMs or CRs [e.g., 5,8] and all COs.

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References: [1] Tachibana S. et al. (2022) *Science* 375: 1011-1016. [2] Lauretta D.S. et al. (in rev.): *Meteoritics & Planetary Science*; arXiv:2404.12536. [3] Busemann H. et al. (2000) *Meteoritics & Planetary Science* 35: 949-973. [4] Riebe M.E.I. et al. (2017) *Meteoritics & Planetary Science*: 52: 2353-2374. [5] Krietsch D. et al. (2021) *Geochimica Cosmochimica Acta* 310: 240-280. [6] King A.J. et al. (2019) *Chemie Erde* 79: 125531. [7] Okazaki R. et al. (2023) *Science* 379: eabo043. [8] Krietsch D. (2020) *Doctoral thesis* 26964, 213 p., ETH Zurich, Switzerland.