

THE HETEROGENEOUS HYDROGEN ISOTOPIC COMPOSITION OF BENNU SAMPLES.

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Introduction: Carbonaceous asteroids are potential contributors to water in the inner solar system and are likely to have contributed to the Earth's water budget. A fundamental tool that provides important constraints on the distribution of water reservoirs at the time of planetary formation is the hydrogen isotopic composition of primitive rocks derived from carbonaceous asteroids. However, only few primitive undifferentiated meteorites (chondrites) are available for certain types of carbonaceous asteroids, and the potential of terrestrial contamination limits our ability to comprehend the distribution of water reservoirs in the protoplanetary disk from such materials.

On September 24, 2023, NASA's OSIRIS-REx mission delivered to Earth 121.6 g of fresh and pristine carbonaceous regolith from asteroid (101955) Bennu [1]. The petrology of Bennu samples revealed that it is the closest meteorite analogs are the chemically primitive chondrites, Ivuna-type carbonaceous chondrites (CIs), and the samples returned by the JAXA's Hayabusa2 mission from the carbonaceous asteroid (162173) Ryugu [1-3]. Bennu's rock fragments underwent extensive aqueous alteration on the parent asteroid and are predominantly composed of hydrated sheet silicates (serpentine, smectite; ~80 vol.%) and other secondary minerals [1-2]. In order to obtain hints on the initial volatile-bearing constituents of Bennu's parent asteroid (i.e., ices and organics), we have measured the D/H and C/H ratios in chondritic matrices by secondary ion mass spectrometry (SIMS) in individual fine- to intermediate-sized particles of Bennu.

Methods: SIMS data were obtained with an IMS 1280-HR2 instrument at CRPG on eleven different particles separated from the OREX-800045-0 aggregate sample at CRHEA (Nice, France). The particles (sub-sample named OREX-800045-113 and OREX-800045-114) were pressed one by one in indium on two 1-inch mounts. Scanning electron microscope (SEM) images of the pressed particles were used to characterize the mineralogy of the particles and select flat areas of ground mass fine-grained matrix for the SIMS measurements. The SIMS data were obtained using a Cs⁺ primary beam accelerated at 10 kV, and H⁺, D⁺, ¹³C⁺ and ²⁹Si⁺ ions were collected from 12 x 12 μm² areas following the procedure described in [4-5]. After SIMS analyses, the location of each analysis was checked with the SEM and areas analyzed that contain cracks or holes were excluded.

Results and discussions: Of the eleven Bennu particles, four particles show sharp angles and flat planar faces and were identified to belong to the angular morphology [1-2], four particles do not show any angularity or flat planar faces and are identified as "non-angular", and three other particles show less-clear angles and were referred to as "unknown". Given their shape and size, non-angular particles could correspond to the round clasts observed in the Bennu's hummocky particles [1-2].

Although the size of the SIMS spots (~15 μm) is much larger than the typical matrix grain size (< μm), the δD and C/H ratios in chondritic material vary according to the proportion of the main H-bearing components: the D-rich organic matter and the relatively D-poor phyllosilicates [4]. In most of the fresh carbonaceous chondrites [5], including the CI-chondrites Orgueil and Oued Chebeika 002, and in the particles of Ryugu [6], the δD and ¹³C/H ratios show a positive correlation that could then be extrapolated to the zero intercept to estimate the δD ratio of water recorded in hydrated minerals without contribution of hydrogen from organics. In Bennu's samples, we observed that angular particles have a D/H composition similar to that of Ivuna-type carbonaceous chondrites (CI) and asteroid (162173) Ryugu. However, the non-angular particles present significant differences in their δD values (with both higher and lower δD than for angular particles) and their δD and C/H positive trends are different from what is observed in other types of hydrated chondritic materials. This variable D/H composition cannot simply be the result of asteroidal evolution and requires either the mobilization of different fluids or the accretion of heterogeneous asteroidal building blocks.

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