OSIRIS-REx: Prospects for the Return of Pristine Carbonaceous Regolith from Asteroid (101955) Bennu

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The primary objective of the OSIRIS-REx mission to asteroid (101955) Bennu is to return pristine carbonaceous regolith that may hold clues to the origins of life. The 500-m near-Earth asteroid Bennu was chosen as a target for sample return based on its orbital characteristics and its spectral properties that suggested an affinity to hydrated, organic-rich carbonaceous chondrites. Primitive chondritic meteorites formed early in solar system history. They provide the opportunity to study the materials, processes, and events that formed our planetary system, including the delivery of pre-biotic organics and volatiles to Earth. The OSIRIS-REx spacecraft arrived at Bennu in December 2018. Proximity operations focused on global mapping using a suite of cameras, spectrometers, and scanning lidar to characterize Bennu’s surface properties, particle size distribution, and composition. With this information, the OSIRIS-REx team performed an extensive site selection process, ultimately designating a primary and a back-up sample site, named Nightingale and Osprey, respectively.

Characterization of Bennu’s surface demonstrates that this asteroid is the ideal target to meet the mission objective of returning hydrated and organic-rich material from the early solar system. Bennu’s near-infrared spectral signature is dominated by a 2.7-μm absorption feature that arises owing to bound hydroxyl molecules and is most consistent with Mg-bearing phyllosilicates. Broadband filter photometry suggests a high abundance of the iron oxide mineral magnetite. Thermal infrared spectra exhibit silicate stretching and bending modes; these modes are also consistent with volumetrically dominant phyllosilicates and the presence of magnetite. These observations indicate that Bennu is compositionally similar to the aqueously altered carbonaceous chondrites and, in particular, the highly altered CI and CM chondrites. Given the enormous (>15 m) boulders on the surface, this aqueous alteration likely occurred on a precursor parent body with a diameter of order 100 km. Catastrophic disruption of this object resulted in the subsequent rubble-pile re-accumulation of Bennu.

Recent observations of Bennu reveal widespread carbonate spectral features. Correlation of these features with imagery shows that, in many cases, they are associated with bright veins that transect exposed boulder surfaces. These veins range in measured thickness from 3 to 14 cm, with lengths of 30 to 60 cm. Further, we observe organics and carbonates occurring together in visible to near-infrared spectra of Bennu. These organic-carbonate spectral mixtures indicate that the abundances, grain sizes, or outcroppings of these materials on Bennu are distinct from those of meteorites and other asteroids. The carbonate detection implies that Bennu’s parent body experienced extensive aqueous alteration, similar

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to, or possibly more intense, than indicated in the carbonaceous chondrite meteorite record. If the observed bright veins are carbonates, this would indicate hydrothermal deposition and crystallization at larger scales than previously anticipated or observed for carbonaceous asteroids, where alteration generally has been presumed to occur locally (at the micron scale) in lithified systems resembling meteorites. We investigate the implications for Bennu's geologic history and hydrothermal conditions on its parent body.

Keywords: (101955) Bennu, OSIRIS-REx, Sample Return, Asteroid, Small Bodies

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