Ontology: /639/33/445/848 ; /639/33/445/2810 ; /639/33/445/849

BOOK

Seeing Bennu through the eyes of OSIRIS-REx

Reviewed by Queenie H.S. Chan[1]. E-mail: queenie.chan@rhul.ac.uk

[1]Centre for Dynamic Earth and the Solar System (CeDESS), Department of Earth Sciences, Royal Holloway University of London, Egham, UK.

Book cover image: see attached

Book title: Bennu 3-D: Anatomy of an asteroid

Book authors: Dante S. Lauretta, Brian May, Carina A. Bennett, Kenneth S. Coles, Claudia Manzoni, Catherine W. V. Wolner

Book publisher: Univ. Arizona Press: July 2023. 208 pp. $50.

Since the 1700s, we have recognized that rocks of extraterrestrial bodies are delivered to the Earth's surface as meteorites, which have seeded the inhabitable ancient Earth with two important ingredients for life — water and organic matter. Over the last few decades, sample-return space missions have offered unique opportunities to collect samples from targeted Solar System bodies and bring them back to our home planet to validate scientific speculations. This year, gearing up our curation facilities and laboratory resources, we await the return of the Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-REx) mission, with samples from a hydrated carbonaceous asteroid — Bennu.

Written by Dante Lauretta, the Principal Investigator for OSIRIS-REx, and a team of mission scientists including musician and astronomer Brian May, who was brought to the mission science team as the three-dimensional (3D) stereoscopic photographic specialist, *Bennu 3-D Anatomy of an Asteroid* unfolds chapter-by-chapter the complexity of the planning and implementation of the OSIRIS-REx mission. The authors have unreservedly showcased throughout the book stunning stereoscopic images collected by OSIRIS-REx. The 3D images provide the most captivating way to experience the mission, visualising the experience as if you were travelling onboard this seven-year long expedition.

As the book begins, it gives a 'lightning explanation' of how generating stereoscopic images is no simple matter: the team factors in the movement of spacecraft, Bennu's orbit and rotation, and shadow adjustments, which must be resolved to produce the 3D images that our minds can properly comprehend. The authors then give readers a grasp of knowledge fundamental to planetary science, providing timelines of asteroid exploration, Bennu's formation history, and OSIRIS-REx mission activities, all of which bring clarity to their temporal complexity to a broad range of readers.

Bennu, carefully selected from > 500,000 asteroid candidates, is a voyager itself. The earliest asteroidal components were formed via accreting ices and organic molecules processed in the molecular cloud that preceded our Solar System. The book explains the journey of the asteroid moving inwards from the outer to the inner Solar System, and its evolution through processing by percolating hydrothermal fluid, colliding and mixing with other Solar System objects, being shattered, and reaccreted into the current rubble pile (a collection of shattered debris) that still hosts boulders of the possible catastrophic impact culprit. These boulders are clearly visible on the stereo images as bright foreign rock fragments that oddly stand out from the average surface of Bennu. OSIRIS-REx observed the asteroid's contemporary evolution, including the process of ricocheting rocks off the asteroid's airless surface that experiences more than 100 °C of daily temperature change, sent to the eyes of the readers by the particle ejection paths illustrated in the 3D images.

Roaming around the Earth are thousands of 'potentially hazardous asteroids (PHAs)' like Bennu. The idea and reality of it fuelled our culture and curiosity for ongoing scientific explorations. The influences of the Yarkovsky effect pushing Bennu towards the Sun and the YORP effect changing the spin of the asteroid, explain how Bennu ended up in the current near-Earth position — which is just about 400,000 km when it is closest to the Earth, threatening us with a projected trajectory to possibly strike Earth in the late 22nd century. This justifies the selection rationale of Bennu as the target asteroid of the OSIRIS-Rex mission, among the various critical criteria discussed in the book.

Being a potential threat of catastrophic natural disaster, as well as a ‘seed of life’, the mission was given the name Osiris — a deity in ancient Egyptian mythology with a dual nature of life and death. Added to the visual enjoyment provided by the range of high-resolution images of Bennu’s terrain are the descriptions and fascinating reasonings for how features were named. Names were given to boulders, craters, and geographically important regions by referencing mythological birds from various cultures, which have added a mysterious vibe to the exploration, decorated with the colour of human culture. For instance, Simurgh Saxum, a 40-m-sized boulder that defines the prime meridian on Bennu and forms the basis of the asteroid’s co-ordinate system, was named after an enormous benevolent bird in Iranian or Persian mythology that bridges the Earth and the sky.

Destined for collecting and returning samples from Bennu, the OSIRIS-REx spacecraft was equipped with a range of cameras and scientific instruments, each has its own assigned purpose. The first glimpse of Bennu was imaged by the telescopic PolyCam imager, the base map was constructed from over 2,000 PolyCam images, and maps reflecting Bennu’s physical and chemical properties, including the distribution of water, were all documented in the book, to leave readers flabbergasted.

Among the many critical decisions made, OSIRIS-REx had to choose its landing site – a safety versus sampleability dilemma to be faced by all space missions that require landing on targets in space, a feat which was particularly difficult on the fast-spinning Bennu. The book describes the unexpected challenge of locating a fine-grained landing site on an alien world of boulders, of which some are as large as a building. Nightingale was chosen as the final landing site, head-to-head against the backup site Osprey, and the decision making was based heavily on studying stereo images.

“Landing a van-sized spacecraft in a narrow area that was only the size of a few parking spaces” was perfectly used as an analogy in the book to envisage the landing challenge. For OSIRIS-REx, with the final sequence operated fully autonomously, and an 18-minute communication delay, this touchdown could not afford to fail. The remarkable series of 3D images reveal every breathtaking moment of the Touch-and-Go operation, stunning us with the dancing surface debris kicked off by the sampling apparatus (Figure 1).

Rightfully the mission’s highlight, OSIRIS-REx has collected over 150 g of materials from an organic-rich site on a pristine asteroid, the largest amount of asteroidal sample ever collected, and it will be returned to Earth in September 2023. The OSIRIS-REx samples will permit numerous state-of-the-art scientific analyses, including using techniques that can reveal the origins of the components as they were initially formed when our Solar System began and how they have evolved. The samples will validate, or revolutionise, our understanding of the building blocks of our Solar System.

Figure 1 | A stereo image showing the breath-taking moment the OSIRIS-REx spacecraft backed away from the surface of Bennu after the successful touchdown. The spacecraft collected 150 g of materials from the sample site in October 2020 and will return it to Earth in September 2023. *Credit: Lauretta et al. (2023).*

Competing Interests

The author declares no competing interests.

ANATOMY OF AN ASTEROID

BENNU

NASA'S OSIRIS-REX MISSION

3-D

DANTE LAURETTA

BRIAN MAY

CARINA A. BENNETT

KENNETH S. COLES

CLAUDIA MANZONI

C. W. V. WOLNER