Rumbling rubble-pile asteroids

Recent missions to the rubble-pile asteroids Bennu and Ryugu have revealed asteroid surfaces that continue to be actively modified by a variety of processes while also recording the geologic history of these small bodies.

Asteroids are small, airless bodies that orbit the Sun. Either rocky or metallic, they come in many shapes and sizes, and display a range of compositions and interior evolutionary histories. Once mainly observed from afar by telescopes, several recent missions have brought spacecraft close to — and even onto — asteroids, bringing the surfaces of these small bodies into unprecedented focus. This issue features three articles about the asteroid Bennu — accompanied by an online collection of papers (https://www.nature.com/collections/ihbccdccff) from across Nature Portfolio — that provide insights into the geologic processes operating on asteroid surfaces and reveal clues about their histories.

In 2018, JAXA's Hayabusa2 mission and NASA's OSIRIS-REx mission arrived at the near-Earth asteroids Ryugu and Bennu, respectively. Both asteroids are of the common carbonaceous variety and are thought to contain pristine material dating from the early Solar System. The missions centred on the exciting prospect of bringing samples back to Earth, with Ryugu's sample capsule successfully returning in late 2020 (see refs. [1,2] for early results) and OSIRIS-REx's sample is expected to touch down in 2023. Collecting the samples required the spacecraft to be instrumented to survey the asteroid surfaces at high resolution, in order to identify potential sampling locations. These images have yielded unexpected insights into the geological evolution of and the processes operating on asteroid surfaces.

Rubble-pile asteroids, as the name suggests, are composed of debris — typically the shattered remains of former asteroids, moons, or planetesimals broken up by past collisions — held weakly together by self-gravity. With limited interior heating, low gravity, and no atmosphere, it had been thought that the surfaces of these asteroids would evolve slowly over time with few disturbances. However, the small asteroids Ryugu (approximately 1 km in diameter) and Bennu (pictured; approximately 500 m in diameter) had some surprises in store.

Credit: NASA/Goddard/University of Arizona

When Hayabusa2 reached Ryugu, it found a very weak and readily damaged surface[3]. And, in this issue, Perry et al. (https://doi.org/10.1038/s41561-022-00937-y) find that Bennu's surface is similarly extremely weak. One implication of this, according to Bierhaus et al. (https://doi.org/10.1038/s41561-022-00914-5) is that gravity, not material strength, controls the size of impact craters. This reassessment implies that the resurfacing of Bennu by impact cratering processes has been occurring much more quickly than previously assumed based on crater mapping. Furthermore, Delbo et al. (https://doi.org/10.1038/s41561-022-00940-3) analyse the orientations of fractures imaged on individual boulders and find that the generation and propagation of the cracks by thermal fatigue — a space weathering process — operates on geologically rapid timescales. Boulders damaged by fracturing are more readily removed by small impacts, contributing to the active resurfacing of the asteroid. Overall, the results from Ryugu and Bennu show that the surfaces of rubble-pile asteroids are constantly being renewed, with consequences for the integrity, as well as geochemical and physical characteristics, of the asteroid as a whole.

International exploration endeavours are underway that will shed further light onto the inner workings and surface processes of a variety of asteroids. Both the Hayabusa2 and OSIRIS-REx spacecraft are speeding towards new targets: Hayabusa2 plans the first visit to a rapidly rotating microasteroid, 1998 KY26, and OSIRIS-REx has been directed to rendezvous with the near-Earth asteroid Apophis. NASA's DART mission — primarily a mission to test planetary defence technologies in asteroid deflection — is set to impact the small asteroid Dimorphos later this year. This will be followed by ESA's Hera mission that, in addition to surveying the consequences of DART, will study up-close the binary asteroid system that Dimorphos is a part of with the larger asteroid Didymos. NASA's Psyche mission to an iron asteroid — possibly the remnant core of a differentiated body — launches this year. Later this decade, JAXA's DESTINY^{+} mission plans to target the Geminid meteor shower's parent Phaethon — an asteroid displaying some puzzling comet-like characteristics — and China has an asteroid mission[4] under development that aims to return regolith samples.

The high-resolution views of Bennu and Ryugu have shown how much geology can happen on small rubble-strewn asteroids, despite conditions so very different from the terrestrial planets, and that it is possible to untangle the active geological processes at work if we can get up close. With so many asteroid missions in the works, we look forward to the geoscience these small worlds have to offer. ❐

Published online: 10 June 2022
https://doi.org/10.1038/s41561-022-00976-5

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