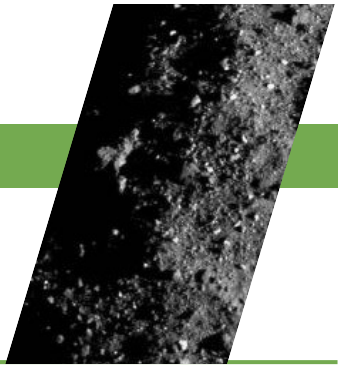
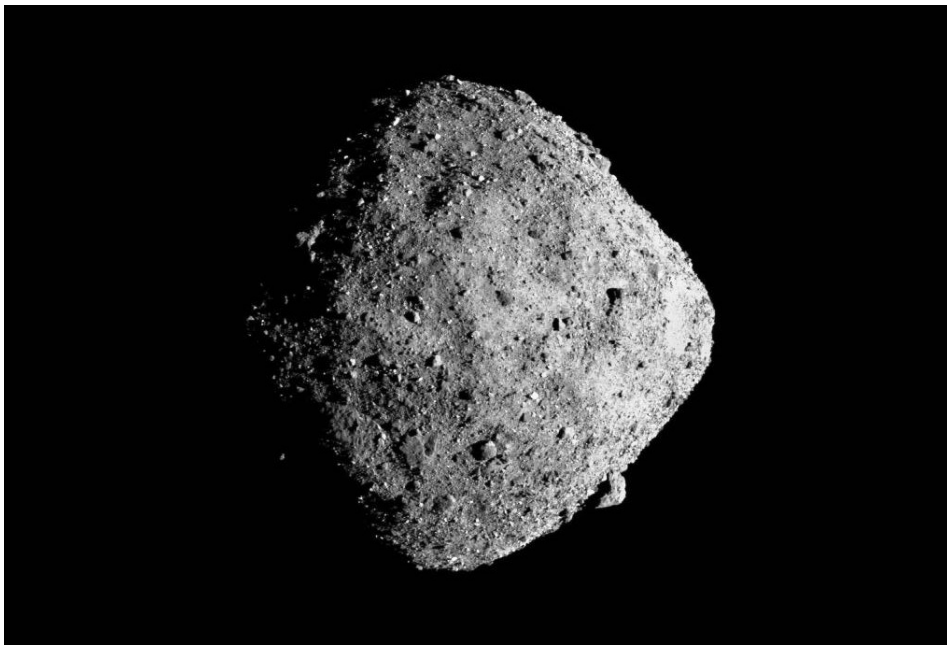


EARTH AND ENVIRONMENTAL SCIENCES

Bennu's Ancient Brine Sheds Light on Recipe for Life



This mosaic image of asteroid Bennu is composed of 12 images taken by the OSIRIS-REx spacecraft from a range of 15 miles. (Credit: NASA/Goddard/University of Arizona)

Scientific Achievement

With the help of the Advanced Light Source (ALS), researchers traced the evolution of minerals ("salts") in an ancient brine, as recorded in samples from the asteroid Bennu, returned to Earth by NASA's OSIRIS-REx mission.

Significance and Impact

The results support the idea that asteroids like Bennu may have delivered water and essential chemical building blocks of life to Earth in the distant past.

To Bennu and back again

During the past year, there's been an unusual set of samples at Berkeley Lab: material gathered from the 4.5-billion-year-old asteroid Bennu when it was roughly 200 million miles from Earth. Berkeley Lab is one of more than 40 institutions investigating Bennu's chemical makeup to better understand how our solar system and planets evolved. The samples from Bennu were gathered by NASA's OSIRIS-REx mission, the first US mission to return samples from an asteroid. The mission collected nearly 122 grams of material from Bennu—the largest sample ever captured in space and returned to Earth from an extraterrestrial body beyond the Moon.

In this study, researchers found evidence that Bennu contained a set of salty mineral deposits that formed in a specific sequence when a brine evaporated, leaving clues about the type of water that flowed billions of years ago. Brines could be a productive broth for cooking up some of the key ingredients of life, and the same type of minerals are found in dried-up lake beds on Earth (such as Searles Lake in California) and have been observed on Jupiter's moon Europa and Saturn's moon Enceladus.

Small samples, big collaboration

A large number of researchers from many institutions used a wide variety of techniques to study the samples. For the portion of the analysis described here, ALS scientists teamed up with researchers from the NASA Ames Research Center, UC Berkeley's Space Sciences Laboratory, and Berkeley Lab's Molecular Foundry. At the Foundry, the samples were carved into thin, microscopic sections and imaged using transmission electron microscopy (TEM).

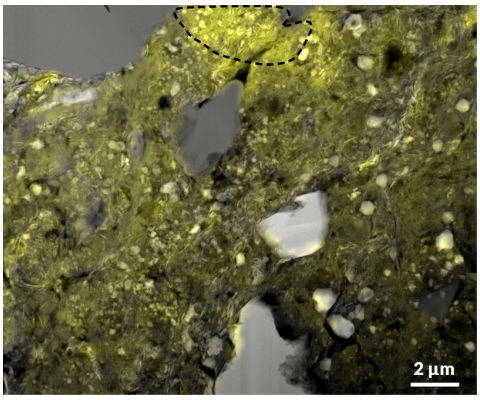
At ALS Beamline 5.3.2.2, scanning transmission x-ray microscopy (STXM) was used to probe the sample at the carbon K edge. The resulting information about molecular carbonate was mapped out at the nanometer scale and correlated with the Foundry's TEM scans. The ability to examine the same atoms using both STXM and TEM removed many of the uncertainties in interpreting the data.

Evaporation over time

The results revealed ubiquitous molecular carbonate that did not diffract as crystals and could represent an important reservoir of carbonate ions. The precipitation of carbonates would have affected the concentration and precipitation of other

salts in the Bennu brine and provides important clues about the processes, environments, and timing that formed the samples. Overall, the researchers concluded that the salts formed in a specific sequence via the evaporation of water from the brine over time.

Understanding these samples is important because they represent the types of materials that were likely seeded on the surface of the early Earth and may have played a role in the origins and early evolution of life. ALS researchers also contributed to a second Bennu paper that identified 14 of the 20 amino acids that life on Earth uses to build proteins. In addition, all five nucleobases (the ring-shaped molecules that form DNA and RNA) were found, as well as ammonia, which on Earth might have helped spark the emergence of early life. Based on the similarities between asteroid Bennu and the icy dwarf planets and moons of the outer solar system, these potential ingredients for life could be widespread.



STXM map shows a significant amount of diffuse carbonate (yellow shading) overlaid on a TEM image of a sample returned from Bennu asteroid. The data provides clues to the conditions under which liquid water evaporated.

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