OSIRIS-REx mission researchers detail history of asteroid Bennu

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Artist's conception of NASA's OSIRIS-REx spacecraft collecting a sample from the asteroid Bennu. Credit: NASA/Goddard/University of Arizona

NASA's OSIRIS-REx spacecraft mission, launched on Sept. 8, 2016, is the first U.S. mission designed to retrieve a pristine sample of an asteroid and return it to Earth for further study. The mission's target is Bennu, a carbon-rich near-Earth asteroid that is potentially hazardous, representing an approximately 1 in 2,700 chance of impacting the Earth late in the 22nd century.

Scientists believe Bennu may contain the molecular precursors to the origin of life and the Earth's oceans, so one of the mission's main objectives is to determine Bennu's physical and chemical properties.

"The spacecraft has been observing the asteroid for nearly two years now," said Joshua Emery, associate professor in NAU's Department of Astronomy and Planetary Science and a member of the OSIRIS-REx science team. "Bennu has turned out to be a fascinating small asteroid and has given us many surprises."

The mission's first attempt to pick up the sample is scheduled for Oct. 20, 2020, and the spacecraft is scheduled to return the sample back to Earth on Sept. 24, 2023. In advance of the sample collection, the science team published a set of six papers in *Science* and *Science Advances*, four of which Emery co-authored, to share its scientific findings to date while building interest in the upcoming event.

"We've been working for over a decade toward the upcoming sampling attempt," he said. "It's such an exciting time. The spacecraft will send back data pretty quickly to let us know if the maneuver itself was successful, and it'll be exciting to see images from the sampling event, which should be sent back within a day."

The papers describe the detailed characterization of the surface using images, spectroscopy (composition) and thermal measurements. Emery summarizes each of the four papers he co-authored:

- "Widespread carbon-bearing materials on near-Earth asteroid (101955) Bennu," published in *Science*: "OSIRIS-REx spectrometer data show absorptions ("fingerprints") of complex organic molecules and carbonate minerals on Bennu's surface.

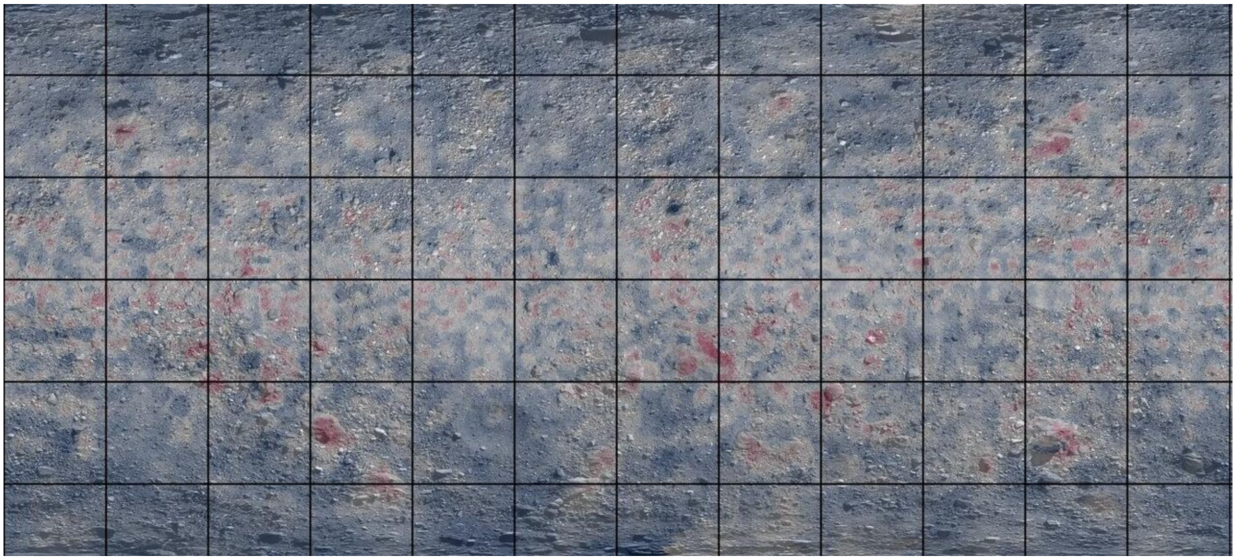
These materials do not appear to be spatially correlated to any specific geologic features or other compositions, but they are widespread across the surface. These data provide the first concrete detection of carbon-bearing materials on a near-Earth asteroid. The presence of organics on Bennu suggests that asteroids like Bennu may have brought organic molecules to Earth."

- "Bright carbonate veins on asteroid (101955) Bennu: Implications for aqueous alteration history," published in *Science*: "Detailed analysis of absorption features in OSIRIS-REx spectrometer data indicate that there are carbonates on Bennu and that these carbonates are similar to those found in certain meteorites. Images of Bennu show that some of the rocks contain bright veins that may be carbonate. Carbonates, and their occurrence in large abundance, mean that fluid flow and hydrothermal deposition on Bennu's parent body would have occurred over distances of kilometers for thousands to millions of years—conditions that suggest large-scale, open-system hydrothermal alteration of carbonaceous asteroids in the early solar system."
- "Asteroid (101955) Bennu's weak boulders and thermally anomalous equator," published in *Science Advances*: "By measuring and mapping the temperature of the surface of Bennu at different times of day, we can see how different rocks heat up and cool down, which enables us to determine physical properties of the surface rocks. This analysis distinguishes two boulder populations on Bennu that differ in thermal inertia (resistance to changes in temperature) and strength. Both have lower thermal inertia and inferred strength than expected for boulders and meteorites. The weaker boulder type probably would not survive atmospheric entry and thus may not be represented in the meteorite collection. Our findings imply that other NEAs likely have boulders similar to those on Bennu, rather than finer-

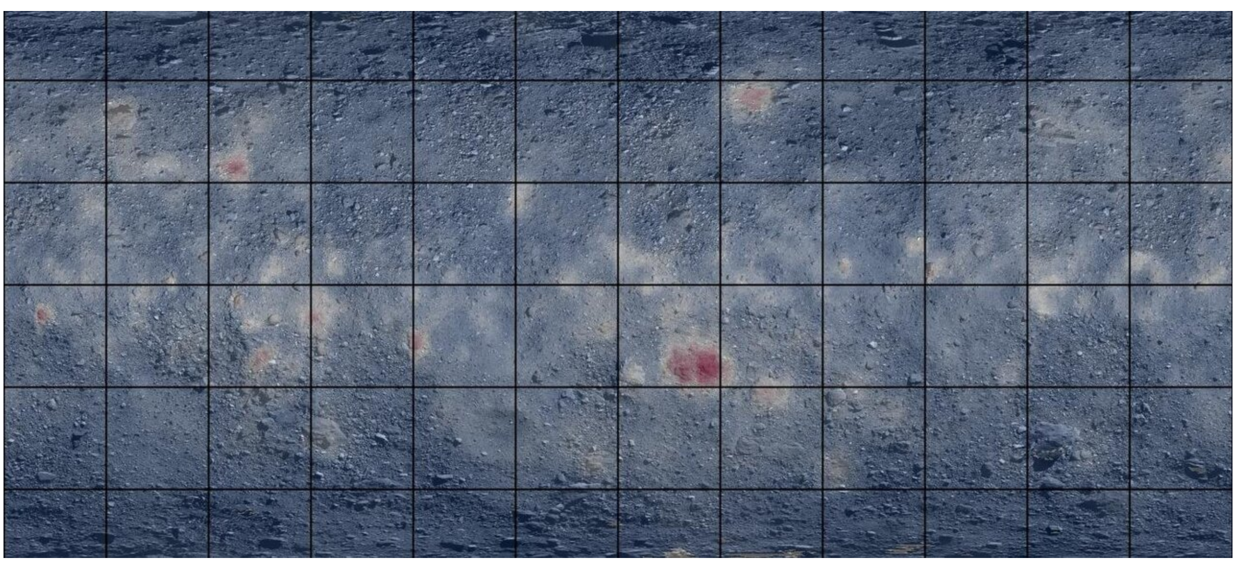
particulate regoliths."

- "Heterogenous mass distribution of the rubble-pile asteroid (101955) Bennu," published in *Science Advances*: "We measured the gravity field of Bennu in great detail using the OSIRIS-REx spacecraft trajectory and by mapping the orbits of small particles ejected from Bennu's surface. The gravity field provides insight into the interior structure of Bennu. These data show that Bennu does not have a uniform interior. Bennu's center appears to have a lower density than its average. The equatorial bulge also has a relatively low density. The lower-density equator is consistent with recent movement of material to the equator. The lower-density center suggests that Bennu used to spin much faster than its current 4.29 period 'day'."

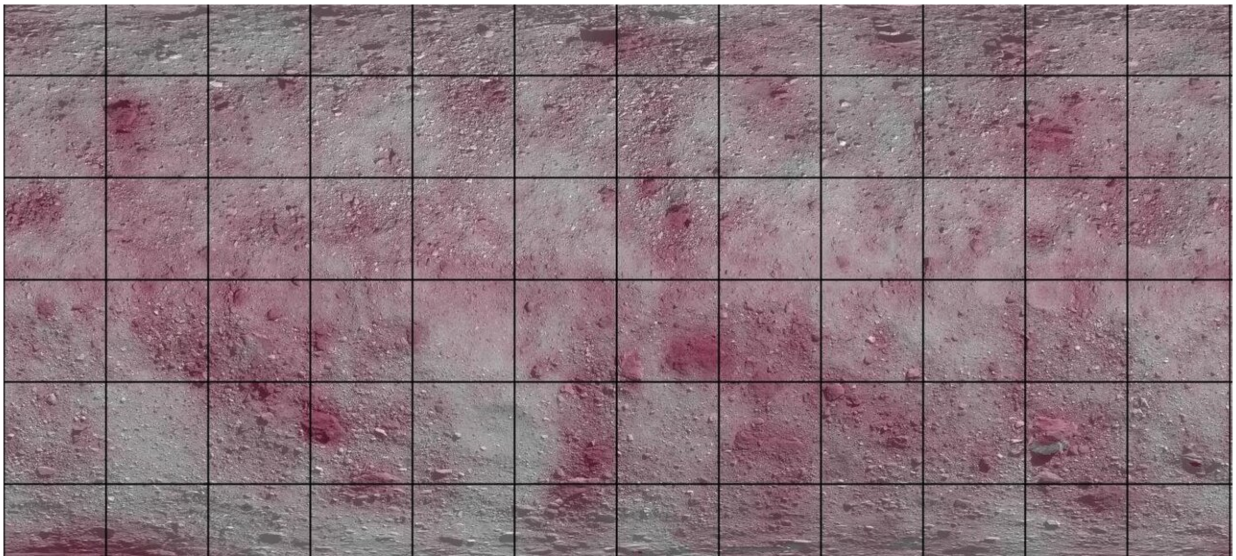
"It's been such thrill and honor to be part of the OSIRIS-REx team," Emery said. "As lead of the thermal analysis working group, it has been very exciting for me to be very involved in planning the observations the spacecraft has made in preparation for sampling and then figuring out from the data what the surfaces is like. The rocks on Bennu look strange, and we found from the thermal data that they are so weak that we could easily crush them in our hands. Still, they have existed on this asteroid for over a billion years! These rocks also contain complex organic molecules that form naturally in space, and asteroids like Bennu could have brought these organic molecules to Earth billions of years ago to seed the beginnings of life. When the sample is returned to Earth, scientists will be able to study these molecules in exquisite detail."



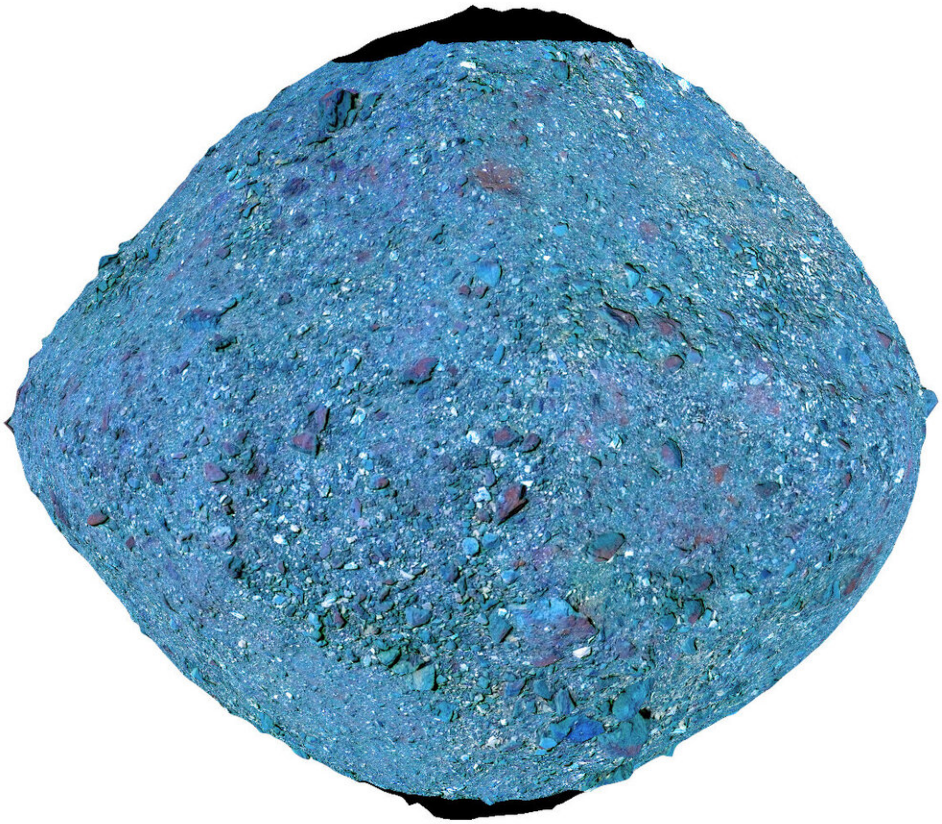
Global map of Bennu, spanning +/- 80 deg of latitude and 360 deg of latitude, showing the absorption attributable to carbon-bearing material; blue corresponds to little absorption, red to deeper absorption features. Credit: Simon et al., Science (2020)



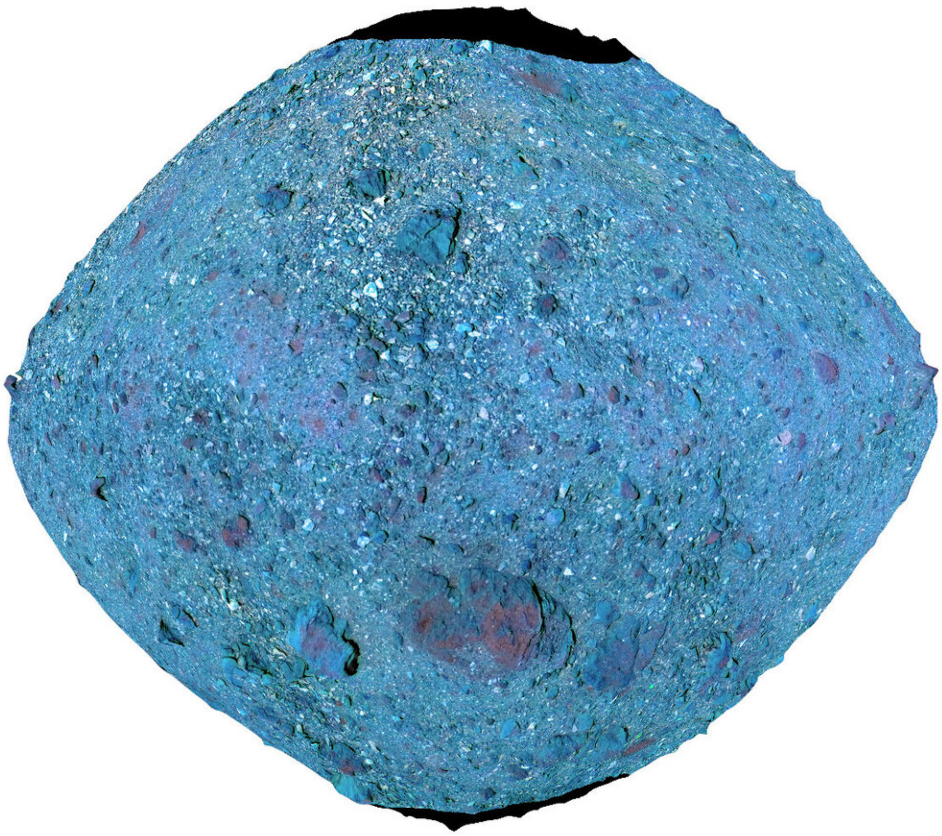
Global map of Bennu, spanning +/- 80 deg of latitude and 360 deg of latitude, showing exaggerated surface colors; the majority of the surface has a bluer slope with a few large redder boulders. Credit: Simon et al., Science (2020)



Global map of Bennu, spanning +/- 80 deg of latitude and 360 deg of latitude, showing peak surface temperature at 12:30 pm local solar time, ranging from 46 C (115 F) to 78 C (172 F). Credit: Simon et al., Science (2020)



False-color Red-Green-Blue (RGB) composites of asteroid Bennu. In these false-color composites, average and bluer than average terrain looks blue, surfaces that are redder than average appear red. Bright green areas correspond to the instances of a mineral pyroxene, which likely came from a different asteroid, (4) Vesta. Black areas near the poles indicate no data. Credit: NASA/Goddard/University of Arizona



False-color Red-Green-Blue (RGB) composites of asteroid Bennu. In these false-color composites, average and bluer than average terrain looks blue, surfaces that are redder than average appear red. Bright green areas correspond to the instances of a mineral pyroxene, which likely came from a different asteroid, (4) Vesta. Black areas near the poles indicate no data. Credit: NASA/Goddard/University of Arizona

Emery, who joined NAU in 2019, applies the techniques of astronomical reflection and emission spectroscopy and spectrophotometry of primitive and icy bodies in the near- (0.8 to 5.0 microns) and mid-infrared (5 to 50 microns) to investigate the formation and evolution of the Solar System and the distribution of organic material.

The Jupiter Trojan asteroids have been a strong focus of his research, and he also regularly observes Kuiper Belt objects, icy satellites and other asteroid groups to understand the state of their surfaces as related to these topics. In addition to contributing to Solar System exploration as a science team member on the OSIRIS-REx asteroid sample return mission, he also collaborated on the upcoming Lucy Trojan asteroid flyby mission and the NEO Surveyor Mission infrared telescope mission.

More information: DOI: 10.1126/science.abc3522 H.H. Kaplan el al., "Bright carbonate veins on asteroid (101955) Bennu: Implications for aqueous alteration history," *Science* (2020). science.sciencemag.org/lookup/ … 1126/science.abc3557

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