Remote sensing data sheds light on when and how asteroid Ryugu lost its water

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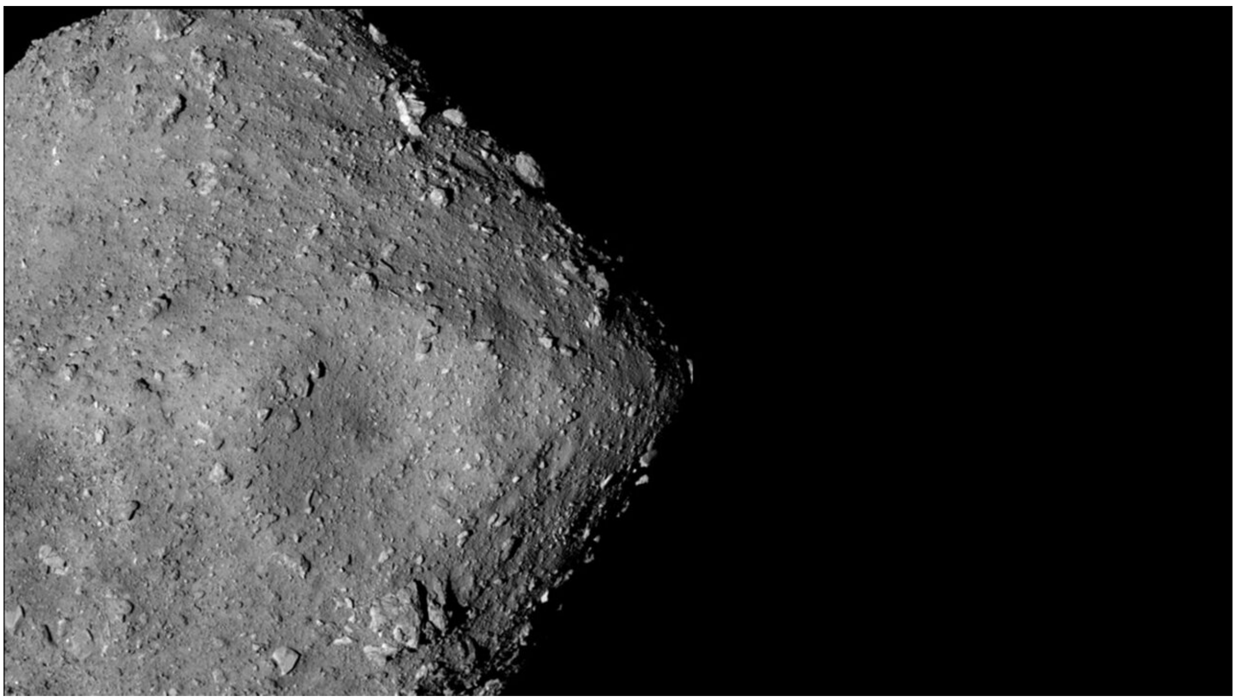

Japan's Hayabusa2 spacecraft snapped pictures of the asteroid Ryugu while flying alongside it two years ago. The spacecraft later returned rock samples from the asteroid to Earth. Credit: JAXA

Last month, Japan's Hayabusa2 mission brought home a cache of rocks collected from a near-Earth asteroid called Ryugu. While analysis of those returned samples is just getting underway, researchers are using data from the spacecraft's other instruments to reveal new details about the asteroid's past.

In a study published in *Nature Astronomy*, researchers offer an explanation for why Ryugu isn't quite as rich in water-bearing minerals as some other asteroids. The study suggests that the ancient parent body from which Ryugu was formed had likely dried out in some kind of heating event before Ryugu came into being, which left Ryugu itself drier than expected.

"One of the things we're trying to understand is the distribution of water in the early solar system, and how that water may have been delivered to Earth," said Ralph Milliken, a planetary scientist at Brown University and study co-author. "Water-bearing asteroids are thought to have played a role in that, so by studying Ryugu up close and returning samples from it, we can better understand the abundance and history of water-bearing minerals on these kinds of asteroids."

One of the reasons Ryugu was chosen as a destination, Milliken says, is that it belongs to a class of asteroids that are dark in color and suspected to have water-bearing minerals and organic compounds. These types of asteroids are believed to be possible parent bodies for dark, water- and carbon-bearing meteorites found on Earth known as carbonaceous chondrites. Those meteorites have been studied in great detail in laboratories around the world for many decades, but it is not possible to determine with certainty which asteroid a given carbonaceous chondrite meteorite may come from.

The Hayabusa2 mission represents the first time a sample from one of these intriguing asteroids has been directly collected and returned to Earth. But observations of Ryugu made by Hayabusa2 as it flew alongside the asteroid suggest it may not to be as water-rich as scientists originally expected. There are several competing ideas for how and when Ryugu may have lost some of its water.

Ryugu is a rubble pile—a loose conglomeration of rock held together by gravity. Scientists think these asteroids likely form from debris left over when larger and more solid asteroids are broken apart by a large impact event. So it's possible the water signature seen on Ryugu today is all that remains of a previously more water-rich parent asteroid that dried out due a heating event of some kind. But it could also be that Ryugu dried out after a catastrophic disruption and re-formation as a rubble pile. It's also possible that Ryugu had a few close spins past the sun in its past, which could have heated it up and dried out its surface.

The Hayabusa2 spacecraft had equipment aboard that could help scientists to determine which scenario was more likely. During its rendezvous with Ryugu in 2019, Hayabusa2 fired a small projectile into the asteroid's surface. The impact created a small crater and exposed rock buried in the subsurface. Using a near-infrared spectrometer, which is capable of detecting water-bearing minerals, the researchers could then compare the water content of surface rock with that of the subsurface.

The data showed the subsurface water signature to be quite similar to that of the outermost surface. That finding is consistent with the idea that Ryugu's parent body had dried out, rather than the scenario in which Ryugu's surface was dried out by the sun.

"You'd expect high-temperature heating from the sun to happen mostly at the surface and not penetrate too far into the subsurface," Milliken said. "But what we see is that the surface and subsurface are pretty similar and both are relatively poor in water, which brings us back to the idea that it was Ryugu's parent body that had been altered."

More work needs to be done, however, to confirm the finding, the researchers say. For example, the size of the particles excavated from the subsurface could influence the interpretation of the spectrometer measurements.

"The excavated material may have had a smaller grain size than what's on the surface," said Takahiro Hiroi, a senior research associate at Brown and study co-author. "That grain size effect could make it appear darker and redder than its coarser counterpart on the surface. It's hard to rule out that grain-size effect with remote sensing."

Luckily, the mission isn't limited to studying samples remotely. Since Hayabusa2 successfully returned samples to Earth in December, scientists are about to get a much closer look at Ryugu. Some of those samples may soon be coming to the NASA Reflectance Experiment Laboratory (RELAB) at Brown, which is operated by Hiroi and Milliken.

Milliken and Hiroi say they're looking forward to seeing if the laboratory analyses corroborate the team's remote sensing results.

"It's the double-edged sword of sample return," Milliken said. "All of those hypotheses we make using remote sensing data will be tested in the lab. It's super-exciting, but perhaps also a little nerve-wracking. One thing is for certain, we're sure to learn a lot more about the links between meteorites and their parent asteroids."

More information: K. Kitazato et al, Thermally altered subsurface material of asteroid (162173) Ryugu, *Nature Astronomy* (2021). DOI: 10.1038/s41550-020-01271-2

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