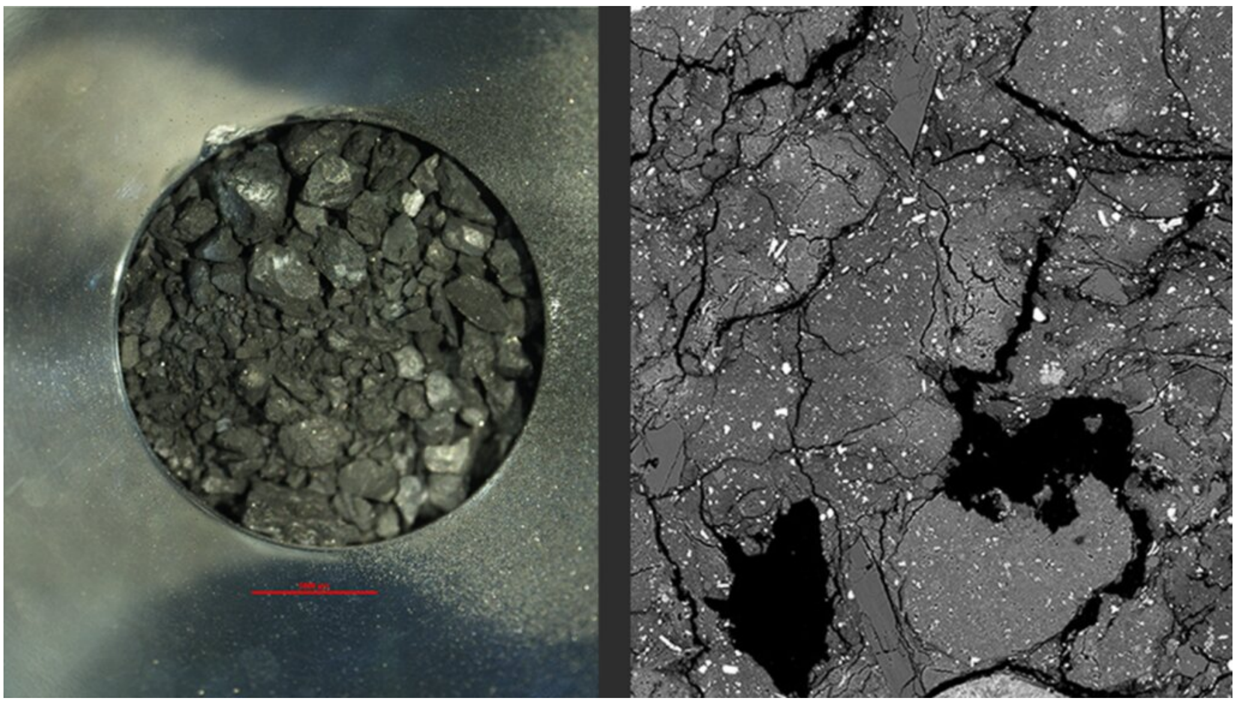
Scientists release first analysis of rocks plucked from speeding asteroid

June 9 2022, by Louise Lerner



Left: A photograph of the rocks retrieved by Hayabusa2 from the asteroid Ryugu. Right: a zoomed-in image of the structure of one of the pieces, taken by an electron microscope. Credit: JAXA/Yokoyama et al.

After a six-year journey, a plucky spacecraft called Hayabusa2 zinged back into Earth's atmosphere in late 2020 and landed deep in the Australian outback. When researchers from the Japanese space agency JAXA opened it, they found its precious payload sealed and intact: a handful of dirt that Hayabusa2 managed to scoop off the surface of a speeding asteroid.

Scientists have now begun to announce the first results from the analysis of this extraordinary sample. What they found suggests that this asteroid is a piece of the same stuff that coalesced into our sun four-and-a-half billion years ago.

"We previously only had a handful of these rocks to study, and all of them were meteorites that fell to Earth and were stored in museums for decades to centuries, which changed their compositions," said geochemist Nicolas Dauphas, one of the three University of Chicago researchers who worked with a Japan-led international team of scientists to analyze the fragments. "Having pristine samples from outer space is simply incredible. They are witnesses from parts of the solar system that we have not otherwise explored."

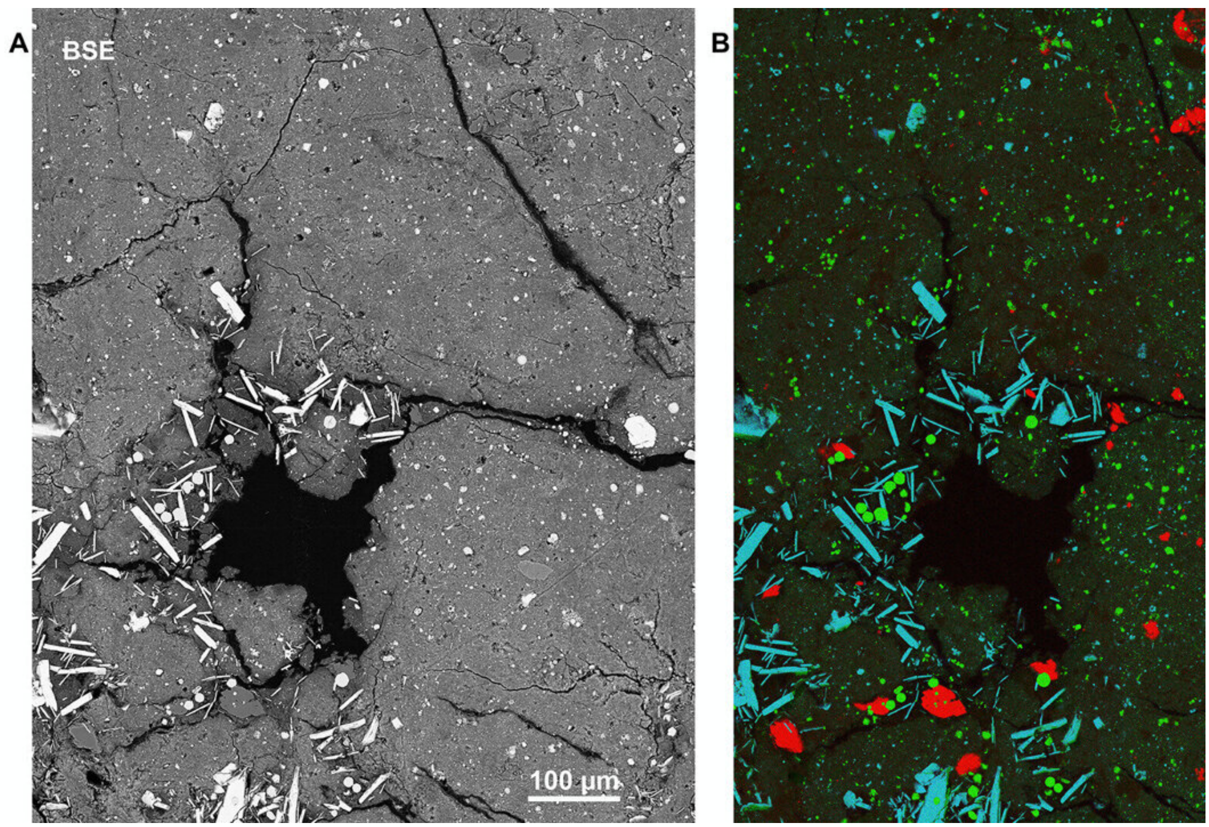
'It's spectacular'

In 2018, Hayabusa2 landed atop a moving asteroid named Ryugu and collected particles from above and below its surface. After spending a year and a half orbiting the asteroid, it returned to Earth with a sealed capsule containing about five grams of dust and rock. Scientists around the world have been eagerly anticipating the unique sample—one that could help redefine our understanding of how planets evolve and how our solar system formed.

Scientists are particularly excited because these particles would never have reached Earth without the protective barrier of a spacecraft.

"Usually, all we get to study of asteroids is the pieces that are big enough to make it to the ground as meteorites," said UChicago geochemist Andrew M. Davis, another member of the analysis team. "If you took this handful and dropped it in the atmosphere, it would burn up. You would lose it, and a lot of evidence about the history of this asteroid would go with it.

"We really haven't had a sample like this before. It's spectacular."



Petrography of the Ryugu sample. (A) Backscattered electron (BSE) image of Ryugu sample A0058-C1001. The black space in the figure is a pore. (B) Combined elemental map of the same sample, with characteristic X-rays of Ca Kα, Fe Kα, and S Kα lines assigned to RGB color channels as indicated in the legend. Carbonate (dolomite), sulfide (pyrrhotite) and iron-oxide (magnetite) minerals are embedded in a matrix of phyllosilicates, and in some cases precipitated in small veins. The sulfide texture is similar to that in the ungrouped chondrite Flensburg. (C) Ternary diagram between Fe, Mg, and Si+Al showing bulk chemical compositions of phyllosilicates in A0058-C1001. Black lines are compositions of solid solution for serpentine and saponite. Each open red circle shows bulk chemical composition of phyllosilicates measured in various locations of panels A and B, each location being 5–10 μm square. We chose each size to exclude minerals other than phyllosilicates in the area. The bulk compositions differ from place to place, with a distribution indicating that the phyllosilicates consist of serpentine and saponite with variable Fe/Mg ratios. Uncertainties on each measurement are smaller than the symbol size. (D) BSE image of Ryugu sample C0002-C1001, showing brecciated matrix. The texture is similar to CI chondrites. Credit: *Science* (2022). DOI: 10.1126/science.abn7850

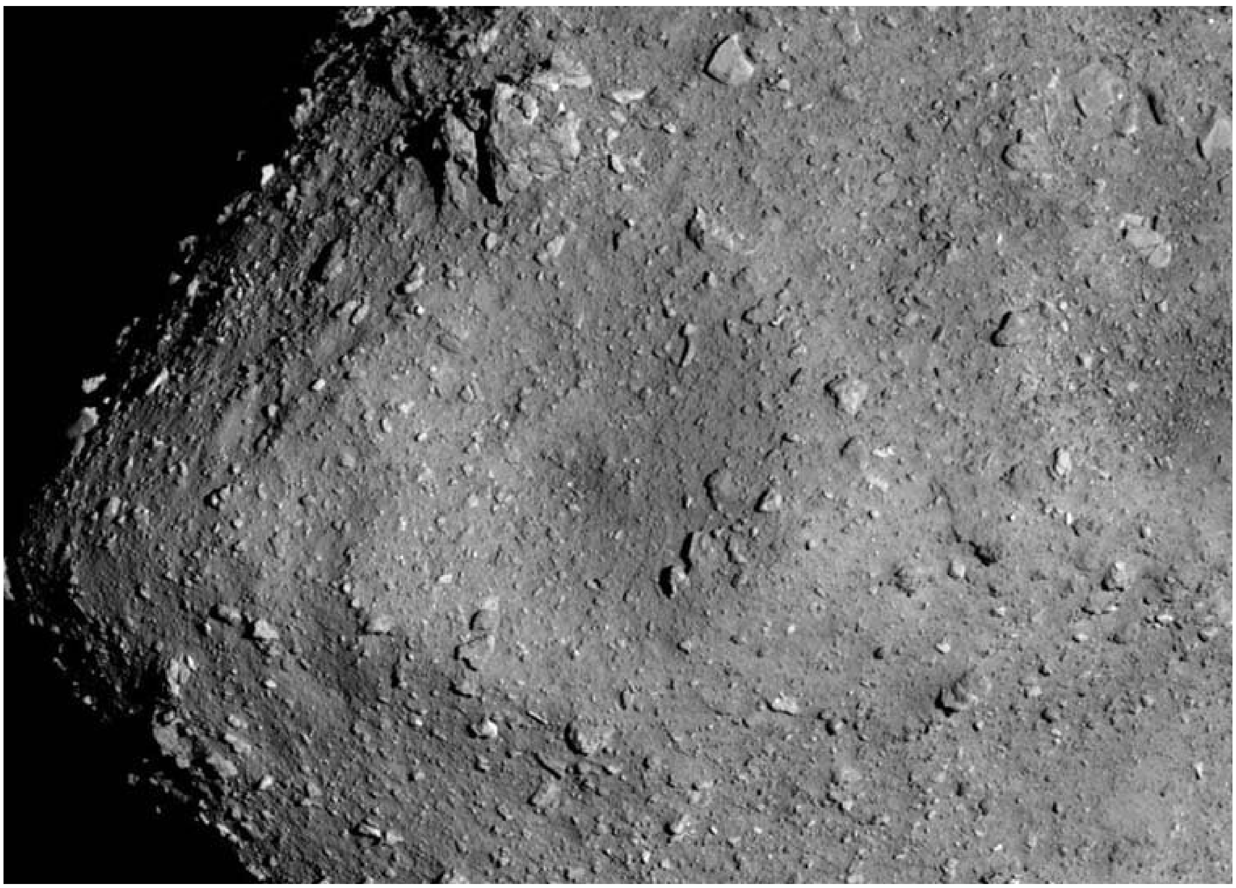
Davis, Dauphas and UChicago colleague Reika Yokochi are all part of a team assembled to help Japanese researchers analyze the samples. Each part of the capsule's contents is being rigorously studied. Yokochi is part of a team that is analyzing the gases that were trapped in the capsule or in the dirt. Dauphas and Davis are part of a team that is studying the chemical and isotopic compositions grains to reveal their history.

The first compilation of these results, reported in *Science* on June 9, reveal the makeup of Ryugu.

The rock is similar to a class of meteorites known as "Ivuna-type carbonaceous chondrites." These rocks have a similar chemical composition to what we measure from the sun and are thought to date back to the very beginnings of the solar system approximately four-and-a-half billion years ago—before the formation of the sun, the moon and Earth.

Back then, all that existed was a gigantic, rotating cloud of gas. Scientists think that most of that gas was pulled into the center and formed the star we know as the sun. As the remnants of that gas expanded into a disk and cooled, it transformed into rocks, which still float around the solar system today; it appears Ryugu may be one of them.

Scientists said the fragments show signs of having been soaked in water at some point. "One must picture an aggregate of ice and dust floating in space, that turned into a giant mudball when ice was melted by nuclear energy from the decay of radioactive elements that were present in the asteroid when it formed," said Dauphas. But surprisingly, today the rock itself appears to be relatively dry.



The surface of asteroid Ryugu from an altitude of 6 km. Credit: JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST

Using radioisotope dating, they estimated that Ryugu was altered by water circulation only about five million years after the solar system formed.

These findings are particularly interesting to researchers because they hint at similar formation conditions between comets and some asteroids such as Ryugu.

"By examining these samples, we can constrain the temperatures and conditions that must have been occurring in their lifetimes, and try to understand what happened," Yokochi explained.

She compared the process to trying to figure out how a soup was made, but with only the final result rather than the recipe: "We can take the soup and separate the ingredients, and try to tell from their conditions how much it was heated and in what order."

The scientists noted that a percentage of the find will be set aside so that we can analyze them in the future with more advanced technology—much as we did with lunar samples from Apollo.

"After we got moon samples from Apollo 50 years ago, our ideas about how the moon formed completely changed," Davis said. "We're still learning new things from them, because our instruments and technology have advanced.

Scientists with the Japanese Space Agency traveled to the Australian outback to retrieve the capsule containing pieces scooped off the surface of a speeding asteroid by the spacecraft Hayabusa2 in December 2020. Credit: JAXA

"The same will be true for these samples. This is a gift that keeps on giving."

This mission is the first of several international missions that will bring back samples from another asteroid named Bennu, as well as unexplored areas on our moon, Mars, and Mars' moon Phobos. This should all be taking place in the next 10 to 20 years.

"It has been very much under the radar for the public and some decision makers, but we are entering a new era of planetary exploration that is unprecedented in history," said Dauphas. "Our children and grandchildren will see returned fragments of asteroids, Mars, and hopefully other planets when they visit museums."

More information: Tetsuya Yokoyama et al, Samples returned from the asteroid Ryugu are similar to Ivuna-type carbonaceous meteorites, *Science* (2022). DOI: 10.1126/science.abn7850

Read more about the Hayabusa2 on the JAXA website.

Provided by University of Chicago

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