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Piecing Together the Early Solar System Using Returned Samples from Asteroid Ryugu

With the exception of some fragments of asteroids which have fallen to Earth as meteorites, astronomers have relied mostly on information they could gather remotely to characterize asteroids. However, the Hayabusa2 spacecraft extracted and returned physical samples of asteroid 162173 Ryugu to Earth. Ryugu - a near-Earth asteroid with an average orbital distance from the sun as that of Earth- is hypothesized to be a carbonaceous asteroid, meaning it consists of hydrated silicate rocks and organic material. Asteroids of this type contain some of the oldest unmodified materials in our Solar System. Remote sensing observations from the Hayabusa2 spacecraft show that Ryugu formed by rocks regrouping after a collision broke apart and potentially chemically altered its parent body. Both these characteristics—its composition and its orbit—make it an intriguing target for detailed investigation.

A truly globe-spanning team of scientists used analytical facilities in Japan, France, and the United States, among others, to characterize the asteroid samples returned by the spacecraft in December 2020. The team measured tactile characteristics, such as the bending strength and hardness of the samples, as well as observing how the samples respond to heat and electricity. The team took measurements to determine the presence and abundance of elements and compounds within the samples.

At the APS, a DOE Office of Science user facility at Argonne National Laboratory, measurements that showed the presence and abundance of elements were carried out using synchrotron Mössbauer spectroscopy at beamline 3-ID-B. Data from synchrotron Mössbauer spectroscopy at the APS were used to identify minerals within the sample as well as the amount and types of iron ions. From the measured elemental abundances, as well as the presence of magnetite and the value of the magnetic hysteresis parameter measured by the Mössbauer spectroscopy, the team confirmed Ryugu as a carbonaceous chondrite.

Synchrotron x-ray measurements were also carried out at SOLEIL (France), the Photon Factory (Japan), and SPring-8 (Japan), along with other meaurements, and their combined results allowed researchers to conclude that its parent body was formed beyond the orbit of Jupiter in the early Solar System and to describe the alteration by water and heat that transformed the parent body into the asteroid as it is today.

– Mary Alexandra Agner

The 17 coarse Ryugu samples used in this study. The images are shown on approximately the same scale. Each panel is labeled with the sample identification number. Mossbauer spectroscopy work was performed on samples A0026 and C0061

See: T. Nakamura* et al., "Formation and Evolution of Carbonaceous Asteroid Ryugu: Direct Evidence from Returned Samples," Science, published on line 22 September 2022. DOI: 10.1126/science.abn8671

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Advanced Photon Source
Bldg. 401/Rm A4113
Argonne National Laboratory
9700 S. Cass Ave.
Argonne, IL 60439 USA
aps.anl.gov
apsinfo@aps.anl.gov