Editorial

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Importance of asteroid sample return

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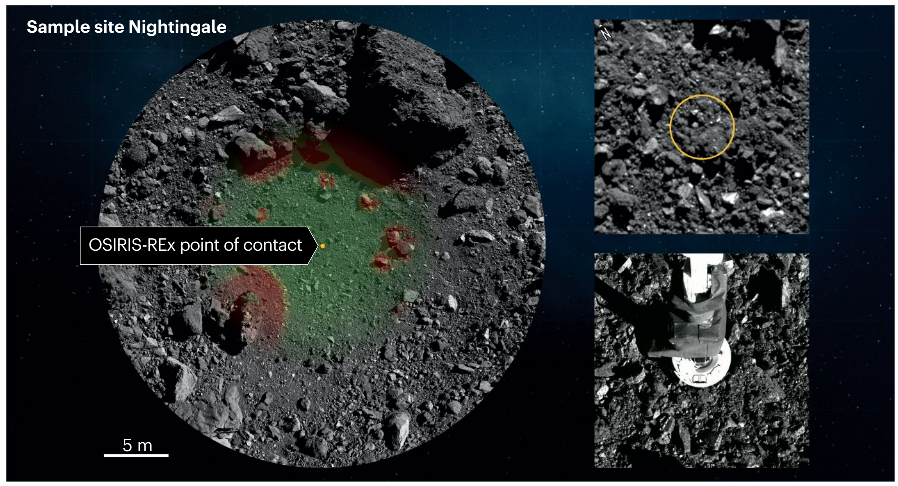
Sample return missions to asteroids provide critical pristine materials lacking from meteorite collections.



The OSIRIS-REx sampling site at asteroid Bennu, and Touch-And-Go sample collection event.

On 24 September, OSIRIS-REx landed in the Utah desert with a cache of approximately two hundred grams of rock from the asteroid 101955 Bennu. The NASA mission follows on the heels of the recent Japan Aerospace Exploration Agency (JAXA) Hayabusa-2 that returned material from asteroid 162173 Ryugu in December 2020. Both missions aim to further our understanding of processes that controlled the early development of the Solar System and the compositions of its most primitive materials, preserved as asteroids. Not only will this help reveal how the Earth first grew, it may even help us narrow in on the origins of fundamental building blocks for life itself. However, sample return missions have a high price tag, with OSIRIS-REx costing about one billion US dollars. In contrast, meteorites are regularly delivered to us through the Earth's atmosphere for free. But returning fresh materials from specially chosen asteroids can yield insights that researchers would struggle to glean from meteorites alone.

As many geoscientists know, any sample without the context of an outcrop or sampling site is extremely difficult to interpret. One of the key scientific questions asked about any meteorite is 'where does it come from?'. Missions to asteroids provide an unparalleled answer to this question. Sample return missions do not simply scoop up a sample – they characterize asteroids and their physical properties, leading to unexpected insights. When OSIRIS-REx arrived at Bennu, scientists were surprised to find a surface with a high amount of brightness variation, suggesting multiple lithologies[1], an observation that will be important for understanding the context of samples returned to labs on Earth. Such insights are difficult with meteorites found on Earth, where the source – or parent – bodies are usually unknown.

The recent sample return missions to asteroids have intentionally targeted bodies where scientists hoped that some of the Solar System's most primitive materials would be preserved. Carbonaceous chondrite meteorites are carbon- and water-rich aggregates of dust and mineral grains that also contain organic compounds. Although they make up just a few percent of meteorite collections, they provide a critical window into the formation and evolution of the Solar System and may have played a disproportionate role in the delivery of volatiles, including water, to Earth[2]. Analyses of returned Ryugu material have already established the asteroid's similarities to the carbonaceous chondrites and highlighted an extensive history of aqueous alteration[3]. Data beamed back from the OSIRIS REx spacecraft at Bennu suggest a similar history[1], though definitive confirmation will only come once the samples are in the lab and high-precision analyses can be made.

Sample return missions are also designed to return relatively pristine material to the Earth. The samples are packed away in a capsule designed to withstand re-entry through the atmosphere and prevent physical or chemical alteration until safely reopened in a custom-built curation facility. In contrast, meteorites must first transit directly through the Earth's atmosphere, generating extreme frictional heating that can cause losses of their precious cargo of volatiles and organic compounds. Once on the surface, a meteorite can become contaminated by terrestrial organic compounds, and instantly begins to weather in our atmosphere, just like any other rock. The carbonaceous Winchcombe meteorite, for example, was only exposed for a few hours after it fell in 2021, but already shows signs of adsorption of water from the atmosphere[4].

The value of asteroid sample return missions for understanding the materials that contributed to forming the Earth is clearly high. Although studies of meteorites continue to form the basis of much Solar System research, the ability to sample pristine materials straight from their asteroid sources is critical to addressing key open questions in Earth and planetary science. In addition, asteroid sample return missions allow scientists and curators to test their readiness for handling materials from other Solar System bodies, in particular the long-anticipated sample return from Mars. The challenges and risks are much greater for sample return from another planet, but the potential advances to our understanding of habitable environments and the possibility of life elsewhere in the Solar System are equally great.

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References

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