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WEEKLY March 9 - 15, 2024

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KLAWE RZECZY

‘Bennu samples may be rocks from an ancient ocean world’

Dante Lauretta leads NASA’s OSIRIS-REx mission. He tells Joshua Howgego why he thinks the material it returned from the asteroid Bennu could be remnants of a planet once fit for life

ON THE morning of 24 September 2023, Dante Lauretta woke up early, his pulse racing. For 20 years, he had been working on a NASA space mission that aimed to scoop up a sample of an asteroid and return it to Earth. Now, it was time for the sample capsule to land. If anything went wrong, it could end up smashed to smithereens on the desert floor, as flat – and as useless to science – as a pancake.

Thankfully, the landing was successful. And since that day, researchers led by Lauretta, a planetary scientist at the University of Arizona, have been busily examining crumbly, jet-black material from the asteroid Bennu. Their mission, called OSIRIS-REx, is one of several similar efforts in what arguably adds up to a golden age of asteroid science. We now have no less than three pristine samples brought back from asteroids and there are thrilling plans afoot to visit others (see “Encounters with asteroids”, page 42).

Lauretta has written a book about the OSIRIS-REx mission called *The Asteroid Hunter*. Here, he tells *New Scientist* about why asteroid samples are important, what his team has discovered so far and his jaw-dropping hypothesis that Bennu might be a fragment of a lost ocean world, one which may have had warm, watery conditions that could have made it an incubator for the building blocks of life.

Joshua Howgego: You watched from a helicopter as the OSIRIS-REx samples landed. How tense was it?

Dante Lauretta: I got up at 1.30 that morning because we had some routine work to do on the spacecraft. I wear a ring that measures my heart rate and I remember it was already 120 beats per minute! This was 20 years of my career, all depending on everything going smoothly on that day.

Later, I was in a helicopter, waiting for the capsule to come down. The capsule got pretty low and there should have been a drag parachute opening, but no one was calling it. I was a mess emotionally, thinking that this was going to be a disaster. But then the air force officer I was with was calling the main chute and, before I could process it, the capsule was safely on the ground. All this stress was released – years and years of anxiety and worrying and effort, pouring your heart into a mission – all of that lifted and I just broke into tears. It was relief, enormous relief.

Compared with planets and moons, asteroids might seem dusty and boring. Why is there so much interest in them?

Asteroids hold an enormous wealth of information, because they are literally the oldest rocks in the solar system. They represent the very first solid material out of which all the beautiful planets grew. That’s why we find them so fascinating. They are the things that grew together to make up the planets, and the ones that are left are kind of the stragglers that survived the chaos of the early solar system.

We have had several asteroid sample-and-return missions already. Where does OSIRIS-REx fit into the story?

Well, it’s the largest sample of asteroidal material ever returned to Earth, by a lot. We have in excess of 120 grams, more than twice what we promised. So that’s super exciting for us.

This story started off two decades ago when we in the community were pushing to have a sample-and-return mission to a carbon-rich asteroid, so we could explore origin-of-life issues. We pitched it to NASA, the European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA). And in the end, NASA and JAXA both funded missions, so it was a double victory. The Japanese missions became Hayabusa [which visited an asteroid called Itokawa] and Hayabusa 2 [which sampled the asteroid Ryugu], and we became very close teams.

As a community, we are ecstatic that we got these three opportunities. The samples are similar yet distinct, so there’s interesting ›

"Asteroids hold the very first solid material out of which all the beautiful planets grew"

things to learn there. Why is Ryugu different than Bennu? Did they come from the same asteroid family? There's a good chance that they did and we're sampling various regions of a much, much larger world.

In your book, you call Bennu "the most dangerous rock in our solar system". Why?
We rank the hazardous asteroids based on the impact probability, and Bennu has the highest probability of impacting the Earth of any known object. The odds are 0.05 per cent, so pretty low as these things go, right, but not zero. It's 500 metres in diameter, so it would not be an extinction level event; it's a regional disaster. But, nevertheless, it would be a big deal.

What does that 0.05 per cent probability really mean?
We know Bennu's orbit exceedingly well and we can trace it to 2135. We will be all right until then, at least. But at that point, Bennu is going to come in between the Earth and the moon. That's where the uncertainty blows up, because of small variations in the time and location of that encounter with the Earth. We have tried modelling what happens to Bennu if we put it in lots of different places at that point, and that probability refers to the chances of it hitting the Earth then.

I wish I could live until the year 2135, because there'll be a resurgence of interest in asteroid Bennu.

What have you learned from the material from Bennu so far?
When you look at the material, most of it looks dark, like charcoal, but there is also some really bright stuff, which, to me, is the most exciting thing we got. Let me try to explain.

One of the first things we did was analysis using a technique called X-ray diffraction, which gives you peaks on a graph that correspond to a known mineral. The sample of Bennu is mostly made up of water-bearing clay, specifically minerals called serpentines. There's the same rock type on Earth, which forms when mantle rock hits ocean water. Then we also found that we have this

Encounters with asteroids

A rundown of our missions to study asteroids, past, present and future

HAYABUSA
JAXA
Launched: 2003
The first attempt at an asteroid sample-and-return mission brought back less than a milligram of material from asteroid Itokawa in 2010.

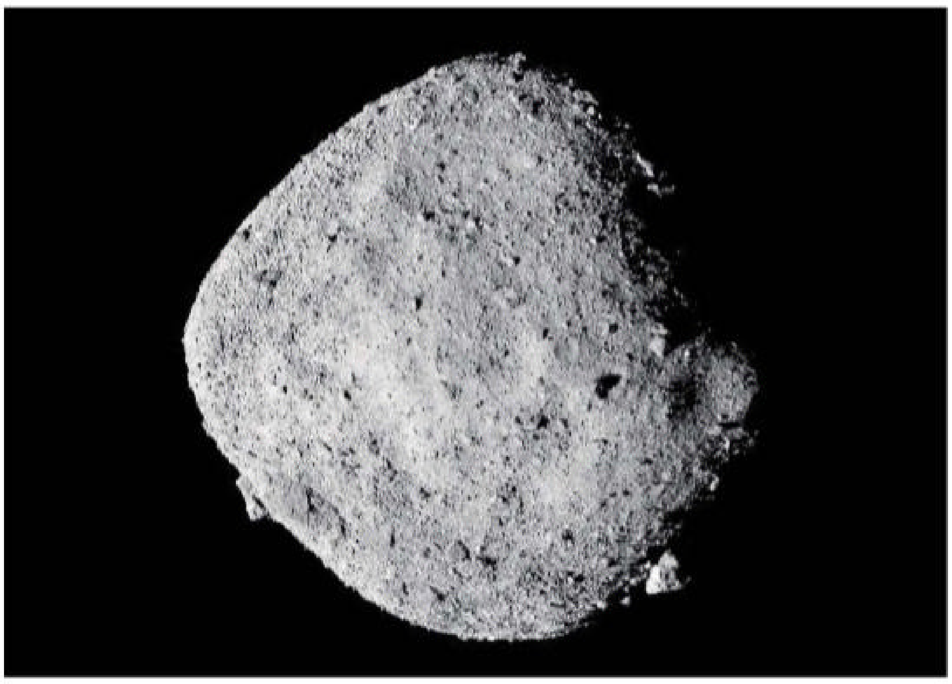
HAYABUSA 2
JAXA
Launched: 2014
Returned in 2020 with 5.4g of material from Ryugu.

OSIRIS-REX
NASA
Launched: 2016
Brought back about 120g of material from asteroid Bennu in September 2023.

PSYCHE
NASA
Launched: 2023
In transit towards Psyche, which is thought to be a metallic asteroid. It should arrive in 2029, but won't bring back samples.

MARTIAN MOONS EXPLORATION (MMX)
JAXA
Due to launch: 2026
MMX will travel to the Red Planet's two moons, Phobos and Deimos, and collect a sample from the former to return to Earth.

MBR EXPLORER
UNITED ARAB EMIRATES SPACE AGENCY
Due to launch: 2028
This mission, currently in development, plans to visit seven asteroids in the belt between Mars and Jupiter, as well as dropping a lander on Justitia, a 50-kilometre-wide asteroid in the asteroid belt.


NASA/GODDARD/UNIVERSITY OF ARIZONA

OSIRIS-REx returned a sample of the asteroid Bennu

NASA

Researchers taking pieces of the Bennu sample from the returned cannister

magnesium-rich phosphate mineral, and this is what makes up those bright sections that I mentioned. This is really rare and it's also a weird type of phosphate that I have never seen before. It's very, very uncommon in geologic settings.

Can you tell me more about why the bright stuff is so interesting?
The thing about the phosphate material is that it looks very odd. It appears like a thin skin that looks like it has been deposited on the material. I was really puzzled by this, so I put out a call to the community, asking: "Has anybody seen this in geologic environments?" I heard from a group that detected sodium phosphate particles in the plumes of water erupting from Enceladus [a moon of Saturn] during the Cassini mission.

So if I put it all together, Bennu samples are hydrated, organic-rich serpentines from the early solar system. Serpentines on Earth, at least, form when rocks from the mantle are forced upwards into the seabed and react with water, in a reaction that releases heat – and it was probably a similar process on Bennu's parent asteroid. So we clearly had a set of rocks that were interacting with a carbonated fluid. That's a huge result to me.

I would say my working hypothesis – and you know, if we can prove it, it's huge – is that Bennu samples are rocks from an ancient ocean world. You would have had phosphate enrichment in the fluid and, ultimately, evaporation and precipitation of that phosphate material.

Phosphate is a key building block in biology, right?
That's right, phospholipids make our cell walls and adenosine triphosphate is the primary energy molecule for all life on Earth. Phosphate molecules also form the backbone of DNA and RNA, and so are critical to our genetic material.

Did you find anything else interesting?
We can also see these things I call nano-globules all over the place. These are spheres with walls of carbon and nitrogen, sometimes empty and sometimes with other phases of mineral or rock inside them. They're enormously abundant. We see them all over this material. These are exciting from an origin-of-life perspective. These could be like a protocell.

Presumably you aren't suggesting that these were living, but what do you think the significance of these nano-globules is?
We're starting to unravel that. I think these are like [spheres made of surfactants called] micelles, so they were probably once suspended in fluid. Think of them like oil droplets in water. It's early days and origin of life is a big area of investigation with these samples. They might be telling us something important, at least about compartmentalisation. If you can get separation of chemical systems, that's the first step towards a cell and that's where metabolism could maybe start to originate.

Some people dream about sending a mission to the ocean floor of Enceladus. But it sounds like what you are saying is that we have almost got that kind of sample in our hands already.
That's my hypothesis; I haven't proved it yet. And look, I love the idea of going into the ocean of Enceladus or Europa, a moon of Jupiter. I wouldn't want to not do that, you would learn so much. But I think, at the very least, we have an abiotic sample of an ancient alkaline hydrothermal system, which means we can explore the hypothesis that critical organic molecular evolution may have taken place in those environments on the early Earth.

The point is, when we look at locations on the early Earth where we think life could have originated – such as hydrothermal vents at the mid-ocean ridge, the white smokers, for example – there's biology all over the place, right? There's worms and crabs and bugs and sea snails. So you can't tell which molecules are building blocks for life and which have been synthesised by living things. With Bennu samples, we don't have that problem.

What about amino acids, the building blocks of proteins – have you found any of those?
This is so interesting. We have found some and the results are fascinating, but they're under review for publication, so I'll have to leave you in suspense for now.

OSIRIS-REx isn't entirely finished yet, is it? Tell me about what's next for the spacecraft.
One of the mission designers came to me a few years ago and said: I can get you to Apophis, which is a famous asteroid in our community. Normally, when you're talking about an extended mission, spacecraft can just do a flyby. But he said, I can get you into orbit around Apophis. I was stunned and super excited. It will arrive in 2029 and rendezvous with that asteroid. It's an S-type ("stony") asteroid, which is the second most common type, and we'll be able to do a nice comparative study between Bennu and Apophis using exactly the same payload of instruments. ■

Joshua Howgego is deputy head of features at *New Scientist*