00:06 Meagan Cantwell: Welcome to the Science Podcast for March 22, 2019. I'm Meagan Cantwell. In this week's show, I talk to Paul Voosen about the feasibility of mining valuable metals in the deep sea, and I also speak with Seiji Sugita about Hayabusa2, a sample return mission, to the asteroid Ryugu, over 180 million miles from Earth.

00:31 MC: You've probably seen photos of the other worldly creatures that reside at the bottom of the ocean, but there are more than just amazing organisms down there. There's also an opportunity for profit. I'm here with staff writer Paul Voosen to talk about an expedition to better understand these treasures. Hey, Paul.

00:48 Paul Voosen: Hello.

00:48 MC: What is the treasure at the bottom of the ocean?

00:50 PV: There are few different kinds, but really it's these rare metals that are often produced on land as a by-product of more traditional metals, like copper, but sort of of things like cobalt, that are used in batteries and phones and they are found in these polymetallic nodules on the sea floor.

01:09 MC: How big are these nodules?

01:11 PV: A potato size. Everyone says they're potato sized. [chuckle]

01:15 MC: Not like easy to bite into potatoes, bigger potatoes, right?

01:19 PV: Mm-hmm.

01:19 MC: Which seems pretty substantial that is.

01:20 PV: Yeah, fairly substantial potatoes. [chuckle]

01:23 MC: So where exactly are these nodules found in the ocean?

01:26 PV: They're found in all the oceans, research has shown, but they're particularly found in these regions where you have deep abyssal planes down four kilometers. This particular zone of interest just between Hawaii and Mexico, where we're expecting deep sea mining to potentially start at some point, and they're usually caused by enough life being at the surface that carbon gets down to the sea floor to prime some of the reactions that cause these metals to leach out onto little things like shark tooth.

01:56 MC: There are also microbes that settle on these nodules. Are there things that researchers
can learn from that?

02:02 PV: There are probably microbes involved in the formation. They power the chemical reactions that allow the oxygen rich conditions that cause these to form. And then also you have corals and other things that live specifically on the nodules, and most of them are new to science when they're pulled up, because these are regions that have not really been explored that much.

02:21 MC: They're part of the ecosystem. It's not like it's just nodule laying there, nothing else around it? Yeah.

02:26 PV: No. Yeah, like everywhere on Earth, wherever we look, there is life.

02:29 MC: How big is the collector that's set to potentially vacuum these nodules?

02:34 PV: So this is a pre-prototype, so it's not a full-size collector, but despite that, it's the size of maybe about a school bus.

02:40 MC: Oh wow, that's big.

02:40 PV: So it's big already. They're not sending these nodules back up to the surface this time, they're just doing the small-scale test to look at the environmental impacts and see if this actually works that they're able to suck these nodules up, and they stick them in a hopper, dump them back out on the see floor.

02:57 MC: But then they're actually looking at the nodules this time. But who is the group that's orchestrating this research to see what the environmental impact is and how are they going about it?

03:05 PV: You have this Belgian dredging company that is doing this trial. They're collaborating with a independent group of European scientists, that are funded by Europe, that are taking out another ship and they're going to be looking at the collector, that's what it's called, as it operates in these two small regions and it will be... Have this array of sensors on autonomous vehicles, these little torpedo-looking things that are remotely operated vehicle and a bunch of other platforms that will monitor everything that goes down.

03:35 MC: What are they hoping to learn?

03:37 PV: So the big question in particular is about the plume, so that the silt and sediment that gets stirred up as the collector goes, these realms are some of the clearest water in the ocean, because the sediment rates are so low. That's part of why the nodules can form. And once you have this collector going through, it might stir up this silt and cut dump a bunch of it, a millimeter or centimeter, on these life forms that are unused to that kind of accumulation. So the question is how far is that silt spread? There's very little data right now, so this will provide that data.

04:07 MC: How long is this expedition lasting, and when will there be some results to see what the impact of this mining was on the environment?
04:15 PV: So it's going on this April from, pretty much all of April, the actual trials will take place in two sites probably over a period of a little over a week in each one, and the German scientists are completely independent, they're going to be releasing all of their data publicly. They're gonna have their first whack at it, so I'm not sure of the exact timetable of when they will publish those results. I imagine it will be in within the next year you'll start seeing bits and pieces coming out.

04:42 MC: Deep sea mining has been a thought for a while, but why is it that it's actually gaining traction now? Are we running out of some of these metals?

04:51 PV: A lot of people don't love where... How they're mined on land, often it's the rain forest and often bad conditions in the Democratic Republic of the Congo, or elsewhere. The technology has gotten better, so it's becoming somewhat more feasible, and the demand for these metals, particularly cobalt, people aren't projecting that to go away at all, because renewable power in particular, that needs a lot of cobalt. If you're gonna get off oil, you might need more of these metals. That's a pitch the industry is making in particular.

05:21 MC: Okay, and this isn't the first expedition, right, to study what the environmental impacts might be?

05:27 PV: The kind of interest in this has waxed and waned since the '60s. People in the past have done these simulated trials where they dredge at the bottom of a sea floor, they don't have the kind of... The technology we have to really monitor it that well, that's been more looking at long-term impacts. So one of these sites is off Peru, that they did in late 1980s. Researchers returned there about three years ago, three-and-a-half years ago, and found these tracks looked fresh, like they have been made the day before, just showing how long this ecosystem takes to bounce back from disturbance.

06:00 MC: What exactly do we know about the deep environment so far? I mean, so little of it has been explored.

06:04 PV: Yeah, the things that really get a lot of attention are things like hydrothermal events that are kind of rich with life and these kind of charismatic creatures. So these nodule realms, I mean, it's expensive to get down there. There just hasn't been much opportunity. Now that you have this interest, it's prompting a lot of scientific research. I believe it's the More Foundation funded another survey into the place called the Clarion Clipperton zone between Hawaii and Mexico to look at the deep sea life there, and they're just finding a host of kind of strange and interesting creatures that I think in the East, one survey found 70% of them were new to science.

06:41 MC: So a lot could be lost potentially?

06:44 PV: Potentially. But these are big, we're losing a lot now. It's a tough call. If the Earth had never been mined, and you were choosing between mining rain forest or mining these environments on the sea floor, it's not the easiest call, it's a complex decision. And so the scientists really, they're trying to be pragmatic in how they approach this and think, "If this is going to happen, let's try and
understand the impacts, try to make sure we are protecting regions.” And this is really the first extractive industry to come about with environmental concerns factoring in from the start. So, since the UN is governing this, there is some hope that it'll be done somewhat responsibly.

07:23 MC: And this is in international water, so they still have to figure out who would even be allowed to mine here, right?

07:29 PV: Yeah, so the UN has this body called the International Seabed Authority that governs the international waters' exploitation. And they're still drafting rules for exploitation. Probably won't happen for another few years. This expedition will probably go into informing those rules.

07:46 MC: The mining isn't gonna happen for a while then?

07:48 PV: Yeah, I mean most projections seemed to be late next decade, but you never know.

07:54 MC: Thanks so much, Paul.

07:55 PV: Yeah, thank you.

07:56 MC: Stay tuned for my interview with Seiji Sugita about what his team has learned so far from Hayabusa2.

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08:07 MC: In 2014, Hayabusa2 was launched, and in June of 2018, it reached its target, the asteroid Ryugu, which is located between Earth and Mars. Just last month, Hayabusa2 collected a sample of the asteroid. I'm here with Seiji Sugita to talk about what his team has learned from the mission so far and what they hope to understand about the asteroid once the sample returns to Earth. Thanks for joining me, Seiji.

08:33 Seiji Sugita: Thank you, and it's really a great pleasure to be here.

08:37 MC: First, I wanna talk a little bit about the fact that this is Hayabusa2. What happened on the first expedition with just Hayabusa?

08:45 SS: The original Hayabusa went to S-type asteroid, it's a world without water or hydro-mineral. We had a little problem here and there, but we finally made it back to the Earth with small pieces of rock and almost like a dust particles of asteroid Itokawa, that really demonstrated the capability of Jackson and the engineers that we can do a round trip to a small asteroid and bring back sample to the Earth.

09:13 MC: The first Hayabusa was with, what you said, was an S-type asteroid, and Hayabusa2's expedition is to Ryugu, which is a C-type asteroid. Could you talk about what that means, and why you specifically chose this type of asteroid?
**09:26 SS:** C-type asteroid, the C stands for Carbon. C-type asteroid is considered to be Carbon because the color is very black and then estimated to have a lot of water and the organics and carbon bearing material. Those are ingredients for life. If it really gets supply to the surface of planetary bodies such as Earth and Mars, that’s why C-type asteroid is far more interesting to scientists to explore.

**09:54 MC:** One of the main goals of the mission is to return a sample from this asteroid home, and although it's not going to be back for a while, what kind of tests do you hope to run and understand about the asteroid once the sample does come back?

**10:06 SS:** There are a series of questions we'd like to address. The content of water and then the kinds of organics and also isotopic characterizations of water molecules and the organic molecules. By identifying the isotopic composition, we can probably identify where in the solar system or what kind of condition of a location within the solar system those materials are coming from. Those are very important pieces of information for understanding the evolution of the solar system or the supply mechanisms of organics and water in a solar system through Earth and other planetary bodies.

**10:47 MC:** Initially, the plan was to get three samples from this asteroid, but that may not be the case now?

**10:53 SS:** The first touchdown was so difficult, because they had a surface really was covered with all kinds of different large boulders, and it was very difficult to find a good location, and then the engineers had to really upgrade and improve the technique to make a really high precision pinpoint touchdown. But that happened. So that consumed a lot of time, so most likely reduced down to two touchdowns in two different locations.

**11:24 MC:** So the touchdown was successful then, but you don't know yet how much of the sample you got from the asteroid?

**11:29 SS:** We don't have a mechanism to measure the amount of asteroid or the samples on our space craft. However, I'm a responsible dreaming scientist that we have a very hopeful finding with a lot of pebbles and fragments coming out of the touchdown sites. Those must have gathered into the sampler horn and then the sample capsule mechanisms.

**11:54 MC:** Hayabusa2 still has a long journey home, but that doesn't mean that you haven't learned things already since it's been surveying the asteroid for a couple of months. And your team has three papers coming out in science that talk a little bit about what you've learned so far.

**12:10 SS:** Several series of findings we made. The first one, it has a shape very close to a spinning top. It probably was formed when Ryugu was spinning at a much faster spinning rate than now. So that really shows that this type of a small asteroid may change its spinning state quite often or quite rapidly. We don't know the profound implication for this, but it's a very important piece of information, and also it's a basis of understanding this type of asteroids. So that's number one. Another important finding was its bulk density. It turns out to be very light, it's only 1.2 grams per
cubic centimeters. Making a 1.2 grams per cc requires a lot of pores. So they had a pore volume ratio is as high as 50%, so half of the Ryugu is void. This really is possible only if Ryugu is a so-called rubble pile, the jumble of all kinds of fragments and then debris just randomly packed loosely together with its gravity. That's the only way we can think of to make 1.2 grams per cc.

13:28 MC: You were also able to study the surface composition of the asteroid as well, right?

13:33 SS: That's right. As for the composition, we found a couple of pieces of very important information. Hydrated mineral. The mineral that has reacted with the liquid water. Those material we thought was quite abundant on the surface of Ryugu, but our measurement has shown that the amount of the hydrated mineral is not as abundant as we were thinking.

13:58 MC: So the hydrated minerals were less abundant than you thought they'd be, does this provide any clues for how Ryugu might have formed?

14:05 SS: The original theory or idea is that those asteroids are created in a very low temperature location of the solar system, then that automatically retains a lot of water or water-bearing minerals. And then when it hits type of bodies such as Earth, we will have a lot of supply of water or other so-called volatile elements, like organics and carbon-bearing molecules. But now, after looking at the moderately dehydrated asteroid, the parent-body processes that are sitting between the accretion and then the final evolution of the asteroid changes the degree or the amount of water and other volatiles in a course of an evolution. So even if those asteroids or it's a parent body are created in a cold place, if the evolution... Subsequent evolution within the parent body really lose those volatiles, we don't necessarily receive too much water or organics in a solar system. So there is one more important process that really controls the amount of life's ingredient available on a large planetary surfaces.

15:23 MC: Speaking of how the asteroid formed, does the color give you any insight about that process?

15:29 SS: Our camera can take a distribution of the different colors of Ryugu. And then the color really tells us about the difference in mineralogical variation. Our observation showed that the material on the surface of Ryugu is quite homogenous. Individual particles of boulders of Ryugu are very similar to each other. So parent body of Ryugu must be quite homogenous, and then the only way we can think of to make the homogeneity of Ryugu parent body is a radiogenic heating in its parent body. Radiogenic heating is heating due to the decay of radioactive isotopes. Those isotope breaks down, and then in the process of a decay, it generates heat. Subsequently, dehydration and other metamorphosis happens as opposed to impact-generated heat and other mechanisms via their homogeneity or heterogeneity over Ryugu's surface can constrain the process that must have happening in a parent body of Ryugu.

16:42 MC: Do you have an idea of when Ryugu's parent body might have formed?

16:46 SS: Ryugu's parent body was formed in the whole evolution of the solar system or at the same time as the planetary system in the solar system.
There's currently another sample return mission happening from NASA, OSIRIS-REx, could you talk about how your study complements NASA's expedition?

There are a lot of surprising things we learn by comparing OSIRIS-REx results and then Hayabusa2 result. OSIRIS-REx is studying a little smaller size asteroid called the Bennu. Bennu is another top-shaped, fast-spinning asteroid, and its color is very black. Very similar to Ryugu. It's probably have a lot of carbon, like Ryugu. The rubble pile nature is also very similar. But the water abundance of Bennu, it's so much more than Ryugu. So there are a lot of similarity. However, somehow water abundance is quite different. And then even their parent body's maybe the same. So how can we really make such contrasting bodies out of such a similarity? When we find out why there is such a difference, that would really place a very important constrains. Only a really great answer can resolve this problem. So I think we have a very important piece of information to work on for years and possibly, not hopefully not a decade, but the many years of a time.

Thank you so much.

Seiji Sugita is a professor at the University of Tokyo in the Department of Earth and Planetary Science and principal investigator of the optical navigation camera of Hayabusa2. You can find a link to his research at sciencemag.org/podcasts.

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