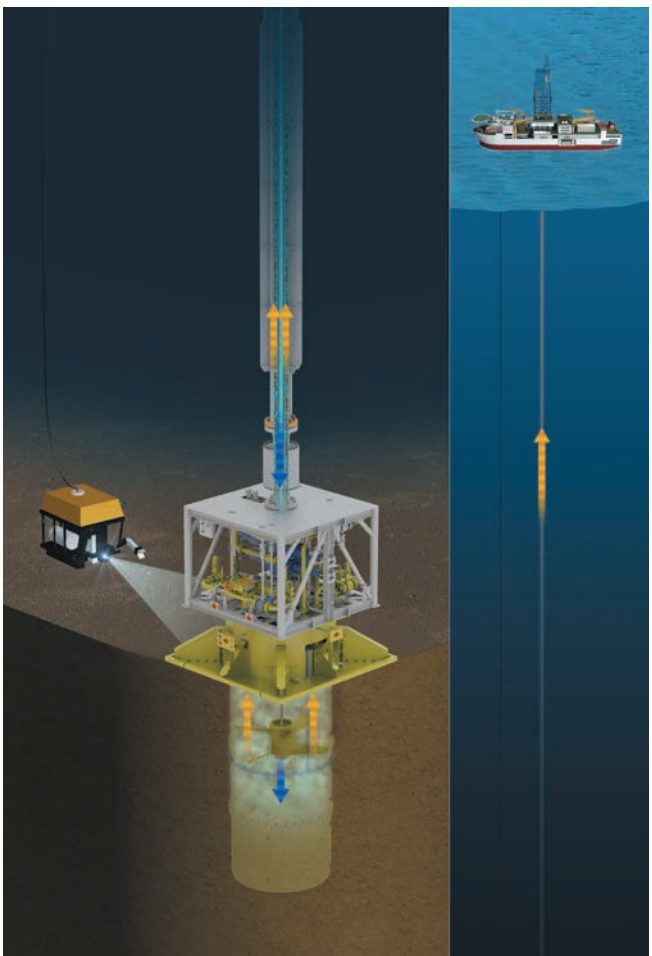
Japan pioneers extracting rare-earth elements from the deep sea

Muds found at roughly 6,000m are an untapped source of resources vital to renewable batteries and other advanced technologies. To reach them, JAPAN MUST FIGURE OUT HOW TO MIX AND PUMP MUD FROM THE DEEP.



A Subsea Factory will turn resource-rich clay into slurry to be pumped to the surface.

In 2012, researchers identified large reserves of rare-earth elements in Japanese muds found at depths of roughly 6,000m. "Thus far, Japan is the only country in the world that has found rare-earth muds in the waters of their exclusive economic zone," notes Yoshihisa Kawamura of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). As a result, his team hopes to now be the first to construct a production pipeline for deep-sea muds.

Used in screen display panels, mobile phones, rechargeable batteries and hybrid cars, rare-earth elements such as neodymium, yttrium and lanthanum are in limited supply. And, unlike rare-earth mining on land, deep-sea rare-earth muds don't contain high levels of radioactive material.

"JAPAN IS THE ONLY COUNTRY IN THE WORLD THAT HAS FOUND RARE-EARTH MUDS FROM THE WATERS OF THEIR EXCLUSIVE ECONOMIC ZONE."

An investigation in Minamitorishima (see *Maps of rare minerals in mud*), revealed enough of these minerals to supply the world's demand for decades to come. But Japan must lead a new industry to harness them, says Kawamura.

"There has never been a demand anywhere else in the world to develop such technology, and we need a few breakthroughs to make it happen."

MIXING THE MUD

Rare-earth muds are only found in deep-sea regions. A notable characteristic of Japan's oceans is depth. While the country's exclusive economic zone (EEZ) ranks sixth in the world for area, it ranks fourth for volume. Less than 30% of Japan's EEZ is shallower than 2,000m, the maximum depth reached in previous seafloor mining projects.

"Technology capable of surveying at depths of 6,000m would allow us to reach 94% of the country's ocean floor," notes Kawamura.

Mining at 6,000m is already achievable by lowering shovel-like equipment with a cable, he points out. "However, at least several thousand tonnes of mud must be collected daily in order to be profitable. Repeatedly lowering and raising shovels won't get us there," he explains. "Instead, we would need to pump large quantities of mud through the pipe continuously."

Building durable and efficient pipes is one of the challenges, as even the longest of pipes – typically used for surveying new oil reserves – are only about 3,500m long.

Getting the mud to flow is also an issue. "The texture of the mud on the seafloor is much like clay, and can neither be crushed like solids, nor made to flow like liquids. To solve this problem, we use machines on the seafloor to mix the mud with seawater and convert it into a slurry-like texture so that

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it flows smoothly like oil," explains Kawamura.

JAMSTEC has partnered with Toyo Engineering Corporation (TOYO) – an engineering firm with vast experience in oil and gas R&D – to use their newly designed, hardy pipes in a TOYO-designed system that turns deep-sea muds into slurry.

A CRUCIAL COMPONENT OF THE SUBSEA FACTORY IS THE MACHINERY TRANSFORMING MUD INTO SLURRY.

JAMSTEC's *Chikyu* vessel will do intial Subsea Factory tests.

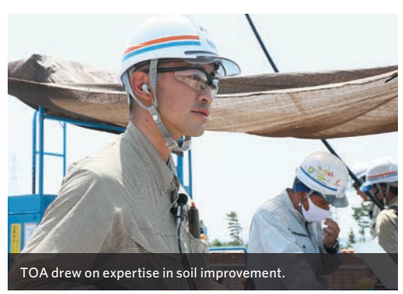
JAMSTEC's supercomputer modelled effective specifications.

A prototype machine must mill clay into 4mm particles.

TOYO has great experience in plant engineering.

JAMSTEC researchers supervised the entire project.

TOYO's wide range of experts designed the Subsea Factory.



TOA drew on expertise in soil improvement.

JAPAN'S SUBSEA FACTORY

Rare-earth muds don't flow as smoothly as oil and gas and are highly abrasive, says Yoichi Komatsu, a project manager at TOYO. "We have had to make detailed plans for optimizing a subsea system with large diameter pipes, pumps, valves, monitoring sensors and electrical and control modules."

Komatsu calls the platform the 'Japanese Subsea Factory', and highlights an industry trend that is placing as much automated equipment as possible on the ocean floor; this reduces operational costs associated with enormous offshore platforms and mining vessels.

The Subsea Factory includes a pump hung from *Chikyu*, a JAMSTEC-owned vessel capable of ultra-deep drilling below the seabed. *Chikyu* is the only research vessel in the world equipped with a type of industrial-grade drill commonly used in oil and gas, consisting of two layers: an inner pipe (drill pipe) that pumps down seawater from the surface, and an outer pipe (riser pipe), in which rare-earth muds and fragments of drilled soil are pushed upwards.

"Since the subsea system will be hung by 6,000m of piping from *Chikyu*, it needs to be within an appropriate weight range to avoid resonant vibration with *Chikyu*, but be safe to withstand the environmental conditions on the ocean floor," explains Komatsu.

The team is also now tackling a new challenge – the foundations under the mud on the ocean floor were more fragile than anticipated. "As we pump seawater down to mix the mud, pressure is put on the substrate underneath," explains Kawamura. "We found that the sediment layer was only 10% as strong as it was thought to be. There is a risk of these collapsing, and the mud slurries escaping down through the cracks, so we are reimagining parts of the platform to ameliorate the pressure."

With a broad range of experts experienced in plant engineering, drilling, offshore production, and metal mining, TOYO is working to finalize the design by early 2021. "These technologies could change the face of mining," notes Komatsu.

FROM CLAY TO SLURRY

A crucial component of the Subsea Factory is the machinery transforming the mud into slurry, designed by JAMSTEC's partner, TOA Corporation. "We are a marine construction company that began by reclaiming land in the Greater Tokyo area, in particular the Keihin Industrial Zone," explains Masaki Akiyama, the CEO of TOA. "The year 2020 marks the 100th anniversary of our company. We have a century of expertise in dredging and reinforcing soils to create better foundations for building structures in the sea."

For TOA, liquifying mud is not a typical end goal; however, it is part of a step taken when reinforcing soil foundations. "In particular, we draw on a process in which we mix mud with cement to create a slurry that turns into stronger soil," explains Tomohiro Morisawa, a project manager at TOA.

In the summer of 2020, the project team tested the slurry machinery in TOA's facility using a prototype one third of the actual size. For this project, rare-earth muds must be milled into particles 4mm or smaller, a mud-liquefaction process significantly more precise than typical *in situ* soil improvement.

"For the mud to travel up the pipe, it needs to be pulverized into particles small enough for the rising current to push it up," explains Morisawa. "Achieving this particle size with this extremely sticky mud, all the while keeping the machinery as simple as possible so it survives deep-sea conditions, proved challenging. As the deep ocean is a space neither machines nor people can easily reach to fix things, the machinery needs to be uncomplicated."

The team has been analysing the proportion of mud successfully pulverized. "Here, we compared factors such as the number and angle of blades in a fan-like structure used to mix the soil, as well as optimal frequencies of rotating the fan and the flow of injected water," says Morisawa. JAMSTEC's Earth Simulator supercomputer modelled the most effective specifications.

While TOA's current role centres around pulverizing mud, Akiyama is also looking at sustainability. "In addition to soil improvement, we also have a wealth of experience in handling the mud residue that comes with dredging. A key consideration moving forward will be how to handle this mud to create minimal environmental impact. Fortunately, the rare-earth muds contains very few radioactive elements, such as uranium and thorium. The remains left over after extracting the most valuable minerals could effectively be used as a land reclamation material, for example.

This article discusses research conducted by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Toyo Engineering Corporation and TOA Corporation. Their research and development programmes are part of the Cross-ministerial Strategic Innovation Promotion (SIP) Program, which is run by Cabinet Office, Government of Japan. ■

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