Marine minerals – two steps forward and one step back?

by Dan McConnell

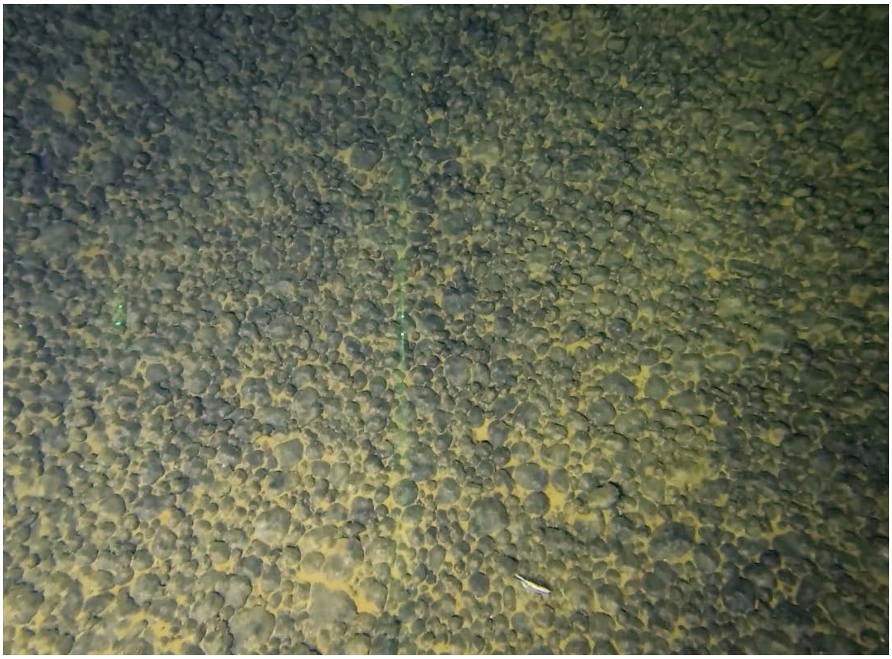
On the tiny island of Rarotonga, 4,500 km (2,800 miles) south of Hawaii and 3,220 km (2,000 miles) northeast of New Zealand, an influential and prescient group of marine mineral experts, scientists and entrepreneurs gathered for the 52nd Underwater Minerals Conference (UMC). In planning for the event, the organizers, the International Marine Mineral Society (IMMS), were not sure how many delegates would be able to make the trip to the distant Cook Islands. It turned out to be the largest convocation of the UMC ever. It is not a huge conference, but it is influential.

Riches in the Pacific

The timing could not have been better. The Cook Islands have long been known to have dense deposits of cobalt-rich polymetallic nodules on the 5,000-m (16,400-ft)-deep abyssal plains between the islands. What has been coming into place is a legal and regulatory framework, demonstrated technology to lift the nodules from the seabed with limited disturbance, and ground-truthing critical questions of ecologic impact and biologic community rebound.

Figure 1

Polymetallic nodules on the seabed in the Cook Islands EEZ, imaged by a remotely operated vehicle (ROV)-mounted camera. Laser measurements are approximately 5 cm along track and 750 cm cross track. (Image credit CIC Ltd, courtesy of Cook Islands Seabed Minerals Authority)



The Cook Islanders have a lot at stake. A recent resource estimate commissioned by the Cook Islands Seabed Minerals Authority based on decades of scientific and resource sampling concluded that based on the sampling done to date, there is an inferred resource of 6.7 billion wet tons of ferromanganese polymetallic nodules with grades of 0.44 percent cobalt (Co), 0.21 percent copper (Cu) and 0.37 percent nickel (Ni) within the Cook Island exclusive economic zone (EEZ). The resource represents tens of trillions of dollars in ultimate value.

The Cook Islands are rich in polymetallic nodules for several reasons, one of which is that the seafloor is some of the oldest on the planet and is distant from any terrigenous sediment input. Polymetallic nodules precipitate directly from dissolved metals in seawater, growing slowly in diameter at a rate of about 2 to 10 mm per million years.

Rich deposits of polymetallic nodules occur elsewhere, such as the Central Indian Ocean, but most of the rich deposits are found in the Pacific. The best studied deposits are in the Clarion-Clipperton Zone (CCZ), which centers along the 12° North latitude and extends 4,800 km (3,000 miles) between the U.S. Kingman Reef and Palmyra Atoll EEZ and Clipperton Island (France). The International Seabed Authority (ISA), the autonomous international body that regulates the development of seabed minerals in international waters outside of national jurisdiction, estimates that there are 21 billion dry tons (approximately 31 billion wet tons) of polymetallic nodules in the CCZ.

Out of the age of hydrocarbons and into the age of metals

Sir Andrew Mackenzie, the chairman of Shell PLC and former chief executive officer of BHP Billiton, has said in recent public talks that people think of the energy transition as a transi-

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tion from fossil fuels to renewables, but really, "When considering the materiality involved, it is a transition from a fossil fuels world to a metals world." He goes on to say that the energy transition will require "an order of magnitude more copper and nickel and maybe lithium, cobalt, and rare earths" as well as much more steel, "because renewable power requires a lot more infrastructure than fossil fuel power."

Mackenzie was confident that geologists would be able to find new deposits to meet the energy transition demand on the continents. Minerals from the deep ocean are still being left out of metals market forecasts by the major market consulting companies. This means that they either do not want to go out on a limb to speculate on the emergence of an industry that has not yet happened, or they have reasonable doubts. They have reason to doubt. Except for offshore diamonds, gold and sporadic activity in tin placers, there are no existing offshore mining operations.

Are we getting closer to producing marine minerals?

The ISA has slowly but methodically built consensus on the regulatory framework since it was established in 1994. Exploration regulations for polymetallic nodules were issued in 2000 and updated in 2013. Exploration regulations for polymetallic sulfides and cobalt-rich ferromanganese crusts were issued in 2010 and 2012, respectively. Exploration contracts were awarded in 2001 to pioneer investors who had explored for polymetallic nodules in the 1970s and 1980s, prior to the establishment of the ISA. Currently, the ISA has granted 31 exploration licenses for deep-sea minerals. The majority of the exploration licenses are for polymetallic nodules in the CCZ.

Exploration contractors cannot begin producing deep-sea minerals under the ISA regime until they have been granted an exploitation license. The draft exploitation regulations were prepared in 2019 but are still being developed and deliberated by the ISA. The ISA had set internal goals to complete the exploitation regulations of the mining code in 2023, but did not complete the work.

The two countries with the most advanced regulations for deep-sea minerals within their respective EEZs are the Cook Islands, as mentioned, and Norway. In 2023, Norway changed the name of the venerable oil regulator, the Norwegian Petroleum Directorate, to the Norwegian Offshore Directorate (NOD) to coincide with the nation's plans to offer offshore mineral exploration licenses after many years of preparation. Neither country has finalized the exploitation regulations or are at the point where they will issue exploitation licenses.

Other offshore mining projects for phosphate fertilizer in Mexico and New Zealand have stalled in the permitting process.

The technology to lift nodules from the seabed is demonstrated

Two companies, Global Sea Mineral Resources (GSR), a wholly owned subsidiary of the dredging and offshore construction company DEME, with state sponsor Belgium, and Nauru Ocean Resources Inc. (NORI), a wholly owned subsidiary of The Metals Company (TMC) have demonstrated, with technical partner and specialist offshore contractor Allseas, the ability to harvest nodules from the seabed with minimal sediment plume generation.

Both GSR and NORI (TMC) have exploration licenses under the ISA regime. Critical threshold activities under the exploration licenses are to prepare a comprehensive environmental impact statement and demonstrate a pilot mining test while measuring the environmental impact of the pilot mining system.

GSR and the German government's oceanographic research organization, BGR conducted comprehensive large-scale collector trials with environmental monitoring in the GSR exploration contract area and in the BGR contract area in the CCZ in 2021. GSR deployed a pre-prototype tracked hydraulic collector vehicle to lift nodules from the seafloor, separate them into a hopper and discharge the sediment through a diffuser at the back of the vehicle. The pre-prototype collector vehicle was able to accurately maneuver at a water depth of 5,000 m (16,400 ft) and efficiently remove the nodules at a rate of 110 to 120 tons per hour. Importantly, a comprehensive array of sensors deployed to measure one of the main environmental concerns showed that the sediment plume was much smaller than anticipated and was contained. Sensors to detect plume density 3 m (10 ft) above the seafloor were, in fact, set too high as the generated plume stayed below 2 m (7 ft) above the seabed. The suspended sediment acted as a turbidity current — most suspended sediment fell along the collector tracks with only a few milligrams per liter or less extending as far as 200 m (656 ft) from the collector track.

The GSR collector trials and environmental test did not lift the nodules to the surface. TMC/Allseas performed a similar nodule collection and environmental measurement test from the NORI exploration contract area in 2022 but lifted the nodules to the hold of a converted

Figure 2

Pilot mining vessel Hidden Gem, converted by Allseas, showing 3,000 tons of polymetallic nodules in the hold. (Top photo: Dan McConnell; bottom photo courtesy of The Metals Company)

deepwater oil and gas drilling vessel, called *Hidden Gem.* The TMC/Allseas pilot mining test was the first to lift nodules from the CCZ since the mining company consortia that pursued the feasibility of mining nodules in the 1970s. The TMC/Allseas pilot mining test lifted more than 3,000 tons of polymetallic nodules from a tracked hydraulic collector similar to the GSR collector through a riser using airlift at a water depth of just over 4,000 m (13,000 ft). The prototype collector vehicle successfully lifted the nodules from the seabed at a rate of 86.4 tons per hour, which is believed can be scaled to production rates of more than 200 tons per hour.

Acoustic and optical monitoring of the sediment plume taken concurrently during the full ocean depth pilot mining test showed that 98 percent of the sediments suspended by the collector fell within 300 m (1,000 ft) of the mining tracks. Importantly, the modeled forecast of sediment plume behavior had a very good match with the data. This is quite important because it shows that operators that develop robust measuring systems and models can inform the regulator of the environmental impact of operations close to real time.

Collection and lift tests for polymetallic sulfides, which require excavation, have been demonstrated by Japanese-led consortia. No scalable collection test and lift for cobalt-rich crusts have been attempted yet. Of the three types of deepwater marine minerals, polymetallic nodules that sit proud on the seabed are much closer to feasibility.

Environmental headwinds

There is a narrative in the public that seabed mining has unknown and potentially disastrous impacts on marine ecosystems. To scientists directly working on the problem, there was quite a bit of uncertainty about the environmental impact of removing nodules from the seabed until they could develop real-world experiments to test their models.

The obligation to protect and preserve the marine environment is established in the U.N. Convention on the Law of the Sea, from which the ISA in Part XI of the 1994 agreement was established. To fulfill the obligation to protect the marine environment, the ISA has invited environmental groups to be nonstate party observers that provide valuable input to regulation development.

Some reasoned technical papers, amplified by environmental activists, suggested that the sediment plume from seafloor mining activities could spread for hundreds of kilometers and for thousands of meters vertically, potentially impacting the entire ocean water column and its ecosystems. It was a valid hypothesis to be tested, and this unanswered question persisted for decades without being countered because few to no tests to validate the hypothesis existed.

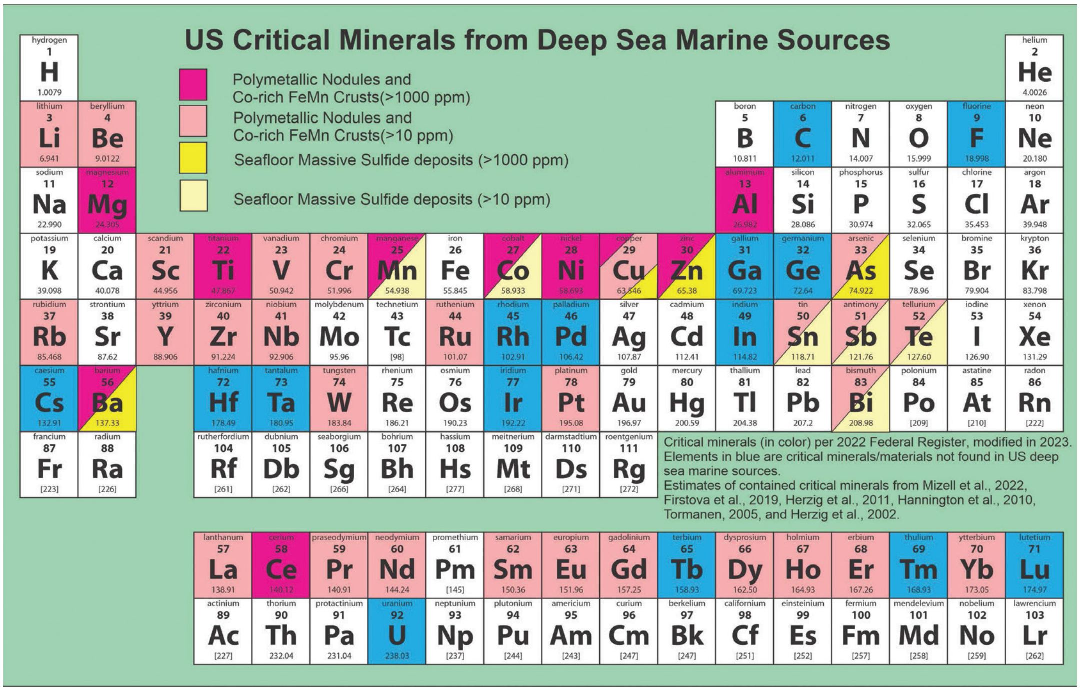
The comprehensive effort put into plume detection and monitoring, and ecologic and taxonomic studies is a push to provide accurate data to answer those questions and begin to allay public perceptions.

The exploration programs by GSR and TMC have conducted multimillion-dollar campaigns to establish environmental baselines, measure the actual sediment plume against models, and establish post-mining impact on biologic communities and their resilience.

In presentations at the meeting in Rarotonga, leading deep-sea ecologists and taxonomists

Figure 3

U.S.-designated critical minerals found in deep-sea minerals in the U.S. and Territorial OCS and EEZ. (Source: Dan McConnell)



reviewed post-impact studies of 11 nodule test collection vehicles that had been deployed over a 42-year span and found no lasting impact on abyssal nodule ecosystems. The post-impact assessment at the GSR and TMC/Allseas sites that used their modern collectors showed no detectable impact on the bacteria that dominate these low-density ecosystems, a 60 percent reduction within the mining track of fauna larger than 1 mm, and limited impact on biodiversity. A study to investigate ecologic rebound 42 years later at the Ocean Minerals Co. (OMCO) test mining site that disturbed almost 3 m (10 ft) of sediment, versus a few centimeters by the modern GSR and TMC/Allseas collectors, showed clear signs of biological recovery and the return of pioneer bottom-attached species.

Advances and setbacks

If the environmental questions are being answered with solid scientific data, what is holding seabed minerals back? Five years ago, marine mineral development seemed like it was on a trajectory that would not be slowed. Commodity prices for nickel and cobalt were high. The price of cobalt reached an all-time high of more than $40/lb. Two years ago, the price of nickel spiked at more than $20/lb. There appeared to be positive consensus that net-zero policy goals were possible and could be implemented. Significant expansion of electricity networks, electric vehicles (EVs), battery storage, wind and solar energy would be required. Within that expansion, the production of battery minerals — lithium, graphite, cobalt, nickel and rare earths — would see dramatic growth.

That is not where we are today. The price of cobalt is near a 10-year low, with prices of nickel and lithium not doing much better. The world is decidedly not on a 2040 or 2060 net-zero path, but additional secure metal supply is still needed even without considering the energy transition.

Critical mineral policies

Economic nationalism affecting global mineral and metal markets is accelerating. The International Energy Agency (IEA) reported that of the 215 national policies related to critical minerals, 112 have been put in place since the COVID-19 pandemic. The United States has initiated one of the most impactful critical mineral requirements through the CHIPS Act, the Inflation Reduction Act and the Energy Act of 2020. For example, one of the mechanisms to increase critical mineral extraction and processing in the United States is leveraged in the timeline for increased U.S. critical mineral components in EV batteries: from 50 percent in 2024 to 80 percent in 2027 in order for consumers to claim a $3,750 credit on the EV purchase. These incentives are likely to change or be eliminated under the Trump administration and Republican Congress, but the first Trump administration took a proactive approach to critical minerals and it seems likely that support for the domestic development of critical mineral supply chains will continue.

Congress has directed the Pentagon to provide a road map of how the United States can source and process critical minerals in response to China's domination of the sources and processing of critical minerals and willingness to curtail supplies for geopolitical reasons, as evidenced by China's recent announcement that it is banning the export of the critical minerals gallium, germanium and antimony to the United States.

Some Republicans in Congress have taken

an interest in marine minerals and may expand on the marine critical mineral assessments in the U.S. Outer Continental Shelf (OCS) and EEZ initiated by the Biden administration.

The U.S. Bureau of Ocean Energy Management (BOEM) Marine Minerals Program is responsible for all nonenergy minerals in the OCS. Partly in response to several executive orders on supply chains and critical minerals from the Trump and Biden administrations, the Marine Minerals Program commissioned a reference document on the known critical minerals in the U.S. and Territorial OCS and EEZ with emphasis on polymetallic nodules, but also covering polymetallic sulfides, cobalt-rich crusts, heavy mineral sands and phosphates.

Thirty-seven of the 52 critical minerals designated by the U.S. Department of Energy are found in known deposits in the U.S. and Territorial OCS and EEZ. Cobalt-rich crusts are present in the OCS off southern California, polymetallic sulfides analogous to the Windy Craggy volcanogenic massive sulfide (VMS) ore deposits are present in the Escanaba Trough on the seafloor spreading center off northern California and Oregon. Much of the OCS and EEZ around the far-flung U.S. Pacific Territories, such as American Samoa, Jarvis Island, Johnston Atoll, Kingman Reef and Palmyra Atoll, and Wake Island are prospective for polymetallic nodules and cobalt-rich crusts based on sparse legacy seafloor sampling and geologic setting. All of these areas are emphatically underexplored with modern seafloor mapping and sampling systems. Notably, several are regionally adjacent to ISA-issued contract areas for polymetallic nodules and cobalt-rich crusts.

When will seabed mining begin?

The timeline for deep seabed mining always seems to shift to the right but, eventually, the future gets here. A *New York Times* article from 1977 quoted the head of one deep-sea mining company as saying, “With the law straightened out, we could be mining in a couple of years.”

That remains true. No seabed mining will take place until the exploitation mining codes by the ISA or national jurisdictions are finalized and licenses granted. The government of Nauru invoked “the two-year rule,” a provision in the ISA regulations to force the issuance of timely regulations, in July 2021. In response, the ISA adopted a roadmap to adopt the final exploitation regulations by July 2023 but failed to complete it. The ISA hoped to complete the mining code during the 2024 sessions, but also failed. NORI intends to submit its application for exploitation to the ISA in 2025 but it is unclear whether the ISA will complete the exploitation code in the 2025 sessions. The matter was further complicated by the election of a new secretary-general of the ISA, who was supported by member states that hope to slow the issuance of exploitation licenses until environmental knowledge gaps are filled, there is greater understanding of impacts, and strict environmental regulations are established.

In Norway, the timeline for the issuance of exploration licenses was knocked off-track by the Socialist Left Party in the governing coalition, which forced a concession to suspend the issuance of exploration licenses until the end of 2025. The exploitation regulations are still being developed by NOD.

The Cook Islands Seabed Minerals Authority completed its exploitation regulations in 2024 and is currently progressing standards and guidelines. Authorizing seabed mining, however, is contingent on further scientific research.

Countries like New Zealand that have legal frameworks for putting forth seabed mining projects have yet to approve them. The United States has a legal framework for issuing leases through the BOEM for marine minerals in the OCS and EEZ, but the framework is viewed by many as needing to be modernized and updated.

So, when will seabed mining begin? This author, not as optimistic as the executive quoted in 1977, thinks that it will be within five to 10 years. For those readers cognizant of the long timelines involved with the permitting of mineral projects on land, a five- to 10- year window to realize deep-sea mineral operations may not seem out of the ordinary. ■

(Dan McConnell is a consultant specializing in marine minerals and marine site characterization for oil and gas and offshore wind development dba Geomarine Resources PLLC and is a qualified person for polymetallic nodule resource surveys.)

Further reading

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