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The false promise of deep-sea mining

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Deep-sea mining of the international seabed could begin soon, despite concerns about its ecological consequences. We join others calling for a ban on international seabed mining, but for a different reason: it is a multi-billion-dollar solution to problems that do not exist. We refute three pro-extraction arguments—about (1) mineral scarcity, (2) social benefits, and (3) economic benefits—that misrepresent the state of the mining industry and mineral supply chains.

In March 2025, the US announced it would unilaterally explore commercial mining of the international seabed in partnership with The Metals Company (TMC), ignoring ongoing multilateral processes and subverting the authority of the International Seabed Authority (ISA). This is an extreme example of a wider trend among countries and firms to team up to mine the deep sea. Viewed by some policymakers and academics as an important pathway for energy transitions and the fight against climate change, commercial mining of deep seabeds could occur in the next few years in marine areas under national jurisdiction. However, the future of mining of the *international* seabed is less clear, in part because of contested authority over its governance¹. Governments are currently developing an international regulatory code to govern the deep-sea mining of metals and minerals such as zinc, manganese, molybdenum, nickel, and—potentially—rare earth elements.

There are fierce divides among scholars, states, and practitioners about the path forward, ranging from vocal support² to growing concern, especially over the ecological damage that would be caused by deep-sea mining³. We join others calling to reverse course on deep-sea mining, though for a different reason: deep-sea mining is a multi-billion-dollar solution to problems that do not exist. At best, these “problems” reflect a misunderstanding of global mineral supply chains that vastly overstates the scarcity of metals and minerals. At worst, they have been manufactured by pro-extraction interests as a way to commodify a global commons that has been legally recognized as “the common heritage of [hu]mankind”⁴.

Our political economy analysis illustrates that arguments in support of deep-sea mining in the international seabed are based on false claims and false hopes. They hinge on misrepresentations of the current state of the mining industry and mineral supply chains. Government investments in deep-sea mining are an expensive distraction from effective, long-term policy planning to address climate change, and to promote metals recycling and ecologically oriented circular economy initiatives to reduce the demand for deep seabed resources.

We show that three arguments often made by proponents of deep-sea mining are unsubstantiated. First, contrary to scarcity arguments, we already have sufficient terrestrial deposits of the metals and minerals

required for energy transitions. We do not “need” to augment supplies through deep-sea mining. Second, proponents argue that deep-sea mining will avoid the negative social effects of terrestrial mining, as it would not displace communities and would create safer working conditions. We maintain that this logic only holds if deep-sea mining replaces terrestrial mining, which is neither economically nor politically plausible. And third, we rebut the economic claim that deep-sea mining will financially benefit local economies and countries of the global South; to date, the record indicates that deep-sea mining is a risky and unprofitable investment. Without these arguments, there is little justification to mine the international seabed, but strong reasons to recommit to better governance of supply chains across mineral lifecycles⁵.

The Mineral Supply Chain Claim

Deep-sea mining proponents argue that the rare earth elements and critical minerals necessary for the energy transition (i.e., solar panels and electric vehicle (EV) batteries) are scarce, and so we need to exploit all possible sources⁶. Some governments have embraced this, either through securing exploration contracts on the international seabed (three governments, and 11 state-owned enterprises), sponsoring private contractors (e.g., Jamaica, Nauru, Tonga), opposing a moratorium (e.g., China), pursuing deep-sea mining domestically (e.g., Norway), or even considering international seabed mining unilaterally (i.e., the US).

In theory, the argument goes, increasing supply from deep-sea deposits will lower raw material prices, thereby facilitating the transition to cleaner technologies. Moreover, this logic suggests diversifying supply will prevent monopolistic control by a subset of countries, thus maintaining competitive pressures and preventing strategic bottlenecks that could slow the energy transition. We show that these claims do not hold up.

It is important to clarify which resources proponents claim are scarce. Rare earth elements are critical to renewable energy technologies, but they are not currently the focus of most deep-sea mining exploration efforts, which so far target polymetallic nodules containing cobalt, copper, manganese, molybdenum, and nickel. Although they are called “rare,” the critical resources that comprise rare earth elements are abundant and can be mined

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on land in many countries⁷. In 2023, world production of rare earth elements was 300,000 tonnes per year compared to known reserves of 130 million tonnes⁸. Production in 2022 was concentrated in China (70%), followed by the United States (14%), Australia (6%), and Myanmar (4%). However, reserves are more widely distributed than current production suggests (see Table 1), and could meet even high projections of a doubling or quadrupling of rare earth element demand by 2040⁹. While rare earths are not the current focus of exploration efforts in the deep sea, they may be in the future.

Terrestrial reserves of the metals and minerals that are currently targeted for seabed mining are already extensive, notably cobalt, copper, manganese, molybdenum, and nickel (see Table 2). Projections of demand for these metals and minerals varies widely, and prices are volatile due to a combination of protectionist trade measures, contentious geopolitics, and market manipulation¹⁰. A series of political and market dynamics have affected nickel and rare earth elements, for instance¹¹. Technological advances in the efficiency of batteries, as well as the development of alternatives (e.g., sodium-ion batteries), could further shift demand forecasts for a series of metal and mineral inputs¹².

Even a cursory sketch of production and reserves shows that there is no shortage of inputs for renewable technologies. These are hollow arguments that misrepresent the economics of terrestrial mineral commodities—and underplay the economics of deep-sea mining. The data demonstrates that even if deep sea reserves are large, there is no pressing need for the increase in supply that deep-sea mining might one day contribute to an energy transition. Deep-sea mining is too speculative, slow, expensive, and unproven to alter mineral supply chain economics, and barring major technological breakthroughs, which do not appear to be forthcoming, these economic constraints will persist for the foreseeable future. Estimates of the cost of deep-sea mining are not available, but there is no evidence to suggest it will be cost-competitive with terrestrial mining given such remote, and deep, operations. Existing mineral reserves, stronger recycling regulations, further terrestrial exploration (if necessary), and ongoing technological advances are all more than sufficient to meet future mineral and metal demand.

Despite its lack of market potential, there is strong pressure for deep-sea mining. State-owned enterprises and state agencies have undertaken much of the exploration to date, although the high-profile public pressure comes from small seabed mining start-ups, such as TMC. These small companies are backed by major infrastructure firms and institutional investors (e.g., Loke Marine Minerals, Blackrock Inc., and The Vanguard

Group, among others.) The current value in deep-sea mining may not be the minerals themselves, but the gains from speculation and rent-seeking as stocks rise and fall, assets are transferred, and companies go bankrupt and are reinvented^{13,14}. Moreover, states and state-owned enterprises with exploration contracts in the international seabed may be more willing to accept market inefficiencies to advance state interests¹⁵. Market forces alone will not prevent the worst impacts of deep-sea mining, which is why a ban is needed.

The Social Benefits Claim

Advocates argue that deep-sea mining will be free of the human rights abuses and conflict zones that pervade terrestrial mining¹⁶. Many so-called “critical” mineral reserves are concentrated in a handful of countries—for instance cobalt in the Democratic Republic of Congo, copper in Chile and the DRC, nickel in Indonesia, and manganese in South Africa. There is pervasive conflict in many of these regions over mining, with concerns over infringement on community and Indigenous rights, political corruption, and the violent suppression of activists and community leaders¹⁷. In central Africa, mineral wealth has contributed to civil war, child labor and soldiers, and weakened political institutions¹⁸. These are important challenges, and governments need to do more to reduce exploitation in the mineral supply chain.

However, deep-sea mining will not reduce the level of terrestrial extraction and the human rights abuses that accompany it. Mining companies have already secured contracts for terrestrial mining that will be in place for decades. States are actively investing in critical mineral projects on land¹⁹, with infrastructure investments with long time horizons. Deep-sea mining—commercially unproven and years away at best—will not prompt terrestrial mining companies to reduce or even slow their future extraction plans. Access to these materials also remains part of many states’ security agendas, suggesting comparative economics alone is not driving decision-making over mining projects²⁰.

More importantly, deep-sea mining may face its own labor challenges. Sea-based industries like offshore oil and gas or distant water fishing are rife with labor violations and modern slavery²¹. It is unclear what labor conditions will be for deep-sea mining, and they will be difficult to verify in remote operations. Though some parts of the mining process may be automated, workers are required for the transport, processing, and distribution of raw materials extracted both on ships and on land.

Put simply, terrestrial and deep-sea mining are not substitutes—as new deposits are discovered they are exploited *in addition to* land-based deposits, not instead of them²². This pro-extraction tactic of presenting new supplies as substitutes is not new, nor is it exclusive to minerals²³. Canadian oil companies promoted some of the most carbon-intensive oil in the world as “ethical” since it is produced in a democracy that respects the rule of law²⁴. But of course, Canadian oil on the market did not slow production in less democratic nations. The same logic holds for deep-sea mining. There is no evidence to suggest that deep-sea mining will have any bearing on the volume, location, or social impacts of terrestrial mining, and it will introduce its own labor challenges.

The Economic Claim

Deep-sea mining has attracted private investment from ambitious entrepreneurs and some of the world’s largest corporations seeking to secure new property rights and revenue sources. They claim that deep-sea mining opens a new resource frontier that can provide shareholder value and mineral wealth for countries, including many in the global South without terrestrial reserves.

But it is not clear that deep-sea mining will ever be a good investment. Some of the industry’s highest-profile investors, including Lockheed Martin and Maersk, have sold off all or most of their stakes in deep-sea mining companies^{25,26}. As noted, the sector is highly speculative and reliant on commercially unproven technology and processes. Entrepreneurs, venture capitalists, and institutional investors can pursue this speculative enterprise for its potential to generate future profits, but so far there are no indications

Table 1 | Production and Known Terrestrial Reserves of Rare Earth Elements 2022⁸

	Production (tonnes)	Known Terrestrial Reserves (tonnes)
China	210,000	44,000,000
Vietnam	4300	22,000,000
Brazil	80	21,000,000
Russia	2600	21,000,000
India	2900	6,900,000
Australia	18,000	4,200,000
United States	43,000	2,300,000
Greenland	0	1,500,000
Tanzania	0	890,000
Canada	0	830,000
South Africa	0	790,000
Myanmar	12,000	Unknown
Thailand	7100	Unknown
Other	500	4,590,000
World Total	300,000	130,000,000

Source: US Geological Survey.

Table 2 | World Production and Known Terrestrial Reserves of Critical Minerals 2022⁸

	Production (metric tons)	Known Terrestrial Reserves (metric tons)
Cobalt	190,000	8,300,000
Copper	26,000,000	890,000,000
Manganese	20,000,000	1,700,000,000
Molybdenum	250,000	12,000,000
Nickel	3,300,000	> 100,000,000

Source: US Geological Survey.

that they will succeed without public subsidies, similar to those used to underwrite deep sea mineral exploration within national jurisdictions²⁷.

It is also difficult to know exactly who will benefit from deep-sea mining. International seabed exploration is undertaken by governments as well as state-owned enterprises or private firms with the backing of a sponsoring state. Sponsoring states must be party to the UN Convention on the Law of the Sea, which precludes the US and a handful of others from sponsoring mining of the international seabed. These state-firm arrangements have been criticized for a lack of transparency, making it hard to determine exactly how prospective benefits would be distributed²⁸. Corporate ownership structures of deep-sea mining companies have been opaque and highly fluid; they are characterized by frequent share transfers, mergers and acquisitions, bankruptcies and subsequent start-ups with the same investors, and asset acquisitions. In total, just 22 contractors have exploration contracts in the deep-sea—one intergovernmental consortium, three governments, 11 state-owned enterprises, and seven private firms—many of which share investors²⁹. A handful of investors and mining companies are positioning themselves to benefit from deep-sea mining, through both the value of minerals extracted and from (indirect) subsidies and other public funds.

A 2018 benefit-sharing proposal commissioned by the ISA, for example, faced opposition from countries in the global South because mining companies were projected to receive about 70% of project proceeds and the sponsoring state 24%; only the remaining 6% would go to the ISA. That 6% included financial benefit-sharing to other states in accordance with common heritage requirements—the African Group projected each country's return under this arrangement to be just USD 100,000 per year³⁰.

So far, early deep-sea mining initiatives have played out as we would predict. Entrepreneurs and institutional investors cut-and-run when investments fail, leaving host states and communities to bear the costs. Canadian company Nautilus's project in Papua New Guinea failed, the company went bankrupt, and PNG was left with \$24 million of debt (roughly the country's annual health care budget)³¹. Though this occurred in a marine area under national jurisdiction, there is no a priori reason to expect different outcomes in the international seabed. Those same investors, released from responsibility through bankruptcy, are now involved with TMC, among the most vocal, prolific, and influential deep-sea mining startups with exploration contracts sponsored by Nauru and Tonga. More recently, TMC has considered pursuing these same exploration sites under US domestic law, thereby circumventing the ISA and common heritage requirements altogether, leaving the fates of Nauru, Tonga, and the ISA unclear should TMC proceed unilaterally¹. Moreover, TMC's active participation in ISA negotiations has raised concerns about companies exercising undue influence³².

Deep-sea minerals in the international seabed are the common heritage of humankind under international law, which means the benefits should be distributed fairly across countries. But investors have already exploited and undermined this benefit-sharing system before operations have even begun. Blue Minerals Jamaica Ltd., for example, was established in Jamaica and briefly owned by a local accountant before ownership was transferred to the same European investor who orchestrated the start-up as its CEO³³. By acquiring local subsidiaries in Nauru and Tonga, TMC, based in Canada,

has exploration rights to areas of the international seabed set aside for the global South²⁹. Cases like these show that before any money is made from deep-sea mining, there are already arrangements in place to ensure the benefits flow to investors. If mining activities expand beyond states' jurisdiction, it seems likely that deep-sea mining will result in a transfer of public goods into private hands. We should not give corporations rights to common heritage resources and then subsidize their extraction, while paying for the clean-up.

Better Options

Scientists, governments, and advocates have shown that deep-sea mining is environmentally destructive. We have demonstrated that it is unnecessary. Terrestrial deposits of the materials needed for renewables are sufficient to meet growing demand. Decades of failure show that deep-sea mining is too expensive and impractical to compete with terrestrial mining on volume or price. Its only path to viability is with the investment of millions (if not billions) of dollars of public funds, and even then, the extracted materials will not solve supply chain or social problems.

Any investment in deep-sea mining that is premised on promises of a renewable energy future would be far better spent on more effective climate action and on efforts to fix known problems and injustices in the terrestrial mining system. Deep-sea mining is an investment in false hope that would only benefit a few concentrated interests, while distracting governments from improving existing climate mitigation policies and accelerating energy transitions.

It is not too late to prevent the mining of the international seabed. Such a reversal has precedent. In 1988, countries concluded negotiations on the Convention on Regulation of Antarctic Mineral Resource Activities (CRAMRA), which would have established rules for Antarctic mining. However, the treaty never entered into force because two key countries, Australia and France, revoked their support. Consequently, no country ratified the agreement. The treaty was subsequently replaced with the 1991 Environment Protocol, which prohibits mineral resource activities in the Antarctic (subject to a series of rules for future modification), and provides detailed regulations for the protection of the Antarctic environment. States should learn from the Antarctic experience.

A political economy analysis demonstrates that the arguments for deep-sea mining are based on false premises. There is no mineral supply shortage. Deep-sea mining will not substitute for terrestrial mining, and it is unlikely to meaningfully contribute to local economies. Deep-sea mining will require public resources both nationally and internationally that would be better spent elsewhere. There is no compelling reason to pursue it. Instead, countries should support a ban on international seabed mining or, failing that, an ongoing moratorium. We do not need a new source of already-abundant minerals to supply energy transitions; we need better climate policies, and greater investment in metals recycling and an anti-extractivist circular economy.

Data availability

No datasets were generated or analyzed during the current study.

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Competing interests

The authors declare no competing interests.

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