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Article *in* Nature Geoscience · February 2017

DOI: 10.1038/ngeo2897

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Subsea mining moves closer to shore

Mark Hannington, Sven Petersen and Anna Krätschell

Mining the deep seabed is fraught with challenges. Untapped mineral potential under the shallow, more accessible continental shelf could add a new dimension to offshore mining and help meet future mineral demand.

The demand for raw materials continues to surge, forcing mining companies to exploit lower-grade ores and deeper deposits. Some speculate that conventional sources of metals might soon reach peak supply, and production may decline in subsequent years[1]. Many developed economies depend on imports of critical metals for their high-technology industries. Often these metals cannot be substituted and exist in ore deposits that are found in only a few countries. Developed countries have thus been compelled to think about alternative sources, including those in the deep sea[2]. As the oceans cover more than 70% of Earth's surface, it is widely believed that they contain vast quantities of mineral resources, which could ease the pressures on raw materials supply[3].

Deep-sea mining is inching closer towards reality, despite concerns about the sensitivity of the ocean environment and ecosystems. The first exploration licences for manganese nodules in the central Pacific Ocean were signed into effect in 2001 by the International Seabed Authority. These licences came to an end in 2016[4,5], but will probably be extended so that contractors can continue exploration or take the next step and mine the nodules that they have discovered. In other parts of the oceans, massive sulfide deposits on the seafloor that form around hydrothermal vents, and cobalt-rich ferromanganese crusts that form on rocky substrates (Fig. 1) have also caught the eye of explorers[5]. However, another much shallower realm, which until now has mostly been the domain of oil and gas producers, may also offer potential for mineral resources — the subsea continental shelf.

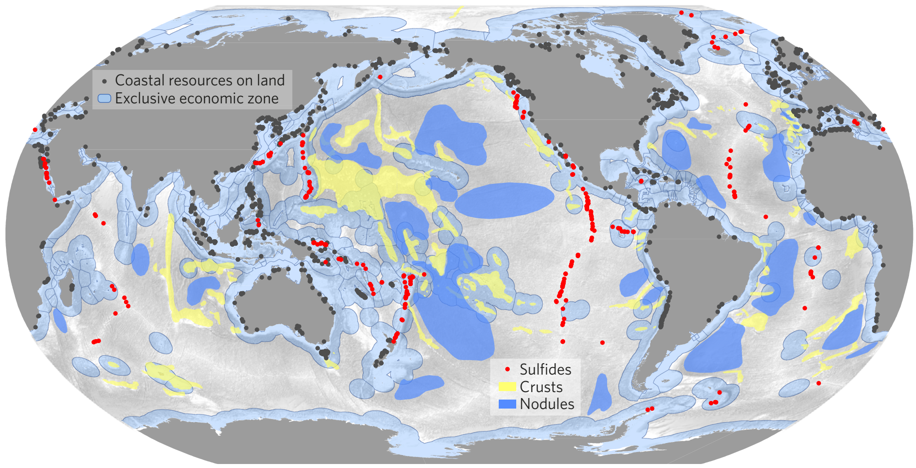

Figure 1 | Global ocean mineral resources. The distribution of massive sulfide deposits at hydrothermal vents, cobalt-rich ferromanganese crusts and manganese nodules, and the locations of more than 1,700 non-fuel mineral deposits on land within 50 km of the coast (produced using data from refs 17, 18).

Deep-sea challenges

Machines for mining in the deep sea have existed since the original exploration boom for manganese nodules in the Pacific Ocean in the early 1980s[2,5]. Pilot mining tests have also been carried out for other types of deep-sea deposits, including in the Red Sea and offshore from Japan. Although challenges are expected, there are probably few insurmountable technology barriers to the recovery of these ores[6]. Many of the difficulties of working in the submarine environment have already been overcome by the oil and gas industry, and the skills and expertise from that sector are readily transferrable to seabed mining.

However, decades of intensive research have failed to establish the possible future economic significance of deep-sea resources. Past economic forecasts have been overly optimistic[7], and so far there are no examples of mining that could serve as benchmarks for economic analysis or assessment of the environmental impacts. Part of the problem is the long lead time required to develop any new mine. For example, diamonds were discovered offshore from Namibia in the 1970s, but it took 15 years to define a resource and 20 years to begin mining them[8]. Nautilus Minerals Incorporated — a mining company licensed to mine massive sulfide deposits in the Manus Basin of eastern Papua New Guinea — first emerged as a private company in 1994, but they did not identify a viable resource until 2007 and will not commence mining before 2018; a lead time of 25 years. And not all discoveries can be mined. A sobering statistic from land-based resource development[9] is that the rate of conversion of newly discovered prospects into actual mines is less than 1 in 1000. By this metric, only a handful of the currently known deep-sea mineral deposits would ever advance to a commercial mining stage.

These challenges pale in comparison to the almost complete lack of knowledge about the fragile ecosystems that exist

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in the deep ocean and the impacts that mining might have on them. Everyone agrees that deep ocean mining cannot proceed unless we have a full understanding of the biodiversity and ecosystem services that could be affected and the means to protect them.

Onto the continental shelf

Some explorers are looking elsewhere for new offshore resources and turning to the continental shelf. Exploitation of mineral resources on the shelf is not a new idea. In addition to diamond mining, near-shore dredging is a significant source of sand for the global aggregate industry, tin has been mined intermittently in Southeast Asia, gold has been mined offshore from Alaska, and iron-rich sands have been targeted for development in New Zealand[10]. In addition to diamond mining, near-shore dredging is a significant source of sand for the global aggregate industry. Marine phosphorite, which is a potential source of fertilizer (and possibly uranium) occurs in abundance in shallow water near the coasts of South America, western Africa, eastern Australia, New Zealand, Baja and the southeastern United States. Recent discoveries beneath the seabed suggest that the continental shelf may offer even greater potential to supply our mineral needs than is currently realized.

Most of the submarine shelf areas are underlain by continental rather than oceanic crust. Globally, an area comparable to one-third of the continental landmasses lies submerged beneath the shelf and slope[11]. Given these vast shelf areas are largely geological extensions of the onshore bedrock, any mineral resource mined on land near the coast could also occur in the offshore continental basement. This was impressively illustrated when on November 10, 2015, the *China Daily* reported the discovery of a giant gold deposit under the Yellow Sea, just offshore from China's largest open-pit gold mines in the famous Jiaodong gold district in Shandong[12]. The news headlines implied a new seafloor mineral deposit had been found, but instead, the discovery was simply the deep offshore extension of the gold lodes that had already been mined on land for centuries. Planned development of the offshore lodes will take place from land via mine workings that extend under the sea.

Exploitation of mineral resources below the seabed has been imagined before[13]. Historically, more than 100 mine shafts have been sunk from land (or artificial islands) to extract offshore coal, iron ore, nickel, tin, gold, copper and even mercury from under the sea in many parts of North and South America, Europe, Australia and Japan. If one considers the numbers of ore deposits already known near the coast on land, then the resource potential of the offshore continental shelf is staggering. Nearly every type of metal in demand today is accessible in mines close to the sea, with more than 1,700 ore deposits located less than 50 km from the ocean (Fig. 1). Among them are some of the most richly endowed mineral belts on Earth. But our knowledge of what might lie beneath the adjacent shelf, even just a few kilometres offshore, is flimsy at best. One reason is that offshore drilling, which has so far been done almost exclusively for oil and gas, is restricted to the overlying sediments; and so drilling generally stops at the basement where the subsea mineral resources are most likely to be found.

Ongoing research in many of the world's marginal seas[14,15] is revealing a rich diversity of mineral deposits similar to those on land, including the first submarine gold deposits in eastern Papua New Guinea, copper-gold mineralization offshore from New Zealand, and massive zinc-rich sulfide deposits in the Okinawa Trough of the East China Sea. Geological intuition tells us that buried deep along the margins of the Atlantic Ocean — the site of break-up of the ancient supercontinent Pangaea — there are likely to be mineral deposits formed and preserved during the initial opening of the ocean basin in the Jurassic. Somewhere in the Arctic Ocean, in the Kara Sea or the Laptev Sea, there may be extensions of Permian-age flood basalts from the Siberian Traps that host the giant Norilsk-type nickel deposits. And somewhere in the Gulf of Mexico or the Mediterranean Sea there are likely to be lead-zinc deposits (similar to those in the Mississippi Valley) associated with salt domes and oil and gas seeps. The list of prospects is long and their exploration could change our view of the world's offshore mineral resources.

The possibility of reduced risks

Seabed mining on the shelf has been banned by a number of countries — in particular for resources such as marine phosphorites and heavy minerals — because of potential environmental impacts and conflicts with other uses of the coastal ocean. Indeed, some countries have set aside vast tracts of their mineral-rich offshore territory as marine reserves[16]. But mining beneath the continental shelf — whether by tunnels from shore, or shafts on artificial islands or platforms — could leave the seabed itself relatively undisturbed and minimize any disruption of seafloor ecosystems.

Global demand for natural resources will continue to grow for the foreseeable future. As exploration for resources reaches farther offshore, issues of sustainability and territorial claims will inevitably arise. Some declared exclusive economic zones and their contained resources are already intensely contested by neighbouring countries. In light of these challenges, the subsea geological resources of the near-shore continental shelves could be a comparatively low-risk option to help meet our metal and mineral demands. ❐

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Acknowledgements

This Commentary stems from a workshop sponsored by the International Futures Program of the Organization of Economic Cooperation and Development. The authors thank B. Stevens (OECD) for the encouragement to organize the event and to contribute to the OECD report on *The Future of the Ocean Economy in 2030*. Data included here are part of a compilation funded by the European Commission under call FWC MARE/2012/06-SCE2013/04. M.H. is supported by the Helmholtz Excellence Initiative and by a Discovery Grant of the Natural Sciences and Engineering Research Council of Canada.

Published online: 6 February 2017

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