Deep-sea mining: An introduction

Deep-sea mining is a collective term generally applied to the extraction of three distinct types of ore deposit found in the deep sea: seafloor massive sulphides, ferromanganese nodules and cobalt crusts. Each deposit type is formed in a different way, requiring three different mining processes and resulting in three different sets of associated environmental impacts. It is therefore important to consider each deposit type separately as statements applicable to one deposit type may not be appropriate for the others. Below we describe some of the key differences in the formation, nature and environmental issues of each of these deposits.

Seafloor massive (polymetallic) sulphide deposits

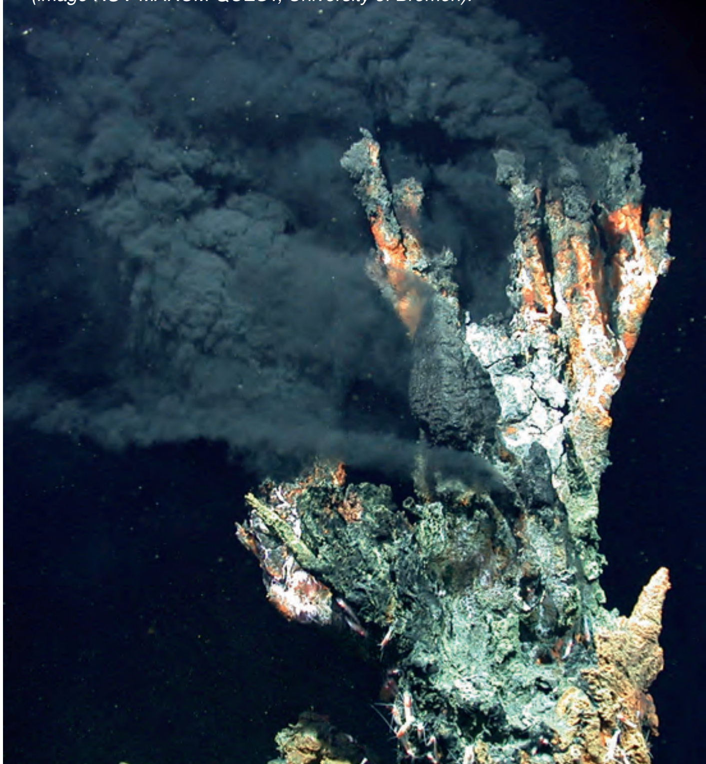
These deposits, often referred to as SMS deposits, form on oceanic plate boundaries at or near sites of volcanic activity. At these locations superheated water containing high levels of dissolved metals is expelled through cracks in the seafloor and can form metal-rich hydrothermal chimneys and sub-seafloor metal ore deposits. Over time, large mounds of collapsed chimneys and other metalliferous debris can build up and, combined with the sub-surface deposits, form ore bodies tens of metres thick. These deposits contain a range of minerals depending on the pressure and temperature regime when they formed.

Commercially interesting deposits generally occur in water depths between 1000 - 4000 metres. To date, nearly three hundred SMS deposits have been identified in the world's oceans but only a handful have commercial potential. The richest deposits may lie adjacent to ridge areas where volcanic activity has ceased.

Mining of seafloor massive sulphide deposits will be similar to open pit mining on land with crushed ore then being pumped from the seabed to a surface barge as a slurry. Because the ore bodies extend below the seafloor, the surficial footprint of the mined area will be much smaller than for nodules or crusts. The Solwara 1 deposit off Papua New Guinea, due to be mined by Nautilus Minerals in 2017, covers an area of 0.1 km^2. Changes to the deep-sea environment will not be confined to the physical removal of material from the seafloor. Plumes of sediment-laden water will likely be generated by the mining operation and also as a result of sediment-laden discharge water from the slurries that are dewatered on the support vessel.

Ecosystems associated with active hydrothermal vent systems tend to have high biomass but relatively low biodiversity, with many species being restricted to vent sites and their immediate surroundings. Although these organisms are able to recolonise relatively rapidly from other vents in the vicinity, much of the mining activity will affect the non-vent fauna at some distance from the active vents. These organisms are less well known but are likely to be similar to seamount fauna, which will recolonise much more slowly.

The Beehive at the Snake Pit vent field on the mid-Atlantic Ridge (image Ifremer/Victor 6000, Bicose cruise 2014)



The Kandelabra vent at the Logatchev field, mid-Atlantic Ridge (image ROV MARUM-QUEST, University of Bremen).

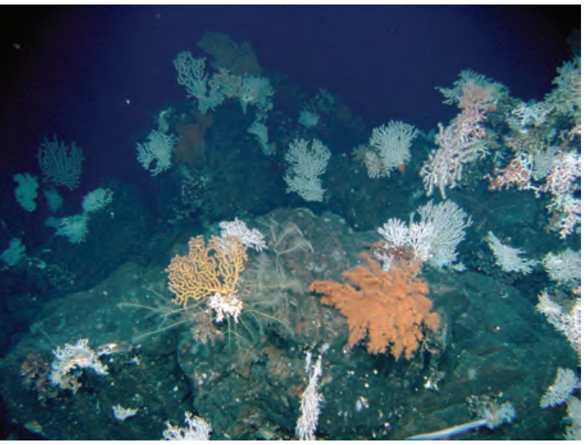
Ferromanganese (polymetallic) nodules

Ferromanganese nodules are generally 5-10 cm in diameter, formed over millions of years by the slow precipitation of metallic compounds from seawater. They are found on the seabed in the deepest parts of the oceans, generally between 4,000 and 6,000 metres water depth, in places where deposition of other particles on the seafloor is very slow. The most common occurrences are in the Pacific Ocean where the nodules can form a near-continuous layer on the seabed, but more usually they lie scattered across the seafloor and within the top 20-30 cm of the seafloor sediments.

Above: A sea cucumber, probably Psychropotes longicauda*, on a nodule field of the NE Pacific at 5000 m depth (image courtesy Ifremer Nodinaut cruise 2004).*

Nodules can be mined easily from the relatively soft sediment, but then need to be pumped to a vessel at the surface, either whole or crushed into a slurry. Because the nodules occur in a thin layer, very large areas of the seafloor need to be mined for the operation to be economically viable. The smothering effect of sediment-laden plumes from both the mining operation and dewatering of slurry may greatly extend the area impacted by the mining, particularly downslope.

Ecosystems on the oceans' abyssal plains comprise a diverse array of species, but with very low biomass. A large proportion of the species are still unidentified but it is known that many individuals are long-lived and slow growing, and are accustomed to a very stable environment. These ecosystems are likely to be very susceptible to both physical disturbance and smothering by sediment plumes, which may greatly extend the areas impacted by mining. The ecosystem may be very slow to recover.



Cobalt-rich crusts

These crusts are precipitated from seawater as a thin surface layer on hard rock surfaces, typically on the tops and flanks of seamounts where sedimentation is minimal. They accumulate at a rate of 1-6 mm per million years and can reach thicknesses of up to 25 cm. Economically important crusts occur between 800 - 2500 metres water depth, primarily in the western Pacific Ocean.

The mining operation requires the removal of the crust without collecting the underlying rock, which would dilute the ore quality. This will likely involve grinding the crust from the host rock and transporting the ore up to a surface vessel in a slurry. Large surface areas will need to be mined.

Ecosystems on seamounts are frequently complex and diverse, and may include reef-forming species such as corals and sponges. Some of these species are long-lived and slow to reproduce, and some may be geographically limited to a small area or group of seamounts. The smothering effect of sediment-laden plumes from both the mining operation and dewatering of slurry may greatly extend the area impacted by the mining, particularly downslope. Ecosystem recovery may be very slow.

Above: Seamount ecosystems, such as these pictured in the Azores, are sensitive to environmental change. Image courtesy IMAR/U. Azores.

*Right: Table comparing characteristics of the three main deposit types of interest for deep-sea mining. * Described as kg of ore per m² of seafloor, or extent of ore body below seabed.*

	Nodules	**Crusts**	**SMS**
Water depth	4000 - 6000 m	800 - 2500 m	1000 - 4000 m
Deposit characteristics*	15-25 kg/m²	25-78 kg/m²	20m deep
Resource	Ni, Co, Cu	Co, Ni, Cu	Cu, Ag, Zn, Ag
Seabed area mined per year for 2 million tons of of ore	80-130 km²	25-80 km²	200 x 200 m

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