Factsheet Cobalt-rich Crusts

Ore Treasure on the Slope of Seamounts

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Due to volcanic activity on the seabed, seamounts have grown in height over millions of years. Seamounts occur in all oceans and commonly reach heights of 1,000 to 4,000 metres. They often form solid, metalliferous layers, which are known to experts as cobalt-rich iron-manganese crusts or cobalt-rich crusts for short.

SHORT PROFILE COBALT-RICH CRUSTS	
Main occurrence	Sediment-free slopes of old submarine volcanoes
Water depth	800 to 2,500 metres
Main ingredients	silicates, manganese and iron oxides
Economically interesting metals	cobalt, nickel, and rare earth elements (in traces also molybdenum, tellurium, zircon and platinum)
Application	High-tech metals, environmental and energy technology

There are around 33,000 seamounts in all oceans - probably. Because the ocean floors are by far not as precisely mapped as the continents. The figure is based on projections of previously known structures. So there are still many opportunities for new discoveries.

The cobalt-rich crusts on the sediment-free flanks of seamounts form in a similar way than manganese nodules, that is by deposition of metal compounds on the rock surfaces over millions of years. As with manganese nodules, this deposition takes place very slowly: per one million years, the crusts commonly grow 1 to 5 millimetres and thus even slower than the manganese nodules. Cobalt-rich crusts are also considered possible submarine ore deposits. However, since they are firmly connected to the rocky substrate, they cannot simply be picked up from the seabed like manganese nodules.

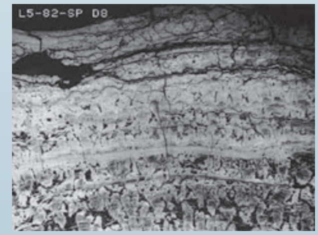
Fragment of a cobalt crust.
The sample was taken at the beginning of 2018 during the MSM70 expedition with the research vessel MARIA S. MERIAN at the Carter Seamount (part of the Bathymetrist Seamount Chain) from a depth of 2,750 to 2,450 metres. Photo: Jan Steffen/GEOMAR

Formation of Cobalt-rich Crusts

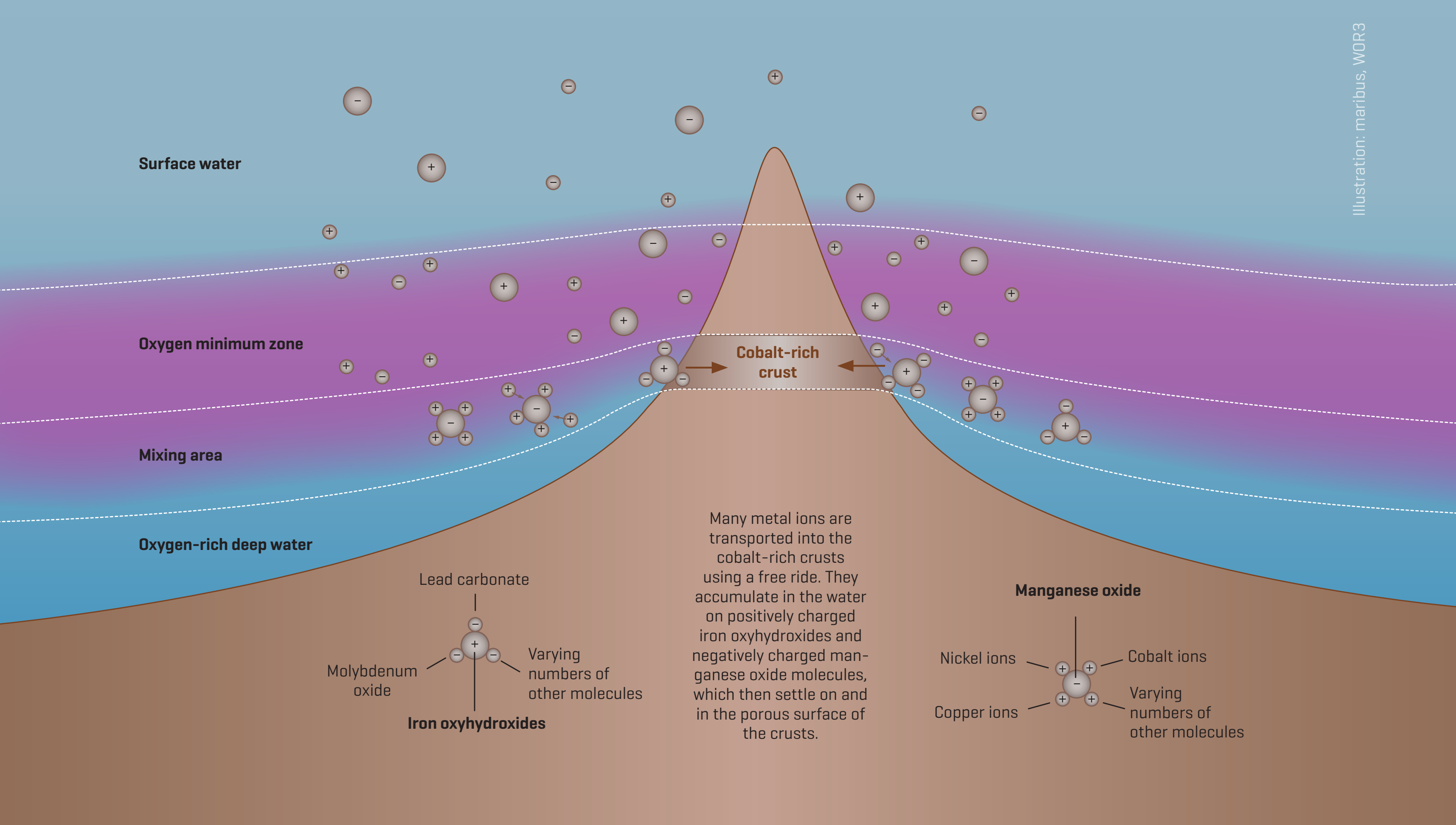
Cobalt-rich crusts occur on all exposed rock surfaces at submarine elevations, especially on seamounts. The rock surfaces absorb metals from the surrounding seawater and, over a long period of millions of years, form coatings of iron and manganese oxides, the thickness of which ranges from a few millimeters to a few decimeters, depending on the age of the seamounts.

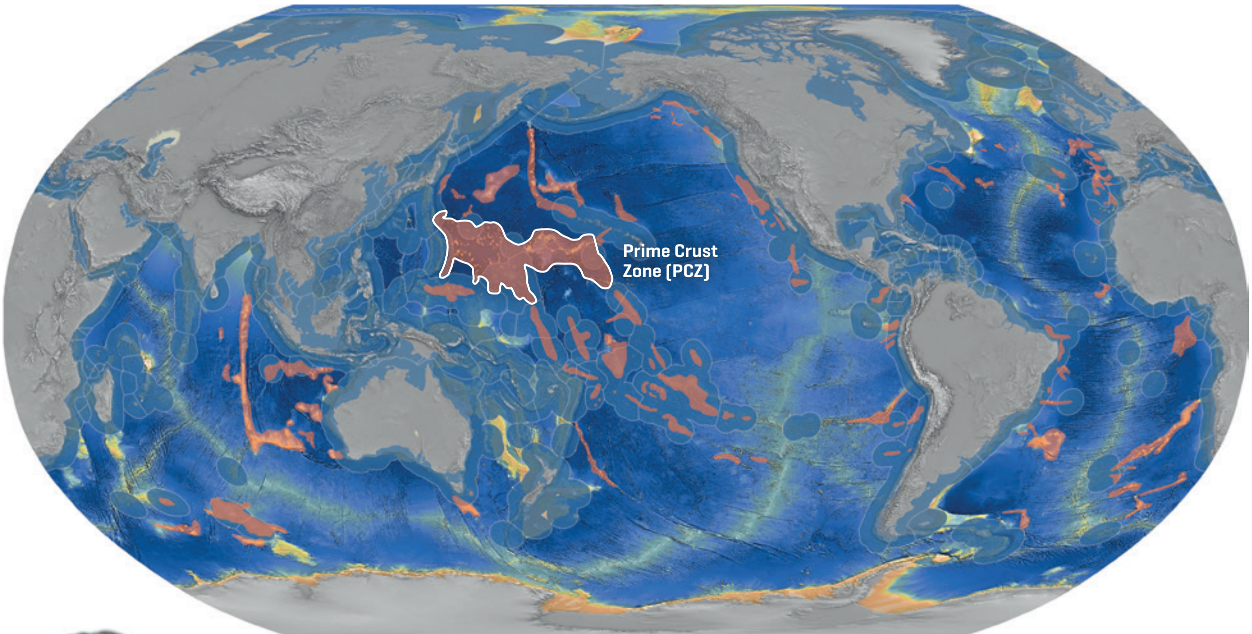
Some seamounts behave like gigantic stirring rods in the sea, which create big vortices. These vortices also contain metal compounds, which are deposited on the rock surfaces. Another important requirement for the formation of cobalt-rich crusts is that the rock or the growing crusts are free of sediments. The conditions at seamounts are ideal for this: the currents carry away the fine sediments and keep the rock and the crusts clean. Cobalt-rich crusts can be found at water depths of 600 to 7,000 metres. However, the thickest and most valuable crusts are found in the upper part of the seamount slopes, where strong currents prevail. On average economically valuable crusts lie in water depths of 800 to 2,500 metres near the oxygen minimum zone.

The cobalt-rich crusts form when metal ions in the water react with oxygen to form oxides, which are deposited on the rock surfaces of the seamounts. However, oxides can only form where the seawater contains sufficient levels of oxygen. Paradoxically, in fact the thickest cobalt-rich crusts can be found on seamounts where the top is close to the oxygen minimum zone, an area where seawater contains the least oxygen. This contradiction can be resolved: Since very little oxygen is present in the oxygen minimum zone, the free metal ions accumulate in the oxygen-poor water. At seamounts, however, oxygen-rich deep water flows up from the seabed. This creates a mixing zone in which metal-oxides can form, which then precipitate on the rock surfaces and form crusts over time.



Complex inner structure.
Similar to a sponge or activated carbon, which is often used as a filter substance in aquariums, cobalt-rich crusts are very porous. Thanks to these pores, which are only a few micrometres in size, the crusts have a large inner surface. Just as pollutants remain suspended in the pores of an activated carbon filter, metal compounds are deposited on the large surface of the crusts. Photo: James Hein / USGS





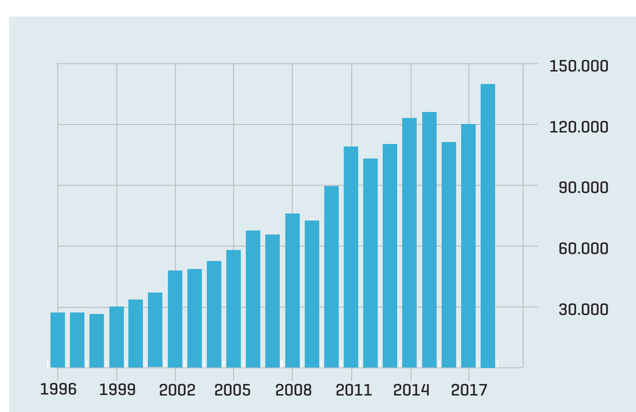
Distribution of cobalt-rich crusts in the ocean.
Areas of special economic interest and boundaries of EEZ are highlighted. In contrast to manganese nodules, the cobalt-rich crusts mainly occur within the 200 nautical mile zones of the respective coastal states. Map: Sven Petersen/GEOMAR

Deposits and Resource Potential of Cobalt-rich Crusts

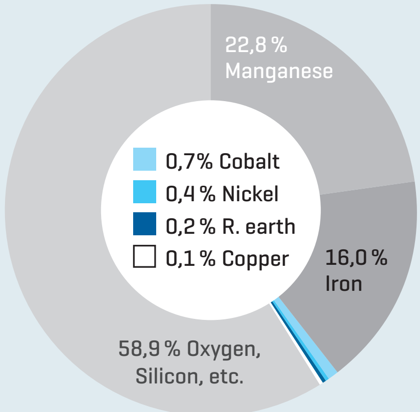
Globally, about 23 million square kilometres are geologically suitable for the formation of economically interesting cobalt-rich crusts. This area can be further limited by a combination of factors such as topography and morphology of the seabed, age of the ocean crust and global sedimentation rates, resulting in an area of about 3 million square kilometres, which could be of economic interest for the exploration of cobalt-rich crusts.

As in the case of manganese nodules, manganese and iron are the dominant metals enriched in the crusts. The main economically interesting metals are cobalt, nickel and the rare earth elements. Cobalt is currently the most important trace metal and often reaches concentrations above 0.5 percent.

Economically interesting crusts with a thickness of more than four centimetres and elevated metal contents are predominantly formed on sediment-free slopes of old seamounts in water depths between 800 and 2,500 metres. Experts estimate that there are at least 33,000 seamounts worldwide. Of these, about 57 percent occur in the Pacific Ocean. The Pacific Ocean is thus the most important cobalt-rich crust region in the world, with the Western Pacific being of particular interest. Here you can find the oldest seamounts, which formed about 150 million years ago. Correspondingly, many metal compounds were deposited here, and over time formed comparatively thick crusts. This area, located about 3,000 kilometres southeast of Japan, is called the Prime Crust Zone (PCZ).



Global production of cobalt from 1996 to 2018 in tons.
The increase in demand reflects the increased use of cobalt in lithium-ion batteries (e.g. for electric vehicles). Source: USGS Mineral Commodity Summaries for Cobalt (1997–2019)



Average metal content of cobalt-rich crusts in the Prime Crust Zone. Source: Hein and Koschinsky, 2014

Sample from approxiamtely 1,700 metres water depth from a seamount of the Louisville chain in the southwest Pacific. The crusts from this region contain up to 1.6 percent cobalt and are significantly enriched in rare earth elements, molybdenum and titanium. Photo: BGR

The rare earth elements are enriched in cobalt-rich crusts, and their concentration of, on average, 0.16 to 0.25 percent is even higher than that in manganese nodules. This makes cobalt-rich crusts an interesting source of raw materials for high-tech metals and applications in environmental and energy technology. Other metals, such as molybdenum and tellurium, occur predominantly in trace concentrations of a few grams per ton. Whether such concentrations are economically recoverable is still being investigated.

Estimates of the tonnage of the crusts in the Prime Crust Zone alone reach over 7.5 billion tons, which contain about four times more cobalt and nine times more tellurium than the known reserves of these metals on land. Similar to the manganese nodules, the cobalt-rich crusts are a raw material whose marine extraction could provide a secure supply for the industry for many years. However, direct sampling and measurement of the thickness of cobalt-rich crusts is difficult, as rocks have to be torn off or drilled out. The local variability in grade and tonnage is hardly known, and the punctual examination is extremely complex and expensive. Precise instruments, which could measure the thickness of the crusts to the centimetre and distinguish them from the underlying substrate rock, do not yet exist.

Unlike manganese nodules, most of the economically interesting crust deposits are not found in international waters of the high seas, but in the EEZ of various island states. Only the respective governments can decide on future mining. However, there are currently no concrete plans in any of these countries. Since 2012, the International Seabed Authority has had a binding set of rules on exploration for crust deposits in international waters. Since then, China, Japan, Brazil, Russia and, since 2018, Korea have acquired exploration licenses for cobalt-rich manganese crusts. However, only concepts for possible mining equipment are available, and industrial-scale tests have not yet taken place.

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Cobalt-rich crusts are a promising seabed resource as they contain large amounts of cobalt, nickel, manganese and other metals, some of which could exceed the contents of land deposits. However, there are only a few occurrences in international waters for which exploration licenses have been applied for. Since cobalt-rich crusts are firmly attached to the rocky substrate, they cannot simply be picked up from the seabed like manganese nodules, but would have to be separated from it at great expense. The direct environmental impact of mining is assumed to be similarly serious to that of massive sulphides and manganese nodules, although, compared to manganese nodules, only smaller mining areas would be affected.

Biodiversity

The species composition at seamounts differs considerably from ocean to ocean. The images shown here show organisms at seamounts in the Clarion-Clipperton-Zone in the Central Pacific: deep-sea crab (1), soft coral (2), anemones and goose barnacles (3), antipatharia coral (4), shrimp (5) stalked sponge (6) and sea cucumber (7).

The large biodiversity at seamounts is due to the special current situation: On the one hand, nutrients are retained by circulating currents near the top of the seamounts, on the other hand, nutrient-rich water is additionally carried up from greater depths by the currents surrounding the seamounts, which leads to increased plankton growth.

Photos: ROV KIEL 6000/GEOMAR