Factsheet Manganese Nodules

Rich Mineral Fields on the Seabed

GEOMAR

In the abyssal plains of the deep sea, metal-bearing lumps lie close together over thousands of square kilometres, like potatoes on a field: Manganese nodules are the most important potential source of raw materials in the marine realm, as they contain larger quantities of some metals than are currently known and mineable on land.

SHORT PROFILE MANGANESE NODULES	
Main occurrence	Sediment-covered deep-sea plains of all oceans
Water depth	3,000 to 6,000 metres
Main ingredients	silicates, manganese and iron oxides
Economically interesting metals	nickel, copper and cobalt (in trace amounts also rare earth elements, molybdenum, lithium and titanium)
Application	Batteries, environmental and energy technology

Manganese nodules in the deep sea have been known since the British Challenger expedition from 1872 to 1876. For a long time, however, they were only regarded as a curiosity. In the 1960s and 1970s, they were first targeted by the industrial nations, who recognised them as a possible source of raw materials. The manganese nodule enthusiasm in the 1970s went so far that alleged mining attempts even had to serve as camouflage for a cover-up operation of the United States Central Intelligence Agency (CIA) in the Central Pacific. Real mining tests quickly showed in fact, that the technology was not yet ready to function smoothly in several thousand metres of water.

In recent years, however, rising commodity prices and growing demand for metals have reactivated plans to mine these nodules from the deep sea floor. Still, mining licenses have not been granted and full-scale mining technology has not been successfully tested. Also, the questions about the large-scale and long-lasting harmful effects on the deep-sea environment cannot be conclusively answered at the moment.

Manganese nodule from the Northwest Pacific Ocean.
This sample was collected during expedition SO265 with the research vessel SONNE at Papanin Ridge from a water depth of 4,490 metres. Photo: Jan Steffen/GEOMAR

Formation of Manganese Nodules

Manganese nodules occur worldwide on the seabed mostly at depths of 3,000 to 6,000 metres. They consist of metals that are transported into the oceans by erosion or originate from hydrothermal vents in volcanically active areas of the oceans. Their growth rate is only a few millimetres in a million years, so larger nodules with a size of 15 centimetres can be up to 15 million years old.

Manganese nodules come in many shapes and sizes. They can be round, elongated or flat. Their appearance is determined by the shape of the core, the surrounding sediment and their type of growth. Manganese nodules grow when metal ions either dissolved in seawater (hydrogenetic growth) or from the sediment pore-water (diagenetic growth) are deposited onto a nucleus. This nucleus may consist of rock fragments, shell remains, or shark teeth. Over time, concentric layers form around the core.

Usually nodules grow both dia- and hydrogenetically, whereby the respective proportions differ in different regions. It is fascinating that manganese nodules grow extremely slowly. With every million years, their thickness increases only millimetre by millimetre. Hydrogenetic nodules grow up to 10 millimetres per million years, diagenetic nodules between 10 and 100 millimetres per million years. As a result, manganese nodules could only form where environmental conditions remained fairly constant over such long periods of time.

Section through a manganese nodule.
Inside, similar to the growth rings of a tree, they have a layered structure that can also be used as a geological archive. Photo: Linda Plagmann

Different growth processes.
Manganese nodules can grow hydrogenetically or diagenetically, or by a mixture of both. Heterogeneous growth rates can lead to asymmetric nodules. Photo: BGR

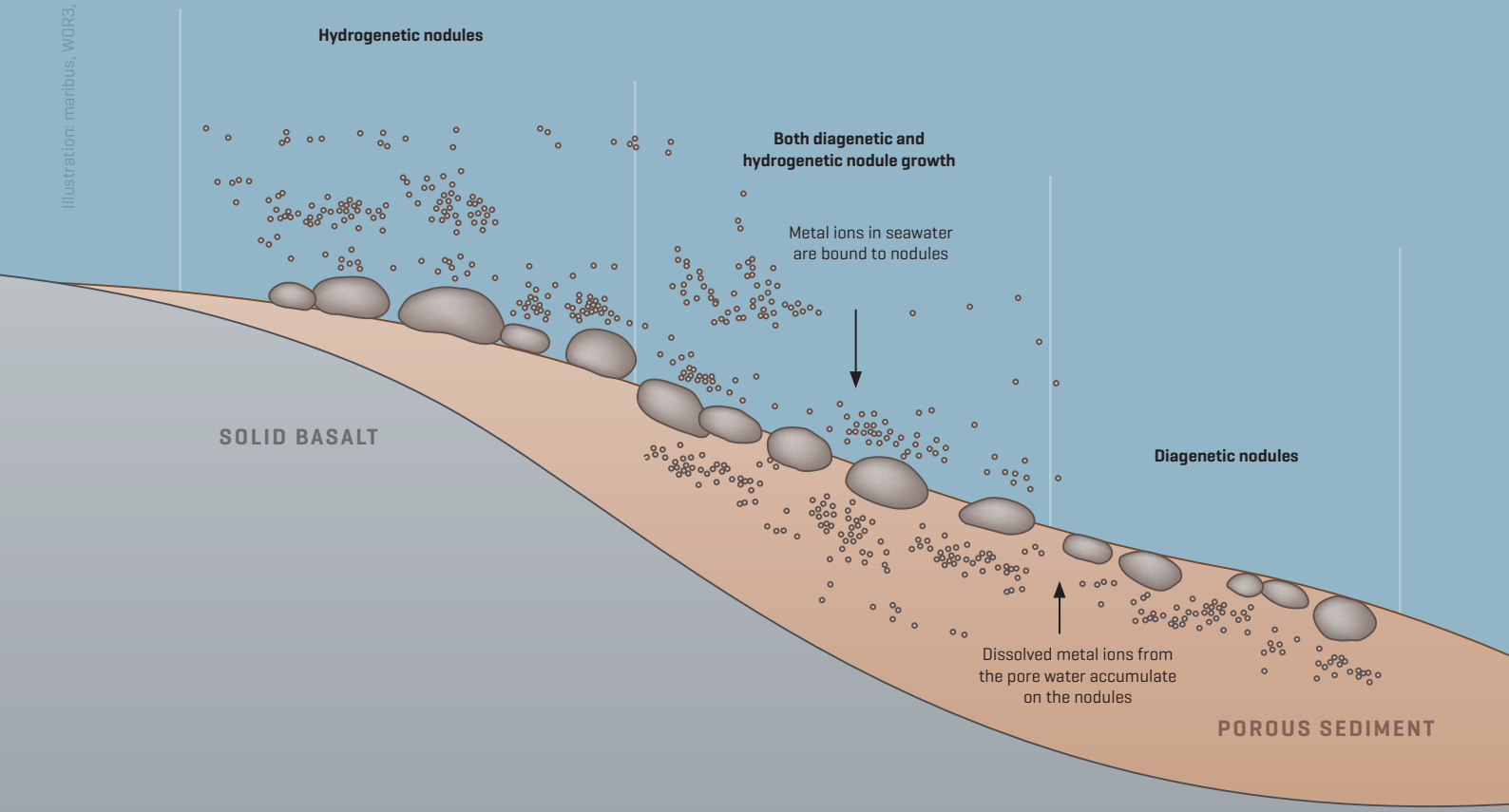
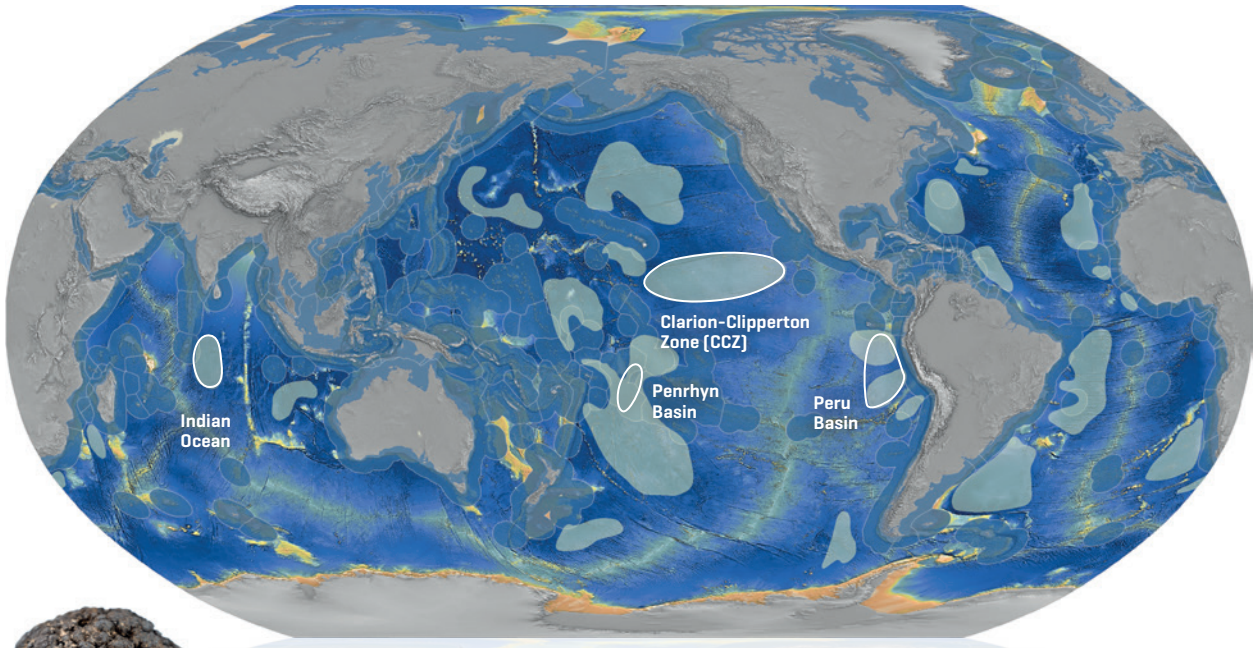


Illustration: maribus, WOR3, edited by C. Kersten/GEOMAR



Distribution of Manganese Nodules in the ocean.
Areas with a significant number of nodules and boundaries of exclusive economic zones (EEZ) are highlighted. Map: Sven Petersen/GEOMAR

Deposits and Resource Potential of Manganese Nodules

Although present in all oceans, only in a few areas the density of manganese nodules is sufficiently high for industrial mining. In these areas the deposits could be important for securing global future metal supply. However, there are currently no applications for mining licences, which is due to the fact that the regulations for exploitation are currently still being drafted by the International Seabed Authority.

Globally, approximately 38 million square kilometres are geologically suitable for the formation of manganese nodules. However, this is only a rough estimate, as large areas of the seabed have been insufficiently investigated. Economically interesting nodule abundances are currently known in four marine regions:

Clarion-Clipperton-Zone (CCZ): This zone is the largest manganese nodule area in the world with an area of around 9 million square kilometres, roughly the size of Europe. The CCZ is located in the Pacific Ocean and stretches from the west coast of Mexico to Hawaii. The manganese nodules are not evenly distributed here. In some places they lie close to each other, while in other areas there are no nodules at all. On average, the CCZ harbours about 15 kilograms of manganese nodules per square metre. Particularly productive areas may reach up to 75 kilograms per square metre. A total mass of manganese nodules of around 21 billion tons is estimated for the entire CCZ.

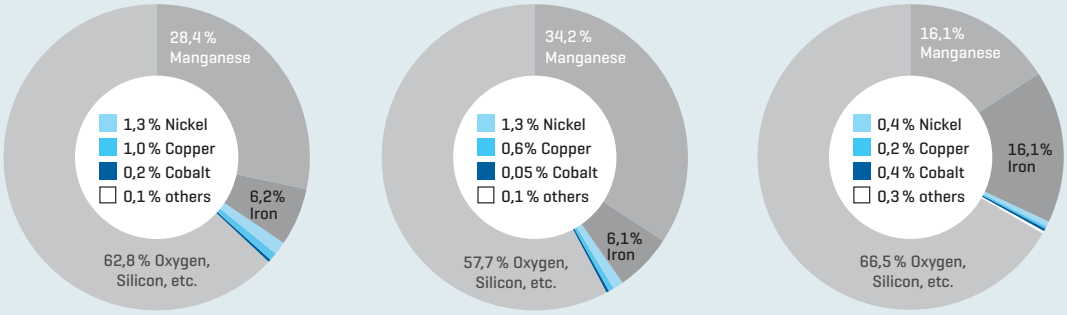
Peru Basin: About 1,000 kilometres off the Peruvian coast lies the Peru Basin. It is about half the size of the Clarion-Clipperton-Zone. Here, an average of ten kilograms of manganese nodules per square metre can be found. (See also DISCOL project on page 32).

Penrhyn Basin: The third major manganese nodule area in the Pacific Ocean is located in the immediate vicinity of the Cook Islands, several thousand kilometres east of Australia. The area extends over approximately 750,000 square kilometres. Large areas in the coastal waters of the Cook Islands contain more than 25 kilograms of manganese nodules per square metre of seabed.

Indian Ocean: So far, only one large area of manganese nodules has been discovered here, having a similar size than the Penrhyn Basin. It is located in the central Indian Ocean. On each square metre of seabed, about five kilograms of manganese nodules are present.

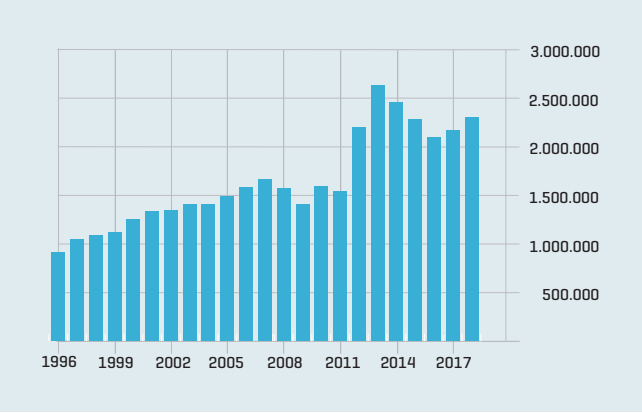
Manganese and iron are the dominant metals in manganese nodules. However, the most economically interesting metals are nickel, copper and cobalt, which together may reach contents of about two to three percent by weight. In addition, there are traces of a whole range of metals in the nodules that are important for the economy in high technology as well as in green technologies. These include molybdenum, rare earth elements, lithium and titanium.

Chemical analyses of manganese nodules have shown that the metal contents of manganese nodules in different marine regions differ significantly. Source: Hein & Petersen, World Ocean Review 3



A conservative calculation of the metals contained in manganese nodules of the CCZ estimates the presence of more than 6 billion tons of manganese, which exceeds the global economically mineable quantity on land. The situation is similar for nickel (270 million tons), copper (230 million tonnes) and cobalt (44 million tons). The manganese nodules of the CCZ alone thus contain three to five times more nickel and cobalt than all known economically exploitable land deposits combined. The amount of copper in the CCZ corresponds to about one third of the global land reserves. With these figures it becomes clear that manganese nodules have a huge resource potential and could be of importance for securing future global raw material supply. However, for economic production, around 2 to 3 million tons of manganese nodules have to be harvested each year. To achieve this, a deep-sea mining contractor would have to exploit an area of 200 to 300 square kilometres per year, roughly equivalent to the size of the city of Munich. Based on global production figures in recent years, the mining of manganese nodules from only five deep sea mining sites would contribute 10 percent to global nickel production, 25 percent for cobalt and less than 1 percent for copper. Under today's economic conditions, however, these production volumes would saturate the world market with manganese to such an extent that the price of manganese nodules could collapse.

When looking at the CCZ it must be considered that large areas of the CCZ are not suitable for commercial extraction because they contain manganese nodules that are too small for mining or that these areas are unsuitable due to their strong relief. The growing interest in manganese nodules is reflected by the increase in applications for deep-sea exploration licences. In 2001, the first licenses of the International Seabed Authority were awarded to six contract partners. India joined in 2002, followed by Germany, which holds a CCZ licence since 2006. After a period of calm, interest has increased significantly since 2012. Currently, 17 exploration licenses with a total area of 1.2 million square kilometres have been granted.



Global production of nickel in the years 1996 to 2018 in tons.
Source: USGS Mineral Commodity Summaries for Nickel (1997-2019)

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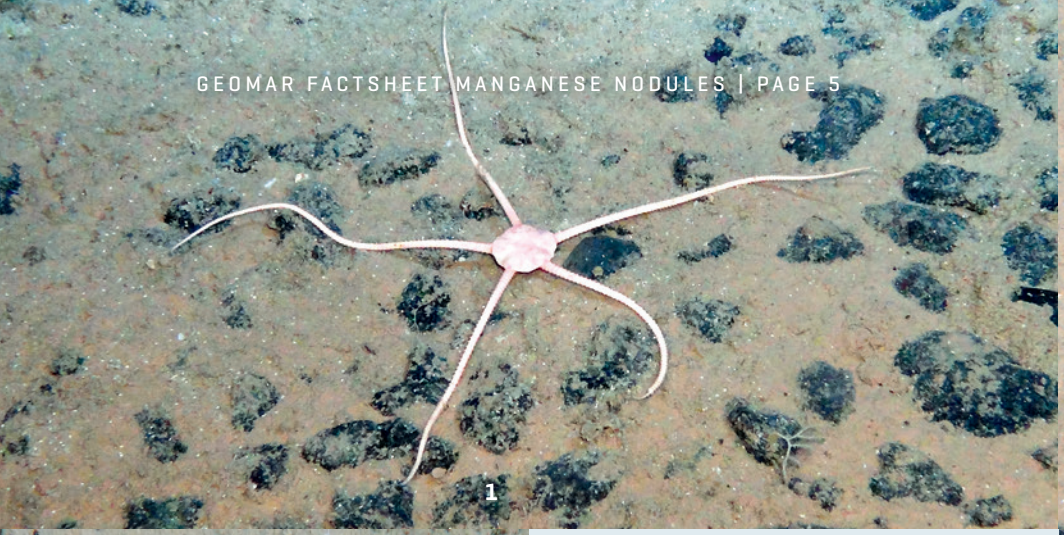
First experiments in the 1970s have shown that, in principle, it is possible to extract manganese nodules from great depths. However, it requires a step further from such tests lasting only several hours or days to industrial production over many months of the year. The adverse effects of large-scale mining on the environment have not yet been sufficiently investigated, even though major scientific projects have been dealing with them more intensively in recent years. Given the current market situation, manganese nodule mining would only be worthwhile for a few contractors, as otherwise the world market price for manganese, which is currently relevant for profitability, would plummet.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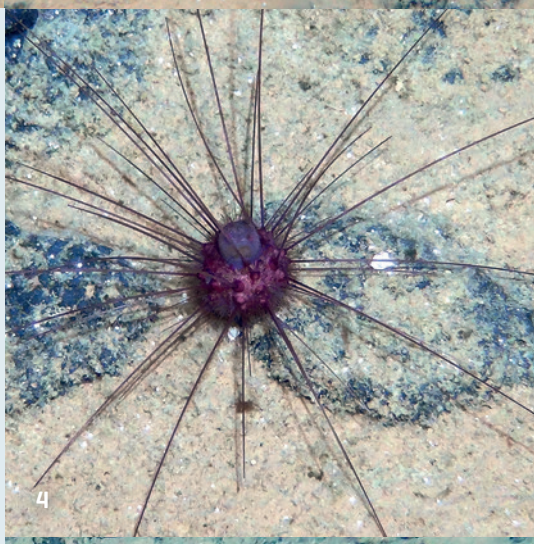
Biodiversity

In the 19th century it was still believed that life was impossible below a depth of a thousand metres. But even today, the deep sea surprises scientists. The perception that the large deep-sea plains in the central Pacific are uniformly flat and only sparsely populated has persisted until the present day. Another mistake, as researchers from the European MiningImpact project found out: The ecological diversity down there is enormous, especially where many manganese nodules cover the seabed: brittle star (1), sea anemone (2), starfish (3), sea urchin (4), soft coral (5), sponge (6) and sea cucumber (7).

Photos: ROV KIEL 6000/GEOMAR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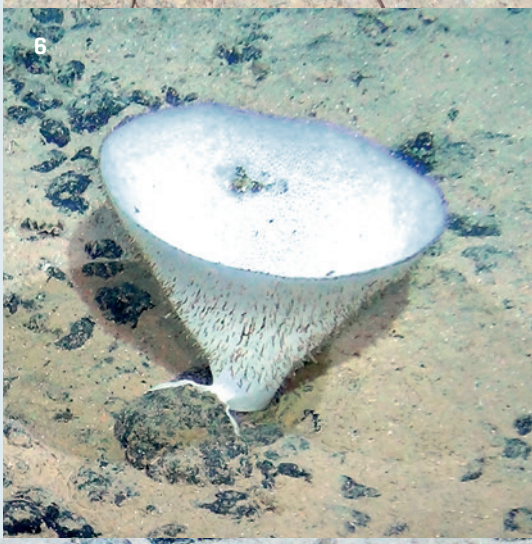
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