Factsheet Massive Sulphides

Black Smokers – Ore factories of the Deep Sea

GEOMAR

Black Smokers are hydrothermal vents in volcanically active zones of the deep ocean. The black "smoke", which exits from the up to 30 meter high chimneys, consists of finely distributed sulphide particles. The chimneys themselves and the mounds they are commonly located on also consist of metal-sulphur compounds, the so-called massive sulphides.

SHORT PROFILE OF MASSIVE SULPHIDES	
Main occurrences	volcanically active zones at submarine plate boundaries
Water depth	1,000 to 4,000 metres
Main components	iron-rich sulphides
Economically interesting metals	copper and zinc (in traces also gold, silver, germanium, indium, tellurium and bismuth)
Application	Components for communication technology

In 1979, the American research submarine Alvin dived into the Pacific Ocean. Through the small portholes of the pressurized hull, the crew saw meter-high chimneys on the seabed at a depth of around 2,600 meters, from which apparently black clouds of smoke were expelled. The scientists had discovered the first hydrothermal vents, so-called "Black Smokers". Investigations showed that minerals were deposited around the springs, forming deposits of so-called massive sulphides. In the meantime, more than 410 occurrences are known in all oceans, although there are enormous differences in the size of these features. Hydrothermal vents are not only a source of raw materials, but also an extraordinary habitat.

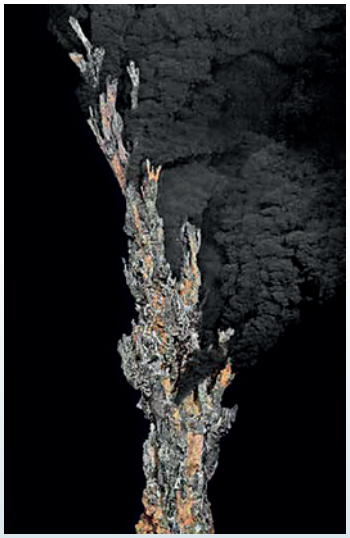
In recent years the economic interest in massive sulphides has increased. The first mining licence for massive sulphides around a weakly active hydrothermal system was granted in 2011 for a deposit off the coast of Papua New Guinea. However, mining has not yet begun (as of 2020).

Black Smoker vent fragment.
The sample was taken in 2016 during a cruise with the research vessel Falkor at Niua Volcano in a water depth of 1,146 meters. Photo: Jan Steffen/GEOMAR

Formation of Massive Sulphides

The fascinating formations of black smokers in the deep sea are created by the interaction of volcanic activity and seawater at active plate boundaries.

At hydrothermal vents, seawater slowly seeps through cracks and crevices deep into the seabed where it interacts with magma chambers at a depth of two to three kilometres. There it is heated and rises again due to its lower density. Chemical processes turn the water into a weak acid. On its way back to the seabed, it leaches elements such as copper, zinc, iron, gold, silver and sulphur from the surrounding rock. Enriched with these substances, the solution, some of which is over 400 degrees Celsius hot, meets the deep ocean water, which is about two to four degrees cold. The metal-sulphur compounds precipitate and are deposited on the seabed as sulphide mounds, chimneys or metal-rich sediments.



Five-metre-high vent of a black smoker in the central Atlantic.
The largest black smoker discovered to date was discovered at the Juan de Fuca Ridge. Its chimney was 45 metres high. Photo: Nico Augustin/GEOMAR

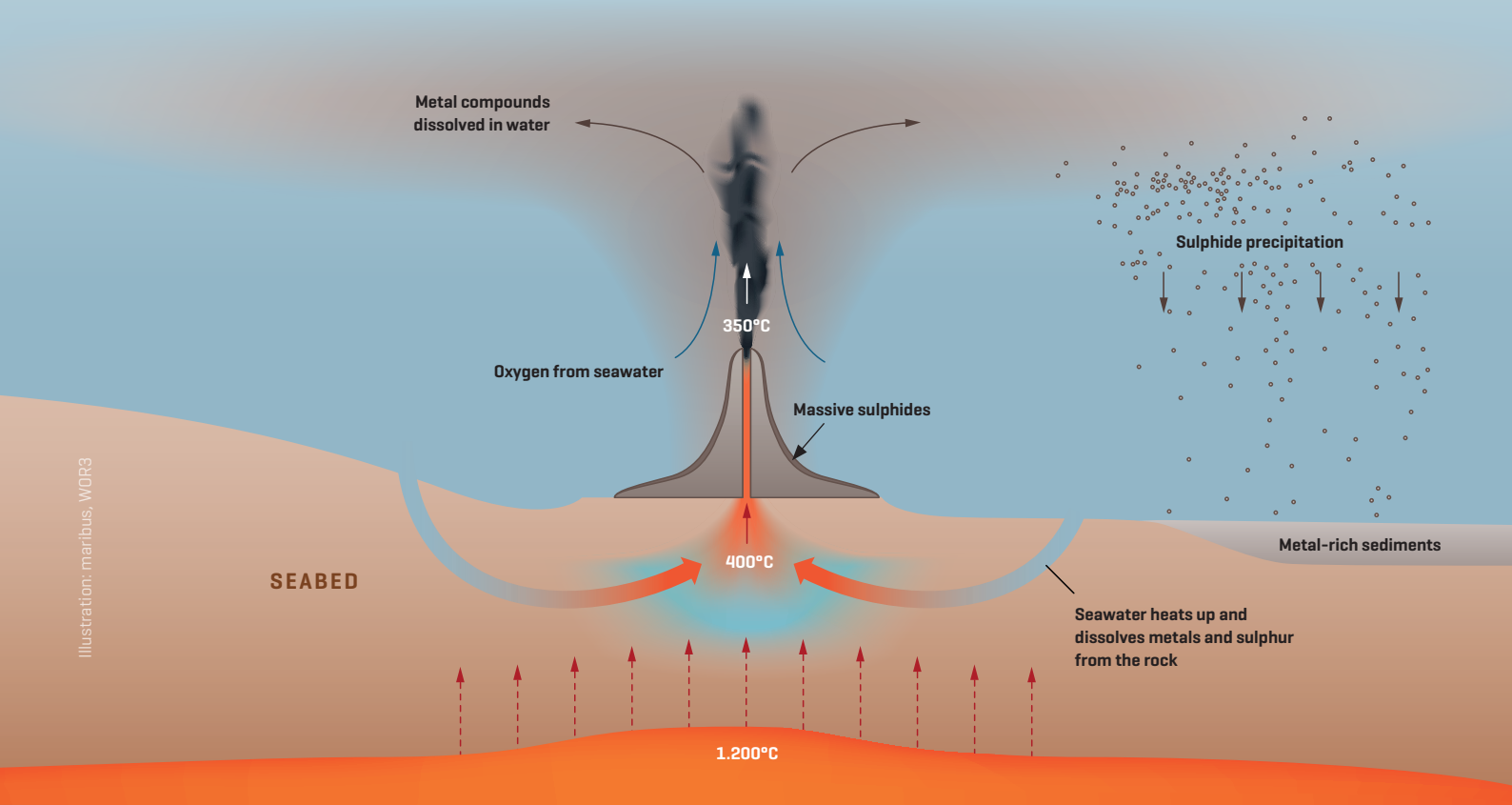
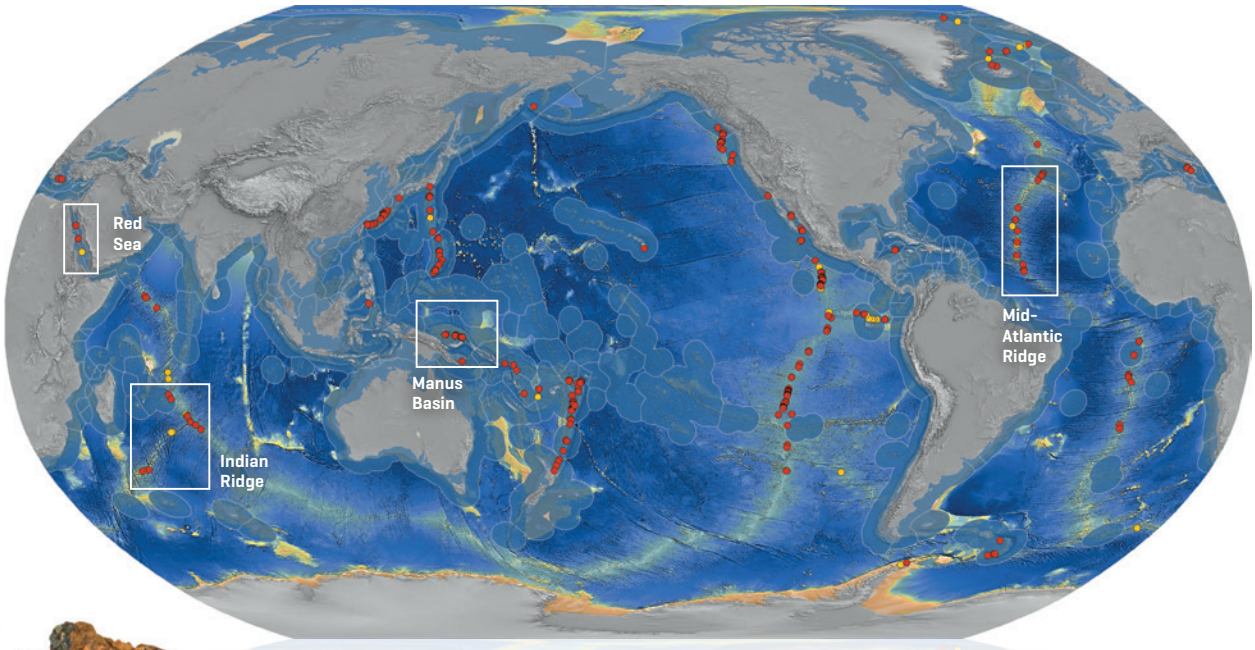


Illustration: maribus, WOR3



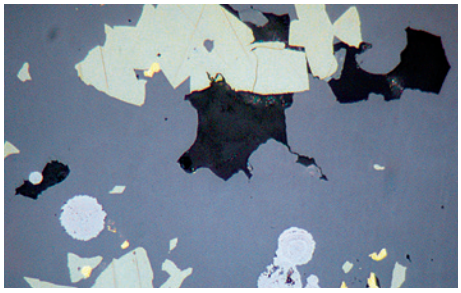
Distribution of known active (red) and inactive (yellow) black smokers in the ocean.
Areas of special economic interest and boundaries of exclusive economic zones (EEZ) are highlighted. Large areas, particularly in the southern oceans, have not yet been explored and occurrences in these regions can therefore not be shown on the map. (as of 2019). Map: Sven Petersen/GEOMAR

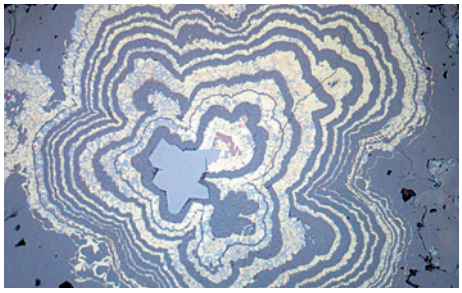
Deposits and Resource Potential of Massive Sulphides

The ore metal contents and the economic potential of massive sulphides differ significantly from those of manganese nodules and cobalt-rich crusts. There are also enormous differences in the size of the individual deposits. In addition, the non-ferrous and precious metal contents of the deposits vary greatly depending on the region.

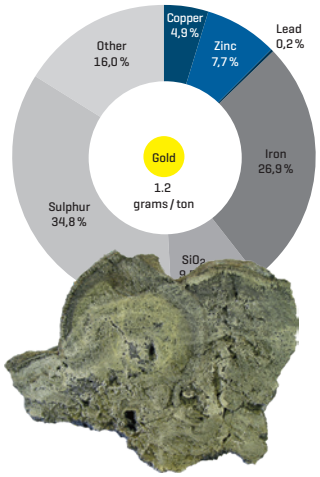
The black smokers along the mid-ocean ridges are predominantly built up from iron-rich sulphides which are of little economic interest. Copper and zinc together make up only about one eighth of the massive sulphides. The gold content is just over 1 gram per ton. A special class of deposits has formed on the ridges of the Atlantic and Indian Oceans at faults off the central volcanic ridge axis. Here, tectonic processes expose rocks of the upper mantle on the seabed. Massive sulphides, which are bound to such rocks, show increased copper and gold contents. Other occurrences, commonly in the Southwest Pacific, such as in the Manus Basin, show the highest copper, zinc and gold contents and are therefore particularly interesting for possible future mining. In addition to the elements mentioned above, there are also a number of metals that can be found in traces of several grams per ton in such sulphides and could be included in an economic consideration. However, the contents of these rare and trace metals are subject to a very large heterogeneity and the results of the investigations on their distribution are still incomplete. The deposits of the Southwest Pacific are also found in comparatively shallow water depths of less than 2,000 metres and in the economic zones of neighbouring

Change in various metal prices from 2000 - 2019. Source: InfoMine.com





Microscopic images of massive sulphides.
Left: small, bright yellow gold grains as inclusions in various sulphides. The size of the gold grains lies between 2 - 10 micrometres. Right: The physicochemical properties of the hot solutions form alternating layers of zinc sulphides (medium grey) and copper sulphides (yellow, light grey, brown).



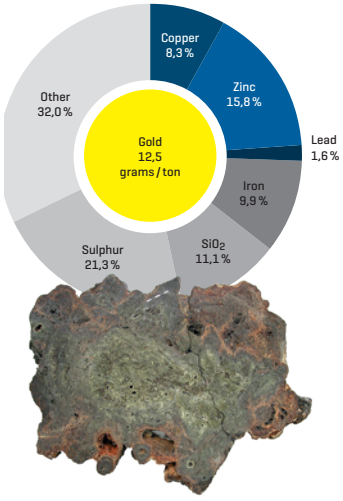
Black smoker from the Mid-Atlantic Ridge.
Many occurrences at mid-ocean ridges are predominantly built up from iron-sulphides.

states, which makes them technologically and legally conducive to possible extraction. In January 2011, Nautilus Minerals received the first mining licence for a deposit of approximately two million tons of sulphides in the territorial waters of Papua New Guinea.

The largest known sulphide deposit is located in the Red Sea. Here the sulphides do not occur as black smoker, but in the form of iron-rich metalliferous muds with elevated contents of copper, zinc, silver and gold. This occurrence in water depths of around 2,000 metres has been known since the 1960s. Thanks to the muddy consistency of these deposits, mining appears technically unproblematic and was already successfully tested in the 1980s. A 30-year mining license for this deposit was granted in 2010, but it is not yet known if and when the mining will commence.

More than 90 percent of all known deposits are too small to be of economic interest. Up to now, exploration has always relied on anomalies in the water column. This means that an active black smoker can easily be found in the water column due to this "plume of smoke". These anomalies can be detected over large distances and traced back to their source. However, such a search is only capable of finding active black smokers. In fact, most of these systems are geologically very young and therefore often also very small. There is a need for research into exploration methodology for finding larger, inactive ore deposits. This issue was addressed within the framework of the recent EU project "Blue Mining", where technologies for the search for these economically more interesting deposits were developed.

While the sampling of manganese nodules and cobalt-rich crusts at the seabed is sufficient for an estimation of their resource potential, for massive sulphides drilling is indispensable in order to obtain information from the interior of the deposits. Many investigations have shown that there are large differences in the metal contents between samples taken from the surface of sulphide mounds when compared to those from the interior. Since such drill holes only exist from a few deposits, it is hardly possible to estimate the global resource potential of massive sulphides.



Black smoker from the eastern Manus Basin off Papua New Guinea.
The difference between the copper-rich core and a brownish zinc-rich exterior is clearly visible. The average gold content for this sample is 15 grams of gold per ton of ore.

+/-

At present, only a few of the known massive sulphide deposits appear to have sufficient size and metal content to be economically viable. To change this picture, it is necessary to develop new exploration technologies that go beyond the search for small, active deposits and are able to discover large, inactive deposits away from the volcanically active zones. Nevertheless, the resource potential of massive sulphides appears to be rather low when compared to that of manganese nodules or cobalt-rich crusts. However, due to the three-dimensional character of the sulphide deposits, the environmental impact of mining them is likely smaller compared to the large areas being disturbed by the mining of manganese nodules and cobalt-rich crusts.


1


2

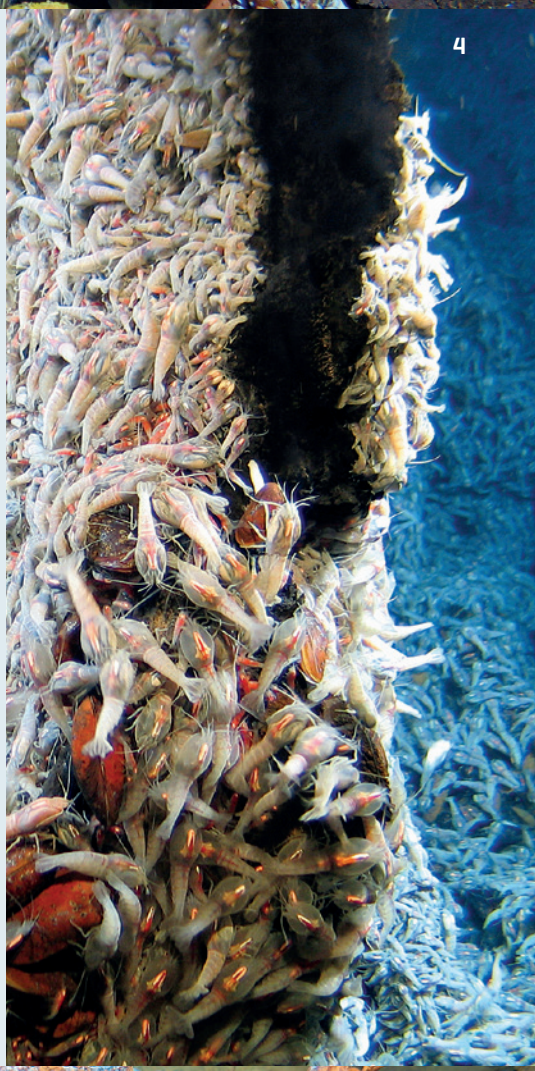

3

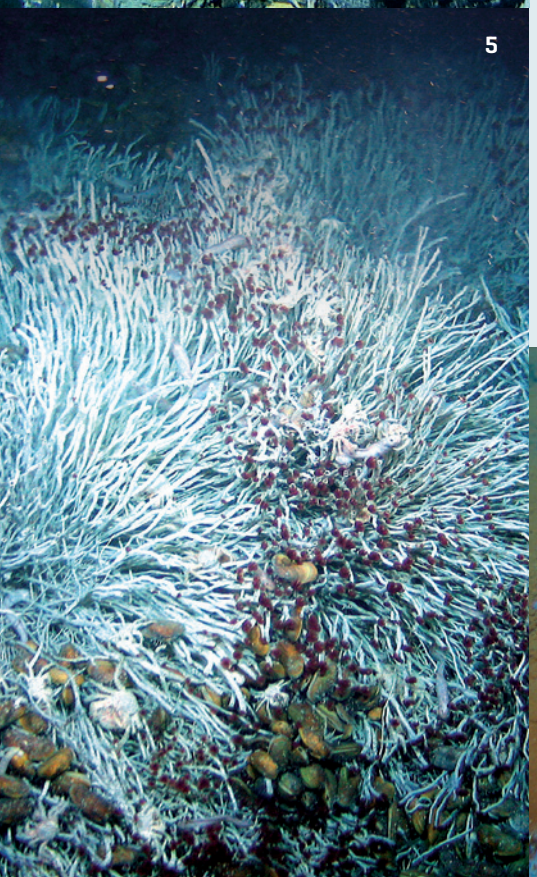
Biodiversity

The first life on Earth could have originated at black smokers in the deep sea. In the course of millions of years, an ecosystem has developed here that is perfectly adapted to conditions that are commonly hostile to life.

In an environment of absolute darkness, extreme water pressure, toxic metal compounds and water heated to more than 350 degrees Celsius, a unique community of species can be found: dense populations of snails (1), mussels (2), crabs (3), shrimps (4) and tube worms (5) populate the hydrothermal vents. This ecosystem is based on mats of primeval microorganisms (6), which draw their energy from the conversion of sulphur and methane independently of light.

Photos: ROV-Team/GEOMAR


4


5


6