

Sonderdrucke So 2002/3

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THE DEEP SEA FLOOR – NEW DISCOVERIES AND VISIONS

In this contribution I want to take you to an excursion into the largely unknown parts of our earth, the deep abyss. I will highlight in this short talk just a few aspects of this interesting and very large component of our earth.

Three arguments why the deep sea deserves our attention:

- The deep sea floor is less known than any other ecosystem on earth
- Major new discoveries are made – even today
- The deep sea floor is one of our last unexploited resources

THE DEEP SEA FLOOR IS LESS KNOWN THAN ANY OTHER ECOSYSTEM ON EARTH

The deep sea floor and the continental slopes deeper than 200 m are a vast expanse covering 65% of the surface of the globe, but it seems to be hardly recognized in its size and importance for this world. It is the largest ecosystem and it is also the least known one. If all benthic investigations in the North Atlantic are put together, the size of the well investigated area covers less than a few football fields. So we draw our knowledge from a very small and not very representative set of samples and we base far reaching economic and political decisions on scant data. It is also rarely recognized how close the links between land, surface water and the deep sea are and that there are a number of direct links. Therefore, the processes occurring in the deep sea are not cut off from the life at the surface.

While the latest new discoveries of unknown lands were made at the beginning of the 20th century with the exploration of Antarctica, major new discoveries in the deep sea are made even today. Most of the interesting recent findings are made along the continental slopes, like the gas hydrate deposits and cold water corals. The reasons for this are the physical gradients at the continental slopes which provide in various ways the basis for life.

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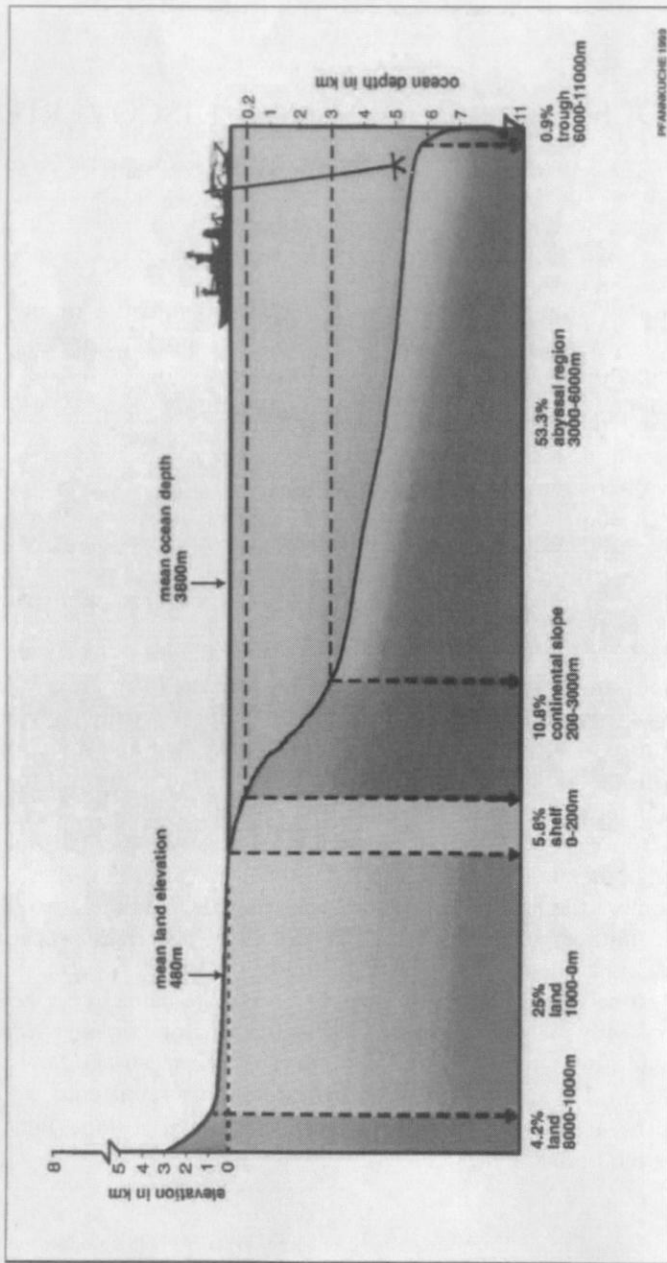


Figure 1. Hypsographic curve.

In many ways the deep sea is similar to the desert. Life in the desert is limited by the supply of water, life in the deep sea is limited by the supply of food.

However, the desert can bloom when it rains and an abundant plant life develops for a short time. This is also true for the deep sea; under certain circumstances, when sufficient food is available, abundant life with very special life forms can develop.

Most people have the idea that the deep sea is remote, cold, dark and sparsely populated (which is true). Figure 2 is a photograph of the normal deep sea floor. Most of the deep sea looks like this and you have to scan many pictures before one larger animal can be seen. Most organisms are very small (bacteria and meiofauna), they are living within the sediment and are mainly responsible for processing the organic material in the deep sea.

The main food source for all organisms living at the deep sea floor are sedimenting organic particles which are mainly made up of decaying microscopic algae. It takes on average between 3–5 weeks for these particles to sink about 4000 m from the surface to the bottom of the ocean. Most of this organic rain from the surface waters

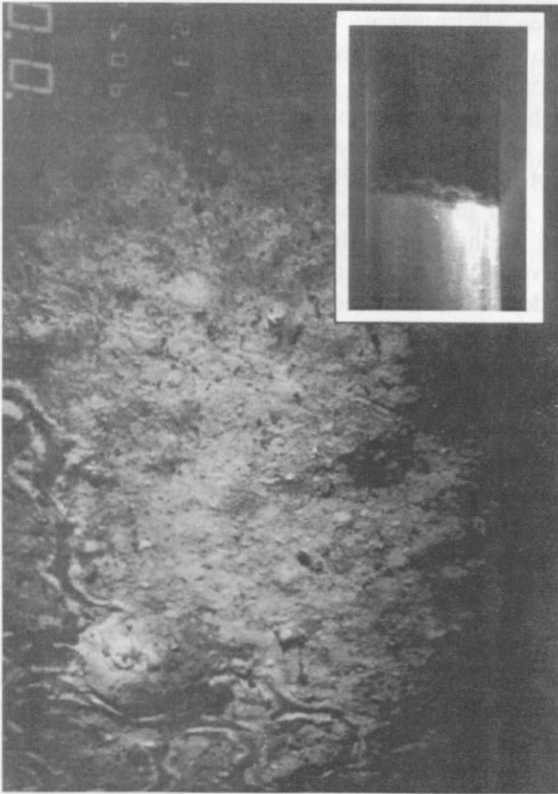


Figure 2. (a) and (b) Normal deep sea.

is processed by deep sea bacteria and small animals which react to such events within less than a week.

MAJOR NEW DISCOVERIES ARE MADE EVEN TODAY

However, life in the deep sea can also look quite different. We can also find rich fauna at a deposit of gas hydrates. Such surprising observations have been made in the last years and they are evidence of alternative supplies of food (= organically bound energy) in the deep sea.

Methane trapped in gas hydrates is not only a potential energy source for humans but also an energy source for life in the deep sea. Certain types of bacteria can oxidize methane and gain energy to produce biomass from this process. Mats of such bacteria (*Beggiatoa*) can be seen covering the sediment. Some bacteria are living as symbionts within larger animals, with the white mussel *Calypptogena*, and are supplying them with the necessary food. Furthermore, large numbers of egg clutches of the snail *Buccinum* have been seen. They are probably feeding as predators on other organisms. Thus methane deposits provide the basis for an abundant life in an otherwise barren environment. The investigation of these communities from bacteria to large animals promises many more new discoveries; part of these are of potential interest for biotechnology.

We trapped Methane under high pressure and low temperature in a cage of water molecules forming an ice-like substance called gas hydrate. 1 dm³ of gas hydrate contains 36 litres of methane gas. When the hydrate is retrieved from the sea floor, pressure decreases and temperature rises which destabilizes the gas hydrate and methane is released. We have made these experiments on board of the research vessel SONNE which investigated the gas hydrate deposits off the coast of Oregon in about 700–800 m depth. The existence of gas hydrates has been known for a while, but new is the discovery of how much methane is bound in marine sediments in form of gas hydrates and what a rich life is supported by these hydrates.

In total in marine sediments and in permafrost soils, it is estimated that 10.000 billion tons of methane are locked in gas hydrates worldwide. This is more than all known resources of oil and coal estimated at 5.000 billion tons. Gas hydrates are a potential energy source, but they are difficult to mine and, hence, exploitation is not a near target. Secondly, gas hydrates are very instable and may under changed environmental conditions release very suddenly large amounts of methane into the atmosphere. Methane is a much more effective green house gas and, hence, such release may have climatic impacts. There are indications that this may have happened in the geological past.

The instability of gas hydrates has been demonstrated by an experiment with a piece of hydrate sampled from 700 m depth. The gas hydrated piece was held in the manipulator arm of a remotely operated vehicle (ROV). Firstly, it remained stable and of similar size in the deep part of the water column. When the ROV ascended and the critical depth was exceeded, the piece of hydrate turns into gas bubbles and disappeared.

In some locations the gas hydrates are deposited in the sediment so closely to their stability limit that even the tides (i.e. slightly changing water pressure) can release methane. Gas bubbles can be detected by sonar rising through the water column and can be seen bubbling up at the sea surface.

Along most continental slopes, cold water corals of the species *Lophelia* are found. These corals live from a few hundred to 6000 m water depth in the dark and cold. Unlike tropical corals they do not contain algal symbionts for their nutrition, but they filter small organic particles from the water column. They give shelter for many other animals (here a red fish) and are an oasis of life in the otherwise rather poor surrounding. They are mainly found on the continental slopes where internal waves break providing the high currents which transport particles towards the corals.

As seen from the map, these corals have been found in many locations around Europe. In other parts of the world they have also been discovered, but we simply did not have enough surveys to investigate the continental slopes around third world countries to know how far-spread they really are.

Trawling for deep water fish is now extending to 1000 m and these corals are sustaining extensive damage. This has reached such a level that protective measures in the deep sea are now being discussed.

One of the most exciting discoveries was the observation that living bacteria exist in sediments up to 750 meters below the sea floor. They have been isolated from the rest of the living world for a few million years. We still do not know how deep this deep biosphere extends into the depth. One estimates that 10% of the world's biomass is contained in this totally unexplored ecosystem. Since these bacteria have been able to develop without link to the rest of the living world, it is expected that many new discoveries in respect to new organisms and biochemical processes can be made which may be of use for biotechnology.

THE DEEP SEA FLOOR IS ONE OF OUR LAST UNEXPLOITED RESOURCES

The deep sea floor is one of our last unexploited ecosystems. It is a vast area and it harbours living and non-living resources. There are numerous potential uses, but their feasibility, both in respect to economic gain and to environmental impact, are generally poorly known.

The deep sea is by no means free of human impact! Anywhere in the world's ocean rubbish is found in the trawls. There was found trash in 4100 m in a remote area of the Arabian Sea. The coke tin had a clearly visible date stamp on the bottom. It was from 1974 and well preserved.

One of the major industrial uses of the deep ocean is drilling for oil. As the shallow resources are already exploited to a large extent, the attention turns to the oil fields in greater depths. Drilling has progressed down the continental slopes. At present the deepest commercially exploited fields are the Roncador and Marlin oil fields off Brazil in ca. 1500–1800 m water depth. This is not the limit and oil fields in 2000 m are being explored. This advance has been made possible by new technologies, like tension leg platforms.

Deep-Sea Cold Water Coral Reefs: *Lophelia* sp.

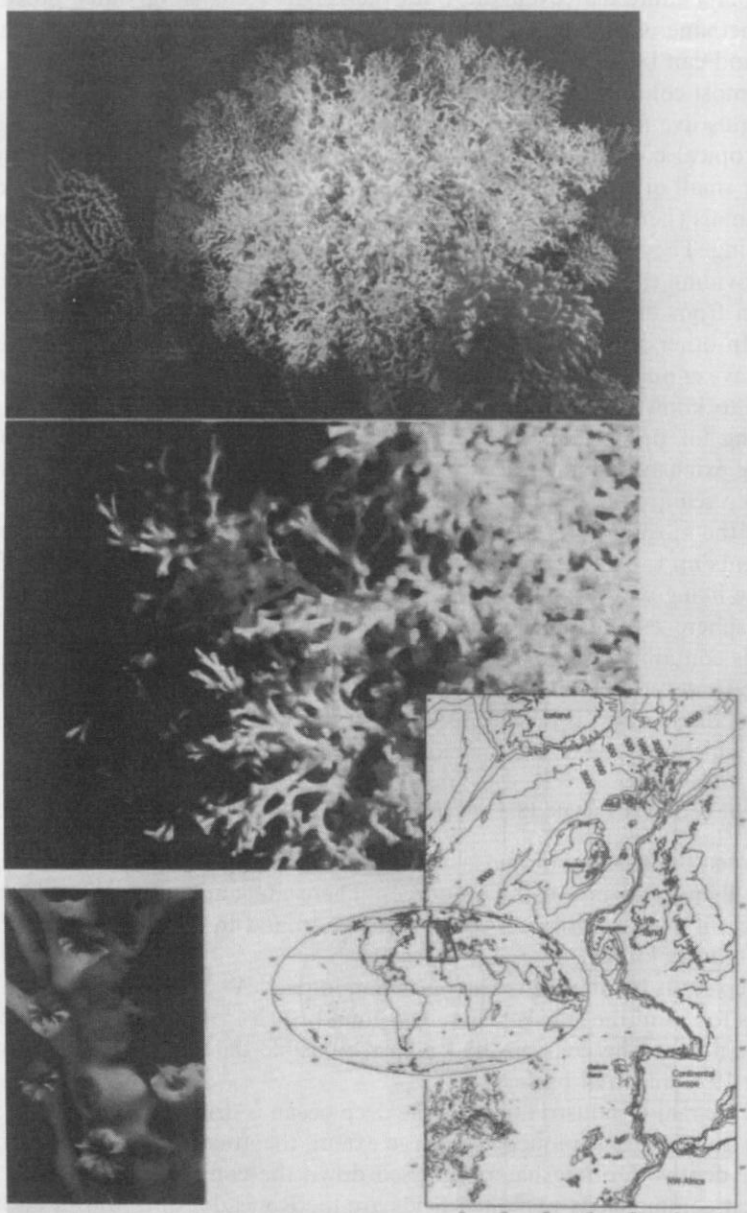


Figure 3. Cold water corals (*Lophelia*).

At the sea floor a host of remotely operated instruments are docked and linked to the central drill unit covering several hundred meters of sea floor. Such hi-tech instrumentation in the deep sea relies critically on high precision forecasts of currents, in particular of sudden deep sea storms with high current speed. Another danger is slope instability, i.e. when sections of the continental slope become instable and slide into the deep sea. Slides of more than several thousand km³ of sediment are known from the past, but smaller events have been occurring in the recent past and there is no safeguard against slope instabilities.

WE NEED NEW TOOLS TO ACCESS AND TO UNDERSTAND THIS LARGEST ECOSYSTEM ON EARTH

The major problem is that the deep sea is very inaccessible for observation. Most instruments do not function under the high pressure in the deep sea. Automatic registration of a few variables is now possible, but suffers from the limitation of power supply. While in the last decade major progress has been made in global observations via satellites, a similar progress was not possible in the deep sea. Hence, all our observations are still based on "snap shots". It is fair to say that the key to the deep sea lies with technological advances.

Lander Systems

At present, measurement in the deep sea can be made by lander systems. Such a measuring system is lowered from the ship on a glass fibre cable and drifts across the sea floor while observing the bottom with a camera. The pictures are transmitted to the ship. Once the right position is found, the lander is released from the launching unit. When settled on the sea bed it carries out the measurements autonomously for a time. It returns to the surface with the stored data when it receives an acoustic command to drop its balast weights. These systems can only operate for a limited period of time.

Other systems are moored at the sea floor for long periods of time and transmit their data via a surface buoy and satellite to the home laboratory. Their problem is mainly a limited power supply.

Remotely Operated Vehicles (ROV)

Remotely operated vehicles (called ROV) are a more sophisticated and also a much more costly way to gain access to the sea floor. These ROV are lowered to the sea floor and are connected by an umbilical cable to the ship. They can then be steered from the ship; there are a number of cameras to observe the sea floor and mechanical arms are available to collect specific samples or to carry out simple experiments. *Kaiko* as the deepest diving ROV can go to even the deep trenches in 10 km depth, whereas *Ropos* can dive to 6000 m.

There are more technical possibilities to access the deep sea. One of the most promising ones is to use deep sea cables to which monitoring units are connected. This way power supply and data transmission are provided by the cable and a long term monitoring would be possible.

Conclusion

In the following I would like to present a few glimpses of the possibilities and problems of observing the deep sea. It has some resemblance to space exploration, both in respect to the inaccessibility of its object of study and in respect to the high costs. However, development of such technologies is the key to gain access to the deep sea and its secrets. It is my conviction that we need to make greater efforts to understand the deep sea much better than up to now. This is not because of curiosity, but because the deep sea harbours many promises and challenges for our future. Human pressure on the deep sea will inevitably increase and we need to make sure that we manage and protect this largest ecosystem on earth wisely.

SUMMARY STATEMENTS

The deep sea is an integral part of the earth system and it harbours a number of resources which we just begin to recognize.

Our understanding of the processes in the deep sea and of its lifeforms is still rudimentary.

We need new technologies and visions to access and monitor this highly inaccessible ecosystem.

Human pressure on the deep sea will inevitably increase and we need to make sure that we manage and protect this largest ecosystem on earth wisely.