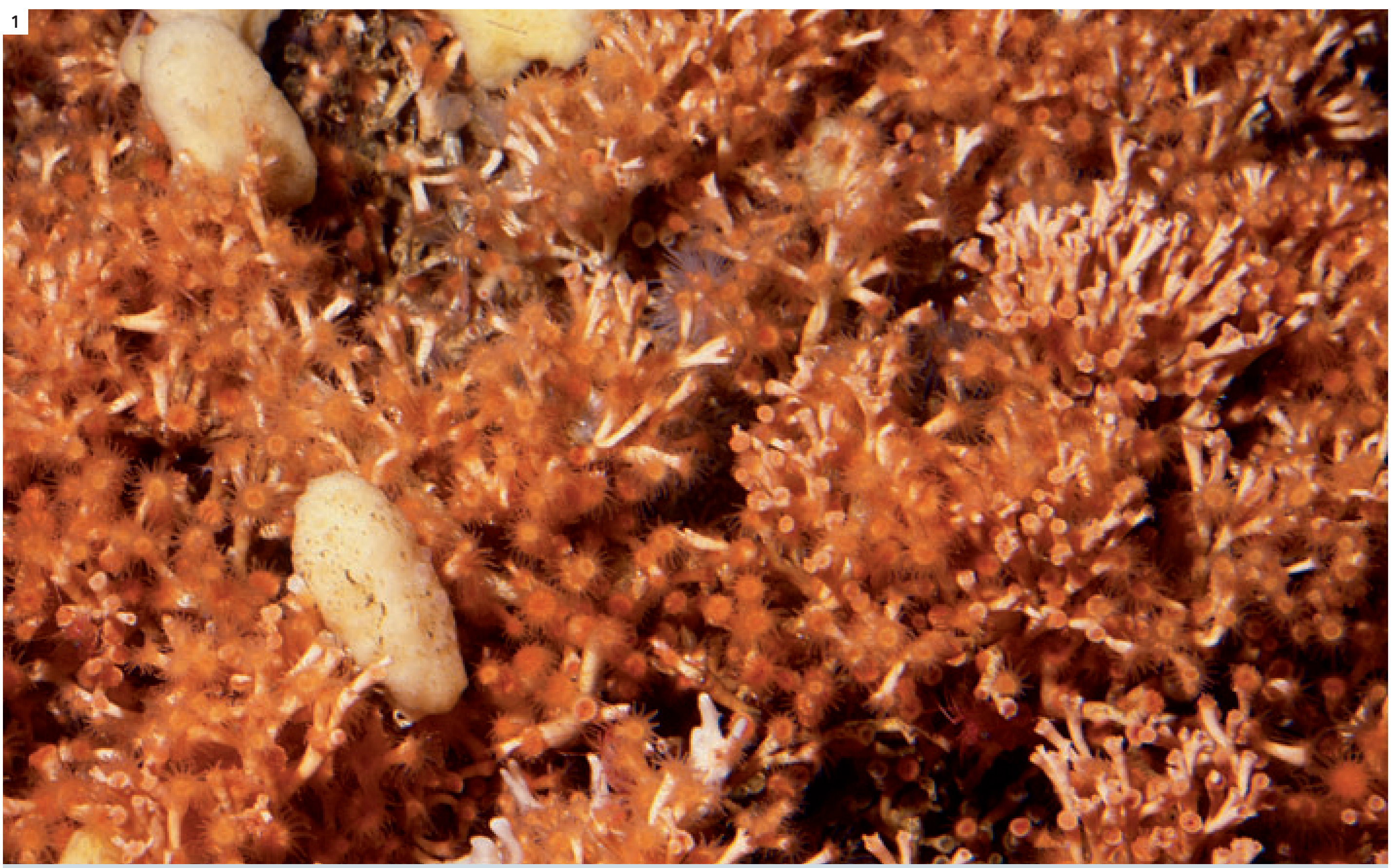
Cold-Water Corals as Climate Archives in the Ocean Depths

Computed Tomography of Sediment Cores Provides Outstanding Insights for Geologists

International deep-sea research over the last decade has led to the stunning discovery of lush coral gardens in the cold, dark waters of the deep. Much like tropical, shallow-water corals, their calcareous skeletons bear detailed chemical records of past climate. Computed tomography scans of sediment cores containing corals provide geologists with an outstanding mode of visualization.

By Matthias López Correa, MSc Geology, PhD-student; Anna Bednorz, MSc-student of Geology;
André Freiwald, Prof. PhD, Institute of Paleontology, University of Erlangen-Nuremberg, Erlangen, Germany.
Monika Demuth, PhD, CT Division, Siemens Medical Solutions, Forchheim, Germany.

1



1 **Submersible image of dense colonies of the cold-water coral *Lophelia pertusa* a 350m waterdepth.**

In our imagination, we usually associate corals with warm, sunlit, tropical waters, with lush and colorful gardens at snorkeling depths, home to an exceptional number of fish and other ocean species. But oceanographic research vessels, equipped with manned submersibles and camera-armed robots, have brought up new insights from the deep-sea bottom at several hundred to a thousand meter depth – far beyond the reach of scuba diving – unveiling rich, cold-water coral ecosystems. These live very differently than tropical, shallow-water corals by feeding on zooplankton rather than depending on sunlight and warm temperatures. They occur in all the world's oceans, typically at 500 to 1000 m depth in complete darkness and at temperatures of 8 to 10° C and below.

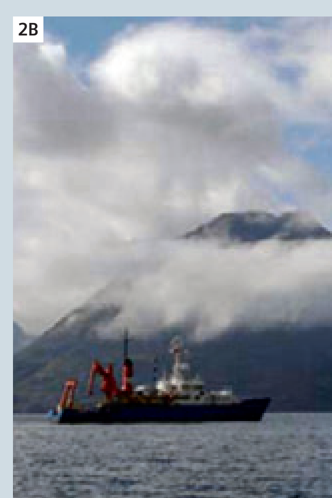
One of the latest ship expeditions with the R/V Poseidon on the Norwegian Shelf documented the world's northernmost corals in the Stjernsund Fjord at 70° northern latitude, far beyond the Arctic Circle. The dives of the submersible JAGO showed a wide-spread distribution of the white, cold-water coral *Lophelia pertusa*, whose skeletons form rigid frameworks that, over time, grew into mounds and reef-like structures on the sea bottom. These mounds formed by corals and sediment, extend over many kilometers and reach several tens of meters in height. The calcareous frameworks were precipitated by the small coral polyps forming the living zone on top of each branch. The coral branches provide a home to many other species of living organisms, forming biological "hotspots" in the depths, comparable to coral reefs in shallow waters. In particular, they provide shelter and breeding grounds for many commercially important fish species. At the same time these vulnerable mound-habitats, which took thousands of years to grow, are at risk of destruction by the vigorous trawling techniques of industrial fishery. An important task of the ongoing research by geologists and biologists is also the mapping of the coral distribution and the promotion of potential marine protected areas put into effect through national and international environmental laws.

Corals – The Ocean's Diary

Cold-water corals provide natural, deep-sea archives. Their skeletons store information on the temperature and salt content of seawater as well as its nutrient concentrations and many other important characteristics needed to reconstruct past ocean currents and their link with past climate changes. Similar to the annual rings of a tree, the minute growth bands in coral skeletons are a geochemist's pages in this diary of the ocean. The ocean depths, long thought to be a static realm, is highly variable and reacts quickly to climatic changes – for example, during shifts from ice-ages to warm periods. The Norwegian fjords, like the Stjernsund trough, were carved out during the last ice age by huge glaciers that reached their maximum extent about 20,000 years ago. The rapid retreat of these ice streams and the resulting sea-level rise at the beginning of the present warm period, about 11,000 years ago, lead to the Atlantic waters flooding the Norwegian shelf and fjords, creating the conditions for the build-up of the coral ecosystems on the ocean bottom. This climatic shift is documented by a sediment change, from boulders and gravels laid down by glaciers to coral-bearing mud and sands of the present warm period. Marine sediment stacks of cold-water corals are routinely sampled by marine geologists with coring devices. Radiocarbon dating of the first corals above the glacial gravels tell us when marine conditions favorable for corals were first established.

Computed Tomography

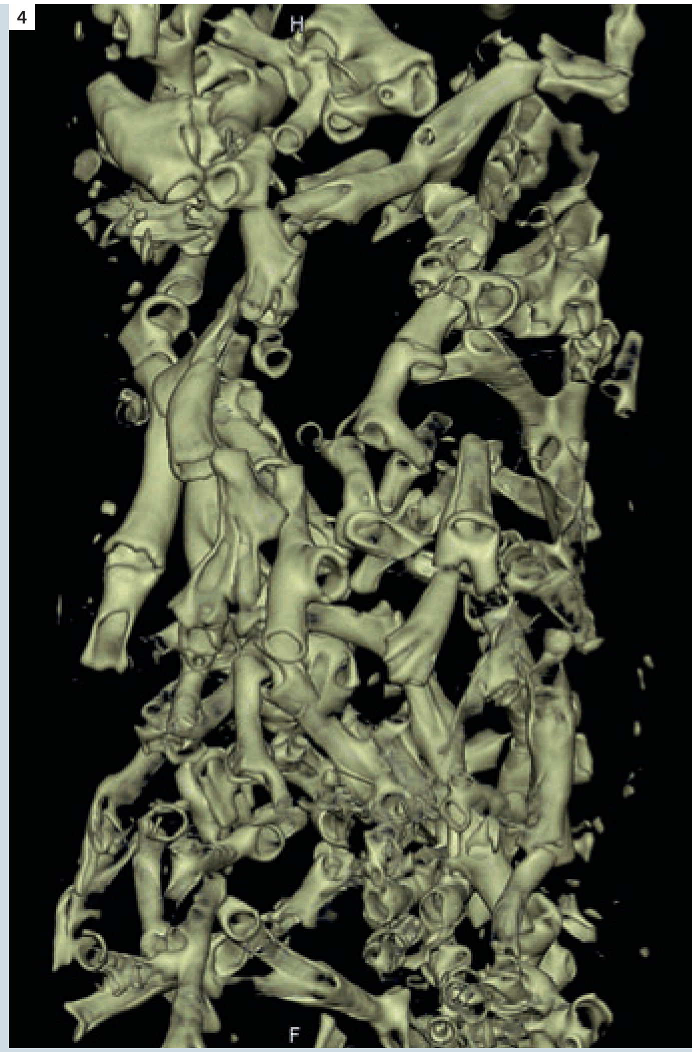
Changes in coral preservation, their three-dimensional arrangement and the sedimentary structures help unravel the mound history related to past oceanographic and climatic changes. Their positions can tell, for example, if the coral colonies are still in their original life positions or were tumbled-over and transported by currents. Previously, an understanding of the third dimension had to be



2 **Oceanographic research vessel R/V Poseidon cruising the north-Norwegian Stjernsund Fjord, home to the world's most northern corals (Fig 2B). Manned submersible JAGO aboard the vessel, being prepared for a dive in the 400 m deep fjord (Fig. 2A).**

3

4



3 Deep-sea sediments and coral mounds grown over thousands of years can be analyzed with gravity cores. One-meter segment of a sediment core showing glacial moraine deposits with rock fragments in the lower half of the last ice-age, overlaid by cold-water coral deposits of the present warm-period. Conventional 2D core cut with corals visible as small white cross-sections (left), x-ray slice showing the pronounced boundary of dense glacial sediments – appearing light, and mud with corals above (middle), 3D-rendering of rock-fragments and corals and their position in the sediment.

4 A SOMATOM Sensation high-resolution, 3D-visualization of corals in the sediment core, allowing core analyses of unprecedented detail and precision.

gathered from single, two-dimensional core cuts and required much knowledge and experience. Scanning of these sediment cores with computed tomography (CT), in particular, the SOMATOM® Sensation and Definition, is a major step forward in the interpretation of these coral mounds. The strong density contrasts of the corals and glacial rock fragments against the sandy and muddy background sediment allow an ideal three-dimensional visualization with minute detail. The high-resolution images provided by the SOMATOM Sensation CT scanner also show the degree of coral fragmentation from current erosion, a characteristic often overseen in two-dimensional core cuts. The non-invasive analysis of core cuts also permits the localization and selection of samples for radiometric dating and often, a first determination of the coral species prior to core opening. Computed tomography opens up a third-dimension in sediment core analysis and is certain to become a standard tool for geological sciences applicable to cores containing heterogeneous materials.

References

1 Freiwald, A., Fosså, J.H., Grehan, A., Koslow, T. & Roberts, J.M. (2004): Cold-water Coral Reefs. – UNEP-WCMC, Cambridge, UK, 84 pp.

2 Roberts, J.M., Wheeler, A.J., Freiwald, A. (2006): Reefs of the deep: the biology and geology of cold-water coral ecosystems. Science 312: 543–547.

This research was supported by HERMES-project, EC contract no. GOCE-CT-2005-511234

www.cool-corals.de
www.eu-hermes.net