R/V Poseidon Cruise 228

Cold-water corals on the Sula Ridge

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Research Programme

In the recent years cold-water carbonate research has become a prime target in sedimentary geology and especially in marine geology (James & Clarke 1997). Benthic carbonate-secreting communities control the depositional environment in various polar, cold-temperate and warm-temperate climatic settings in the North Atlantic (Henrich et al. 1996).

The POSEIDON cruise No. 228 was dedicated to document the dimension and internal structure of a giant aphotic coral reef on the Sula Ridge, Mid-Norwegian Shelf (see cover and Fig. 1). Previous cruises (Freiwald et al. 1994, 1995) and Norwegian biological surveys (Mortensen et al. 1995) have demonstrated the existence of a more than 5 km long coral reef in 250 to 300 m water depth. The main reef constructor is the azooxanthellate colonial scleractinian *Lophelia pertusa* (Linné, 1758) which forms, in places, more than 30 m high build ups.

Coral banks, patches or reefs are widely distributed along the continental margins of the Northwest European shelves (Teichert 1958). In Norwegian waters, *Lophelia* occurrences are found in mid-shelf positions and on deep-seated sills in large fjords. All these occurrences have in common that they are bathed in food-rich waters fed by the North Atlantic Current. The northernmost *Lophelia* reefs exist in the Finnmark District, northern Norway (Dons 1944, Freiwald et al. 1997).

Aside the mapping of the large-scale reef structure on Sula Ridge, ground-truthing with a manned submersible unravelled environmental controls which fostered reef formation during the last glacial-interglacial transition. Special emphasize was laid on the growth history of the deep coral reef and the fossilisation processes (taphonomy) which generate geological signals in the dead reef base. Of special scientific interest is the ongoing discussion on a methane seep control which should trigger the formation of *Lophelia* reefs (Hovland 1990, Hovland & Thomsen 1997, Henriet et al. 1998). Therefore, the submersible dives were also planned to document the diet of *Lophelia* and its feeding habits by direct observation and sampling and to detect venting or seep sites which are generally indicated by pockmarks, concentrations of chemosymbiotic communities or unusual accoustic patterns in the echosounder records which may count for gas plumes in the water column.

Scientific equipment

Submersible

The JAGO is two-seated submersible of low weight and dimensions but high manoeuverability. A large set of bulbs and flashes are installed to support illumination for visual inspection and video documentation. A laser-scale continously provides a scale of the documented objects. Sampling was carried out with a stick-controlled manipulator at high precision. Samples were stored in a collector box or in special designed tubes to prevent contamination of the samples during the dives. Depth, heading and water temperature is recorded continously.

Bottom sampling

The sampling of sediment was carried out with Van Veen grab and a benthic dredge.

Results

RV POSEIDON reached the working area on Sula Ridge in the night of 11th February. It was planned to use the night times for detailed echosounder mapping of the reef structure while during day light conditions the submersible dives were performed. Dredge hauls and sediment sampling was added during rough weather conditions when launching operations of the submersible were endangered.

Mapping Survey

The Sula Ridge was mapped sector by sector using a narrow-beam 30-kHz and an 18-kHz echosounder with DGPS navigational support. The ship-based facilities allowed online recording and logging of the ships track, coordinates and water depth to create a contour map. The coral reef structure has a total length of 13 km and a width of 150 to 300 m. Average framework thickness is 10 m but up to 35 m high build ups were found. The aerial coverage of the reef is in the range of 3.25 x 10^6 km^2. Previous high-resolution side scan sonar surveys have already shown that the reef chain is formed by numerous elongated pairs of reef bodies en echelon. The deviation of the reef mound long axis in respect to the long axis of the Sula Ridge is apparent and needed ground-truthing dives with the research submersible.

„JAGO"-Dives

Reef zones

The submersible dives were carried out with the German JAGO. This manned submersible has an operational depth of 400 m. Her high manoeuverability makes this submersible very efficient for the dives into the complex topography of the coral reef structure. The ground-truthing shows that the reef is flanked by a 3 to 5 m high gently-sloped coral debris belt. The coral fragments are heavily bioeroded and microbially corroded. The tops of these debris mounds are rather flat and even. The sediment infill consist of silty sands with an Arctic foraminiferal fauna. On top of this debris mound nearly vertical flanked *Lophelia* framework forms the volumetrically most important part of the reef structure. The corals are preserved as *in situ* colonies, slightly dislocated meter-sized coral blocs, or, coral rubble. Terrigenous sediment infill is present in this section of the reef but shows a higher carbonate content of 25 % on average. The carbonate is contributed by Holocene benthonic and planktonic foraminifers, coccoliths and *Aka*-chips. The cushion-like yellow sponge *Plakortis simplex* plays an important role in the biological stabilisation of the decaying coral framework and as filling agent of the coral framework porosity. The top sections of the reef are colonized by up to 3 m-large hemispheroidal coral colonies which are detectable on the high resolution sonographs as „cauliflowers"which serve as a shelter for various fishes. Huge fans of the octocoral *Paragorgea arborea* are common on the reef top.

Paleoenvironmental hazards

There is increasing evidence supported by radiocarbon datings that the life history of the reef is complex and can be used as a recorder of paleoenvironmental hazards. The debris mounds can now be interpreted as the remains of a catastrophic event, the second Storegga Slide (Bugge et al. 1987). The position of the Sula Ridge is just above the northern Storegga escarpment on the Norwegian shelf. The age of the second slide event is precise known through datings of tsunami deposits along the northern Scottish coast (Dawson et al. 1988, Long et al. 1989) and the western Norwegian coast (Bondevik et al. 1997) with 7200 YBP. This is approximately 1000 years after the onset of *Lophelia* reef formation on Sula Ridge (Freiwald et al. in prep.). The shock wave transported sands and silts killed the corals and induced collapsing of the initial reef stages. This is the mode of the debris mound formation. In addition, the import of Pleistocene sediments is indicated by the Arctic foraminifer communities that are found as infill of the early Holocene coral framework and debris.

Control on reef geometry

The JAGO dives confirmed our previous hypothesis that the reef geometry is controlled by icebergs. During the decay of the Fennoscandian Iceshield, the Norwegian Sea was filled by northward drifting icebergs which scoured heavily on the shelf, especially on topographic highs such as Sula Ridge (Lien 1983). The force of grounding icebergs has ploughed-out meter-sized blocs of the Paleocene sandstone basement of Sula Ridge in form of fringing boulder barricades with a 3 to 10 m deep plough mark furrow between the boulder levees. These hard substrates were colonized later by the *Planula* larvae of *Lophelia*. The drift direction of the icebergs crossed the Sula Ridge at a deviation of 30 degrees in respect to the long axis of the ridge. This glacial heritage is still preserved in the en echelon package of the 13 km long groups of reef mounds (Fig. 9).

Biological observations: Food web

The biological observations were carried out during the dives and shed light on the diet and feeding habits of *Lophelia* for the first time. *Lophelia pertusa* preferentially captures copepods *(Calanus)* and cumaceans with the tentacles. There is evidence of pronounced day and night rhythmicities in the aphotic coral reef triggered by the vertical migration of the zooplankton stocks. During day time, zooplankton is sparse at the reef location while in the evening the density of crustacean swarms increases considerably. These observations are documented on video tapes and are under analysis now. The studies of the fauna in the reef and nearby surroundings show no evidence of chemosymbionts which indicate hydrocarbon emanation. Pockmarks are more than a kilometer off the reef site. Although elevated hydrocarbon contents have been documented by Hovland & Thomsen (1997) in the sediment near the coral bioherms, only background values are found in direct vicinity of the reef and zero-notations are documented in the water column near the reef.

Taking the global occurrences of *Lophelia* and other azooxanthellate corals into consideration, there is much more support for a bentho-pelagic control fostered by zooplankton-rich waters rather than the distribution of seeping hydrocarbons which seemed to be a coincidence. However, much more geochemical and biological investigations are needed for a final answer of this controversive discussion.

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