

phases which can scavenge heavy metals and finally precipitate as hydrated oxides and oxyhydroxide phases with mixture of MnO_2 , amorphous FeOOH and Fe-aluminosilicates (Koschinsky et al., 1995). According to this genetic model, the existence of an Oxygen Minimum Zone (OMZ) is an important precondition for the formation of hydrogenetic crusts.

Because of the slow formation of hydrogenetic crusts (1-15 mm/Ma), their layers have the potential to record and preserve information of the chemical and isotopic evolution of the seawater. The ferromanganese crusts are therefore useful for paleoceanographic studies. Their thickness is not only controlled by the duration of their growth but also by the rate of accumulation of ferromanganese oxides, which in turn depends on geochemical and oceanographic conditions at the site of formation (Cronan, 1992). For the growth of thick crusts, geologic stability is required as slumping and erosion at seamounts can destroy or abrade the crusts reducing their thickness. According to Manheim (1986), it seems that significant covers of crusts essentially occur on seamounts after 60-80 Ma or more.

A suitable explanation for the thickness of some crusts recovered could be a well developed OMZ, possibly affected by the degree of bioproductivity in the overlying waters. The presence of a regional OMZ, however, may not be necessary if horizontal advection occurs or if there is local obstruction upwelling around the seamounts and ridges, causing an increase of bioproductivity in the surficial water and localized OMZ in the layers below (Cronan, 1992). Another possible explanation for the occurrence of thick ferromanganese encrustations could be two or more periods of growth (Cronan, 1992).

On the other hand, the crusts of many samples dredged are too thin to have been continuously accumulated since the formation of their substrates. This apparent discrepancy may reflect processes such as reworking, abrasion, burial and local volcanic activity. The first two possibilities are consistent with the occurrence of volcanoclastic breccias and rounded fragments in the dredge hauls. Further investigations including mineralogical and geochemical analyses and traverses across the layers of representative ferromanganese samples will be carried out in order to reconstruct the environmental and geochemical conditions and growth rates during formation of these crusts.

1.4.5 Biology

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An important aim for the participation on this cruise was the selective collection of azooxanthellate deep-water corals to reconstruct the palaeoceanographic ventilation of the deep Atlantic. Alone from this point of view, cruise M51/1 was very successful since abundant deep-water corals could be sampled, apart from other organisms including sponges, bryozoans, bivalves, serpulides and gastropods, from over 70 dredge stations.

The impetus for the global mixture of water masses is the formation of deep water in the North Atlantic and the surface water currents in the oceans. The intrusion of oxygen-enriched, young, deep water in the deep basins of the Atlantic and Pacific is called ventilation. Climatic changes are generally accompanied by a change of these circulations in the North Atlantic. Detailed information about the ventilation during the glacial and interglacial periods as well as changes in ventilation during sudden climatic changes are of great importance for the understanding of these global events and especially for their modelling with the aim of

prediction. The study of the Cd/Ca ratio and the $\delta^{13}\text{C}$ values of benthic foraminifera in sediment cores of different water depths in the North Atlantic shows a dependance on the circulation of water masses (Bertram et al., 1995; Venz et al., 1999). Venz et al. (1999) describe three different scenarios for the circulation of deep water in the North Atlantic: during the glacials, at their termination and today.

In particular, poor ventilation is assumed during the termination of a glacial period between 1000 m and 2000 m water depth. Because of the increased influx of melted snow and ice, the production of Glacial North Atlantic Intermediate Water (GNAIW) decreases and older Southern Source Water (SSW) intruded into the upper Intermediate Water. In comparison the North Atlantic has a better ventilation today and had during the glacial period. A central parameter for reconstructing the ventilation is the so-called "age of ventilation" (age of the deep water). A measure for the age of ventilation is the difference of the $^{14}\text{C}/^{12}\text{C}$ ratio between the surface water, which is represented in the carbonate of planktonic foraminifera, and the deep water as represented in the carbonate of benthic foraminifera (Shackleton et al., 1988; Duplessy et al., 1988, 1989; Broecker et al., 1990; Adkins & Boyle, 1997). Up to now, only a few ages of ventilation from foraminifera of the North Atlantic have been published (Broecker et al., 1990). Only deep water cores with high sedimentation rates can be used for the reconstruction of the ages of ventilation to achieve an exact stratigraphic classification and to minimize the disturbing influence of bioturbation. Broecker et al. (1999) were able to show that bioturbation and temporal modifications of the influence of different foraminifera species lead to mistakes in determining the ages of ventilation. In contrast, azooxanthellate colonial or solitary deep-water corals are unique archives in view of the concentration of ^{14}C and nutrients of deep water in the past. The age of deep-water corals can be exactly determined using the $^{230}\text{Th}/^{234}\text{U}$ dating method. Comparison of the ^{14}C -age of the corals, influenced directly by the exchange of carbon between atmosphere and ocean, with the $^{230}\text{Th}/^{234}\text{U}$ -age, representing the exact age of the coral, gives the age of ventilation of the deep water (Mangini et al., 1998; Adkins et al., 1998). Unlike the zooxanthellate hermatypic corals living in the euphotic zone, the biotope of deep-water corals is the cold and aphotic bottom of the deep sea. Some solitary species of Scleractinia occur in the Mediterranean Sea in depths of up to 2500 m and in the North Atlantic down to 4800 m where they are especially abundant around Iceland, the Azores and the Cape-Verde Islands (Zibrowius, 1980; Cairns & Stanley, 1981). Colonial species like *Lophelia pertusa* partly build large reef complexes. A compilation of the distribution of *Lophelia pertusa* gives evidence of the existence of an open coral belt reaching from the Iberian Peninsula as far north as the Scandinavian Shelf (Freiwald, 1998).

Deep-water corals were considered to be impossible to date for a long time because most samples were covered by a layer of Fe- and Mn-oxides/hydroxides several 100 μm thick. However, a newly developed procedure using the thermion mass spectrometry (TIMS) the $^{230}\text{Th}/^{234}\text{U}$ dating method has been applied to deep-water corals for the first time (Lomitschka & Mangini, 1999). During the Pleistocene / Holocene transition between 25 to 8 ka before present several periods with higher ages of ventilation can be observed, which point to a more intense input of southern (old) deep water. The determination of the ages of ventilation using deep-water corals is recommended by Boyle (2000) and Stocker (2000) as a very useful proxy for the decoding of global ocean circulations during climatic transitions.

On the basis of this background, the participating biologists and palaeontologists on cruise M51/1 collected all fossil and Recent organisms with the focus on the scleractinian reef-forming deep-water corals of the eastern North Atlantic (working area I-III) and western Mediterranean Sea (working area IV) from different submarine seamounts of water depths between 4600 m and 260 m. Of particular interest was the occurrence of the colonial corals *Lophelia* and *Madrepora* as well as the solitary corals *Desmophyllum* and *Deltocyathus*. Notable is the frequent occurrence of the deep-water coral *Lophelia* in working area I in water depths of about 1100 m and 2500 m, while in the working areas II and III *Lophelia* is found more seldom, although the occurrence of *Lophelia* in these areas has been reported from some earlier cruises (e.g. POSEIDON 235). One possible reason for this phenomenon could be the great water depths of more than 3000 m of many dredge stations in working areas II and III.

As already known in literature the Mediterranean Sea can be called a "fossil hot spot" of *Lophelia* coral thickets. Through the Strait of Gibraltar, *Lophelia* invaded the Mediterranean deep sea after the Messinian Event in the Pliocene and is concentrated in regions of intense tectonic uplift (for detail see e.g. Freiwald, 1998). In working area IV the occurrence of *Lophelia* and some other deep-water corals (like e.g. *Madrepora* and *Desmophyllum*) could be recognized very often in bathyal marls in close vicinity to palaeo-escarpments as well as from some deep sea hardgrounds. The coral pieces are often covered by Fe/Mn-crusts and sometimes filled by biomicrite.

Looking at the dredged corals there are some diagnostic features to recognize. The main framework constructing, azooxanthellate coral reefs are formed by only one or two different species (e.g. *Lophelia* and *Madrepora*). Furthermore, the bioerosional impact on deep-water coral reefs seems to be relatively high. The corals are infested by heterotrophs such as bryozoans and sponges. Also conspicuous is the frequent presence of encalcified, long, sinuous and anastomosing networks of tubes of the polychaete *Eunice*. It is interpreted that the existence of this worm stimulates the thickening of the coral reef and strengthens the architectural framework (Freiwald, 1998; Rogers, 1999).

The living organisms within the dredges were mainly represented by different species of epifaunal Porifera, Octocorallia, Hydrozoa, Mollusca, Polychaeta, Bryozoa, Brachiopoda and Ophiuroidea, seldom by Crustacea. The organic content of the sediment within the sediment tubes is mainly composed of Foraminifera and Pteropoda, secondary of Gastropoda, Bivalvia, Ostracoda, fish-otoliths and fragments of Balanomorpha and Echinodermata. All living specimens were preserved in 70% ethanol. The sediment and the dead corals were dried for later studies.

The sampled material of this cruise will be investigated in detail and compared with other known deeper water coral ecosystems along the European Atlantic Margin (e.g. the Galicia Bank, Porcupine Slope, Rockall Trough and Sula Ridge) to cover the variation of environmental factors. Important aims will be to get further informations about possible changes of the biogeographic diversity of azooxanthellate coral reefs in the eastern North Atlantic and the western Mediterranean Sea and to use the aragonitic coral skeleton to obtain new data of oceanographic proxies.