Summary

Environmental Constraints on Cold-water Coral Growth and Carbonate Mound Formation

This thesis is devoted to establish and extend the knowledge about cold-water coral carbonate mound formation, especially focussing on the environmental conditions governing recent and past cold water coral growth and, in the final stage mound build-up. This thesis is divided in two major parts. One part (Chapters 2-4) focuses on the recent processes that shape the margin and influence and govern coral growth and mound formation. In the second part of the thesis (Chapters 5-7) past processes involving mound build-up and the possible use of cold water corals and associated species as paleo-thermometers are discussed.

This study describes the distribution and development of cold water carbonate mounds at the SW RT and SE RT margin, to allow better recognition of the various mound types and mound morphologies. High resolution side scan sonar imaging and seismic and acoustic profiling revealed the presence of mound clusters, with a shape which is elongated in the direction of the strongest currents and showed that all mound structures formed above a strong, regionally found characteristic reflector.

Recent environmental constraints on cold water coral growth and mound formation were subsequently measured by long and short term deployments of BOttom BOundary (BOBO) seabed observatories, measuring current velocity, temperature, salinity and the amount of particles in the water column and water column studies by recordings of CTD's in the two mound provinces at the SW and SE RT margins. Daily, seasonal and annual variations of near bed conditions were also measured with long term deployed seabed observatories, which were equipped with sediment traps, providing insight in the vertical as well as lateral flux of particles reaching the cold water corals. The mound areas at the SW and SE RT margin both demonstrate the influence and presence of tidal currents, internal waves and enhanced turbidity in the water column, with a strong relation between the tidal cycle and the food supply to the corals. These observations in combination with seabed imagery and sediment sampling established the connection between processes in the water column and carbonate mound build-up.

A pistoncore from a mound summit was studied to determine paleo-environmental conditions influencing mound construction and development. Stable isotopes and component analysis showed one cold water coral mound facies in the core where secondary processes have occurred in the form of dissolution and cementation of the coral framework. This exemplified the limitations of the use of cold water coral species as paleo-thermometers, since coral branches are not well preserved and most common coral species show kinetic fractionation patterns. Associated bivalve species collected on the mounds however, showed the absence of kinetic fractionation in their stable isotopes, indicating that some species have a great potential for delimiting (paleo)environmental conditions.

Chapter 2 provides an overview of carbonate mound distribution at the Southwest Rockall Trough margin and related sedimentary features. High-resolution side-scan sonar images and seismic profiling show the presence of kilometres long and wide clustered and single carbonate mounds, all having their summits at a specific depth level. Sedimentary structures and shape of the mounds reflect the influence of strong near-bed currents. 2D high resolution seismic profiling in general does not reveal strong internal reflectors within the mounds, but rather indicate that discontinuous, chaotic reflectors make up the mound body. In contrast, the presence of two strong reflectors representing unconformities in the sedimentary sequence underneath the mounds suggests at least two stages of mound formation, the oldest reflector defining the possible onset of mound formation in the Middle Miocene, while the second stage of mound formation is on top of a strong reflector considered as of late Early Pliocene age.

Chapter 3 provides the hydrodynamic controls on carbonate mound development. The presence of living corals on and around the summit of carbonate mounds appears linked to the presence of internal waves and tidal currents, as observed with bottom landers (BOBO), consequently the carbonate mound structures are considered shaped by the local hydrodynamic regime. Current speeds above 45 cm s^{-1} are not uncommon and prevent local sedimentation, in addition they provide sufficient food particles to the corals, so that the corals at the mound summits thrive. Tidal currents at both margins force the formation of Intermediate and Bottom Nepheloid Layers; the distribution of corals in both mound areas is considered directly related to the presence of enhanced turbidity in the water column as the tidal currents are bringing fresh food particles to the

mounds during periods of increased velocity. A clear relationship was observed between the ambient water temperature and the amount of particles in the water column.

Chapter 4 shows the seasonal variability of particle supply and provides evidence for the baffling capacity of the coral framework. Seasonal variability of particle supply was measured with bottom landers equipped with sediment traps. These were deployed at a station with a dense coral cover and a station without coral cover, both situated in a high turbidity cloud observed directly above the mound summits at the SW RT margin. Major differences between the stations in particle flux, chemical composition and freshness of the trapped material is directly related to the presence of a coral framework, which baffles a large amount of the particles settling from the vertical flux, which ultimately results in the development of cold water coral mounds. The amount, composition and type of particles collected in the traps is found related to the amplitude of daily temperature fluctuations and changes in current speed in the mound area. Resuspension of relatively old sediment at the station without coral cover dilutes the signal of material arriving from the vertical flux. The diurnal tidal cycle forms an important component in the vertical and lateral transport of particles to the cold water corals. ^{15}N values of the trapped material show a signal of fresh material arriving at the seafloor in late spring and summer. However this signal is small compared to a strong seasonal cycle, which is directly related to the yearly variability in near bed current regime.

In *chapter 5* recent sedimentological processes involved in mound construction are considered and discussed, to allow better assessment of past conditions and parameters of mound development. Cold water coral mounds on both margins of the Rockall Trough have a strongly different morphology. Single, isolated mounds occur on the Southeast Rockall Trough margin and are mainly found on the upper slope between 900-650 m water depth, while large mound clusters are found on the Southwest Rockall Trough margin in water depths between 600 and 1000 m, in a narrow zone almost parallel to the slope. Sedimentation rates on the mounds are higher then on the surrounding seabed as a result of baffling of biogenic carbonate debris and sediment particles by the coral framework covering the mounds. The 3-dimensional coral framework and the presence of extensive hardgrounds and firmgrounds are considered to be responsible for the stability of the relatively steep slopes of the mounds. High current velocities in the intra-mound areas result in local non-sedimentation and erosion, as is shown by the presence of IRD lag deposits on the seabed and moats around some of the mounds. The morphology and sedimentology of cold-water coral (mainly *Lophelia pertusa* and *Madrepora oculata*) covered mounds on the southern Rockall Trough Margins (NE Atlantic Ocean) is discussed and a model is presented describing the development of these mounds along the Rockall Trough Margins.

Chapter 6 describes the accumulation of mainly carbonate sediment on a mound in a pistoncore from a mound summit. Photo and video surveys at this station show the presence of living coral colonies on top of a thick layer of coral debris, which becomes slowly abraded and bio-eroded. The coral framework is mainly filled with sediment composed of phytodetritus and skeletal parts of fauna of associated species living at the mounds, resulting in a 120 cm thick layer of sediments deposited since 10,850 yr BP, confirmed by stable isotope analysis of planctonic and benthic foraminifera. Component analysis further provides a complete record of the cold-water coral mound facies, showing an alternation of skeletal and cement dominated sections. The older part of the core, with mainly intermediate values of stable isotopes is dominated by the presence of large hiatuses, of up to 200,000 yr. Hiatuses in the core possibly are linked to climate change, which had a large effect on the ocean circulation patterns, thereby influencing the local hydrodynamic regime, food supply and sedimentation rate around the carbonate mounds.

In *chapter 7* stable isotope data are presented of cold water corals and associated species, which were alive when collected. Tropical corals have proven to provide high resolution records of marine conditions and consequently cold-water corals may well form an archive of ambient intermediate and deep watermass conditions. However, as several studies have indicated, the most common coral species *Lophelia pertusa* and *Madrepora oculata*, show distinct kinetic fractionation patterns in their stable isotopes and are therefore considered as unsuitable for paleo-climate reconstructions. The commonly associated bivalve *Asperarca nodulosa* lives on top of coral debris, feeds on the same food source as the cold water corals and builds in oxygen isotopes close to equilibrium with seawater. Ambient sea water temperatures calculated on the basis of stable oxygen isotopes confirms bottom water temperatures in the range as has been measured with bottom landers. A direct relation between the presence of relatively warm water and an increased amount of (food) particles might indicate that shells and corals mainly grow when the encounter rate of food particles is high at the mounds.

Chapter 8 (synthesis) describes and discusses the forcing factors and environmental constraints regulating the distribution of cold water habitats in the North Atlantic. These factors and constraints are compared with current knowledge regarding mounds of the Rockall Trough region. The largest (highest and widest at their base) cold water coral mounds in the NE Atlantic Ocean dominated by the cold water corals *Lophelia* and *Madrepora* analysed so far, are found on the SW RT margin. These mounds have mainly formed because of the presence of tidal currents and internal waves transporting (fresh) food particles from the surface layers to the deeper waters and a sufficiently high current

regime to prevent the coral framework from getting buried. Corals at the SE and SW RT margin retrieve their food supply mainly from the lateral and cross slope transport of phytodetritus via nepheloid layers. The stable carbon isotope values provide no indication for any link between seepage and cold water corals.

A comparison between the evolution of the mound areas at both RT margins, shows that climate variability most probably had a major effect on the environmental forcing conditions in the mound provinces by influencing the tidal current regime, as well as the particle and food supply, in combination with the lowering of sea-level and changes in the general circulation pattern. Mounds at the SW RT margin all reach a specific depth level below the seasurface which corresponds with high turbidity layers just above the mounds. Presently mounds at the SE RT margin have reached their maximum height and become eroded or are in the stage of being buried.