Impact of diagenesis on carbonate mound formation

van der Land, C.

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Summary

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This thesis is devoted to define the parameters influencing cold-water coral growth and therefore carbonate mound development with a focus on the impact of diagenesis on mound sediments. The first part of this thesis (Chapters 2 to 4) discusses the distribution and growth history of carbonate mounds, the sedimentary processes leading to sediment accumulation at mound sites and the primary sediment composition of cold-water coral carbonate mounds along the Irish margin. The second part of the thesis (Chapters 5 to 7) elaborates on the post-depositional processes (diagenesis) affecting mound sediments, the timing of these diagenetic processes and their impact on carbonate mound development.

Piston cores obtained from mound summits were studied to determine paleo-environmental conditions influencing mound development. Component analysis, thin section petrography and X-ray fluorescence scanning revealed the impact of diagenesis in the form of dissolution and cementation of the coral framework. U-series dating of coral skeletons and stable isotope measurements on foraminifera provided us with a chrono stratigraphic framework for carbonate mound build-up. Coral ages showed that large hiatuses are present in the mounds, which can be linked to multiple phases of erosion or non-deposition in the mound history.

In *Chapter 2* the morphology and sedimentology of carbonate mounds from two mound provinces at the southeast and southwest margin of the Rockall Trough (RT) (NE Atlantic Ocean) are investigated. Cold-wat er coral mounds on both margins have a strongly different morphology. Single, isolated mounds occur on the SE RT margin and are mainly found on the upper slope between 650 and 900 m water depth, while large mound clusters are found on the SW RT 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 than on the surrounding seabed as a result of baffling of biogenic carbonate debris and sediment particles by the coral framework. The three-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 RT margins is discussed and a model is presented describing the development of these mounds.

Chapter 3 focuses on U-series dating of constructional cold-water corals. Dating of the coral skeleton of *Lophelia pertusa* and *Madrepora oculata* from mounds along the RT margin and in the Porcupine Seabight reveal that the Holocene (past 11 kyr) was a period generally favourable for coral mound development. Vertical mound growth rates are directly linked to the presence or absence of a dense coral cover at the mound summits. During times of reduced coral growth or the absence of a coral framework, mound growth rates are by far smaller. Periods favourable for coral growth on the SW RT and in the Porcupine Seabight are related to overall climatic warm phases and coral growth is largely reduced or even absent on mounds during cold phases such as glacial periods.

Chapter 4 describes the accumulation of mainly carbonate sediment on a mound at the SW RT margin. 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. Component analysis of a piston core from a mound summit shows that the coral framework is mainly filled with sediment composed of phytodetritus and skeletal parts of fauna living at the mounds. The mound sediment record displays an alternation of skeletal and cement dominated intervals. Dating of coral skeletons and the oxygen stable isotope signature of planktonic and benthic foraminifera indicate a continuous sedimentation pattern since the Younger Dryas. 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 patterns around the carbonate mounds. This affected coral growth and therefore carbonate mound development.

In *Chapter 5* piston cores obtained at three mound crests reveal the complex internal structure of the mound build up, with alternating unlithified coral-dominated intervals and lithified intervals. Coral ages obtained by U-series dating show the presence of several hiatuses in mound build-up. Down core X-ray fluorescence scanning (XRF), computed tomography scan images and petrographic observations indicate different degrees of diagenetic alteration. Aragonitic coral material is absent or only present as mouldic porosity in the lithified intervals and coccoliths display widespread calcite overgrowths. The dissolution of the unstable aragonitic coral skeletons is linked to organic matter oxidation and the subsequent lowering of the saturation state of the carbonate system. A model is presented describing the sedimentary and diagenetic processes leading to the formation of lithified intervals.

Chapter 6 focuses on the enrichment of redox-sensitive elements and the dissolution of primary magnetic ferric iron minerals in the depth interval below lithification levels in carbonate mound sediments. By combining the magnetic susceptibility with the XRF signal of Fe and Ti specifically, intervals with susceptibility variations related to the conversion of strongly magnetic into weakly magnetic iron species were defined. In all three studied cores a succession is recognised with a lithified interval with aragonite dissolution and low-Mg calcite precipitates that is underlain by an interval of magnetite dissolution and of iron and manganese enrichment. For the most recent lithified interval it is demonstrated that initial lithification occurred before an erosional regime was in place, most likely near the end of an interglacial or at the start of glacial periods.

In *Chapter 7* the carbonate mound development and sediment composition of the mounds at the SW RT margin and the Galway Mound in the Porcupine Seabight are compared. Differences in sediment composition between these mound provinces are related to the local environmental conditions. Mound accumulation rates at the Galway Mound are higher due to a higher influx of off-mound derived fine grained non-carbonate sediments. At both locations mound growth has been continuous for the last 11 kyr, before this period several hiatuses exist in the mound record. The most recent hiatus can be traced across multiple mounds and mound provinces at the Irish margin. At the SW RT margin these are associated with post-depositional aragonite dissolution in and lithification of certain intervals, while at Galway Mound no lithification occurs. This study shows that the influx and composition of material transported to carbonate mounds have a direct impact on the carbonate mound accumulation rate and on post-depositional processes.

Chapter 8 (synthesis) describes and discusses the impact of diagenesis on carbonate mound formation. It is debated whether lithified layers play a crucial role in carbonate mound development/vertical mound growth by providing a stable colonisation surface for cold-water corals and by stabilising the steep mound flanks. The underlying processes leading to post-depositional modifications are discussed, including their link to climate cycles. Furthermore, a compilation of coral ages at the Irish margin older than 11 kyr is shown.