

The Darwin Mounds, N Rockall Trough: how the dynamics of a sandy contourite influenced cold-water coral growth

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Abstract: The Darwin cold-water coral mounds in the northern Rockall Trough have often been considered potential analogues for the initial stages of giant cold-water coral mounds. However, the origin and formation mechanism of the 5m high mounds, which sit in a thin sandy contourite, have never been clear. A new set of piston cores that sampled two Darwin Mounds from top to base now provides unprecedented insight in the mound initiation and development history, in relation to the regional palaeoceanography and contourite development. Radiocarbon and U-series dating, together with CT-scanning and grainsize analysis established that the first corals started to grow in the early Holocene. Vigorous coral growth was maintained until ca. 8.8ka, after which an increased current regime caused partly reduced growth. From 3-5ka coral growth seems to have been very limited, although live coral can still be found on the mounds today. The pattern is similar to coral records found at the top of large mounds in the region, and tentatively can be linked to variations in regional circulation patterns.

Key words: cold-water corals, sandy contourite, cold-water coral mound, Rockall Trough.

INTRODUCTION

The Darwin Mounds are small cold-water coral mounds, up to 75m across and 5m high, discovered in 1998 in the N Rockall Trough, at ~1000 m water depth. They sit in a thin (10-12cm) sandy contourite, located on the upstream flank of a large sediment drift, which formed as a result of the slow-down of, and consequent sediment deposition by, the lower Shelf Edge Current as it sweeps around the head of Rockall Trough due to the presence of the Wyville-Thomson Ridge.

The origin and formation mechanism of the mounds have been debated for more than a decade. Masson et al (2003) suggested they may be coral-topped sand volcanoes, linking their initiation to fluid (pore water) escape, also observed further downstream in the shape of a field of pockmarks. However, both Wheeler et al. (2008), based on a thorough analysis of mound morphology and bedform patterns, and Huvenne et al. (2009), who studied the sediment characteristics both on- and off-mound, concluded that sediment baffling most probably caused the build-up of the mounds.

So far, none of the mounds had been sampled from top to base, leaving a lack of conclusive evidence, especially about their initial stages. In 2011, during expedition JC060 on board the *RRS James Cook*, two piston cores were obtained from two Darwin Mounds, coring right through the mound base. An Ultra Short Base-Line beacon on the coring equipment, together with high-resolution, AUV-based sidescan sonar maps, ensured precise positioning of the cores.

The detailed study of the cores, presented here, had the following objectives: (1) to identify and date the

process of mound initiation; (2) to understand the coral growth and mound development in relation to the formation of the surrounding sandy contourite; and (3) to place the mound development in the context of the regional palaeoceanography.

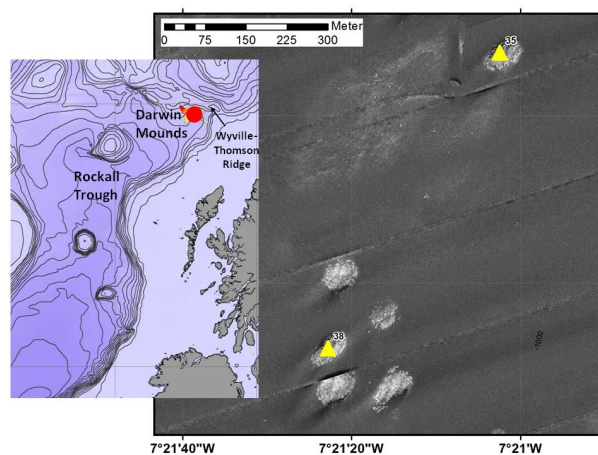


FIGURE 1. Sidescan sonar detail of the two Darwin Mounds cored during JC060. Left: location map of the Darwin Mound area

DATA AND RESULTS

The top 4m of both cores, containing the mound sequence, were imaged using X-ray Computerised Tomography (CT-scanning) at the μ -Vis facility of the University of Southampton. Image analysis was carried out in VG Studio Max and ImageJ, and allowed visualisation of coral content in 3D. Volume % coral was measured, and coral bio-erosion state and species composition were noted. Once imaged, the cores were split in frozen state, and grainsize was analysed at 25cm intervals using a Malvern2000 laser particlesizer. Four

coral fragments were radiocarbon dated by Beta-Analytic Inc. (USA); 10 fragments were dated using U/Th in the LSCE laboratories in Gif sur Yvette.

The moundbase was found at 343cm resp. 285cm depth in the two cores, depths that correspond well with the total height of the mounds as identified from high-resolution AUV bathymetry. The base was characterised by a sharp grainsize change, from silty clay or clayey silt to fine sand. The first coral fragments were found to coincide with this sharp contact in core JC060-035, and occurred 12cm higher in core JC060-038. They were dated at 10.0-10.4 ka, indicating that coral growth, and mound formation, started in the early Holocene. Coral volume % was highest in the first phase following mound initiation (4-14%). Grainsize decreased slightly, compared to the very base of the mounds, probably as a result of current slow-down by the coral framework, supporting the model of mound build-up through baffling. This first phase lasted until ca. 8.8ka, and resulted in 70-90cm of mound build-up, equivalent to a mound growth rate of 58-70cm/ka.

From 8.8ka onwards, grainsize increased slightly, coral volume % decreased (<4%) and mound growth rate reduced to ~40cm/ka. When mound growth rates are extended to the core tops, growth appears to have stopped at ca. 3ka resp. 5ka. However, ROV video surveys and high-resolution sidescan sonar records have shown that live coral colonies are still present on the Darwin Mounds, suggesting that coral growth did not stop at 3-5ka, but instead was strongly reduced.

Bio-erosion rates are variable in both cores, and do not appear correlated to grainsize or coral volume %. The majority of the coral is *Lophelia pertusa*, although in both cores the proportion of *Madrepora oculata* increases towards the top.

DISCUSSION

The analysis of the JC060 cores has shown that the Darwin Mounds are not merely coral-topped sand volcanoes, but that they contain coral fragments/framework throughout, confirming their formation through sediment baffling. Coral growth started in the early Holocene, shortly after the Younger Dryas cold reversal, when the warming climate resulted in increased bottom current speeds, eroding and winnowing the underlying glaciogenic fine-grained sediments. Coral settlement most probably started on winnowed boulders and dropstones. At the same time an increase in surface productivity in the region will have caused increased food input for the corals.

The initial period of intense coral growth and fast mound build-up finished around 8.8ka, when mound growth rates nearly halved. This reduction corresponds to a grainsize increase, a decrease in coral volume % and an increase in *Madrepora oculata*. Although the inverse relation between coral volume and grainsize may be caused by the fact that a denser coral framework slows currents down more, resulting in deposition of finer-

grained sediments, the dominance of *M. oculata* may point to a change in environmental conditions. The smaller polyps of *M. oculata* are less susceptible to the adverse effects of increased or coarser sediment loads, suggesting that an increase in local current regime may have reduced coral growth and mound accumulation.

A similar pattern of coral growth, with (re-)initiation in the early Holocene, intense growth until ca. 8.5ka and reduced growth until ca. 4ka has been observed in other locations in the Rockall Trough and Porcupine Seabight (Frank et al., 2009). Part of this pattern could potentially be linked to changes in dominance of the Sub-Polar Gyre versus the Sub-Tropical Gyre in the area, which affected the hydrodynamical regime and primary productivity in the region.

CONCLUSIONS

For the first time, small cold-water coral mounds set within a sandy contourite have been cored from top to base. CT-scanning, grain-size analysis and dating have given insight in mound initiation and development. Cold-water coral growth in the Darwin Mounds started in the early Holocene, with a first pulse of intense growth. After ca. 8.8ka, growth rates halved, probably as the result of a coarser sediment input and an intenser current regime. By 3-5ka, coral growth became sporadic and patchy, a pattern also observed elsewhere in the region. The results illustrate once again the close interplay between current regime, sediment dynamics and coral growth/mound development.

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