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## Cold-water coral habitats of Rockall and Porcupine Bank, NE Atlantic Ocean: Sedimentary facies and benthic foraminiferal assemblages

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## ABSTRACT

The extent of the cold-water coral mounds in the modern ocean basins has been recently revealed by new state-of-the-art equipment. However, not much is known about their geological extent or development through time. In the facies model presented here seven different types of seabed substrate are distinguished, which may be used for reconstruction of fossil coral habitats. The studied substrates include: off-mound settings, (foram) sands, hardgrounds, dead coral debris, and substrates characterized by a variable density of living coral framework. Whereas sediment characteristics only provide a basis for distinguishing on- and off-mound habitats and the loci of most prolific coral growth, benthic foraminiferal assemblages are the key to identifying different mound substrates in more detail. Specific foraminiferal assemblages are distinguished that are characteristic of these specific environments. Assemblages from off-mound settings are dominated by (attached) epifaunal species such as *Cibicides refulgens* and *Cibicides variabilis*. The attached epibenthic species *Discanomalina coronata* is also common in off-mound sediments, but it is most abundant where hardgrounds have formed. In contrast, the settings with coral debris or living corals attract shallow infaunal species that are associated with more fine-grained soft sediments. The typical 'living coral assemblage' is composed of *Cassidulina obtusa*, *Bulimina marginata*, and *Cassidulina laevigata*. The abundance of these species shows an almost linear increase with the density of the living coral cover. The benthic foraminifera encountered from off-mound to top-mound settings appear to represent a gradient of decreasing current intensity and availability of suspended food particles, and increasing availability of organic matter associated with fine-grained sediment trapped in between coral framework.

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## 1. Introduction

Cold-water coral ecosystems occur widely in all ocean basins. However, only recently advanced acoustic mapping techniques and small submersibles have revealed the spatial extent and richness of these hidden ecosystems (Freiwald et al., 2004; Roberts et al., 2006). Although they do occur globally, the available data suggest that cold-water coral mounds are most prolific along the eastern margin of the Northern Atlantic, extending from Norway to the Gulf of Cadiz (Freiwald et al., 2004; Freiwald and Roberts, 2005; Roberts et al., 2006). Further, the distribution and diversity of cold-water coral mounds has been shown to relate to the carbonate chemistry and the aragonite saturation depth in

particular (Guinotte et al., 2006; Roberts et al., 2006). Their occurrence is also limited to deeper water with temperatures between 4 and 12 °C (Roberts et al., 2006; Rogers, 1999). As light does not penetrate to these depths, cold-water corals do not rely on photosymbionts for energy supply. Instead, these corals depend on filter feeding and are restricted to nutrient-rich zones where currents, mainly related to internal waves, or down welling provide nutrients and reduce sediment deposition (Davies et al., 2009; Freiwald et al., 1997; Kenyon et al., 2003; Rogers, 1999).

On Rockall and Porcupine Bank (Fig. 1) cold-water corals occur in a depth range between 600 and 1000 m. The crests of the mounds, and to a lesser extent the slopes, are covered by the Scleractinian coral species *Lophelia pertusa* and *Madrepora oculata*, which are the main framework builders. The frameworks provide a habitat to a diverse fauna including sponges, hydroids, mollusks, echinoderms, brachiopods, bryozoans, and ascidians. The mounds grow by the accumulation of locally produced skeletal debris and entrapment of settling pelagic material (De Haas et al., 2009;

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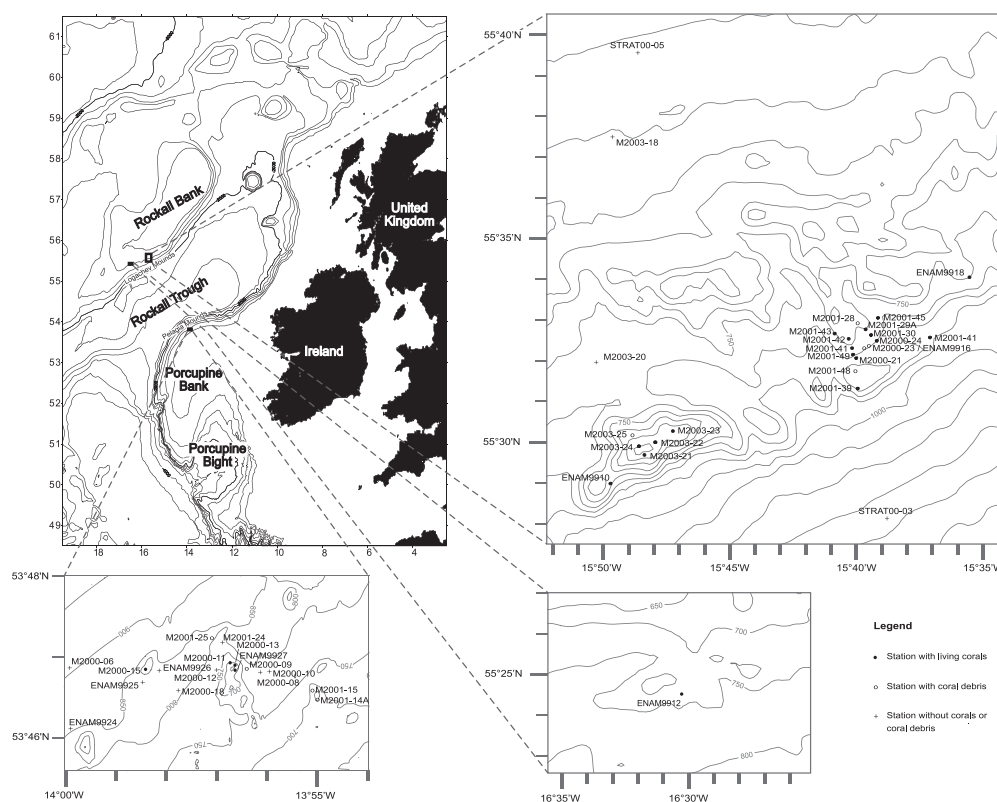


Fig. 1. Map of the Rockall Trough margin with sampling locations indicated. Depth contours are in meters.

Mienis et al., 2009). Coral cover is generally patchy, and open spaces and dead corals are infilled mainly with particles settling from the vertical flux and particles derived from the mounds themselves (Akhmetzhanov et al., 2003; Van Weering et al., 2003). The seabed surrounding coral mounds consists of foraminiferal ooze or relict glacial sediments. The sand is often rippled and at the shallow upper slope of the SW Rockall Trough large sand waves are present (Mienis et al., 2006). In many locations along the NW and SW Rockall Trough margin, the seabed is littered with dropstones, which are often also present at the base of mounds and in intramound areas (Mienis et al., 2006; Wheeler et al., 2007). The glacial dropstone pavement is part of a coarse-grained lag deposit usually only a few cm thick, resting on top of stiff glacial silty clay (Howe et al., 2001). In off-mound areas as well as on mounds, hardgrounds are observed locally. In the present environment dropstones and hardgrounds often provide a suitable substrate for corals to settle.

Presently, in the Rockall Trough area the most favorable conditions for coral growth and buildup of carbonate mounds seem to be found on Rockall Bank. Underwater camera surveys demonstrated that mound crests in this area are densely covered with corals. The mound slopes typically show a more patchy coral cover and much reduced Holocene sedimentation rates. In between the mounds, wide areas are covered with relict glacial sand littered with ice-rafted stones and boulders, indicating a lack of recent sediment deposition. At the loci of most prolific coral production, average Holocene sedimentation rates determined in sediment cores are in the order of  $10 \text{ cm ka}^{-1}$ , and recent sedimentation rates in the order of  $25 \text{ cm ka}^{-1}$  (Mienis et al., 2009; Van der Land et al., 2010). These studies also show, however, that average long-term accumulation rates are an order of magnitude lower, about  $1 \text{ cm ka}^{-1}$ . Evidence from piston cores covering the Holocene and latest Pleistocene suggests that periods of optimum growth may have alternated with periods of non-deposition, erosion and hardground formation. These features

are often attributed to glacial periods, when carbonate production was reduced or absent (Dorschel et al., 2005; Van Weering et al., 2003). The reduced coral growth has been related to a lower supply of organic material and changing currents during glaciation (Rüggeberg et al., 2007). However, it has also been shown that coral growth can be significantly reduced or cease in interglacial periods, which leads to infillment of the coral framework or erosion. These processes have been attributed to changing environmental or oceanographic conditions leading to reduced amounts of organic material reaching the seafloor (Dorschel, 2003; Huvenne et al., 2005). At present there is no general consensus about the causes of reduced mound growth in the Rockall Trough area, and whether these occurred randomly through time or were related to distinct climatic stages.

Benthic foraminiferal assemblages are sensitive recorders of environmental conditions (Jorissen et al., 2007 and references therein) and they possess a carbonate shell, or a test, that readily fossilizes. Therefore, they are commonly applied in paleoceanographic studies to reconstruct past environmental conditions. Recent work on benthic foraminiferal assemblages from coral mounds has demonstrated their potential in identifying various carbonate mound settings (Hawkes and Scott, 2005; Margreth et al., 2011, 2009; Morigi et al., 2012; Schönfeld et al., 2011). For example, dead coral facies have been shown to be characterized by epifaunal species, including *Planulina ariminensis*, *Hanzawaia boueana*, and infaunal species, like *Spiroplectinella wrightii*, *Angulogerina angulosa* and *Epistominella vitrea*. In contrast, the living coral facies seem to be dominated by the epifaunal *Discanomalina coronata* (Margreth et al., 2009), which has been suggested to be an endemic to this facies. Furthermore, marker species, such as *Discanomalina semipunctata*, which can attach to coral and are not commonly found on the continental margin in non-coral areas and may provide in situ evidence of past coral habitat (Hawkes and Scott, 2005). The previous work on benthic foraminifera from the coral mounds thus suggests that changes in species composition

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