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From sediment to rock: diagenetic processes of hardground formation in deep-water carbonate mounds of the NE Atlantic

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Modern cool-water carbonate mounds topped by corals form an extended reef belt along the NW European continental margin at 200-1200 m water depth. The basic element of the start-up stage of mound growth are hardgrounds in that they provide a stable substratum for mound-building invertebrate colonisation and stabilise the steeply inclined mound flanks in current-influenced continental slope settings. Evaluating the degree of lithification and the slope stability against erosion represents an important task within the EU program EUROMARGINS. Sampling of hardgrounds during Meteor cruise M61-3 in summer 2004 by means of the Bremen QUEST ROV focused on carbonate mounds of the Porcupine Seabight and northwestern Rockall Bank off the British Isles.

Bedded lithified carbonates of mid-Pleistocene age forming hardgrounds on top and flanks of numerous carbonate mounds are colonised by living corals and associated invertebrates. The sediments are composed of foraminiferal-nannoplankton oozes and admixed mound-derived invertebrate skeletons, now lithified to highly porous chalks or dense wackestones to packstones respectively. These facies clearly differ from bacterially induced authigenic carbonate crusts typical of hydrocarbon seep settings by showing current-induced sedimentary structures and by a marine isotopic signature lacking any depleted carbon regime which is typical of anaerobic methane oxidation.

Hardground formation includes the following steps on sea floor and in subsurface:

1. Sedimentation (sea floor stage I): accumulation of pelagic foraminiferal-nannoplankton oozes and benthic invertebrate debris predominantly composed of corals, echinoderms and molluscs;

2. Early cementation: precipitation of calcitic isopachous-fibrous rim cements in foraminiferal molds (sea floor to shallow subsurface);

3. Compaction: physical compaction of sediments by increasing overburden pressure resulting in water escape and eventually in crushing of invertebrate skeletons (shallow to deeper subsurface);

4. Cementation: precipitation of micritic to microsparitic calcite cements growing on coccoliths and invertebrate skeletons which produced a fitted fabric with strongly reduced porosity; this process turned the poorly lithified sediment into a lithified rock (deeper subsurface);

5. Neomorphism: partial replacement of metastable aragonitic corals and high-magnesium calcitic echinoderm fragments by stable low-magnesium calcitic microspar; this mineralogical stabilisation commonly extended from the skeletal grains into a magnesium-enriched groundmass, overprinting the grain boundaries (deeper subsurface);

6. Final steps of hardground formation (sea floor stage II):

a) current-induced exhumation of the buried lithified carbonates; **b)** intensive boring by micro- and macroorganisms and trapping of Holocene hemipelagic sediments in large sponge borings; **c)** Fe/Mn impregnation of exposed mound surfaces; **d)** biogenic encrustation of the lithified hardgrounds.

These results provide evidence that similar end-products of the lithified carbonates which vary in compositional and mineralogical structure depending on environmental and diagenetic conditions of the sampling sites may indicate a uniform mechanism of hardground formation in the Porcupine and Rockall areas. Physico-chemical processes such as circulation and chemistry of pore fluids seem to be the major controls on carbonate lithification and hardground formation in this part of the NW European continental margin.