Some reflections on mounds and water masses: a tentative typology of the North Atlantic Mound Basin

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The Atlantic Ocean, and in particular the North Atlantic, features a unique concentration of provinces of giant cold-water coral mounds. On the North American margin, where surface waters reach depths, greater than on the European margin, the mounds of the Florida-Hatteras slope and Blake Plateau occur in depth from 440 m to 1300 m and are fully bathed by the Florida current. The larger mounds occur in the lower interval of this surface water layer, between 1000 and 1300 m. On the north-west European margin, west of Ireland, the mound provinces in Porcupine Seabight range in depth from 750 to 1050 m and are bathed by Mediterranean Outflow Water (MOW), which grades upward into Eastern North Atlantic Water (ENAW) at a depth between 800 to 700 m. Strong internal waves guided by the permanent thermocline have been reported and modelled in the depth interval of the mounds, which also coincides with an oxygen minimum zone. In Rockall Trough, cold-water coral mounds occur in a depth range of 600 to 1000 m, within the lower interval of warm and saline ENAW, overlaying the cooler Labrador Sea Water (LSW) at some 1200 m. Rockall Channel and the Faeroe-Shetland Channel are sites of intense mid-slope resuspension by internal waves. On the north-west African margin, the carbonate mounds on the Pen Duick Escarpment off Larache occur in water depths of 530 to 580 m, in North Atlantic Central Water (NACW) containing several nepheloid layers, and overlying Antarctic Intermediate Water (AAIW) found at a depth of 600 m. Further south, an elongated carbonate mound range occurs in Mauritanian waters at depths of 450 to 550 m, over a linear extent of at least 190 km. Warm and saline Tropical Surface Water (TSW) overlays low salinity South Atlantic Central Water (SACW) down to 600 m, where a sharp halocline marks the boundary with fresher AAIW. The SACW forms an oxygen minimum layer and is the nutrient-rich source of upwelling water in the region.

In the South Atlantic, cold-water coral ecosystems and elongated patches of deep-water coral mounds have been reported on the slopes of the Campos Basin, off Brasil, clustering between 570 m and 800 to 850 m within the upper horizons of the AAIW, right below the South Atlantic Central Water (SACW). On the Patagonian slope off Argentina, cold-water coral mounds occur mainly between 400 and 1000 m depth, in the basal horizons of the AAIW which flows in northward direction over the Upper Circumpolar Deep Water (UCDW).

The intensive charting of continental margins worldwide makes it unlikely that major recent, outcropping cold-water coral mound provinces would have remained unspotted today in other oceans. The virtual absence of large cold-water coral mound provinces in the Pacific and other parts of the global ocean can be primarily explained by a (negative) chemical control on the mound-builders. Most scleractinian corals build their skeletons of aragonite, a metastable form of calcium carbonate that dissolves at shallower depths than calcite. The base of the saturated

water mass in which scleractinian mound building corals (*Lophelia pertusa*, *Madrepora oculata*, etc.) can thrive is given by the aragonite saturation horizon (ASH). So, the majority of large-scaled cold-water coral mound provinces plots in the seabed areas characterized by a deep aragonite saturation horizon (1000-2000 m or more). Such deep aragonite saturation horizons are especially present in the (North) Atlantic.

The building of large provinces of giant mounds however implies an exceptional (positive) control, capable of enhancing the flux of nutrients.

In the absence of photosynthesis, substantial fluxes of nutrients are simply crucial for feeding deep-water carbonate factories. What makes the Atlantic unique is a highly dynamic stratified structure. The mound provinces in the North Atlantic Mound Basin (NAMB) literally girdle subtropical gyres and cluster either right above the present-day base of the warm upper water masses, or just below. The already dynamically stratified Atlantic basin is further stirred by oscillations at various frequencies. At the pace of the glacial-interglacial rhythm, shifts of polar fronts force north-south displacements of cold nutrient-rich intermediate waters and surface productivity. These shifts stimulate coral growth on the European margins in interglacial times, and on the African margins in the arid times that coincide with glacial conditions further north. Furthermore, at the pace of the North Atlantic Oscillations, the upwelling on the north-west African margin can be significantly enhanced (NAO+ phases).

Summarizing, and keeping in mind that large deep-water carbonate mounds in the Atlantic may well have been born over 2.5 My ago, as evidenced by IODP Exp. 307, in a water mass architecture differing from the present one, a general observation today is that the deep carbonate mound provinces seem to closely fringe the roof of the intermediate to deep water masses of the present, dynamically stratified ocean. On the east Atlantic margin, they thrive in the nutrient-rich, low-oxygen horizons either just above or just below the base of the surface circulation layer, in the beat zone of internal waves guided along an interface with significant density contrast (Porcupine-Rockall basins) or in zones of upwelling: the vast and heterogeneous Eastern Boundary Upwelling System stretches along the Atlantic margin from the northern tip of Iberia at 43°N to south of Dakar at about 10°N.

Seen from an energy sourcing and energy processing perspective, the Recent ocean’s carbonate world hence essentially splits in two boundary layers, one at the top and one at the interface of ocean water masses. The upper carbonate world directly thrives on light as a main source of energy: it is the domain of the Photozoan carbonates, confined by water depth and the penetration of light. However, heterozoan mound-builder guilds in intermediate water masses directly forage on fluxes of nutrients, which percolate from the photic zone as pelagic rain, and/or get generated by in situ benthic processes, and/or raise from the lower compartment through deep-sourced upwelling. While the occurrence of cold-water coral mounds appears to be frequently coupled to a major interface between water masses, it is not confined in accommodation space: deep water mounds can grow in a virtually unconstrained way, to the dimension of giants. Yet, the subtle functioning of the working parts that underpins the performance of the mound engine remains to be elucidated’.