

Seawater density reconstruction of intermediate waters along the European continental margin

Andres Rüggeberg^{1,2,3}, Sascha Flögel², Jacek Raddatz² and Christian Dullo³

- 1 Dept. of Geology and Soil Sciences, Ghent University, B-9000 Gent, Belgium. Andres.Ruggeberg@UGent.be
- 2 GEOMAR Helmholtz Centre for Ocean Research Kiel, D-24148 Kiel, Germany. arueggeberg@geomar.de, sfloegel@geomar.de, jraddatz@geomar.de, cdullo@geomar.de
- 3 Present address: Dept. of Geosciences, University of Fribourg, CH-1700 Fribourg, Switzerland. andres.rueggeberg@unifr.ch

Abstract: *The reconstruction of past ocean seawater densities can be helpful to understand benthic hydrodynamics and ecological processes important for ecosystems such as the cold-water coral (CWC) reefs along the European continental margin. DFG-project INWADE (Cold-Water Coral Mound Development Related to INtermediate WATER Density Gradient) concentrates on the observation that the density of seawater is an important environmental factor for the Northeast Atlantic coral reefs. For three transects at 37°N, 51°N and 65°N across the European continental slope, the Recent distribution of temperature, salinity and seawater density is compared to modelled distribution during the Last Glacial Maximum. Geochemically reconstructed temperature and seawater density data from benthic foraminifera in sediment cores validate the modelled data (or vice versa) and raise the possibility to reconstruct seawater densities for the Pleistocene period.*

Key words: *cold-water coral reefs, carbonate mounds, environmental control, seawater density.*

INTRODUCTION

Recent studies underline the environmental control like temperature, salinity, current intensity, food supply, sedimentation rate, or substrate on the growth and development of cold-water coral (CWC) reefs along the European continental margin (e.g., Freiwald, 2002; Rüggeberg et al., 2007). The density of seawater, a function of temperature, salinity and pressure, is also reported to be an environmental prerequisite for the NE Atlantic CWC reefs (Dullo et al., 2008). At the density range of 27.35–27.65 kg·m⁻³, which is coherent with the position and stability of the thermocline for the Porcupine Seabight and Rockall Bank carbonate mounds (White and Dorschel, 2010), stable and favourable environmental conditions occur even over longer time scales. These conditions involve a constant food supply by continuous or tidally controlled currents allowing CWCs to create large reef ecosystems and to form giant carbonate mounds of up to 300m high.

DFG-project INWADE implements and utilises two different approaches: 1) the possibility to reconstruct palaeo-densities (Lynch-Stieglitz et al., 1999) and palaeo-temperatures (Marchitto et al., 2014) from stable oxygen isotope data of benthic foraminifera, and 2) using modelled temperature and salinity data from PMIP 2 HadCM3M2 to calculate seawater densities. Both approaches give us the opportunity to determine past environmental water mass characteristics, which we compare to the recent setting and interpret in relation to CWC growth and carbonate mound development.

RESULTS AND DISCUSSION

At three transects along 37°N, 51°N and 65°N (Fig. 1) intermediate water masses with warmer temperatures

and higher salinities occur on the shelves and at the slopes compared to the open water settings (Fig. 2). The corresponding seawater density also shows a deepening structure towards the European continental margin, with values around 27.5 kg·m⁻³ at depths where CWC are reported along the Norwegian (65°N) and Irish (51°N) margins.

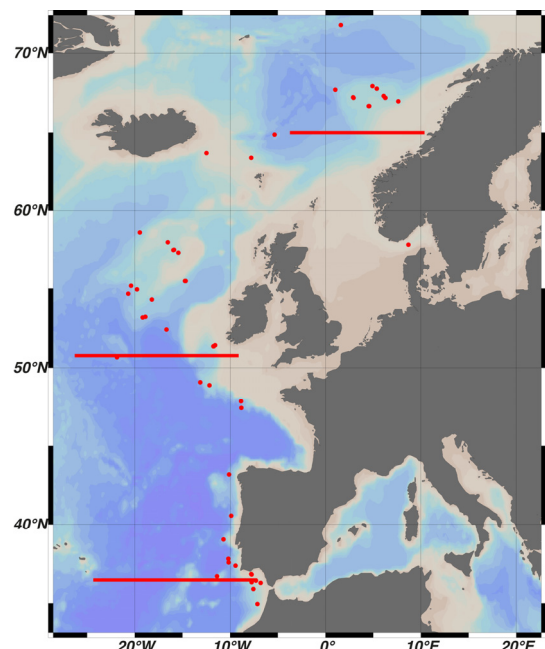


FIGURE 1. Location of oceanographic transects across the European continental margin and sediment core data collected for the data base.

The CWC carbonate mounds in the Gulf of Cadiz are situated at 500 to 700m water depth. Recently, a deeper chain of fossil CWC mounds at 800–900m water depth has been discovered (Henriet, pers. comm.). The mounds occur in less dense waters compared to their

northern occurrences. AMS ¹⁴C or U/Th dates of coral fragments indicate growth during glacial phases (Wienberg et al., 2010). For the Last Glacial Maximum the 27.5–pycnocline is located at 200m (65°N), < 500m (51°N) and 600–700m water depth for the Gulf of Cadiz region (37°N, see Fig. 2).

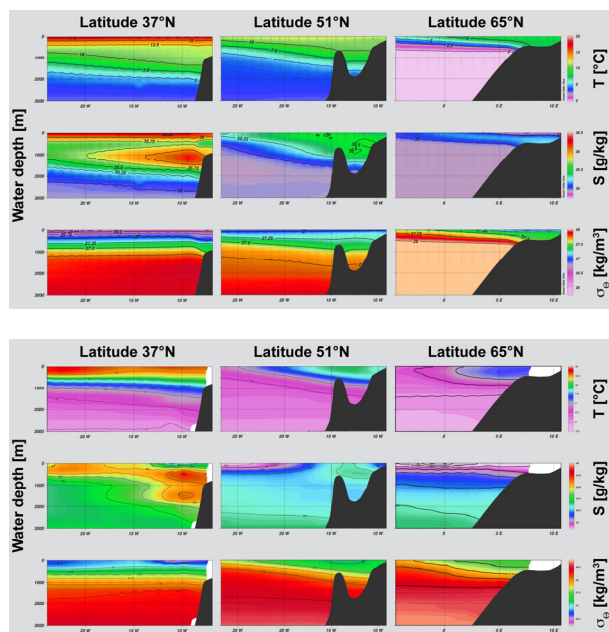


FIGURE 2. Recent (top) and LGM (bottom) temperature, salinity and density (σ_{θ}) distribution along 37°N, 51°N, and 65°N (see Fig. 1). Annual mean data from World Ocean Atlas 2009 (Locarnini et al., 2010; Antonov et al., 2010) and from 21k-OAV-PMIP2 experiment using HadCM3M2 model (Braconnot et al., 2007).

The distribution of living coral reef structures follows the hydrography of intermediate water masses with σ_{θ} as an important parameter. Where σ_{θ} of $27.5 \pm 0.15 \text{ kg.m}^{-3}$ hits the slope of the continental margin (Fig. 2) cold-water coral reefs may occur when substrates to settle and supply of nutrition is sufficiently available. This occurs not only in the Northeast Atlantic but is more and more reported from other areas in the Atlantic Ocean (e.g., Brazil, Argentina, Greenland).

During glacial times modelled data indicate a general freshening and cooling of water masses resulting in slightly heavier σ_{θ} values. This is coherent with calculated σ_{θ} values of benthic foraminifera $\delta^{18}\text{O}$ from off-mound or drift deposits around the carbonate mounds (Tab. 1).

OUTLOOK

Downcore records of environmental parameters like temperature and seawater density in carbonate mound and off-mound or drift deposit sequences will provide further evidence if seawater density can be reliably reconstructed through the Pleistocene and whether variations in this parameter controls coral reef and carbonate mound development.

		Recent / Holocene		Last Glacial Maximum	
		measured	calc. ¹	model	calc. ²
65°N	T [°C]	7.24	7.6	6.5	5.63

(300m)	σ_{θ} [kg.m ⁻³]	27.58	27.41	27.51	27.68
51°N (800m)	T [°C]	9.6	10.0	4.9	4.1
	σ_{θ} [kg.m ⁻³]	27.43	27.37	27.85	28.07
37°N (600m)	T [°C]	10.9	10.2	10.1	9.96
	σ_{θ} [kg.m ⁻³]	27.25	27.05	27.56	27.61

TABLE 1. Comparison of measured, modelled and calculated temperatures and seawater densities.

¹Calculations based on Recent $\delta^{18}\text{O}_{\text{OC}}$ and $\delta^{18}\text{O}_{\text{SW}}$ values of 1.8 and 0.25 ‰ at 65°N, 1.5 and 0.5 ‰ at 51°N, and 1.4 and 0.42 ‰ at 37°N, respectively.

²Calculations based on LGM $\delta^{18}\text{O}_{\text{OC}}$ and $\delta^{18}\text{O}_{\text{SW}}$ values of 3 and 1 ‰ at 65°N, 3.6 and 1.25 ‰ at 51°N, and 2.2 and 1.17 ‰ at 37°N, respectively.

ACKNOWLEDGEMENTS

We thank Deutsche Forschungsgemeinschaft for funding DFG project INWADE (Du 129/48-1) and ESF and FWO for their support to the COCARDE network.

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