

1 **Cold-water coral mounds in the southern Alboran Sea (western Mediterranean**  
2 **Sea): Internal waves as an important driver for mound formation since the last**  
3 **deglaciation**

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13

14 **Abstract**

15 Cold-water corals (CWCs) are widely distributed in the entire Alboran Sea (western Mediterranean Sea), but only  
16 along the Moroccan margin they have formed numerous coral mounds, which are constrained to the West and  
17 the East Melilla CWC mound provinces (WMCP and EMCP). While information already exists about the most  
18 recent development of the coral mounds in the EMCP, the temporal evolution of the mounds in the WMCP was  
19 unknown up to the present. In this study, we present for the first time CWC ages obtained from four sediment  
20 cores collected from different mounds of the WMCP, which allowed to decipher their development since the last  
21 deglaciation. Our results revealed two pronounced periods of coral mound formation. The average mound  
22 aggradation rates were of 75-176 cm kyr<sup>-1</sup> during the Bølling-Allerød interstadial and the Early Holocene, only  
23 temporarily interrupted during the Younger Dryas, when aggradation rates decreased to <45 cm kyr<sup>-1</sup>. Since the  
24 Mid Holocene, mound formation significantly slowed-down and finally stagnated until today. No living CWCs  
25 thrive at present on the mounds and some mounds became even buried. The observed temporal pattern in  
26 mound formation coincides with distinct palaeoceanographic changes that significantly influenced the local

27 environment. Within the Alboran Sea, enhanced surface ocean productivity and seabed hydrodynamics prevailed  
28 during the Bølling-Allerød and the Early Holocene. Only with the onset of the Mid Holocene, the area turned into  
29 an oligotrophic setting. The strong hydrodynamics during the mound formation periods are most likely caused  
30 by internal waves that developed along the water mass interface between the Modified Atlantic Water and the  
31 Levantine Intermediate Water. In analogue to observations from modern CWC settings, we assume that internal  
32 waves created turbulent hydrodynamic conditions that increased the lateral delivery of particulate material,  
33 promoting the availability of food for the sessile CWCs. Overall, our data point to the dominant role of the water  
34 column structure in controlling the proliferation of CWCs and hence the development of coral mounds in the  
35 southern Alboran Sea.

36

37 **Keywords:** Cold-water coral mounds, coral mound formation, mound aggradation rate, last deglaciation, internal  
38 waves, Levantine Intermediate Water, Alboran Sea

39

40 Highlights:

- 41 1. Coral mounds formation in southern Alboran Sea reinitiated since the onset of B/A interstadial.
- 42 2. Coral mound aggradation rate reached up to 704 cm kyr<sup>-1</sup>.
- 43 3. Internal waves play a dominant role in controlling mound formation.
- 44 4. Coral mound formation stagnated since the Late Holocene.

45

## 46 1. Introduction

47 Scleractinian framework-forming cold-water corals (CWCs) show a world-wide distribution and form  
48 important deep-sea ecosystems providing habitats for numerous marine organisms (e.g., Henry and  
49 Roberts, 2007; Roberts et al., 2009). The most prominent species *Lophelia pertusa* and *Madrepora*  
50 *oculata* tolerate a wide range of physico-chemical conditions in the ocean, with temperature, salinity,  
51 dissolved oxygen concentrations, pH, aragonite saturation, and water mass density being the most  
52 important properties of the surrounding water masses that influence their occurrence (e.g. Freiwald  
53 et al., 2002; Davies et al., 2008; Dullo et al., 2008; Davies and Guinotte, 2011; Flögel et al., 2014;  
54 Büscher et al., 2017). However, the proliferation of CWCs is even more controlled by the availability of  
55 sufficient food (phytoplankton, zooplankton, particulate organic material), which is steered by  
56 enhanced surface productivity and/or the local hydrodynamic regime (including geostrophic currents,  
57 internal tides and waves, cascading and down-welling processes), providing periodic to constant  
58 delivery of sufficient food particles (White et al., 2005; Mienis et al., 2007; Duineveld et al., 2007;  
59 Davies et al., 2009; Duineveld et al., 2012; Taviani et al., 2016).

60 Over geological timescales, the sustainable growth of CWCs can shape the seabed topography along  
61 the continental margins by forming three-dimensional structures, named coral mounds (Roberts et al.,  
62 2009; Wienberg and Titschack, 2017; Lo Iacono et al., 2018). In the Atlantic, coral mounds are usually  
63 found at water depths between 200 and 1000 m and are often arranged as clusters or coral mound  
64 provinces consisting of hundreds to thousands of mounds (e.g. De Mol et al., 2002; Fosså et al., 2005;  
65 De Haas et al., 2009; Correa et al., 2012; Glogowski et al., 2015; Vandorpe et al., 2017; Hebbeln et al.,  
66 2019). Individual mounds have oval to elongated shapes, and appear as ridge-like structures, which  
67 extend over hundreds to thousands of metres (Wheeler et al., 2007). The height of individual mounds  
68 varies from a few to hundreds of metres (e.g., Van Weering et al., 2003; Mienis et al., 2007; Wheeler  
69 et al., 2007; Collart et al., 2018).

70 Although food delivery plays a crucial role in the proliferation of CWCs, the formation of coral mounds  
71 is even more sensitive to the complex interplay between the sustained growth of CWC, their baffling  
72 capacity and sediment supply that eventually result in the formation of coral mounds (Wheeler et al.,  
73 2005; Huvenne et al., 2009; Mienis et al., 2009; Titschack et al., 2015; Titschack et al., 2016; Victorero  
74 et al., 2016). Consequently, coral mounds consist of coral frameworks and fragments, remains of coral  
75 associated fauna, and hemipelagic sediments. Their development can last from thousands to even  
76 millions of years (e.g., Kano et al., 2007; Frank et al., 2011; Raddatz et al., 2014). Therefore, the coral  
77 mounds provide unique archives to reconstruct the palaeoceanographic constraints during their  
78 formation as well as the development of CWC populations in relation to changing environments.

79 Studies from various coral mound provinces in the NE Atlantic revealed distinct temporal patterns of  
80 mound formation which appear to be closely related to climate changes, such as those induced by  
81 glacial-interglacial variability (e.g., Kano et al., 2007; Frank et al., 2011). On a regional scale, mound  
82 formation is controlled by strong near-bottom hydrodynamics and enhanced paleo-productivity  
83 (Dorschel et al., 2005; Rüggeberg et al., 2007; Wienberg et al., 2010; Eisele et al., 2011; Matos et al.,  
84 2015), while low dissolved oxygen concentrations might hinder the development of coral mounds  
85 (Wienberg et al., 2018). Moreover, the water column structure and water mass circulation at  
86 intermediate water depths seem to play an important role in stimulating or suppressing the formation  
87 of coral mounds (White and Dorschel, 2010; Raddatz et al., 2014; Matos et al., 2017; Wienberg et al.,  
88 2018). Nevertheless, our knowledge about environmental parameters and their complex interplay  
89 controlling coral mound formation is still limited.

90 In the Mediterranean Sea, coral mounds are mainly found along the Moroccan margin, in the southern  
91 Alboran Sea, where they are constrained to two coral mound provinces 35 km northwest and 15 km  
92 northeast of the Spanish enclave Melilla (Cape Tres Forcas; Fig. 1). Within the West Melilla CWC mound  
93 province (WMCP), more than 100 oval to elongated coral mounds occur in two clusters at water depths  
94 of 300-430 m (Fig. 1; Lo Iacono et al., 2014). They have diameters of 50-476 m, and arise 8-21 m above  
95 the seafloor. In addition, few isolated circular coral mounds with heights of 10-35 m were found in

96 water depths of 450-590 m (Fig. 1). Today, no living CWCs are observed on the mounds of the WMCP,  
97 and some of the mounds are partly buried (Lo Iacono et al., 2014). The East Melilla CWC mound  
98 province (EMCP) displays different morphologies and dimensions of mounds. In the north, three very  
99 steep ridges occur at water depths of 250-450 m, which have heights of 50-150 m and stretch from 3  
100 km to almost 20 km in length (Brittlestar ridges I, II and III; Hebbeln, 2019). To the south, more than 40  
101 oval to arcuate coral mounds (height: 20-40 m) and partly buried elongated ridges (height: 10 m) occur  
102 at water depths of 200-300 m (Comas et al., 2009; Hebbeln, 2019). Spotted colonies of living CWCs  
103 have been observed on the Brittlestar ridges and on some of the smaller mounds, displaying a rather  
104 sparse distribution (Hebbeln et al., 2009; Fink et al., 2013).

105 Recent studies provided some first information on the temporal development of the CWCs and coral  
106 mounds in the EMCP during the past 14 kyr. CWCs experienced marked proliferation during the late  
107 Bølling-Allerød (B/A) interstadial and the Early Holocene, associated with high mound aggradation  
108 rates (ARs) of 140-420 cm kyr<sup>-1</sup> (Fink et al., 2013; Stalder et al., 2015). These two periods of pronounced  
109 mound formation contrast with a period of nearly stagnation, coinciding with the Younger Dryas (YD),  
110 when ARs decreased to 30-50 cm kyr<sup>-1</sup>. Since the late Early Holocene, CWC growth was reduced and  
111 coral mound formation significantly slowed down until present (Fink et al., 2013; Stalder et al., 2015).  
112 Overall, it is assumed that coral mound formation in the EMCP is controlled by a variable set of  
113 environmental parameters such as sea surface and export productivity, strong hydrodynamics, and  
114 bottom water oxygenation, which in turn seem to be steered by changes in the water column structure  
115 (Fink et al., 2013; Stalder et al., 2015). So far, nothing is known about the timing of CWC growth and  
116 coral mound formation in the WMCP. Based on seismic data, it is assumed that a simultaneous initial  
117 CWC colonisation took place in the WMCP and that some of the mounds became buried concurrent to  
118 the effects of sea-level rise that likely induced changes in near-bottom hydrodynamics and  
119 sedimentation rates on the slope (Lo Iacono et al., 2014). However, no temporal framework for the  
120 evolution of the coral mounds in the WMCP has been established so far, mainly due to the lack of  
121 sediment cores collected in this region.

122 The main aims of this study are therefore (i) to reconstruct the temporal development of coral mounds  
123 in the WMCP, and (ii) to relate the derived temporal patterns in mound formation to changes in the  
124 regional environmental setting. For this purpose, coral-bearing (on-mound) cores were collected from  
125 different coral mounds in the WMCP, and complemented by one off-mound sediment core (barren of  
126 any coral fragments) retrieved close to the studied mounds. The on-mound cores were described and  
127 dated to elucidate the local coral mound formation pattern, while the off-mound core was used for  
128 multi-proxy analyses to assess the (palaeo-) environmental controls on mound development.  
129 Furthermore, we evaluated any differences in mound evolution between the WMCP and the EMCP,  
130 and addressed the decisive role of water mass circulation, in particular distinct processes at water mass  
131 boundaries, as a crucial local factor driving the development of coral mounds in the southern Alboran  
132 Sea.

133

## 134 **2. Regional Setting**

135 The Alboran Sea is located at the westernmost part of the Mediterranean Sea, and is connected to the  
136 Atlantic Ocean through the Gibraltar Strait (Fig. 1). The oceanography of the Alboran Sea is  
137 characterized by three different water masses, the Modified Atlantic Water (MAW), the Levantine  
138 Intermediate Water (LIW) and the Western Mediterranean Deep Water (WMDW). The MAW, formed  
139 by the mixing of Atlantic Water and the surface waters of Alboran Sea (Millot and Taupier-Letage,  
140 2005), flows at the surface down to 150-200 m water depth (Millot, 1999). Within the Alboran Sea, the  
141 MAW forms two anti-cyclonic gyres, the quasi-permanent West and the variable East Alboran Gyres  
142 (WAG and EAG; Fig. 1), which have diameters of 100 km and reach down to 200-300 m water depth  
143 (Heburn and La Violette, 1990). Their intensity is closely related to the strength of the Atlantic Water  
144 inflow (Heburn and La Violette, 1990; Vargas-Yáñez et al., 2002). The LIW, which originates in the  
145 eastern Mediterranean Sea, flows westward beneath the MAW at depths between 200 m and 600 m.  
146 The core of the LIW is found at around 400 m water depth in the Alboran Sea indicated by the salinity  
147 maximum (Millot, 2009). Its thickness decreases gradually from the European to the African

148 continental margin (Brankart and Pinardi, 2001; Fabres et al., 2002). The WMDW is formed in the Gulf  
149 of Lions, and spreads into the Balearic Sea and further into the Alboran Sea, where it flows westward  
150 underneath the LIW, at water depths of >600 m (Millot, 1999).

151 The Alboran Sea is the area with the highest productivity within the overall oligotrophic Mediterranean  
152 Sea (Morán and Estrada, 2001; D'Ortenzio and Ribera d'Alcalà, 2009;). The increased productivity is  
153 driven by locally restricted upwelling that occurs along the edge of the WAG and at the eastern limb  
154 of the EAG (Sarhan et al., 2000; Baldacci et al., 2001). The siliciclastic sediment fraction in the Alboran  
155 Sea is a mixture of aeolian dust, which is transported northward from the Sahara (Stuut et al., 2009),  
156 and fluvial input, which mainly derives from the Iberian Peninsula (Fabres et al., 2002). The only larger  
157 river along the Moroccan coast is the Moulouya River, which enters the Alboran Sea 50 km east of the  
158 EMCP.

159

### 160 **3. Material and Methods**

161 Within this study, four “on-mound” gravity cores retrieved from coral mounds of the WMCP and one  
162 “off-mound” gravity core collected from the adjacent seafloor were analysed (Fig. 1; Table 1). The two  
163 on-mound cores MD13-3451G and MD13-3452G were collected in 2013 during the MD194 “Gateway”  
164 Eurofleets Cruise onboard the RV Marion Dufresne (Van Rooij et al., 2013). The other two on-mound  
165 cores GeoB18127-1 and GeoB18130-1, and the off-mound core GeoB18131-1 were collected in 2014  
166 during the MSM-36 “MoccoMebo” cruise on board the RV Maria S. Merian (Hebbeln et al., 2015). The  
167 on-mound cores have recovery lengths between 148 cm and 563 cm, and the off-mound core has a  
168 recovery length of 851 cm (Table 1).

169 The four on-mound cores were frozen for 24 hours to -20 °C before cutting them lengthwise with a  
170 diamond saw to secure that the sediment, consisting of coral fragments embedded in hemi-pelagic  
171 sediment, is kept intact during the opening process. The cores were described, and coral fragments  
172 were sampled at various core depths for absolute dating.

173 The off-mound core GeoB18131-1 was split in a conventional way into working and archive halves and  
174 was used for palaeoceanographic multi-proxy analyses.

175

### 176 **3.1 On-mound core analyses**

#### 177 **3.1.1 Sedimentological core description**

178 Cores MD13-3451G and MD13-3452G were visually described to provide (qualitative, 2D) information  
179 on variations in coral content and clast size throughout the cores. The coral content was estimated  
180 based on its coverage on the cutting surface (unit: surface (surf.) %) of the core halves, and changes in  
181 CWC clast size were described (see Fig. S1 in Supplementary Material).

182 In contrast, the core description provided for cores GeoB18127-1 and GeoB18130-1, is based on the  
183 analyses of computer tomography (CT) scan data. These analyses were further used to define CWC  
184 preservation pattern (CPP) by quantifying coral clast size and orientation (see Table S1 in  
185 Supplementary Material) in close accordance to a CPP classification introduced by Titschack et al.  
186 (2015).

187

188 The CT scans were performed by using Toshiba Aquilion 64 computer tomography at the hospital  
189 Klinikum Bremen-Mitte (Bremen, Germany). The X-ray source voltage was 120 kV and the current was  
190 600 mA. Images were reconstructed based on the Toshiba patented helical cone beam reconstruction  
191 technique. The CT scan resolution was 0.35 mm in x-y and 0.5 mm in z direction (0.3 mm reconstruction  
192 interval). The CT data were processed with the Zuse Institute Berlin edition of Amira software (version  
193 2015.37; Stalling et al., 2005; <http://amira.zib.de>), following the method described in Titschack et al.  
194 (2015) with only minor modification (for further processing details, see Supplementary Material).

195

#### 196 **3.1.2 Radiocarbon and Uranium-series dating**

197 A total of 38 fragments of *L. pertusa* and *M. oculata* were sampled from the four on-mound cores at  
198 various depths and used for dating. Prior to the analyses, all coral fragments were cleaned



199 mechanically to remove cortical corrosion, bioerosion holes, and adhering detritus from the coral  
200 skeletons.

201 Twelve coral samples collected from cores MD13-3451G and MD13-3452G, were dated by accelerator  
202 mass spectrometry (AMS) radiocarbon ( $^{14}\text{C}$ ) age determination. Prior to the measurement, the coral  
203 fragments were chemically cleaned with hydrogen peroxide. The measurements were conducted at  
204 the Poznan Radiocarbon Laboratory, Poznan, Poland. All the obtained ages were corrected for  $^{13}\text{C}$  and  
205 a mean ocean reservoir age of 400 years. The AMS  $^{14}\text{C}$  ages were converted to calendar years using  
206 the MARINE13 curve (Reimer et al., 2013) of the web-based CALIB 7.10 software (Stuiver and Reimer,  
207 1993; <http://calib.org/calib/calib.html>) and reported as kiloyears before present (kyr BP, Present=AD  
208 1950; Table 2).

209 Twenty-six coral samples from cores GeoB18127-1 and GeoB18130-1 were collected for Uranium-  
210 series dating. Before the analyses, coral fragments were cleaned mechanically according to a  
211 procedure described by Frank et al., (2004). The U-series isotope measurements were performed on a  
212 ThermoFisher iCAP-Qs inductively coupled plasma mass spectrometer (ICP-MS) at the Institute of  
213 Environmental Physics, at the Heidelberg University (IUP), Germany. The reproducibility was assessed  
214 using the international uranium standard material HU1 (Cheng et al., 2000; Frank et al., 2004; Wefing  
215 et al., 2017). U-series coral ages are reported as kyr BP (Table 3). Finally, all coral mound ARs were  
216 calculated based on the linear interpolation between the dated depths of each core (Tables. 2, 3).

217

## 218 **3.2 Off-mound core analyses**

### 219 **3.2.1 Radiocarbon dating**

220 The chronostratigraphy of the off-mound core GeoB18131-1 is based on six AMS  $^{14}\text{C}$  dates. Therefore,  
221 around 8 mg of calcium carbonate of mixed planktonic foraminifers of the size fraction  $>150\ \mu\text{m}$  were  
222 analysed at the Poznan Radiocarbon Laboratory, Poznan, Poland. The obtained ages were corrected as  
223 described above (Table 4).

224

### 225 **3.2.2 Stable oxygen and carbon isotope analyses**

226 For stable oxygen ( $\delta^{18}\text{O}$ ) and carbon ( $\delta^{13}\text{C}$ ) isotope measurements, the core was sampled at a 5 cm  
227 resolution. Each sample was wet-sieved and the  $>150\ \mu\text{m}$  fraction was used to collect around 10  
228 specimens of the two epibenthic foraminifera species: *Cibicoides mundulus* (also described as  
229 *Cibicoides kullenbergi*) and *Cibicoides pachyderma*. To exclude a potential species-specific  
230 fractionation effect (vital effect) on the measured isotopic compositions of the paired samples,  $\delta^{18}\text{O}$   
231 and  $\delta^{13}\text{C}$  of both species were measured separately on 16 samples.

232 The analyses were performed at MARUM, University of Bremen, Germany, using a Finnigan MAT 251  
233 mass spectrometer coupled either to a Kiel I or Kiel IV automated carbonate preparation device. With  
234 a constant temperature of  $75\ ^\circ\text{C}$ , the measurements were conducted on  $\text{CO}_2$  that evolved by  
235 phosphoric acid treatment. Ground Solnhofen limestone was used as internal standard, which has  
236 been calibrated against Vienna Pee Dee Belemnite (V-PDB) using the NBS 19 standard. The measured  
237 data were reported relative to the V-PDB standard. The analytical standard deviation for  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$   
238 was  $\pm 0.04\text{‰}$  and  $\pm 0.03\text{‰}$  for the paired samples and  $\pm 0.06\text{‰}$  and  $\pm 0.03\text{‰}$  for the mono-species  
239 samples, respectively. The  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  anomaly between the two species has a mean value of  $0.04\text{‰}$   
240 and  $-0.04\text{‰}$ , respectively, with a standard deviation of less than 0.25 for both. Given the standard  
241 deviation during the measurement, our record from mixed samples is valid.

242 The benthic foraminifera  $\delta^{18}\text{O}$  record ( $\delta^{18}\text{O}_{\text{Cib}}$ ) was used to establish a chronostratigraphy for the off-  
243 mound core (supplemented by the AMS  $^{14}\text{C}$  dates). The  $\delta^{13}\text{C}_{\text{Cib}}$  record was applied to trace past changes  
244 in the water column structure. Epibenthic foraminifera are commonly used in palaeoceanographic  
245 studies as their tests incorporate  $\delta^{13}\text{C}$  in equilibrium with the ambient water (e.g., Curry et al., 1988;  
246 Curry and Oppo, 2005; Zahn et al., 1986). However, it has been shown that *C. mundulus* and *C.*  
247 *pachyderma* may record lighter  $\delta^{13}\text{C}$  values than those of the ambient water suggesting an occasional  
248 infaunal habitat (Schmiedl et al., 2004; Martínez-Méndez et al., 2013; Schmittner et al., 2017 and  
249 references therein).

250

### 251 **3.2.3 Grain-size analysis**

252 Grain-sizes were measured on the terrigenous fraction of the sediment ( sampling interval: 5cm). Prior-  
253 to the analyses, the samples were chemically treated following the method of McGregor et al. (2009).  
254 Deionized, degassed and filtered water (filtered with mesh size: 0.2  $\mu\text{m}$ ) was used during the entire  
255 process to reduce the potential influence of air bubbles or particles within the used water. The analyses  
256 were performed in the Particle-Size Laboratory at MARUM, University of Bremen, Germany, with a  
257 Beckman Coulter Laser Diffraction Particle Size Analyzer LS 13320. The obtained results provide the  
258 grain-size distribution of individual sample from 0.04  $\mu\text{m}$  to 2000  $\mu\text{m}$  in 116 size classes. All provided  
259 statistic values are based on a geometric statistic. In this study, the mean grain size is used to trace  
260 changes in bottom current strength (see also Fink et al., 2013).

261

### 262 **3.2.4 Benthic foraminifer accumulation rate**

263 Benthic foraminifer accumulation rates (BFARs) were analysed for the upper 368 cm of the off-mound  
264 core. From the core top to 158 cm, the sampling resolution was 10 cm whereas the resolution was  
265 increased to 5 cm between 158 cm and 368 cm core depth. The bulk samples were wet sieved and  
266 the  $>150 \mu\text{m}$  fraction was used for benthic foraminifer counts. Each sample was split until it contained  
267 approximately 300 individuals of benthic foraminifers, and counted (Patterson and Fishbein, 1989). All  
268 counts were corrected for splits and the BFAR (unit:  $\times 10^3$  individuals  $\text{cm}^{-2} \text{kyr}^{-1}$ ) was calculated  
269 according to the equation from Ehrmann and Thiede. (1985):

$$270 \quad \text{BFAR} = \text{SR} \times \text{DBD} \times \text{foram}/1000$$

271 BFAR: benthic foraminifer accumulation rate;

272 SR: Sedimentation Rate (unit:  $\text{cm kyr}^{-1}$ );

273 DBD: Dry bulk sediment density (unit:  $\text{g cm}^{-3}$ );

274 foram: number of foraminifers per gram in the dry bulk sample (unit: individuals  $\text{g}^{-1}$ ).

275 Due to the linear relation between the BFAR and the organic matter flux to the seafloor, the BFAR  
276 represents an established proxy for the export productivity (e.g., Berger and Herguera, 1992).

277

## 278 **4. Results**

### 279 **4.1 On-mound core description**

#### 280 **4.1.1 Visual core description of on-mound cores MD13-3451G and MD13-3452G**

281 For the two on-mound cores MD13-3451G and MD13-3452G, a visual core description is provided (see  
282 Fig. S1 in Supplementary Material), as CT scan data, allowing for a detailed quantitative description or  
283 determining of CPPs, are not available for these cores. Core MD13-3451G reveals CWC fragments  
284 embedded in predominantly grey muddy matrix sediments. Based on distinct variations in coral  
285 content and coral clast size, the core is subdivided into three units. The lowermost part of the core  
286 (522-460 cm core depth) exhibits relatively high coral contents of around 30-50 surf.% with generally  
287 large coral clasts of 3-5 cm. Between 460 and 190 cm core depth, the coral contents decrease to around  
288 10-30 surf.%. The size of the coral clasts varies mainly between 1-3 cm in length, while large coral clasts  
289 of about >3 cm in length occur occasionally at core depths of 495-460 cm, 415-335 cm and 250-200  
290 cm. In the uppermost section of the core (190 cm to core top), very low coral content of <5 surf.%  
291 comprising coral clasts of 1-2 cm in size concentrated at core depths of 180-168 cm, 85-79 cm, and 20-  
292 0 cm, while in between these intervals, no coral clasts are visible.

293 Core MD13-3452G contains CWC fragments throughout the core, which are embedded in olive grey  
294 muddy matrix sediments. Changes in coral content and coral clast size allowed to divide the core into  
295 three units. The lowermost three meters of the core(558-270 cm core depth) reveal the highest coral  
296 content that varies between 30 and 70 surf.%, with overall rather large coral clasts of 1-5 cm in size.  
297 Between 270 and 92 cm core depth, the coral content decreases to 30-50 surf.% and also the coral  
298 clast sizes decrease to 1-2 cm. For the uppermost part of the core (92 cm to core top), coral content  
299 again decreases to 10-30 surf.%. Coral clasts are rather small, with sizes of ~1 cm, only in the  
300 uppermost 20 cm, large coral clasts are found.

301

#### 302 **4.1.2 CT-based classification of cold-water coral preservation patterns of on-mound cores**

##### 303 **GeoB18127-1 and GeoB18130-1**

304 For the two on-mound cores GeoB18127-1 and GeoB18130-1, the CT analyses allowed for the  
305 differentiation of three CPPs following the approach of Titschack et al. (2015). Considering the CWC  
306 clast size and orientation, the three CPPs are defined as (i) CPP A: coral framework in living position  
307 characterised by large average coral clast size of  $>4.7 \Phi$  ( $>2.6$  cm) and variable orientations of up to  
308  $90^\circ$ ; (ii) CPP B: slightly collapsed coral framework marked by moderate average coral clast sizes of  $-4.7$   
309 to  $-4.4 \Phi$  ( $\sim 2.6$ - $2.1$  cm) and orientation  $< 60^\circ$ ; and (iii) CPP C: coral rubble defined by small average  
310 coral clast sizes of  $< -4.5 \Phi$  ( $\sim 1.3$  cm) and orientations of  $< 45^\circ$  or no clear orientation (Figs. 2, 3). The  
311 average coral content varying between 9 and 23 vol.% could not be applied to clearly distinguish  
312 between the CPPs, and the values for clast sizes and orientation of the different CPPs slightly vary  
313 between the two cores (see Table S1 in Supplementary Material).

314 In core GeoB18127-1, CPP A occurs at core depths of 473-395 cm (CPP A<sub>1</sub>) and 190-70 cm (CPP A<sub>2</sub>; Fig.  
315 2), and CPP B was recognized between CPP A<sub>1</sub> and CPP A<sub>2</sub> at core depths of 360-190 cm. CPP C was  
316 identified at various core depths of 563-500 cm (CPP C<sub>1</sub>), 500-473 cm (CPP C<sub>2</sub>), 395-360 cm (CPP C<sub>3</sub>)  
317 and 70-0 cm (CPP C<sub>4</sub>). It is notable that the CPP C<sub>1</sub>, identified at the bottom of the core GeoB18127-1  
318 directly below CPP C<sub>2</sub> exhibits remarkably smaller coral clasts ( $\sim 2.8 \Phi$  /  $0.7$  cm) and lower coral contents  
319 ( $\sim 9$  vol.%) compared to all other core sections containing coral rubble (clast size:  $> -4.2 \Phi$  /  $> 2.1$  cm;  
320 average coral contents:  $> 16$  vol.%; Fig. 2; see also Table S1 in Supplementary Material). In core  
321 GeoB18130-1, CPP A was identified at core depths of 106-71 cm, while CPP B occurs below and above  
322 CPP A (CPP B<sub>1</sub>: 148-106 cm; CPP B<sub>2</sub>: 71-34 cm). Coral rubble (CPP C) was only recognised between 34  
323 cm and the core top (Fig. 3).

324

## 325 **4.2 Coral ages and coral mound aggradation rates**

326 Four AMS <sup>14</sup>C ages were obtained from core MD13-3451G, which range from 13.8 kyr BP to 4.5 kyr BP.

327 One age (13.8 kyr BP) plots into the B/A interstadial, two ages (11.5 kyr BP and 9.5 kyr BP) into the  
328 Early Holocene, and one age (4.5 kyr BP) into the Late Holocene (Table 2, Fig. 4). Between 13.8 kyr BP  
329 and 11.5 kyr BP, the coral mound AR amounts to 46 cm kyr<sup>-1</sup>. During the Early Holocene, the coral  
330 mound AR was enhanced with 96 cm kyr<sup>-1</sup> before it dropped to 38 cm kyr<sup>-1</sup> between 9.5 kyr BP and 4.5  
331 kyr BP (Table 2, Fig. 4).

332 For core MD13-3452G, eight AMS <sup>14</sup>C dates were obtained ranging from 14.0 kyr BP to 3.5 kyr BP (Table  
333 2). Four ages (14.0-12.9 kyr BP) fall into the B/A, three ages (10.9-9.3 kyr BP) into the Early Holocene,  
334 and one age (3.5 kyr BP) into the early Late Holocene (Table 2, Fig. 4). During the B/A interstadial, the  
335 average coral mound AR amounts to 176 cm kyr<sup>-1</sup> (min: 132 cm kyr<sup>-1</sup>, max: 205 cm kyr<sup>-1</sup>). Between 12.9  
336 kyr BP and 10.9 kyr BP, a low average coral mound AR of 43 cm kyr<sup>-1</sup> was obtained. In the Early Holocene,  
337 the average coral mound AR increased to 107 cm kyr<sup>-1</sup> (min: 64 cm kyr<sup>-1</sup>, max: 182 cm kyr<sup>-1</sup>). The mound  
338 AR dropped to 15 cm kyr<sup>-1</sup> in the following period between 9.3 kyr BP and 3.5 kyr BP (Table 2, Fig. 4).

339 For the core GeoB18127-1, sixteen U-series ages were obtained, ranging from 14.1 kyr BP to 5.4 kyr  
340 BP. Four ages (14.1-13.3 kyr BP) coincide with the B/A interstadial, nine ages (11.1-8.2 kyr BP) with the  
341 Early Holocene and four ages (7.8-5.4 kyr BP) with the Mid Holocene (Table 3, Fig. 4). One age at 159  
342 cm core depth (8.55±0.12 kyr BP), is in the error range of the slightly younger age obtained at 189 cm  
343 core depth (8.51±0.17 kyr BP; Table 3), and was ignored for the calculation of the coral mound AR. In  
344 addition, two ages obtained from *M. oculata* and *L. pertusa* at the same core depth of 79 cm, revealed  
345 slightly differing ages of 7.81±0.16 kyr BP and 8.23±0.14 kyr BP, respectively. However, this difference  
346 is most likely due to the 3-dimensional complexity of the depositional environment, potentially linked  
347 to a reduction of the mound AR (enhanced time averaging effect). The younger age may probably result  
348 from the recolonization of *M. oculata*, hence was not used for the calculation of coral mound ARs.  
349 During the B/A interstadial, the calculated average mound AR amounts to 113 cm kyr<sup>-1</sup> (min: 20 cm kyr<sup>-1</sup>  
350 <sup>1</sup>, max: 547 cm kyr<sup>-1</sup>; Table 3). Between 13.3 kyr BP and 11.1 kyr BP, no CWC ages were obtained, and

351 the coral mound AR during this short interval exhibits low values of 14 cm kyr<sup>-1</sup>. Between 11.1 kyr BP  
352 and 7.6 kyr BP (largely corresponding to the Early Holocene), a mean mound AR of 90 cm kyr<sup>-1</sup> (min:  
353 40 cm kyr<sup>-1</sup>, max: 479 cm kyr<sup>-1</sup>) was obtained. During the Mid Holocene (5.8-5.4 kyr BP; Fig. 4), low  
354 coral mound ARs of 21 and 37 cm kyr<sup>-1</sup> are reported (Table 3; Fig. 4).

355 Within the core GeoB18130-1, ten U-series ages ranging from 9.4 kyr BP to 5.0 kyr BP were obtained,  
356 with seven ages (9.4-7.9 kyr BP) corresponding to the Early Holocene and three ages (7.9-5.0 kyr BP)  
357 to the Mid Holocene. One age reversal occurs at the top of the core, most likely due to sediment  
358 disturbance during the coring process. The age of 5.28±0.04 kyr BP at 2 cm core depth, was used for  
359 the calculation of the coral mound AR. Three ages obtained at the bottom of the core (128-147 cm  
360 core depth), show slightly increasing ages from bottom to top (9.37±0.05 kyr BP to 9.40±0.05 kyr BP),  
361 though the differences of these ages are within each other's error ranges. This points to a short phase  
362 of fast mound formation (9.37-9.40 kyr BP), during which the AR reached values of >270 cm kyr<sup>-1</sup>.  
363 Between 9.1 kyr BP and 7.9 kyr BP (largely corresponding to the Early Holocene), the average coral  
364 mound AR was 76 cm kyr<sup>-1</sup> (min: 24 cm kyr<sup>-1</sup>, max: 704 cm kyr<sup>-1</sup>; Table 3, Fig. 4), while between 7.9 kyr  
365 BP and 5.0 kyr BP, the coral mound AR declined to ~12 cm kyr<sup>-1</sup> (Table 3).

366

### 367 **4.3 Background palaeo-environmental record from off-mound core GeoB18131-1**

#### 368 **4.3.1 Chronology**

369 The chronology of the off-mound core GeoB18131-1 is constrained by six AMS <sup>14</sup>C ages, which range  
370 between 20.3 kyr BP (at 360 cm core depth) and 0.3 kyr BP (core top; Table 4). The age model is  
371 supported by the visual correlation between the δ<sup>18</sup>O<sub>Cib</sub> record and the LR04 δ<sup>18</sup>O stack record (Lisiecki  
372 and Raymo, 2005). For the tie-point correlation of the lower part of the core (855-360 cm core depth),  
373 six visual correlation-points were selected. The obtained age model suggests an age of approximately  
374 110 kyr BP for the bottom of the core (~850 cm core depth), hence the entire record covers the last  
375 interglacial (Marine Isotope Stage 5, MIS 5), the last glacial (MIS 2-4) and the recent interglacial (MIS  
376 1; Fig. S2 in Supplementary Material). The δ<sup>18</sup>O<sub>Cib</sub> record shows values of 4.0-1.9‰ for the last

377 interglacial, heavy values of 4.3-3.1‰ for the last glacial, and light values of 3.3-1.5‰ for the Holocene.  
378 The calculated sedimentation rate displays an increasing trend towards the Holocene. During the MIS  
379 5, the sedimentation rate was less than 5 cm kyr<sup>-1</sup>, while during most of the last glacial period, it  
380 amounts to 6-9 cm kyr<sup>-1</sup>. Only during the Last Glacial Maximum (LGM), the sedimentation rate  
381 significantly increased to 27 cm kyr<sup>-1</sup>. During the Holocene, the sedimentation rate varied between 8  
382 cm kyr<sup>-1</sup> and 21 cm kyr<sup>-1</sup> (Fig. S2 in Supplementary Material).

383

#### 384 **4.3.2 Palaeo-environmental proxies**

385 The main aim of this research is to relate the temporal occurrence of CWCs and coral mound  
386 development to distinct changes in the palaeo-environment. As the herein presented coral ages reach  
387 only 14.1 kyr BP back in time, all presented proxy records are restricted to the last 26 kyr to elucidate  
388 any changes across the last glacial-interglacial transition (the entire off-mound core proxy records are  
389 presented in Fig. S2 in the Supplementary Material).

390 During the last 26 kyr, the  $\delta^{13}\text{C}$  values of the mixed benthic foraminifera ( $\delta^{13}\text{C}_{\text{Cib}}$ ) range from 1.1‰ to  
391 0.3‰ (Fig. 5A). Before ~13.3 kyr BP, the  $\delta^{13}\text{C}$  values fluctuate between 0.6‰ and 1.1‰. Between 13.3  
392 kyr BP and 7.6 kyr BP, the  $\delta^{13}\text{C}_{\text{Cib}}$  record displays a conspicuous decreasing trend, declining from 1.0‰  
393 to 0.5‰. Since 7.6 kyr BP, the  $\delta^{13}\text{C}_{\text{Cib}}$  values fluctuate between 0.3‰ and 0.6‰ (Fig. 5B).

394 The mean grain size ranges from ~17  $\mu\text{m}$  to 5  $\mu\text{m}$  during the last 26 kyr (Fig. 5B). Between 26 kyr BP  
395 and ~16 kyr BP, the mean grain size is low with values mainly below 8  $\mu\text{m}$ . Since 16 kyr BP, the mean  
396 grain size gradually increases, reaching a maximum value of 17  $\mu\text{m}$  at ~12 kyr BP. Since then it shows  
397 a decreasing trend, and the mean grain size value remains again below 8  $\mu\text{m}$  for the last 8 kyr (Fig. 5C).

398 The BFARs vary between 1 and  $27 \times 10^3$  individuals  $\text{cm}^{-2} \text{kyr}^{-1}$  during the last 26 kyr (Fig. 5C). Before ~17  
399 kyr BP, the BFARs are low, only showing peak values of up to  $13 \times 10^3$  individuals  $\text{cm}^{-2} \text{kyr}^{-1}$  during the  
400 LGM. Since ~17 kyr BP, the BFARs show a gradually increasing trend until the highest BFARs of up to  
401  $\sim 27 \times 10^3$  individuals  $\text{cm}^{-2} \text{kyr}^{-1}$  at ~10.8 kyr BP. Between 10.8 kyr BP and 7.6 kyr BP, the BFARs rapidly



402 decline to  $\sim 8 \times 10^3$  individuals  $\text{cm}^{-2} \text{kyr}^{-1}$ . Afterwards, the BFARs remain low, with values of below  $5 \times 10^3$   
403 individuals  $\text{cm}^{-2} \text{kyr}^{-1}$  (Fig. 5D).

404

## 405 **5. Discussion**

406 Within the Alboran Sea, the two most common framework CWC species, *L. pertusa* and *M. oculata*,  
407 have been found on various seamounts and volcanic banks along the continental slope off Spain, on  
408 ridges (e.g., Alboran ridge), and on some mud volcanoes in the western Alboran Sea (Lo Iacono et al.,  
409 2008; Margreth et al., 2011; Palomino et al., 2011; De Mol et al., 2012; Lo Iacono et al., 2012; Palomino  
410 et al., 2015; Wienberg, 2019). Coral mounds are far more seldom and mainly concentrate in the  
411 southern Alboran Sea, comprising the mound clusters of the EMCP and the WMCP (Lo Iacono et al.,  
412 2014; Hebbeln, 2019; Wienberg, 2019). The discrepancy between the restricted occurrence of coral  
413 mounds in contrast to the widespread distribution of CWCs, though today mainly occurring as fossil  
414 accumulations rather than as living occurrences, hints to far more constrained (palaeo-)environmental  
415 conditions controlling coral mound formation compared to those promoting CWC growth (Wienberg  
416 and Titschack, 2017). The proliferation of CWCs, which is steered by various biotic and abiotic factors  
417 such as food supply, water masses properties, local hydrodynamic regime (e.g. Roberts et al., 2006;  
418 Davies and Guinotte, 2011) is a prerequisite for coral mound formation. Nevertheless, the construction  
419 of CWC mounds as complex geological structures is the result of a well-balanced interplay between a  
420 sustained growth of CWC, which form coral frameworks with high sediment baffling capacity, and a  
421 contemporaneous supply of sediments stabilizing the biogenic construction (e.g., Thierens et al., 2013;  
422 Titschack et al., 2015).

423 Any variations in the temporal development of coral mounds are reflected by varying ARs as well as by  
424 changes in the preservation state of the deposited CWC clasts (see Titschack et al., 2015; Titschack et  
425 al., 2016). In this context, high vertical mound aggradation is the result of pronounced CWC growth  
426 and enhanced sediment supply, thereby current-transported sediments become entrapped within the

427 coral framework. The fast burying of CWC frameworks prevents them from biodegradation and  
428 physical fragmentation, and may even allow the deposition of CWC framework in living position  
429 (Titschack et al., 2015). In contrast, during times of reduced CWC growth, coral mounds aggradation is  
430 slowed down and can eventually stagnate, the latter being documented as unconformities in the  
431 sedimentary record. Furthermore, when the dead coral framework (not covered by an organic tissue)  
432 remains exposed for a prolonged time on the mound's surface due to lack of substantial sediment  
433 cover, degradation and fragmentation of the coral skeletons may occur, eventually resulting in the  
434 formation of coral rubble. Thus, mound ARs calculated from coral dates in combination with the CPPs  
435 can be used to reconstruct the temporal development of coral mounds in much detail.

436

## 437 **5.1 Cold-water coral mound formation in the southern Alboran Sea since the last** 438 **deglaciation**

### 439 **5.1.1 Re-activation of coral mound formation during the B/A interstadial**

440 While quite some information exists already on the formation of the coral mounds of the EMCP since  
441 the last deglaciation (Fink et al., 2013; Stalder et al., 2015), up to this study no information was  
442 available about the temporal development of the mounds in the neighbouring WMCP. Considering  
443 their present-day average height of 8-35 m above the seafloor and their additional subsurface  
444 extension on one hand (Lo Iacono et al., 2014), and the maximum on-mound core recovery of less than  
445 6 m on the other hand (Table 1), this study, can however only decipher the most recent period(s) of  
446 mound development.

447 The oldest ages obtained from the coral mounds of the WMCP range between 14.1 kyr BP and 12.9  
448 kyr BP, and represent a pronounced coral mound formation stage during the B/A interstadial with high  
449 ARs of 113-176 cm kyr<sup>-1</sup> on average (and even maximum ARs of up to 500 cm kyr<sup>-1</sup>; Tables 2, 3, Fig. 4).  
450 The CPP obtained from the core GeoB18127-1 indicate that coral rubble of B/A age (defined as CPP C<sub>2</sub>  
451 in Fig. 2) rest on small-sized CWC rubble (defined as CPP C<sub>1</sub> in Fig. 2). Both CWC rubble-dominated  
452 sections are separated by a distinct unconformity. The high fragmentation grade of the pre-B/A CWC

453 rubble deposits indicate that these coral clasts rested for a long time exposed on the mound's surface  
454 without any coverage (by sediments or living CWCs). Unfortunately, these CWC clasts were too small  
455 and showed strong corrosion avoiding their usage for absolute dating. Therefore, without the support  
456 of longer dated core records, the timing of coral mound development before the last deglaciation  
457 cannot be further constrained.

458 Nevertheless, the re-initiation of coral mound formation during the last deglaciation started at ~14.1  
459 kyr BP, interestingly fitting with similar observations obtained from various coral mound records of the  
460 EMCP (~13.3-13 kyr BP; Fink et al., 2013; Stalder et al., 2015). The slight temporal off-set (~800 years)  
461 in the timing of the deglacial coral re-colonization, and hence, re-initiation in mound formation  
462 between both provinces might simply be explained by the limited length of the mound core records  
463 available for the EMCP, avoiding to collect coral fragments of early B/A-age. The CPP displayed in core  
464 GeoB18127-1, with CWC rubble (CPP C<sub>2</sub>) being present at the base of the B/A period along with the  
465 associated initial low AR of 21 cm kyr<sup>-1</sup> (Figs. 2, 4), point to a rather slow post-glacial start-up phase in  
466 coral mound formation for the WMCP. This observation contrasts with results from the EMCP, which  
467 suggest a sudden and fast start-up phase of CWC colonization (Fink et al., 2013; Titschack et al., 2016).  
468 Since ~13.5 kyr BP, the CPP in core GeoB18127-1 changed from CWC rubble to CWC framework being  
469 preserved in living position (CPP A<sub>1</sub>; Fig. 2), which indicates enhanced CWC growth as well as increased  
470 sediment deposition. Also both MD cores show rather large coral clasts (3-5 cm in size) in their lower  
471 core intervals that correspond to the B/A (see Fig. S1 in the Supplementary Material), indicating that  
472 coral frameworks were rapidly buried by sediments, preventing them from being strongly fragmented.  
473 This is further supported by a significant increase of the coral mound ARs to average values of 176-493  
474 cm kyr<sup>-1</sup> (calculated for cores MD13-3452G and GeoB18127-1; Tables 2, 3, Fig. 4), which are in the  
475 range of coeval average ARs of 385-416 cm kyr<sup>-1</sup> obtained from mounds in the EMCP (Fink et al., 2013;  
476 Stalder et al., 2015).

477

478 **5.1.2 Temporal stagnation in mound formation during the YD cold event**

479 During the YD, coral mound formation significantly slowed down. No coral ages were obtained  
480 between 12.9 kyr BP and 11.5 kyr BP, and coral mound ARs significantly decreased to 14-43 cm kyr<sup>-1</sup>  
481 (calculated for cores MD13-3452G and GeoB18127-1; Tables 2,3, Fig. 4). Moreover, a distinct  
482 unconformity was identified in core GeoB18127-1 marked by an abrupt change in the CPPs from CWC  
483 framework preserved in living position (CPP A<sub>1</sub>) to CWC rubble (CPP C<sub>3</sub>; Fig. 2). Also for the coral  
484 mounds of the EMCP, a distinct reduction in mound aggradation was indicated during the YD (AR: 31-  
485 38 cm kyr<sup>-1</sup>; see also Fig. 5; Fink et al., 2013; Stalder et al., 2015), although based on the available  
486 datings it appears that this reduction seems to encompass a shorter time period only corresponding  
487 to the late YD (12.2-11.6 kyr BP; Stalder et al., 2015).

488

489 **5.1.3 Coral mound formation during the Early Holocene**

490 The most recent period of coral mound formation in the WMCP started at ~11.5 kyr BP during the  
491 onset of the Early Holocene, and simultaneously to the start of the Early Holocene mound formation  
492 period indicated for the EMCP (11.6-11.4 kyr BP; see Fig. 5; Fink et al., 2013; Stalder et al., 2015). As  
493 already identified for the B/A mound formation period, there seems to be again a slow start-up phase  
494 in mound formation in the WMCP. The CPP in core GeoB18127-1 reveals at the beginning of this period  
495 the deposition of CWC rubble (CPP C<sub>3</sub>; Fig. 2), and also for the cores MD13-3451G and MD13-3452G,  
496 the lower Early Holocene deposits are marked by small sized coral clasts (see Fig. S1 in Supplementary  
497 Material). This overall points to hampered CWC growth and low sediment deposition, which is further  
498 evidenced by rather low to moderate ARs of 46-97 cm kyr<sup>-1</sup>. However, already within a few hundreds  
499 of years, ARs increased to values of >100 cm kyr<sup>-1</sup> (even temporarily reaching values of up to 700 cm  
500 kyr<sup>-1</sup>; Tables 2, 3, Fig. 4), although the available CWC ages do not allow to temporally constrain this  
501 transition. The increased ARs are accompanied by CPPs that vary between slightly collapsed CWC  
502 framework and CWC framework preserved in living position (indicated for cores GeoB18127-1 and  
503 GeoB18130-1; Figs. 2, 3). Overall, the average coral mound ARs during the Early Holocene range

504 between 75 and 107 cm kyr<sup>-1</sup> (Tables 2, 3, Fig. 4). Hence, in comparison to average ARs obtained for  
505 the EMCP, which varied between 140 and 291 cm kyr<sup>-1</sup> (Fink et al., 2013; Stalder et al., 2015), coral  
506 mound formation in the WMCP seems to be less pronounced. In addition, while the highest mound  
507 aggradation in the EMCP (ARs mainly above 190 cm kyr<sup>-1</sup>) already occurred directly at the beginning of  
508 the Early Holocene mound formation period at 11.6 kyr BP and lasted until ~10.2 kyr BP, the coral  
509 mounds of the WMCP experienced their most pronounced Holocene aggradation (ARs mainly above  
510 150 cm kyr<sup>-1</sup>) between ~9.9 and 8.3 kyr BP, thus about 1700 years later than the boost of the EMCP  
511 mound formation (Fig. 5).

512

#### 513 **5.1.4 Slow-down in coral mound formation since the Mid Holocene**

514 Coral mound formation in the WMCP significantly slowed down since the early Mid Holocene (at ~7.6  
515 kyr BP), which is mainly reflected by a strong decrease of the coral mounds ARs to values of 12-38 cm  
516 kyr<sup>-1</sup> (indicated for all cores; Tables 2, 3, Fig. 4). Moreover, in both GeoB cores, the CPPs abruptly  
517 changed from coral framework to CWC rubble (GeoB18127-1: CPP A<sub>2</sub> to C<sub>4</sub>, Fig. 2; GeoB18130-1: CPP  
518 B<sub>2</sub> to C, Fig. 3) during this period, as also shown in both MD cores, where only a sparse occurrence of  
519 small-sized coral clasts was indicated, pointing to a reduced CWC growth and a low sediment input,  
520 both favouring the fragmentation of coral clasts. For the EMCP, a slow-down in mound formation with  
521 a significant decrease of the ARs to 4-22 cm kyr<sup>-1</sup> already started at ~9.8 kyr BP (Fink et al., 2013; Stalder  
522 et al., 2015), thus over 2,000 years earlier compared to the WMCP.

523 The youngest CWC ages (n=5) obtained for the coral mounds of the WMCP range between 5.8 and 3.5  
524 kyr BP (Tables 2, 3, Fig. 4), hence coral mound formation likely stagnated since the Late Holocene.  
525 Present day conditions suggest that CWCs seem to be completely absent from the coral mounds of the  
526 WMCP, with some of the ground-truthed mounds being buried by coral-barren sediments (Hebbeln et  
527 al., 2015; Lo Iacono et al., 2014). Also for the EMCP, the youngest obtained CWC ages (~2.9-2.6 kyr BP)  
528 are of Late Holocene ages, but in contrast to the WMCP, these mounds actually are covered by dead  
529 coral framework/rubble with sparse living CWC colonies (Hebbeln et al., 2009; Fink et al., 2013).

530

## 531 **5.2 Palaeo-environmental controls on coral mound formation in the southern Alboran Sea**

532 The temporal pattern in mound formation obtained for the coral mounds of the WMCP since the last  
533 deglaciation correlates well with distinct changes in the local palaeo-environmental conditions. In  
534 particular variations in the surface productivity and food supply, the water column structure, and the  
535 near-bottom hydrodynamics were identified to be the most important local or regional driver on the  
536 development of the CWC mounds (Fig. 5). Nevertheless, the reactivation of mound formation during  
537 the B/A interstadial, both in the WMCP and the EMCP, coincide with a major re-organisation of the  
538 thermohaline circulation in the entire Mediterranean basin. The rapid last deglacial sea-level rise (Fig.  
539 5; Lambeck et al., 2014) resulted in an increased injection of low saline Atlantic waters due to a  
540 deepening of the Gibraltar sill (Sierro et al., 2005). Moreover, the enhanced glacial melting in the Alps  
541 and Apennines increased the inflow of freshwater into the Mediterranean Basin (e.g., Cacho et al.,  
542 2002; Ivy-Ochs et al., 2007; Rogerson et al., 2008), both leading to a freshening and reduced density of  
543 the surface waters. Concurrently, the sea surface temperatures increased up to 14°C (e.g., Balearic Sea;  
544 Dubois-Dauphin et al., 2017). All these processes resulted in a slowdown of the Mediterranean Sea  
545 thermohaline circulation and caused a collapse of deep-water (WMDW) production in the western  
546 Mediterranean Sea (Gulf of Lion), which led to an increased stratification of the water column and  
547 weakened ventilation of intermediate and deep-water masses (Cacho et al., 2001; Sierro et al., 2005;  
548 Rogerson et al., 2008; Toucanne et al., 2012). At the same time, the production of LIW in the eastern  
549 Mediterranean Sea (Levantine Basin) was enhanced, which caused intensification and increased inflow  
550 of the LIW into the western basin (Jiménez-Espejo et al., 2015). The strong influence of the LIW at the  
551 intermediate depths in the Alboran Sea since the last deglaciation is also documented in the  
552 neodymium isotopic composition of CWCs collected from the EMCP, though the Alboran Sea seems to  
553 be rather insensitive to hydrological variations of the LIW, at least since 13.5 kyr BP until present  
554 (Dubois-Dauphin et al., 2017).

555 Studies from various sites in the western Mediterranean Sea revealed that the surface productivity  
556 gradually increased during the B/A (Fig. 5) due to a shoaling of the nutricline, and consequently also  
557 the export of organic matter was enhanced (Cacho et al., 2002; Jimenez-Espejo et al., 2008; Rogerson  
558 et al., 2008; Ausín et al., 2015; Jimenez-Espejo et al., 2015) resulting in the deposition of the organic  
559 rich layer 1 (ORL1; 14.5-8.2 kyr BP) in the deep western Mediterranean Sea (Cacho et al., 2002). The  
560 BFAR record from the WMCP reveals a low export production during the last glacial before it  
561 significantly increased since 14 kyr BP, reached its maximum during the Early Holocene and dropped  
562 rapidly at the onset of the Mid Holocene (Fig. 6). This suggests a more or less synchronous increase of  
563 the BFAR export production with the formation of the ORL1, supporting the enhanced surface  
564 productivity, and even more important, highlighting an improved food delivery to the WMCP during  
565 this time interval since the deglaciation until the Mid Holocene has likely favoured the proliferation of  
566 CWCs and mound formation within the region, by contributing to their food supply (Fig. 5).

567 However, considerable differences in the BFAR between the two main mound formation phases  
568 marked by similar mound aggradation rates call for additional parameters in addition to palaeo-  
569 productivity that control mound formation. Interestingly, the grain-size distribution shows a similar  
570 pattern as the BFAR with coarser sediments occurring between 15 and 8 kyr BP (Fig. 5). The enhanced  
571 hydrodynamic energy reflected by this coarsening of the sediments further contributed to the food  
572 supply of the CWCs. The change in the grain size distribution coincides with our  $\delta^{13}\text{C}_{\text{Cib}}$  record, which  
573 here is adopted to trace past changes in the water column structure (Fig. 5). During the last glacial, the  
574 intermediate depths of the WMCP were influenced by waters with relatively high  $\delta^{13}\text{C}_{\text{Cib}}$  values (0.8-  
575 1.1‰; Fig. 5), which we interpret to represent the effect of a dominant influence of the MAW  
576 coinciding with the sea level considerably lower than today. On the contrary after the cessation of  
577 deglacial sea-level rise and the final establishment of the modern circulation, the intermediate depths  
578 of the WMCP were mainly bathed by waters with relatively low  $\delta^{13}\text{C}_{\text{Cib}}$  values (0.3-0.6‰; Fig. 5), which  
579 are likely due to the predominance of the LIW. However, from the B/A interstadial to the Mid Holocene  
580 (~13.3-7.6 kyr BP), the  $\delta^{13}\text{C}_{\text{Cib}}$  record shows a gradual change from MAW to LIW dominance, though

581 also revealing strong fluctuations (Fig. 5). Thus, we assume that in pace with the deglacial sea level rise,  
582 the coral mounds of the WMCP, which today occur at water depths of 300-490 m (Lo Iacono et al.,  
583 2014), were bathed by the MAW before the B/A interstadial. Between the B/A interstadial and Early  
584 Holocene the mounds became affected by the interface between the MAW and the LIW, and were  
585 mainly influenced by the LIW since the Mid Holocene, when the water mass interface was shifted  
586 towards shallower depths above the coral mounds (Fig. 6). Interestingly, the time interval when the  
587 coral mounds of the WMCP were placed within the interface between the MAW and the LIW – marked  
588 by the strong gradient in the  $\delta^{13}\text{C}_{\text{cib}}$  record - almost exactly encompasses the timing of mound  
589 formation in the WMCP during the B/A interstadial (14.1-12.9 kyr BP) and the Early Holocene (11.6-7.6  
590 kyr BP; Figs. 4, 5).

591 Common features that occur at the interface between two water masses of different densities are  
592 internal waves (Small and Martin, 2002; Pomar et al., 2012;). Such waves propagate along the  
593 pycnocline, due to friction between the two water bodies caused by different flow velocities, and  
594 eventually break against facing slopes (Pomar et al., 2012). Therefore, internal waves are a potentially  
595 relevant source of turbulent energy as they enable mixing and particle re-suspension, and hence the  
596 lateral transportation of particulate organic materials. Moreover, these features can force the  
597 accumulation of particulate material, and hence, the formation of nepheloid layers (Mienis et al., 2007).  
598 The positive feedback of internal waves on mound formation is described for various modern coral  
599 mound settings in the NE Atlantic (Frederiksen et al., 1992; White et al., 2005; Mienis et al., 2007;  
600 Davies et al., 2009; White and Dorschel, 2010; Hebbeln et al., 2014). Internal waves transport fresh or  
601 re-suspend recently deposited food particles with increased velocity to the CWCs thriving on mounds  
602 (Mienis et al., 2007). Thereby, they act as a nutritional pump that makes food particles repeatedly  
603 available for CWCs, flushing particles laterally through the CWC framework, thus enhancing the chance  
604 for the coral polyps to catch them (Davies et al., 2009; Mienis et al., 2009; Hebbeln et al., 2016). Also  
605 for the fossil record, a strong relationship between the existence of a water mass interface and coral  
606 mound formation has already been postulated. For example, mound aggradation along the Irish



607 margin (Porcupine Seabight) was active when the interface between the Mediterranean Outflow  
608 Water and the Eastern North Atlantic Water was placed towards the depth level of the mounds,  
609 thereby the stable water mass stratification between both water masses caused enhanced food supply  
610 (Raddatz et al., 2014). Recently, the positive effect of internal waves has been hypothesised for a coral  
611 mound province in the Gulf of Mexico (Campeche Bank; Matos et al., 2017). There, mound formation  
612 is restricted to interglacial periods, when internal waves propagated along the pycnocline between the  
613 Atlantic Intermediate Water and the Tropical Atlantic Central Water, while during glacial times this  
614 water mass interface was shifted away from the coral mounds (Matos et al., 2017). It is very likely that  
615 such a scenario is also valid for the WMCP, where internal waves propagating along the MAW-LIW-  
616 interface enhanced the supply of food particles to the CWCs and hence promoted the pronounced  
617 aggradation of the mounds during the B/A and Early Holocene (Fig. 6). The enhanced hydrodynamic  
618 energy resulting from the internal waves along the water mass interface is reflected by the grain size  
619 data from the off-mound record in the WMCP and the EMCP (Figs. 5, 6).

620 By comparing the palaeo-environmental conditions between the WMCP and the neighbouring EMCP,  
621 very similar trends with respect to export production and near-bottom hydrodynamics are indicated  
622 for the past 23 kyr (Fig. 5; see also Fink et al., 2013). However, the mounds of the EMCP experienced  
623 a slightly earlier (at ~9.8 kyr BP) slow-down in mound formation during the Early Holocene (Fink et al.,  
624 2013; Stalder et al., 2015) compared to the mounds of the WMCP (at ~7.6 kyr BP; Fig. 5). This might  
625 simply reflect the natural mound formation variability along continental margins as was recently  
626 shown by Wienberg et al. (2018). These authors identified distinct temporal differences in mound  
627 formation stages within a giant coral mound province off Mauritania, even for directly neighbouring  
628 coral mounds. Alternatively, the temporal offset in mound formation between the EMCP and the  
629 WMCP might be related to the influence of the Cape Tres Forcas, which today separates both provinces  
630 and whose morphology probably significantly modified the circulation pattern in pace with the rising  
631 sea level since the last deglaciation. During the LGM, the sea level was ~130 m lower than at present  
632 (Fig. 5), and the Moroccan coastline was located much further off-shore, thus much closer to the coral

633 mounds of the WMCP and the EMCP (see also Lo Iacono et al., 2014). At ~14.5 kyr BP the sea-level  
634 rapidly rose about 20 m in about 500 years (Deschamps et al., 2012), and reached the present-day  
635 level between 8 and 6 kyr BP (Lambeck and Chappell, 2001; Lambeck et al., 2014; Fig. 5). As suggested  
636 by Lo Iacono et al. (2014), the morphological alteration of the Cape Tres Forcas due to the sea-level  
637 rise probably modified the current regime and subsequent sedimentation rates in the WMCP, leading  
638 to the demise of coral mounds.

639 One period that remains enigmatic is the YD cold event, when mound formation temporarily stagnated,  
640 though our off-mound record reveals significant enhancement of productivity and hydrodynamics (Figs.  
641 5, 6). Enhanced productivity conditions in combination with a well-ventilated, high energetic  
642 intermediate water mass regime during the YD was also assumed for other sites in the western  
643 Mediterranean Sea (Bárcena et al., 2001; Rogerson et al., 2008; McCulloch et al., 2010; Margreth et al.,  
644 2011; Toucanne et al., 2012). However, while these overall optimal environmental conditions explain  
645 the frequent reports of corals of YD-age from various sites in the Mediterranean Sea (Balearic,  
646 Tyrrhenian, Ionian and Aegean Seas; McCulloch et al., 2010; Taviani et al., 2011; Fink et al., 2015), the  
647 reduced occurrence (or even absence) of CWCs in the southern Alboran Sea point to rather local  
648 environmental controls that suppressed their proliferation. Fink et al. (2015) assumed that this local  
649 control on CWC growth in the southern Alboran Sea might be related to changes in the two-gyres-  
650 system that induced upwelling and density fronts in the upper 200-300 m (Heburn and La Violette,  
651 1990).

652

## 653 **6. Conclusions**

654 Within the Alboran Sea, coral mounds formed by the scleractinian framework-forming CWCs *L. pertusa*  
655 and *M. oculata* were so far only discovered along its southern margin just 15-30 km off the Moroccan  
656 coastline. These mounds are grouped in two provinces, the WMCP and EMCP, which are located east  
657 and west of the Spanish enclave Melilla (Cape Tres Forcas) in intermediate water depths of 200-450 m

658 (Lo Iacono et al., 2014; Hebbeln, 2019). This study provided for the first time insight into the temporal  
659 evolution of the coral mounds in the WMCP and clearly revealed that mound formation re-initiated  
660 (almost) simultaneously in both provinces with the onset of the last deglaciation. Subsequently, the  
661 mounds experienced periods of pronounced aggradation corresponding to the B/A interstadial and the  
662 Early Holocene. Highest ARs were reached during the B/A, with average ARs of 1-2 m kyr<sup>-1</sup> obtained for  
663 the WMCP. These ARs are in the range of or even above the values found for mound provinces in the  
664 NE Atlantic (e.g., Frank et al., 2009; Wienberg and Titschack, 2017). The CPPs identified for the mounds  
665 of the WMCP indicate for both periods a slow start-up phase rapidly followed by a "booster" stage in  
666 mound formation which partly supports an early mound evolution model introduced by Henriot et al.  
667 (2002).

668 The re-initiation of mound formation and subsequent mound development in the southern Alboran  
669 Sea was likely the result of (i) the strong hydrodynamics triggered by internal waves related to the sea  
670 level-driven re-organisation of the water column structure, and (ii) the concurrently enhanced ocean  
671 productivity. For modern Atlantic coral mound settings, internal waves are frequently observed to  
672 develop along pycnoclines related to water mass boundaries. They create enhanced turbulent energy  
673 and lateral transport (and/or enrichment) of particulate material (food, sediments; e.g., Mienis et al.,  
674 2007; White et al., 2005), thus supporting CWC growth as well as mound formation. We assume that  
675 such a scenario also promoted mound formation in the southern Alboran Sea from the last deglaciation  
676 until the end of the Early Holocene (see also Fink et al., 2013). During the Mid Holocene, the MAW-  
677 LIW-interface shifted to shallower water depths above the mounds and altered the environmental  
678 conditions at the sea floor to a less turbulent condition. At the same time, the area turned into an  
679 oligotrophic setting. These caused a significant slow-down (EMCP) and even stagnation (WMCP) in  
680 mound formation that persists until today.

681 The water column structure most likely played a dominant role in controlling mound formation in the  
682 southern Alboran Sea. However, the locally and temporarily restricted processes might also have  
683 influenced the development of the coral mounds. During the YD, mound formation was suppressed in

684 both provinces which might be related to the changes of the two gyre circulation that triggering  
685 upwelling and density fronts at intermediate water depths (Fink et al., 2015; Heburn and La Violette,  
686 1990). Moreover, slight temporal offsets in mound formation identified between the two provinces  
687 might be related to the Cape Tres Forcas that acts as a morphological barrier possibly affecting the  
688 hydrodynamic processes in both provinces in a different manner. However, these offsets also simply  
689 might reflect the natural variability in mound formation, which according to recent studies seems to  
690 be a common pattern (even between directly neighboring coral mounds) rather than an exceptional  
691 feature (e.g., Wienberg et al., 2018).

692 While this study provides detailed insight into the most recent coral mound development in the  
693 southern Alboran Sea, the timing and environmental controls of mound formation before the last  
694 deglaciation remains unknown. Only with the recovery of longer sedimentary records, we may possibly  
695 elucidate any large-scale pattern related to older climate fluctuations, as identified for NE Atlantic  
696 mound provinces (e.g., Frank et al., 2011).

697

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720

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1042 Table 1. Metadata of gravity cores collected in the WMCP (southern Alboran Sea) during the cruise MD 194  
1043 “GATEWAY” with the French RV Marion Dufresne and cruise MSM 36 “MoccoMeBo” with the German RV Maria  
1044 S. Merian.

Cruise	Core Type	Core ID	Latitude [N]	Longitude [W]	Water depth [m]	Recovery [cm]
MD194	On-mound	MD13-3451G	35°29.996'	3°02.398'	370	522
MD194	On-mound	MD13-3452G	35°28.128'	3°04.661'	305	558
MSM-36	On-mound	GeoB18127-1	35°28.969'	3°04.641'	365	563
MSM-36	On-mound	GeoB18130-1	35°28.099'	3°08.747'	379	148
MSM-36	Off-mound	GeoB18131-1	35°28.093'	3°09.301'	457	851

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1047 Table 2. AMS <sup>14</sup>C dates obtained from CWC fragments collected from the on-mound cores MD13-3451G and  
 1048 MD13-3452G. The ages were corrected for <sup>13</sup>C and a reservoir age of 400 years. The AMS <sup>14</sup>C ages were converted  
 1049 into calendar age with the CALIB 7.10 (Stuiver and Reimer, 1993; <http://calib.org/calib/calib.html>), using the  
 1050 MARINE-13 curve (Reimer et al., 2013). Coral mound aggradation rates (ARs) are calculated based on a linear  
 1051 interpolation of the coral ages.

Core ID (MD13-)	Core Depth [cm]	Lab-code	Coral Species	Conventional Age [kyr]		2σ range cal. age [kyr BP P=AD 1950]		Median Probability	AR
				<sup>14</sup> C age	± error			Age [kyr BP]	[cm kyr <sup>-1</sup> ]
3451G	5	Poz-62332	<i>M. oculata</i>	4.37	0.03	4.41	4.61	4.51	-
3451G	197	Poz-62333	<i>L. pertusa</i>	8.90	0.04	9.47	9.66	9.54	38.1
3451G	382	Poz-62334	<i>L. pertusa</i>	10.39	0.05	11.24	11.74	11.47	96.3
3451G	488	Poz-62335	<i>L. pertusa</i>	12.32	0.05	13.63	13.95	13.79	45.5
3452G	13	Poz-62336	<i>M. oculata</i>	3.58	0.03	3.38	3.56	3.47	-
3452G	99	Poz-62337	<i>M. oculata</i>	8.61	0.04	9.13	9.40	9.28	14.8
3452G	203	Poz-62338	<i>M. oculata</i>	9.11	0.05	9.66	10.09	9.85	181.8
3452G	267	Poz-62339	<i>L. pertusa</i>	9.90	0.04	10.70	11.02	10.85	63.6
3452G	355	Poz-62340	<i>M. oculata</i>	11.45	0.05	12.75	13.08	12.91	42.7
3452G	406	Poz-62341	<i>L. pertusa</i>	11.83	0.07	13.16	13.44	13.30	131.8
3452G	467	Poz-62342	<i>L. pertusa</i>	12.17	0.05	13.46	13.78	13.62	191.8
3452G	550	Poz-62343	<i>L. pertusa</i>	12.54	0.05	13.87	14.16	14.02	204.9

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1055 Table 3. U/Th dates, uranium and thorium isotope concentrations and ratios obtained from CWC fragments  
 1056 collected from the on-mound cores GeoB18127-1 and GeoB18130-1 (n.d. not determinable). Coral mound  
 1057 aggradation rates (ARs) are calculated based on a linear interpolation of the coral ages.

Core ID [GeoB]	Core Depth [cm]	Lab-code	Coral Species	Age [kyr BP]	± [kyr]	<sup>238</sup> U [ppm]	± [ppm]	<sup>232</sup> Th [ppb]	± [ppb]	δ <sup>234</sup> U <sub>0</sub> [‰]	error	AR [cm kyr <sup>-1</sup> ]
18127-1	1	IUP-7734	<i>M. oculata</i>	5.39	0.12	4.218	0.0006	0.282	0.009	150.5	2.7	-
18127-1	15	IUP-7735	<i>M. oculata</i>	5.76	0.09	4.233	0.0005	n.d.		146.9	3.1	37.2
18127-1	52	IUP-7736	<i>L. pertusa</i>	7.56	0.20	3.362	0.0007	n.d.		150.3	3.0	20.5
18127-1	79	IUP-7737	<i>M. oculata</i>	#7.81	0.16	4.122	0.0005	0.101	0.006	149.5	2.6	-
18127-1	79	IUP-7738	<i>L. pertusa</i>	#8.23	0.14	3.445	0.0004	0.199	0.007	149.4	3.1	40.4
18127-1	90	IUP-7739	<i>L. pertusa</i>	8.30	0.12	3.182	0.0004	0.057	0.002	149.3	3.0	158.3
18127-1	159	IUP-7740	<i>L. pertusa</i>	8.55	0.12	4.168	0.0005	0.622	0.010	150.7	2.8	-
18127-1	189	IUP-7741	<i>L. pertusa</i>	8.51	0.17	3.921	0.0005	0.229	0.007	151.9	3.4	479.0
18127-1	252	IUP-7742	<i>L. pertusa</i>	9.28	0.14	3.234	0.0004	n.d.		148.2	2.7	82.0
18127-1	274	IUP-7743	<i>L. pertusa</i>	9.70	0.08	3.659	0.0004	0.091	0.002	149.3	2.6	51.7
18127-1	337	IUP-7744	<i>L. pertusa</i>	10.35	0.09	3.420	0.0003	0.179	0.002	143.3	2.5	97.7
18127-1	373	IUP-7745	<i>L. pertusa</i>	11.14	0.07	4.177	0.0003	0.293	0.002	145.8	1.9	45.2
18127-1	404	IUP-7746	<i>L. pertusa</i>	13.30	0.10	3.398	0.0002	0.354	0.002	149.8	2.1	14.4
18127-1	460	IUP-7747	<i>L. pertusa</i>	13.40	0.10	3.712	0.0002	0.224	0.002	148.7	1.4	546.9
18127-1	478	IUP-7748	<i>L. pertusa</i>	13.45	0.09	3.758	0.0002	0.323	0.002	149.6	2.2	335.2
18127-1	491	IUP-7749	<i>L. pertusa</i>	14.07	0.11	3.288	0.0002	0.362	0.002	148.9	1.5	20.2
18130-1	2	IUP-7750	<i>M. oculata</i>	5.28	0.04	4.514	0.0003	0.166	0.001	146.8	2.0	-
18130-1	9	IUP-7751	<i>M. oculata</i>	*5.00	0.03	3.989	0.0002	0.050	0.000	149.9	1.8	-
18130-1	34	IUP-7752	<i>M. oculata</i>	7.88	0.05	3.957	0.0002	0.256	0.002	148.6	1.4	12.4
18130-1	61	IUP-7753	<i>M. oculata</i>	8.41	0.06	3.773	0.0003	0.136	0.001	148.1	1.9	51.0
18130-1	71	IUP-7754	<i>L. pertusa</i>	8.83	0.05	4.062	0.0002	0.387	0.001	149.5	0.9	23.6
18130-1	106	IUP-7755	<i>L. pertusa</i>	8.88	0.04	3.506	0.0002	0.232	0.001	149.1	0.9	704.2
18130-1	118	IUP-7756	<i>M. oculata</i>	9.07	0.05	3.735	0.0002	0.334	0.002	147.7	0.9	63.1
18130-1	128	IUP-7757	<i>L. pertusa</i>	9.40	0.05	3.483	0.0002	0.713	0.003	149.3	1.1	> 270
18130-1	138	IUP-7758	<i>L. pertusa</i>	9.38	0.05	3.851	0.0002	0.627	0.002	149.1	0.9	
18130-1	147	IUP-7759	<i>L. pertusa</i>	9.37	0.05	4.131	0.0002	0.306	0.001	148.9	1.4	

1058 \*: age reversal. #: two different ages obtained from *L. pertusa* and *M. oculata* at the same core depth, see text  
 1059 for explanation.

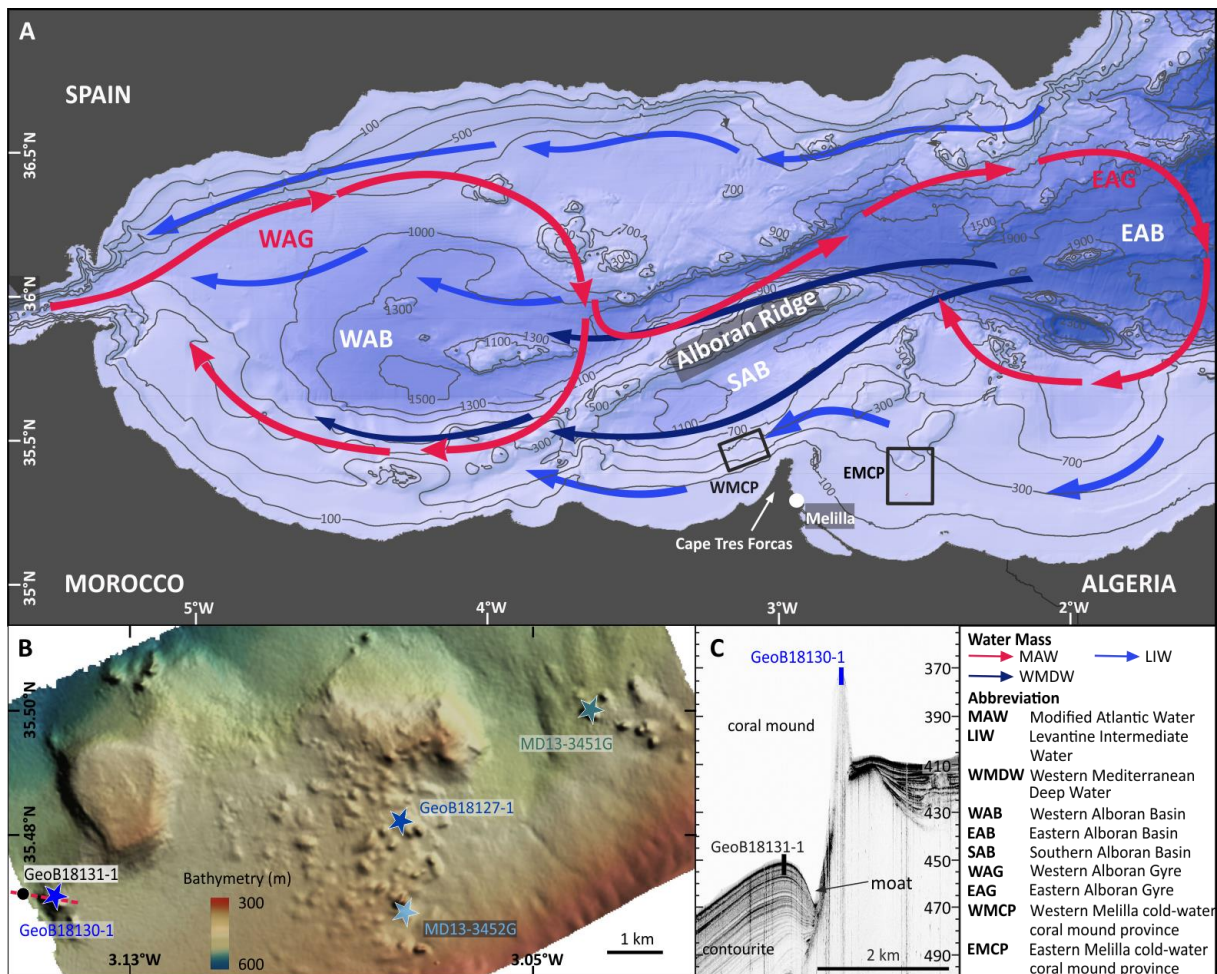
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1061 Table 4. AMS <sup>14</sup>C dates of mixed planktonic foraminifers obtained from the off-mound core GeoB18131-1. The  
 1062 ages were corrected for <sup>13</sup>C and a reservoir age of 400 years. The AMS <sup>14</sup>C ages were converted into calendar age  
 1063 with the CALIB 7.10 (Stuiver and Reimer, 1993; <http://calib.org/calib/calib.html>), using the MARINE-13 curve  
 1064 (Reimer et al., 2013). Below 400 cm core depth, the age model is based on visual tie-point correlation between  
 1065 the  $\delta^{18}\text{O}$  record of core GeoB18131-1 and the LR04  $\delta^{18}\text{O}$  stack record (Lisiecki and Raymo, 2005). Sedimentation  
 1066 rates are calculated based on a linear interpolation of the AMS <sup>14</sup>C dates and tie points.

Core ID [GeoB]	Core Depth [cm]	Lab-code	Conventional Age		2 $\sigma$ range cal. age		Median Probability	Sedimentation
			<sup>14</sup> C age [kyr]	$\pm$ error [kyr]	[kyr BP P=AD 1950]	Age [kyr BP]	Rate [cm kyr <sup>-1</sup> ]	
18131-1	3	Poz-84167	0.63	0.03	0.189	0.376	0.3	-
18131-1	168	Poz-84348	7.84	0.05	8.183	8.394	8.3	20.5
18131-1	193	Poz-84349	9.49	0.05	10.217	10.484	10.3	12.3
18131-1	198	Poz-84350	9.74	0.05	10.506	10.793	10.6	16.5
18131-1	273	Poz-84351	17.50	0.1	20.335	20.913	20.6	7.5
18131-1	363	Poz-84300	20.27	0.32	23.040	24.697	23.9	27.5
Core ID [GeoB]	Core Depth [cm]					Tie-Point Age	Sedimentation	
						[kyr BP]	Rate [cm kyr <sup>-1</sup> ]	
18131-1	423					32	7.4	
18131-1	608	Tie points to the LR04 $\delta^{18}\text{O}$ stack record (Lisiecki & Raymo, 2005)				52.5	9.0	
18131-1	708					68	6.5	
18131-1	758					80	4.2	
18131-1	768					82	3.0	
18131-1	848					110	2.9	

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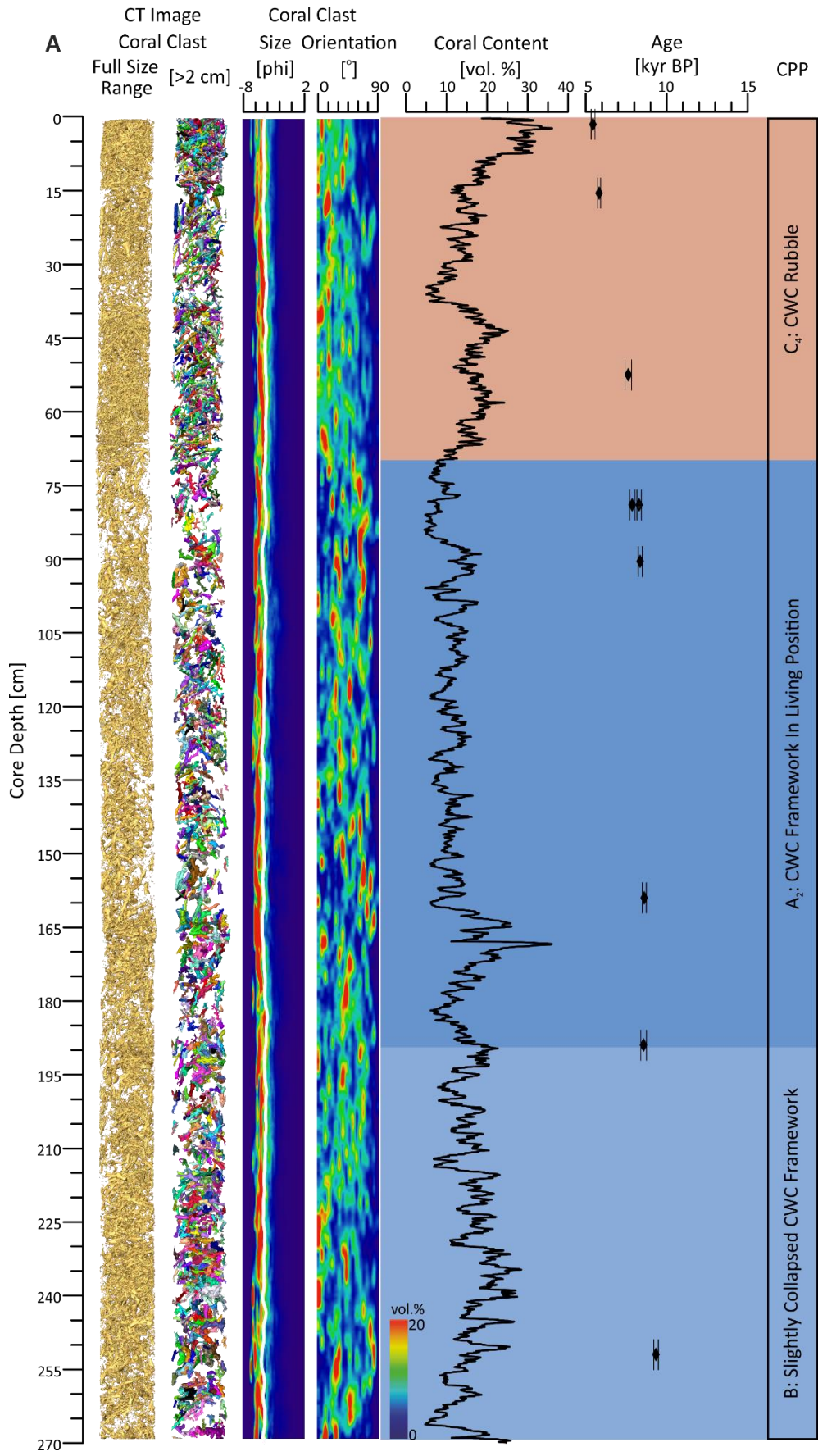


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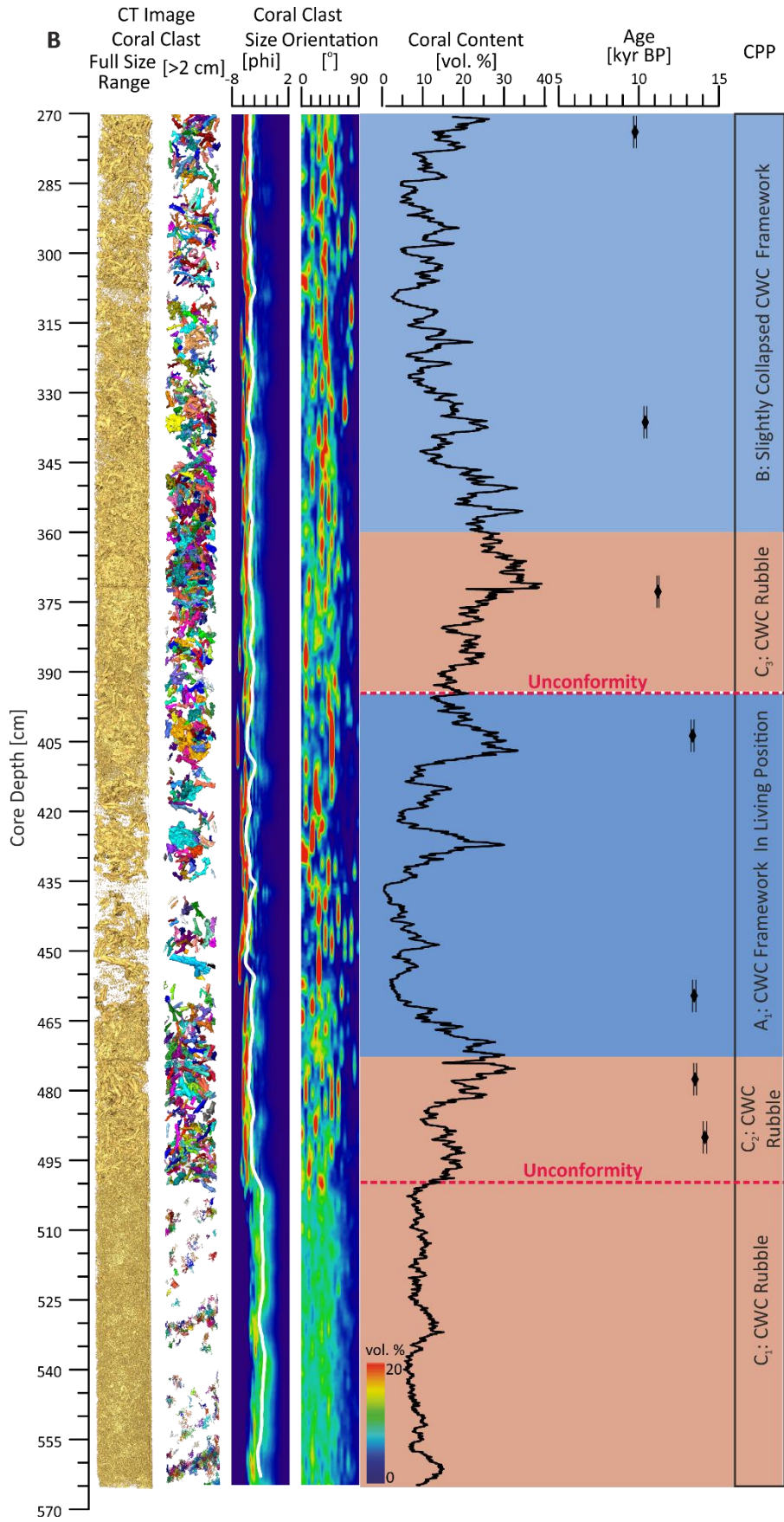
1070 **Figure 1.** (A) Bathymetry map of the Alboran Sea (western Mediterranean Sea) (Map: Marine Information Service  
 1071 (2016); EMODnet Digital Bathymetry, <http://doi.org/10.12770/c7b53704-999d-4721-b1a3-04ec60c87238>).  
 1072 Displayed is the schematic present-day oceanic circulation pattern in the Alboran Sea. Two black rectangles  
 1073 represent the West Melilla cold-water coral mound province (WMCP; this study) and the East Melilla cold-water  
 1074 coral mound province (EMCP). (B) Shaded relief map of the WMCP showing the location of the four on-mound  
 1075 cores (stars; MD13-3451G, MD13-3452G, GeoB18127-1, and GeoB18130-1) and one off-mound core (dot;  
 1076 GeoB18131-1) presented in this study. (C) Sub-bottom profile (parasound) from the WMCP (modified after  
 1077 Hebbeln et al., 2009) indicating the sampling sites of the on-mound core GeoB18130-1 and the off-mound core  
 1078 GeoB18131-1. The location of the cross profile is indicated as a red dashed line in (B).

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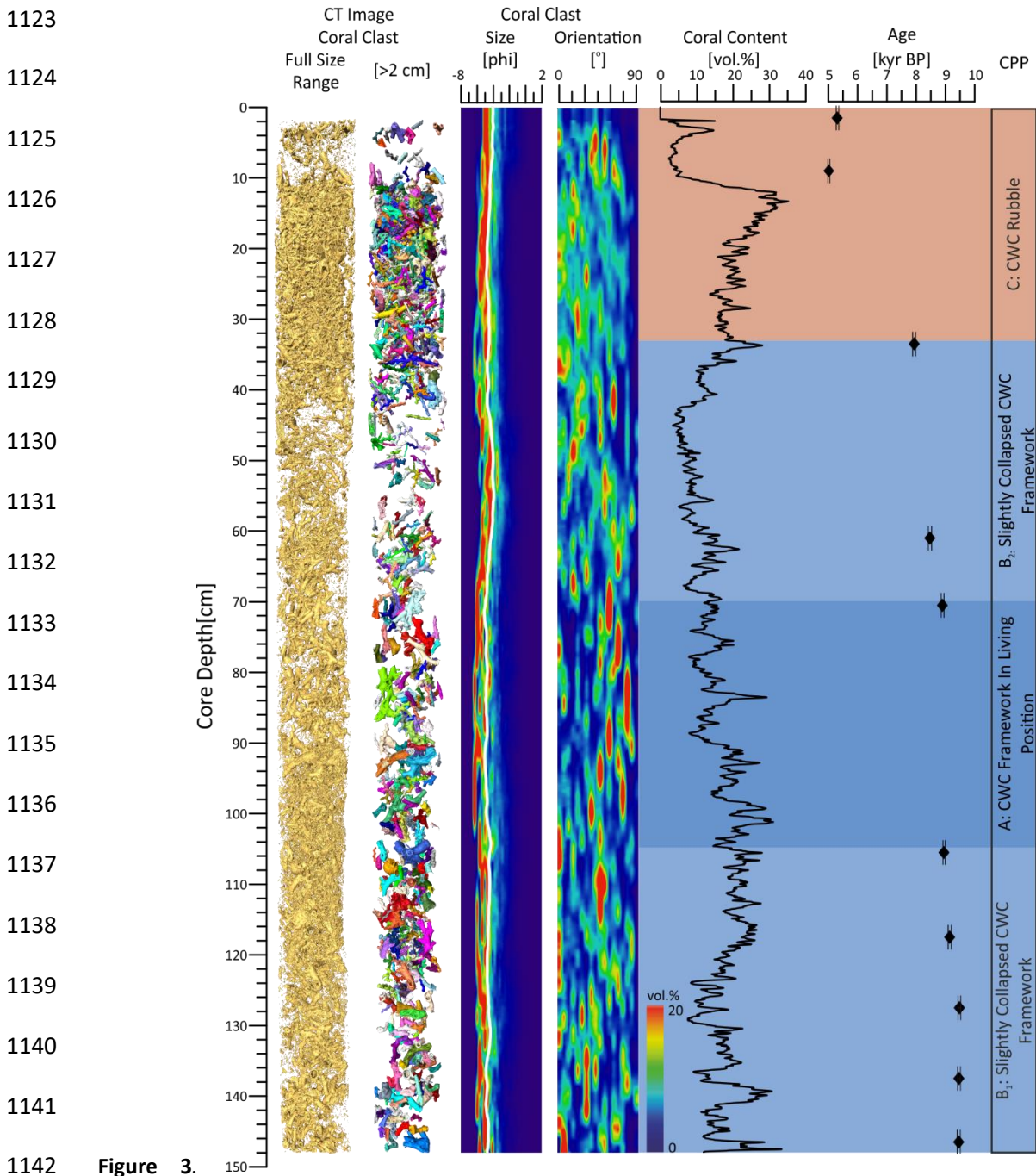


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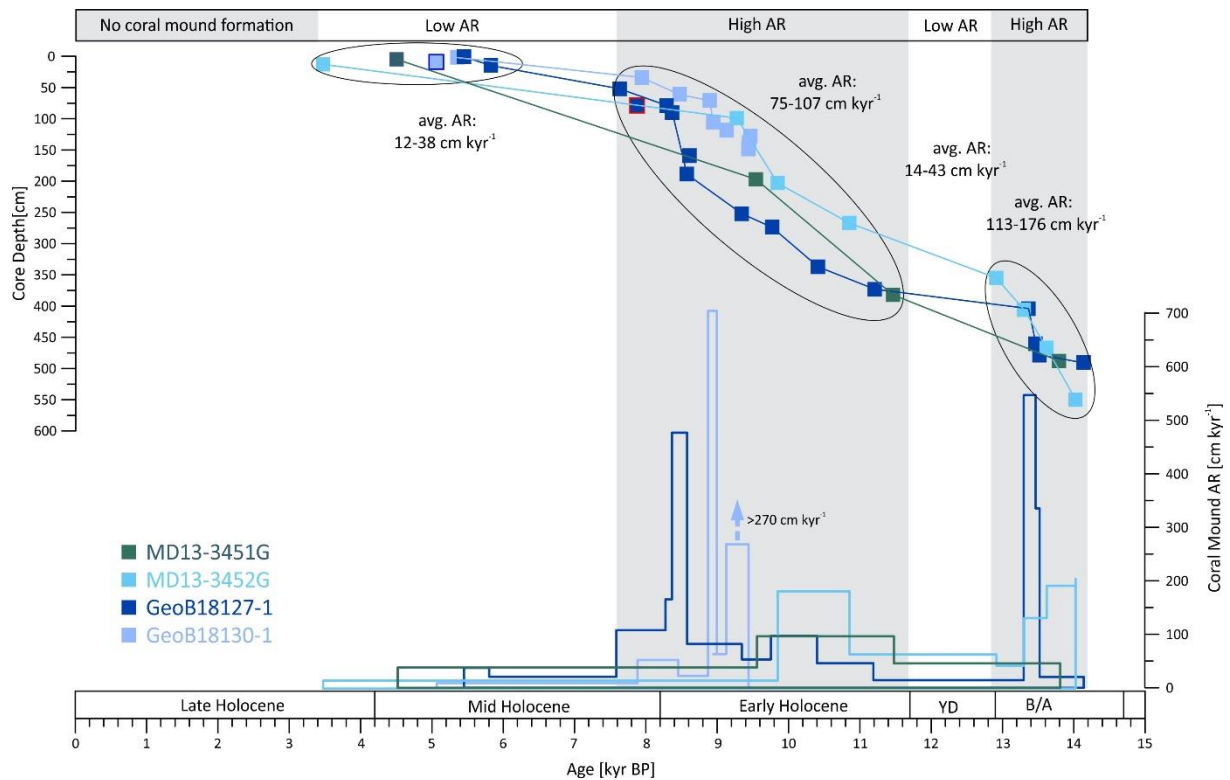
1114 **Figure 2.** Log of the on-mound core GeoB18127-1 (**A:** 0-269 cm, **B:** 270-563 cm core depth) retrieved from a coral  
1115 mound of the West Melilla cold-water coral mound province. From left to right: Core CT 3D image of coral clast  
1116 in full size range, coral clast larger than >2 cm, coral clast size distribution (white line indicates the mean clast  
1117 size), coral clast orientation, quantified coral content based on the CT data, and U-series coral ages. Three  
1118 different cold-water coral (CWC) preservation patterns (CPPs) were recognized. CPP A: CWC framework in living  
1119 position (highlighted by blue shading), CPP B: slightly collapsed CWC framework (highlighted by light blue  
1120 shading), and CPP C, CWC rubble (highlighted by light red shading). Red dashed lines represent two  
1121 unconformities identified at core depths of 500 cm and 395 cm.

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**Figure 3.** Log of the on-mound core GeoB18130-1 (0-148 cm core depth) collected from a coral mound in the West Melilla cold-water coral mound province. From left to right: Core CT 3D image of coral clast in full size range, coral clast large than >2 cm, coral clast size distribution (white line indicates the mean clast size), coral clast orientation, quantified coral content based on the CT data, and U-series coral ages. Three different cold-water coral (CWC) preservation patterns (CPPs) were recognized. CPP A: CWC framework in living position (highlighted by blue shading), CPP B: slightly collapsed CWC framework (highlighted by light blue shading), and CPP C: CWC rubble (highlighted by light red shading).

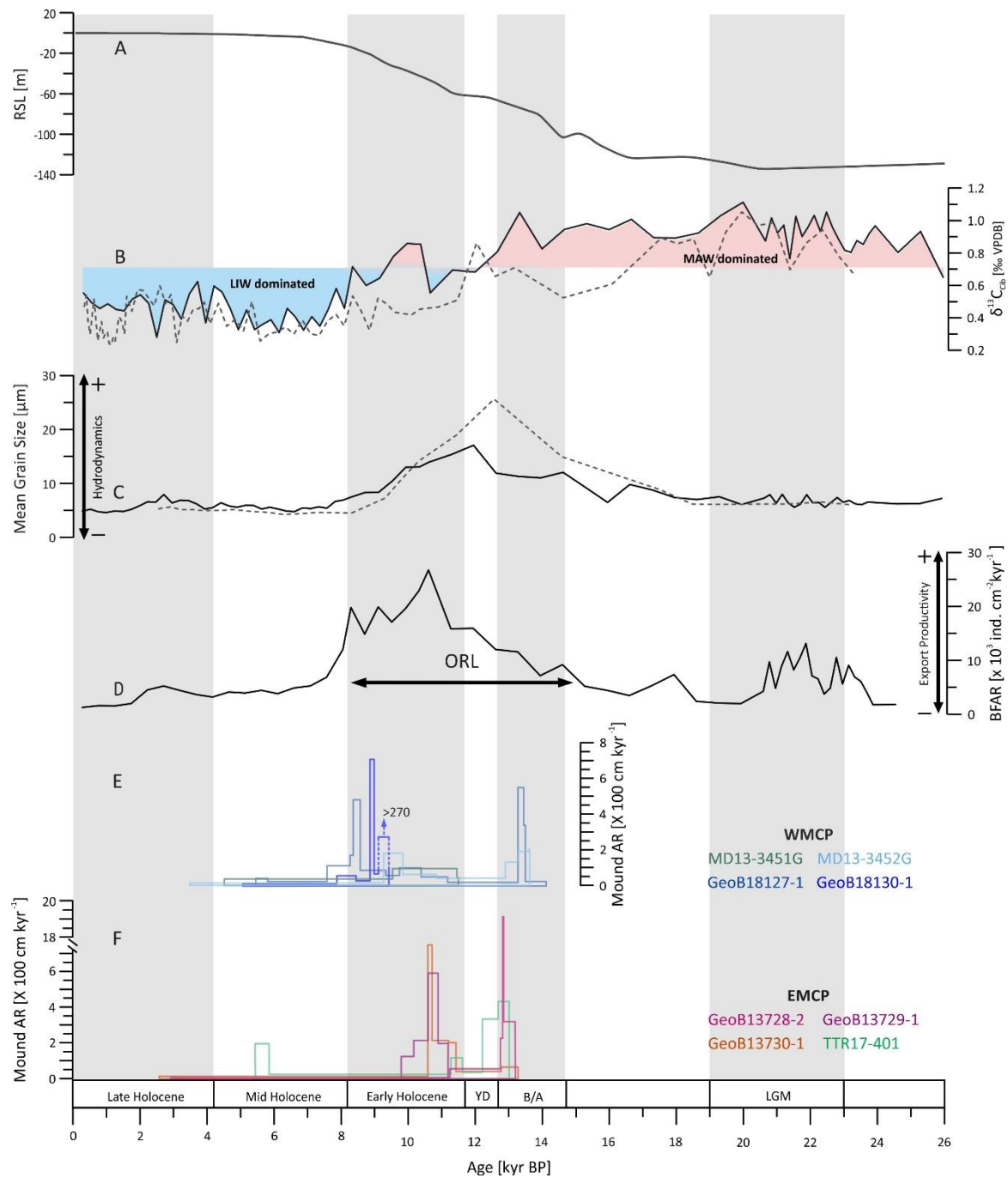
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1153 **Figure 4.** Cold-water coral (CWC) ages (filled squares) versus core depth and corresponding calculated coral  
1154 mound aggradation rates (ARs) of four on-mound cores collected in the West Melilla cold-water coral mound  
1155 province (WMCP, see legend for core-ID and color code). Filled square with blue frame indicates an age reversal  
1156 and filled square with red frame indicates an age obtained from *Madrepora oculata*, both of which were not  
1157 used for the calculation of ARs (see text for explanation). The CWC ages cluster in three periods, which mainly  
1158 correspond to the Bølling-Allerød (B/A) interstadial, the Early Holocene and the Mid Holocene (highlighted by  
1159 ovals). During the B/A and the Early Holocene, highest ARs are obtained with average (avg.) values ranging  
1160 between 75 and 176 cm kyr<sup>-1</sup>. During the Younger Dryas (YD), the avg. ARs decreased to 14-43 cm kyr<sup>-1</sup>. In the  
1161 Mid Holocene, the avg. ARs range between 12 and 38 cm kyr<sup>-1</sup>. Since the onset of the Late Holocene, mound  
1162 formation in the WMCP seems to stagnate. The B/A, the YD and the sub-periods of the Holocene are temporally  
1163 defined according to Walker et al. (2012) and Lowe et al. (2008).

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1166 **Figure 5.** Compilation of paleoceanographic multi-proxy data obtained from the off-mound core GeoB18131-1  
 1167 collected in the West Melilla cold-water coral mound province (WMCP) focusing on the past 26 kyr supplemented  
 1168 by other paleoceanographic records. **(A)** Relative Sea Level (RSL) record (Lambeck et al., 2014). **(B)**  $\delta^{13}\text{C}_{\text{Cib}}$  records  
 1169 of mixed benthic foraminifers (*Cibicidoides mundulus* and *Cibicidoides pachyderma*) obtained for the WMCP  
 1170 (black line; this study) and of *Cibicidoides kullenbergi* obtained for the East Melilla cold-water coral mound  
 1171 province (EMCP; grey dashed line; Fink et al., 2013) used as a proxy for water column structure. Pink shading  
 1172 indicates a dominance of the Modified Atlantic Water (MAW) during the last glacial, while light blue shading  
 1173 marks a dominance of the Levantine Intermediate Water (LIW) since the Mid Holocene. **(C)** Mean grain size used  
 1174 as proxy for bottom current strength (WMCP: black line, this study; EMCP: grey dashed line, Fink et al., 2013). **(D)**

1175 Benthic foraminifera accumulation rate (BFAR) record obtained from the WMCP and used as a proxy for export  
1176 productivity. (e-F) Cold-water coral mound aggradation rates (ARs) obtained from various on-mound cores  
1177 collected from (E) the WMCP (this study) and (F) the EMCP (Fink et al., 2013; Stalder et al., 2015). The Last Glacial  
1178 Maximum (LGM) and rapid events during the deglaciation (B/A: Bølling-Allerød, YD: Younger Dryas) and sub-  
1179 periods of the Holocene are temporally defined according to Walker et al. (2012) and Lowe et al. (2008). MIS:  
1180 Marine Isotope Stage.  
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1191 interface (indicated by enhanced bottom current strength) promoted increased delivery of food particles to the  
1192 CWCs. At the same time, increased sea surface productivity also contributed to the enhanced export of  
1193 particulate material. **(C)** Younger Dryas (YD): Temporary slow-down of coral mound formation despite overall  
1194 optimal environmental conditions for CWC growth. **(D)** Early Holocene to early Mid-Holocene: Enhanced coral  
1195 mound formation. Similar environmental conditions prevailed as indicated for the B/A interstadial. **(E)** Mid  
1196 Holocene: Slow-down of coral mound formation. Coral mounds became submerged by the LIW and a relatively  
1197 stable hydrodynamic setting was established. Surface and export productivity significantly decreased. **(F)** Late  
1198 Holocene until present. CWCs completely declined, mound formation stagnated and some coral mounds in the  
1199 WMCP became buried by sediments.

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