



HAL
open science

From platform top to adjacent deep sea: new source-to-sink insights into carbonate sediment production and transfer in the SW Indian Ocean 2 (Glorieuses archipelago)

Stéphan Jorry, Gwenael Jouet, Evan N. Edinger, Samuel Toucanne, J W Counts, Elda Miramontes, Simon F Courgeon, Natalia Vazquez Riveiros, P Le Roy, Gilbert Camoin

► To cite this version:

Stéphan Jorry, Gwenael Jouet, Evan N. Edinger, Samuel Toucanne, J W Counts, et al.. From platform top to adjacent deep sea: new source-to-sink insights into carbonate sediment production and transfer in the SW Indian Ocean 2 (Glorieuses archipelago). *Marine Geology*, 2020, 423, pp.106144. 10.1016/j.margeo.2020.106144 . hal-02386235

HAL Id: hal-02386235

<https://hal.science/hal-02386235v1>

Submitted on 29 Nov 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

1 From platform top to adjacent deep sea: new source-to-sink insights into 2 carbonate sediment production and transfer in the SW Indian Ocean 3 (Glorieuses archipelago) 4

5 Jorry S.J.^{1*}, Jouet G.¹, Edinger E.N.², Toucanne S.¹, Counts J.W.^{1,3}, Miramontes E.⁴,
6 Courgeon S.⁵, Vázquez Riveiros N.¹, Le Roy P.⁴, Camoin G.F.⁶

7
8 ¹ Ifremer, Unité Géosciences Marines, Technopôle la Pointe du Diable, 29280 Plouzané, France

9 ² Memorial University, Departments of Geography and Biology, St. Johns, Newfoundland, Canada

10 ³ University of College Dublin, School of Earth Sciences, Belfield, Dublin 4, Ireland

11 ⁴ Univ Brest, CNRS, IUEM, UMR 6538 Géosciences Océan, F-29290 Plouzané, France

12 ⁵ University of Geneva, Department of Earth Sciences, 13 rue des Maraichers, 1205 Geneva, Switzerland

13 ⁶ Aix Marseille Université, CNRS, IRD, Collège de France, CEREGE, Technopôle Environnement, Arbois-
14 Méditerranée BP80, 13545 Aix en Provence, France

15
16 * Corresponding author: stephan.jorry@ifremer.fr
17

18 Abstract 19

20 Over the past ten years, a huge amount of source-to-sink studies have aimed to unravel the
21 tectonic, climatic and other processes that shape the landscape from mountains to the deep
22 ocean. Interestingly, these studies have been mainly dedicated to siliciclastic or mixed
23 systems, for which the connection between drainage basins, continental shelves, slope and
24 basin environments are often well constrained. Here we present a study focusing on a source-
25 to-sink study dedicated to a pure carbonate system, located in the SW Indian Ocean
26 (Glorieuses archipelago). Extensive field sampling and geophysical acquisition across the
27 carbonate platform have allowed us to estimate the composition, the lateral variability, and
28 volumes of neritic sands deposited on the platform top. Additional seismic and bathymetric
29 surveys across the platform interior illustrate the presence of plurimetric sandy bodies
30 deposited along the leeward platform edge, corresponding to the export of carbonate
31 sediments from the platform top toward the platform edge, under the influence of dominant
32 currents and wind-driven processes. High-resolution seismic, bathymetric data and sediment
33 cores acquired along slope and basin adjacent to the carbonate platform highlight the presence
34 of channel-levee complexes and turbiditic lobes, which have accumulated on top of a 250m-
35 thick sedimentary basin at 2000-3400 m water depth. Our study points out that a half of
36 carbonate sands and aragonitic mud have been shed from the platform top to the adjacent
37 basin during the Holocene. We also demonstrate that this routing system was active at least
38 through the last three glacial/interglacial cycles. This study has important consequences for
39 our understanding of carbonate sedimentation processes occurring in the vicinity of isolated
40 carbonate platforms, and contributes to a first quantification of a carbonate source-to-sink
41 system.
42

43 1. Introduction 44

45 Other than fluvial sediment, calcium carbonate (CaCO₃) is the greatest source of sediment in
46 the present-day ocean, estimated to be about 5 bt per year, of which about 3 bt accumulate in
47 sediments, while the other 40 % is dissolved (Milliman, 1993). Therefore, the burial of
48 CaCO₃ and organic carbon in marine sediments is the largest sink for carbon from Earth's
49 surface environment (Falkowski et al., 2000; Milliman, 1993; Milliman and Droxler, 1996).
50 Unlike fluvial sediments, modern carbonates accumulate more or less equally in the neritic
51 and pelagic environments. The estimated present-day carbonate accumulation (32x10¹²

52 moles.yr⁻¹) is 1.5 times the sum of calcium influx from rivers and the amount estimated to
53 weather out of mid-ocean ridge crests (21x10¹² moles.yr⁻¹). Although this difference lies
54 within some uncertainties, the hypsometry of the ocean basins and the much greater rates of
55 production and accumulation in the neritic environment suggest that steady state is elusive
56 when sea level changes (Milliman and Droxler, 1996).

57
58 Biogenic calcification is an important process in the building of coral reefs and for the supply
59 of carbonate sands to coastal lagoons (Kangwe, 2006). The contribution of carbonates to the
60 sedimentary composition of the marine environments is particularly significant in particular in
61 the West Indian Ocean (Kangwe, 2006; Rees et al., 2005), with approximately 50 per cent of
62 all CaCO₃ stored in shallow coastal regions and continental shelves as well as in coral reef
63 environments (Andersson and Gledhill, 2013). Many studies have demonstrated that an
64 appreciable portion of neritic carbonates produced on banks and shelves (characterized by
65 rapid production of metastable aragonite and magnesian calcite) is exported to the deep sea by
66 nepheloid plumes (Wilson and Roberts, 1995) and gravity flows (Andresen et al., 2003;
67 Droxler and Schlager, 1985; Glaser and Droxler, 1993; Jorry et al., 2010, 2008; Schlager et
68 al., 1994; Webster et al., 2012). Until recently, the seismic architecture of neritic-dominated
69 carbonate basins has been largely unexplored. The first evidence came from core, logging and
70 high-resolution seismic data from ODP Leg 166 (Eberli et al., 1997a, 1997b), where Miocene-
71 Lower Pliocene calciturbidites are arranged into mounded lobes with feeder channels along
72 the Great Bahama Bank (Betzler et al., 1999). Recently, new investigations along the western
73 slope of Great Bahama Bank have pointed out notable differences when comparing carbonate
74 gravity systems to siliciclastic counterparts, which include the lack of connection with the
75 shallow bank top, the small size of the sedimentary system, and the lack of sandy turbidites
76 (Mulder et al., 2014, 2012).

77
78 A complete understanding of the production, preservation, and accumulation of neritic
79 carbonates at the scale of a carbonate platform thus necessitates investigating the entire
80 depositional system, by integrating production, transfer and storage of neritic CaCO₃ along
81 the sediment routing system. Our study presents an example of a modern carbonate source-to-
82 sink system, by investigating the platform top and the adjacent slope and basin of Glorieuses,
83 an isolated carbonate platform located in the SW Indian Ocean. The study of the entire system
84 allows us to attempt to a first quantification of sediment volume produced during the present-
85 day highstand and presently stored on the platform top, and to estimate the sediment of
86 volume exported toward the deep sea since the last reflooding of the platform. Links with
87 platform top production and sediment export and trigger mechanisms are also discussed at the
88 scale of the glacial/interglacial high-amplitude sea level fluctuations of the Late Quaternary.

90 2. Study area

91
92 Located in the volcanic axis of the Comoros, the Glorieuses archipelago developed at the top
93 of a seamount in the northern part of the Mozambique Channel, North of Madagascar and
94 North-East Mayotte (Figure 1A). The volcanic edifices of this region are interpreted as
95 resulting from the activity of a hot spot under the Somali plate (Emerick and Duncan, 1982).
96 An alternative hypothesis considers that the islands may be the product of the injection of
97 basaltic magma along old lithospheric fractures trending NW–SE related to the drift of
98 Madagascar relative to Africa (Nougier et al., 1986).

99
100 The base of the Glorieuses seamount is composed of encrusted trachy-andesite to trachyte
101 lavas (Courgeon et al., 2016). The flanks of the Glorieuses platform and the nearby areas

102 contain several flat-topped terraces and associated slope breaks ranging from 1100 m to 35 m
103 water depths, interpreted as drowned carbonate platforms, the oldest one being Paleocene in
104 age (Courgeon et al., 2016). The shallowest reef terraces located between 120m to 35m of
105 water depth have been interpreted as reflecting brief periods of extremely rapid sea-level rise
106 during the last deglaciation (Jorry et al., 2016) initiated 20,000 years ago (Blanchon and
107 Shaw, 1995; Clark et al., 2004; Deschamps et al., 2012; Hanebuth et al., 2000; Weaver et al.,
108 2003).

109
110 The Glorieuses carbonate platform is organized in distinctive morphological units, including a
111 reef flat developed along the windward side, an apron, and a semi-enclosed inner platform (up
112 to 15 m water depth; Figure 3). The composition of carbonate sediments includes *Halimeda*
113 segments, coral fragments, large benthic foraminifers, red algae, and molluscs (Jorry et al.,
114 2016). The distribution of all these fragments is controlled mainly by the location of carbonate
115 producers on the archipelago, by local hydrodynamics (tide and waves) and exceptional
116 events such as storms and cyclones which induce the reworking of sediments, and the
117 winnowing of mud (Prat et al., 2016). The development and lateral migration of the sand
118 dunes on the platform (about 43m/year toward the southwest) reveal the importance of the
119 activity of shallow currents (waves or tide) on the inner platform, despite the shelter induced
120 by the presence of the barrier reef (Prat et al., 2016).

121
122 The climate of this region is tropical and characterized by two distinct seasons. The cool
123 season, from May to November (Austral winter), is dominated by SE trade winds with daily
124 average temperatures ranging from 24.8 to 27.7 °C. The hot season, from December to April
125 (Austral summer), is influenced by the NW monsoon; daily temperatures average 28 °C and
126 the humidity ranges from 81 to 84%. At Glorieuses, the dominant trade winds blow from the
127 east during March and December, and monsoon winds come from southwest to northwest
128 during January and February (Figure 1C). Rainfall is about 110 to 210 mm per month, with a
129 maximum in January. The Glorieuses Islands are directly affected by the Northeast
130 Madagascar Current (NEMC), flowing westwards off north Madagascar. The NEMC
131 transports about 30 Sv and supplies water for the Mozambique Channel flow and the East
132 African Coastal Current (Schott et al., 2009; Swallow et al., 1988). The NEMC has a weak
133 seasonal variability (Schott et al., 2009; Schott and McCreary, 2001). (Swallow et al., 1988)
134 estimated a seasonal variation in the transport of about 2 Sv at 10-12°N, presenting the
135 highest values in August/September and the lowest in January/February.

136 137 **3. Materials and methods**

138
139 Data were collected during a set of scientific expeditions between 2011 and 2015 in
140 Glorieuses. Data from shallow areas (up to 200 m water depth) were acquired in the frame of
141 the REEFCORES (REEFs and CORals from the EparseS) program, during two cruises
142 completed in 2013 and in 2015 onboard the *Antsiva* schooner. Data concerning the slope and
143 basin adjacent to the Glorieuses platform were acquired onboard the R/V *L'Atalante* during
144 the 2014 PTOLEMEE (Jorry, 2014) and PAMELA-MOZ1 (Olu, 2014) expeditions, part of
145 the PAMELA project (PAssive Margins Exploration LAboratory).

146 147 *3.1. Oceanographic measurements*

148
149 Maximal daily velocity of the wind at 10 m above the ground were registered on the
150 Météofrance station in the Glorieuses Island (station number 98403001, 47°17'18''E
151 11°34'54''S) from January 2007 to November 2013. Wind speed and direction at sea was

152 obtained from the meteorological station onboard the *R/V L'Atalante* during the PTOLEMEE
153 survey in 2014. At the same time, current velocity data were obtained from a hull-mounted
154 ADCP (150 kHz). The ADCP data were processed using the Cascade 7.1 software (Ifremer
155 in-house software).

156

157 *3.2. Bathymetry and backscatter sonar images*

158

159 A bathymetric survey was performed in 2015 along the Glorieuses platform edge, in water
160 depths varying from 5 to 200 m. We operated a Kongsberg EM3002 multibeam echo sounder
161 (293 or 300 or 307 kHz, 160 beams, emission and reception angles of 0.5° and 1°, 50 to
162 400 ms pulse length) onboard the *Antsiva* schooner.

163

164 Multibeam surveys were conducted onboard the *R/V L'Atalante* to systematically map slope
165 and basins adjacent to the Glorieuses archipelago. The deeper seafloor data (> 1000 m) were
166 acquired with a Kongsberg EM122 multibeam echo sounder (12 kHz, 288 beams, emission
167 and reception angles of 1° and 2°, 2 or 5 or 15 ms pulse length), with automatic swath width
168 control and an equidistant sounding pattern over water depths varying from 1500 to 5000 m.
169 The shallower seafloor data (100-1000m) were acquired with a Kongsberg EM710 multibeam
170 echo sounder (70 to 110 kHz, 256 beams, emission and reception angles of 1.5°, 0.15 to 2 ms
171 pulse length), with manual swath width control over water depths varying from 200 to
172 1500 m.

173

174 Furthermore, laser bathymetry and topography (LiDAR) were available through the area
175 (Litto3D® database). The LiDAR acquisition was published in 2012
176 (<https://diffusion.shom.fr/pro/risques/altimetrie-littorale/litto3d-eparses2012.html>) by the
177 French Institut Geographique National (IGN) and Service Hydrographique et
178 Oceanographique de la Marine (SHOM). Bathymetric and topographic LiDAR allowed metric
179 accuracy on the plane and decimetric precision of heights and depths.

180

181 *3.3. Seismic acquisition*

182

183 A Sparker Source, a single-channel SIG streamer and a numerical DELPH acquisition system
184 were used to acquire about 250 km of high-resolution seismic profiles in shallow waters
185 (<200m water depth). The sparker emission energy ranges from 25 to 160 J, the shooting rate
186 was 250 ms and the vessel bottom speed was 4 to 5 knots. Raw data were processed using
187 Delph Interpretation (developed by iXBlue). Interpretation of seismic lines was conducted
188 using Kingdom Suite software (HIS Markit). Seismic lines are displayed with two-way travel
189 time in ms. Time–depth conversions have been made assuming an average velocity of 1800
190 m/s for unconsolidated sediments. The signal penetration is satisfactory in lagoonal
191 sediments, although the attenuation of the high-resolution signal is significant beneath the
192 high amplitude reflectors that correspond to reefal substrates, and amplifies the seabed
193 multiple reflector in shallow water. These limitations prevent the examination of inner reefal
194 structures and the lower part of seismic records.

195

196 Seismic lines along slope and basin (areas deeper than 200 m) were collected using the
197 seismic acquisition system SEAL (Sercel, Ifremer). Multichannel seismic data were acquired
198 at 10 knots using a short (600 m) streamer (24 traces of 12.5 meters group length each)
199 without any active depth controller or buoy, and two sub-arrays of a single GI air gun each
200 which were towed at 6 meters depth using tow fishes. Fast seismic processing consisted of a
201 basic trace stacking and migration at constant velocity (1500 m/s).

202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251

3.4. Sediment cores

Four sediment cores (RC-GLO-C024/C025/C029/C030) were collected on top of the Glorieuses platform in intertidal zones (see locations on Figure 1 and Figure 3), using a 1-m-long hand corer. Physical properties (which includes the gamma density) and X-Ray images were measured by using a Multi-Sensor Core Logger and a X-CT Scan, respectively, both manufactured by Geotek. Two piston cores (MOZ1-KS04 and MOZ1-KS07) were collected in the Glorieuses basin using a Kullenberg corer system (see location on Figure 1). Physical properties and X-ray computed tomography were acquired following the same process as for the platform cores. A sedimentological description of all cores has been done during the postcruise sampling, and main types of sediments and sedimentary structures were differentiated.

The stratigraphy of the two basin cores was established thanks to oxygen isotopes measured on batches of several specimens of *Globigerinoides ruber*. Samples were collected in layers composed of pelagic periplatform carbonate, purposely excluding turbidites. On average, 10 to 15 specimens were picked from the >250 mm fraction. Analyses were performed with a Thermo MAT253 Mass Spectrometer, operated by Pôle Spectrométrie Océan (PSO), located at the Institut Universitaire Européen de la Mer (IUEM / UBO), Plouzané, France. Isotopic data are reported in the conventional δ notation relative to VSMOW for $\delta^{18}\text{O}$. The repetition of 10 measurements of a calcite working standard gave a precision (1σ) lower than 0.2‰ for $\delta^{18}\text{O}$.

Nine radiocarbon dates were also obtained from the upper parts of the deep basin cores. For each AMS dating, approximately 500 specimens of *G. ruber* were picked from the >250 μm fraction, washed in an ultrasonic bath with distilled water, and dried. These aliquots were analyzed by Beta Analytic Limited. Reported radiocarbon ages (Table 1) have been calibrated using the Marine13 radiocarbon age calibration curve (Reimer et al., 2013).

Variation in Strontium (Sr) content was measured by a X-Ray fluorescence core scanner (XRF-CS). The Sr XRF-CS profile was quantified using Wavelength Dispersive X-ray Fluorescence (WD-XRF) measurements of sediments collected along core MOZ1-KS04, and the aragonite percentage was determined by X-ray diffraction (XRD). Aragonite fluxes were calculated in order to estimate the contribution of platform top-derived fine sediments in the deep adjacent basin. The aragonite fluxes (AF; $\text{g}\cdot\text{cm}^{-2}\cdot\text{kyr}^{-1}$) at site MOZ1-KS04 were quantified according to the following formula: $\text{AF} = \text{LSR} \times \text{DBD} \times (\% \text{ aragonite})$, with LSR: Linear Sedimentation Rate ($\text{cm}\cdot\text{kyr}^{-1}$) and DBD: Dry Bulk Density ($\text{g}\cdot\text{cm}^{-3}$).

3.5. Estimating platform top sedimentary facies distribution

The distribution of sedimentary facies on the platform top was mapped using a combination of the satellite images and direct observations of bottom type and biota (including 138 sediment samples collected with box corer), as previously documented in detail by Prat et al. (2016).

3.6. Estimating Recent and Holocene carbonate production

In order to estimate the total volume and mass of calcium carbonate produced on the Glorieuses platform through the Holocene, we combined the volume of sediment preserved in

252 the Holocene sand bodies on the platform with the volume of sediment represented in the
253 submarine fans draining the platform to the northwest.

254
255 The area and volume of the carbonate sand bodies on the platform top were estimated using
256 the 2D shallow seismic profiles. Enough profiles along and across the sand bodies were
257 collected to allow estimation of the volume of the sandy isopach.

258
259 The area of the submarine fans draining the rise of the Glorieuses seamount was estimated
260 from multibeam bathymetry, backscatter and seismic profiling. The thickness of Holocene
261 sands and muds was based on the average thickness of sand and mud facies within the two
262 cores, which has accumulated since the earliest Holocene (radiocarbon dates of 10.9 ka cal BP
263 in MOZ1-KS04, 10.5 ka cal BP in MOZ1-KS07; Table 1).

264
265 In order to compare the volume of sediment produced on the Glorieuses platform with
266 regional and global carbonate production estimates, we converted volumes to mass via the
267 gamma ray measured bulk density (from MSCL acquisition) of sand and mud facies within
268 sediment cores. We used the four gravity cores collected through the sand bodies atop the
269 Glorieuses platform to estimate density of the platform-top sand bodies. Gamma ray density
270 measurements of these four cores were used to convert the volume of carbonate sand in these
271 sand bodies into a total mass of calcium carbonate. Bulk density of sandy calciturbidites and
272 muddy intervals within the two deep basin cores were measured separately.

273

274 **4. Results**

275

276 *4.1. Oceanography*

277

278 Hull mounted ADCP data acquired in September 2014 (during the period of highest transport
279 according to Swallow et al., 1988) show mainly a NW-W direction of the surface currents (at
280 60-150 m water depth). Current velocity is very high, reaching up to $150 \text{ m}\cdot\text{s}^{-1}$ at the north of
281 the island and $80\text{-}90 \text{ cm}\cdot\text{s}^{-1}$ at the northern and southern flanks of the island (Figure 2A).
282 These values are in agreement with the measured and simulated magnitude of the NEMC of
283 around $100 \text{ cm}\cdot\text{s}^{-1}$ (Jose et al., 2016; Schott and McCreary, 2001). In contrast, currents are
284 slower at the western flank of the island ranging between 20 and $40 \text{ m}\cdot\text{s}^{-1}$ (Figure 2A). Wind
285 data acquired onboard at the same time show that the winds around the Glorieuses Island
286 present mainly an easterly component (Figure 2B), in concordance with the measurements
287 from the station on the island (Figure 1C). In the Glorieuses Island the dominant wind is from
288 the east, although there are some periods of opposing wind (from SW, W and NW), especially
289 during the rainy season (December to April) (Figure 1C). The wind and current directions are
290 coherent with the sediment plume extending from the western part of the island observed
291 from a satellite image (Figure 2C). The strong east winds may favour the export of fine
292 sediment through the western part of the island. Moreover, currents in the same direction may
293 also transport the sediment westwards; sediment would be concentrated along the west side of
294 the island, where the currents are the lowest (Figure 2A).

295

296 *4.2. Sediment distribution on Glorieuses platform top*

297

298 The Glorieuses platform exhibits several facies areas including islands, the reef flat, the reef
299 front, the apron, a shallow and a deep inner platform, and the fore-reef (Table 2). Sediments
300 on Glorieuses platform top, dominated by *Halimeda* fragments (Jorry et al., 2016), are mainly
301 derived from typical tropical carbonate producers such as corals, large benthic foraminifers,

302 *Halimeda*, and molluscs. These sediments accumulate on three main localities: the back reef
303 (including a sand apron), the leeward platform edge, and at the northeastern edge of the
304 platform where carbonate sands are deposited on top of successive submarine terraces (Figure
305 3).

306
307 Two main seismic sequences can be identified on seismic profiles: a lower sequence
308 characterized by chaotic seismic facies interpreted as an old reef substrate, and an upper
309 sequence showing stratified seismic facies, interpreted as uncemented sands deposited since
310 the last reflooding of the platform top and mostly during the Holocene (Figure 4).

311
312 Sand dunes form a large sand apron beside the reef flat. The sand dunes are sub-parallel
313 bodies, 1.5 m high on average and are oriented SW–NE. They are less than 100 m wide, and
314 their length ranges from 500 to 600 m; the top of the sand dunes is on average 0.2 to 1 m deep
315 at low tide. The general morphology of sand dunes is characterized by a gentle southeast
316 (seaward) flank and a steeper face to the northwest (bankward). This morphology is
317 seemingly influenced by E–W currents, whereas the intertidal and deeper sand dunes on the
318 inner platform are probably shaped by NW–SE currents. The migration of intertidal sand
319 dunes has been estimated at about 43 m/year, with a significant migration observed towards
320 the south/southwest, increasing in the same direction over several years (2004 to 2009, after
321 Prat et al., 2016). Based on seismic profiles, the overall sediment accumulation on the back
322 reef is approximately 15 m thick, few hundreds of meters off the sand apron. It shows some
323 progradation toward the platform interior with a decreasing thickness, before completely
324 disappearing 8 km from the reef flat (Figure 4A and Figure 4B).

325
326 Sediments that have accumulated along the leeward edge of the platform form large
327 subaqueous dunes, in 40 - 60 m water depth (Figure 1E). These dunes are elongated (5 to 16
328 km-long) sand bodies of about 5 to 20 m-thick, showing some plurimetric prograding sets
329 separated by erosional surfaces (Figure 4C and Figure 4D). They are lying on a seismic unit
330 characterized by chaotic seismic reflections and incisions. This unit is interpreted as an old
331 reef sequence, whose irregular top probably results from erosion during past sea level
332 lowstands. Three radiocarbon dates have been performed on monospecific assemblage of
333 large benthic foraminifera (*Amphistegina lessonii*) which have been picked in sediments
334 collected on top of these bodies (Sample RC-GLO-B248, Table 1, location on Figure 3A).
335 These samples give ages ranging from 630 to 1170 cal BP, attesting that the feeding of these
336 bodies was active during the late Holocene. Taking into account observations on the
337 displacement of sand dunes at present-day (Prat et al., 2016), we assume that the deposition of
338 carbonate sands along the leeward platform edge is probably still active at present.

339
340 The deposition of carbonate sands is also observed on top of submerged terraces located at the
341 north-eastern edge of the Glorieuses platform, those terraces having been interpreted as the
342 imprint of the last deglacial sea-level rise (Jorry et al., 2016). Sands are preferentially
343 accumulated on the largest (4 to 5 km-wide) terrace located at 35m water depth, forming an 8
344 m-thick horizontally stratified sand sheet (Figure 4E and Figure 4F).

345
346 Based on the seismic interpretation and geomorphological observations, the volume of
347 sediments accumulated on the Glorieuses platform top (which represents a surface of about
348 188 km², with 80% of the area ranging between 0 and 20 m of water depth) has been
349 estimated at about 0.3 km³ (Table 3). A significant amount of sands appears preferentially
350 accumulated and stored along the leeward platform edge, forming thick elongated carbonate
351 sand dunes. Taking into account that the main carbonate productivity occurs in the inner

352 platform and the reef flat, we interpret these dunes as the result of transportation of sediment
353 mainly from the back-reef apron, where sand dunes migrate towards the south/southwest with
354 a possible outlet located at the northwest of main island, i.e. Grande Glorieuse (Prat et al.,
355 2016). The storage of carbonate sands along the leeward platform edge is also in agreement
356 with reduced current and wind effects measured at this location (Figure 2).

357

358 4.3. Sediment accumulation along the Glorieuses slope and adjacent basin

359

360 Bathymetry acquired offshore the Glorieuses archipelago revealed the presence of a steep
361 slope (about 45°) with lineaments, probably volcanic in origin (Figure 1B). Some incisions
362 are observed, but these do not connect to the platform top, originating instead from the
363 smooth, steeper upper platform slope. The floor of these incised channel features is generally
364 flat, lacking a thalweg, and seem to collect platform-derived sediments delivered to the upper
365 slope / platform edge transition (Figure 1D). The increased backscatter seen in these channels
366 indicates that sediment within channel margins is probably coarser-grained than that
367 surrounding it. The basin, in approximately 3700 m water depth, shows some lobe-shaped
368 sedimentary accumulations and channels imprinted on the sea floor, at the base of the
369 leeward-platform slope (Counts et al., 2018) (Figure 1B). All these accumulations are typified
370 by a basin extent of 35 to 50 km maximum. Sediments accumulated in the deep basin are
371 characterized by the stacking of thick (up to 450 ms TWT, i.e ~ 250 m-thick) seismic bodies,
372 which together rest on a volcanic substrate (Counts et al., 2018) (Figure 5). The upper 200 ms
373 show some seismic units composed of amalgamated erosive features, interpreted as channel-
374 levees systems and turbiditic lobes, and chaotically bedded debris flows (Counts et al., 2018).
375 Based on seismic data, Counts et al. (2018) also interpreted some of these uppermost
376 sedimentary deposits as depositional thrusts resulting from downslope mass movement of
377 slope sediments. Undulating surface features seen on the proximal basin floor may be the
378 surface expression of these thrusts, but may also be sediment waves.

379

380 Two sediment cores were collected in the deep basin adjacent to the Glorieuses platform.
381 MOZ1-KS04 was collected in 3167 m water depth along a channel levee system, and core
382 MOZ1-KS07 was retrieved from 3751 m water depth on a distal lobe (Figure 1B). Analysis
383 and description of both sediment cores shows bundled calciturbidites and carbonate mud
384 (Figure 6A and Figure 6B). The calciturbidites form centimeter to decimeter well-laminated
385 and normally graded beds, with erosive bases (Figure 6C and Figure 6D). They represent
386 6.5% (73 cm) and 20% (146 cm) of the total sediment composition, in core MOZ1-KS07 and
387 core MOZ1-KS04, respectively, the remaining content being composed of carbonate mud
388 (containing 25% aragonite on average). While calciturbidites appear more abundant in core
389 MOZ1-KS04 than in core MOZ1-KS07, we noted that the composition of the calciturbidites
390 of both sediment cores is very similar to coarse carbonate sands collected on the platform
391 tops, including coral, *Halimeda* and mollusc fragments, as well as well-preserved large
392 benthic foraminifera tests (Figure 6E and Figure 6F).

393

394 We also noted that the Sr signal is different between the two sediment cores (Figure 6A and
395 Figure 6B), with Sr concentrations much higher in the proximal core MOZ1-KS04 than in the
396 distal core MOZ1-KS07. Sr peaks are correlated with the presence of calciturbidites in both
397 cores, while some progressive downcore enrichment in the Sr content observed also in
398 hemipelagic layers in core MOZ1-KS04, between 0 and 450 cm core depth. By measuring the
399 aragonite percentage and the Sr abundances along core MOZ1-KS04, it can be demonstrated
400 that Sr variations (at least in hemipelagic sediments) are mainly driven by the aragonite
401 composition of sediments (which ranges between 3% and 44%). Therefore, we can consider

402 the XRF Sr variation as a proxy to estimate the relative concentration in aragonite of basin
403 sediments (Figure 7).

404

405 According to the extent of lobes and channel-levee complexes that can be seen in the basin
406 adjacent to the leeward-platform slope (Figure 1B), the depositional area in the deep basin
407 approximates 600 km² in Glorieuses (Table 3). It is bounded at its northeastern extremity by a
408 volcanic ridge about 1 km high, which may act as a topographic barrier for gravity flows
409 coming from the platform top.

410

411 *4.4. Estimate of the carbonate routing system since the last reflooding of the Glorieuses*
412 *platform*

413

414 Age models have been established on the two sediment cores using $\delta^{18}\text{O}$ isotope stratigraphy.
415 Core MOZ1-KS04 displays a 250 kyr record, and MOZ1-KS07 core goes back to 350 ka (see
416 **Figure 10**). For the two cores, fluctuations of the $\delta^{18}\text{O}$ are in agreement with the well-
417 established global sea level changes. Based on the nature of the deposits observed at the two
418 core sites in the basin, two main processes at the origin of sediment transfer from the platform
419 top toward the basin can be invoked: neritic carbonate sands have been transferred downslope
420 by turbidity currents, and aragonitic mud has been winnowed from the platform under the
421 action of currents and dominant wind and deposited by settling through the water column (c.f.
422 Counts et al., 2019). Considering that the mean depth of the modern Glorieuses platform edge
423 is located at -60m, we tried to estimate the carbonate budget of the entire platform/basin
424 system since the latest deglacial sea level rise, when the Glorieuses platform was flooded and
425 started to produce carbonate sediments (Table 3).

426

427 The average bulk density of sand and mud facies within the deep basin cores is 1.590 g/cm³.
428 The two cores have considerable differences in density properties, with proximal core MOZ1-
429 KS04 displaying much greater variation in density, and much higher density of sand layers
430 than in mud layers, particularly in the lower 1/3 of the core (Figure 9A). In order to estimate
431 the density of sediments exported since the Holocene transgression, we measured the bulk
432 density of sandy and muddy facies within each core from the Last Glacial Maximum to the
433 present (18.6 ka in core MOZ1-KS04; 19.1 ka in core MOZ1-KS07); the age range was
434 extended to LGM for both cores to ensure that both sandy and muddy facies since the
435 Holocene transgression were represented, and because linear sediment accumulation curves
436 cannot be assumed based upon the core age model. The average density of post-LGM sand
437 bodies was 1.640 ± 0.086 , while the average density of muds was 1.655 ± 0.045 . Surprisingly,
438 the bulk density of muds in the proximal core, MOZ1-KS04, was greater than that in the distal
439 core (1.851 ± 0.047 , 1.501 ± 0.018 , respectively). This difference may be attributable to a
440 larger grain size in the proximal core, in which muds are dominantly silty in its upper 1m, as
441 opposed to dominantly clay muds in the distal core.

442

443 Based on age models from sediment cores collected in the deep-basin, it appears that 23 cm
444 on average of neritic carbonate sands have been exported from the platform top since its last
445 reflooding, i.e. 25% of the total sediment deposited in the deep basin (Table 3). To estimate
446 the portion of carbonate muds derived from the local platform, we used the % aragonite
447 values within the muddy portions of the deep basin cores, noting that most tropical pelagic
448 carbonates in the region are calcitic (e.g. coccolithophores, planktonic foraminifera), while
449 carbonate muds derived from the platform are almost exclusively aragonitic, being composed
450 primarily of fine bioclasts of Scleractinian corals, *Halimeda*, benthic foraminifera, and
451 mollusc shells, much like the neritic carbonate sands (Jorry et al., 2016). Calciturbidite lobes

452 and channels cover an area of about 600 km²; we estimate that about 0.55 km³ of carbonate
453 sediments have been deposited in the deep basin during the last 10 kyr, including 0.14 km³ of
454 neritic sands transferred by turbidity currents and 0.13 km³ of aragonitic muds, the latter
455 being winnowed from the platform top and settled down through the water column (Table 3).
456 Our data from sediment cores suggest that the aragonite represents 32% of the fine sediments
457 deposited during the last 10 kyr (Figure 7), with aragonite percentage decreasing offshore
458 with water depth.

459
460 To explain the preservation of well-laminated calciturbidite beds (Figure 6C and Figure 6D),
461 we suggest that turbidity currents might have also incorporated some mud, which would
462 favour the occurrence of wavy and planar laminations (Figure 6C and Figure 6D). We also
463 suggest that turbidity currents originating from carbonate slopes might have a low transport
464 capacity, explaining the relatively short distance of propagation on the Glorieuses abyssal
465 plain (less than 50 km).

466
467 Based on these estimates, we may conclude that the average carbonate production of the
468 Glorieuses platform since the last reflooding can be estimated at about 0.57 km³. This volume
469 includes 0.3 km³ of neritic sands which are still presently stored on the platform top, and 0.27
470 km³ of carbonate sand and mud exported to the basin. The estimated volume of carbonate
471 muds exported from the platform is a minimum estimate, based on the area of deposition
472 within the sediment lobes and fans mapped. Carbonate mud winnowed from the platform and
473 exported in other directions has not been estimated. Thus we may infer that at least half of the
474 sediments produced on the Glorieuses platform during the last 10 kyr have been reworked and
475 transported onto the slopes or into the proximal basin (Figure 9).

476 477 *4.5. Comparison with regional and global carbonate production estimates*

478
479 The validity of these carbonate production estimates was tested by comparing them with
480 various global and regional production estimates produced by a variety of methods. Three
481 global tropical reef carbonate production estimates (Kleypas, 1997; Milliman, 1993; Vecsei,
482 2004) were applied to the Glorieuses example by calculating the average annual production
483 rate per km², and applying this to the marine area of the Glorieuses platform (183 km², Table
484 3). In addition, three regional production estimates from the Torres Straits (Leon &
485 Woodroffe 2013) the central Great Barrier reef (Hamyton et al., 2017) the Indian Ocean
486 (Perry et al., 2015) were considered, and the % of estimated production was calculated
487 relative to the global estimate (Table 4). For the Torres Strait example, which represents a
488 mesotidal to macrotidal environment similar to Glorieuses, only the crescentic reefs were
489 considered, as this was the reef morphology most similar in shape to the Glorieuses platform.
490 Average Holocene annual carbonate production estimates for the Glorieuses archipelago
491 ($9.26 \cdot 10^8$ mol) were 13-33% of the carbonate production estimated from regional or global
492 average carbonate per km² production rates.

493
494

495 **5. Discussion**

496
497
498

497 *5.1. Lessons from past interglacials in the Glorieuses basin*

499 By comparing records of the two sediment cores, the number of turbidites deposited in the
500 Glorieuses basin appears to be greater during interglacial periods when sea level rose above -
501 60 m of water depth, which corresponds to the mean depth of the present-day Glorieuses

502 platform edge (Figure 10D and Figure 10E). During these periods, the deposition of turbidites
503 seems to be preferentially preserved in the proximal basin (i.e. location of core MOZ1-KS04,
504 where 126 cm of carbonate sands have been accumulated). The thickest accumulation of
505 turbidites during these periods (sea level above -60 m) occurred during MIS7 on both cores
506 (Figure 10D and Figure 10E). In addition, the increase of aragonite flux observed at core
507 MOZ1-KS04 (Figure 10A) when sea level rose above -60 m is consistent with the highstand
508 shedding model. According to this model, when the platform is flooded, excess sediment
509 produced on the platform top is exported to the adjacent deep sea (Counts et al., 2019;
510 Droxler and Schlager, 1985; Glaser and Droxler, 1993; Jorry et al., 2010; Schlager et al.,
511 1994).

512
513 The difference in turbidite frequency in each core indicates that individual turbidite events do
514 not result in deposits that cover the entire proximal basin floor on the north western side of the
515 platform. However, except for MIS7, flooding of the Glorieuses platform at the beginning of
516 each interglacial, was apparently marked by systematic and sudden increases of aragonite
517 fluxes on core MOZ1-KS04 (Figure 10A). Increased aragonite flux appears decisive for
518 calciturbidite deposition in the adjacent basin, as reported for several examples described in
519 worldwide carbonate basins (Andresen et al., 2003; Webster et al., 2012). For MIS7, there has
520 been considerable ambiguity regarding the relative heights of the three highstands, namely
521 MIS7a, MIS7c and MIS7e. Sea levels estimated from reconstructions based in whole or part
522 on benthic oxygen isotope ($\delta^{18}\text{O}$) data (Bintanja et al., 2005; Lisiecki and Raymo, 2005;
523 Waelbroeck et al., 2002) predict similar peak sea level at, near, or just below that of the
524 present day, whereas some sea-level curves based on other proxies indicate a lower elevation
525 for MIS 7c, near -18m (Dutton et al., 2009; Lea et al., 2002; Siddall et al., 2003).
526 Interestingly, our data show that turbidite deposition thickness was much higher during MIS7
527 than for any other interglacials in the Glorieuses basin (Figure 10D and Figure 10E). This
528 could be explained by a sea level which persisted at a level between 0 and -60 m for a long
529 time (Bintanja et al., 2005; Dutton et al., 2009; Lea et al., 2002; Thompson and Goldstein,
530 2005; Waelbroeck et al., 2002). The absence of calciturbidites during the last interglacial
531 (MIS 5e) is also noted on both cores. Considering that sea level rose at +5 to +8m above
532 modern sea level during MIS5e (Dutton and Lambeck, 2012; Lambeck and Chappell, 2001),
533 it might suggest that the Glorieuses platform was totally submerged, increasing the potential
534 area for sediment storage by 15% ($\pm 46 \text{ km}^2$) due to the drowning of the modern reef flat and
535 exposed islands. The earliest calciturbidites of the last interglacial occurred during the sea
536 level drop subsequent to MIS5e, and during the following MIS5c and MIS5a highstands,
537 when sea level fluctuated between 0 and -40 m.

538
539 The relatively high number of calciturbidites deposited during MIS6 at both sites suggest that
540 reworking processes along the carbonate slope might have occurred during lower sea levels
541 (corresponding to periods when sea level was stagnated between 60 and 100 m water depth).
542 This interpretation is reinforced by the presence of sediments that presently drape the
543 upslope of Glorieuses during the modern highstand (Figure 1D and Figure 3). All these
544 observations demonstrate that the topography of carbonate platform edges and leeward slopes
545 is playing an important role by storing sediment that might be initially shed during
546 highstands, which is then re-mobilized during lowstands and deposited as calciturbidites.

547
548 Because hemipelagic sediments of core MOZ1-KS07 exhibit some relatively low Sr
549 concentrations, we infer that the flushing of aragonitic mud from the platform top was limited
550 in how far it could travel offshore in suspension to about 30km maximum, as observed in the
551 present day where this process seems to be mainly influenced by dominant winds coming

552 from the east (Figure 2C). Another explanation for the low Sr counts in MOZ4-KS07 may be
553 related to the greater depth of this core (3751 m water depth) compared to MOZ1-KS04 (3167
554 m water depth), as the dissolution of aragonite occurs more readily at greater depths. At the
555 present time the carbonate compensation depth (CCD) in the Indian Ocean occurs at
556 approximately 5000 meters of water depth, assuming that the Somali Basin is a typical
557 equatorial area with no significant dilutions by terrigenous debris (Kolla et al., 1976). Because
558 aragonite is more soluble than calcite, its compensation depth is generally considered as
559 shallower than for the calcite. In the Mozambique Channel, some aragonite dissolution has
560 been previously documented in the basin adjacent to Juan de Nova island (at about 1900 m
561 water depth), in the form of pitting on the surface of aragonite needles (Counts et al., 2019).

562

563 5.2. Implications for modern and ancient counterparts

564

565 Carbonate production by coral reefs located throughout the tropical and sub-tropical oceans is
566 an important component of the global carbon cycle (Vecsei, 2004). Global estimates are
567 dependent on up-scaling from a small number of individual coral reef studies that represent
568 limited coverage of the world's reefs. At the reef platform scale, carbonate production
569 estimates are also of critical importance in understanding the geological and geomorphic
570 development of coral reefs and islands. Furthermore, carbonate production by primary frame
571 builders and secondary benthic organisms, along with mechanical and biological erosion,
572 control the generation of detrital sediment on reef platforms, sediment which is subsequently
573 follows one or more of several possible pathways: reincorporation into reef framework
574 (Hubbard et al., 1990), storage on reef surfaces, transportation off-reef (Hughes, 1999; Jorry
575 et al., 2010, 2008; Webster et al., 2012), transferred to infill lagoons (Kench, 1998; Macintyre
576 et al., 1987; Purdy and Gischler, 2005) or transfer landward to build islands (Hopley, 1982;
577 Maragos et al., 1973; Woodroffe and Grime, 1999; Yamano et al., 2002, 2000). For the
578 Glorieuses, the carbonate productivity initiated by reef corals, *Halimeda*, benthic
579 foraminifera, and other reef-dwelling benthic organisms, since the last transgression at least,
580 contributes actively to the general evolution of the platform, at least since the last
581 transgression. Detrital carbonate sediments are mainly stored on the platform top and along
582 the leeward edge, and exported downslope. Our study can be compared to previous estimates
583 of carbonate production on coral reefs and carbonate platforms (Table 4). The annual CaCO_3
584 carbonate production of the Glorieuses platform approximates $9.27 \cdot 10^8 \text{ mol.km}^{-2}$ Compared
585 with the global CaCO_3 production of coral reefs in the world oceans (i.e. $9 \cdot 10^{12} \text{ mol.yr}^{-1}$ for
586 an area of about $6 \cdot 10^5 \text{ km}^2$ (Milliman, 1993), i.e. $27.5 \cdot 10^8 \text{ mol.yr}^{-1}$ for a carbonate platform of
587 about 188 km^2), the estimated carbonate production rates at Glorieuses are of comparable
588 order of magnitude, but somewhat lower than predicted (Table 4).

589

590 The Glorieuses carbonate platform appears to produce carbonate sediments at 25-60% of most
591 regional and global carbonate production rate estimates. The net carbonate production rate for
592 the Chagos archipelago (pre-bleaching; Perry et al. 2018) refers strictly to the coral reefs of
593 Chagos, and does not consider the associated non-reefal carbonate facies, hence is not
594 completely representative of Glorieuses, even though it is the closest example geographically.
595 The gross production rate from crescentic reefs in the Torres Strait is the weighted average of
596 36 crescentic reefs ranging in size from 0.9 to 194 km^2 (average 26.7 km^2), and with gross
597 production rates ranging from $0.5 - 10 \text{ kg/m}^2/\text{y}$ (Leon & Woodroffe 2013), emphasizing the
598 tremendous range of variability in carbonate production within reef or platform types.

599

600 Several factors may account for the lower production estimates on Glorieuses. First, the
601 observed lower CaCO_3 carbonate production estimates in Glorieuses reflect a large amount of

602 carbonate mud which has not been considered in our estimates, because, after winnowing
603 from the platform, carbonate mud has been deposited in other areas outside the footprint of
604 the mapped carbonate slope deposits. Secondly, because much of the Glorieuses platform is
605 relatively deep, half < 10 m, (x% < 20 m), the average rate of carbonate production on the
606 entire platform should be expected to be lower than for shallow water reef and platform facies
607 where the most rapidly growing corals flourish (Hamylton et al., 2017; Perry et al., 2015,
608 2013). Third, most of the Glorieuses platform is occupied by non-reef carbonate facies,
609 especially *Halimeda* meadows, which are generally considered to have a much lower
610 carbonate production rate than the coral reef components of platforms, which are more
611 intensely studied (Hamylton et al. 2017). Furthermore, the lack of oolites or other abiogenic
612 carbonate sediment particles observed on the platform, indicates that platform sediment
613 production is limited to typical coral reef sediment producers. Finally, actualistic survey-
614 based carbonate production estimates likely underestimate the long-term rates of carbonate
615 export during rare, intense storm events (Hubbard et al. 1990, Hubbard 1992). The Glorieuses
616 estimate, being a Holocene average, necessarily incorporates these, in the basinal
617 calciturbidites, although it is possible that not all of the sediment exported was retained within
618 the calciturbidite fan system.

619
620 All these processes are also in agreement with the highstand shedding model (Droxler and
621 Schlager, 1985), and confirms that “reflooding windows” at glacial terminations may very
622 rapidly switch on carbonate production on platform tops and export the excess sediment to the
623 deep-sea (Counts et al., 2019; Jorry et al., 2010). While many studies on carbonate basins
624 have demonstrated that most of the calciturbidites are deposited during highstands (Andresen
625 et al., 2003; Glaser and Droxler, 1993; Jorry et al., 2008; Webster et al., 2012), our results in
626 Glorieuses show that periods with low sea levels (e.g. MIS6 and MIS10) may have also
627 experienced the export of carbonate sands into deep adjacent basins, as previously
628 documented in the Northern Nicaragua Rise (Reijmer and Andresen, 2007) and in the Exuma
629 Sound, Bahamas. According to (Reijmer and Andresen, 2007), the increased coarse-fraction
630 percentage during glacials may be the result of various interacting processes such as a lower
631 input of fine neritic sediments, redepositional processes at the upper slope during lowered sea
632 level, and the export of this material to “proximal basinal” sites (28 km in the basin adjacent
633 to the Pedro Bank). In Glorieuses, it appears that the more frequent and bigger turbidites
634 during MIS6 indicate that sediment was stored on ledges near the platform edge during
635 highstand, then re-exported during lowstand turbidites. This suggests that some calciturbidites
636 behave like siliciclastic turbidites, with sediment accumulating at or slightly below the shelf
637 break, then being removed catastrophically during lowstands.

638
639 Based on observations on modern and fossil examples, fundamental differences in large-scale
640 margin transitions and stratal patterns indicate contrasting ratios of material exported
641 downslope relative to the volume of material required to fill the slope profile, creating
642 significant lateral variations between leeward and windward margins in their degree of
643 contribution to the foreslope (Eberli et al., 2004; Mullins, 1983; Playton et al., 2010).
644 Compared to ancient analogues, the Glorieuses carbonate system provides some close
645 similarities in terms of size, seismic expression, sediment composition, and slope processes.
646 The turbiditic system observed at Glorieuses is consistent with the classification of Playton et
647 al. (2010) who proposed that grain-dominated facies extend for great distances along strike
648 (up to 10s of kilometers), as documented for Upper Aptian to Danian carbonates series
649 outcropping at the Gargano Peninsula (SE Italy) where a bioclastic base-of-slope apron
650 developed 25 km far from the platform edge (Hairabian et al., 2015). Our observations also
651 clarify that channel–fan complexes are characterized by lower slope to toe-of-slope onlaps

652 and erosive channel-form morphologies on the slope that pass into mounded, non-erosive
653 lobate bodies in distal settings (as described in the Miocene Sardinia Basin, Vigorito et al.,
654 2005). At a smaller observation scale, sediment cores collected in the Glorieuses basin may
655 also serve as analogues for grain-dominated deposit transport processes which are related to
656 well-sorted hyperconcentrated and concentrated flow when finer grained fractions are present
657 (see review based on outcrop features proposed by Mulder and Alexander (2001), resulting in
658 the expression of partial to full Bouma sequences (Figure 6C and Figure 6D).

660 **6. Conclusions**

661
662 Our study provides an estimate of the functioning of a modern carbonate routing system
663 located in the SW Indian Ocean, which helps to improve our knowledge of the processes
664 related to the production, storage, and export of carbonate sediments from the platform top to
665 the deep sea.

666
667 The Glorieuses case study clearly illustrates the physiographic connection between the
668 platform top, the slope and the adjacent basin where shed carbonate products are collected.
669 Our findings conclude that a large proportion (about 1/2) of the production of the carbonate
670 platform during the Holocene has been exported downslope, the remaining 1/2 of the
671 production being stored on the platform top, in the form of on windward terraces, a sand
672 apron composed of migrating sand dunes, and dominantly along the leeward edge where
673 subtidal dunes are accumulated.

674
675 During the last two climatic cycles, calciturbidites have been deposited during successive
676 lowstands and highstands, being transferred to the deep-sea through turbidite channels and
677 deposited on lobes, with a maximum extent of 50 km into the abyssal plain. We note that the
678 thickest sand deposits are transferred mainly during high sea levels when the platform top was
679 flooded, in particular during MIS 7. Deposition of turbidites also occurred during glacial
680 stages and was particularly important during MIS 6, which may imply some reworking
681 processes occurring along the upper slope.

682
683 Interestingly, we found that the annual carbonate production calculated from the overall
684 Holocene production on the Glorieuses platform was slightly lower than what has been
685 proposed in the literature for modern reefs and carbonate platforms. We conclude that such
686 small-size carbonate platforms can potentially illustrate the carbonate budget in the ocean, at a
687 regional or global scale.

689 **Acknowledgements**

690
691 We are grateful to PTOLEMEE (PI: SJ) and PAMELA-MOZI (PI: K. Olu) cruise
692 participants, to CTDI (Ifremer) for bathymetry grid processing and to O. Lebau and R.
693 Courvaisier (University of Brest) who ran oxygen isotopes analyses. Y. Thomas and E.
694 Thereau (IFREMER) are warmly thanked for seismic processing, as well as A. Boissier and S.
695 Cheron (IFREMER) for XRF and XRD acquisition and interpretation. PTOLEMEE and
696 PAMELA-MOZI cruises, and E. Miramontes' postdoctoral fellowship were co-funded by
697 TOTAL and IFREMER as part of the PAMELA (Passive Margin Exploration Laboratories)
698 project, in collaboration with IFPEN, Université de Rennes, Université de Brest, UPMC, and
699 CNRS. The REEFCORES program was cofunded by France's "Iles Eparses" program (2011-
700 2013), CEREGE, IFREMER, and TOTAL (FR00006152). Part of this research including J.
701 Counts' postdoctoral fellowship was also funded by by the "Laboratoire d'Excellence"

702 LabexMER (ANR-10-LABX-19) and cofounded by a grant from the French Government
703 under the program “Investissements d'Avenir,” and by a grant from the Regional Council of
704 Brittany (SAD programme). E. Edinger’s contributions to the paper were made during a
705 sabbatical leave at IFREMER, funded by a Memorial University of Newfoundland sabbatical
706 research grant, and by an NSERC Discovery Grant to EE.
707

708 **List of figures**

709

710 Figure 1: (A) Location of the Glorieuses archipelago in the SW Indian Ocean, north of
711 Madagascar. (B) Satellite image of the Glorieuses archipelago (Google Earth) and bathymetry
712 acquired along slopes and adjacent basin. The black dashed lines underline turbiditic lobes
713 deposited into the deep-basin. The red lines and arrows describe the canyon network and
714 sediment pathways connected to the distal lobes. Black lines represent seismic lines acquired
715 in that region, and are shown in Figure 5. Yellow circles correspond to the location of
716 sediment cores. (C) Diagram showing maximal daily wind velocity registered at the
717 Météofrance station in Glorieuses, from January 2007 to November 2013. (D) Back-scattered
718 image acquired on the leeward slope of Glorieuses platform. Data are shown with high
719 backscatter in black, interpreted as the presence of a coarse-grained sediment blanket. Red
720 lines refer to transfer axes shown on B. (E) Detailed bathymetry acquired along the
721 northwestern edge of the Glorieuses platform, indicating the presence of submarine sand
722 dunes deposited along the platform edge.

723

724 Figure 2: Current at 60-150 m water depth from a hull-mounted ADCP (A) and wind velocity
725 from the vessel meteorological station (B) acquired during the 2014 Ptolemee cruise. (C)
726 Satellite image of the Glorieuses archipelago showing bank-derived carbonate sediment
727 plume being exported offshore (Prat et al., 2016). The white dashed line corresponds to the
728 platform edge.

729

730 Figure 3: (A) Map of the Glorieuses platform showing the main depositional environments
731 (modified after Jorry et al., 2016). Black dots correspond to surface sediment samples
732 collected in the Archipelago, which have been used to characterize bottom types and biota (cf.
733 Prat et al., 2016). White dots correspond to sediment cores collected on the platform top, in
734 intertidal settings. Small black dots within the fore-reef facies are coral pinnacles. (B) Satellite
735 image (Google Map) of the Glorieuses platform and back-scattered image acquired along
736 adjacent slopes. The red lines represent the seismic survey done on the Glorieuses platform
737 during the REEFCORES 2 and REEFCORES 3 cruises. The green lines correspond to seismic
738 profiles illustrated in Figure 4. Yellow areas represent the main sediment depocenters which
739 have been deduced from interpretation of the seismic lines.

740

741 Figure 4: Illustration of Sparker seismic lines acquired on the Glorieuses platform. (A) and
742 (B) represent respectively processed and interpreted seismic profile acquired along the back-
743 reef. (C) and (D) correspond respectively to processed and interpreted seismic profile
744 acquired along the leeward platform edge. (E) seismic profile (interpreted in (F)) acquired on
745 submerged terraces located at the north-eastern edge of the Glorieuses platform. The location
746 of the seismic profiles A, B, and C can be found on Figure 3.

747

748 Figure 5: (A) and (C) are seismic profiles acquired in the Glorieuses basin, with interpretation
749 in (B) and (D). Both profiles show a combination of sedimentary features atop the clearly
750 defined volcanic basement, notably sandy turbidite lobes, identified by their better-organized
751 and mixed-to high-amplitude reflections, that pinch out distally over the course of tens of
752 kilometres. Chaotically bedded, low amplitude debris flows can also be seen in Figure 5A and
753 5B (labelled). These gravity-flow deposits interfinger with the evenly bedded, fine-grained
754 pelagic sediments.

755

756 Figure 6: (A) and (B) Sedimentological description and Sr XRF record of two sediment cores
757 collected in the Glorieuses basin (see core location on Figure 1). Yellow facies correspond to

758 calciturbidites, and carbonate mud correspond to orange facies. Blue dots represent
759 radiocarbon dates and corresponding ages (cal BP). The location of both cores can be found in
760 Figure 1. (C) and (D) represent pictures (left) and XCT (right) of two calciturbidite sequences
761 identified on the two sediment cores, characterized by typical laminated, fining-upward
762 sequences. (E) Petrographic content of a calciturbidite sampled in core MOZ1-KS04 (at
763 245cm). (F) Petrographic content of sediment sampled on the apron of the Glorieuses
764 archipelago (core top of RC-GLO-C030, see Figure 1 and 3 for location).
765

766 Figure 7: Relationships between the WD-XRF Sr (ppm) and the XRD Aragonite (%), and the
767 WD-XRF Sr (ppm) with the XRF-CS Sr (counts). R2 indicates the correlation coefficient for
768 each linear regression. The black squares indicate Holocene samples.
769

770 Figure 8: Density from cores collected in the Glorieuses basin (A) and on the platform top
771 (B).
772

773 Figure 9: Summary diagram illustrating the sediment volume partitioning in Glorieuses since
774 the last reflooding of the platform, from platform top to deep basin. Estimates show that the
775 Glorieuses platform has produced about 0.57 km^3 of sediment, with 0.3 km^3 presently stored
776 on the platform top, and 0.27 km^3 being exported downslope and deposited in the adjacent
777 basin.
778

779 Figure 10: Timing of sandy turbidites and aragonite deposition across the last three glacial-
780 interglacial cycles. (A) Antarctica (EDC3) sea-level curve in blue (Rohling et al., 2009), with
781 numbers corresponding to isotopic stages. The dashed black line centered on -60m water
782 depth represents the mean depth of the Glorieuses platform edge. The red line represents the
783 aragonite flux calculated along core MOZ1-KS04. B: Planktonic oxygen isotopes along core
784 MOZ1-KS04. Blue circles and associated numbers indicate radiocarbon dates with
785 corresponding ages (cal BP). Bands crossing (A) and (B) represent the base of the
786 calciturbidites identified along core MOZ1-KS04, which were deposited during periods when
787 sea level was above (orange bands) or below (yellow bands) the mean platform edge (i.e. -
788 60m water depth). (C) Antarctica (EDC3) sea-level curve in blue (Rohling et al., 2009), with
789 numbers corresponding to isotopic stages, and planktonic oxygen isotopes (white circles)
790 along core MOZ1-KS07. The dashed black line centered on -60m water depth represents the
791 mean depth of the Glorieuses platform edge. Bands represent the base of the calciturbidites
792 identified along core MOZ1-KS07, which were deposited during periods when sea level was
793 above (orange bands) or below (yellow bands) the mean platform edge (i.e. -60m water
794 depth). Turbidite thicknesses and frequencies have been calculated for both MOZ1-KS04 (D)
795 and MOZ1-KS07 (E) sediment cores. Both diagrams illustrate cumulative thickness and
796 number of turbidites recognized in each marine isotope stages (MIS), for periods when the
797 Glorieuses platform was flooded (sea level above -60m water depth) or exposed (sea level
798 below -60m water depth).
799

800 List of tables

801

802 Table 1: Radiocarbon dates for cores MOZ1-KS04 and MOZ1-KS07, collected in the
803 Glorieuses basin, and for surface sediment RC-GLO-B248 collected on the leeward platform
804 edge, at 31m water depth. ^{14}C ages were calibrated using the Marine13 radiocarbon age
805 calibration curve (Reimer et al., 2013).
806

807 Table 2: Main facies areas of the Glorieuses platform and gross productivity estimate (G,
808 expressed in $\text{g.CaCO}_3\cdot\text{m}^{-2}\cdot\text{d}^{-1}$).
809

810 Table 3: Glorieuses volume and mass of sediment stored on platform sand bodies and
811 exported in submarine fans. Estimates for Holocene mud samples take into account a
812 composition of 32% aragonite of the average of 2 cores with a total of 3 samples.
813

814 Table 4: Glorieuses volume and mass of sediment produced during Holocene compared with
815 global and regional reef production estimates. *NB: these results are based on the assumption
816 that the measured value of 32% aragonite in basin muds corresponds to the proportion of
817 aragonite muds derived from the platform, i.e. assuming that the majority of the platform
818 sediments are aragonite, and include only the mud within the footprint of the basin sediment
819 lobes.
820

821
822
823
824

Table 1

Core label	Depth (cm)	Lab. Number	Species	¹⁴ C age (yr BP)	error (1σ)	Calendar age range (yr BP, 2σ)
MOZ1-KS04	10	Beta-409928	<i>G. ruber</i>	5450	30	5734-5901
MOZ1-KS04	40	Beta-423385	<i>G. ruber</i>	9940	30	10750-11057
MOZ1-KS04	60	Beta-423386	<i>G. ruber</i>	15750	50	18848-18754
MOZ1-KS04	70	Beta-423387	<i>G. ruber</i>	21690	80	25405-25838
MOZ1-KS04	105	Beta-423388	<i>G. ruber</i>	38680	410	41847-42955
MOZ1-KS07	0	Beta-475302	<i>G. ruber</i>	8240	40	8411-8842
MOZ1-KS07	24	Beta-475303	<i>G. ruber</i>	9750	30	10314-10685
MOZ1-KS07	54	Beta-475304	<i>G. ruber</i>	16380	60	18905-19324
MOZ1-KS07	120	Beta-475305	<i>G. ruber</i>	43320	650	44925-47590
RC-GLO-B248A	0	Beta-361147	<i>A. lessonii</i>	1430	30	640-1030
RC-GLO-B248B	0	Beta-361148	<i>A. lessonii</i>	1560	30	730-1170
RC-GLO-B248C	0	Beta-361149	<i>A. lessonii</i>	1410	30	630-990

Table 2

Facies	Area (%)	Area (km ²)	Productivity (G)	Source for CaCO ₃ Productivity Estimate
islands	2.5	4.79	0	n/a
reef flat	11.1	20.85	1.66	Leon and Woodroffe (2013)
reef front	17	31.97	4	Kinsey and Hopley (1991)
apron	5.8	10.9	0.2	Cyronak et al. (2013) in Hamylton et al. (2017)
shallow inner platform	11.4	21.34	2.2	Rees et al. (2007) in Hamylton et al. (2017)
deep inner platform	27	50.78	1.1	Half of shallow inner platform
fore-reef	25.2	47.38	2.2	Vecsei (2004)
Total Area / weighted average production rate	100	188.01	1.76	n/a

825
826
827
828
829
830

Table 3

Location	Sediment body (Holocene)	Area (m ²)	Average thickness (m)	% aragonite	Volume (m ³)	Density (kg/m ³)	Kg CaCO ₃	Mol CaCO ₃
Platform	Sand lenses	18.8 · 10 ⁶		100 %	3.0 · 10 ⁸	1603.9 ±25	4.81 · 10 ¹¹	4.80 · 10 ¹²
Basin	All sediment in fans	600 · 10 ⁶	0.92	--	5.52 · 10 ⁸	1590 ±9.5	8.77 · 10 ¹¹	8.77 · 10 ¹²
	Calci-turbidite sands	600 · 10 ⁶	0.23	100 %	1.38 · 10 ⁸	1640 ±86	2.26 · 10 ¹¹	2.26 · 10 ¹²
	Carbonate muds	600 · 10 ⁶	0.69	32 %	1.32 · 10 ⁸	1655 ±45	2.19 · 10 ¹¹	2.19 · 10 ¹²

831
832
833
834
835
836

837
838
839
840
841
842
843
844
845
846

Table 4

Author (year)	Scale	CaCO ₃ production (mol/y)	CaCO ₃ production (Gt/y)	Area (km ²)	Production rate (mol,kg/km ² /y)	Applied to Glorieuses (mol,kg/y)	Glorieuses estimate (this study)* (mol,kg/y)	% of regional or global rate
Milliman (1993)	Global	$9.0 \cdot 10^{12}$	n/a	$6.0 \cdot 10^5$	$1.50 \cdot 10^7$ mol	$2.75 \cdot 10^9$ mol	$9.26 \cdot 10^8$ mol	33.73
Kleypas (1997)	Global	n/a	0.9-1.68	$6.65 \cdot 10^5$	$2.07 \cdot 10^6$ kg	$3.80 \cdot 10^8$ kg	$9.27 \cdot 10^7$ kg	24.37
Vecsei (2004)	Global	n/a	0.73	$3.037 \cdot 10^5$	$2.40 \cdot 10^6$ kg	$4.40 \cdot 10^8$ kg		21.04
Leon & Woodroffe (2013)	Regional (Torres Strait; crescentic only)		3.2×10^{-6}	961	$3.3 \cdot 10^6$ kg	$6.10 \cdot 10^8$ kg		15.19
Hamylton et al. (2017)	Regional (GBR, all reef types)	n/a	$4.8 \cdot 10^{-7}$	181	$2.7 \cdot 10^6$ kg	$4.95 \cdot 10^8$ kg		18.72
Perry et al. (2015)	Local (Chagos)	n/a	n/a	n/a	$3.7 \cdot 10^6$ kg	$6.78 \cdot 10^8$ kg		13.67

847
848

849 **References**

- 850
- 851 Andersson, A.J., Gledhill, D., 2013. Ocean Acidification and Coral Reefs: Effects on
852 Breakdown, Dissolution, and Net Ecosystem Calcification, in: Carlson, C.A., Giovannoni,
853 S.J. (Eds.), *Annual Review of Marine Science*, Vol 5. Annual Reviews, Palo Alto, pp. 321–
854 348.
- 855 Andresen, N., Reijmer, J.J.G., Droxler, A.W., 2003. Timing and distribution of calciturbidites
856 around a deeply submerged carbonate platform in a seismically active setting (Pedro Bank,
857 Northern Nicaragua Rise, Caribbean Sea). *Int. J. Earth Sci.* 92, 573–592.
858 <https://doi.org/10.1007/s00531-003-0340-0>
- 859 Betzler, C., Reijmer, J.J.G., Bernet, K., Eberli, G.P., Anselmetti, F.S., 1999. Sedimentary
860 patterns and geometries of the Bahamian outer carbonate ramp (Miocene-Lower Pliocene,
861 Great Bahama Bank). *Sedimentology* 46, 1127–1143. <https://doi.org/10.1046/j.1365-3091.1999.00268.x>
- 863 Bintanja, R., van de Wal, R.S.W., Oerlemans, J., 2005. Modelled atmospheric temperatures
864 and global sea levels over the past million years. *Nature* 437, 125–128.
865 <https://doi.org/10.1038/nature03975>
- 866 Blanchon, P., Shaw, J., 1995. Reef drowning during the last deglaciation: Evidence for
867 catastrophic sea-level rise and ice-sheet collapse. *Geology* 23, 4.
868 [https://doi.org/10.1130/0091-7613\(1995\)023<0004:RDDTLD>2.3.CO;2](https://doi.org/10.1130/0091-7613(1995)023<0004:RDDTLD>2.3.CO;2)
- 869 Clark, P.U., McCabe, A.M., Mix, A.C., Weaver, A.J., 2004. Rapid Rise of Sea Level 19,000
870 Years Ago and Its Global Implications. *Science* 304, 1141–1144.
871 <https://doi.org/10.1126/science.1094449>
- 872 Counts, J.W., Jorry, S.J., Leroux, E., Miramontes, E., Jouet, G., 2018. Sedimentation adjacent
873 to atolls and volcano-cored carbonate platforms in the Mozambique Channel (SW Indian
874 Ocean). *Mar. Geol.* 404, 41–59. <https://doi.org/10.1016/j.margeo.2018.07.003>
- 875 Counts, J.W., Jorry, S.J., Vazquez Riveiros, N., Jouet, G., Giraudeau, J., Cheron, S., Boissier,
876 A., Miramontes, E., 2019. A Late Quaternary record of highstand shedding from an isolated
877 carbonate platform (Juan de Nova, southern Indian Ocean). *Depositional Rec.* 0.
878 <https://doi.org/10.1002/dep2.57>
- 879 Courgeon, S., Jorry, S.J., Camoin, G.F., BouDagher-Fadel, M.K., Jouet, G., Revillon, S.,
880 Bachelery, P., Pelleter, E., Borgomano, J., Poli, E., Droxler, A.W., 2016. Growth and demise
881 of Cenozoic isolated carbonate platforms: New insights from the Mozambique Channel
882 seamounts (SW Indian Ocean). *Mar. Geol.* 380, 90–105.
883 <https://doi.org/10.1016/j.margeo.2016.07.006>
- 884 Cyronak, T., Santos, I.R., Eyre, B.D., 2013. Permeable coral reef sediment dissolution driven
885 by elevated pCO₂ and pore water advection. *Geophys. Res. Lett.* 40, 4876–4881.
886 <https://doi.org/10.1002/grl.50948>
- 887 Deschamps, P., Durand, N., Bard, E., Hamelin, B., Camoin, G., Thomas, A.L., Henderson,
888 G.M., Okuno, J., Yokoyama, Y., 2012. Ice-sheet collapse and sea-level rise at the Bølling
889 warming 14,600 years ago. *Nature* 483, 559–564. <https://doi.org/10.1038/nature10902>
- 890 Droxler, A., Schlager, W., 1985. Glacial Versus Interglacial Sedimentation-Rates and
891 Turbidite Frequency. *Geology* 13, 799–802. [https://doi.org/10.1130/0091-7613\(1985\)13<799:GVISRA>2.0.CO;2](https://doi.org/10.1130/0091-7613(1985)13<799:GVISRA>2.0.CO;2)
- 893 Dutton, A., Bard, E., Antonioli, F., Esat, T.M., Lambeck, K., McCulloch, M.T., 2009. Phasing
894 and amplitude of sea-level and climate change during the penultimate interglacial. *Nat.*
895 *Geosci.* 2, 355–359. <https://doi.org/10.1038/NGEO470>
- 896 Dutton, A., Lambeck, K., 2012. Ice Volume and Sea Level During the Last Interglacial.
897 *Science* 337, 216–219. <https://doi.org/10.1126/science.1205749>
- 898 Eberli, G.P., Anselmetti, F.S., Betzler, C., Konijnenburg, J.-H.V., Bernoulli, D., 2004.

899 Carbonate Platform to Basin Transitions on Seismic Data and in Outcrops: Great Bahama
900 Bank and the Maiella Platform Margin, Italy. AAPG Mem. 81, 207–250.

901 Eberli, G.P., Swart, P.K., Malone, M.J., Al, A.E., 1997a. Proceedings, initial reports, Ocean
902 Drilling Program, Leg 166; Bahamas transect. ODP Tex. M Univ. Coll. Stn.

903 Eberli, G.P., Swart, P.K., McNeill, D.F., Kenter, J.A.M., Anselmetti, F.S., Melim, L.A.,
904 Ginsburg, R.N., 1997b. A synopsis of the Bahamas Drilling Project: results from two deep
905 core borings drilled on the Great Bahama Bank, in: Proceedings of the Ocean Drilling
906 Program, Initial Reports. pp. 23–41.

907 Emerick, C., Duncan, R., 1982. Age Progressive Volcanism in the Comores Archipelago,
908 Western Indian-Ocean and Implications for Somali Plate-Tectonics. Earth Planet. Sci. Lett.
909 60, 415–428. [https://doi.org/10.1016/0012-821X\(82\)90077-2](https://doi.org/10.1016/0012-821X(82)90077-2)

910 Falkowski, P., Scholes, R.J., Boyle, E., Canadell, J., Canfield, D., Elser, J., Gruber, N.,
911 Hibbard, K., Hogberg, P., Linder, S., Mackenzie, F.T., Moore, B., Pedersen, T., Rosenthal,
912 Y., Seitzinger, S., Smetacek, V., Steffen, W., 2000. The global carbon cycle: A test of our
913 knowledge of earth as a system. Science 290, 291–296.
914 <https://doi.org/10.1126/science.290.5490.291>

915 Glaser, K., Droxler, A., 1993. Controls and Development of Late Quaternary Periplatform
916 Carbonate Stratigraphy in Walton Basin (northeastern Nicaragua Rise, Caribbean Sea).
917 Paleooceanography 8, 243–274. <https://doi.org/10.1029/92PA02876>

918 Hairabian, A., Borgomano, J., Masse, J.-P., Nardon, S., 2015. 3-D stratigraphic architecture,
919 sedimentary processes and controlling factors of Cretaceous deep-water resedimented
920 carbonates (Gargano Peninsula, SE Italy). Sediment. Geol. 317, 116–136.
921 <https://doi.org/10.1016/j.sedgeo.2014.11.001>

922 Hamylton, S.M., Duce, S., Vila-Concejo, A., Roelfsema, C.M., Phinn, S.R., Carvalho, R.C.,
923 Shaw, E.C., Joyce, K.E., 2017. Estimating regional coral reef calcium carbonate production
924 from remotely sensed seafloor maps. Remote Sens. Environ. 201, 88–98.
925 <https://doi.org/10.1016/j.rse.2017.08.034>

926 Hanebuth, T., Statterger, K., Grootes, P.M., 2000. Rapid Flooding of the Sunda Shelf: A
927 Late-Glacial Sea-Level Record. Science 288, 1033–1035.
928 <https://doi.org/10.1126/science.288.5468.1033>

929 Hopley, D., 1982. The Geomorphology of the Great Barrier Reef: Quaternary Development of
930 Coral Reefs, Wiley. ed. New York.

931 Hubbard, D., Miller, A., Scaturro, D., 1990. Production and Cycling of Calcium-Carbonate in
932 a Shelf-Edge Reef System (St-Croix, United-States Virgin-Islands) - Applications to the
933 Nature of Reef Systems in the Fossil Record. J. Sediment. Petrol. 60, 335–360.

934 Hughes, T.P., 1999. Off-reef transport of coral fragments at Lizard Island, Australia. Mar.
935 Geol. 157, 1–6. [https://doi.org/10.1016/S0025-3227\(98\)00187-X](https://doi.org/10.1016/S0025-3227(98)00187-X)

936 Jorry, S.J., 2014. PTOLEMEE cruise, L'Atalante R/V. <https://doi.org/10.17600/14000900>

937 Jorry, S.J., Camoin, G.F., Jouet, G., Le Roy, P., Vella, C., Courgeon, S., Prat, S., Fontanier,
938 C., Paumard, V., Bouille, J., Caline, B., Borgomano, J., 2016. Modern sediments and
939 Pleistocene reefs from isolated carbonate platforms (Iles Eparses, SW Indian Ocean): A
940 preliminary study. Acta Oecologica-Int. J. Ecol. 72, 129–143.
941 <https://doi.org/10.1016/j.actao.2015.10.014>

942 Jorry, S.J., Droxler, A.W., Francis, J.M., 2010. Deepwater carbonate deposition in response to
943 re-flooding of carbonate bank and atoll-tops at glacial terminations. Quat. Sci. Rev. 29, 2010–
944 2026. <https://doi.org/10.1016/j.quascirev.2010.04.016>

945 Jorry, S.J., Droxler, A.W., Mallarino, G., Dickens, G.R., Bentley, S.J., Beaufort, L., Peterson,
946 L.C., Opdyke, B.N., 2008. Bundled turbidite deposition in the central Pandora Trough (Gulf
947 of Papua) since Last Glacial Maximum: Linking sediment nature and accumulation to sea
948 level fluctuations at millennial timescale. J. Geophys. Res.-Earth Surf. 113, F01S19.

949 <https://doi.org/10.1029/2006JF000649>
950 Jose, Y.S., Penven, P., Aumont, O., Machu, E., Moloney, C.L., Shillington, F., Maury, O.,
951 2016. Suppressing and enhancing effects of mesoscale dynamics on biological production in
952 the Mozambique Channel. *J. Mar. Syst.* 158, 129–139.
953 <https://doi.org/10.1016/j.jmarsys.2016.02.003>
954 Kangwe, J., 2006. Calcareous Algae of a Tropical Lagoon: Primary Productivity, Calcium
955 and Carbonate Production. Department of Botany, Stockholm University, Sweden.
956 Kench, P.S., 1998. Physical controls on development of lagoon sand deposits and lagoon
957 infilling in an Indian ocean atoll. *J. Coast. Res.* 14, 1014–1024.
958 Kinsey, D.W., Hopley, D., 1991. The significance of coral reefs as global carbon sinks—
959 response to Greenhouse. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 89, 363–377.
960 [https://doi.org/10.1016/0031-0182\(91\)90172-N](https://doi.org/10.1016/0031-0182(91)90172-N)
961 Kleypas, J.A., 1997. Modeled estimates of global reef habitat and carbonate production since
962 the Last Glacial Maximum. *Paleoceanography* 12, 533–545.
963 <https://doi.org/10.1029/97PA01134>
964 Kolla, V., Be, A., Biscaye, P., 1976. Calcium-Carbonate Distribution in Surface Sediments of
965 Indian-Ocean. *J. Geophys. Res.-Oceans Atmospheres* 81, 2605–2616.
966 <https://doi.org/10.1029/JC081i015p02605>
967 Lambeck, K., Chappell, J., 2001. Sea level change through the last glacial cycle. *Science* 292,
968 679–686. <https://doi.org/10.1126/science.1059549>
969 Lea, D.W., Martin, P.A., Pak, D.K., Spero, H.J., 2002. Reconstructing a 350 ky history of sea
970 level using planktonic Mg/Ca and oxygen isotope records from a Cocos Ridge core. *Quat. Sci.*
971 *Rev.* 21, 283–293. [https://doi.org/10.1016/S0277-3791\(01\)00081-6](https://doi.org/10.1016/S0277-3791(01)00081-6)
972 Leon, J.X., Woodroffe, C.D., 2013. Morphological characterisation of reef types in Torres
973 Strait and an assessment of their carbonate production. *Mar. Geol.* 338, 64–75.
974 <https://doi.org/10.1016/j.margeo.2012.12.009>
975 Lisiecki, L.E., Raymo, M.E., 2005. A Pliocene-Pleistocene stack of 57 globally distributed
976 benthic delta O-18 records (vol 20, art no PA1003, 2005). *Paleoceanography* 20, PA2007.
977 <https://doi.org/10.1029/2005PA001164>
978 Macintyre, I., Graus, R., Reinthal, P., Littler, M., Littler, D., 1987. The Barrier-Reef Sediment
979 Apron - Tobacco Reef, Belize. *Coral Reefs* 6, 1–12. <https://doi.org/10.1007/BF00302206>
980 Maragos, J.E., Baines, G.B.K., Beveridge, P.J., 1973. Tropical Cyclone Bebe Creates a New
981 Land Formation on Funafuti Atoll. *Science* 181, 1161–1164.
982 <https://doi.org/10.1126/science.181.4105.1161>
983 Milliman, J., 1993. Production and Accumulation of Calcium-Carbonate in the Ocean -
984 Budget. *Glob. Biogeochem. Cycles* 7, 927–957. <https://doi.org/10.1029/93GB02524>
985 Milliman, J., Syvitski, J., 1992. Geomorphic Tectonic Control of Sediment Discharge to the
986 Ocean - the Importance of Small Mountainous Rivers. *J. Geol.* 100, 525–544.
987 <https://doi.org/10.1086/629606>
988 Milliman, J.D., Droxler, A.W., 1996. Neritic and pelagic carbonate sedimentation in the
989 marine environment: Ignorance is not bliss. *Geol. Rundsch.* 85, 496–504.
990 <https://doi.org/10.1007/s005310050090>
991 Mulder, T., Alexander, J., 2001. Abrupt change in slope causes variation in the deposit
992 thickness of concentrated particle-driven density currents. *Mar. Geol.* 175, 221–235.
993 [https://doi.org/10.1016/S0025-3227\(01\)00114-1](https://doi.org/10.1016/S0025-3227(01)00114-1)
994 Mulder, T., Ducassou, E., Eberli, G.P., Hanquiez, V., Gonthier, E., Kindler, P., Principaud,
995 M., Fournier, F., Leonide, P., Billeaud, I., Marsset, B., Reijmer, J.J.G., Bondu, C.,
996 Joussiaume, R., Pakiades, M., 2012. New insights into the morphology and sedimentary
997 processes along the western slope of Great Bahama Bank. *Geology* 40, 603–606.
998 <https://doi.org/10.1130/G32972.1>

999 Mulder, T., Ducassou, E., Gillet, H., Hanquiez, V., Principaud, M., Chabaud, L., Eberli, G.P.,
1000 Kindler, P., Billeaud, I., Gonthier, E., Fournier, F., Leonide, P., Borgomano, J., 2014. First
1001 Discovery of Channel-Levee Complexes in a Modern Deep-Water Carbonate Slope
1002 Environment. *J. Sediment. Res.* 84, 1139–1146. <https://doi.org/10.2110/jsr.2014.90>
1003 Mullins, H., 1983. Base-of-Slope Carbonate Aprons - an Alternative to Submarine Fan
1004 Model. *Aapg Bull.* 67, 521–521.

1005 Nougier, J., Cantagrel, J.M., Karche, J.P., 1986. The Comores archipelago in the western
1006 Indian Ocean: volcanology, geochronology and geodynamic setting. *J. Afr. Earth Sci.* 1983 5,
1007 135–144. [https://doi.org/10.1016/0899-5362\(86\)90003-5](https://doi.org/10.1016/0899-5362(86)90003-5)

1008 Olu, K., 2014. PAMELA-MOZ01 cruise, L'Atalante R/V. <https://doi.org/10.17600/14001000>

1009 Perry, C.T., Kench, P.S., Smithers, S.G., Yamano, H., O'Leary, M., Gulliver, P., 2013. Time
1010 scales and modes of reef lagoon infilling in the Maldives and controls on the onset of reef
1011 island formation. *Geology* 41, 1111–1114. <https://doi.org/10.1130/G34690.1>

1012 Perry, C.T., Murphy, G.N., Graham, N.A.J., Wilson, S.K., Januchowski-Hartley, F.A., East,
1013 H.K., 2015. Remote coral reefs can sustain high growth potential and may match future sea-
1014 level trends. *Sci. Rep.* 5, 18289. <https://doi.org/10.1038/srep18289>

1015 Playton, T.E., Janson, X., Kerans, C., 2010. Carbonate slopes. *Facies Models* 4, 449–476.

1016 Prat, S., Jorry, S.J., Jouet, G., Camoin, G., Vella, C., Le Roy, P., Caline, B., Boichard, R.,
1017 Pastol, Y., 2016. Geomorphology and sedimentology of a modern isolated carbonate
1018 platform: The Glorieuses archipelago, SW Indian Ocean. *Mar. Geol.* 380, 272–283.
1019 <https://doi.org/10.1016/j.margeo.2016.04.009>

1020 Purdy, E.G., Gischler, E., 2005. The transient nature of the empty bucket model of reef
1021 sedimentation. *Sediment. Geol.* 175, 35–47. <https://doi.org/10.1016/j.sedgeo.2005.01.007>

1022 Rees, S.A., Opdyke, B.N., Wilson, P.A., Fifield, L.K., 2005. Coral Reef Sedimentation on
1023 Rodrigues and the Western Indian Ocean and Its Impact on the Carbon Cycle. *Philos. Trans.*
1024 *Math. Phys. Eng. Sci.* 363, 101–120.

1025 Rees, S.A., Opdyke, B.N., Wilson, P.A., Henstock, T.J., 2007. Significance of Halimeda
1026 bioherms to the global carbonate budget based on a geological sediment budget for the
1027 Northern Great Barrier Reef, Australia. *Coral Reefs* 26, 177–188.
1028 <https://doi.org/10.1007/s00338-006-0166-x>

1029 Reijmer, J.J.G., Andresen, N., 2007. Mineralogy and grain size variations along two carbonate
1030 margin-to-basin transects (Pedro Bank, Northern Nicaragua Rise). *Sediment. Geol.* 198, 327–
1031 350. <https://doi.org/10.1016/j.sedgeo.2007.01.018>

1032 Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Ramsey, C.B., Buck, C.E.,
1033 Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Hafflidason, H.,
1034 Hajdas, I., Hatte, C., Heaton, T.J., Hoffmann, D.L., Hogg, A.G., Hughen, K.A., Kaiser, K.F.,
1035 Kromer, B., Manning, S.W., Niu, M., Reimer, R.W., Richards, D.A., Scott, E.M., Southon,
1036 J.R., Staff, R.A., Turney, C.S.M., van der Plicht, J., 2013. Intcal13 and Marine13 Radiocarbon
1037 Age Calibration Curves 0-50,000 Years Cal Bp. *Radiocarbon* 55, 1869–1887.
1038 https://doi.org/10.2458/azu_js_rc.55.16947

1039 Rohling, E.J., Grant, K., Bolshaw, M., Roberts, A.P., Siddall, M., Hemleben, C., Kucera, M.,
1040 2009. Antarctic temperature and global sea level closely coupled over the past five glacial
1041 cycles. *Nat. Geosci.* 2, 500–504. <https://doi.org/10.1038/ngeo557>

1042 Schlager, W., Reijmer, J., Droxler, A., 1994. Highstand Shedding of Carbonate Platforms. *J.*
1043 *Sediment. Res. Sect. B-Stratigr. Glob. Stud.* 64, 270–281.

1044 Schott, F.A., McCreary, J.P., 2001. The monsoon circulation of the Indian Ocean. *Prog.*
1045 *Oceanogr.* 51, 1–123. [https://doi.org/10.1016/S0079-6611\(01\)00083-0](https://doi.org/10.1016/S0079-6611(01)00083-0)

1046 Schott, F.A., Xie, S.-P., McCreary, J.P., 2009. Indian Ocean Circulation and Climate
1047 Variability. *Rev. Geophys.* 47, RG1002. <https://doi.org/10.1029/2007RG000245>

1048 Siddall, M., Rohling, E.J., Almogi-Labin, A., Hemleben, C., Meischner, D., Schmelzer, I.,

1049 Smeed, D.A., 2003. Sea-level fluctuations during the last glacial cycle. *Nature* 423, 853–858.
1050 <https://doi.org/10.1038/nature01690>
1051 Swallow, J., Fieux, M., Schott, F., 1988. The Boundary Currents East and North of
1052 Madagascar .1. Geostrophic Currents and Transports. *J. Geophys. Res.-Oceans* 93, 4951–
1053 4962. <https://doi.org/10.1029/JC093iC05p04951>
1054 Thompson, W.G., Goldstein, S.L., 2005. Open-System Coral Ages Reveal Persistent
1055 Suborbital Sea-Level Cycles. *Science* 308, 401–404. <https://doi.org/10.1126/science.1104035>
1056 Vecsei, A., 2004. A new estimate of global reefal carbonate production including the fore-
1057 reefs. *Glob. Planet. Change* 43, 1–18. <https://doi.org/10.1016/j.gloplacha.2003.12.002>
1058 Vigorito, M., Murru, M., Simone, L., 2005. Anatomy of a submarine channel system and
1059 related fan in a foramol/rhodalgial carbonate sedimentary setting: a case history from the
1060 Miocene syn-rift Sardinia Basin, Italy. *Sediment. Geol.* 174, 1–30.
1061 <https://doi.org/10.1016/j.sedgeo.2004.10.003>
1062 Waelbroeck, C., Labeyrie, L., Michel, E., Duplessy, J.C., McManus, J.F., Lambeck, K.,
1063 Balbon, E., Labracherie, M., 2002. Sea-level and deep water temperature changes derived
1064 from benthic foraminifera isotopic records. *Quat. Sci. Rev.* 21, 295–305.
1065 [https://doi.org/10.1016/S0277-3791\(01\)00101-9](https://doi.org/10.1016/S0277-3791(01)00101-9)
1066 Weaver, A.J., Saenko, O.A., Clark, P.U., Mitrovica, J.X., 2003. Meltwater Pulse 1A from
1067 Antarctica as a Trigger of the Bølling-Allerød Warm Interval. *Science* 299, 1709–1713.
1068 <https://doi.org/10.1126/science.1081002>
1069 Webster, J.M., Beaman, R.J., Puga-Bernabeu, A., Ludman, D., Renema, W., Wust, R.A.J.,
1070 George, N.P.J., Reimer, P.J., Jacobsen, G.E., Moss, P., 2012. Late Pleistocene history of
1071 turbidite sedimentation in a submarine canyon off the northern Great Barrier Reef, Australia.
1072 *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 331, 75–89.
1073 <https://doi.org/10.1016/j.palaeo.2012.02.034>
1074 Wilson, P.A., Roberts, H.H., 1995. Density Cascading: Off-shelf Sediment Transport,
1075 Evidence and Implications, Bahama Banks. *J. Sediment. Res.* 65.
1076 Woodroffe, C.D., Grime, D., 1999. Storm impact and evolution of a mangrove-fringed
1077 chenier plain, Shoal Bay, Darwin, Australia. *Mar. Geol.* 159, 303–321.
1078 [https://doi.org/10.1016/S0025-3227\(99\)00006-7](https://doi.org/10.1016/S0025-3227(99)00006-7)
1079 Yamano, H., Kayanne, H., Matsuda, F., Tsuji, Y., 2002. Lagoonal facies, ages, and
1080 sedimentation in three atolls in the Pacific. *Mar. Geol.* 185, 233–247.
1081 [https://doi.org/10.1016/S0025-3227\(02\)00188-3](https://doi.org/10.1016/S0025-3227(02)00188-3)
1082 Yamano, H., Kayanne, H., Yonekura, N., Kudo, K., 2000. 21-year changes of backreef coral
1083 distribution: Causes and significance. *J. Coast. Res.* 16, 99–110.
1084
1085
1086
1087