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Growth and demise of Cenozoic isolated carbonate platforms: New insights from the Mozambique Channel seamounts (SW Indian Ocean)

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Abstract :

Although long-term evolutions of isolated shallow-water carbonate platforms and demise episodes leading to guyot formation have been the subject of numerous studies during the last decades, their driving processes are still the subject of active debates. The Mozambique Channel (SW Indian Ocean) is characterized by several flat-topped seamounts ranging from 11°S to 21°S in latitudes. Based on a comprehensive geomorphologic study and on dredged samples analysis, we show that these features correspond to tropical isolated shallow-water carbonate platforms. Coupling strontium isotopy and foraminifera biostratigraphy, well-constrained chronostratigraphy results indicate that shallow-water carbonate production started in the Mozambique Channel during distinct Cenozoic periods ranging from Paleocene to Early Miocene. Our data also demonstrate that these carbonate platforms were subsequently characterized by different evolutions locally marked by tectonic and rejuvenated volcanism. While some of them kept developed until present days, forming modern carbonate systems, some others were drowned during Late Neogene and subsided to form guyots. Although different factors can be discussed, tectonic and volcanism appear as good potential triggers for demise episodes during Late Miocene-Early Pliocene times. Chronology and location of this geodynamical activity tend to emphasize influence of East African rift system until southern Mozambique Channel.

Highlights

► The flat-top seamounts of the Mozambique Channel correspond to drowned isolated shallow-water carbonate platforms. ► Chrono-stratigraphy indicate that these carbonate systems colonized their substratum during distinct Cenozoic periods. ► Major backstepping and drowning episodes were most likely triggered by geodynamical activity (tectonic and volcanism). ► Mozambique Channel isolated carbonate platforms recorded southern and diffuse propagation of the East African rift system.

Keywords : Carbonate platform, Drowning, Cenozoic, Mozambique Channel, East African rift system

44

1. Introduction

45 Seamounts are presently defined as oceanic isolated positive topographic features
46 either submarine, or sub-aerially exposed; their elevation is greater than 100m with respect to
47 the surrounding seafloor (Wessel et al., 2010). They are essentially volcanic edifices formed
48 by both intrusive and eruptive processes and located in oceanic intra-plate settings over
49 upwelling mantle plumes, on- or off-axis mid-ocean ridges or along island-arcs (Staudigel and
50 Clague, 2010). Guyots are seamounts that have built at or above sea level and whose flat top
51 morphology is related to wave erosion (Staudigel and Clague, 2010). The top of guyots were
52 once at the surface because they contain evidence of fossil shallow-water biological
53 assemblages (e.g. Camoin et al., 1998).

54 During their geodynamic evolution, seamounts can reach the photic zone and be
55 colonized by shallow-water carbonate builders (e.g. Hawaiian Islands; Moore and Clague,
56 1992). Subsequent carbonate growth phases and seamount subsidence often lead to the
57 formation of shallow-water isolated carbonate platforms (e.g. Pacific: Camoin et al., 1998;
58 Wilson et al., 1998). While some of them have survived and aggraded until present-day to
59 form modern isolated carbonate platforms (e.g. Enewetak and Pikinni atolls; Wilson et al.,
60 1998), many of them were subsequently drowned, forming „guyots“ (or tablemounts; Camoin
61 et al., 1998). Many interactive factors are considered to explain platform drowning, including
62 (1) an abrupt increase in accommodation space outpacing carbonate growth potential and
63 flooding the shallow-water carbonate platform below the photic zone (e.g. Schlager, 1981;
64 Toomey et al., 2013), (2) a sharp decrease in carbonate factory production related to the
65 degradation of environmental and climatic conditions, including subaerial exposure (e.g.
66 Schlager, 1998) and excess of clastic and/or nutrient input (e.g. Hallock and Schlager, 1986;
67 Camoin et al., 1998; Wilson et al., 1998; Schlager, 1999; Betzler et al., 2009), and (3) long

68 term geodynamical processes, such as dynamic subsidence (e.g. Schlager, 1999; DiCaprio et
69 al., 2010). Under stress, the surface area of the factory may often shrink and retreat towards
70 more elevated or more protected topographies to overcome inimical environmental conditions
71 or to keep pace with the rapid increase in accommodation space. In this situation, the
72 drowning of the carbonate system is therefore only partial and is recorded by typical
73 backstepping morphologies (e.g. Schlager, 2005).

74 The growth and demise of isolated carbonate platform are common in the geological
75 record (e.g. Camoin et al., 1998; Wilson et al, 1998) but the processes involved on time scales
76 of tens of millions years have been barely determined and quantified (Schlager et al, 1999). A
77 great diversity of isolated carbonate platforms initiated and developed during Cenozoic times
78 in the Indo-Pacific realm. In the Maldives, shallow-water carbonate production was initiated
79 during the Eocene when shallow-water carbonate banks were formed (Aubert and Droxler,
80 1992). Subsequent depositional sequences were characterized by multiple carbonate growth
81 phases separated by periods of sub-aerial exposure and drowning events driven either by
82 eustatic sea-level changes (Purdy and Bertram, 1993; Beloposky and Droxler, 2004), bottom
83 current activity (Lüdmann et al, 2013) or Indian Monsoon activity (Betzler et al., 2009). On
84 Limalok guyot, occurring at 1255m deep in the Pacific Ocean, the shallow-water carbonate
85 production was initiated during the Late Paleocene on a volcanic substrate and the subsequent
86 carbonate platform development, including periods of sub-aerial exposure, ended with its
87 drowning during middle Eocene times (Ogg et al., 1995). Drowning events affecting late
88 Cretaceous and early Cenozoic Pacific guyots are thought to be related to the motion of the
89 Pacific plate that displaced shallow-water carbonate platforms into low-latitude, inimical
90 environmental conditions (Wilson et al., 1998). The large diversity of geological processes
91 which control the development and the drowning of Cenozoic isolated carbonate platforms
92 illustrates the sensitivity of such systems to changes in accommodation space and

93 environmental conditions on relatively long time scales. New case studies improve our
94 understanding of shallow-water isolated carbonate systems.

95 The Mozambique Channel (MC) is located in the SW Indian Ocean, between the
96 eastern African margin and Madagascar, and is characterized by several and distinct modern
97 isolated carbonate systems forming the “Iles Eparses”. In addition to these islands, low-
98 resolution GEBCO bathymetrical grids indicate that, in the MC, several seamounts and guyots
99 currently occur hundreds of meters deep and are good potential analogues of classic drowned
100 carbonate platforms. Based on new data collected during oceanographic cruises carried out in
101 2014, this work aims at: (1) investigating the morphology and the nature of the flanks of
102 modern isolated systems and surrounding flat-top seamounts, (2) determining the ages of
103 major episodes of shallow-water carbonate production and comparing them to the records of
104 other isolated carbonate platforms from the Indo-Pacific oceans and, (3) discuss timing and
105 processes of shallow-water carbonate platforms demise and (4) describing isolated platform
106 geodynamic specificities and replacing the seamounts in the MC regional context.

107 **2. Geological Setting**

108 The MC is a broad, almost triangular, trough bounded by the Mozambique continental
109 slope to the west and the Madagascar continental slope to the east (Fig. 1A & 1B). The
110 formation of the MC modern structure is related both to the break-up of the Gondwana Super-
111 Continent which occurred during the Early Jurassic-Early Cretaceous time span, and to the
112 relative drifting between the African and “Antarctico-Indio-Madagascarian” continental
113 blocks (Coffin and Rabinowitz, 1987). This main structuration phase was followed by
114 stabilization and tectonic\volcanic stages as, for instance, during the separation of India and
115 Antarctica from Madagascar around 84 Ma (Bassias, 1992), or more recently, with tectonic
116 activity linked to the onset and development of the East African rift system (EARS) from the

117 Oligocene up to present days (Salman and Abdula, 1995, Chorowicz, 2005, McGregor, 2015,
118 Fig. 2).

119 The southward motion of Madagascar relative to Africa occurred from the Middle
120 Jurassic to the Early Cretaceous (~165-120 Ma) through the activity of a major transform
121 fault known as “Davie Ridge” (DR, e.g. Coffin and Rabinowitz, 1987; Fig. 1B & 2). This
122 fracture zone currently corresponds to a NNW-SSE bathymetrical high of ~1200 km in width
123 and crossing longitudinally the MC (Fig. 1B). The DR is made of crystalline continental
124 basement consisting of gneiss and meta-arkose, covered in places by alkaline lava, tuff and
125 breccias and by a thin layer of Cretaceous to modern carbonate oozes (Leclaire et al., 1989;
126 Bassias, 1992). The DR hosts several prominent submarine morphologies including, from
127 north to south, the Saint Lazarus, Paisley, Macua and the Sakalaves seamounts whose nature
128 and morphology remain poorly known. The south central part of the MC is characterized by a
129 cluster of seamounts including the Hall and the Jaguar banks, the Bassas da India atoll and the
130 Europa platform (Fig. 1B & 1C). Although the origin of these seamounts is seemingly related
131 to oceanic volcanism, no dredging has been carried out in that region to confirm this
132 hypothesis. The Sakalaves and southern MC seamounts (i.e. Bassas da India, Hall and Jaguar
133 banks) are located in a diffuse zone of the southern EARS (Kusky et al., 2010; Rovuma plate,
134 Calais et al., 2006) between the Nubian and African plates (Fig. 2).

135 The northernmost part of the MC hosts the Comoro Archipelago (Fig. 1B) which is
136 composed of four volcanic islands, from West to East: Grande Comore, Mohély, Anjouan and
137 Mayotte. Geochronological data indicate a diachronous magmatic activity, from about 20 Ma
138 in Mayotte to present-day in Grande Comore (Emerick and Duncan, 1982; Michon, 2016).
139 The origin of this archipelago is still debated and could correspond either to a deep mantle
140 plume developing a hotspot track or, conversely, to a lithospheric deformation that reactivated
141 transform faults and controlled the magma path (Michon, 2016). To the Northwest, the

142 Glorieuses carbonate platform, the northernmost Iles Eparses, may also have developed on a
143 volcanic edifice linked to this regional trend (Emerick and Duncan, 1982).

144 Nowadays, the modern isolated carbonate platforms forming the Iles Eparses are small
145 and flat coral platforms. Covering a total of 44 sq. km with a highest elevation which does not
146 exceed a few meters, the shallow-marine carbonate production typically reflects tropical
147 neritic productivity dominated by corals, large benthic foraminifera (LBF), green algae, and
148 molluscs (Battistini, 1976; Jorry et al., 2016; Prat et al., 2016). Last interglacial reefs form
149 localized outcrops, which are affected by karstic processes (presence of plurimeter dissolution
150 cavities), more or less colonized by vegetation.

151 **3. Material and Methods**

152 This work is mainly based on geophysical and geological data acquired during the
153 2014 PTOLEMEE and PAMELA-MOZ1 cruises onboard the RV *L'Atalante*, as part of the
154 PAMELA (Passive Margin Exploration Laboratory) research project. Geological
155 interpretations presented in this study result from the combined analysis of (1) bathymetry
156 DEMs and associated slope maps, (2) rock samples, and (3) underwater videos.

157 Bathymetric data were acquired with Kongsberg EM122 (Frequency of 12kHz) and
158 Kongsberg EM 710 (Frequency from 71 to 100kHz) multibeam systems. Data were processed
159 using CARAIBESTM v4.2 software and were respectively gridded into 10m and 5m resolution
160 DEMs (WGS84). Geomorphological and morphometric analysis, as well as slope maps, were
161 processed with ArcGISTM v10.3 using customized MercatorTM projections. Analysis and
162 geological interpretation were supported by 3D visualization with FledermausTM v7 system.
163 We also used laser bathymetry and topography (LiDAR) grids acquired between 2009 and
164 2011 by the Litto3D program to illustrate the modern geomorphology of the Iles Eparses.

165 Underwater videos and associated pictures were collected through an interactive,
166 submarine camera system (SCAMPI) developed by IFREMER. Viewing, analyzing and geo-
167 referencing of the videos were carried out with the ADELITM Video v3-beta system
168 (Ifremer©). Rock samples were collected using Niwa (DNxx - samples) and Warren (DWxx -
169 samples) dredges on flat surfaces capping the seamounts, and using rock dredges (DRxx -
170 samples) along the flanks of the seamounts.

171 The sedimentological interpretation combines hand sample and thin section
172 observations. The reconstruction of carbonate depositional environments is based on the
173 interpretation of biological assemblages and depositional textures. In our definitions of
174 stratigraphic ranges, we primarily use the planktonic foraminifer zonal scheme described by
175 BouDagher-Fadel (2015), which is tied to the timescale defined by Gradstein et al. (2012).
176 We also used previous benthic and foraminiferal zonal scheme from BouDagher-Fadel (2008;
177 2013).

178 Some limestone samples were dated using Sr Isotope Stratigraphy (SIS; McArthur,
179 2012). To avoid bias in measured $^{87}\text{Sr}/^{86}\text{Sr}$ ratios related to post depositional processes, we
180 adopted a sequential dissolution method using weak acetic acid prior to Sr separation using
181 Eichrom® Sr spec Resin (Pin and Santos Zalduegui, 1997). Sr isotope compositions were
182 measured in static mode on a Thermo TRITON at the PSO (“Pôle de Spectrométrie Océan”)
183 in Brest, France. All measured ratios were normalized to $^{86}\text{Sr}/^{88}\text{Sr} = 0.1194$ and NBS987
184 (recommended value 0.710250). Ages were obtained using the LOWESS fit 4babacuses of
185 McArthur (2012). Uncertainties on ages were calculated by combining the external
186 reproducibility on measured $^{87}\text{Sr}/^{86}\text{Sr}$ ratios with uncertainties on the LOWESS fit
187 mathematical model. Detailed values of SIS analysis are presented in additional data online
188 (see supplementary 1).

189 **4. Results**

190 **4.1. General geomorphology of the Mozambique Channel flat top seamounts**

191 The southern part of the MC is characterized by a SW-NE trending irregular ridge
192 morphology supporting three flat top seamounts (Fig. 1C): the Bassas da India atoll (Fig. 3A),
193 the Hall Bank (Fig.4A) and the Jaguar Bank (Fig. 5A). This ridge is characterized by crater
194 and cones morphologies (Fig. 3A, 3B & 5A) that suggest a volcanic origin.

195 Bassas da India (Fig. 3A) is a roughly circular atoll of about 10 km in diameter and 80
196 sq.km. The width of the reef rim averages 100 m and completely encloses a shallow lagoon
197 which displays a maximum depth of 15 m. The southern flank of the modern atoll of Bassas
198 da India is typified by a 12km-wide flat top morphology (B1, Fig. 3A & 3C). The bathymetry
199 of this terrace ranges from -680m to -440m and is bounded by two linear escarpments, 50 to
200 200m high, extending towards the seabed (>1500m water-depth). These escarpments are
201 seemingly associated to major normal faults inducing important vertical offsets of terraces. A
202 minor and shallower flat top level can be observed around 220m deep (B2, Fig. 3A & 3C).
203 The Hall Bank (Fig. 4) averages 90 sq.km.in areal extent and is characterized by two terraces
204 (H1 & H2, Fig. 4A & 4E). The most prominent level is the shallowest one (H2) which occurs
205 between 430m and 525m while the secondary and deepest one (H1) is located at 600m water
206 depth. The Jaguar Bank (Fig. 5) is located 20km west of the Hall Bank (Fig. 1C) and covers
207 an area of 320 sq.km approximately. This seamount also exhibits an overall flat-topped
208 morphology but is characterized by an extensive, high escarpments network (Fig. 5A). These
209 lineaments, interpreted as normal faults, seemingly structure the overall morphology of the
210 Jaguar Bank (Fig. 5C). They limit several tilted panels ranging from 700m to 170m deep on
211 the northern margin and on the summit (southern extremity, Fig. 5A & 5C) respectively.
212 Bassas da India, the Hall and Jaguar banks flat-topped submarine morphologies exhibit sharp

213 and abrupt margins that are commonly incised by well-developed, 0.5 to 4.5 km wide, steep
214 convex bankward embayments (Fig. 3A, 4A & 5A). The most important embayment is
215 located on the northeastern flank of Bassas da India, and seems responsible for the “notched”
216 morphology of the modern atoll (Fig. 3A).

217 The DR is typified by an overall flat top morphology of 275 sq.km known as the
218 “Sakalaves Seamount” (Fig. 1B & 6A) which is located at about 18° S, in the middle of the
219 MC. This platform morphology extends over a distance of 30 km from north to south and over
220 12km from west to east, and is characterized by an elongated shape following the NNW-SSE
221 orientation of the DR (Fig. 6A). The Sakalaves Platform is affected by numerous linear
222 escarpments displaying the same trend, and dividing the overall morphology into multiple flat
223 top levels ranging from 500m (overall platform margin) to 335m (NW and SE extremities)
224 deep (Fig. 6A & 6C). These escarpments exhibit typical characteristics of normal faults on
225 bathymetrical data (Fig. 6C). To the west, a shallower level is characterized by its very rugged
226 morphology (“ru”, Fig. 6A). The abrupt slopes of the seamount are also incised by well-
227 developed truncation embayment morphologies, especially along its western flank (Fig. 6A).

228 The Glorieuses carbonate platform (Fig. 1B & 7A) is located about 160km northwest
229 of Madagascar. It displays SW-NE and SE-NW extensions respectively of more than 20 km
230 and of 17 km (Fig. 7A), and covers an area of about 230 sq.km. This platform includes an
231 archipelago comprised of a group of islands and rocks covering 5 sq.km. The flanks of the
232 Glorieuses platform and the nearby areas are characterized by several flat-topped
233 morphologies and associated slope breaks (Fig. 7A) ranging from 1100m (G1) to 200m (G3)
234 water depths. The NNW flank of the Glorieuses platform exhibits a drowned terrace around
235 750m deep (G2, Fig. 7). The latter is incised by a 2.5 km wide embayment. All these flat-
236 topped terraces are located on a rough submarine ridge, the top of which occurs at -1000 m
237 water depth, northwest of the Glorieuses Platform.

239 **4.2. Surface morphologies**

240 The coupled analysis of high-resolution bathymetry grids (Fig. 3B, 4B, 4C, 4D, 5B,
241 6B & 7B) and underwater videos (Fig. 8) were used to determine the nature of geological
242 features. The flanks of the drowned platforms are characterized by flat, smooth and bright
243 rocky slabs (e.g. Hall Bank and Glorieuses, Fig. 8A & 8B respectively) that are frequently
244 characterized by thin and regular networks of fractures; these formations display common
245 characteristics of carbonate rocks. Along the northeastern flank of the Hall Bank, the slope
246 between the two main terraces (i.e.. H1 and H2, Fig. 4A) is characterized by smaller-scale,
247 successive and parallel terrace morphologies that typify backstepped margins (Fig. 4D).
248 Except for the Glorieuses, the MC drowned flat-topped morphologies are also characterized
249 by well-developed closed to semi-enclosed circular depressions (e.g. Fig. 4A & 6B) that are
250 tens of meters to 1300m wide and up to 40m deep.

251 With the exception of the Glorieuses, the tops of the overall flat top morphologies are
252 characterized by a great diversity of rugged and positive morphologies that seemingly
253 intersect and partially cover the previous flat-topped topographies (Fig. 3, 4, 5 & 6). The very
254 rugged flat top level located on the western side of the Sakalaves Platform (“ru.”, Fig. 6B)
255 exhibits a dense network of 50 to 2000m long, and 10 to 30m wide linear positive ridges.
256 Although these ridges mostly display a regional NNW-SSE trend, they commonly form
257 polygonal patterns and irregular heaps. Rugged morphologies and irregular reliefs are also
258 observed on top of the Bassas da India terrace level (B1, Fig. 3A & 3C), as well as on top of
259 Hall (Fig. 4) and Jaguar Banks (Fig. 5). Underwater pictures made along these morphologies
260 (Fig. 8D, 8E & 8F) illustrated outcrops of very dark rocks associated both with rounded rocky
261 formations resembling pillow-lavas, and dense polygonal fracturing networks that are similar

262 to the tensional/contraction cracks that typically develop during submarine volcanic eruptions
263 (e.g. Yamagishi, 1991; Chadwick et al., 2013). On top of the Jaguar Bank, some of these
264 rugged morphologies exhibit lobate and interdigitated downslope-flowing morphologies (Fig.
265 5B) displaying striking similarities with submarine lobate lava flows (see Gregg and Fink,
266 1995). Underwater pictures taken on the western part of the Sakalaves platform top (ru level,
267 Fig. 6A) show dark intrusions into brighter rocky outcrops (Fig. 8C), suggesting that the ridge
268 network (Fig. 6B) corresponds to eroded volcanic dyke system.

269 **4.3. Dredged samples**

270 Rock samples collected along rough ridges (Dredges DR -04, -13, -17 & -19, see
271 respective locations Fig. 1C, 6A & 7A) on which platform morphologies are established
272 correspond to blocks of volcanic rocks (pictures available in additional data online; see
273 supplementary 2). They are mostly composed of alkali mafic lavas (olivine basalts to
274 nephelinites) at Bassas da India, Hall Bank, Jaguar Bank, and Sakalaves Platform. Rock
275 samples collected on the NW ridge of the Glorieuses include encrusted trachy-andesite to
276 trachyte lava. Polygenic pebbles that have been collected at the top of the Hall Bank (DW05,
277 see location on Fig 4A) are composed of altered volcanic material (lavas and volcanic
278 breccias; see additional data available online for illustrations) and limestones. These pebbles
279 are systematically encrusted by very dark Fe-Mn oxyhydroxides layers that are up to 7mm
280 thick. Overall, rock samples collected on the upper flanks and at the top of drowned flat-
281 topped morphologies are limestones (Fig. 9, Tab. 1).

282 Rock sample collected along the SW flank of the Hall Bank (DR18-01, see location on
283 Fig. 4A) corresponds to a skeletal packstone bearing large corals grains encrusted by red algae
284 and encrusting foraminifera, many robust LBF as well as *Halimeda* algae (Fig. 9A, 9B & 9C;
285 Table 1). Such biological composition typically reflects tropical shallow-water depositional

286 settings. The microfauna assemblage is characterized by *Miogypsina regularia* (Fig. 9C) and
287 *Lepidocyclina brouweri* (Fig. 9B) which corresponds to N8a planktonic foraminifera zone
288 (Burdigalian, BouDagher-Fadel, 2008; 2015). The isotopic strontium stratigraphy (SIS)
289 indicates a consistent age of 16.29 +/- 0.10 Ma (Tab. 1; detailed SIS values are presented in
290 supplementary 1 online). In addition to volcanic pebbles and undated highly altered corallgal
291 limestones, the top of the Hall Bank (DW05; Fig. 4A) is characterized by the occurrence of a
292 planktonic foraminifera packstone (DW5-C1, Fig. 9D, Tab. 1) typifying an outer neritic
293 environment. It includes *Sphaeroidinella dehiscens* (Fig. 9D), *Globorotalia tumida*,
294 *Globigerinoides quadrilobatus* (Fig. 9D) as well as common *Globigerina* spp. and
295 *Globorotalia* spp; this assemblage corresponds to N18-N19 planktonic foraminifera zone
296 defined by BouDagher-Fadel, 2015 (Late Messinian - Early Zanclean, 5.8-3.8 Ma), in
297 agreement with the Zanclean age given by the isotopic strontium stratigraphy (i.e. 5.09 Ma,
298 Tab. 1).

299 Rock sample collected along the southeastern flank of Bassas da India (DR20-01, see
300 location on Fig. 3A) corresponds to a skeletal packstone mainly comprised of planktonic
301 foraminifera, encrusting foraminifera and coral fragments, red algae and bivalves (Fig. 9E &
302 9F, Tab. 1). The microfauna assemblage includes *Orbulina suturalis* (Fig. 9E), *Orbulina*
303 *universa*, *Globoquadrina dehiscens* as well as *Dentoglobigerina altispira* and corresponds to
304 the N9-N20a planktonic foraminifera zone (Middle Miocene - Early Pliocene). SIS gives a
305 consistent late Miocene age of 8.48 +/- 0.49 Ma (Tortonian, Tab. 1).

306 Dredgings carried out along the eastern flank of the Sakalaves Platform (DR13, see
307 location on Fig. 5A) recovered volcanic rocks and limestones which correspond to a LBF-rich
308 grainstone typified by rhodoliths and volcanic fragments (DR13-08; Fig. 9G & 9H, Tab. 1).
309 These limestones include *Spiroclypeus vermicularis* (Fig. 9C) and *Cycloclypeus koolhoveni*,
310 which can be attributed to the P18-P19 foraminifera zones (BouDagher-Fadel, 2013; 2015,

311 Rupelian, 33.9-30.3 Ma, Tab. 1). The obtained SIS age is of 33.11 +/- 0.14 Ma (Early
312 Oligocene, Rupelian) for DR13-08 and is therefore consistent with biostratigraphic data. Rock
313 samples recovered from the top of the Sakalaves Platform (DW04, see location on Fig.6A) are
314 comprised of corallgal boundstone (DW04-01, Fig. 9I) and outer shelf planktonic foraminifera
315 packstone (DW04-02a, Fig. 9J). The occurrence of *Cycloclypeus postinornatus* and
316 *Cycloclypeus carpenteri* in DW04-01 indicates the N14 to N21 shallow benthic zones
317 (BouDagher-Fadel, 2008; 2015, Late Miocene-Pliocene, 11.6-1.8 Ma). SIS gives an age of
318 8.80 +/- 0.35 Ma (Tortonian) for DW04-01 (Fig. 9). DW04-02a includes *Sphaeroidinella*
319 *subdehiscens*, *Globoquadrina* sp. and *Orbulina universa* (Fig. 9J) and is associated to N19-
320 N20 planktonic foraminifera zone (Zanclean; BouDagher-Fadel, 2015; Tab. 1). For the latter,
321 no SIS age is available.

322 Finally, rock samples collected on the flat top morphology located NW of the
323 Glorieuses (DN01, see location on Fig. 6J) correspond to corallgal boundstones with pockets
324 of Discocyclinid LBF packstones (Fig. 9K & 9L). The relevant assemblage, characteristic of a
325 tropical shallow-water depositional environment, includes *Discocyclina sella* (Fig. 9L) and
326 *Daviesina* sp. and coincides with the P3-P5a foraminifera zone (BouDagher-Fadel, 2008,
327 Paleocene). SIS analysis on DN01-01 provides three potential ages of 67.11 +/-0.27 Ma,
328 61.52 +/- 1.80 Ma and 33.89 +/- 0.15 Ma. The foraminifera assemblage indicates that this
329 limestone is Selandian to Thanetian in age (Paleocene), thus suggesting that the correct SIS
330 age is of 61.52 +/- 1.80 Ma (Tab. 1).

331 **5. Discussion**

332 **5.1. Origin of Mozambique Channel flat top seamounts**

333 While most of flat top seamounts are currently drowned at hundreds of meters deep
334 (i.e below the photic zone), the MC submarine plateaus and terraces display typical

335 geomorphological features of shallow-water carbonate platforms. Their morphologies are
336 characterized by successive very steep margins delineating distinct terraces levels (Fig. 3, 4,
337 5, 6 & 7) that are interpreted as resulting from different phases of carbonate platform
338 development and backstepping. The observed very steep margins, characterized by bright
339 rocky slabs (Fig. 8A & 8B), are very reminiscent of shallow-water carbonate flanks that
340 typically accumulate along tropical carbonate platforms. The biological assemblages that
341 characterize the limestones samples recovered along MC carbonate platforms are mainly
342 composed of hermatypic corals, coralline red algae, green algae (*Halimeda*) and LBF (Fig. 9),
343 thus confirming a tropical shallow-water depositional environment. The combination of
344 biostratigraphic and strontium isotopic data demonstrates that MC shallow-water carbonate
345 platforms colonized their volcanic substrates during distinct Cenozoic time windows, ranging
346 from the Paleocene to the Early Miocene.

347 The rounded depressions (Fig. 4A & 6B) observed on top of the drowned terraces of the south
348 MC and Sakalaves flat-top seamounts could be related to explosive events or gravity collapses
349 associated to volcanic activity (e.g. Chadwick et al., 2013). They might also correspond to
350 karst pits caused by carbonate dissolution processes and associated collapses (e.g. Grigg et al.,
351 2002; Guidry et al., 2007) into a carbonate platform which underwent (a) long period(s) of
352 subaerial exposure. As observed along numerous ancient and modern carbonate platforms
353 margins (e.g. Bahamas Archipelago, Jo et al., 2015), the MC drowned platform margins are
354 incised by well-developed steep convex-bankward embayments (mfs, Fig 3A, 4A, 5A, 6A &
355 7B). These truncation features, also called "scalped margins" (Mullins and Hine, 1989) are
356 interpreted as erosional features resulting from catastrophic large-scale margin failures
357 usually induced by earthquake shocks in tectonically active areas, and by dissolution
358 processes and/or deep water currents in stable regions (Mullins and Hine, 1989; Jo et al.,
359 2015).

360 **5.2. Long-term (Paleocene to Present) evolution of the Glorieuses carbonate**
361 **platform**

362 In the northern part of the MC channel, the Glorieuses volcanic ridge (Fig. 7A) was
363 colonized by an isolated carbonate system during the Paleocene (Fig. 10) at the latest, as
364 indicated by the Selandian to Thanetian age (Tab. 1) of its second terrace level (G2, Fig. 7B)
365 which crops out at 750m deep. The coralgall limestones that are associated with abundant
366 Discocylinid LBF suggest that this drowned terrace developed in a shallow-water
367 depositional environment. Although Early Paleogene platform carbonates are often poorly
368 preserved and/or inaccessible (Baceta et al., 2005), LBF-rich reef carbonates have been well
369 documented in Paleocene shallow-water formations (e.g. Bryan, 1991; Scheibner and Speijer,
370 2008b). The occurrence of a carbonate terrace (G1, Fig 7A), at approximately 1100m deep,
371 suggests that carbonate production started even before the Late Paleocene, i.e. most likely
372 during Early Paleocene or Late Cretaceous. Overall, the distinct terrace levels (G1, G2 & G3;
373 Fig. 7) observed along the flanks of the Glorieuses carbonate platform are interpreted as
374 resulting from successive development and backstepping episodes, before the initiation of
375 modern shallow-water carbonate systems.

376 The drowning of the 750m deep coralgall Paleocene terrace (G2, Fig. 7B) could be
377 associated with the major long-term climatic warming of the Paleocene-Eocene transition
378 during which many Tethyan coral reef systems declined (Scheibner and Speijer, 2008a,b).
379 Furthermore, the narrowness of the volcanic ridge which is located NW of the Glorieuses
380 platform potentially deprived the carbonate builders of an appropriate large substrate on
381 which the platform could have backstepped. Despite the occurrence of successive terraces
382 (Fig. 7), the long-term evolution of the Glorieuses carbonate platform appears relatively
383 continuous at the Cenozoic time scale. The development of shallow-water carbonate

384 platforms during the Cenozoic is quite common in the Western Indian Ocean, as indicated for
385 instance at de Saya de Malha and Nazareth Banks (Mascareign Ridge), where exploration
386 wells SM1 and NB-1 (Texaco Inc.) have penetrated Late Paleocene to Pliocene shallow-water
387 carbonate platform limestones (Kamen-Kaye and Meyerhoff, 1980).

388 **5.3. Oligo-Miocene growth of south MC and Sakalaves shallow-water carbonate** 389 **platforms**

390 The shallow-water carbonate production on the Sakalaves Platform, presently drowned
391 at 335 m deep, was initiated on the DR during the Oligocene (Tab. 1, Fig. 10). The occurrence
392 of many volcanic fragments (Fig. 9G) into the skeletal packstone recovered along the western
393 flank of the Sakalaves platform suggests the presence of nearby volcanic reliefs during
394 carbonate deposition, confirming that the colonization occurred during Rupelian time. The
395 LBF and red algae-rich carbonate assemblage that characterizes the relevant carbonates (Fig.
396 9G & 9H, Tab. 1) is quite similar to that of other Oligocene shallow-water carbonate
397 platforms, such as the *Lepidocyclina* limestones that have been described in early Oligocene
398 deposits of the Cayman Brac isolated carbonate bank (Caribbean, Jones and Hunter, 1994).
399 Drilling operations carried out on the Kerendan platform (Oligocene, Indonesia) also reported
400 packstones that are rich in large benthic foraminifera and fragments of coralline algae (Saller
401 and Vijaya, 2002). The Sakalaves carbonate platform most likely continued its development
402 during Miocene times (Fig. 10) until the deposition of Late Miocene (Tortonian) corallgal
403 frameworks (Fig. 6A & 9I). This result is consistent with a previous study reporting Miocene
404 limestones on top of the platform (Leclaire et al., 1989). The presence of Zanclean outer shelf
405 packstones suggests that the drowning of the Sakalaves shallow-water carbonate platform
406 occurred during Late Miocene to Early Pliocene times (Fig. 10)

407 In the South MC, the analysis of limestone samples collected along the southwestern
408 flank of the Hall Bank (Tab. 1) suggests that carbonate production started at the latest during
409 the Early Miocene (Fig. 10). Although no Early Miocene carbonate samples have been
410 collected along the flanks of Bassas da India and of the Jaguar Bank, these features are
411 located on the same volcanic ridge and presently occur at similar depths (i.e. 600-800m, Fig.
412 3, 4 & 5), thus suggesting that they may have appeared during the same period. The
413 abundance of encrusted coral fragments, robust large benthic foraminifera and *Halimeda*
414 algae (DR18-01 & DR20-01; Tab. 1) indicates that the South MC Miocene limestones were
415 deposited in shallow-water carbonate environments. Similar Miocene carbonate assemblages
416 have been commonly reported in the Indo-Pacific realm and were often associated to reef
417 systems (e.g. Australia, Betzler and Chapronière, 1993; Bornéo, Wilson, 2005; Indonesia,
418 Novak et al., 2013). During its evolution, the Hall Bank underwent a major backstepping
419 episode which shifted carbonate production from H1 to H2 terrace (Fig. 4A & 4D). The
420 demise of shallow-water carbonate sedimentation on the Hall Bank is marked by the
421 deposition of outer shelf carbonates during early Pliocene times (Tab. 1, Fig. 10). Conversely,
422 in Bassas da India, aggradation processes continued until present days to form a modern atoll.
423 The Fe-Mn crusts observed on pebbles collected on top of the Hall Bank have been
424 commonly reported on top of drowned shallow-water carbonate platforms (e.g. Pacific
425 guyots, Bogdanov et al., 1995; Camoin et al., 1998) where they have been interpreted as
426 resulting from a slow precipitation onto hard substrates in areas swept by strong bottom
427 current (e.g. Mangini et al., 1986).

428 **5.4. Late Miocene - Early Pliocene drowning phases: tectonic and rejuvenated**
429 **volcanism as major triggers ?**

430 The occurrence of extensive volcanic morphologies (Fig. 3, 4 & 5) and material, and
431 of widespread faults and fracturing networks on tops of drowned carbonate terraces suggest
432 that geodynamic activity could be involved in shallow-water carbonate platforms demises
433 during Late Miocene to Early Pliocene times. Morphological analysis as well as underwater
434 pictures and dredge samples display many evidences of subaqueous extrusive volcanism (e.g.
435 pillow lavas and lobate lava flow, Fig. 4C, 5B, 8D, 8E & 8F) but also of intrusive volcanism
436 especially typified by dyke morphologies as observed along the Sakalaves Platform (Fig. 6B
437 & 8C). Relevant eruptive phases brought volcanic material (e.g. lava flow, volcanoclasts) and
438 significant environmental changes (e.g. water transparency, water temperature) that likely
439 stressed and smothered shallow-dwelling carbonate producers. In parallel, The MC drowned
440 carbonate platforms are affected by widespread and extensive faults and fracturing networks
441 which display extensional deformation patterns such as frequent high-offset normal faults
442 (e.g. Fig. 3, 5A, 5C & 6). In this context, drowning of the MC shallow-water carbonate
443 platforms could be related to extensional deformation and rapid pulses of tectonic subsidence
444 outpacing carbonate accumulation rates. For instance, the occurrence of two high-offsets
445 normal faults delimiting Bassas da India first terrace (B1, Fig. 3A) suggests that tectonic
446 movements were involved in the major backstepping phase through the sudden drowning of
447 shallow-water carbonate producers below the photic zone. The continuous development of
448 Bassas da India isolated carbonate systems after late Miocene-Pliocene drowning events
449 suggests the occurrence of topographic highs, such as tectonically raised area, that
450 subsequently allowed the backstepping of the shallow-water carbonate factory. Volcanic
451 morphologies (e.g. lava deltas, Hawaii; Puga-Bernabéu et al., 2016) may be also colonized by
452 shallow-water carbonate systems during backstepping processes in response to a rapid
453 increase in accommodation space or to environmental deterioration. Along Tonasa carbonate
454 platform (Sulawesi, Indonesia), Wilson (2000) also described shallow-water carbonate

455 platform evolution and demise that were primarily controlled by tectonic and volcanic
456 activity.

457 Environmental disturbances (e.g. nutrient input, paleo-climatic and -oceanographic changes)
458 are frequently invoked to explain the demise of shallow-water carbonate platform and also
459 have to be discussed. Dredge samples analysis suggest that demise of the Sakalaves Platform
460 and drowning episodes of south MC carbonate platforms took place during late Miocene to
461 early Pliocene times (Fig. 10). In the Indo-Pacific realm, several drowning episodes induced
462 by environmental deterioration have reported during the same Neogene time span. On the
463 Marion Plateau (Australia), cooling and re-organization of ocean circulation triggered during
464 Late Miocene, successive drowning events of the carbonate platform (Eberli et al., 2010).
465 Along Maldives carbonate platform, Betzler et al. (2009) proposed that late Miocene-Early
466 Pliocene partial drowning of the platform is linked to onset and intensification of the
467 Monsoon trough injection of nutrient into shallow-water. Coeval drowning episodes in the
468 Indo-Pacific realm suggest that environmental conditions deterioration linked to paleo-
469 climatic and paleo-oceanographic reorganization could also be involved in Late Neogene
470 demise of the MC shallow-water carbonate platforms. Finally, the rounded depressions
471 observed on Hall Bank top and that potentially correspond to karst pits, might suggest
472 extended periods of subaerial exposure which are potential triggers of major drowning events
473 (e.g. Schlager et al., 1998).

474 **5.5. Geodynamical implications**

475 Two primary conditions are required for the initiation and development of a tropical
476 isolated carbonate system: (1) the existence of a hard substrate available for the settlement of
477 shallow-water carbonate producers, and (2) the occurrence of such a substrate in the euphotic
478 zone. This study demonstrated that the MC carbonate platforms developed on irregular and

479 isolated volcanic reliefs (Fig. 1C, 3, 5 & 7; rock samples pictures available on supplementary
480 2 online). In the Glorieuses, the record of a Selandian to Thanetian terrace (G2, Fig. 7 & Tab.
481 1) implies that the volcanic event that was responsible for the formation of the seamount
482 occurred before the Late Paleocene (Fig. 10). This volcanic phase could be related to the
483 interaction between Madagascar and the Marion Hotspot (Meert and Tamart, 2006) and to the
484 coeval breakup of Madagascar and Greater India during late Cretaceous times (Storey et al.,
485 1995). The Glorieuses seamount may belong to a SE-NW volcanic axis running from
486 northwestern Madagascar coast towards Aldabra Atoll and encompassing the Leven Bank
487 (Fig. 2). The minimum Paleocene age of the Glorieuses seamount seemingly excludes its links
488 with the volcanic activity recorded in the Comoros Archipelago and that has been recently
489 interpreted as resulting from a lithospheric deformation in relation to the East African Rifting
490 during late Cenozoic times (Michon, 2016, Bachélery and Hémond, 2016). With the
491 exception of the G2 terrace, the Glorieuses platform does not exhibit evidences of major
492 drowning events during its Cenozoic development. In parallel, no evidence of tectonic or of
493 any renewed volcanic activity has been observed along its flank and in the nearby areas
494 suggesting that the Glorieuses carbonate platform has evolved in an overall stable
495 geodynamical setting since Early Paleogene times. Taking into account that Paleocene
496 eustatic sea level was approximately 50m above present day sea level (Miller et al., 2005), the
497 average subsidence of the Glorieuses seamount since the Paleocene is estimated between 10
498 and 15m/Myr.

499 Based on volcanic substrates, south MC and Sakalaves drowned carbonate platforms
500 display striking evidences of volcanic and tectonic activities during and/or after carbonate
501 platform development. In the southern MC, the eruptive phases responsible for the
502 development of a volcanic ridge (Fig. 1C) probably occurred during Oligocene to early
503 Miocene times, before its colonization by isolated carbonate systems and subsequent

504 development of carbonate platforms during the Miocene (Fig. 10). A phase of rejuvenated
505 volcanism and tectonic deformation took place in the Middle Miocene to Pliocene time span,
506 and possibly until the Pleistocene (Fig. 10). Along the DR, on the Sakalaves Platform, the
507 combination of geomorphological analysis and the dating of carbonate samples also
508 demonstrate that tectonic deformation and volcanism occurred from the Oligocene to the
509 present days. The Sakalaves Platform, which is affected by a dense fault network parallel to
510 NNW-SSE DR trend, is located in a seismically active area which seemingly corresponds to
511 an extension of the EARS offshore branch (McGregor, 2015; Fig. 2). The large margin failure
512 scars incising carbonate platform slopes (Fig. 3, 4, 5 & 6) could also indicate a sustained
513 tectonic activity (e.g. Mullins and Hine, 1989) along MC Cenozoic carbonate platforms. The
514 volcanic and extensional tectonic phases that have been identified along the Sakalaves
515 Platform and in the southern Mozambique Channel are coeval with the activity of the EARS
516 during Cenozoic times (McGregor, 2015), i.e. from Oligocene to present-day. Moreover, the
517 Sakalaves and southern MC carbonate platforms are located in a diffuse zone of the EARS
518 (Kusky, 2010) between Nubian and Somalian plates (Fig. 2). This area has been also
519 interpreted as another plate (Rovuma plate; Calais et al., 2006) and is characterized by
520 scattered but significant modern seismicity (Fig. 2). The formation of the volcanic basement
521 which forms the substrate of some MC carbonate platforms, as well as the extensional
522 tectonic and rejuvenated volcanism observed at the top of the platforms are thus interpreted as
523 links to EARS development and tend to confirm its southern diffuse propagation (Kusky,
524 2010). This example illustrates again that isolated shallow-water carbonate production has the
525 ability to record regional-scale geodynamic activity but also, conversely, that geodynamical
526 processes appear as major control parameters of tens of millions year shallow-water carbonate
527 platform evolution (e.g. Wilson, 2000; Yubo et al., 2011).

528 **6. Conclusions**

529 The main results of this study can be summarized as follow:

530 (1) The flat top and drowned seamounts of the Mozambique Channel correspond to
531 ancient tropical and isolated shallow-water carbonate platforms that initially settled on
532 volcanic substrates.

533 (2) The Mozambique Channel isolated carbonate platforms, located in different
534 geodynamical settings, set on during distinct Cenozoic periods ranging from Paleocene to
535 Early Miocene. These chronostratigraphic results are consistent with important phases of
536 shallow-water carbonate platform growth in the Indo-Pacific realm during the Cenozoic.

537 (3) The Mozambique Channel isolated carbonate platforms underwent distinct
538 polyphase evolutions that locally comprised tectonic deformation, volcanism and major
539 backstepping and drowning phases. Although the origin of demise episodes remain unclear,
540 tectonic and rejuvenated volcanism appear as most likely triggers. In parallel, Glorieuses and
541 Bassas da India shallow-water carbonate platforms survived and kept on developing until
542 present-day.

543 (4) Along the Sakalaves and the south Mozambique Channel carbonate platforms,
544 Cenozoic tectonic and volcanic activity is coeval and seems spatially linked to the
545 development and the propagation of the Eastern African rift system. The Paleocene onset of
546 shallow-water carbonate production at the Glorieuses carbonate platforms suggest Late
547 Mesozoic volcanism north of Madagascar, decoupled from more recent EARS activity.

548 Processes controlling shallow-water carbonate platform growth and demise on time
549 scales of tens of millions year periods are actively discussed but they remain poorly mastered.
550 The MC, representing a new promising area to study shallow-water carbonate platforms
551 growth and drowning events, suffers from lack of coring data to quantify numerous crucial
552 parameters such as growth rates or high frequencies environmental fluctuations. In this

553 context, drilling operations along the MC channels flat-top seamounts would offer an
554 outstanding opportunity to improve our understanding of isolated shallow-water carbonate
555 platforms systems.

556

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568

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740 **Captions**

741 **Figure1:** (A) Location of the Mozambique Channel in the Western Indian Ocean (B) General
742 physiography of the Mozambique Channel, bathymetry grid comes from GEBCO (100m
743 resolution, 2008). Studied seamounts are in bold.(C) Detailed physiography of Southern
744 Mozambique Channel seamounts, red line and lettering correspond to dredging. Isobaths have
745 been computed every 500m water depth.

746 **Figure2:** The Mozambique Channel and the East African rift system. Glo means Glorieuses
747 Platform. The Sakalaves Platform (Sa) and south MC carbonate platform (Ba) are located in a
748 diffuse zone of the EARS (Kusky et al., 2010). This area between western and southeastern
749 branches is also interpreted as another plate: the Rovuma plate (Calais et al., 2006). The two
750 white lines drawn north of Madagascar represent an hypothetical Late Mesozoic volcanic
751 alignment (see details in the text). Elevation/bathymetry grid comes from GEBCO (100m
752 resolution).

753 **Figure3:** (A) Geomorphology of Bassas da India Atoll seamount (see location on figure 1B &
754 1C). Green italic lettering corresponds to the nomenclature for successive flat-topped features
755 interpreted as drowned carbonate terraces and platforms. Red lines and lettering correspond to
756 dredgings. White boxe corresponds to the location of specific geomorphologies shown in
757 figure 3B. The yellow star corresponds to a sea bottom picture presented in figure 8. Black
758 dashed lines and lettering correspond to the location of morphological cross-sections shown in
759 figure 3C. fe: fault escarpments; mfs: margin failure scar. (B) Close up of volcanic cones

760 morphology (C) Morphological cross-sections of Bassas da India terraces. The red star
761 corresponds to the approximate location of DR20 dredge along morphological cross-section.

762 **Figure4:** (A) Overall geomorphology of the Hall Bank seamount (see location on figure 1B &
763 1C). Green italic lettering corresponds to the nomenclature for successive flat-topped features
764 interpreted as drowned carbonate terraces and platforms. Red lines and lettering correspond to
765 dredgings. White boxes correspond to the location of specific geomorphologies shown in
766 figure 4B, 4C & 4D. The yellow star corresponds to a submarine picture shown in figure 8.
767 Black dashed lines and lettering correspond to the location of morphological cross-sections
768 shown in figure 4E. fe: fault escarpment; mfs: margin failure scar.(B) Close up of rounded
769 depressions interpreted as resulting from volcanic or karstic processes. (C) Close up of
770 rugged, positive features along the H2 drowned carbonate terrace. This morphology is
771 interpreted as resulting from submarine volcanic eruptions. The yellow star corresponds to an
772 underwater picture shown in figure 8. (D) Close up of backstepping features interpreted as
773 successive "backstepped" carbonate terraces. (E) Morphological cross-sections of Hall Bank
774 margins. The red star corresponds to the approximate location of DR18 dredge along
775 morphological cross-section.

776 **Figure5:** (A) Overall geomorphology of the Jaguar Bank seamount (see location on figure 1B
777 & 1C). The red box corresponds to the location of a specific morphologies shown in figure
778 5B. fe: fault escarpment; mfs: margin failure scar. This overall flat-topped feature, interpreted
779 as a drowned carbonate platform, is characterized by a dense normal fault network delimiting
780 several tilted blocs. Black dashed line and lettering correspond to the location of the
781 morphological cross-section shown in figure 5C (B) Close up of a positive, rough and lobate,
782 morphology interpreted as a submarine lava flow (see text for more details). (C)
783 Morphological cross-sections of the Jaguar Bank.

784 **Figure6:** (A) Overall geomorphology of the Sakalaves Platform (see location on figure 1B)
785 interpreted as a drowned shallow-water carbonate platform. Red lines and lettering
786 correspond to dredge sampling. ru. in green italic lettering locates a flat-topped level
787 characterized by very rugged reliefs. The white box corresponds to the location of a specific
788 morphology shown in figure 6B. Black dashed line and lettering correspond to the location of
789 the morphological cross-section shown in figure 6C. fe: fault escarpment; mfs: margin failure
790 scar (B) Close up of the very rough flat topped level located on the western part of the
791 Sakalaves Platform. These dense network comprised of linear positive ridges and surrounding
792 heaps is interpreted as an eroded volcanic dyke system (for more details see the text).The
793 yellow stars correspond to the location of underwater pictures shown in figure 8. (C)
794 Morphological cross-sections of the Sakalaves Platform. The red star corresponds to the
795 approximate location of DW04 dredge along morphological cross-section.

796 **Figure7:**(A) Overall geomorphology of the Glorieuses platform (see location on figure 1B).
797 Green italic lettering corresponds to the nomenclature for successive flat-topped features
798 interpreted as drowned carbonate terraces and platforms. No fault nor recent volcanic features
799 are observed. The white box corresponds to the location of a specific morphology shown in
800 figure 7B. mfs: margin failure scar.(B) Close up of the drowned carbonate platform G2 which
801 occurs at 750m deep, northwest of the modern Glorieuses Platform. Red lines and lettering
802 correspond to the location of dredgings. The yellow star corresponds to the location of sea
803 bottom pictures shown in figure 8.

804 **Figure8:**Sea bottom pictures. (A) Limestone slab along the northern flank of the Hall Bank
805 (see location on figure 3A). (B) Limestone slab along the G2 drowned carbonate terrace,
806 northwest of the Glorieuses Platform (see location on figure 7B). (C) Volcanic dyke at the top
807 of the Sakalaves Platform (see location on figure 6B). (D) Pillow lavas at the top of the
808 Sakalaves Platform (see location on figure 6B).(E) Very dark volcanic outcrops with well-

809 developed fracturing network at the top of the Hall Bank (H2, see location on figure 4C).(F)
810 Lobate submarine lava flow on top of the B1 drowned carbonate terrace (Bassas da India, see
811 location on figure 3A).

812 **Figure9:** Thin sections micrographs. RA: Rodophyte Algae; Co: Coral; Ha: Halimeda algae;
813 EF: Encrusting Foraminifera, Ech: Echinoids. DR18-01 (A, B, C): Burdigalian skeletal
814 packstone with encrusted coral grains, *Lepidocyclina brouweri* Rutten (Lb) and *Miogypsina*
815 *regularia* BouDagher-Fadel and Price (Mio). DW05-C1 (D): Late Messinian - Early Zanclean
816 packstone of planktonic foraminifera typified by *Sphaeroidinella dehiscens* Parker and Jones
817 (Sa), *Globigerinoides quadrilobatus* d'Orbigny (Gdes) and *Globoquadrina dehiscens*
818 Chapman, Parr, and Collins (Gq). DR20-01 (E,F): Middle Miocene - Early Pliocene skeletal
819 Packstone characterized by *Cycloclypeus carpenteri* Brady (Cc) and *Orbulina suturalis*
820 d'Orbigny (Os). DR18-03 (G, H): Rupelian skeletal packstone of LBF with volcanic
821 fragments (v); *Lepidocyclina* sp. (L), *Daviesina* sp. (Da) and *Spiroclypeus vermicularis* Tan
822 Sin Hok (Sv). DW04-01 (I): Coralgal Boundstone. DW04-02 (J): Zanclean packstone of
823 planktonic foraminifera typified by *Sphaeroidinella subdehiscens* Parker and Jones (Ss),
824 *Globoquadrina* sp. and *Orbulina universa* d'Orbigny (Ou). DN01 (K, L): Coralgal
825 Boundstone with pockets of LBF packstones typified by *Discocyclina sella* d'Archiac (Di).

826 **Figure10:** Timing of major phases of shallow-water carbonate platform development and
827 geodynamic activity along Mozambique channels seamounts during Cenozoic times.

828 **Table1:** : Table summarizing dating results, depositional textures, main composition and
829 interpreted depositional environments of carbonate samples described and used in this study.

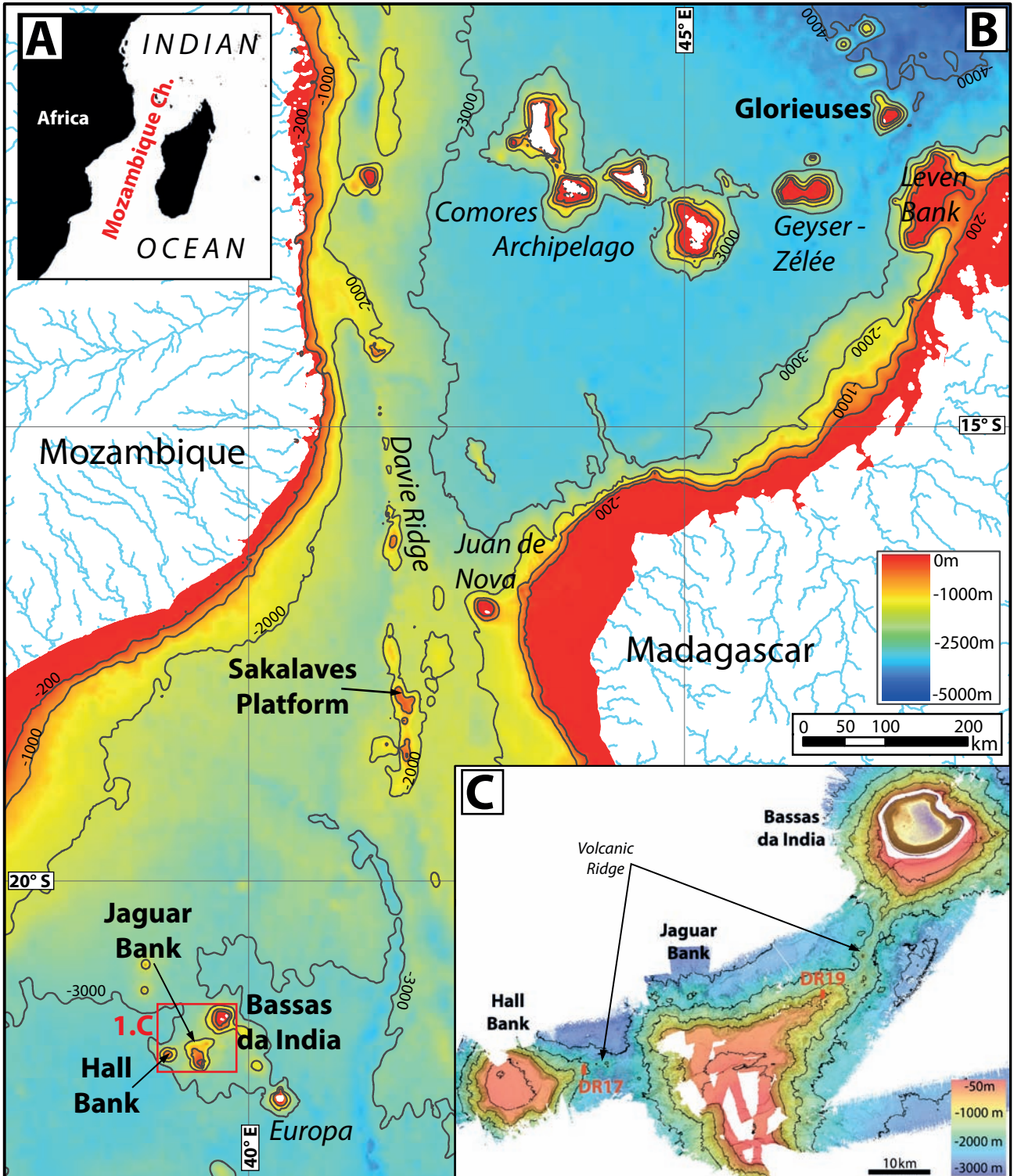
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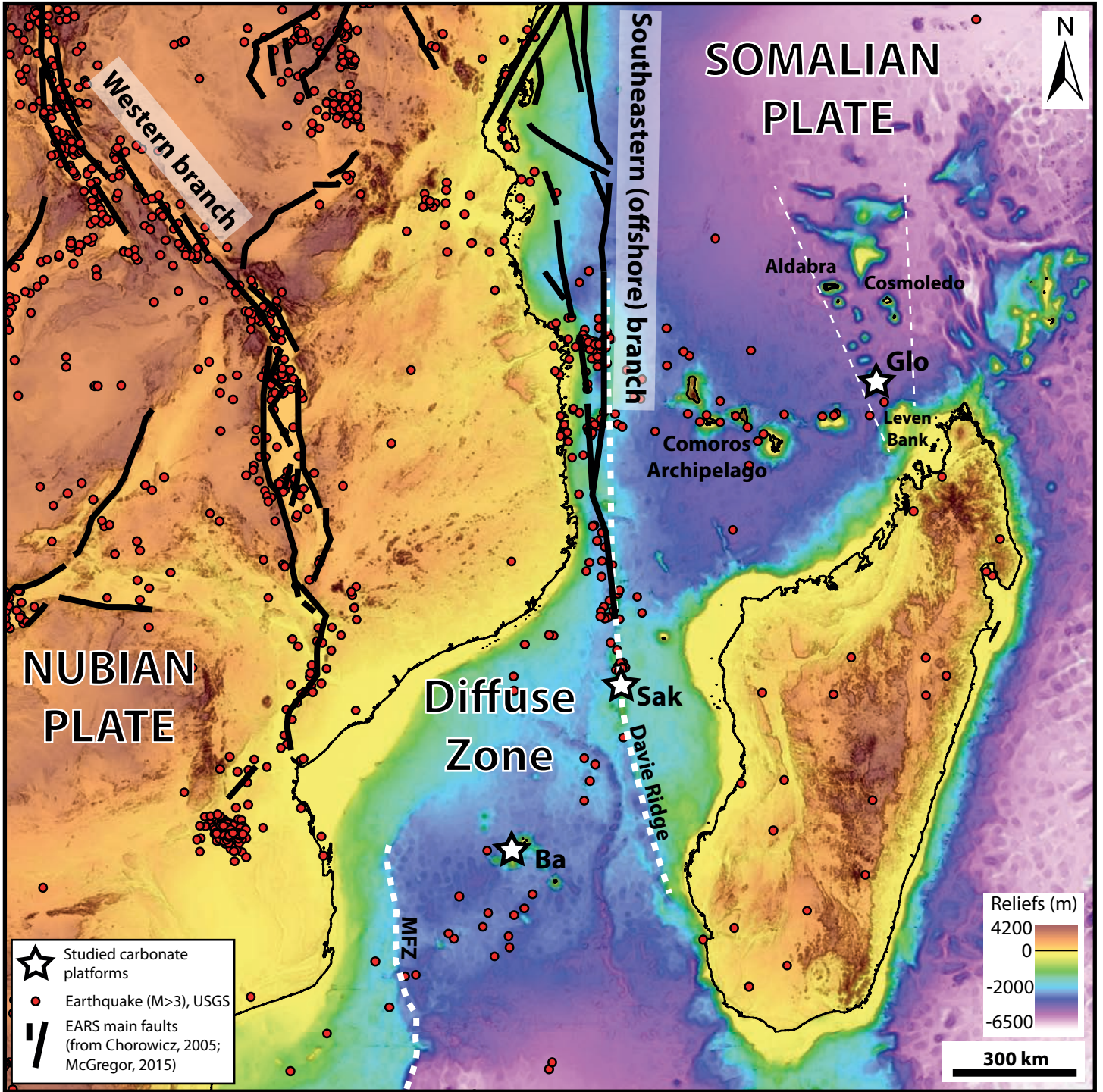
831 **Supplemental Data Captions**

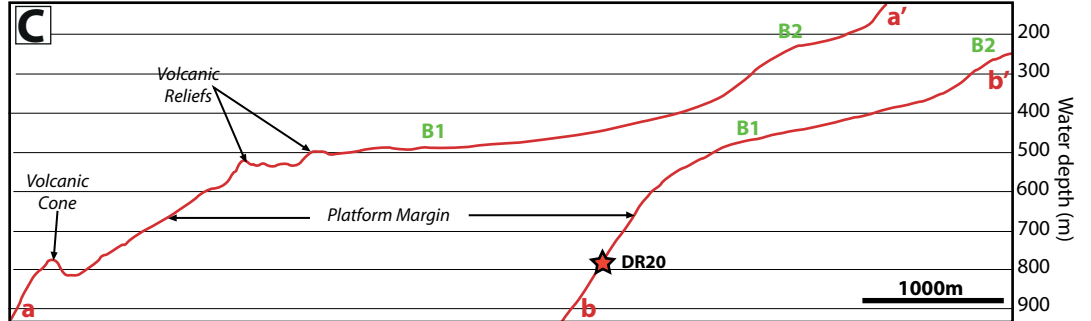
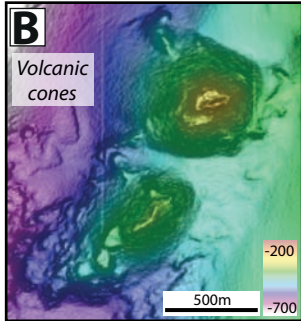
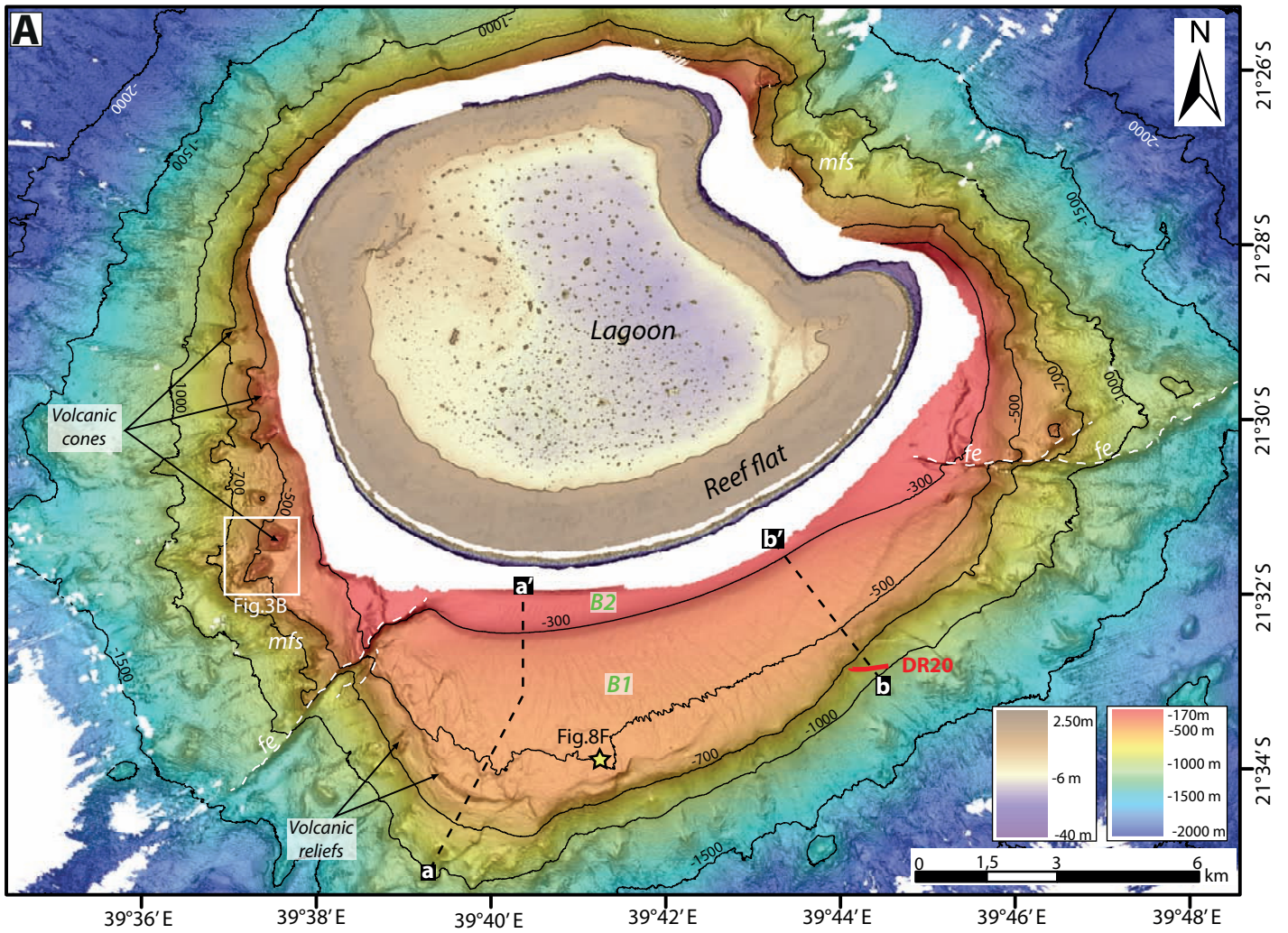
832 **Supplementary 1:** Synthetic tab about strontium isotopic stratigraphy (SIS) including
833 SR87/SR86 ratios, ages and associated errors.

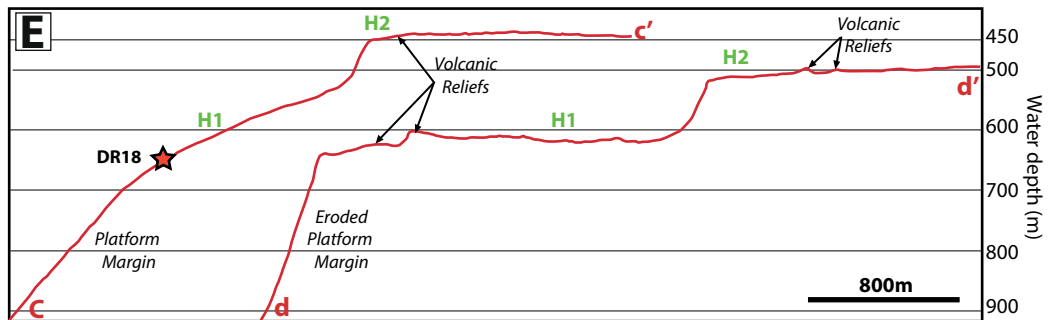
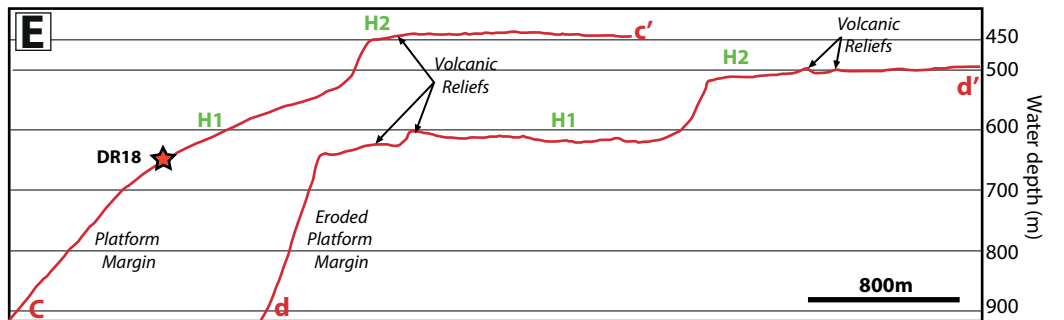
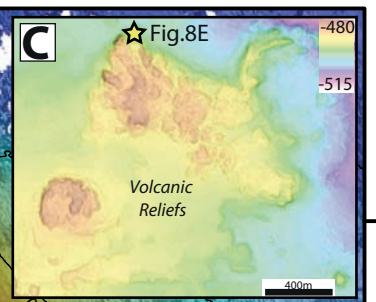
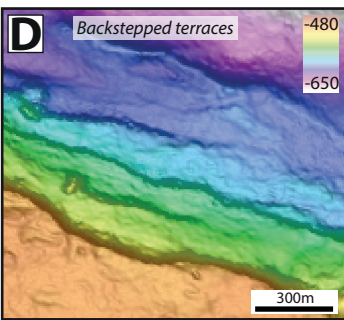
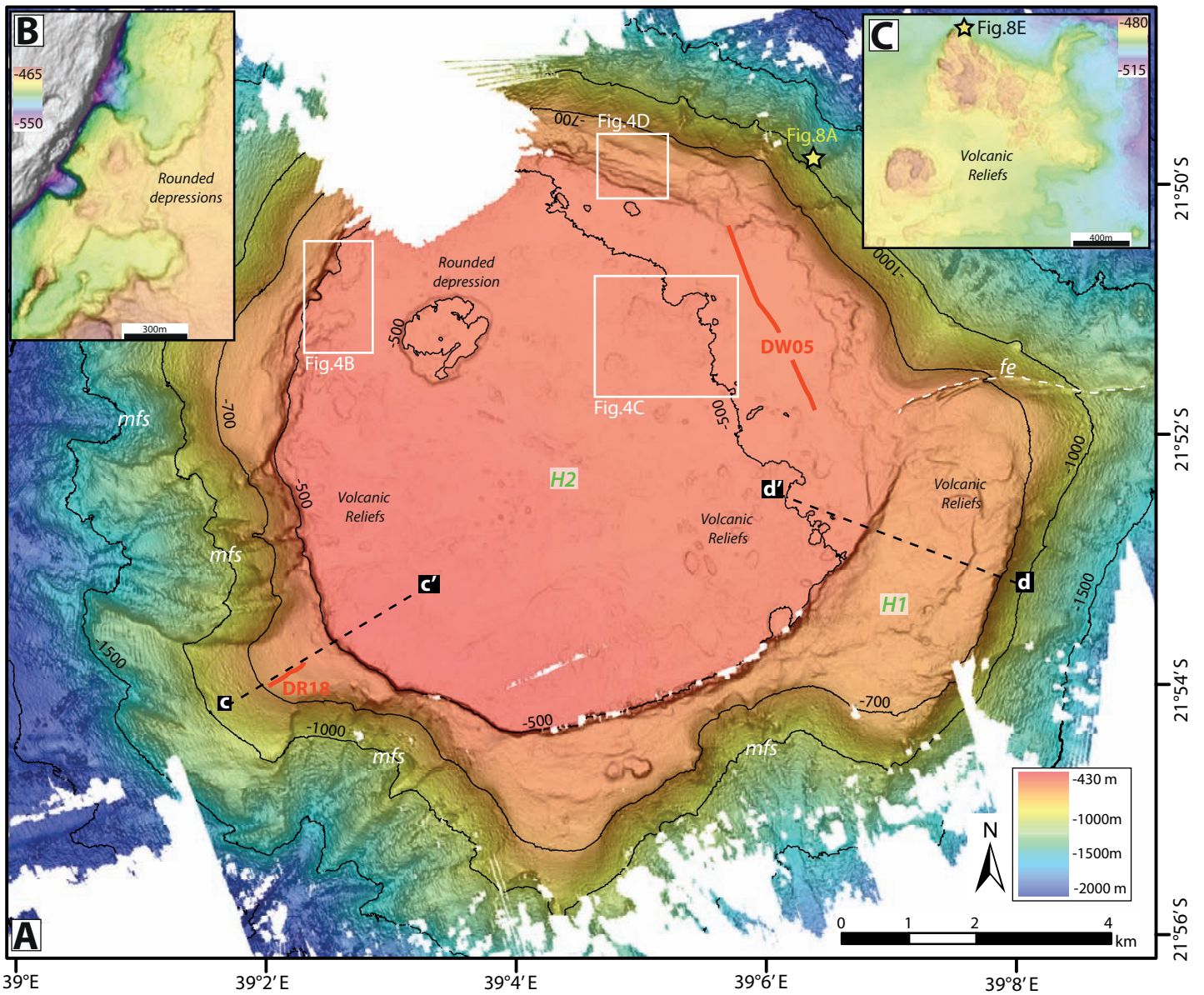
834 **Supplementary 2:** Volcanic rock samples collected along rough isolates ridges of the
835 Mozambique Channel. DR17-05, DR19-03, DR13-01 & DW05-01: Alkali mafic lava
836 fragments; DW05-01: heterogeneous volcanic breccia; DR04-22: trachy-andesite to trachyte
837 lava block

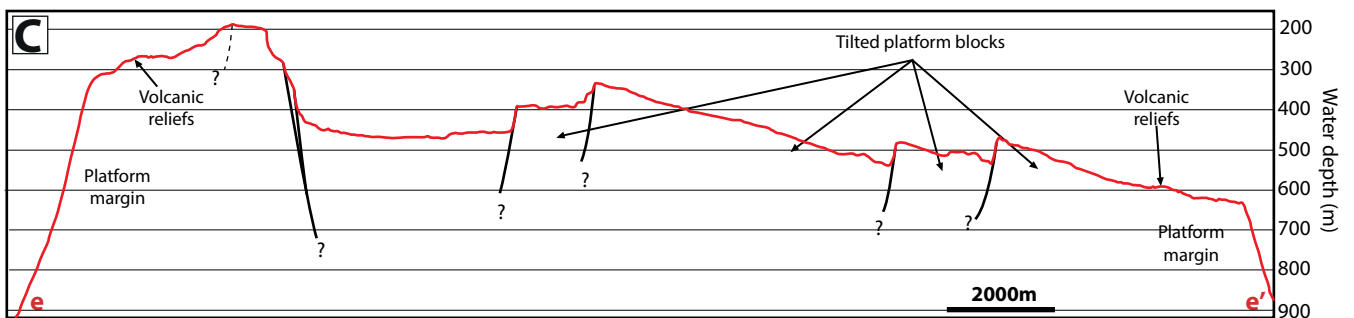
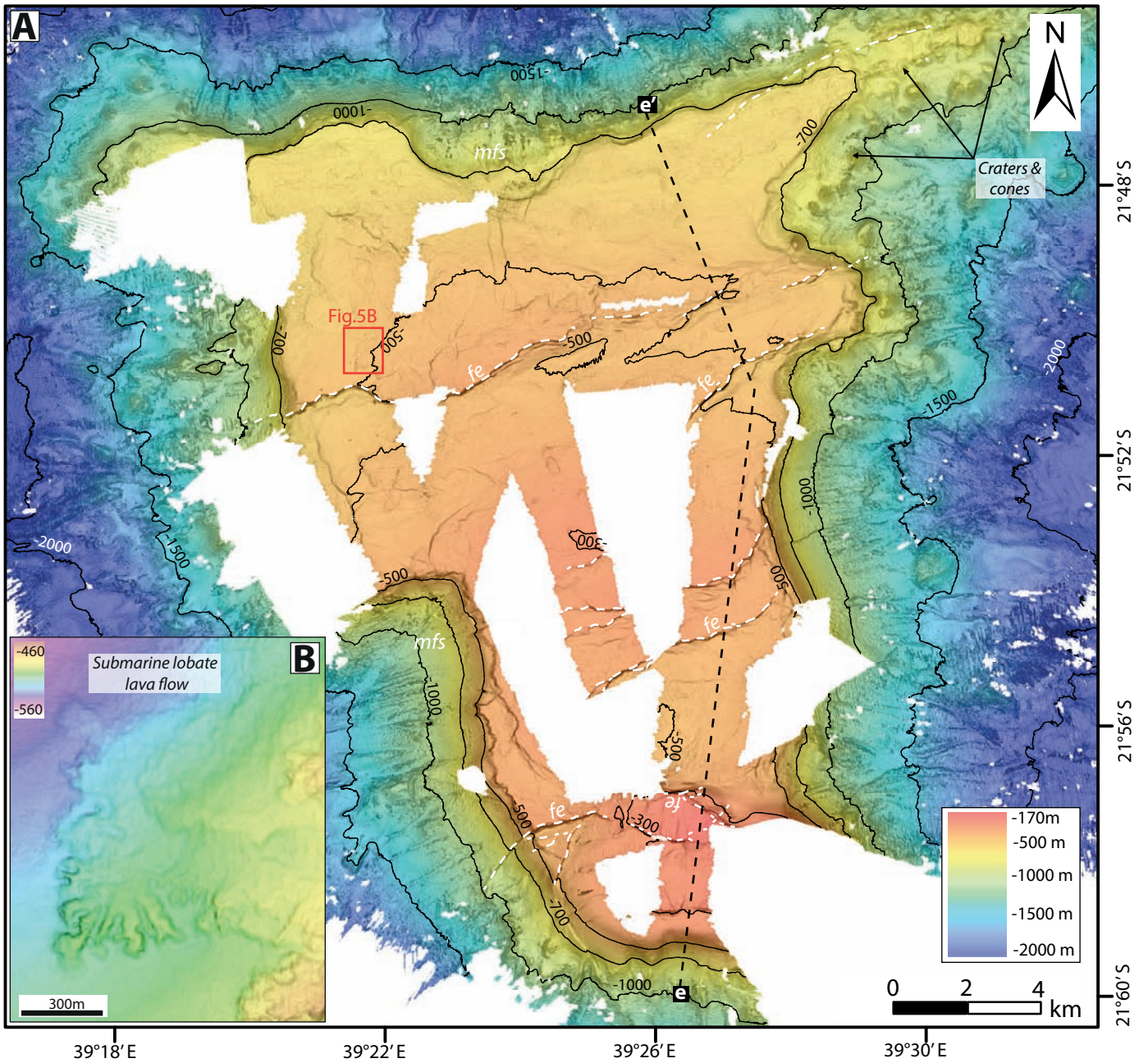
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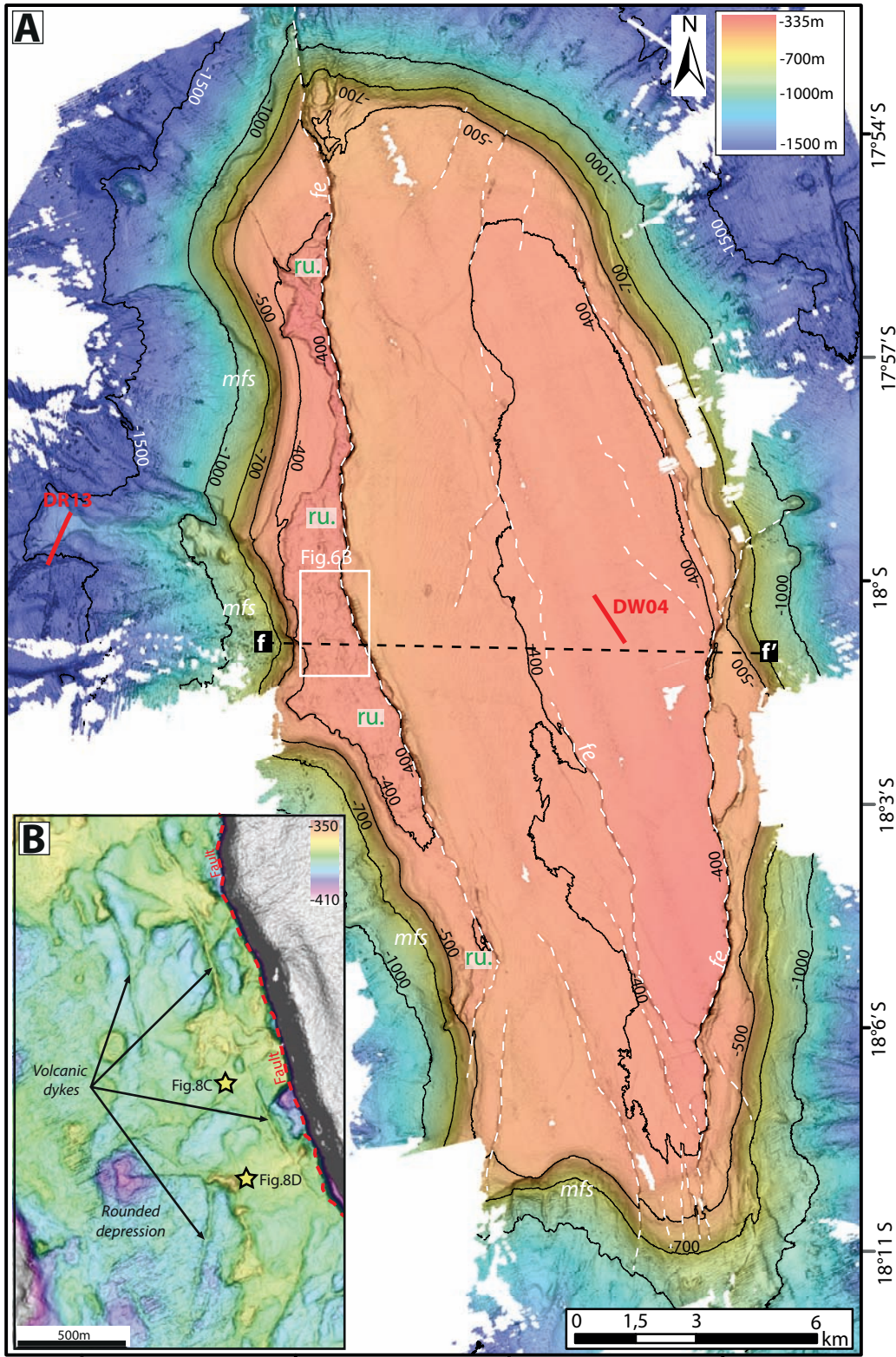


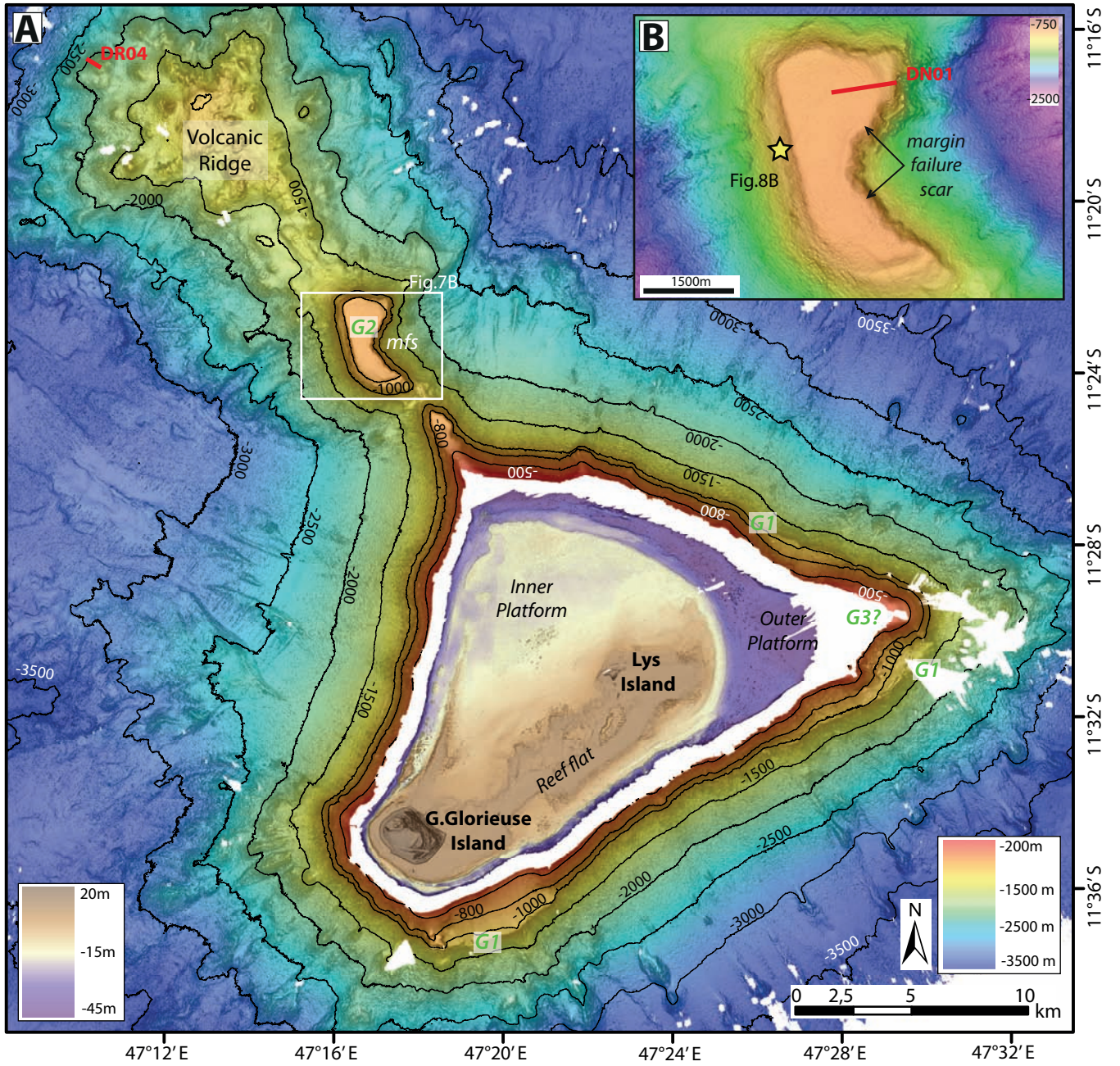


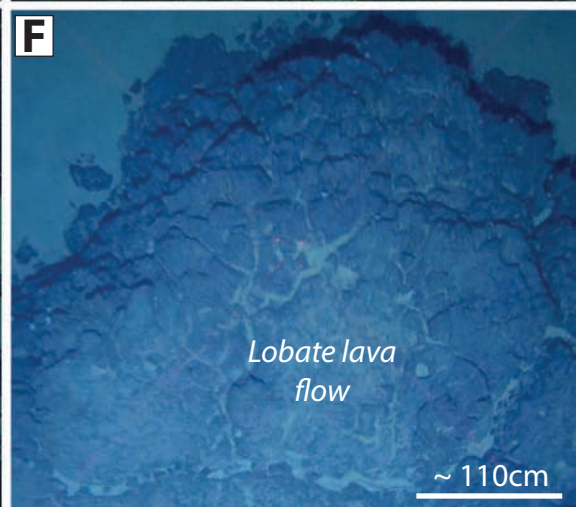
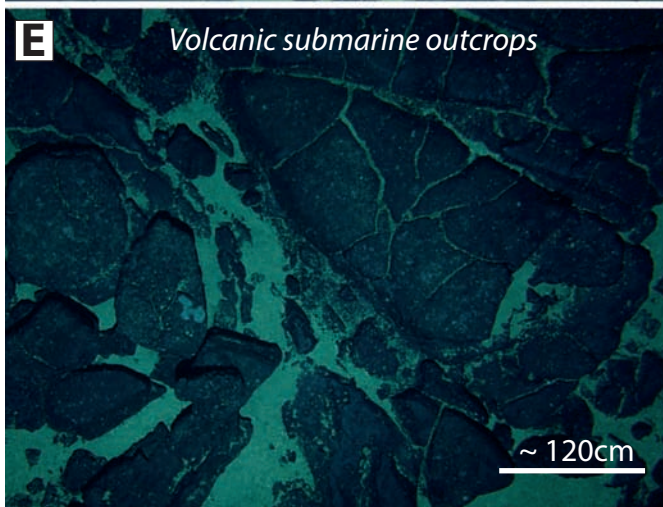
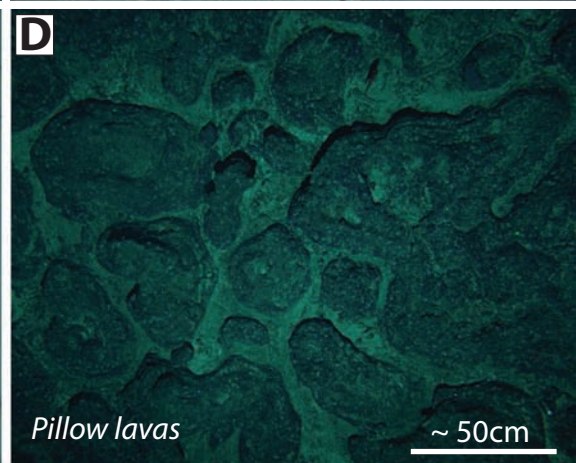
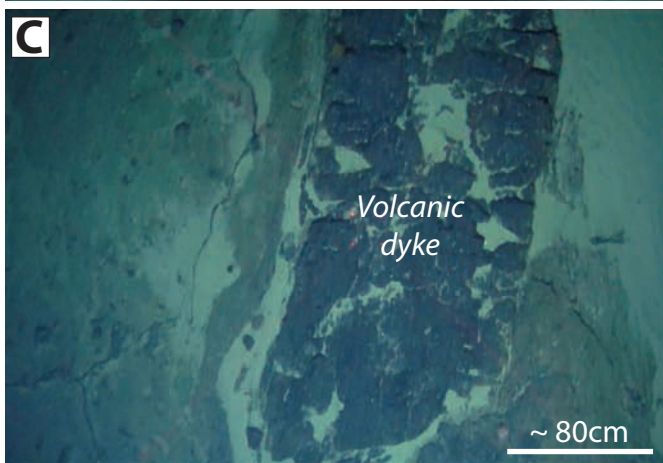
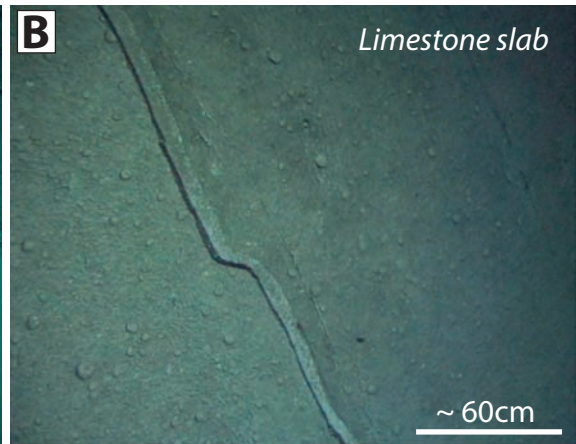


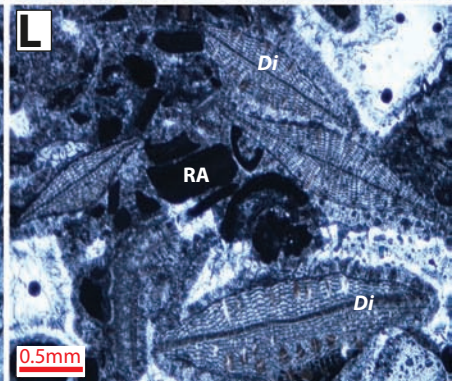
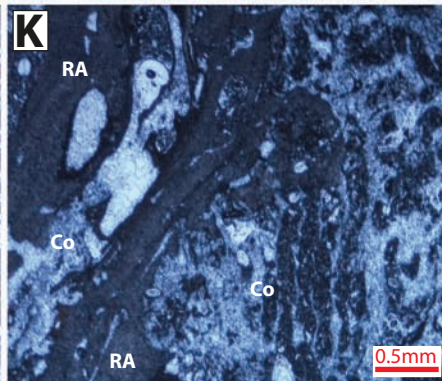
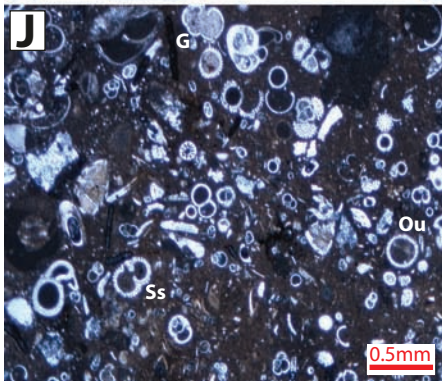
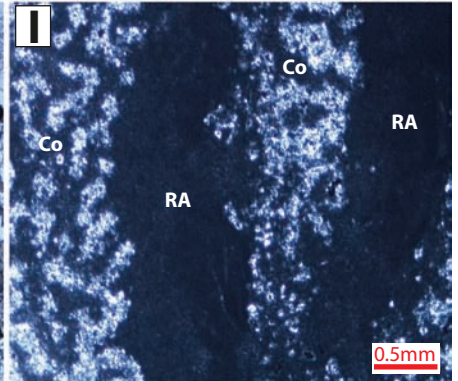
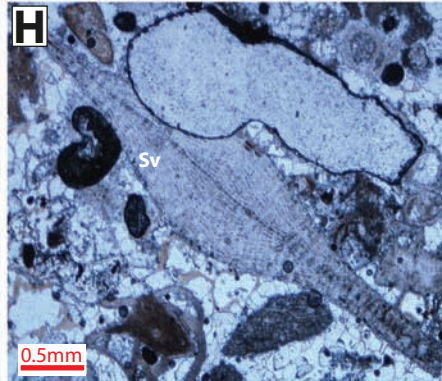
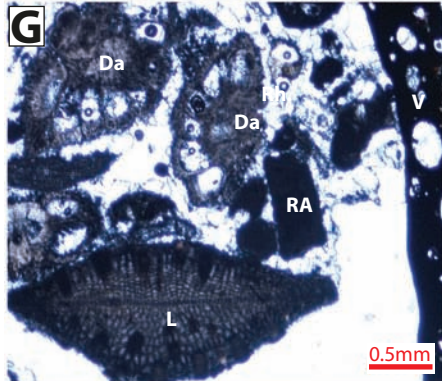
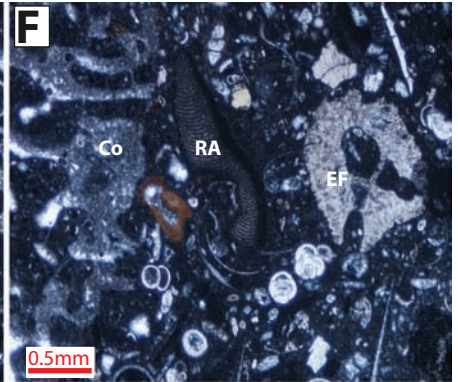
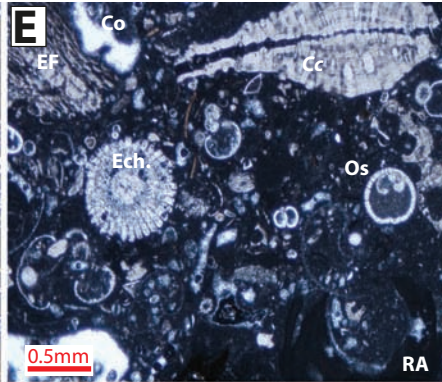
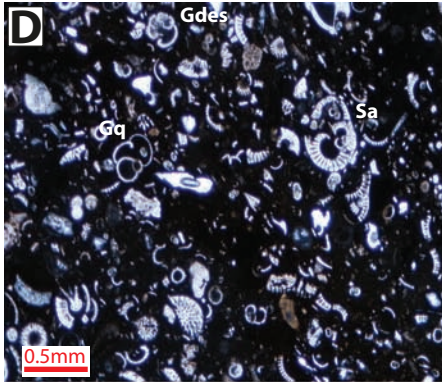
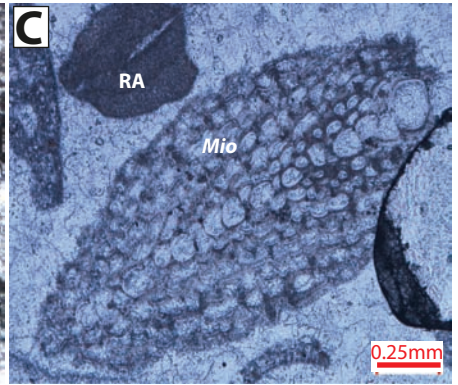
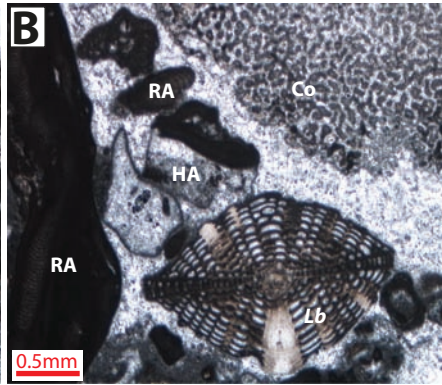
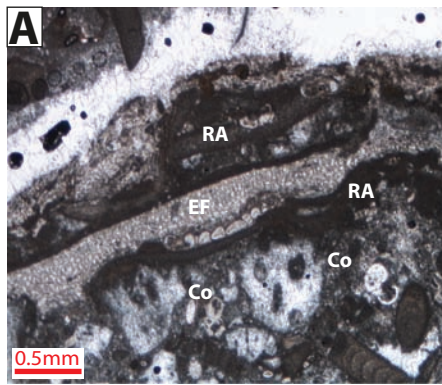






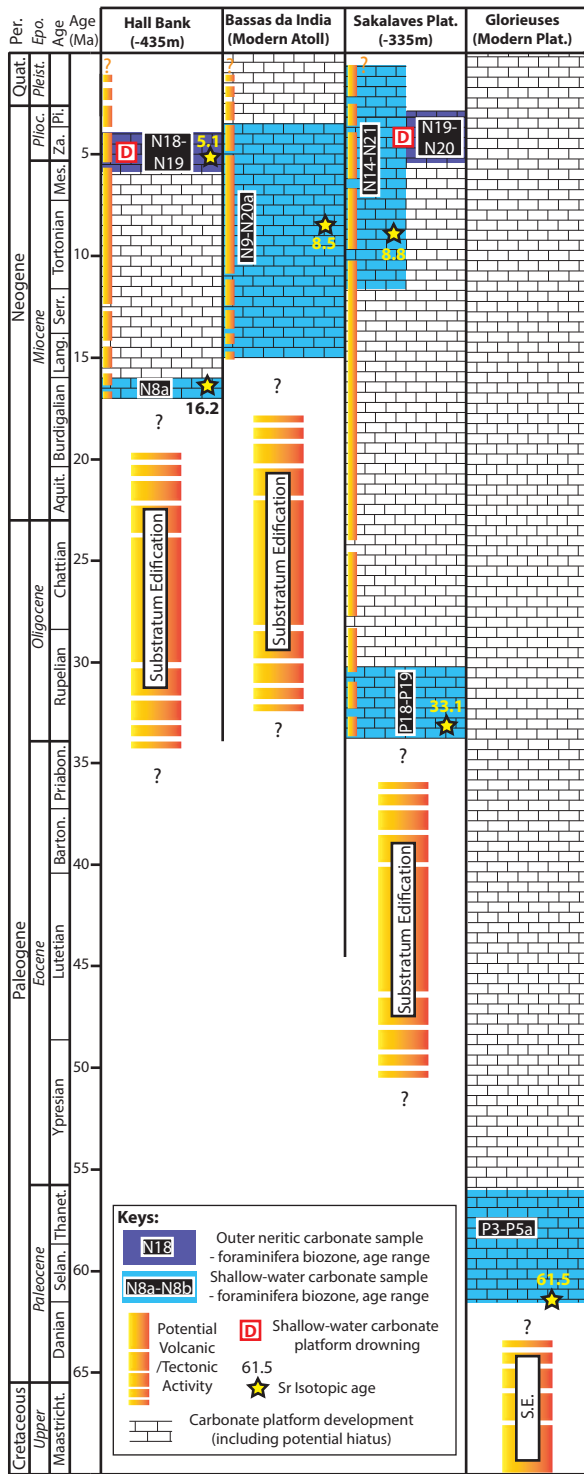






Site	Sample	Age based on Foraminifera first appearances. <i>Planktonic Foraminiferal zones, Shallow benthic zones and letter stages after BouDagher-Fadel (2008, 2013 & 2015)</i>	Age based on Strontium Isotopic Stratigraphy (SIS) <i>Reference curve from McArthur (2012)</i>	Depositional Texture	Composition Major components (in order of abundance) <i>Minor components</i>	Depositional Environment
Hall Bank	DR18-01	N8a, 17-15.9 Ma, Burdigalian (Early Miocene)	16.29 +/- 0.10 Ma, Burdigalian (Early Miocene)	Skeletal packstone with encrusted coral grains	Coral, Red Algae, LBF, <i>Halimeda</i> sp., EF <i>Echinoids, Bryozoans, Bivalves, Gastropods, PF</i>	Shallow-water tropical platform
	DW05-C1	N18-N19, 5.8 - 3.8 Ma, Late Messinian - Early Zanclean	5.09 +/- 0.08 Ma, Zanclean (Early Pliocene)	Packstone of planktonic foraminifera	PF <i>Echinoids, Bivalves, Gastropods</i>	Outer Neritic/Pelagic
Bassas da India	DR20-01	N9-N20a, 15.0 - 3.6 Ma, Middle Miocene - Early Pliocene	8.48 +/- 0.49 Ma, Tortonian (Late Miocene)	Skeletal packstone	PF, EF, Corals, Red Algae, LBF (some reworked forms), bivalves <i>Echinoids, Gastropods, Bryozoans, Halimeda sp.</i>	Shallow-water tropical platform
Sakalaves platform	D13-08	P18-P19, 33.9 - 30.3 Ma, Rupelian (Oligocene)	33.11 +/- 0.14 Ma, Rupelian (Oligocene)	Skeletal grainstone of LBF with rodolith fragments	LBF, Red algae, Volcanic fragments, EF <i>Bivalves, Echinoids, Gastropods, Bryozoans, Green algae</i>	Shallow-water tropical platform
	DW04-01	N14-N21 , 11.6 - 1.6 Ma, Late Miocene- Pleistocene	8.80 +/- 0.35 Ma, Tortonian (Late Miocene)	Coralgal boundstone	Coral, Red algae <i>LBF, Gastropods</i>	Shallow-water tropical platform
	DW04-02a	N19-N20, 5.3 - 3.4 Ma, Zanclean (Early Pliocene)	No data	Packstone of planktonic foraminifera	PF <i>Bivalves, Echinoids, Gastropods, SBF</i>	Outer Neritic/Pelagic
Glorieuses	DN01-01	P3-P5a, 61.6 - 56.0 Ma, Selandian - Thanetian (Paleocene)	61.52 +/- 1.80 Ma*; Selandian (Paleocene)	Coralgal boundstone with pockets of LBF packstone	Red algae, LBF, Coral, EF <i>Bryozoans, Echinoids, Bivalves, Gastropods, SBF, PF</i>	Shallow-water tropical platform

*(or 33.89 +/- 0.15 Ma or 67.11 +/- 0.27 Ma) LBF: Large Benthic Foraminifera; SBF: Small Benthic Foraminifera; EF: Encrusting Foraminifera; PF: Planktonic Foraminifera



Sample	$^{87}\text{Sr}/^{86}\text{Sr}$	1sigma error	Age (Ma)	+/- (Ma)
DR18-01	0.708702	0.000003	16.29	0.10
DW05-C1	0.709033	0.000005	5.09	0.08
DR20-01	0.708927	0.000003	8.48	0.49
D13-08	0.707856	0.000004	33.11	0.14
DW04-01	0.708921	0.000008	8.80	0.35
DN0-01	0.707812	0.000003	33.89	0.15
			61.52	1.80
			67.11	0.27

Supplementary 1



Supplementary 2