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Foraminiferal sandy contourite of the Limpopo Corridor (Mozambique margin): Facies characterization and paleoceanographic record

Authors names and affiliations:

Lopes U.^{1*}, Babonneau N.¹, Fierens R.¹, Révillon S.¹⁻², Raison F.³, Miramontes E.⁴⁻⁵, Rabineau M.¹, Aslanian D.¹, Moulin M.¹

¹ Geo-Ocean, Univ Brest, CNRS, Ifremer, UMR6538, F-29280 Plouzané, France

² SEDISOR, place N. Copernic, 29280, Plouzané, France

³ TotalEnergies, CSTJF, Avenue Larribau, 64000 Pau, France

⁴ MARUM-Center for Marine Environmental Sciences, University of Bremen, Bremen, 28359, Germany

⁵ Faculty of Geosciences, University of Bremen, Bremen, 28359, Germany

Corresponding author: lopes-ugo@hotmail.fr

Highlights:

- Continuous and homogenous foraminiferal sandy contourite facies.
- Very low sedimentation rate of 0.26 cm.kyr⁻¹.
- This sedimentary facies results from the action of strong bottom currents related to the AAIW/NADW interface.
- Bottom current speed increases during glacial stages and decreases during interglacial stages.

Abstract:

Contourites encompass a wide variety of sedimentary facies. Some of them show common facies with others deep-water deposits, such as turbidites and hemipelagites. Sedimentological characterization at macro- and microscales is valuable to discriminate those close facies but the distinction is not always clear. Contourites are increasingly used in paleoceanographic and paleoclimatic reconstructions. Improving their characterization is therefore essential to their interpretations.

This study aims at characterizing a foraminiferal sandy contourite facies from a sediment core collected on top of a contourite drift under the influence of the Antarctic Intermediate Water/North

29 Atlantic Deep-Water interface located in the Limpopo Corridor (Mozambique margin, Indian Ocean) at
30 2000 meters depth. This work is based on a detailed analysis of the sedimentary record using physical
31 properties (gamma density and magnetic susceptibility) as well as laser grain size and X-Ray
32 Fluorescence core scanning data.

33 Our results show that: (1) the foraminiferal sand is vertically continuous and homogenous over
34 633 kyr with an average sedimentation rate of 0.26 cm.kyr⁻¹; (2) this contourite facies results from
35 sedimentation with low terrigenous inputs under stable hydrodynamic conditions over time, with
36 relatively strong bottom currents for this water depth (~16 cm.s⁻¹); (3) during glacial stages,
37 sedimentation rates are lower and bottom current speed is higher than during interglacial stages. We
38 also propose the concept of “Contourite Graphical Chart” which summaries the theoretical distribution
39 of contourite endmembers from cross-plot of “sorting versus grain-size median D₅₀” and their related
40 sedimentary processes.

41 This study highlights the relevance of condensed foraminiferal sandy contourites as long time-
42 scale paleoceanographic archives and provides new insights for studies related to paleoclimatology and
43 paleoecology.

44
45 **Keywords:** bottom current; contourite; foraminiferal sand; paleoceanography; Mozambique Channel;
46 Indian Ocean; Quaternary.

47 1. INTRODUCTION

48 Contourites are sediments deposited or significantly affected by the action of bottom currents
49 (Stow et al., 2002; Rebesco, 2005; Stow and Faugères, 2008). Their accumulations, i.e., contourite drifts
50 and related erosional features, i.e., contourite channels, moats and furrows, form large sedimentary
51 structures on continental margins called contourite depositional systems (Hernández-Molina et al.,
52 2003). Since their discovery in the 1960s (Heezen and Hollister, 1964; Hollister, 1967), contourite drifts
53 have raised a growing interest for their applications in the petroleum industry as potential reservoir
54 (e.g., Viana and Rebesco, 2007; Sansom, 2018; Fonnesu et al., 2020; Yu et al., 2020), paleoclimatic and
55 paleoceanographic studies as high resolution sedimentary records (e.g., Knutz, 2008; Miramontes et al.,

56 2016; Tallobre et al., 2017; Gruetzner et al., 2019; Martorelli et al., 2021), sequence stratigraphy and
57 slope instability for their influence on continental margin morphologies (e.g., Brackenridge et al., 2011;
58 Mosher et al., 2017; Miramontes et al., 2018). At large scale, morphological features and internal
59 structures of contourite drifts are well recognized from seismic profiles and bathymetric data, but at
60 macro- and microscale, discrimination of contourites from other deep-water sedimentary deposits is
61 still challenging.

62 Contourites are part of a sedimentary continuum from continental shelves to deep-sea basins
63 (summarized in Stow and Smillie, 2020). Therefore, contourites are often associated or mixed with
64 other sedimentary deposits like turbidites, hemipelagites or debrites (Rebesco et al., 2008). To establish
65 clear criteria to distinguish contourites, most of the recent studies highlight the usefulness of sediment
66 characterization according to their grain-size parameters (i.e., grain-size indicators such as D_{50} , sorting,
67 skewness, kurtosis), principal component analysis and their microstructural features (Brackenridge et
68 al., 2018; Bankole et al., 2021; de Castro et al., 2020, 2021a, b; Rodrigues et al., 2022). These studies
69 provided useful tools to discriminate contourites from other deep-water deposits, and need to be
70 complemented by further work on lesser-known contourites to obtain a comprehensive understanding.

71 The Atlantic-Indian Ocean gateway is a key element of the global ocean thermohaline circulation
72 (de Ruijter et al., 1999; Sloyan and Rintoul, 2001). It constitutes an exchange area where warm Indian
73 Ocean surface waters enter the Atlantic Ocean and with the volume lost are compensated at depth by
74 the influx of North Atlantic Deep Water (NADW) and Antarctic Bottom Water (AABW). The seismic study
75 of Gruetzner et al. (2019) on a contourite drift from the Agulhas Plateau (South Africa, Fig.1) has
76 shown that the most important global climate and oceanographic changes of the last 7 Ma can be
77 recorded in contourite drift sedimentation and used to understand the regional bottom current paleo-
78 variability. In that study area, only two studies have explored the behavior of bottom currents over the
79 last 200 kyr (Molyneux et al., 2007; Krueger et al., 2012) and suggest an increase of NADW during glacial
80 stages.

81 To the north-east of the Agulhas Plateau, the Mozambique Channel hosts a huge diversity of
82 contourite systems and provides a good area for the study of contourite deposits and bottom current

83 behavior over the Plio-Quaternary (Breitzke et al., 2017; Counts et al., 2018; Thiéblemont et al., 2019,
84 2020; de Castro et al., 2021b; Evain et al., 2021; Miramontes et al., 2019, 2020, 2021; Babonneau et al.,
85 2022). In the scope of the Passive Margins Exploration Laboratories project (PAMELA), the PAMELA-
86 MOZ3 cruise (Moulin and Aslanian, 2016) has acquired five piston cores (MOZ3-CS03, CS02, CS07, CS06
87 and CS05) in a contourite system located in the Limpopo Corridor (Figs. 1 and 2). Recent results of
88 Babonneau et al. (2022) on this contourite system have highlighted the existence of a contourite facies
89 composed of foraminiferal sand covering the 11.47 m length of core MOZ3-CS07. Based on two
90 strontium dating at 6 and 11 m, the foraminiferal sand seems to be continuous and condensed over 5
91 Ma with very low sedimentation rate about 0.3 cm.kyr^{-1} and without influence of gravity deposits or
92 erosional features (Fig. 3). Therefore, this sedimentary succession could provide a good record for
93 Plio-Quaternary paleoceanographic/paleoclimatic reconstructions and contourite characterization.

94 Bioclastic contourite, and in particular foraminiferal sandy facies, are very poorly known. Some
95 studies mention their existence within contourite systems (Lonsdale and Malfait, 1974; Huizhang and
96 McCave, 1990; Robinson and McCave, 1994; Mulder et al., 2019), but none of them has really studied
97 their characteristics and their depositional processes in depth. However, it is frequently observed in
98 outcrops within fossilized contourites (Schiller et al., 1994; Carter, 2007; Hüneke et al., 2021;
99 Hernández-Molina et al., 2022).

100 This study is a continuation of the work of Babonneau et al. (2022) with three objectives: (1)
101 improve the knowledge on foraminiferal sandy contourite using physical, geochemical and grain-size
102 analyses on core MOZ3-CS07; (2) compare characteristics of the foraminiferal sandy contourite facies
103 with other sandy facies found in the same contourite system; and (3) explore its potential as
104 sedimentary record of paleoceanographic changes.

105 2. REGIONAL SETTING

106 2.1. Geodynamic setting

107 The Mozambique Basin is located in the south-west of the Indian Ocean, between Africa and
108 Madagascar (Fig. 1). Its formation results from the breakup of Gondwana and the southwards
109 movement of eastern Gondwana (i.e., Madagascar, India, Australia and Antarctica) in respect to the

110 western Gondwana (South America and Africa) during the Jurassic (Thompson et al., 2019). The
111 Mozambique Basin is fringed to the east by the Davie Fracture Zone (DFZ), which marks the dextral
112 southward movement of Madagascar in respect to Africa between 155 Ma and 120 Ma (Fig. 1). To the
113 west, the Mozambique Fracture Zone (MFZ) marks the southward drift of the Antarctica plate
114 (Watkeys and Sokoutis, 1998; Jokat et al., 2003; Gradstein et al., 2012; Leinweber et al., 2013; Thompson
115 et al., 2019). The southern part of the Mozambique Channel hosts two major topographic highs (Fig. 1):
116 the Mozambique Ridge to the West (MozR) and the Madagascar Ridge to the East (MadR).

117 The western part of the Mozambique Channel, the Limpopo Corridor, is marked by high positive
118 gravity anomalies (e.g., Mueller and Jokat, 2017) but recent data acquired during the PAMELA project
119 showed that these anomalies are related to large and thick contourite drifts above a thin continental
120 intruded crust (Moulin et al., 2020; Evain et al., 2021; Li et al., 2021; Matsinhe et al., 2021).

121 The Limpopo Corridor corresponds to a strike-slip or slightly transtensional margin, where the MFZ
122 marks the continent-ocean transition (Evain et al., 2021).

123 ***2.2. Oceanographic and morpho-sedimentary setting***

124 The ocean circulation within the Mozambique Channel is constrained by its complex and incised
125 morphology. The warm and surface water masses (>1200 m) coming from the northern Indian Ocean
126 and the Red Sea, constitute the Mozambique Current (MC) and flow preferentially southward along the
127 African coast (Fig. 1). Conversely, the intermediate and deep-water masses from the Atlantic (North
128 Atlantic Deep Water "NADW" 2200-3500 m) and Antarctic (Antarctic Intermediate Water "AAIW" 800-
129 1500 m and Antarctic Bottom Water "AABW" >4000 m) flow northwards (de Ruijter et al., 2002; Ullgren
130 et al., 2012; Miramontes et al., 2019). Bottom currents strongly interact with the seafloor and their
131 circulation is impacted by the submarine reliefs. The AABW and part of the NADW are thus redirected
132 in a southward rip current to meet the shoals of the Northern Mozambique Basin (Fig. 1; van Aken et al.,
133 2004; Miramontes et al., 2019). The oceanographic circulation in the Mozambique Channel is also
134 affected by large oceanic eddies coming from the north and the east, flowing southward along the
135 African margin. These eddies are known to impact the seafloor until 3000 meters below the sea-level
136 (mbsl; Fig. 1; Sætre and da Silva, 1984; Swart et al., 2010; Halo et al., 2014).

137 Thiéblemont et al. (2019) mapped the contourite depositional system of the Limpopo Corridor.
138 Their results show four contourite terraces, and they propose as the main factors for the formation of
139 these contourite terraces, the internal waves of tidal period generated at the transition zone between
140 two water masses.

141 Gao et al. (2020) and Thiéblemont et al. (2020), confirmed the influence of water mass
142 circulation and their interactions on the shaping of the African margin. Using seismic reflection data
143 acquired in the northern Mozambique margin, their work shows the morpho-sedimentary evolution of
144 the ridge since the Cretaceous in relation to changes in global ocean circulation. They defined four stages
145 of sedimentary construction: (1) Lower Cretaceous, development of progradational clinoforms with
146 hemipelagite drape after the initial break-up phase; (2) Upper Cretaceous, development of the first
147 contourite system; (3) Paleocene-Eocene, sedimentation dominated by gravity processes; (4) Middle
148 Miocene, re-establishment of contourite systems in the lower part of the continental slope with the
149 formation of the various present contourite terraces.

150 ***2.3. Contourite system studied***

151 The study area is characterized by the presence of a contourite system located in the Limpopo
152 Corridor between 1800 and 2200 mbsl (Fig. 1). It is 75 km long and 50 km wide, with a NNE-SSW
153 orientation. The system is divided into two mounded drifts, surrounded by two main channels on the
154 eastern and western edges, separated by an intermediate channel (Fig. 2A). According to the closest
155 water mass depths measurement from our study area (Thiéblemont et al., 2019; Gao et al., 2020), the
156 present contourite system is located at the transition zone between the base of the AAIW (1500 mbsl)
157 and the top of the NADW (2200 mbsl; both flowing northward) corresponding to a progressive change
158 in seawater density about 700 m thick (Thiéblemont et al., 2019).

159 Babonneau et al. (2022) studied the sedimentary architecture of the contourite system since the
160 Cretaceous based on seismic profile and its recent behavior through stratigraphic correlations from
161 sediment cores. The contourite drift evolution shows three stages of construction (Fig. 3): (1) initiation
162 and development of the drift/channel system from the Cretaceous to the Miocene; (2) an intermediate
163 stage with successive incisions/aggradations, and; (3) channel infill and drift erosion since the Plio-

164 Quaternary. The depositional process of the contourite system during the stage 3 is explained by the
165 lateral and vertical change in the area of high current speed and by the morphological evolution of the
166 system itself. This stage of channel filling is also recognized by Thiéblemont et al. (2020) and interpreted
167 as resulting from the onset of NADW and AAIW in the Southern Hemisphere during the middle Miocene,
168 which significantly changed the water circulation along the Mozambique margin.

169 Since the Plio-Quaternary, the drift growth has stopped. Low sedimentation rates of 3 to 1.9
170 cm.kyr⁻¹ are recorded in the western channel, and about 0.3 cm.kyr⁻¹ on the western flank of the drift.
171 The top and the eastern flank of the drift are in erosion. The sedimentary facies vary from the western
172 to the eastern part of the contourite system, with mixed siliciclastic-bioclastic sediments (clay to
173 fine-sand in grain size) in the western channel, transitioning into pelagic-sourced bioclastic sands
174 (foraminifers dominated) near the top of the drift (Fig. 3).

175 3. MATERIALS AND METHODS

176 3.1. Bathymetry and sediment cores

177 Five Calypso piston cores (Figs. 2 and 3) were collected on the contourite system during the
178 PAMELA-MOZ3 oceanographic cruise aboard the R/V "Pourquoi pas?" (Moulin and Aslanian, 2016) at
179 water depths ranging from 1853 to 2125 mbsl (Table 1 and Fig. 2). All the data acquired on the
180 piston cores are summarized in Table 2.

181 The regional bathymetric map (Fig. 1) is the "General Bathymetric Chart of the Ocean"
182 (GEBCO_08, version 2010-09-27, <http://www.gebco.net>). The detailed bathymetry (Figs. 2A and 2B) is
183 acquired with a multibeam echosounder (SMF) ©RESON-Seabat 7150 bi-frequency 12/24 kHz, allowing
184 the acquisition of reflectivity images and the bathymetry of the seafloor with 20x20m resolution grid.
185 The MOZ3-SDS-0038 seismic profile (Fig. 2C) was acquired with a CHIRP sediment echosounder with a
186 signal frequency varying between 5300 and 1800 Hz, allowing for ~80 m penetration into the sediment
187 with an average resolution of 0.75 m.

188 **3.2. X-Ray Fluorescence (XRF) core scanner and Multi-Sensor Core Logger (MSCL) data**

189 X-Ray Fluorescence (XRF) measurements are used to analyze the variations of the geochemical
190 composition of the sediment. XRF measurements were performed at a 1 cm interval with the Avaatech
191 X-Ray Core Scanner from Ifremer on split cores. Two energy sources were used (10 and 30 kv at 0.6 mA
192 and 1 mA) to measure the semi-quantitative value (in count per second) of more than 25 elements
193 having an atomic mass between aluminum and uranium. Among them, we use the log-normalized ratios
194 $\ln(\text{Ca/Fe})$ and $\ln(\text{Zr/Rb})$ as a respective indicator of the terrigenous versus biogenic sediment
195 proportion and as an indicator of the bottom current intensity (Weltje and Tjallingii, 2008; Vandorpe et
196 al., 2019; Wu et al., 2020).

197 Physical parameters (gamma-density and magnetic susceptibility) were acquired with a Multi-
198 Sensor Core-Logger (MSCL Geotek Ltd) at Ifremer (Brest), with a sampling interval of 1 cm. X-ray
199 radiography (CT scan, Geotek Ltd) was also acquired on the core half-sections at Ifremer (Brest).

200 **3.3. Grain-size analysis**

201 Laser grain-size measurements were performed on bulk sediment with the ©Malvern 2000G
202 from UMR Geo-Ocean (Brest) giving an accurate measurement of particles with a size from 0.02 to 2000
203 μm . A total of 907 measurements were performed on cores MOZ3-CS03, MOZ3-CS02, MOZ3-CS07 and
204 MOZ3-CS06. On the cores MOZ3-CS03, MOZ3-CS02 and MOZ3-CS06, measurements were performed on
205 selected parts (most frequently on coarser intervals), whereas on MOZ3-CS07, sampling resolution
206 ranges from 1 to 3 cm and is defined according to the $\ln(\text{Ca/Fe})$ and $\ln(\text{Zr/Rb})$ curves. For all core
207 samples, ~10 mg of sediment was collected over a 5 mm width, placed in distilled water for 24 hours
208 and vibrated during 4 minutes to deflocculate the particles before laser grain-size measurement.

209 The grain-size data were processed with the GRADISTAT program (Blott and Pye, 2001). The
210 grain-size indicators (sorting, skewness and D_{50}) were calculated using the method of Folk and Ward
211 (1957). The grain-size fractions used are those defined by Friedman and Sanders (1978). The use of
212 cross-plots "skewness versus D_{50} " and "sorting versus D_{50} " provides the characterization of the grain-
213 size sorting evolution and grain-size distribution trend as a function of the increase of the D_{50} for each
214 sample (Blott and Pye, 2001).

215 **3.4. Microfacies**

216 Microfacies analyses were performed at TotalEnergies Scientific and Technical Center (Pau)
217 with Qemscan ® technology, which allows inventory, mapping and particle count on the sections. A total
218 of twelve thin sections were analyzed and collected for the core MOZ3-CS07 (Table 3). For each section,
219 the proportion of quartz, feldspar, carbonate, clay and mica, as well as unidentified elements (“Others”),
220 is given. Bulk quantitative mineralogy (BQM) analysis, including elementary composition by DX, density,
221 insoluble residue, loss on ignition (LOI) and cation exchange capacity (CEC) measurements were carried
222 out in addition on 4 of these samples for calibration. Qemscan ® and BQM analysis diverge slightly in a
223 few cases (heavy minerals, quartz content).

224 **3.5. Isotopic stratigraphy**

225 Oxygen isotope ($\delta^{18}\text{O}$) measurements were performed on planktonic foraminifers,
226 *Globigerinoides ruber*. On core MOZ3-CS07, 233 samples were collected from 1 to 4.93 meters below the
227 seafloor (mbsf) with the same resolution as grain-size measurements (Table 2). On average, for each
228 sample, 12 specimens were picked (representing 60-120 μg) in the fraction $>250 \mu\text{m}$ and analyzed using
229 the MAT253-KIEL IV isotope ratio mass spectrometer at the IUEM (Brest). Samples are normalized with
230 a standard routine MNHN (V-PDB=-1.93 and std=0.03) and with the international carbonate standards
231 NBS-18=-23.20 and NBS-19=-2.20. The analytical precision is $< 0.05\text{‰}$.

232 To complete the oxygen isotope measurements, 38 new strontium isotope measurements were
233 performed between 3.51 and 11.45 mbsf (Table 2 and 4) using the Sr Isotope Stratigraphy method (SIS;
234 Elderfield, 1968; McArthur, 1994). Samples (foraminifer tests or bulk material) are dissolved in weak
235 acetic acid. After centrifugation and evaporation to dryness, dry residues are taken up into 1 ml of HNO_3
236 1M and centrifuged before loading on Biorad® columns using Triskem® Sr resin (Pin and Santos
237 Zalduegui, 1997). Sr is eluted in 2 ml of hot ultrapure H_2O . Samples are loaded on W filaments for
238 thermal ionization mass spectrometry (TIMS) measurements. Sr isotope compositions were measured
239 in static mode on a Thermo TRITON at the PSO (Pôle de Spectrométrie Océan) in Brest, France. All
240 measured ratios are normalized to $^{86}\text{Sr}/^{88}\text{Sr}=0.1194$ and the Sr isotope compositions of standard
241 solution NBS987 is routinely measured with a frequency of one full analysis each five samples. Six

242 measurements were made on bulk sediment and 34 measurements were made on the fraction $>250\ \mu\text{m}$
243 (Table 4) to remove as much as possible the detrital sediments and keep exclusively the carbonates,
244 composed mainly of foraminiferal tests.

245 4. RESULTS

246 4.1. *Facies and sedimentological characteristics*

247 4.1.1. *Facies*

248 Core MOZ3-CS07 presents a single homogenous sedimentary facies, beige, composed of 76.5%
249 fine sand (mostly foraminifers), 19.9% silt and 3.6% clay (Fig. 4). The facies is slightly bioturbated,
250 lamination is difficult to discern (Fig. 5). On the X-ray images, pseudo-cross-bedding can be seen in the
251 lower part of the core (at 9 and 10 mbsf, Fig. 4). Despite being mainly homogenous, the facies of core
252 MOZ3-CS07 shows two variations: (1) foraminiferal pockets, corresponding to lighter intervals with
253 coarser sediments, low content of fine particles and present mainly in the upper part of the core; (2)
254 very fine mottled sand, corresponding to darker intervals with finer sediments, characterized by the
255 presence of black spots (reduced organic matter) and a higher proportion of clay (Figs. 4 and 5).

256 The magnetic susceptibility and gamma density curves indicate similar trends, with values
257 ranging respectively from 5 to 22 SI^{-1} and from 1.4 to 1.8 $\text{g}\cdot\text{cm}^{-3}$ (Fig. 4). Magnetic susceptibility shows
258 an increase from the base of the core to 7.5 mbsf, then a progressive decrease to the top of the core with
259 higher variations. Gamma density shows a progressive decrease from the bottom to the top of the core
260 that appears to be related to the increase in grain size indicated by a decrease in clays and silts and an
261 increase in sands and D_{50} (Fig. 4).

262 The $\ln(\text{Ca}/\text{Fe})$ ratio reveals an increase in the amount of terrigenous sediment from the base to
263 8 mbsf, followed by a progressive increase in the amount of biogenic sediment to the top of the core.
264 The $\ln(\text{Zr}/\text{Rb})$ ratio indicates a slight increase in current intensity during deposition according to the
265 increase in grain size described above. In general, an increase in the proportion of biogenic sediments
266 and current intensity is observed during the facies formation.

267 *4.1.2. Composition and microfacies*

268 Based on microfacies analyses, the sediment is defined as a foraminiferal calcarenite with a small
269 proportion of silty-clayey mud. The proportion of carbonates varies between 60 and 76%, and the
270 proportion of clay and mica between 6 and 12% (Table 3). The other minerals (i.e., quartz and feldspar)
271 are less abundant and represent between 1.8 and 10% of the sediment.

272 The detailed description of section 3 (Fig. 5) illustrates the general sedimentary facies
273 composition of core MOZ3-CS07. The X-ray images and photography show a homogenous sediment with
274 no or unclear erosional structures and bioturbation traces. The very fine mottled sands are
275 systematically marked by an increase in gamma density, magnetic susceptibility, clays and silts
276 (corresponding to silty-clayey mud) and by a decrease in D_{50} , and conversely for the foraminiferal
277 pockets. The proportion of silty-clayey mud varies between 10 and 40%. The sample taken at 2.36 mbsf
278 is composed of 62.8% carbonates, 24.5% clay and mica, 7.8% feldspar and 3.7% quartz (Fig. 5B).

279 **4.2. Grain-size analysis of core MOZ3-CS07**

280 *4.2.1. Grain-size distribution*

281 Grain-size measurements on core MOZ3-CS07 provide an average grain-size distribution (Fig.
282 6) that corresponds to a coarse silty sand sediment, very poorly sorted and finely skewed. On average,
283 the mean grain size is 157 μm , the D_{50} is at 344 μm , and the grain-size distribution is unimodal with
284 a mode at 598 μm . Nevertheless, two other peaks not considered as modes are observable at 3 and 100
285 μm . The general shape of the grain-size distribution allows us to divide it into two major fractions: (1)
286 the fraction $>30 \mu\text{m}$, corresponds to 80% of the sediment, it is composed mostly of foraminifer tests and
287 in lesser proportion of quartz grains, feldspar and fragmented or juvenile foraminifer tests (Qemscan
288 analysis, Fig. 6); (2) the fraction $<30 \mu\text{m}$, corresponds to 20% of the sediment, represented by a silty-
289 clayey mud composed of clays and micas.

290 *4.2.2. Grain-size modes*

291 The grain-size distributions of the samples are characterized according to their number of
292 modes. Four types of grain-size distributions are identified with the GRADISTAT program (Fig. 7):

293 -unimodal distributions, characterized by low variance and a major mode at 600 μm . The curves
294 also show two other peaks not considered as grain-size modes at 3 and 100 μm .

295 -bimodal distributions, with mode 1 also located at 600 μm and mode 2 between 2 and 3 μm .
296 Some distributions, such as the red curve in figure 7, show modes 1 and 2 in the fraction >30 μm at 500
297 and 100 μm respectively.

298 -trimodal distributions, with mode 1 around 500 μm , modes 2 and 3 are located either in the
299 fraction <30 μm or in the fraction >30 μm .

300 -quadrимodal distributions show a high diversity of grain-size distributions. On average, mode
301 1 mostly corresponds to 500-600 μm , mode 2 to 100 μm , mode 3 to 3 μm and the fourth mode to 20 μm .

302 The unimodal and bimodal distributions are the most represented, with 230 and 216 samples,
303 respectively. The proportion of the fraction <30 μm increases significantly between the unimodal and
304 bimodal distributions from 12.9% to 25.3% and is approximately the same for the trimodal and
305 quadrимodal distributions with respectively 27.5% and 27.2%. The frequency of occurrence of
306 unimodal distributions increases towards the top of the core and is correlated with sand enrichment
307 during deposition (Fig. 4). The other distributions are observed rather in the lower part of the core.

308 *4.2.3. Sorting/Skewness versus D_{50}*

309 The cross-plot of "skewness versus D_{50} " shows two trends: (1) for bimodal, trimodal, and
310 quadrимodal distributions, as D_{50} increases, skewness increases; (2) for unimodal distributions, as D_{50}
311 increases, skewness decreases. Thus, for bimodal, trimodal, and quadrимodal distributions, an increase
312 in D_{50} results in a higher deviation of the distribution toward fine particles, and thus a larger proportion
313 of the fraction <30 μm . Conversely, for unimodal distributions, the larger the grain size is, the more
314 symmetrical the grain-size distribution is, and the lower the fraction <30 μm is.

315 Two trends in sorting are also observed: (1) for bimodal, trimodal, and quadrимodal
316 distributions, there is no clear relationship between D_{50} and sorting; (2) for unimodal distributions,
317 there is an increase in sorting as D_{50} increases. The most poorly sorted sediments are those with
318 bimodal, trimodal and quadrимodal distributions. For unimodal distributions, there is a progressive

319 increase in sorting as D_{50} increases. A trend can be defined that the coarser the grain size is, the fewer
320 the modes are and the better the sediment is sorted.

321 For both cross-plots shown in figure 8, the transition zone between the two trends for bimodal
322 and unimodal distributions suggests that some bimodal distributions could be reinterpreted as
323 unimodal and *vice versa*.

324 **4.3. Grain-size comparison with the other cores**

325 To complete the characterization of the sedimentary facies from cores MOZ3-CS03, MOZ3-CS02,
326 MOZ3-CS07 and MOZ3-CS06 performed by Babonneau et al. (2022), the grain-size samples are analyzed
327 using a cross-plot of "sorting versus D_{50} " (Fig. 9).

328 The sediments of core MOZ3-CS07 (yellow points, Fig. 9) form a continuous point cloud ranging
329 from a very poorly sorted sediment with a D_{50} of 70 μm to a moderately well sorted sediment with a D_{50}
330 of 700 μm . The sediments of core MOZ3-CS03 (green points) are more diffuse, but broadly divided
331 between a point cloud showing very poorly sorted and very fine sediment with a D_{50} ranging from 7 to
332 70 μm and a second point cloud showing moderately sorted to moderately well sorted sediments with
333 a D_{50} around 140 μm . The sediments of core MOZ3-CS02 (blue points) mark the transition between the
334 point clouds of MOZ3-CS03 and MOZ3-CS07. For moderately sorted to moderately well sorted
335 sediments, the points of MOZ3-CS02 correspond to the sediments with the highest D_{50} , at 900 μm .
336 Finally, 12 laser grain-size measurements were performed in the foraminiferal sand and muddy
337 sediments of core MOZ3-CS06 (red points in Fig. 9). These measurements belong to the best sorted and
338 coarsest sediments for the foraminiferal sand and the worst sorted and finest points for the muddy
339 sediments.

340 Figure 10 shows the mean grain-size distribution and the mineral composition for the four
341 sedimentological poles of the figure 9 called; "Mainly terrigenous", "Mainly biogenic", "Siliciclastic sand"
342 and "Foraminiferal sand" after interpretation. The mineral composition of each grain-size mode (Fig.
343 10) is determined from Qemscan analysis.

344 -The pole "Mainly terrigenous" based on samples from the core MOZ3-CS03, shows a bimodal
345 distribution with the mode 1 at 4 μm composed of clay and mica, representing 50% of the sediment; the

346 mode 2 at 70 μm composed of quartz and feldspar representing 40% of the sediment and a peak at 400
347 μm composed of foraminifer tests representing 10% of the sediment.

348 -The pole “Mainly biogenic” based on samples from the cores MOZ3-CS07 and MOZ3-CS02,
349 reveals a bimodal distribution with the mode 1 at 400 μm mainly composed of foraminifer tests and in
350 lesser proportion of quartz and feldspar, representing 75% of the sediment and; the mode 2 at 3 μm
351 composed of clay and mica, representing 25% of the sediment.

352 -The pole “Silicilastic sand” based on samples from the cores MOZ3-CS03 and MOZ3-CS02, shows
353 an unimodal distribution with a mode at 140 μm composed of quartz and feldspar, representing 95% of
354 the sediment and; a peak at 20 μm composed of mica, representing 5% of the sediment.

355 -The pole “Foraminiferal sand” based on samples from the cores MOZ3-CS07 and MOZ3-CS02,
356 has an unimodal distribution with a mode at 750 μm composed of foraminifer tests, representing 87%
357 of the sediment; a peak at 100 μm composed of quartz and feldspar, representing 5% of the sediment
358 and; a large peak at 6 μm composed of clay and mica, representing 8% of the sediment.

359 ***4.4. Isotopic stratigraphy of core MOZ3-CS07***

360 The isotopic stratigraphy of core MOZ3-CS07 is based on $\delta^{18}\text{O}$ measurements correlated with
361 the reference $\delta^{18}\text{O}$ curve LR04 (Lisiecki and Raymo, 2005, Fig. 11) over the first 5 mbsf. This stratigraphy
362 is completed with strontium isotope measurements translated into ages using the global strontium
363 variation reference curve (McArthur et al., 2012) from 3.51 to 11.45 mbsf. The obtained ages are
364 grouped and fitted according to a power regression to better approximate a model of non-linear
365 sedimentation rate evolution over time (Fig. 12).

366 *4.4.1. Oxygen isotopic stratigraphy*

367 The $\delta^{18}\text{O}$ measurements acquired along the first 5 mbsf of core MOZ3-CS07 vary from 0.1 to 1.5
368 ‰. The $\delta^{18}\text{O}$ curve can be divided into two parts (Fig. 11): (1) from 0 to 1.53 mbsf, the $\delta^{18}\text{O}$ curve shows
369 high-amplitude variations; (2) from 1.53 to 5 mbsf, the $\delta^{18}\text{O}$ curve shows shorter wavelength and lower
370 amplitude changes, with one major peak at 3.7 mbsf.

371 Over the first 1.53 m, the $\delta^{18}\text{O}$ curve of MOZ3-CS07 correlates with the first 11.5 m of MOZ3-CS03
372 (Babonneau et al., 2022) and corresponds to the LR04 reference curve to 100 kyr climate cycles (Lisiecki and

373 Raymo, 2005). Sixteen isotopic stages are identified along this part. The first 1.53 m of core MOZ3-CS07 and
374 the 11.5 m of MOZ3-CS03 are estimated to cover the last 632 kyr, with average sedimentation rates
375 respectively about 0.24 cm.kyr⁻¹ and 1.82 cm.kyr⁻¹. Sedimentation rate of core MOZ3-CS07 is therefore
376 calculated 7.6 times lower than that of MOZ3-CS03.

377 Given the sedimentary record resolutions of cores MOZ3-CS07 and MOZ3-CS03, interglacial
378 phases of the last 800 kyr (Past Interglacials Working Group of PAGES, 2015) cannot be distinguished.
379 Therefore, complete odd-numbered MIS (except MIS 3) are labelled as interglacial stages, being aware
380 that they include more than the interglacial phases themselves. The $\delta^{18}\text{O}$ curves of cores MOZ3-CS07
381 and MOZ3-CS03 thus show interglacial stages that are expressed over thicker sedimentary intervals
382 than glacial stages (in proportion to their actual duration). The $\ln(\text{Ca}/\text{Fe})$ and $\ln(\text{Zr}/\text{Rb})$ ratio of core
383 MOZ3-CS07 reveal an increase in the amount of terrigenous sediment and a decrease in current speed
384 during interglacial stages and conversely during glacial stages.

385 At 1.53 mbsf in core MOZ3-CS07, the change in the frequency of $\delta^{18}\text{O}$ oscillations is interpreted
386 to mark the end of the Mid-Pleistocene Transition (MPT). Below this level, grain-size proxies the
387 sampling resolution is no longer adapted to the change in frequency and does not allow us to assign an
388 isotopic stage with variations of the $\delta^{18}\text{O}$ curve.

389 *4.4.2. Strontium Isotopic Stratigraphy*

390 The strontium measurements at 3.51, 4 and 4.51 mbsf (green, purple and orange lines in Fig. 11)
391 with uncertainties ranging from 50 to 150 kyr, give ages of 1.36, 1.46 and 1.74 Ma, respectively. A
392 sedimentation rate about 0.26 cm.kyr⁻¹ can be estimated at 4.51 mbsf.

393 Figure 12 combines the estimated ages from oxygen and strontium measurements. The x-axis is
394 the age in millions of years, and on the y-axis is the depth below the seafloor in meters.

395 The $\delta^{18}\text{O}$ points (corresponding to the ages of the red lines in Fig. 11) line up along a straight
396 axis and have very little dispersion (power regression, $R^2=0.98$). Conversely, the strontium points are
397 more scattered (power regression, $R^2=0.71$). The sediment fraction chosen evolved according to the
398 results obtained during the measurement of the sample series (Table 4). The points outside the grey
399 area were not selected for the age model determination (discussed in section 5.3.2).

400 The power regression equation gives an age of 4.08 Ma at 11.45 mbsf. Nevertheless, the
401 strontium ages dispersion and uncertainties related to SIS method (up to 1 Ma) do not allow to affirm
402 this result.

403 5. DISCUSSION

404 *5.1. Foraminiferal sand accumulation in contourite system*

405 *5.1.1. Atypical sedimentary facies*

406 The absence of erosional structures, clear bioturbation traces, and the homogeneity of the
407 sedimentary facies observed in MOZ3-CS07 are characteristic and diverge from the current model of
408 organization and classification of contourite sequences proposed by Stow and Faugères (2008).
409 Composed of 70% foraminiferal sand, the sedimentary facies of MOZ3-CS07 is atypical for a
410 homogenous deposit of several meters in thickness on a present-day contourite system. Contourite
411 facies with a similar content of foraminifers are documented from outcrops (Schiller et al., 1994; Carter,
412 2007; Hüneke et al., 2021) or correspond to sequences of a few tens of centimeters with a lower
413 proportion of foraminifers (e.g., Viana et al., 1998; Brackenridge et al., 2018; de Castro et al., 2020;
414 Hüneke et al., 2020).

415 In addition to its particular facies, core MOZ3-CS07 presents an extremely low sedimentation
416 rate of about 0.26 cm.kyr^{-1} for the first 4.51 mbsf, corresponding to the lowest sedimentation rates
417 measured on a contourite deposit. This condensed sedimentation appears to be continuous over 11.45
418 meters and could provide one of the few contourite sedimentary records that allow accessing climate
419 changes and its regional oceanographic impacts at the Plio-Quaternary scale. Nevertheless, the
420 establishment of such a particular facies and its preservation over time raise some questions, which are
421 discussed in the following sections.

422 *5.1.2. Sedimentary processes inducing foraminiferal sandy contourite formation*

423 The sediments of core MOZ3-CS07 correspond to coarse sand, composed of 70% foraminifer
424 tests and 30% clayey-silty mud. This high content of foraminifer tests is likely due to: (1) a depositional
425 environment with low terrigenous inputs attested by the low sedimentation rates and the pelagic origin

426 of the particles; (2) significant bottom currents inducing the winnowing of fine particles shown by the
427 grain-size results. This last point is supported by the presence of an erosional surface just above the
428 core MOZ3-CS07 (Fig. 2B) indicating that the core is close to an area subject to strong bottom current
429 influence. In these depositional conditions, the low content of fine particles results from their trapping
430 in the interstices between foraminifer tests (Fig. 13). The sedimentation process can be divided into two
431 steps: (1) the pelagic sedimentation, settling of foraminifer tests on the seafloor; (2) the interstitial
432 sedimentation, when suspended particles are trapped in the interstices formed between tests (Fig. 13).
433 This interpretation is supported by the gap observed in the grain-size distribution (Fig. 6) that
434 corresponds to a natural break in the distribution of grain-size fractions that reflects a change of the
435 sediment origin/processes (Smalley, 1966; Pettijohn, 1975). In this foraminiferal sandy contourite, the
436 break separates biogenic (pelagic sedimentation) from terrigenous (interstitial sedimentation)
437 sediments.

438 For the facies variations, observed along core MOZ3-CS07 (Figs. 4 and 5), it is assumed that:

439 -for very fine mottled sand, bottom currents are weaker, all the sizes of foraminifer tests can be
440 deposited, increasing the potential of trapping fine particles.

441 -for foraminiferal pocket, bottom currents are stronger, only larger sized foraminifer tests are
442 deposited. Under these conditions, the surface sediments are reworked, transport of foraminifer tests
443 by saltation/traction allows to resuspend both the fine particles trapped and the small and medium-
444 sized foraminifer tests (corresponds to tests <300 μm). Being transported on the seafloor, the tests are
445 fragmented and concentrated, forming foraminiferal pockets.

446 One centimeter of deposition in core MOZ3-CS07 records about four thousand years of
447 sedimentation. We assume that the preservation of fine particles (clays and silts) over such a long period
448 results from stable hydrodynamic conditions over the time (more explanations in section 5.3.1) and it
449 seems that once fine particles are trapped in interstices between foraminifer tests, the bottom currents
450 are not strong enough to winnow them except in the case of the foraminiferal pockets.

451 This foraminiferal contourite facies does not show typical contourite sedimentary layers
452 organized in bi-graded sequences (Gonthier et al., 1984). The only evidence for variations in bottom

453 current speed is the variations in geochemical and grain-size proxies (ln (Zr/Rb) and
454 sorting/skewness). The two main diagnostic criteria for distinguishing contourite are based on the
455 presence and abundance of bioturbation (e.g., Lovell and Stow, 1981; Gonthier et al., 1984; Wetzel et al.,
456 2008) or on the presence of primary sedimentary structures (e.g., Shanmugan, 2000; Martín-Chivelet et
457 al., 2008). The foraminiferal sandy contourite facies of core MOZ3-CS07 is interpreted slightly
458 bioturbated because of the absence of sedimentary structures. Nevertheless, even on X-ray images, no
459 clear bioturbation structures have been observed. This observation could be explained by a benthic
460 community mainly composed of grazing animals that destroy pre-existing sedimentary structures and
461 do not produce burrows as commonly observed in contourite deposits (summarized in Rodríguez-Tovar
462 et al., 2022).

463 *5.1.3. Estimation of bottom current speed*

464 The equation of McCave et al. (2017) on the value of the "Sortable Silt mean size" (\overline{SS} ,
465 corresponds to the grain-size average of the classes between 10 and 63 μm) is applied on the bulk
466 sediment to estimate the current speed according to the following equation: $\overline{SS}=0.808U+15.46$ (with U:
467 the current speed in $\text{cm}\cdot\text{s}^{-1}$). Taking $\overline{SS}=28.63 \mu\text{m}$ (corresponds to the average \overline{SS} of MOZ3-CS07), we
468 obtain $U=16.30 \text{ cm}\cdot\text{s}^{-1}$. Without carbonate dissolution and deflocculating agent, this value is only an
469 estimation of the average current speed (certainly overestimated due to the flocculation process of the
470 finest particles). Nevertheless, the latest work by Miramontes et al. (2021), using the Regional Ocean
471 Modelling System (ROMS, CROCO version: <https://www.croco-ocean.org/>), shows a similar bottom
472 current speeds at the location of the contourite drift where the core MOZ3-CS07 was collected.

473 Taking the smallest value of \overline{SS} (19.27 μm at 7.29 mbsf), a speed of 4.72 $\text{cm}\cdot\text{s}^{-1}$ is obtained. The
474 maximum current speed is not calculable because in this case no sediment smaller than 63 μm is
475 deposited (at 0.84 mbsf). According to the work of Lonsdale et al. (1972), foraminiferal sand motion
476 threshold is at 17 $\text{cm}\cdot\text{s}^{-1}$. Miller and Komar (1977) and McCave and Hall (2006), also calculated the
477 critical speed for the movement of foraminifers with sizes between 200 and 300 μm and found 20-25
478 $\text{cm}\cdot\text{s}^{-1}$. Following these estimations, sediments of core MOZ3-CS07 seem to have been deposited under
479 the action of a bottom current speed ranging from 4.72 to 17-20 $\text{cm}\cdot\text{s}^{-1}$.

480 **5.2. Contourite system of the Mozambique Ridge**

481 The results of Babonneau et al. (2022) suggest that the entire contourite system is almost
482 disconnected from continental inputs, fed by hemipelagic/pelagic sediments and sediment transfer
483 processes within the contourite channels. This contourite depositional system provides a perfect study
484 area to investigate contourite without the impact of gravity-driven processes.

485 *5.2.1. Evolution of the sedimentary processes from the channel to the drift*

486 Three major sedimentary sources are identified in figure 10, according to the grain-size modes:
487 (1) suspended particles forming the clayey and fine silty modes composed of clay and mica; (2) biogenic
488 inputs, mainly foraminifer tests forming the coarse sand mode and (3) the along-slope transfer of
489 siliciclastic material (i.e., quartz and feldspars) into the channel creating the fine sand mode. Depending
490 on the location in the contourite system, these sedimentary sources are found in different proportions
491 in the sediment and reflect changes in bottom currents speed creating unimodal or bimodal grain-size
492 distributions. These distributions (Fig. 10) can be divided into two contourite sedimentary processes
493 proposed by Miramontes et al. (2021): (1) contourites dominated by depositional processes and; (2)
494 contourites dominated by winnowing/reworking processes. For each sedimentary process, two
495 sedimentological poles are defined from the cross-plot of “sorting versus D_{50} ” (Fig. 9).

496 **Contourites dominated by depositional processes** show a bimodal grain-size distribution
497 developed under weak bottom currents allowing the deposition of fine and coarse particles. For the
498 “mainly terrigenous” pole, corresponding to sediments close to the channel, fine particles are composed
499 of clay and micas, and; coarse particles are composed of quartz and feldspars. For the “mainly biogenic”
500 pole, corresponding to sediments from the drift, fine particles consist of clay and micas, and coarse
501 particles are composed of foraminifer tests and in lesser proportion of quartz and feldspars.

502 **Contourites dominated by winnowing/reworking processes** show an unimodal grain-size
503 distribution, which is set up under strong bottom currents where fine particles are winnowed, and only
504 coarse particles can be deposited. For the “siliciclastic sand” pole, corresponding to sediments close to
505 the channel, coarse particles are composed of quartz and feldspar. For the “foraminiferal sand” pole,
506 corresponding to sediments from the drift, the coarse particles are composed of foraminifer tests.

507 If the bottom current speed increases, contourites dominated by depositional processes will
508 evolve into contourites dominated by winnowing/reworking processes adopting a siliciclastic or
509 foraminiferal sand depending on the location in the system and thus the composition of the sediment
510 (Fig. 9 and 10).

511 *5.2.2. Contourite endmembers and their relationships*

512 Sorting and size of contourite sediments are controlled by the bottom current speed and
513 sediment sources. Using cross-plots of "sorting versus D_{50} " provide a better characterization of these
514 deposits (Brackenridge et al., 2018; de Castro et al., 2020, 2021a, 2021b; Bankole et al., 2021;
515 Rodrigues et al., 2022). Nevertheless, the continuity and the possible interplay between contourite,
516 hemipelagite and turbidite processes, make it difficult to distinguish clearly these deposits from this
517 type of graph.

518 The contourite system studied here is disconnected from gravity driven continental inputs, thus
519 only two types of sedimentary deposits are present in this system, contourites and hemipelagites. Based
520 on our results (Fig. 9) and on previous studies (Brackenridge et al., 2018; de Castro et al., 2020, 2021a,
521 2021b; Bankole et al., 2021) using cross-plots of "sorting versus D_{50} ", two contourite trends can be
522 defined: (1) siliciclastic trend (already shown by de Castro et al., 2021), mainly represented by the
523 sediments of core MOZ3-CS03 and partly by those of MOZ3-CS02; (2) foraminiferal trend, mainly
524 represented by the sediments of core MOZ3-CS07 and partly by those of CS02. Both trends illustrate an
525 increase in current speed from contourites dominated by depositional processes to contourites
526 dominated by winnowing/reworking processes. As foraminifer tests have a lower density than
527 siliciclastic particles (i.e., quartz), for the same given current speed, they will therefore be larger than
528 siliciclastic particles, thus explaining the size difference between a foraminiferal sand and a siliciclastic
529 sand. These results conducted us to propose the "Contourite Graphical Chart" (inspired by the work of
530 Bankole et al., 2021) allowing to locate and understand the repartition of contourite deposits and their
531 related trends (Fig. 14).

532 The "Contourite Graphical Chart" highlights three contourite endmembers; the silty contourites,
533 , the siliciclastic sandy contourite and the foraminiferal contourite. The silty contourites represent a

534 starting point from which the sedimentary facies will evolve during deposition to another type of
535 contourite facies depending on the current speed and/or the source of sediments. As previously shown
536 by Bankole et al. (2021), silty contourites become hemipelagites in the case where the current speed is
537 almost nil.

538 Each endmember is associated to a sedimentary process; the silty contourites are associated to
539 depositional processes under low bottom current speed, the sandy siliciclastic and foraminiferal
540 contourites to winnowing or reworking processes (Fig. 14). During deposition or over the time, a
541 siliciclastic sandy contourite can evolve into a foraminiferal contourite if terrigenous inputs decrease or
542 if its distance from the contourite channel increases, as previously shown core MOZ3-CS02 (Fig. 9).

543 ***5.3. Bottom current processes and paleoceanographic record***

544 *5.3.1. Contourite system in AAIW/NADW interface*

545 The contourite system studied is currently at the depth of the AAIW/NADW interface
546 (Thiéblemont et al., 2019; Babonneau et al., 2022). The processes operating at water mass interfaces in
547 the Mozambique Channel are described by Thiéblemont et al., (2019). Among them, internal waves are
548 suggested by some authors as a relevant mechanism in the erosion and non-deposition of sediments in
549 some contourite systems (e.g., MC/AAIW interface at 800 mbsl; Thiéblemont et al., 2019). The
550 AAIW/NADW interface corresponds to a progressive transition zone where no high value in buoyancy
551 (Brunt-Väisälä) frequency is observed (Thiéblemont et al., 2019), and thus there is probably no
552 intensification of internal wave activity compared to the surrounding water masses.

553 The study area is on the main pathway of oceanic eddies (Fig. 1). In the Mozambique channel,
554 eddies can affect the whole water column impacting the seafloor in the whole basin (de Ruijter et al.,
555 2002). Schouten et al. (2003) showed that eddies current speed at 2000 mbsl can reach up to 10 cm.s⁻¹.
556 As previously demonstrated by Thiéblemont et al. (2019) and Miramontes et al. (2021), elongated-
557 mounded drifts in the Mozambique Channel at the AAIW and NADW depths are formed by water mass
558 channeling processes under the influence of Coriolis force creating erosive surfaces on the left sides of
559 the channels. These processes would explain erosion surfaces on the eastern flanks of the contourite
560 system (Fig. 2 and 15). Small erosional surfaces on some western flanks of the contourite system could

561 indicate southward flowing of the bottom current due to interactions with the bathymetry forming an
562 anti-clockwise circular current also observed in the modelled bottom current by ROMS (CROCO version,
563 Miramontes et al., 2021). Babonneau et al. (2022) proposed that this circular current around the
564 contourite drift could facilitate the capture of other circular hydrodynamic processes, such as eddies
565 (Fig. 15).

566 The variability of bottom current speed in the channels (cores MOZ3-CS03 and MOZ3-CS02) is
567 high, allowing both silty-clayey and siliciclastic sediments to be deposited during certain glacial stages,
568 in contrast to the variability of bottom current speed in core MOZ3-CS07, which is much lower and
569 allows the formation of a continuous foraminiferal sandy contourite facies without erosional surfaces
570 indicating relative stable hydrodynamic conditions over time. This difference in bottom current
571 variability between the drift and the channels could be explained by the thickness of the AAIW/NADW
572 interface (~700 m) offering stable conditions even with the Quaternary eustatic variations. The
573 sedimentary variability observed in the western channel (Fig. 3 and 15) could be related to channeling
574 processes that accentuate bottom current speed variations through climate cycles. These variations are
575 also recorded in core MOZ3-CS07 facies and discuss in the following part.

576 *5.3.2. Paleoceanographic record during 100 kyr Quaternary climate cycles*

577 The end of the MPT is observed at 1.55 msbf on core MOZ3-CS07 corresponding to 632ka (Fig.
578 11). After the MPT, sedimentation rates of 100 kyr climate cycles are calculated from the correlations
579 with the reference curve LR04 (red lines in Fig. 11). The interglacial stages show a higher sedimentation
580 than the glacial stages with an average rate of 0.5 cm.kyr⁻¹ compared to 0.15 cm.kyr⁻¹. The ln (Zr/Rb)
581 curve reveals a greater intensity of bottom currents during glacial stages than during interglacial stages.
582 The work of Babonneau et al. (2022) has allowed us to propose a general circulation pattern at the scale
583 of the contourite system during the Quaternary period. By combining these results with those of this
584 study, it is possible to propose an interpretation of the dynamics of the AAIW/NADW interface during
585 the 100 kyr climate cycles (Fig. 15):

586 -interglacial stages: bottom current speed is relatively low (compared to glacial stages). Sandy
587 particles are transported through the western channel, bottom current induce winnowing of fine

588 particles which are deposited by hemipelagic sedimentation on site MOZ3-CS03 and CS02. On the drift,
589 only foraminiferal sands are deposited, between which particles in suspension are trapped.

590 -glacial stages: bottom current speed is higher. Fine particles continue to be deposited on site
591 MOZ3-CS03 and MOZ3-CS02, but in smaller proportions. For some glacial stages, cores MOZ3-CS03 and
592 MOZ3-CS02 show siliciclastic sands that reflect higher intensity of bottom currents and greater
593 transport (Figs. 3 and 15). On the western side of the drift, coarse foraminifer tests continue to be
594 deposited and are sometimes winnowed and condensed into foraminiferal pockets.

595 Variations of bottom current speed generated at the AAIW/NADW interface during 100 kyr
596 climate cycles result from the variations of intensity of the AAIW, NADW, the impact of internal waves,
597 eddies and how all these factors are increased or reduced by interaction with the seafloor morphology.
598 As the contourite system is close to the upper part of the NADW, it is assumed that the intensity of the
599 AAIW/NADW interface at this depth depends more on the behavior of the NADW than that of the AAIW.

600 Molyneux et al. (2007) showed an increase in the influence of the NADW on the Agulhas Plateau
601 (Fig. 1) during glacial periods over the last 200 kyr. Our results confirm that this behavior of the NADW
602 during climatic cycles is the same over the last 633 kyr. The recent study of van der Lubbe et al. (2021)
603 provides a 7 Myr record of wind-driven circulation of the tropical Indian Ocean, as recorded in
604 Mozambique Channel Throughflow (MCT) flow speed variations at the IODP Site U1476 located on the
605 Davie Ridge at 2166 mbsf (Fig. 1). Their results show an increase in MCT flow speed during glacial
606 periods. Coupled with our study, it appears that from the Agulhas Plateau (southern entrance of the
607 Mozambique Channel) to the Davie Ridge (northern entrance of Mozambique channel), the behavior of
608 the surface and bottom ocean circulation is synchronous in this region over the 100 kyr climatic cycles.

609 The absence of the MIS 14 on the $\delta^{18}\text{O}$ curves of MOZ3-CS07 and MOZ3-CS03 (Fig. 11), could
610 be linked to the lower sedimentation rates in glacial stages. This isotopic stage corresponds to a
611 short and moderately cold glacial stage, attenuated on the reference curve LR04. The sampling
612 resolution and the condensation of the sedimentary records (especially for MOZ3-CS07) probably
613 contribute to hide this glacial period in the $\delta^{18}\text{O}$ curve of MOZ3-CS07.

614 4.08 Ma age is estimated at 11.45 m in core MOZ3-CS07 from the power regression on Sr-
615 isotope measurements inside the grey area in figure 12. The points outside the grey area were not
616 selected for the age estimation. These different choices are discussed below.

617 Measurements of series 1 and 2 were made on bulk sediment. Despite the presence of clay,
618 the values appear consistent except for two samples (at 5 and 8.45 mbsf). These two points outside
619 the grey zone with abnormally old ages (or low strontium ratios) can more likely be explained
620 either by contamination via volcanic ash or by old carbonates from sedimentary structures outside
621 the contourite system, than by a protocol or analytical errors during the analyses.

622 Measurements of series 3, 4 and 5 are performed on the fraction $>250\ \mu\text{m}$ of the same
623 samples but the samples of series 4 were placed in ultrasonic bath treated with ultrasounds. It
624 would appear that the ultrasound waves destabilize the structure of clay (residual clays probably
625 present within the foraminiferal tests), which are therefore more easily dissolved during the acidic
626 passages and can influence the measured $^{87}\text{Sr}/^{86}\text{Sr}$ ratio (by increasing it because the measured
627 Sr will be the result of both Sr from the detrital fraction which are very radiogenic and Sr from the
628 carbonates).

629 Despite these precautions, the uncertainties related to the SIS method do not allow
630 confirming an age of 4.08 Ma at the base of core MOZ3-CS07. This age requires verification with
631 other dating methods. Nevertheless, this estimation and the singularity of the foraminiferal sandy
632 contourite facies of core MOZ3-CS07 highlight its potential as long-term palaeoceanographic
633 record.

634 **6. CONCLUSIONS**

635 This study provides the characterization of a foraminiferal sandy contourite facies from the drift
636 of a contourite system localized in the Limpopo Corridor. This foraminiferal sandy contourite facies
637 diverges from the conceptual contourite facies model and, due to its condensed sedimentation, offers a
638 long-term, low-resolution paleoceanographic record. The comparisons with others contourite facies
639 from the near-by channels allow to understand bottom current processes and variations in sediment

640 distribution through 100 kyr climate cycles in a contourite system with low terrigenous inputs and
641 influenced by the AAIW/NADW interface.

642 Core MOZ3-CS07 shows continuous and homogenous foraminiferal sandy facies over 11.45 m.
643 This sedimentary facies results from the trapping of fine particles in suspension between the
644 foraminifer tests interstices. This process of interstitial sedimentation induces the deposition of a
645 significant content of clay and silt (about 20%) under stable and intense hydrodynamic conditions over
646 a long period of time with an average sedimentation rate of 0.26 cm.kyr⁻¹.

647 The cross-plot of "sorting versus D₅₀" allows us to propose the concept of "Graphical Contourite
648 Facies Chart" that helps to characterize the contourite facies and their related sedimentary processes.
649 Three contourite endmembers are identified; silty contourite, siliciclastic sandy contourite and
650 foraminiferal sandy contourite. The silty contourites are considered as a starting point from which the
651 facies can evolve to another endmember depending on the bottom current speed and the nature of the
652 sediment inputs.

653 At the scale of 100 kyr climate cycles, the contourite system is under the influence of the
654 AAIW/NADW interface. The sedimentation rates are lower and bottom current speed is higher during
655 glacial stages than interglacial stages. These hydrodynamic variations are not visible on the sedimentary
656 facies of core MOZ3-CS07 unlike those of cores located in the near-by channels of the contourite system
657 (MOZ3-CS03 and CS02). These results show that the sediments from the top of the drift (core MOZ3-
658 CS07) are deposited under relatively stable hydrodynamic conditions compared to those from the
659 channels.

660 Foraminiferal sandy contourite facies have great potential as sedimentary record. From this
661 study, it appears that contourite systems disconnected from gravity flows provide more easily
662 exploitable and interpretable sedimentary records. Following this reasoning, the depleted continental
663 margins should host areas more favorable for the study of long paleoceanographic record from
664 contourite systems.

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673 **8. CONFLICT OF INTEREST**

674 We declare that we have no commercial or associative aim that might represent a conflict of
675 interest in connection with the work submitted.

676 **9. DATA AVAILABILITY**

677 Lopes, Ugo; Babonneau, Nathalie; Fierens, Ruth; Révillon, Sidonie; Raison, Francois;
678 Miramontes Elda; Rabineau, Marina; Moulin Maryline; Aslanian, Daniel (submitted), "Foraminiferal sandy
679 contourite of the Mozambique Channel: facies characterization and Paleooceanographic record", Mendeley Data,
680 doi: ...

681 <https://doi.org/10.1111/sed.13045>

682 **10. REFERENCES**

- 683 **Babonneau, N., Raison, F., Genêt, A., Lopes, U., Fierens, R., Miramontes, E., ... & Aslanian, D. (2022).**
684 Contourite on the Limpopo Corridor, Mozambique margin: Long-term evolution, facies
685 distribution and Plio-Quaternary processes. *Sedimentology*.
686 <https://doi.org/10.1111/sed.13045>
- 687 **Bankole, S., Stow, D., Smillie, Z., Buckman, J., & Lever, H. (2021).** Mudrock Microstructure: A
688 Technique for Distinguishing between Deep-Water Fine-Grained Sediments. *Minerals*, 11(6),
689 653. <https://doi.org/10.3390/min11060653>

- 690 **Blott, S. J., & Pye, K.** (2001). Gradistat: A grain size distribution and statistics package for the analysis
691 of unconsolidated sediments. *Earth Surface Processes and Landforms*, 1248, 1237–1248
- 692 **Brackenridge, R., Stow, D. A. V. & Hernández-Molina, F. J.** (2011) Contourites within a deep-water
693 sequence stratigraphic framework. *Geo-Mar Lett* 31, 343–360.
694 <https://doi.org/10.1007/s00367-011-0256-9>
- 695 **Brackenridge, R. E., Stow, D. A. V., Hernández-Molina, F. J., Jones, C., Mena, A., Alejos, I., Ducassou,**
696 **E., Llave, E., Ercilla, G., Nombelas, M. A., Perez-Arlucas, M., & Frances, G.** (2018). Textural
697 characteristics and facies of sand-rich contourite depositional systems. *Sedimentology*, 65,
698 2223–2252. <https://doi.org/10.1111/sed.12463>
- 699 **Breitzke, M., Wiles, E., Krockner, R., Watkeys, M. K., & Jokat, W.** (2017). Seafloor morphology in the
700 Mozambique Channel: evidence for long-term persistent bottom-current flow and deep-
701 reaching eddy activity. *Marine Geophysical Research*, 38(3), 241-269.
- 702 **Carter, R. M.** (2007). The role of intermediate-depth currents in continental shelf-slope accretion:
703 Canterbury Drifts, SW Pacific Ocean. Geological Society, London, Special Publications, 276(1),
704 129-154. <https://doi.org/10.1144/GSL.SP.2007.276.01.07>
- 705 **Counts, J. W., Jorry, S. J., Leroux, E., Miramontes, E., & Jouet, G.** (2018). Sedimentation adjacent to
706 atolls and volcano-cored carbonate platforms in the Mozambique Channel (SW Indian Ocean).
707 *Marine Geology*, 404, 41-59. <https://doi.org/10.1016/j.margeo.2018.07.003>.
- 708 **de Castro, S., Hernández-Molina, F. J., Rodríguez-Tovar, F. J., Llave, E., Ng, Z. L., Nishida, N., & Mena,**
709 **A.** (2020). Contourites and bottom current reworked sands: Bed facies model and implications.
710 *Marine Geology*, 428(January). <https://doi.org/10.1016/j.margeo.2020.106267>
- 711 **de Castro, S., Hernández-Molina, F. J., Weger, W., Jiménez-Espejo, F. J., Rodríguez-Tovar, F. J.,**
712 **Mena, A., Llave, E., & Sierro, F. J.** (2021a). Contourite characterization and its discrimination
713 from other deep-water deposits in the Gulf of Cadiz contourite depositional system.
714 *Sedimentology*, 68(3), 987–1027. <https://doi.org/10.1111/sed.12813>
- 715 **de Castro, S., Miramontes, E., Dorador, J., Jouet, G., Cattaneo, A., Rodríguez-Tovar, F. J., &**
716 **Hernández-Molina, F. J.** (2021b). Siliciclastic and bioclastic contouritic sands: Textural and

717 geochemical characterisation. *Marine and Petroleum Geology*, 128(December 2020), 105002.
718 <https://doi.org/10.1016/j.marpetgeo.2021.105002>

719 **de Ruijter, W. D., Biastoch, A., Drijfhout, S. S., Lutjeharms, J. R. E., Matano, R. P., Pichevin, T., ... &**
720 **Weijer, W.** (1999). Indian-Atlantic interocean exchange: Dynamics, estimation and
721 impact. *Journal of Geophysical Research: Oceans*, 104(C9), 20885-20910.
722 <https://doi.org/10.1029/1998JC900099>

723 **de Ruijter, W. P. M., Ridderinkhof, H., Lutjeharms, J. R. E., Schouten, M. W., & Veth, C.** (2002).
724 Observations of the flow in the Mozambique Channel. *Geophysical Research Letters*, 29(10), 3–
725 5. <https://doi.org/10.1029/2001GL013714>

726 **Elderfield, H.** (1986). Strontium isotope stratigraphy. *Palaeogeography, palaeoclimatology,*
727 *palaeoecology*, 57(1), 71-90. [https://doi.org/10.1016/0031-0182\(86\)90007-6](https://doi.org/10.1016/0031-0182(86)90007-6)

728 **Evain, M., Schnürle, P., Leprêtre, A., Verrier, F., Watremez, L., Thompson, J. O. ... & Moulin, M.**
729 (2021). Crustal structure of the East African Limpopo margin, a strike-slip rifted corridor along
730 the continental Mozambique Coastal Plain and North Natal Valley. *Solid Earth*, 12(8), 1865-1897.
731 <https://doi.org/10.5194/se-12-1865-2021>

732 **Folk, R. L., & Ward, W. C.** (1957). Brazos River Bar: A study in the significance of grain size parameters.
733 *Journal of Sedimentary Petrology*, 27(1), 3–26. [https://doi.org/10.1306/74D70646-2B21-](https://doi.org/10.1306/74D70646-2B21-11D7-8648000102C1865D)
734 [11D7-8648000102C1865D](https://doi.org/10.1306/74D70646-2B21-11D7-8648000102C1865D)

735 **Fonnesu, M., Palermo, D., Galbiati, M., Marchesini, M., Bonamini, E., & Bendias, D.** (2020). A new
736 world-class deep-water play-type, deposited by the syndepositional interaction of turbidity
737 flows and bottom currents: The giant Eocene Coral Field in northern Mozambique. *Marine and*
738 *Petroleum Geology*, 111(May 2019), 179–201.
739 <https://doi.org/10.1016/j.marpetgeo.2019.07.047>

740 **Friedman, G. M., & Sanders, J. E.** (1978). *Principal of Sedimentology* (Vol. 50, Issue Chapter 8).
741 <https://doi.org/10.1002/esp.3290040317>

742 **Gao, Y., Stow, D. A. V., Tang, Y., Xie, X., & Piper, D. J. W.** (2020). Seismic stratigraphy and deep-water
743 sedimentary evolution of the southern Mozambique margin: Central Terrace and Mozambique

744 Fracture Zone. *Marine Geology*, 427(December 2019), 106187.
745 <https://doi.org/10.1016/j.margeo.2020.106187>

746 **Gonthier, E. G., Faugères, J. C., & Stow, D. A. V. (1984).** Contourite facies of the Faro Drift, Gulf of Cadiz.
747 *Geological Society Special Publication*, 15, 275–292.
748 <https://doi.org/10.1144/GSL.SP.1984.015.01.18>

749 **Gradstein, F. M., Ogg, J. G., Schmitz, M. B., & Ogg, G. M. (Eds.). (2012).** The geologic time scale 2012.
750 Elsevier.

751 **Gruetzner, J., Jiménez Espejo, F. J., Lathika, N., Uenzelmann-Neben, G., Hall, I. R., Hemming, S. R.,**
752 **Levay, L. J., Barker, S., Berke, M. A., Brentegani, L., Caley, T., Cartagena-Sierra, A., Charles,**
753 **C. D., Coenen, J. J., Crespin, J. G., Franzese, A. M., Han, X., Hines, S. K. V., Just, J., ... Zhang, H.**
754 (2019). A New Seismic Stratigraphy in the Indian-Atlantic Ocean Gateway Resembles Major
755 Paleo-Oceanographic Changes of the Last 7 Ma. *Geochemistry, Geophysics, Geosystems*, 20(1),
756 339–358. <https://doi.org/10.1029/2018GC007668>

757 **Halo, I., Backeberg, B., Penven, P., Ansorge, I., Reason, C., Ullgren, J.E. (2014).** Eddy properties in the
758 Mozambique Channel: a comparison between observations and two numerical ocean circulation
759 models. *Deep sea Res. II Top. Stud. Oceanogr.* 100, 38–53.
760 <https://doi.org/10.1016/j.dsr2.2013.10.015>

761 **Hancke, L., Roberts, M. J., & TERNON, J. F. (2014).** Surface drifter trajectories highlight flow pathways
762 in the Mozambique Channel. *Deep Sea Research Part II: Topical Studies in Oceanography*, 100,
763 27-37. <https://doi.org/10.1016/j.dsr2.2013.10.014>

764 **Heezen, B. C., & Hollister, C. (1964).** Deep sea current evidence from abyssal sediments. *Marine*
765 *Geology*, 1(2), 141–174. [https://doi.org/10.1016/0025-3227\(64\)90012-X](https://doi.org/10.1016/0025-3227(64)90012-X)

766 **Hernández-Molina, J., Llave, E., Somoza, L., Fernández-Puga, M. C., Maestro, A., León, R., ... &**
767 **Gardner, J. (2003).** Looking for clues to paleoceanographic imprints: a diagnosis of the Gulf of
768 Cadiz contourite depositional systems. *Geology*, 31(1), 19-22. [https://doi.org/10.1130/0091-](https://doi.org/10.1130/0091-7613(2003)031%3C0019:LFCTPI%3E2.0.CO;2)
769 [7613\(2003\)031%3C0019:LFCTPI%3E2.0.CO;2](https://doi.org/10.1130/0091-7613(2003)031%3C0019:LFCTPI%3E2.0.CO;2)

770 **Hernández-Molina, F. J., Hüneke, H., Rodríguez-Tovar, F. J., Ng, Z. L., Llave, E., Mena, A., ... & de la**
771 **Vara, A.** (2022). Eocene to middle Miocene contourite deposits in Cyprus: A record of Indian
772 Gateway evolution. *Global and Planetary Change*, 219, 103983.
773 <https://doi.org/10.1016/j.gloplacha.2022.103983>

774 **Hollister, C.D.**, (1967). Sediment distribution and deep circulation in the western North Atlantic. (PhD
775 thesis) Columbia University, New York.

776 **Huizhong, W., & McCave, I. N.** (1990). Distinguishing climatic and current effects in mid-Pleistocene
777 sediments of Hatton and Gardar Drifts, NE Atlantic. *Journal of the Geological society*, 147(2),
778 373-383. <https://doi.org/10.1144/gsjgs.147.2.0373>

779 **Hüneke, H., Hernández-molina, F. J., Rodríguez-Tovar, F. J., Llave, E., Chiarella, D., Mena, A., &**
780 **Stow, D. A. V.** (2020). Diagnostic criteria using microfacies for calcareous contourites, turbidites
781 and pelagites in the Eocene – Miocene slope succession, southern Cyprus. *International*
782 *Association of Sedimentologists*. <https://doi.org/10.1111/sed.12792>

783 **Hüneke, H., Hernández-Molina, F. J., Rodríguez-Tovar, F. J., Llave, E., Chiarella, D., Mena, A., &**
784 **Stow, D. A. V.** (2021). Diagnostic criteria using microfacies for calcareous contourites, turbidites
785 and pelagites in the Eocene–Miocene slope succession, southern Cyprus. *Sedimentology*, 68(2),
786 557-592. <https://doi.org/10.1111/sed.12792>

787 **Jokat, W., Boebel, T., König, M., & Meyer, U.** (2003). Timing and geometry of early Gondwana breakup.
788 *Journal of Geophysical Research*, 108. <https://doi.org/10.1029/2002JB001802>

789 **Knutz, P. C.** (2008). Palaeoceanographic significance of contourite drifts. *Developments in*
790 *sedimentology*, 60, 511-535. [https://doi.org/10.1016/S0070-4571\(08\)10024-3](https://doi.org/10.1016/S0070-4571(08)10024-3)

791 **Krüger, S., Leuschner, D. C., Ehrmann, W., Schmiedl, G., & Mackensen, A.** (2012). North Atlantic Deep
792 Water and Antarctic Bottom Water variability during the last 200 ka recorded in an abyssal
793 sediment core off South Africa. *Global and Planetary Change*, 80, 180-189.
794 <https://doi.org/10.1016/j.gloplacha.2011.10.001>

795 **Leinweber, V. T., Klingelhoefer, F., Neben, S., Reichert, C., Aslanian, D., Matias, L. ... & Jokat, W.**
796 (2013). The crustal structure of the Central Mozambique continental margin—Wide-angle

797 seismic, gravity and magnetic study in the Mozambique Channel, Eastern Africa. *Tectonophysics*,
798 599, 170-196. <https://doi.org/10.1016/j.tecto.2013.04.015>

799 **Li, H., Tang, Y., Moulin, M., Aslanian, D., Evain, M., Schnurle, P. ... & Li, J.** (2021). Seismic evidence for
800 crustal architecture and stratigraphy of the Limpopo Corridor: New insights into the evolution
801 of the sheared margin offshore southern Mozambique. *Marine Geology*, 435, 106468.
802 <https://doi.org/10.1016/j.margeo.2021.106468>

803 **Lisiecki, L. E., & Raymo, M. E.** (2005). A Pliocene-Pleistocene stack of 57 globally distributed benthic
804 $\delta^{18}\text{O}$ records. *20(May)*, 1-17. <https://doi.org/https://doi.org/10.1029/2004PA001071>

805 **Lonsdale, P., Normark, W. R., & Newman, W. A.** (1972). Sedimentation and erosion on Horizon Guyot.
806 *Geological Society of America Bulletin*, 83(2), 289-316. [https://doi.org/10.1130/0016-](https://doi.org/10.1130/0016-7606(1972)83[289:SAEOHG]2.0.CO;2)
807 [7606\(1972\)83\[289:SAEOHG\]2.0.CO;2](https://doi.org/10.1130/0016-7606(1972)83[289:SAEOHG]2.0.CO;2)

808 **Lonsdale, P., Malfait, B.,** (1974). Abyssal dunes of foraminiferal sand on the Carnegie Ridge. *Geol.*
809 *Soc.Am. Bull.* 85, 1697-1712. [https://doi.org/10.1130/0016-](https://doi.org/10.1130/0016-7606(1974)85%3C1697:ADOF50%3E2.0.CO;2)
810 [7606\(1974\)85%3C1697:ADOF50%3E2.0.CO;2](https://doi.org/10.1130/0016-7606(1974)85%3C1697:ADOF50%3E2.0.CO;2)

811 **Lovell, J. P. B., & Stow, D. A. V.** (1981). Identification of ancient sandy contourites. *Geology*, 9(8), 347-
812 349. [https://doi.org/10.1130/0091-7613\(1981\)9<347:IOASC>2.0.CO;2](https://doi.org/10.1130/0091-7613(1981)9<347:IOASC>2.0.CO;2)

813 **Martín-Chivelet, J., Fregenal-Martínez, M. A., & Chacón, B.** (2008). Traction structures in
814 contourites. *Developments in Sedimentology*, 60, 157-182. [https://doi.org/10.1016/S0070-](https://doi.org/10.1016/S0070-4571(08)10010-3)
815 [4571\(08\)10010-3](https://doi.org/10.1016/S0070-4571(08)10010-3)

816 **Martorelli, E., Bosman, A., Casalbore, D., Chiocci, F., Conte, A. M., di Bella, L., Ercilla, G., Falcini, F.,**
817 **Falco, P., Frezza, V., Gaglianone, G., Giaccio, B., & Mancini, M.** (2021). Mid-to-late Holocene
818 upper slope contourite deposits off Capo Vaticano (Mediterranean Sea): High-resolution record
819 of contourite cyclicity, bottom current variability and sandy facies. *Marine Geology*,
820 431(November 2020), 106372. <https://doi.org/10.1016/j.margeo.2020.106372>

821 **Matsinhe, N. D., Tang, Y., Li, C., Li, J., Mahanjane, E. S., Li, H., & Fang, Y.** (2021). The crustal nature of
822 the northern Mozambique Ridge, Southwest Indian Ocean. *Acta Oceanol. Sin*, 40(7), 170-182.
823 <https://doi.org/10.1007/s13131-021-1747-9>

- 824 **McArthur, J. M.** (1994). Recent trends in strontium isotope stratigraphy. *Terra nova*, 6(4), 331-358.
825 <https://doi.org/10.1111/j.1365-3121.1994.tb00507.x>
- 826 **McArthur, J. M., Howarth, R. J., & Shields, G. A.** (2012). Strontium isotope stratigraphy. In *The Geologic*
827 *Time Scale 2012*. Felix M. Gradstein, James G. Ogg, Mark Schmitz and Gabi Ogg.
828 <https://doi.org/10.1016/B978-0-444-59425-9.00007-X>
- 829 **McCave, I. N., & Hall, I. R.** (2006). Size sorting in marine muds: Processes, pitfalls, and prospects for
830 paleoflow- speed proxies. *Geochemistry*, 7(10). <https://doi.org/10.1029/2006GC001284>
- 831 **McCave, I. N., Thornalley, D. J. R., & Hall, I. R.** (2017). Relation of sortable silt grain size to deep sea
832 current speeds: Calibration of the 'Mud Current Meter.' *Deep sea Research Part I: Oceanographic*
833 *Research Papers*, 127(July), 1–12. <https://doi.org/10.1016/j.dsr.2017.07.003>
- 834 **Miller, M. C., & Komar, P. D.** (1977). The development of sediment threshold curves for unusual
835 environments (Mars) and for inadequately studied materials (foram sands). *Sedimentology*, 24,
836 709–721. <https://doi.org/10.1111/j.1365-3091.1977.tb00266.x>
- 837 **Miramontes, E., Cattaneo, A., Jouet, G., Thereau, E., Thomas, Y., Rovere, M., ... & Trincardi, F.** (2016).
838 The Pianosa contourite depositional system (northern Tyrrhenian Sea): Drift morphology and
839 Plio-Quaternary stratigraphic evolution. *Marine Geology*, 378, 20-42.
840 <https://doi.org/10.1016/j.margeo.2015.11.004>
- 841 **Miramontes, E., Garziglia, S., Sultan, N., Jouet, G., & Cattaneo, A.** (2018). Morphological control of
842 slope instability in contourites: a geotechnical approach. *Landslides*, 15, 1085-1095.
843 <https://doi.org/10.1007/s10346-018-0956-6>
- 844 **Miramontes, E., Penven, P., Fierens, R., Droz, L., Toucanne, S., Jorry, S. J., ... & Raisson, F.** (2019).
845 The influence of bottom currents on the Zambezi Valley morphology (Mozambique Channel, SW
846 Indian Ocean): In situ current observations and hydrodynamic modelling. *Marine Geology*, 410,
847 42-55. <https://doi.org/10.1016/j.margeo.2019.01.002>
- 848 **Miramontes, E., Jouet, G., Thereau, E., Bruno, M., Penven, P., Guerin, C., ... & Cattaneo, A.** (2020).
849 The impact of internal waves on upper continental slopes: insights from the Mozambican margin

850 (southwest Indian Ocean). *Earth Surface Processes and Landforms*, 45(6), 1469-1482.
851 <https://doi.org/10.1002/esp.4818>

852 **Miramontes, E., Thiéblemont, A., Babonneau, N., Penven, P., Raison, F., Droz, L., Jorry, S. J.,**
853 **Fierens, R., Counts, J. W., Wilckens, H., Cattaneo, A., & Jouet, G. (2021).** Contourite and mixed
854 turbidite-contourite systems in the Mozambique Channel (SW Indian Ocean): Link between
855 geometry, sediment characteristics and modelled bottom currents. *Marine Geology*, 437(May).
856 <https://doi.org/https://doi.org/10.1016/j.margeo.2021.106502>

857 **Molyneux, E. G., Hall, I. R., Zahn, R., & Diz, P. (2007).** Deep water variability on the southern Agulhas
858 Plateau: Interhemispheric links over the past 170 ka. *Paleoceanography*, 22(4).
859 <https://doi.org/10.1029/2006PA001407>

860 **Mosher, D. C., Campbell, D. C., Gardner, J. v, Piper, D. J. W., Chaytor, J. D., & Rebesco, M. (2017).** The
861 role of deep-water sedimentary processes in shaping a continental margin: The Northwest
862 Atlantic. *Marine Geology*, 393(August), 245-259.
863 <https://doi.org/10.1016/j.margeo.2017.08.018>

864 **Moulin M. and Aslanian D. (2016)** PAMELA-MOZ03 cruise, RV Pourquoi pas ?
865 <http://dx.doi.org/10.17600/16001600>

866 **Moulin, M., Aslanian, D., Evain, M., Leprêtre, A., Schnurle, P., Verrier, F., ... & PAMELA-MOZ35**
867 **Team. (2020).** Gondwana breakup: messages from the North Natal Valley. *Terra Nova*, 32(3),
868 205-214.

869 **Past Interglacials Working Group of PAGES. (2016).** Interglacials of the last 800,000 years. *Reviews*
870 *of Geophysics*, 54(1), 162-219. <https://doi.org/10.1002/2015RG000482>

871 **Pettijohn, F. J. (1975).** *Sedimentary rocks* (Vol. 3, p. 628). New York: Harper & Row

872 **Pin, C., & Zalduegui, J. S. (1997).** Sequential separation of light rare-earth elements, thorium and
873 uranium by miniaturized extraction chromatography: application to isotopic analyses of silicate
874 rocks. *Analytica Chimica Acta*, 339(1-2), 79-89. [https://doi.org/10.1016/S0003-](https://doi.org/10.1016/S0003-2670(96)00499-0)
875 [2670\(96\)00499-0](https://doi.org/10.1016/S0003-2670(96)00499-0)

876 **Rebesco, M.** (2005). Contourites. *Encyclopedia of Geology*, 513–527.
877 <https://doi.org/10.1016/B0-12-369396-9/00497-4>

878 **Rebesco, M., Camerlenghi, A., & van Loon, A. J.** (2008). Contourite Research. In *Contourites*.
879 [https://doi.org/10.1016/S0070-4571\(08\)10001-2](https://doi.org/10.1016/S0070-4571(08)10001-2)

880 **Robinson, S. G., & McCave, I. N.** (1994). Orbital forcing of bottom-current enhanced sedimentation on
881 Feni Drift, NE Atlantic, during the mid-Pleistocene. *Paleoceanography*, 9(6), 943-972.
882 <https://doi.org/10.1029/94PA01439>

883 **Rodrigues, S., Hernández-Molina, F. J., Hillenbrand, C. -D., Lucchi, R. G., Rodríguez-Tovar, F. J.,**
884 **Rebesco, M., & Larter, R. D.** (2022). Recognizing key sedimentary facies and their distribution
885 in mixed turbidite–contourite depositional systems: The case of the Pacific margin of the
886 Antarctic Peninsula. *Sedimentology*. <https://doi.org/10.1111/sed.12978>

887 **Rodríguez-Tovar, F. J.** (2022). Ichnological analysis: A tool to characterize deep-marine processes and
888 sediments. *Earth-Science Reviews*, 228, 104014.
889 <https://doi.org/10.1016/j.earscirev.2022.104014>

890 **de Ruijter, W. P., Ridderinkhof, H., Lutjeharms, J. R., Schouten, M. W., & Veth, C.** (2002).
891 Observations of the flow in the Mozambique Channel. *Geophysical Research Letters*, 29(10),
892 140-1. <https://doi.org/10.1029/2001GL013714>

893 **Sætre, R., & da Silva, A. J.** (1984). The circulation of the Mozambique Channel. *Deep sea Research*,
894 31(5), 485–508. [https://doi.org/10.1016/0198-0149\(84\)90098-0](https://doi.org/10.1016/0198-0149(84)90098-0)

895 **Sansom, P.** (2018). Hybrid turbidite–contourite systems of the Tanzanian margin. *Petroleum*
896 *Geoscience*, 24(3), 258-276. <https://doi.org/10.1144/petgeo2018-044>

897 **Schiller, D. M., Seubert, B. W., Musliki, S., & Abdullah, M.** (1994). The reservoir potential of
898 globigerinid sands in Indonesia.

899 **Schouten, M. W., de Ruijter, W. P. M., van Leuwen, P. J., & Ridderinkhof, H.** (2003). Eddies and
900 variability in the Mozambique Channel. *Deep sea Research II*, 50, 1987–2003.
901 [https://doi.org/10.1016/S0967-0645\(03\)00042-0](https://doi.org/10.1016/S0967-0645(03)00042-0)

- 902 **Shanmugam, G.** (2000). 50 years of the turbidite paradigm (1950s—1990s): deep-water processes and
903 facies models—a critical perspective. *Marine and Petroleum Geology*, 17(2), 285-342.
904 [https://doi.org/10.1016/S0264-8172\(99\)00011-2](https://doi.org/10.1016/S0264-8172(99)00011-2)
- 905 **Sloyan, B. M., & Rintoul, S. R.** (2001). Circulation, renewal, and modification of Antarctic Mode and
906 Intermediate Water. *Journal of physical oceanography*, 31(4), 1005-1030.
907 [https://doi.org/10.1175/1520-0485\(2001\)031%3C1005:CRAMOA%3E2.0.CO;2](https://doi.org/10.1175/1520-0485(2001)031%3C1005:CRAMOA%3E2.0.CO;2)
- 908 **Smalley, I. J.** (1966). Formation of quartz sand. *Nature*, 221, 476–479.
- 909 **Stow, D. A. V., Faugères, J.-C., Howe, J. A., Pudsey, C. J., & Viana, A. R.** (2002). Bottom currents,
910 contourites and deep-sea sediment drifts: current state-of-the-art. *The Geological Society of*
911 *London*, 22, 7–20. <https://doi.org/10.1144/GSL.MEM.2002.022.01.02>
- 912 **Stow, D. A. V., & Faugères, J.-C.** (2008). Contourite Facies and the Facies Model. *Developments in*
913 *Sedimentology*, 60(08), 223–256. [https://doi.org/10.1016/S0070-4571\(08\)10013-9](https://doi.org/10.1016/S0070-4571(08)10013-9)
- 914 **Stow, D. A. V., & Smillie, Z.** (2020). Distinguishing between deep-water sediment facies: Turbidites,
915 contourites and hemipelagites. *Geosciences*, 10(2), 68.
916 <https://doi.org/10.3390/geosciences10020068>
- 917 **Swart, N. C., Lutjeharms, J. R. E., Ridderinkhof, H., & De Ruijter, W. P. M.** (2010). Observed
918 characteristics of Mozambique Channel eddies. *Journal of Geophysical Research: Oceans*, 115(C9). <https://doi.org/10.1029/2009JC005875>
- 920 **Tallobre, C.** (2017). Mise en évidence d'un système de dépôt contouritique et des processus
921 sédimentaires associés sur le plateau de Demerara (marge guyanaise).
- 922 **Thiéblemont, A., Hernández-Molina, F. J., Miramontes, E., Raison, F., & Penven, P.** (2019).
923 Contourite depositional systems along the Mozambique channel: The interplay between bottom
924 currents and sedimentary processes. *Deep sea Research Part I: Oceanographic Research Papers*,
925 147(February), 79–99. <https://doi.org/10.1016/j.dsr.2019.03.012>
- 926 **Thiéblemont, A., Hernández-molina, F. J., Ponte, J., Robin, C., Guillocheau, F., Cazzola, C., &**
927 **Raison, F.** (2020). Seismic stratigraphic framework and depositional history for Cretaceous

928 and Cenozoic contourite depositional systems of the Mozambique Channel, SW Indian Ocean.
929 Marine Geology, 425(March), 106192. <https://doi.org/10.1016/j.margeo.2020.106192>

930 **Thompson, J. O., Moulin, M., Aslanian, D., De Clarens, P., & Guillocheau, F.** (2019). New starting point
931 for the Indian Ocean: Second phase of breakup for Gondwana. *Earth-Science Reviews*, 191, 26-
932 56. <https://doi.org/10.1016/j.earscirev.2019.01.018>

933 **Ullgren, J.E., van Aken, H.M., Ridderinkhof, H., de Ruijter, W.P.M.,** (2012). The hydrography of the
934 Mozambique Channel from six years of continuous temperature, salinity, and speed
935 observations. *Deep sea Res. I Oceanogr. Res. Pap.* 69, 36–50.
936 <https://doi.org/10.1016/j.dsr.2012.07.003>

937 **van Aken, H. M. van, Ridderinkhof, H., & de Ruijter, W. P. M.** (2004). North Atlantic deep water in the
938 south-western Indian Ocean. 51, 755–776. <https://doi.org/10.1016/j.dsr.2004.01.008>

939 **van der Lubbe, H. J. L., Hall, I. R., Barker, S., Hemming, S. R., Baars, T. F., Starr, A., ... & Joordens, J.**
940 **C. A.** (2021). Indo-Pacific Walker circulation drove Pleistocene African aridification. *Nature*,
941 598(7882), 618-623. <https://doi.org/10.1038/s41586-021-03896-3>

942 **Vandorpe, T., Collart, T., Cnudde, V., Lebreiro, S., Hernández-Molina, F. J., Alonso, B., Mena, A.,**
943 **Antón, L., & van Rooij, D.** (2019). Quantitative characterisation of contourite deposits using
944 medical CT. *Marine Geology*, 417(November 2018), 106003.
945 <https://doi.org/10.1016/j.margeo.2019.106003>

946 **Viana, A. R., Faugères, J. C., & Stow, D. A. V.** (1998). Bottom-current-controlled sand deposits—a
947 review of modern shallow-to deep-water environments. *Sedimentary Geology*, 115(1-4), 53-80.
948 [https://doi.org/10.1016/S0037-0738\(97\)00087-0](https://doi.org/10.1016/S0037-0738(97)00087-0)

949 **Viana, A. R., & Rebesco, M.** (2007). Economic and Palaeoceanographic Significance of Contourite
950 Deposits. <https://doi.org/https://doi.org/10.1144/GSL.SP.2007.276>

951 **Watkeys, M. K., & Sokoutis, D.** (1998). Transtension in southeastern Africa associated with Gondwana
952 break-up. *Geological Society, London, Special Publications*, 135(1), 203-214.
953 <https://doi.org/10.1144/GSL.SP.1998.135.01.13>

954 **Wetzel, A., Werner, F., & Stow, D. A. V.** (2008). Bioturbation and biogenic sedimentary structures in
955 contourites. *Developments in sedimentology*, 60, 183-202. [https://doi.org/10.1016/S0070-](https://doi.org/10.1016/S0070-4571(08)10011-5)
956 4571(08)10011-5

957 **Wu, L., Wilson, D. J., Wang, R., Yin, X., Chen, Z., Xiao, W., & Huang, M.** (2020). Evaluating Zr/Rb ratio
958 from XRF scanning as an indicator of grain-size variations of glaciomarine sediments in the
959 Southern Ocean. *Geochemistry, Geophysics, Geosystems*, 21(11), e2020GC009350.
960 <https://doi.org/10.1029/2020GC009350>

961 **Yu, X., Stow, D. A. V., Smillie, Z., Esentia, I., Brackenridge, R., Xie, X., Bankole, S., Ducassou, E., &**
962 **Llave, E.** (2020). Contourite porosity, grain size and reservoir characteristics. *Marine and*
963 *Petroleum Geology*, 117(January), 104392. <https://doi.org/10.1016/j.marpetgeo.2020.104392>

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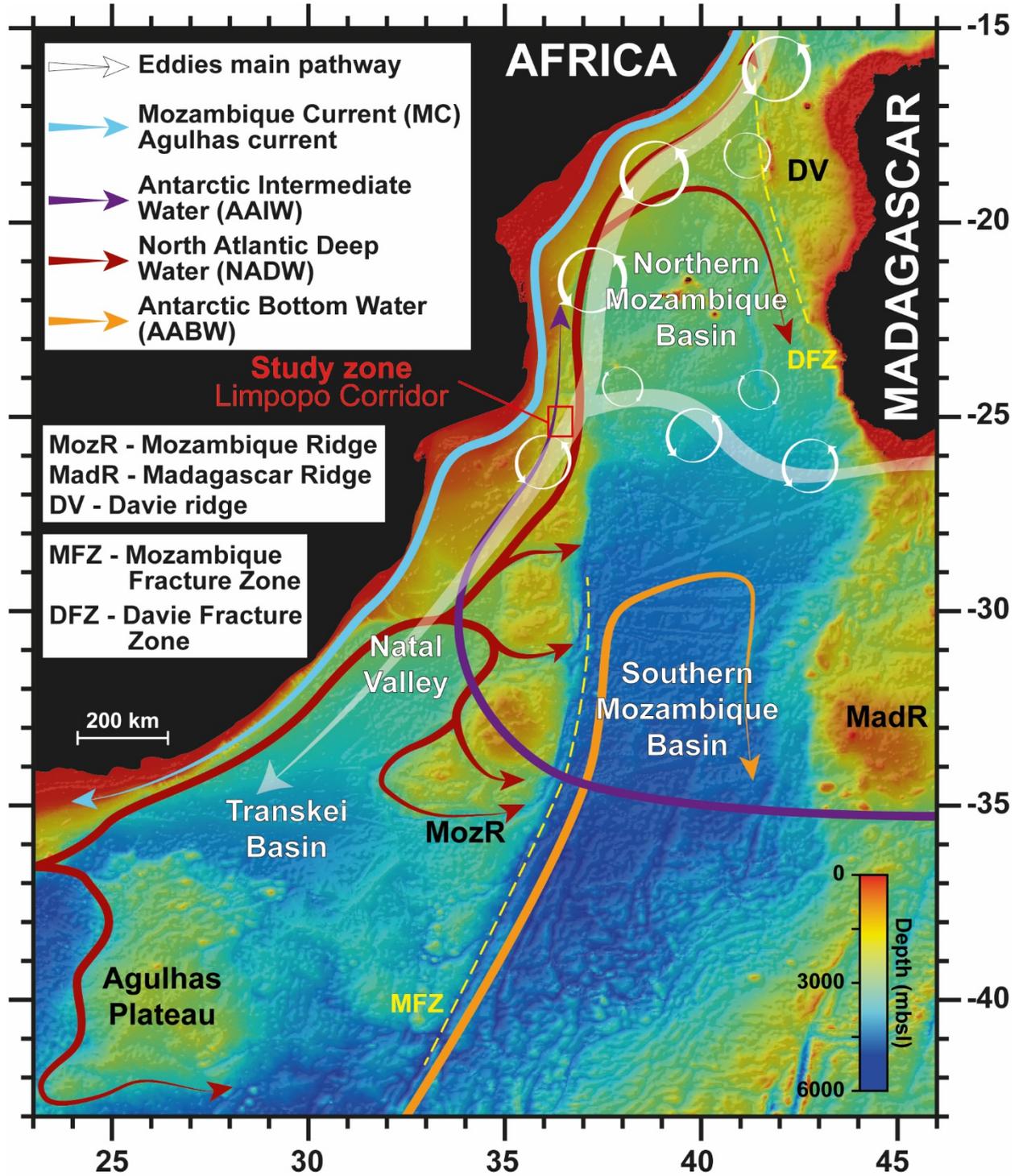
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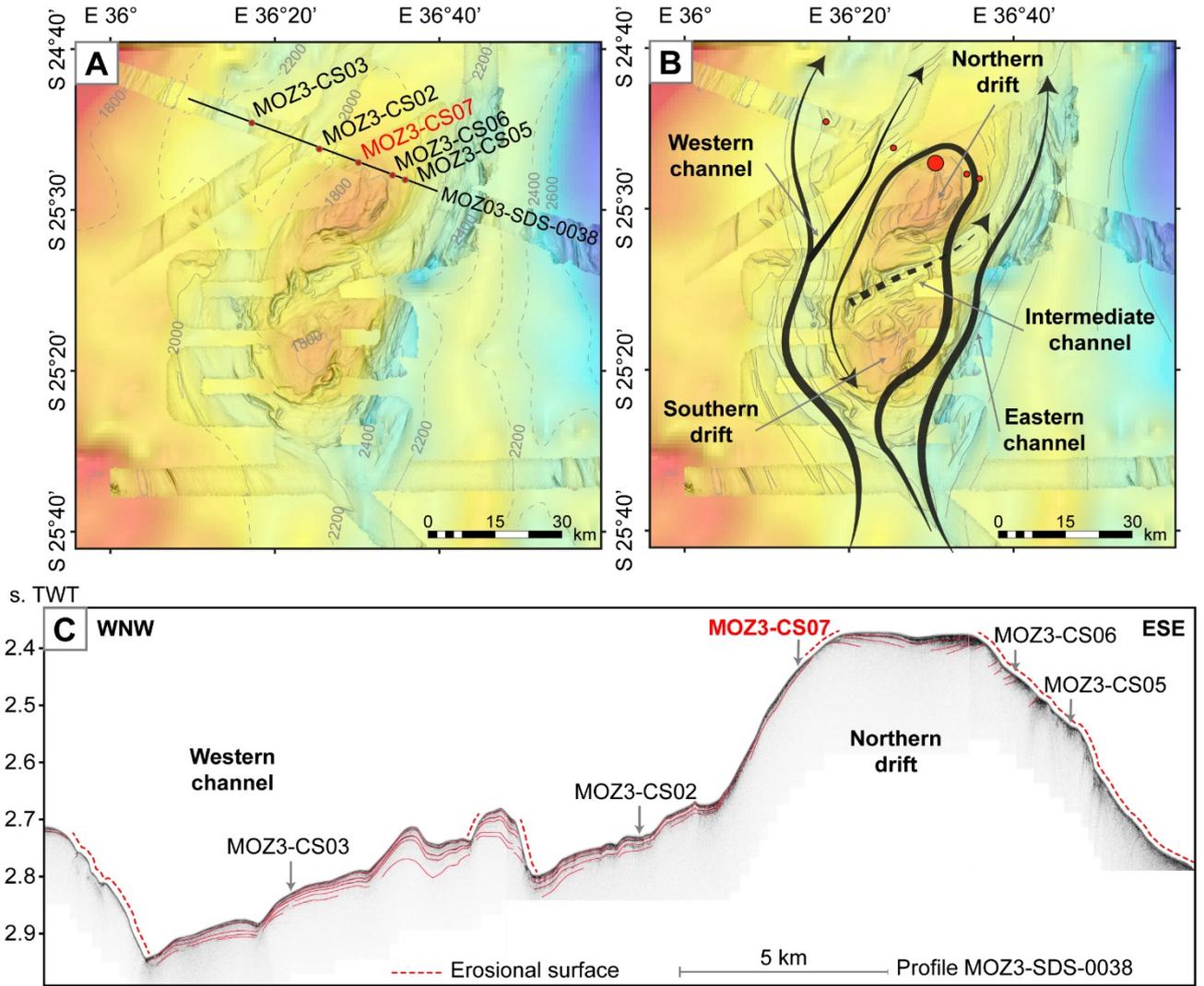
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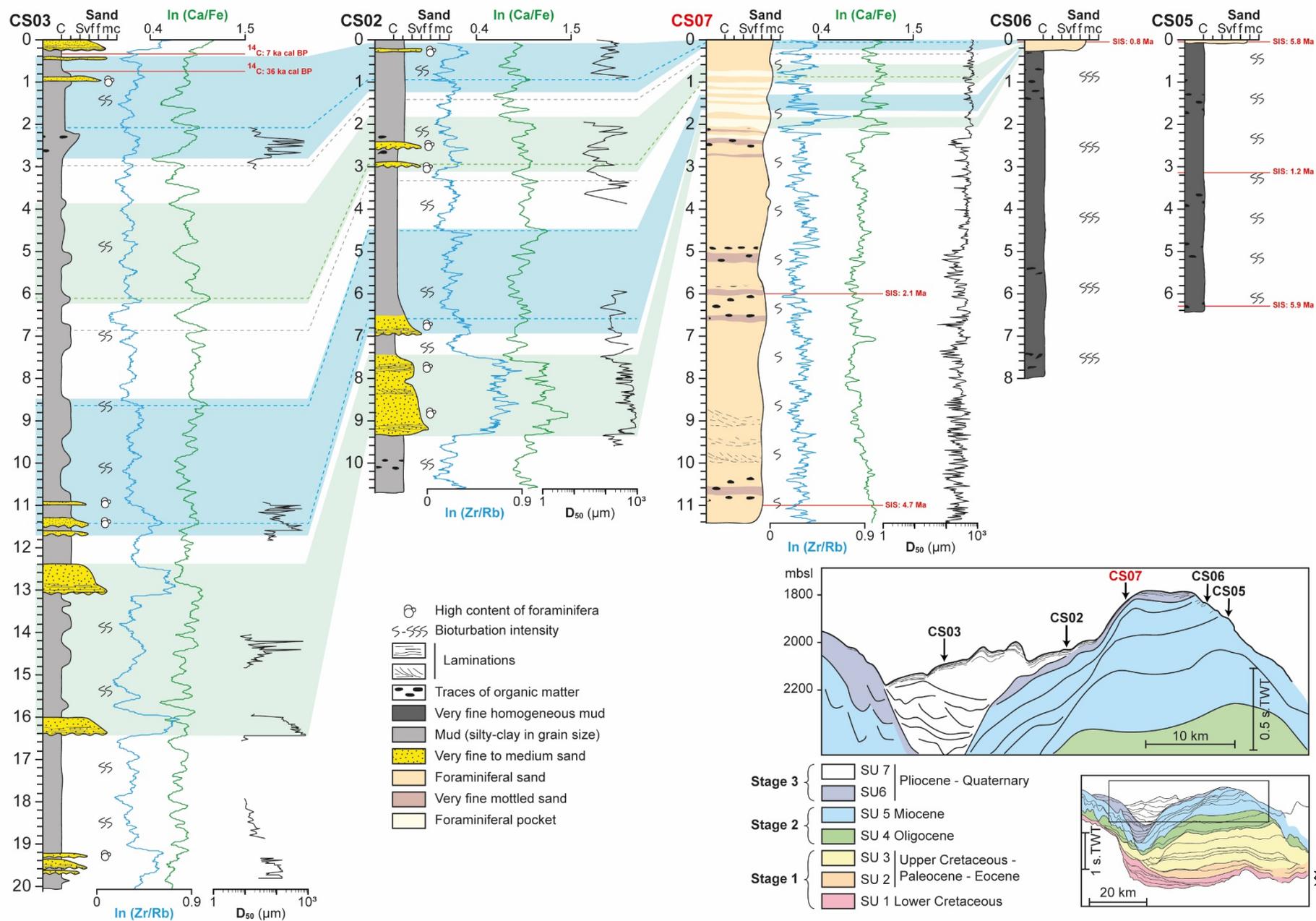
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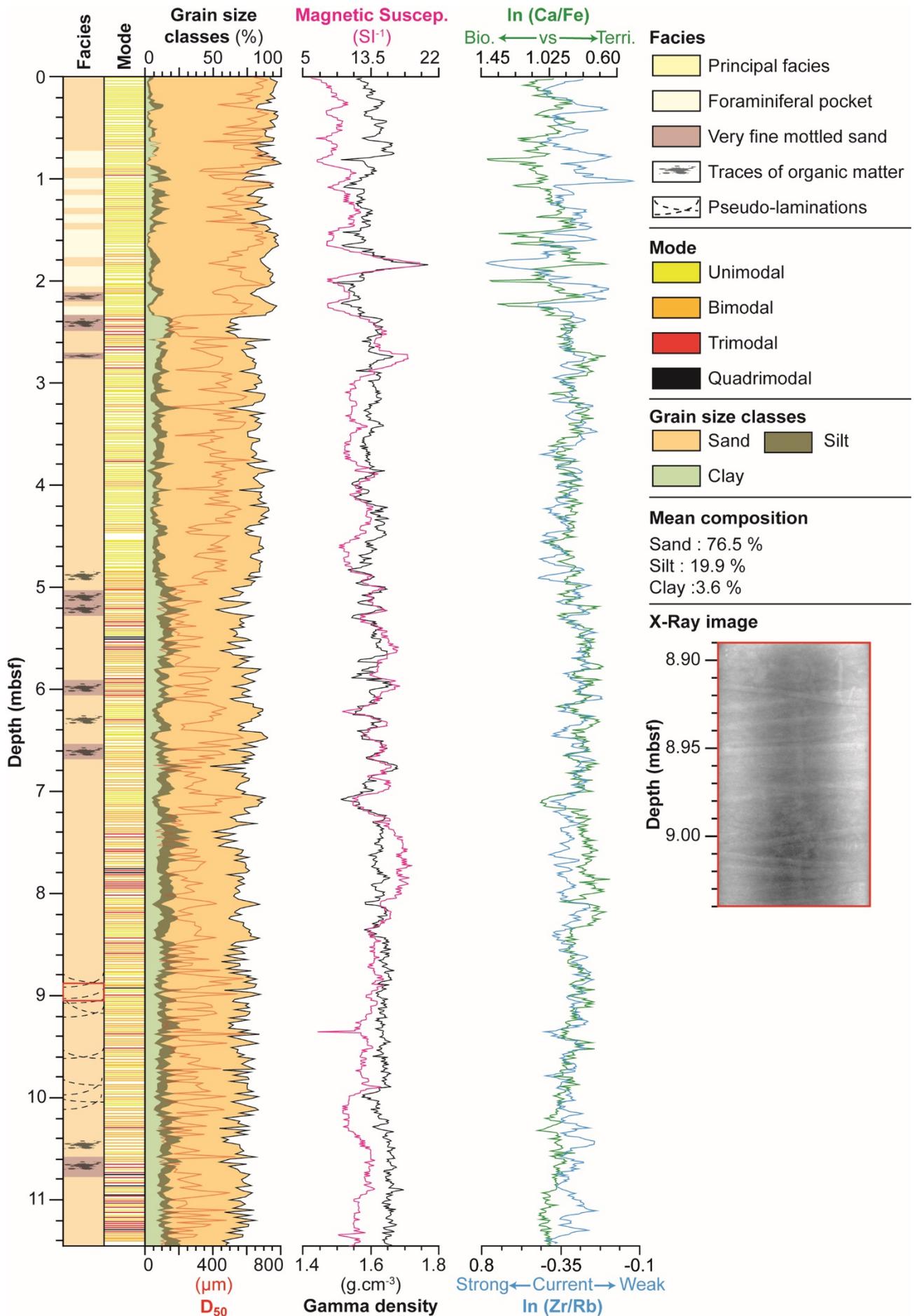
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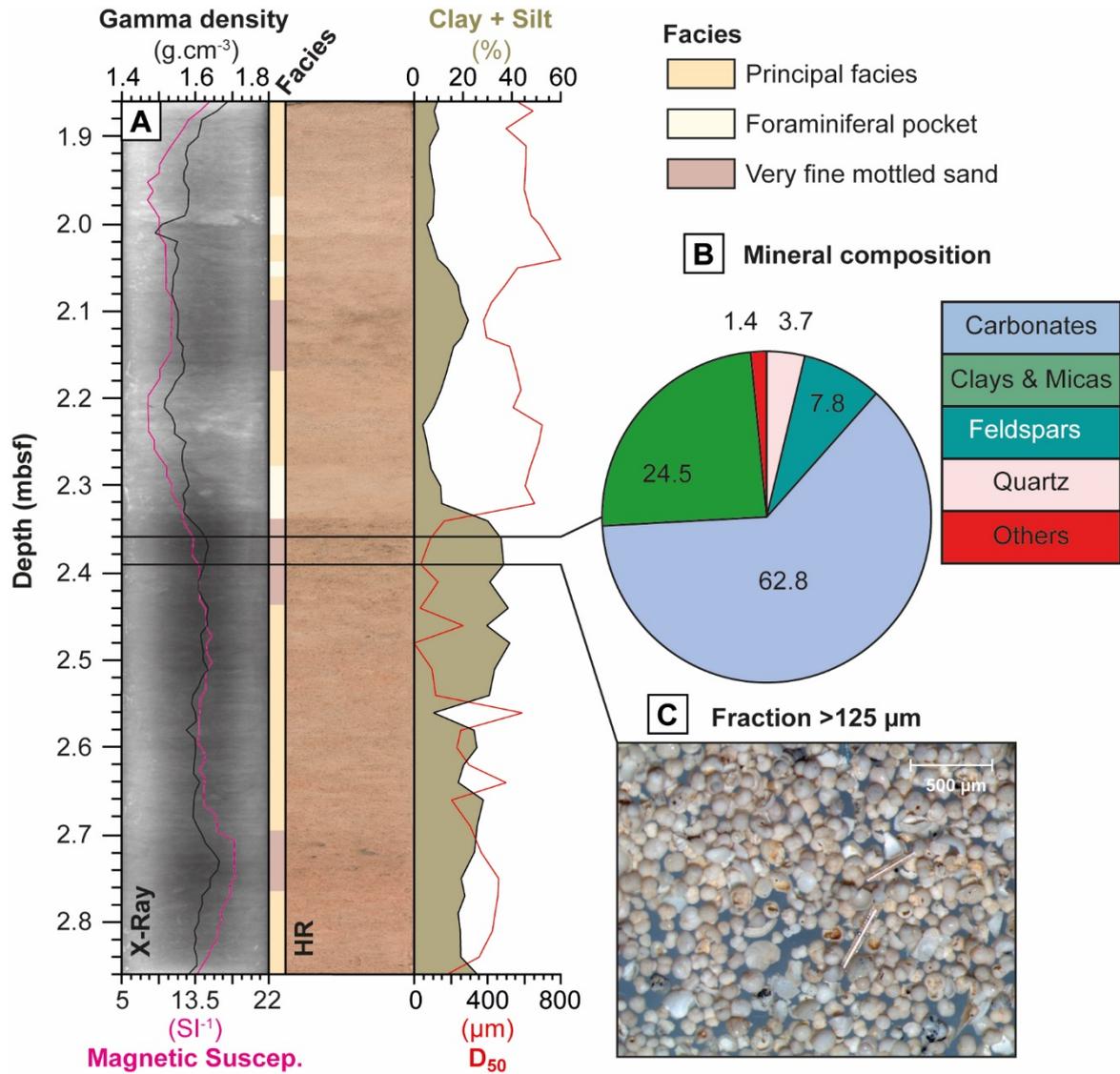


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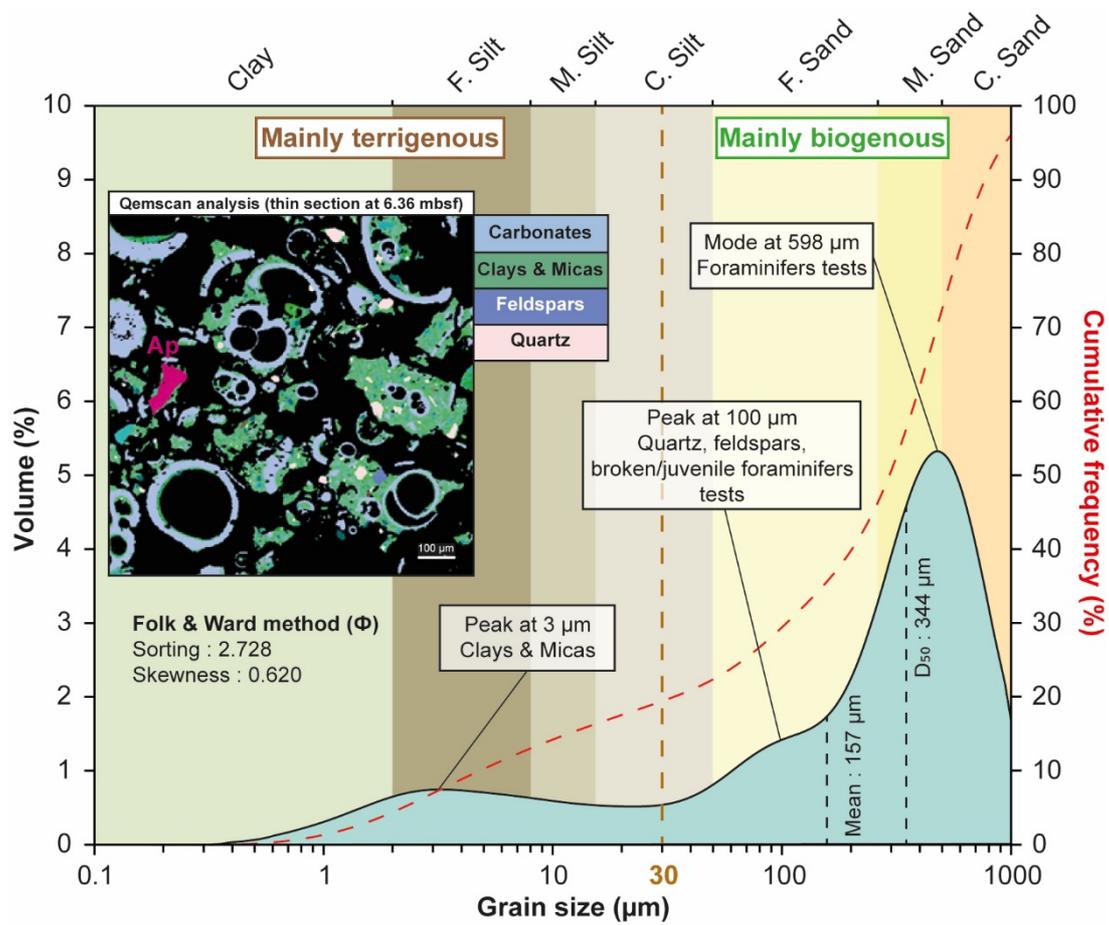
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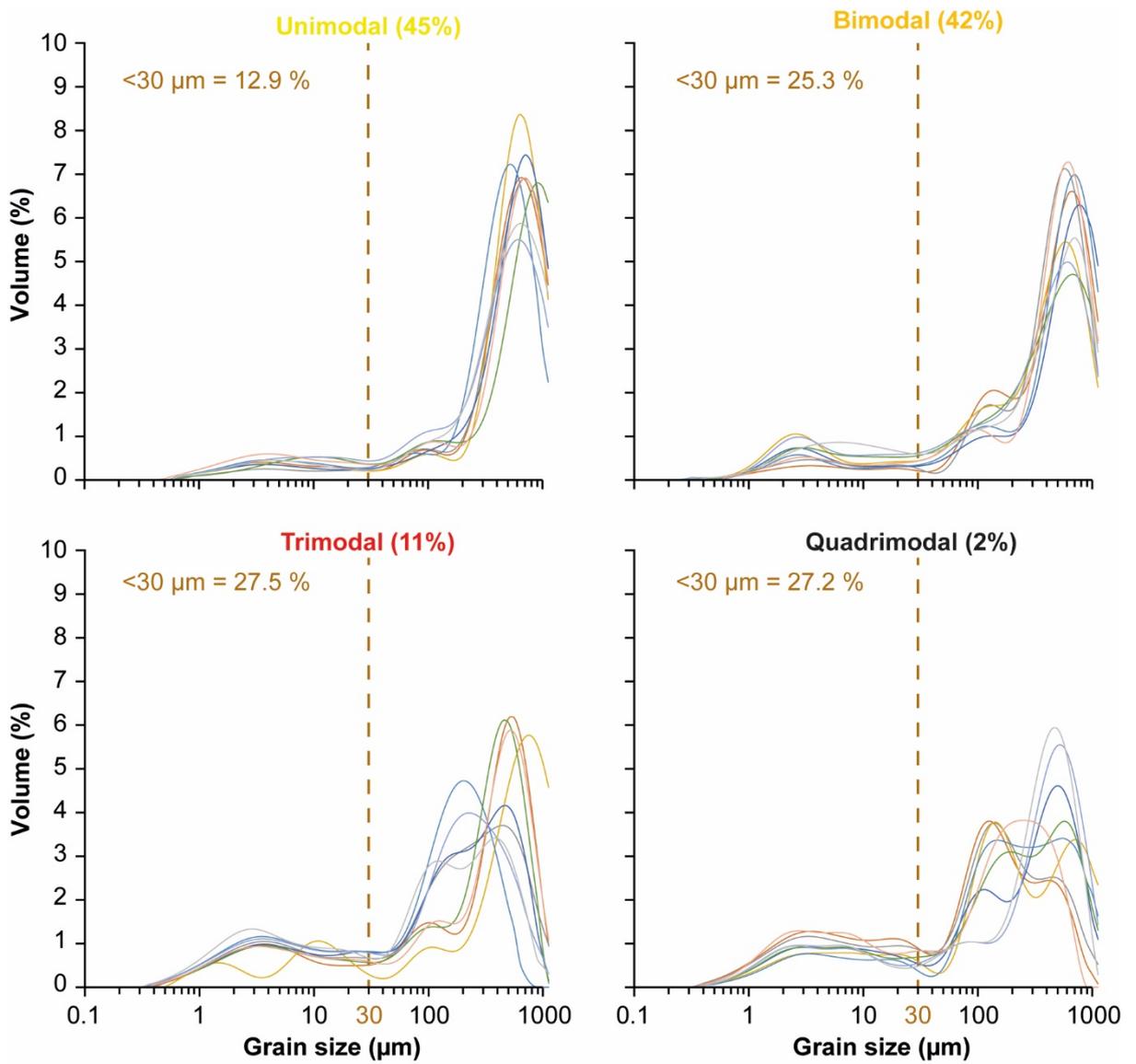
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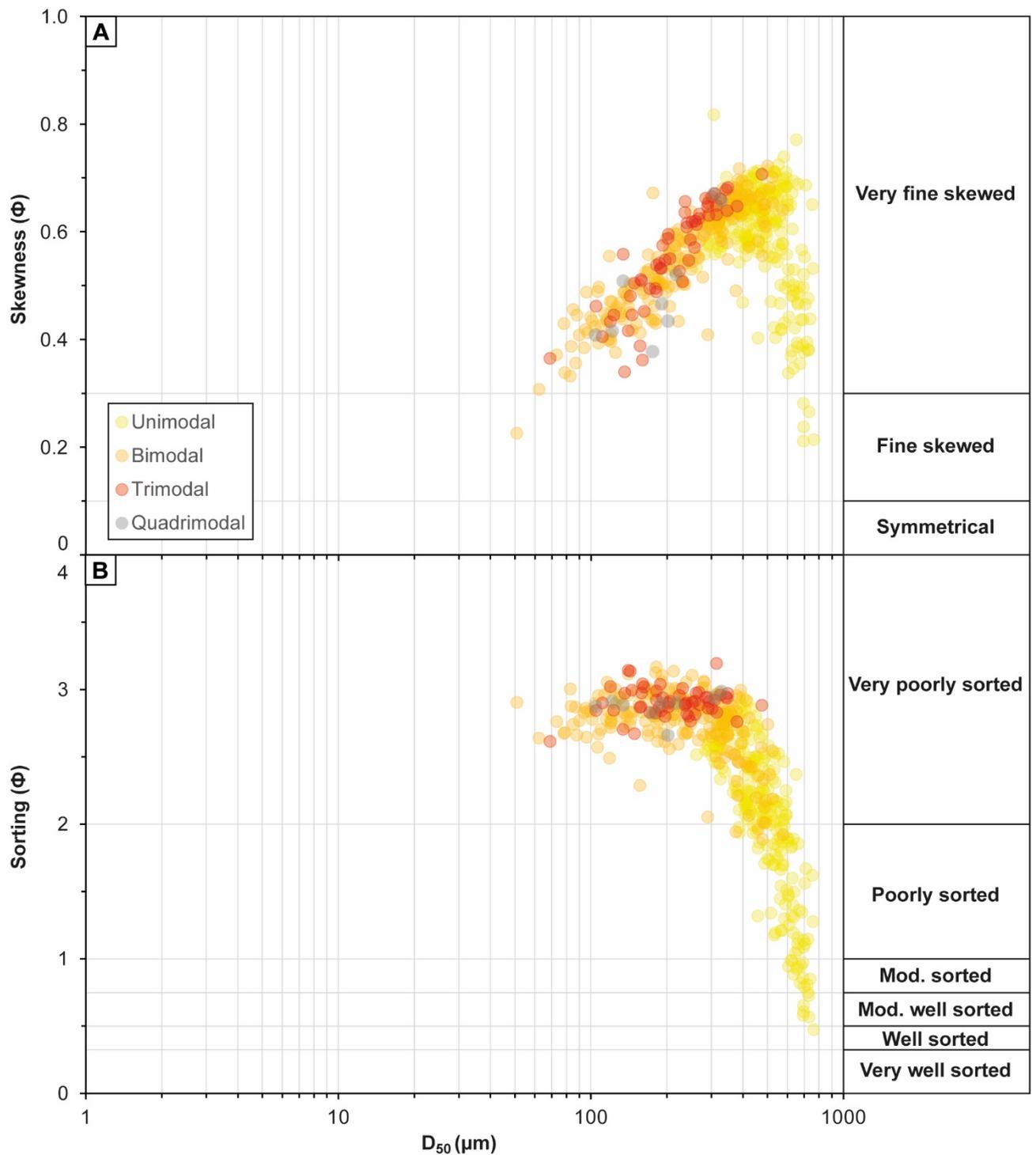
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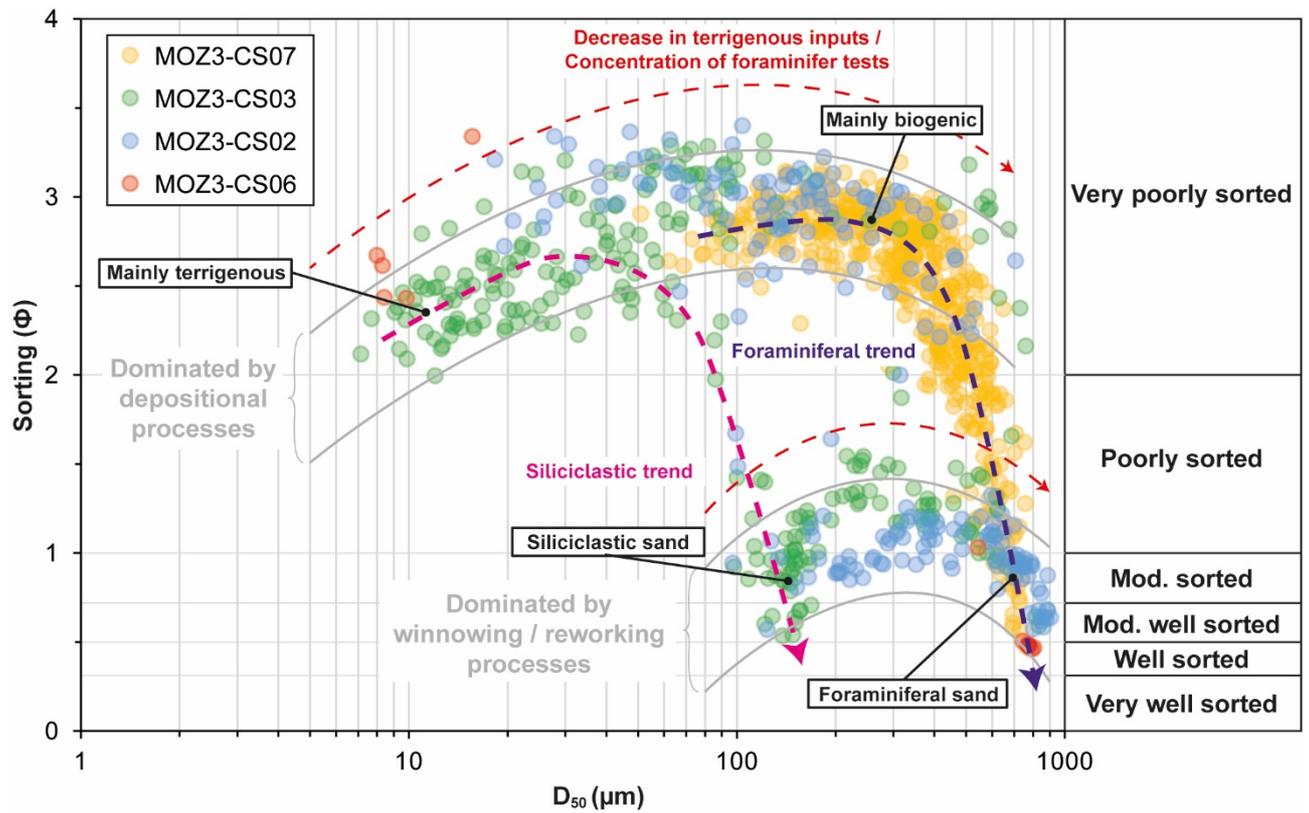
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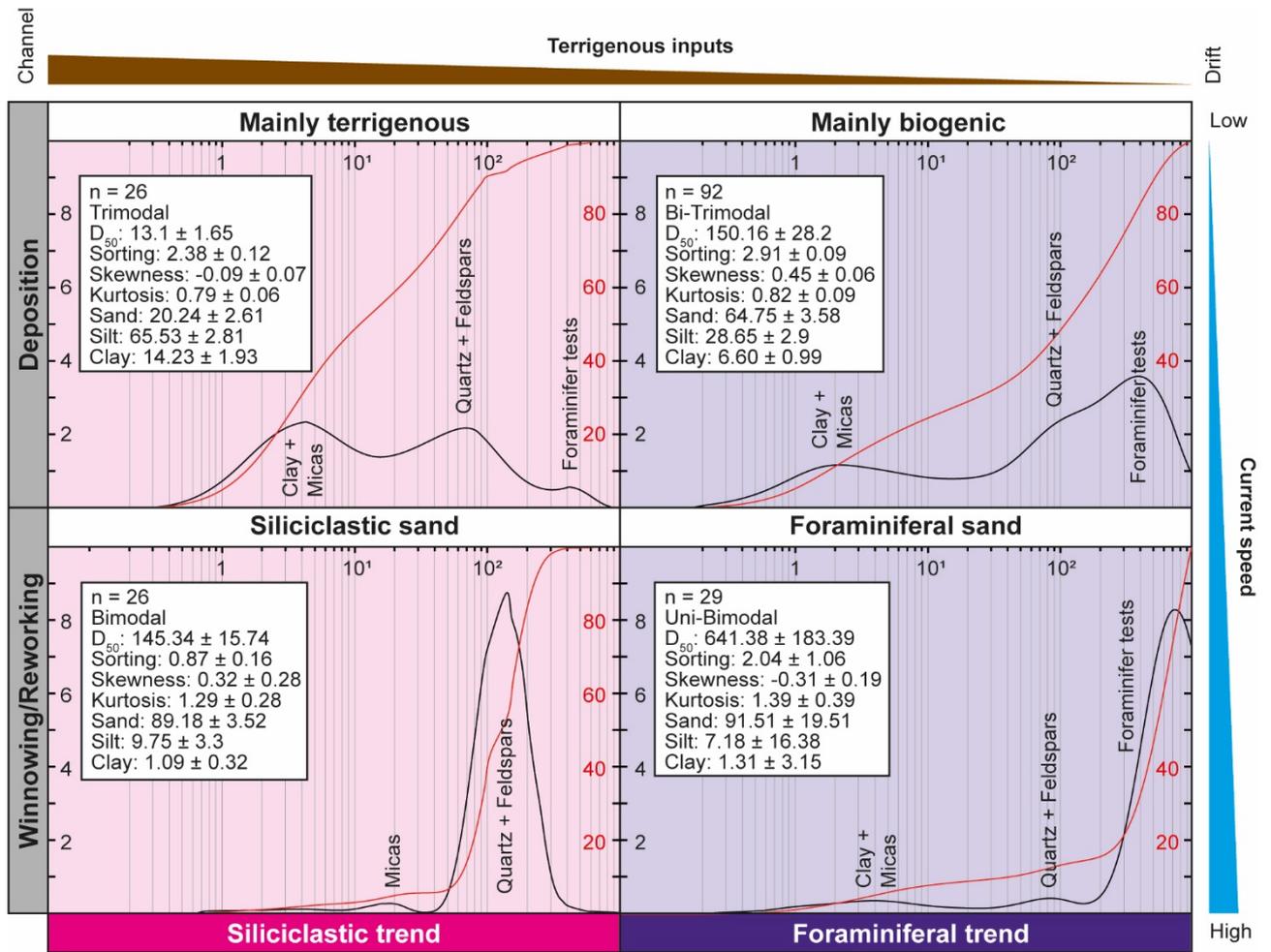
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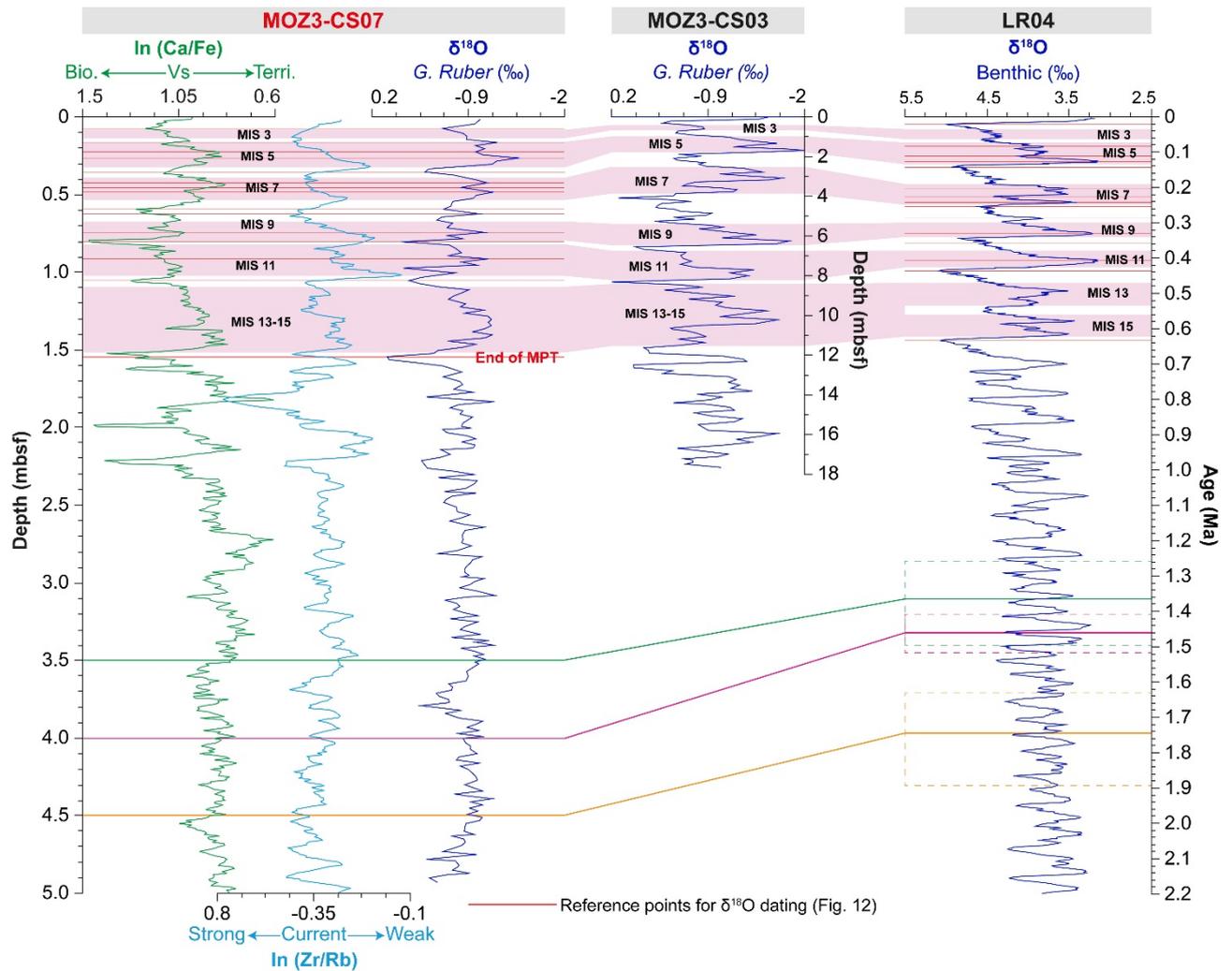
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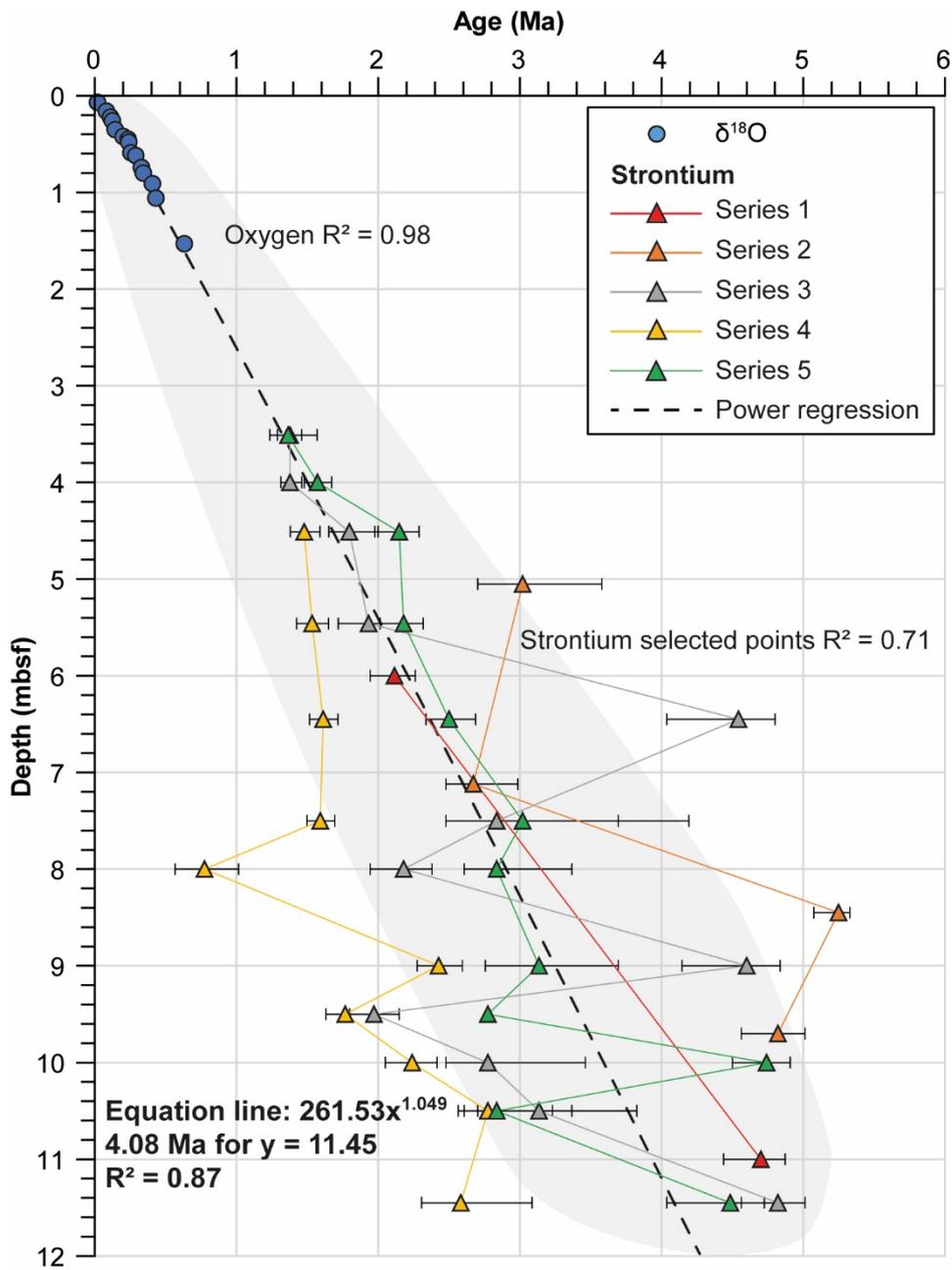
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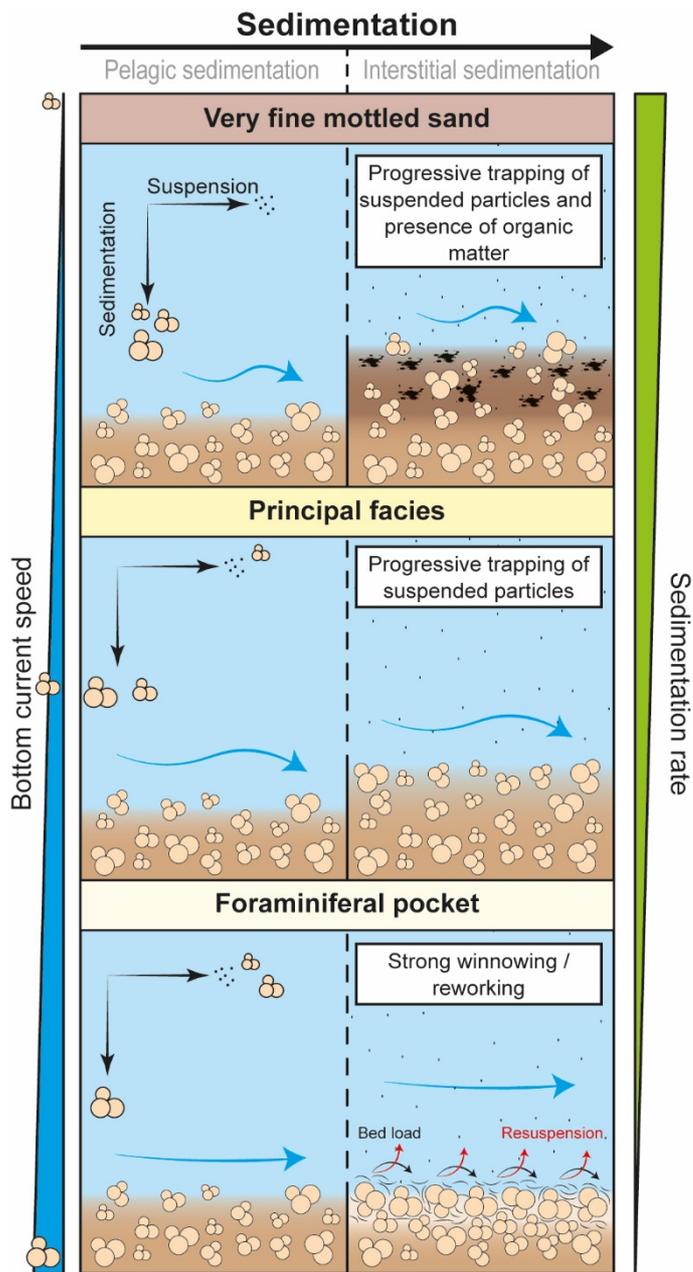
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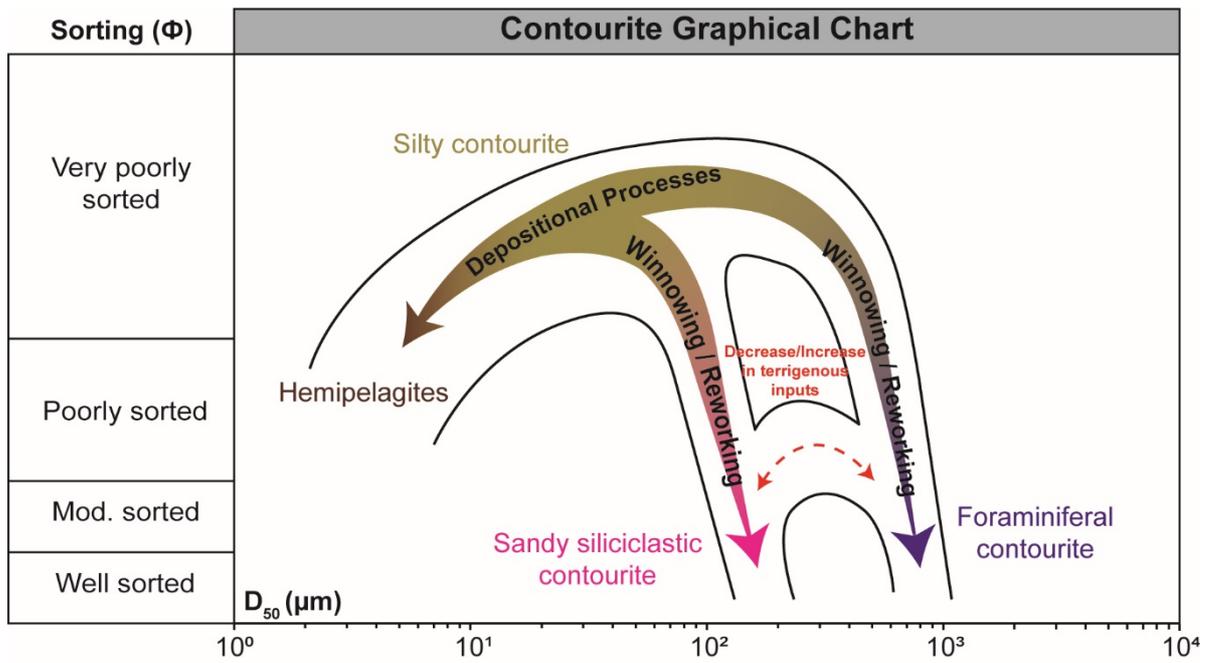


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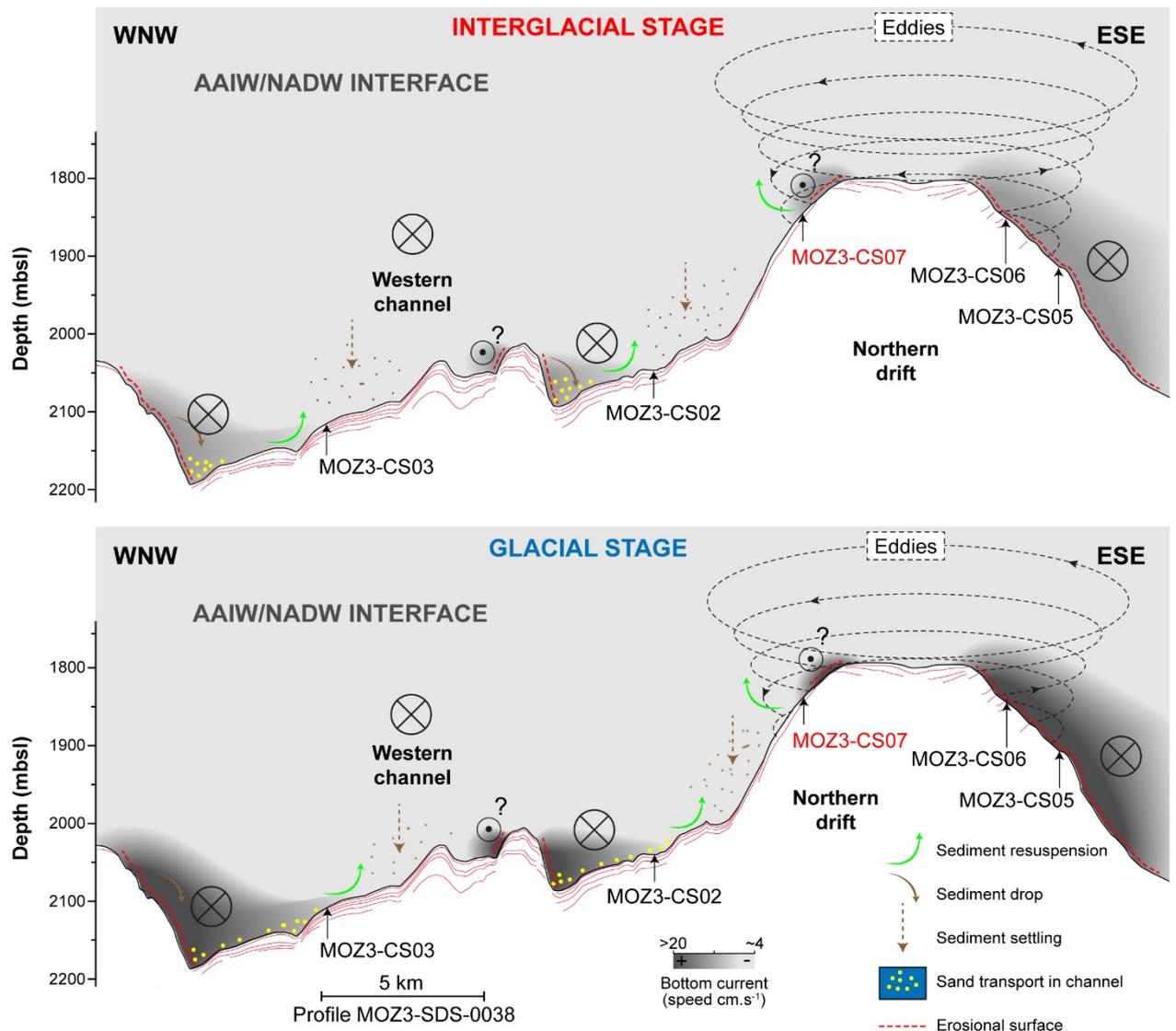
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Core	Latitude	Longitude	Water depth (mbsl)	Core length (m)	Section number
MOZ3-CS03	S 24° 49.195	E 36° 17.210	2125	20.06	21
MOZ3-CS02	S 24° 52.441	E 36° 25.424	2041	10.66	11

MOZ3-CS07	S 24° 54.129	E 36° 30.192	1853	11.47	12
MOZ3-CS06	S 24° 35.685	E 36° 34.311	1868	7.89	8
MOZ3-CS05	S 24° 56.685	E 36° 35.854	1926	6.35	7

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 1126 isotope measurements.

Core	Spectrocolori metry (Res.)	MSCL (Res.)	XRF (Res.)	Mineral composition (No.)	¹⁴ C (No.)	δ ¹⁸ O (Res.)	⁸⁷ Sr/ ⁸⁶ Sr (No.)	Laser grain size
MOZ3- CS03	1 cm	1 cm	1 cm	8	3	10- 20 cm	ND	1-7 cm on coarsest parts
MOZ3- CS02	1 cm	1 cm	1 cm	6	ND	ND	ND	1-20 cm
MOZ3- CS07	1 cm	1 cm	1 cm	12	ND	1-4 cm	2 + 38	1-4 cm (27 + 484 analyses)
MOZ3- CS06	1 cm	1 cm	1 cm	ND	ND	ND	ND	12 analyses
MOZ3- CS05	1 cm	1 cm	1 cm	ND	ND	ND	ND	ND

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1128 **Table 3.** Mineral composition obtained on thin sections by QEMSCAN analysis on core MOZ3-
 1129 CS07.

Depth (mbsf)	Carbonates	Quartz	Feldspars	Clays & Micas	Others
0.33	76,4%	12,5%	4,8%	1,8%	4,6%
1.33	70,7%	20,9%	5,5%	2,4%	0,7%
2.36	62,8%	24,5%	7,8%	3,7%	1,4%
3.33	65,0%	23,7%	7,7%	3,2%	0,6%
4.33	73,3%	16,7%	6,2%	3,5%	0,5%
5.33	64,0%	22,9%	8,7%	3,7%	0,8%
6.33	60,6%	25,8%	10,0%	3,2%	0,5%
7.33	62,2%	24,6%	9,1%	3,7%	0,7%
8.33	66,3%	22,2%	8,1%	2,9%	0,7%

9.33	67,6%	21,4%	7,7%	3,0%	0,5%
10.33	66,5%	18,1%	6,8%	3,4%	5,2%
11.33	69,4%	20,4%	6,9%	2,9%	0,6%
Average	67,1%	21,1%	7,5%	3,1%	1,4%

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Table 4. Summarize of strontium series measurements made on core MOZ3-CS07 presented in figure 12. Sigma (σ) correspond to the standard deviation of the 6th decimal. In red are the data previously acquired by Babonneau et al., (2022).

Series	No. of samples	Fraction	Ultrasound	NBS 987 Measured	NBS 987 Standard
1	2	Total	No	0.710248 (2σ)	
2	4	Total	No	0.710272 (3 σ)	
3	12	>250 μm	No	0.710279 (2 σ)	0.710250
4	10	>250 μm	Yes	0.710269 (2 σ)	
5	12	>250 μm	No	0.710267 (3 σ)	

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