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1 **Fatty acid biomarkers as indicators of organic matter origin and processes**
2 **in recent turbidites: the case of the terminal lobe complex of the Congo**
3 **deep-sea fan**

4
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17 **Abstract**

18 The Congo River is connected to its submarine canyon and supplies large quantities of terrestrial
19 organic carbon via powerful turbiditic currents down to the Congo deep-sea fan. We investigated
20 sediment cores from the terminal lobe complex of the Congo deep-sea fan (~ 750 km offshore, ~ 5000
21 m water depth), in order to assess the value of fatty acid biomarkers as indicators of organic matter
22 origin and processes affecting its distribution and preservation in recent turbidites.

23 Sediments from the Congo deep-sea fan are enriched in fatty acids compared to the surrounding
24 abyssal plains and their composition closely resembles that of sediments recovered in the Congo
25 River. Long chain fatty acid (LCFA) biomarkers in conjunction with the branched vs isoprenoid
26 tetraether index (BIT) show that organic matter mostly originates from soil erosion and continental
27 higher plants. This material has undergone limited reprocessing during transit certainly due to tight
28 interactions with mineral particles and rapid transfer. The presence of phytoplankton biomarkers at the
29 entrance of the terminal lobe area highlights that, albeit limited, inputs of fresh organic matter can
30 reach the lobe complex.

31 Relating fatty acid profiles to a suite of geochemical proxies enable to show that (1) organic matter
32 degradation is mostly limited to the oxic layer, and (2) fine soil-derived particles and the coarser
33 higher plant detritus display distinct depositional dynamics. Finally, LCFA are remarkably well
34 preserved under anoxic conditions at different time scales, in recent turbidites deposited during the last
35 century and those deposited several thousand years ago.

36

37

38 **Keywords**

39 Congo deep-sea fan; terminal lobe complex; turbidite deposition; fatty acid biomarkers; soil
40 derived-organic matter; degradation; preservation

41 **1. Introduction**

42 What happens to terrestrial organic matter (OM) in the deep ocean is still an open question because
43 of our limited knowledge of the biogeochemical transformations which occur during transport and
44 after deposition on abyssal plains (Hedges et al., 1997; Benner, 2004; Burdige, 2005; Blair and Aller,
45 2012; Bianchi et al., 2014). The fate of terrestrially-derived OM depends on many factors, among
46 which its sources and inherent properties, physical protection mechanisms shielding labile components
47 from microbial degradation, or aging processes occurring on the continental shelf and beyond (Mayer
48 et al., 2004; Ding and Sun, 2005; Wakeham and Canuel, 2006; Dai et al., 2009; Bao et al., 2019). The
49 depositional setting itself and the surrounding physicochemical conditions also constrain the fate of
50 the deposited OM (Sun and Wakeham, 1994; Hedges and Keil, 1995; Hoefs et al., 2002; Wakeham
51 and Canuel, 2006). Disentangling the contribution of all these factors on the cycling of OM in deep
52 basins is thus challenging, as each environment is unique. Due to the diversity of sources and
53 complexity of the processes involved, combining bulk geochemical proxies and molecular markers is
54 often necessary to get accurate insights into the origins of sedimentary OM and its diagenetic
55 evolution (Prahl et al., 1997; Shi et al., 2001; Weijers et al., 2009). Ancient turbidites from the
56 Madeira Abyssal Plain have provided geochemists with a natural laboratory to study the effects of
57 long-term oxygen exposure (ca. 8000 years or more, Buckley and Cranston, 1988) on terrestrial OM
58 preservation and lipid biomarker records (Prahl et al., 1997; Hoefs et al., 2002; Huguet et al., 2008).
59 They found that up to 80% of the OM initially deposited was degraded in the oxic layer of the
60 turbidites and that re-exposure to oxygen severely impacted the lipid biomarker content and
61 composition. However, the drivers of OM degradation and the extent of lipid biomarker alteration in
62 recent turbiditic deposits, as those observed in active submarine canyons remain largely unknown.

63 The Congo deep-sea fan is an ideal context to study the processes affecting the fate of recent inputs
64 of terrestrial OM in the deep-sea. The Congo River is the 2nd largest exporter of terrestrial organic
65 carbon (OC) to the world's ocean and delivers 14.4 Tg of OC per year to the equatorial Atlantic
66 Ocean, of which 2 Tg are particulate organic carbon (POC) (Coynel et al., 2005). The submarine
67 canyon of the Congo River extends across the entire continental shelf directly into the estuary,
68 maintaining a constant connection between the African continent and a deep-sea channel-levee-lobe

69 system (Heezen et al., 1964; Fig. 1). Long-lasting turbidity currents are frequently generated in the
70 canyon and enable the rapid export of sediments along the meandering active channel downslope to
71 the terminal lobe complex located ~ 750 km from the African coast at a depth of ~ 5000 m (Fig. 1,
72 Savoye et al., 2009; Babonneau et al., 2010; Azpiroz-Zabala et al., 2017). This non-steady state
73 depositional pattern characterised by high sedimentation rates and rapid burying is a key driver of the
74 preservation of terrestrial organic carbon, because it tends to limit the exposure of the POC to oxygen
75 in the water column (Hedges and Keil, 1995). Hence, in this remarkable depositional context, the
76 terminal lobe complex of the Congo deep-sea fan represents the main present-day depocenter for the
77 POC delivered by the Congo River (Stetten et al., 2015; Baudin et al., 2017a) and is a major carbon
78 sink in the equatorial Atlantic Ocean (Rabouille et al., 2019; Baudin et al., 2020). The suspended OM
79 delivered by the Congo River is mainly composed of soil-derived mineral-associated OM and to a
80 lesser extent of recently fixed rainforest vegetation and plant debris (Spencer et al., 2012). Terrestrial
81 OM is regarded as being relatively refractory, owing to the presence of lignocellulosic polymers in
82 terrestrial plants, the formation of complex geomacromolecules during humification and the tight
83 association of soil OM with the mineral matrix (Hedges and Oades, 1997). Therefore, the terrestrial
84 OM transferred by turbidity currents to the terminal lobe complex of the Congo deep-sea fan should
85 have a high potential for preservation. However, the suspended sediment exported by the Congo River
86 is characterised by higher loads of functionalised lipids (fatty acids and alcohols) relative to alkanes
87 (Hemingway et al., 2016). Since fatty acids and alcohols degrade faster than bulk OC and alkanes,
88 their prevalence in the suspended sediments indicates they are sourced from local surface soils with
89 limited exposure to diagenesis prior export (Hemingway et al., 2016). This also means that a pool of
90 reactive OM is delivered by the Congo River to the Atlantic Ocean.

91 The current study focuses on fatty acids, a versatile class of lipid biomarkers commonly used to
92 trace the sources and evolution of riverine OM in the land-ocean continuum (Bianchi and Canuel,
93 2011). Owing to the generally assumed sensitivity of fatty acids to diagenesis and degradation, these
94 biomarkers are also ideal proxies to explore processes participating in OM alteration during transit and
95 after deposition in the deep-sea fan. Using fatty acid biomarkers, their isotopic composition and the
96 branched versus isoprenoid tetraether (BIT) index, a proxy of fluvially exported soil OM (Hopmans et

97 al., 2004; Weijers et al., 2009), this study complements parallel investigations undertaken in the same
98 area (Stetten et al., 2015; Baudin et al., 2017a, 2017b; Schnyder et al., 2017; Pruski et al., 2017 and
99 Méjanelle et al., 2017) and aims to provide new insights into (1) the origins, (2) source to sink
100 transformations and (3) post-depositional processes affecting the OM in the terminal lobe complex of
101 the Congo deep-sea fan.

102 To this aim, we first identified the most likely biological sources of fatty acids in seven sediment
103 cores collected in the terminal lobe complex. We then compared these records to terrestrial and marine
104 end-members (sediments from the Congo River and marine suspended OM) in order to highlight
105 compositional changes occurring during transit. We finally related fatty acid distribution and
106 downcore evolution to the geochemical proxies reported here and in earlier studies (Table 1). This
107 multiproxy approach enables to address the general question: “Are fatty acids good indicators of OM
108 sources and processes in recent turbidites?”.

109

110 **2. Material and methods**

111 *2.1. Environmental setting: The Congo deep-sea fan and the terminal lobe area*

112 Marine productivity off the mouth of the Congo River ranges from $50 \text{ gC}\cdot\text{m}^{-2} \text{ y}^{-1}$ to $\sim 450 \text{ gC}\cdot\text{m}^{-2}$
113 y^{-1} (Berger, 1989; Wenzhöfer and Glud, 2002). This marine productivity is sustained by strong coastal
114 upwellings on either side of the Congo River estuary (Schneider et al., 1994; Schefuß et al., 2004) and
115 by the river plume, which persists 800 km from the coast (Van Bennekom and Berger, 1984).

116 Dissolved OM ($< 0.7 \mu\text{m}$) and a high proportion of fine POM ($< 63 \mu\text{m}$) are mainly exported through
117 this turbid plume (Cadée, 1984) where they are widely recycled by microbial processes and extensive
118 photo-degradation (Spencer et al., 2009), while the remaining (fine and coarse) POM is mainly
119 exported by the Congo River canyon (Cadée, 1984).

120 The Congo deep-sea fan extends nearly 1000 km off the African coast and covers an estimated area
121 of $330\,000 \text{ km}^2$ (Savoye et al., 2000). It is considered as one of the major deposition centre in the
122 South Atlantic Ocean with $5.4 \cdot 10^{13} \text{ t}$ of OC accumulated since 34 Ma (Baudin et al., 2010). Turbidity
123 currents triggered in the Congo canyon are funnelled in the unique and meandering active channel
124 whose present-day length is 1 135 km, and ultimately reach the terminal lobe complex (Fig. 1a;

125 Babonneau et al., 2010).

126 The terminal lobe complex, which covers 2500 km² (less than 1% of the total area of the Congo
127 deep-sea fan) (Rabouille et al., 2017) was explored during the Congolobe cruise (Rabouille, 2011).
128 Five sites (A, F, C, B and E) corresponding to distinct geomorphological features were selected for the
129 present study (Fig. 1b). Three sites are located along the active channel (A, F and C) (Fig. 1b,
130 Rabouille et al., 2017). Site A is located at the entry of the lobe complex and presents a well-
131 pronounced channel-levee structure compared to site F, which is located 40 km downstream. Site C is
132 located at the end of the feeding channel and represents the ultimate sink for turbidity currents. This
133 site collects the dilute upper part of the turbidity current (Dennielou et al., 2017) and in the rest of this
134 paper, is referred to as the terminal depocenter. Short-lived radionuclide activities (¹³⁷Cs and ²¹⁰Pb_{xs}) in
135 sediment cores from these three sites revealed that huge amounts of sediments have been deposited in
136 the last century (0.5 cm.y⁻¹ to 12 cm.y⁻¹ Stetten et al., 2015; Rabouille et al., 2017). Site B is located
137 ~15 km north east of the active channel and remains exposed to turbidity current overflow (Bonnell,
138 2005; Dennielou et al., 2017). In contrast, site E is located ~40 km northward site B in an older lobe
139 complex and is completely disconnected from the active system since at least the Holocene as shown
140 by the absence of caesium in sediments sampled at this site and by the dominant marine geochemical
141 signature in the top ten centimetres (Stetten et al., 2015; Schnyder et al., 2017). This site has not been
142 exposed to turbidity currents for ca. 4 000 years (Picot et al., 2016, 2019), and will thus be considered
143 as abandoned.

144

145 2.2. *Sampling*

146 Seven sediment cores corresponding to 42 samples of sediments from the terminal lobe complex
147 were analysed in this study (Fig. 1). Sampling took place in December 2011-January 2012 during the
148 Congolobe oceanographic campaign (Rabouille, 2011). Short sediment cores were collected using a
149 MUC 8/100 multicorer (Oktopus GmbH) and were rapidly sliced into 11 layers (0–0.5 cm; 0.5–1 cm;
150 1–2 cm; 2–3 cm; 3–5 cm; 5–7 cm; 7–10 cm; 10–13 cm; 13–16 cm; 16–19 cm; 19–22 cm). The layers
151 were carefully homogenised, placed in Falcon tubes, and stored at –80 °C until analysis.

152 Five samples of suspended POM from the surface waters overlaying the study area were also

153 collected by filtering 10 L of seawater on pre-combusted glass fibre filters (45 mm Whatman GF/F).
154 Our sampling was completed with 6 samples from the Malebo Pool floodplain wetlands near Kinshasa
155 (donated by H. Talbot and R. Spencer). Organic matter from the Malebo Pool is considered as a good
156 reference for the terrestrial OM exported by the Congo River as limited compositional changes occur
157 between this site and the head of the estuary (Spencer et al., 2012). The samples were collected from
158 two distinct depths (surface: 0–5 cm and subsurface: 5–15 cm) at 3 sites encompassing permanently
159 flooded sediment, sediment inundated during high discharge months only and sediment from above
160 the seasonal high water point (Talbot et al., 2014). These samples will be referred in the text as
161 permanently submerged, recently exposed and floodplain sediments.

162

163 *2.3. Contextual geochemical and sedimentological properties*

164 Bulk geochemical and sedimentological data for sediments from the distal lobe complex have been
165 published previously: grain size, elemental composition and bulk stable carbon and nitrogen isotope
166 values in Stetten et al. (2015), Rock-Eval signatures in Baudin et al. (2017b) and total hydrolysable
167 amino acid composition in Pruski et al. (2017) for 34 of the 42 samples. Analyses reported here and in
168 previous studies were performed on aliquots of the same samples.

169 Briefly, sediment grain size was assessed using a Malvern Mastersizer 2000 laser diffraction
170 particle size analyser following treatment of wet sediments with HCl to remove carbonate. Total
171 organic carbon content was measured on dried sediments using a high temperature combustion method
172 (LECO IR 212 with an induction furnace HF-100, LECO Corporation) with correction for inorganic
173 carbon content measured by carbonate-bomb and/or a pyrolytic method (Baudin et al., 2015).
174 Pyrolytic analyses were carried out using a Rock-Eval 6 Turbo device, operating in a mode devoted to
175 recent sediments (Baudin et al., 2015). Among the parameters delivered by Rock-Eval analysis, the
176 oxygen index (OI) provides insights on the amount of oxygen relative to the amount of OC present in
177 a sample and was selected for this study as a proxy of the oxidation state of the OM. Subsamples of
178 freeze-dried sediments were pre-treated with 1N HCl to remove carbonates prior stable isotope
179 analysis. C/N molar ratios, and stable isotope compositions of carbon and nitrogen were determined by
180 on-line combustion of the decarbonated sediments on a Carlo Erba NC 2500 instrument connected to

181 an Isoprime isotope ratio mass spectrometer (Stetten et al., 2015). Total hydrolysable amino acids
182 (THAA) were extracted from freeze-dried sediments by acid hydrolysis (hot 6N HCl, 24 h, 110°C).
183 After neutralisation with NaOH 6N, carbamates were produced from amino acids by alkylation with
184 propyl-chloroformate in the presence of *n*-propanol and pyridine (Dettmer et al., 2012). Carbamates
185 were recovered by liquid-liquid partition using iso-octane, purified and analysed on a gas
186 chromatograph (CLARUS 580) fitted with a flame ionization detector (Perkin Elmer). The obtained
187 mole percentages were used to calculate the degradation index (DI), which synthesises subtle changes
188 in the amino acid composition linked with diagenesis into a univariate variable indicative of OM
189 degradation state (Dauwe et al., 1999). As arginine does not produce stable carbamates, this amino
190 acid was omitted from the DI calculation. In Dauwe's initial dataset, the DI varied from -2.2 for
191 extensively degraded sediments to +1.5 for fresh algae, but more extreme values have been reported
192 (Unger et al., 2005).

193

194 *2.4. Lipid biomarker analysis*

195 *2.4.1. GDGT analysis and BIT index determination*

196 Extractions for the glycerol dialkyl glycerol tetraether (GDGT) lipids were performed on the
197 surface (0–1 cm layer) and deeper (19–22 cm) intervals of each core from the lobe complex according
198 to the protocol described in Coffinet et al. (2014). Since limited amounts of surface sediments were
199 available, freeze-dried sediments from the two first horizons were pooled before extraction (0.5g of
200 the 0–0.5 cm layer and 0.5g of the 0.5–1 cm layer), whereas 1g of the 19–22 cm layer was weighted.
201 GDGT analysis was performed by high performance liquid chromatography-atmospheric pressure
202 chemical ionization mass spectrometry (HPLC-ACPI-MS), with a Shimadzu LC-MS 2020. During
203 elution, the proportion of hexane and isopropanol was modified by time steps in the conditions
204 described in Coffinet et al. (2014). The injection volume was 10 µL. Semi-quantification of GDGTs
205 was performed by comparing the integrated signal of the respective compound with the signal of a C₄₆
206 synthesized internal standard (Huguet et al., 2006) assuming their response factors to be identical.
207 The branched vs isoprenoid tetraether (BIT) index, a proxy for fluvial input of soils, was calculated
208 according to the equation proposed by Hopmans et al. (2004):

$$\text{BIT} = \frac{(\text{I} + \text{II} + \text{III})}{(\text{I} + \text{II} + \text{III} + \text{IV})}$$

209

210 where I, II, III are branched GDGT and IV is crenarchaeol (refer to Hopmans et al. (2004) for the
211 GDGT structures). Triplicate injections of three samples indicated that the analytical error for the BIT
212 was 0.01.

213

214 2.4.2. Fatty acid extraction and analysis

215 Fatty acid analyses were performed on the 11 layers of the cores from the site C channel and from
216 the abandoned site E, on the surface, sub-surface, mid-layer and deeper horizons of all the other cores
217 (0–0.5 cm; 0.5–1 cm; 5–7 cm and 19–22 cm) as well as on the marine and terrestrial references.

218 Aliquots of freeze-dried material (~1.5 g) were treated with a solution of methanol, sulphuric acid and
219 chloroform (at 90 °C for 90 min) in the presence of an internal standard (nonadecanoic acid: C_{19:0})
220 and an antioxidant (butyl-hydroxytoluene, Christie, 1993). This direct acid transesterification protocol
221 enables in one single step to extract the lipids, release the fatty acids and produce simultaneously the
222 corresponding methyl esters (see Bourgeois et al., 2011 for the detailed procedure). Fatty acid methyl
223 esters (FAME) were dissolved in 50 µL of hexane prior to their analysis by gas chromatography and
224 mass spectrometry (GC-MS; GC Varian 3900 coupled to a Saturn 2100T ion trap detector). FAME
225 were separated on a capillary ZB wax column (30 m×0.25 mm ID, 0.25 µm thickness; Phenomenex)
226 using helium at 1 mL min⁻¹ and a specific temperature gradient (Bourgeois et al., 2011). The MS
227 system was operated with electron impact ionization at 70 eV in full scan mode (scanning m/z 40–650
228 in a 1 s cycle). Based on the total ion chromatograms (TIC), FAME were identified by comparing their
229 retention times with those of commercial FAME standards (Qualmix Fish Synthetic, Ladoran Fine
230 Chemicals, INTERCHIM, France; Supelco 37, PUFA No. 1 and No. 3, SUPELCO France) and
231 matching the mass spectra with the NIST library. The quantifier ion of each analyte was extracted
232 from the TIC and used for quantitation. External calibration curves then obtained from a series of
233 dilutions of a quantitative standard mixture (Supelco 37) supplemented with 4 fatty acids (C_{19:0}, C_{26:0},
234 C_{28:0} and C_{30:0}) and used to determine fatty acid concentrations. Repeatability of the analysis,

235 determined by comparing relative standard deviations of 41 fatty acids in six different preparations of
236 our standard solution, ranged from 1.0 to 5.4% with a mean value of 2.4%. Fatty acid concentrations
237 initially expressed in μg per gram dry weight ($\mu\text{g}\cdot\text{g}^{-1}$ dw) were normalised to the OC content of the
238 respective sample (stated as $\text{mg}\cdot\text{g}^{-1}$ OC).

239 Five fatty acid subgroups were defined for the study: short-chain saturated fatty acids (SCFA; $\text{C}_{14:0}$
240 – $\text{C}_{23:0}$), long chain saturated fatty acids (LCFA; $\text{C}_{24:0}$ – $\text{C}_{30:0}$), monounsaturated fatty acids (MUFA;
241 $\text{C}_{16:1\omega7}$, $\text{C}_{18:1\omega9}$ cis, $\text{C}_{18:1\omega7}$, $\text{C}_{20:1\omega9}$), polyunsaturated fatty acids (PUFA; $\text{C}_{18:2\omega6}$ cis, $\text{C}_{20:4\omega6}$, $\text{C}_{20:5\omega3}$, $\text{C}_{22:6\omega3}$),
242 and bacterial fatty acids (BAFA; $\text{C}_{15:0}$, $\text{C}_{17:0}$, $i\text{C}_{14:0}$, $i\text{C}_{15:0}$, $ai\text{C}_{15:0}$, $i\text{C}_{16:0}$, $i\text{C}_{17:0}$, 3-OH- C_{12} , 3-OH- C_{14}).
243 Source assignment of individual fatty acid was based on the literature (Table 1). Compound specific
244 stable isotope analysis of fatty acids in sediments was further performed at the Center for Applied
245 Isotope Studies (University of Georgia) to confirm their provenance (see Supplementary Methods for
246 detailed procedures).

247 The unsaturation index (UI), average chain length (ACL_{16-30}) and carbon preference index (CPI) of
248 the fatty acids were calculated from the following formula (Claustre et al., 1992; Wiesenberg et al.,
249 2010; Angst et al., 2016):

250 $\text{UI} = \sum(z_n \cdot x)$ where z_n is the relative amount of the fatty acids with n carbon atoms and x is the
251 number of unsaturation

252 $\text{ACL}_{16-30} = \sum(z_n \cdot n) / \sum z_n$ where z_n is the relative amount of the fatty acids with n carbon atoms and
253 n was 16 to 30 carbon atoms

254 $\text{CPI} = 0.5 \times \left[\frac{\sum \text{C}_{12-30}^{\text{even}}}{\sum \text{C}_{11-29}^{\text{odd}}} + \frac{\sum \text{C}_{12-30}^{\text{even}}}{\sum \text{C}_{13-31}^{\text{odd}}} \right]$; CPI was calculated for the entire, lower- and higher-,
255 molecular weight ranges.

256

257 2.5. Statistical analyses and data treatment

258 Statistical analyses were performed using R software (3.6.3). Due to the non-normal distribution of
259 most of the variables, non-parametric statistical analyses were used to examine relationships between
260 variables (Spearman non-parametric test, ρ). p -values below 0.05 were considered statistically
261 significant.

262 Unconstrained multivariate analyses were performed to explore relationships among sediment
263 samples and to determine whether fatty acid profiles were related to the other biogeochemical
264 parameters. Sediment samples were associated with respect to their fatty acid profiles using
265 hierarchical agglomerative clustering with the Bray-Curtis dissimilarity index and Ward's minimum
266 variance linkage method. The *agnes* function of package "cluster" was used for clustering (Maechler et
267 al., 2019) and the Bray-Curtis distances were square-rooted before applying Ward's algorithm.
268 Variations in fatty acid distribution between sampling sites and sediment depths were visualised using
269 non-metric multidimensional scaling (nMDS) based on a Bray-Curtis dissimilarity distance matrix
270 (function *metaMDS* of package "vegan", Oksanen et al., 2016) as described by Wakeham et al.
271 (2012). The resulting ordination plot displays samples defined by sites and sediment depth, and fatty
272 acid distribution. The function *envfit* ("vegan" package) was used to overlay environmental factors
273 (biogeochemical parameters) on the nMDS ordination and find significant correlations. Environmental
274 factors were fitted in the ordination plot as vectors, whereby the arrow indicates the direction of the
275 increasing gradient of the environmental variable and the length of the arrow is proportional to the
276 correlation coefficient between the variable and the nMDS ordination. Fatty acid data were square root
277 transformed prior to analysis to down-weight the contribution of very dominant fatty acids, while
278 absolute numbers were used for all other variables.

279

280 **3. Results**

281 *3.1. Contextual geochemical and sedimentological properties*

282 Despite being collected in different morpho-sedimentary settings, the bulk properties of sediments
283 from the recent lobe complex (sites A, F, C and B) were similar (Table 2). They were characterised by
284 high OC contents (2.2% – 4.1%), highly negative $\delta^{13}\text{C}_{\text{org}}$ values around -26.5‰ , $\delta^{15}\text{N}$ values ranging
285 between 4.6 and 5.9, and high C/N ratios (14.0 – 22.5). In these sediments, OI values ranged from 244
286 to $324 \text{ mg CO}_2\text{.g}^{-1} \text{ TOC}$, which indicates variable degrees of oxidation of the OM. The DI generally
287 exhibited slightly negative values in the oxic surface layers with a trend for higher values with depth,
288 indicative of a lower degradation state. Sediments were composed of silt (70–79%) and clay (12–28%)
289 with a minor and variable proportion of coarser material (0–16%).

290 The geochemical properties of sediments from the abandoned site (site E) enable to identify two
291 distinct intervals. The top seven centimetres were characterised by low OC contents (0.7 – 0.9%),
292 lower C/N ratios (11.0 – 11.7), higher $\delta^{13}\text{C}_{\text{org}}$ values (–23.9 to –22.8‰), higher OI values (up to 609
293 $\text{mg CO}_2\text{.g}^{-1}\text{ OC}$) and lower DI values (around –1) indicative of a more advanced stage of degradation.
294 In contrast, sediments in the deeper layers (7–22 cm) have increasing OC contents (from 1.2 to 2.8%),
295 higher C/N ratios (12.3 – 15.9), lower $\delta^{13}\text{C}_{\text{org}}$ values (below –24.1‰), lower OI values (less than 270
296 $\text{mg CO}_2\text{.g}^{-1}\text{ TOC}$) and higher DI values (–0.52 to +0.24). The changes of the geochemical properties
297 across the sediment core are consistent with a major shift in the sources of the OM incorporated in the
298 sediments, from degraded hemipelagic inputs on the top layers to less degraded terrestrial OM in
299 deeper layers (Stetten et al., 2015).

300

301 *3.2. GDGT-based proxy*

302 GDGT analyses were performed on two sediment layers (0–1 cm and 19–22 cm). Relative
303 abundances of GDGTs and concentrations in isoprenoid and branched GDGTs are reported in Table
304 Sx. Branched GDGTs were more abundant than isoprenoid GDGTs, especially crenarchaeol, in almost
305 all sediments, resulting in high BIT index values (> 0.7). In the present-day active lobe complex, BIT
306 values displayed a narrow range (0.75 to 0.84) with lower values in surface sediments than in deeper
307 ones (Table x). One lower value (0.48), explained by the low abundance of branched GDGTs vs.
308 crenarchaeol, was obtained for the surface sediment at the abandoned site E, but the deeper layer had a
309 BIT value of 0.76, similar to those measured in sediments from the active lobe complex.

310

311 *3.3. Fatty acid composition and concentration in the terrestrial and marine references*

312 The fatty acid composition of Congo River sediments collected on land and marine suspended
313 POM recovered above the terminal lobe complex is presented in Fig. 2 (see Supplementary Table S3
314 for the detailed composition of the terrestrial and marine references). At the Malebo Pool, the recently
315 exposed sediments were enriched in OC by a twofold factor in comparison to recently exposed and
316 floodplain sediments, but OC-normalised fatty acid concentrations were similar and ranged in the

317 upper horizon between $7.1 \text{ mg.g}^{-1} \text{ OC}$ for the recently exposed sediments and $9.1 \text{ mg.g}^{-1} \text{ OC}$ for the
318 floodplain (Fig. 3). The fatty acid composition of the river sediments was characterised by high
319 contributions of saturated fatty acids (SAFA: 55.6 to 70.7%) with the dominance of $\text{C}_{16:0}$, medium
320 contributions of bacterial fatty acids (BAFA: 16.8 to 26.9%), and lower contributions of
321 monounsaturated fatty acids (MUFA: 9.5 to 15.2%) and polyunsaturated fatty acids (PUFA: 0.5 to
322 8.4%) (Fig. 2). Among the SAFA, long chain fatty acids (LCFA) accounted for 16.4 to 28.9% of all
323 fatty acids with the preponderance of $\text{C}_{24:0}$. MUFA $\text{C}_{18:1\omega9\text{cis}}$ and PUFA $\text{C}_{18:2\omega6\text{cis}}$ were abundant in river
324 sediments, particularly in the surface layer from the floodplain with contributions of these two fatty
325 acids reaching 9.8 and 8.1%, respectively (Supplementary Table S2).

326 Fatty acid concentrations of suspended POM ranged from $7.8 \text{ }\mu\text{g.L}^{-1}$ at site B to $94.2 \text{ }\mu\text{g.L}^{-1}$ at site
327 A (Supplementary Table S3). Surface waters were characterised by the predominance of SAFA (47.1
328 to 66.7%), in particular $\text{C}_{16:0}$ and $\text{C}_{18:0}$ (Fig. 2). The suspended POM also contained MUFA (12.2 to
329 17.9%) and PUFA (9.2 to 30.5%), and small amounts of BAFA (3.3 to 5.3%). The surface water at
330 site A stood out from the other samples because its fatty acid concentration was one order of
331 magnitude higher. In addition, this sample was enriched in PUFA (32.4%), with $\text{C}_{22:6\omega3}$ accounting for
332 21.8% of all fatty acids (Supplementary Table S3).

333

334 *3.4. Fatty acid composition of sediments from the terminal lobe complex*

335 Sediments from the lobe complex contained approximately 1.5 times less fatty acids than the
336 wetland sediments collected at the Malebo Pool with concentrations ranging from 3.3 to $6.0 \text{ mg.g}^{-1} \text{ OC}$
337 (Table 4). Their fatty acid composition closely resembled that in the river sediments. SAFA were the
338 most abundant fatty acids (60.7 to 84.5%) and were dominated by $\text{C}_{16:0}$ (13.9 to 27.4%) and LCFA
339 (13.9% in the surface layer at site E to 40.9% in the middle layer at site B) with a strong predominance
340 of $\text{C}_{24:0}$ (5.2 to 26.8% of all fatty acids). BAFA were present in all sediment samples (11.7 to 25.6%)
341 with a tendency to be higher in the surface horizons. 3-OH- C_{14} and iso $\text{C}_{15:0}$ were the most abundant
342 bacterial fatty acids and were more abundant in the surface sediments. MUFA ranged from 1.2% at the
343 abandoned site E (surface layer) to 13.7% in the channel at site C (mid layer). They were dominated

344 by C_{16:1 ω 7}, C_{18:1 ω 9cis} and C_{18:1 ω 7}, while C_{20:1 ω 9} was present in very small amounts (< 0.4%). A trend to
345 lower MUFA contributions in the surface layers was observed in all the cores except for the one
346 collected in the channel at site A.

347 PUFA contributions to the sediments were consistently low. However, in the surface sediments
348 collected at the entry of the terminal lobe complex (the channel at site A), the PUFA contribution
349 reached 2.7%, reflected by a higher degree of unsaturation (UI= 23.2, Table 4) than in other samples.
350 C_{20:5 ω 3} and C_{22:6 ω 3} were the predominant PUFA in these surface sediments, whereas C_{18:2 ω 6cis} was
351 present in smaller amounts.

352 The CPI was comprised between 8.4 and 17.5 with lower values at site E, and a trend for higher
353 values with increasing depth. The ACL₁₆₋₃₀ varied between 19.1 and 22.2.

354 Fig. 4 shows the downcore distribution of the fatty acids in sediments from the present-day
355 depocenter (the channel at site C) and the abandoned lobe (site E). LCFA made a substantial
356 contribution to the fatty acid pool at both sites. The contribution of LCFA increased from 14 to 40%
357 with sediment depth in the abandoned lobe (site E), while it accounted for an average of 25% in the
358 channel at site C with higher contributions in deeper layers (>16 cm in depth). The contribution of
359 BAFA in the channel at site C remained relatively constant throughout the core (~20%), whereas it
360 decreased by half (from 25 to 12%) in sediments sampled at site E. At both sites, the contribution of
361 MUFA was remarkably lower in the surface sediment than in the deeper layers with a transition that
362 corresponded to the limit of the oxygen penetration depth (1.47 cm at site C and 6.65 cm at site E;
363 Pozzato et al., 2017). Only trace amounts of PUFA were found at site E, while their contribution
364 reached 4% at site C.

365 $\delta^{13}\text{C}$ values of bulk OM was fairly constant in the channel at site C, whereas terrestrial phytoclasts
366 varied from 25 to 88%. In contrast, $\delta^{13}\text{C}$ values of bulk OM decreased progressively with increasing
367 depth at site E (from -23.1 to -26.9‰), while terrestrial phytoclasts increased (7 to 84%).

368

369 *3.5. Clustering and relationships with contextual geochemical and sedimentological parameters*

370 The results of the cluster analysis based on fatty acid composition are shown in Fig. 5. The 42
371 samples corresponding to 7 sites and several sediment horizons (4 to 11 depending of the site) were

372 clustered into four clusters (Fig. 5A). The seven first centimetres of the core collected at site E formed
373 a single cluster (cluster 4), whereas deeper sediments from this core were grouped with most of the
374 surface sediments from the cores collected in the active lobe (cluster 1). The interval 1 to 16 cm of the
375 core collected in the channel at site C formed another cluster (cluster 2). The last cluster grouped the
376 deeper layers (16–19 and 19–22 cm), the intermediary layer (5–7 cm) and most surface samples (0–0.5
377 and 0.5–1 cm) from site A (cluster 3). These 4 clusters displayed distinct fatty acid profiles (Fig. 5B)

378 As sediments from site E accounted for most of the dissimilarity within the dataset, this site was
379 omitted in the following analyses. The remaining sediment samples were clustered in three clusters
380 with the same partition as observed with the whole dataset (see supplementary material for HCA
381 results on sediments from the active lobe). The non-metric multidimensional scaling (nMDS)
382 ordination analysis shows the relationships between sediment samples, fatty acid biomarkers and
383 sediment properties defined by grain size, OC content and several proxies of OM origin and quality
384 (Fig. 6). Almost all environmental variables had low p values (<0.05), indicating highly significant
385 fitted vectors with the exception of sand, OI and $\delta^{15}\text{N}$. The highest goodness-of-fit statistics were
386 observed with UI (r^2 0.89), followed by CPI (r^2 0.78), ACL (r^2 0.63), $\delta^{13}\text{C}$ (r^2 0.59) and then DI (r^2
387 0.47) (Table 5).

388

389 **4. Discussion**

390 *4.1. Sources of fatty acids in the terminal lobe complex*

391 Fluxes of fatty acids from the surficial ocean to the abyssal plains are usually limited due to the
392 efficient and rapid degradation of these labile components during transit through the water column
393 (Wakeham et al., 1997a). Hence, most deep-sea sediments are characterised by low fatty acid contents
394 and benthic communities are food limited (Svetashev, 2022; Wakeham et al., 1997b). Fatty acid
395 concentrations in sediments from the Congo deep-sea fan are much higher (between 3.8 and 5.4 $\text{mg}\cdot\text{g}^{-1}$
396 OC) than the standard background values measured in abyssal plains in the Atlantic Ocean (between
397 0.02 to 1.04 $\text{mg}\cdot\text{g}^{-1}$ OC; Van Vleet and Quinn, 1979; Santos et al., 1994). These values are high, even
398 in comparison with coastal sediments unaffected by turbidity currents north of the mouth of the Congo
399 River where fatty acid yields do not exceed 0.96 $\text{mg}\cdot\text{g}^{-1}$ OC (Schefuß et al., 2001). Thereby, while

400 deep-sea communities usually only benefit from pulse inputs of labile OM deriving from seasonal and
401 rare planktonic blooms, turbidity flows feed the terminal lobe complex area with a more persistent
402 (one turbidite every 6–17 years; Dennielou et al., 2017) source of labile components such as
403 functionalised lipids and amino acids (this study and Pruski et al., 2017).

404

405 *4.1.1. Tracing inputs from the Congo River using glycerol dialkyl glycerol tetraethers and fatty acid* 406 *biomarkers*

407 The suspended OM delivered by the Congo River is mainly composed of soil-derived mineral
408 associated OM and to a lesser extent of well-preserved plant detritus (Spencer et al., 2012). Knowing
409 that (i) fine soil particulate OM (< 63 µm) accounts for more than 80% of the total particulate load of
410 the Congo River at Kinshasa (Spencer et al., 2012) and that (ii) most of this material is rapidly
411 channelled by turbidity currents to the recent lobe complex (Savoye et al., 2009; Babonneau et al.,
412 2010), soil-derived OM is expected to be a major source of OM in the lobe complex. Using carbon
413 isotopic values in a two source mixing model, Stetten et al. (2015) previously estimated that the
414 relative proportion of terrestrial OM ranges from 70 to 80% in sediments from the active lobe complex

415 Two proxies of terrestrial OM were used in the present study: (i) the branched vs isoprenoid
416 tetraether (BIT) index whose use is based on the initial assumption that branched GDGTs are mainly
417 produced by bacteria in soils, while crenarchaeol is specific for non-extremophilic, aquatic
418 *Thaumarchaeota* (Hopmans et al., 2004) and (ii) LCFA deriving from the epicuticular waxes of higher
419 plants (Eglinton and Hamilton, 1967).

420 The BIT index was originally introduced as a proxy for the fluvial export of terrestrial OM
421 (Hopmans et al. 2004), but was later shown to trace specifically soil OM (Huguet et al., 2007). BIT
422 index values in suspended particulate matter from the Congo River are close to the hypothetical
423 terrestrial end member value of 1 (mean value: 0.98, Weijers, 2017) and decrease in the surface
424 sediments with increasing distance to the estuary, reflecting the fluvial transport of soil OM (Hopmans
425 et al., 2004). It should be noted that over the past decades, the *in situ* production of branched GDGTs
426 in marine sediments from different settings has been confirmed, which complicates somehow the
427 interpretation of GDGT-based proxies (Sinninghe Damsté, 2016). Branched GDGTs were indeed

428 found in distal marine surface sediments from the Atlantic Ocean, albeit in low amount and BIT index
429 values were close to the marine end member value of 0 showing that marine production of branched
430 GDGTs had a limited influence on the BIT index (0.01-0.07, Weijers et al., 2014). Here, BIT values
431 were high (>0.75 , Table 3) in the active lobe area, confirming that soil OM is efficiently exported
432 through the Congo submarine canyon and represents the main source of OM.. The significant negative
433 correlation between $\delta^{13}\text{C}_{\text{org}}$ and the BIT index (Spearman rank correlation, $\rho = -0.69$, $p\text{-value} < 0.05$)
434 further confirms that the BIT index is a good proxy to trace soil inputs in the channel-levee system of
435 the Congo River deep-sea fan, as previously observed in this region (Weijers et al., 2009).

436 Even though our results suggest that soil is the principal source of OM in the actual lobe complex,
437 this is not the only source of OM in the Congo River, as coarse particles deriving from recent
438 vegetation inputs are also exported (Spencer et al., 2012). Schnyder et al. (2017) highlighted the
439 outstanding good preservation of terrestrial phytoclasts, cuticle particles and wood fragments, which
440 often dominated palynofacies assemblages. Likewise, plant macrodetritus were often observed in our
441 samples (Stetten, personal observation). Hemingway et al. (2016) showed that lipid biomarkers make
442 it possible to get a better picture of the nature of the OM exported by the Congo River and that
443 different classes of lipids reflect different source signals in the watershed, such as BIT index for soil
444 OM, and plant wax lipids for terrestrial plant inputs. Functionalised lipids (LCFA and alcohols) from
445 plant waxes derive predominantly from a recently reworked local source, whereas *n*-alkanes include a
446 broader watershed signal and have undergone more intense diagenesis (Hemingway et al., 2016). As
447 such, the latter are found in relatively low amounts in the material exported by the river and
448 subsequently in sediment records from the Congo submarine canyon (e.g. alkane concentrations are 1
449 – 2 orders of magnitude lower than those of fatty acids or alcohols Treignier et al., 2006; Hemingway
450 et al., 2016; Méjanelle et al., 2017). In the Black Sea, LCFA have been successfully used to trace the
451 dilution of the material delivered by the Danube River with autochthonous OM (Saliot et al., 2002).
452 Sediments from the Malebo Pool consist in a mixture of mineral particles and plant debris, and
453 consequently contain high proportions of LCFA (16.4–28.9% of all fatty acids, Fig. 2). For
454 comparison, the contribution of these higher plant biomarkers is 16% in the Amazon River floodplain
455 (Mortillaro et al., 2011). Their concentration in sediments from the active lobe was high (0.6 to 2.5

456 mg.g⁻¹ OC), but consistent with values for the suspended sediments collected in the Congo River (0.97
457 ± 0.34 mg.g⁻¹ OC, recalculated from Hemingway et al., 2016). LCFA are thus exported along with the
458 sediments down to the Congo deep-sea fan where they accumulate in concentrations that are high even
459 when compared to continental margins. This reflects the efficient export and burial of the OM derived
460 from terrestrial plants in the Congo watershed. Nevertheless, LCFA were heterogeneously distributed
461 even across a given core (e.g. Fig. 4a) and did not behave like most bulk geochemical proxies in the
462 study area (Stetten et al., 2015). In the Rhône prodelta (France) and the Englebright Lake (California),
463 the contribution of LCFA was higher in sediment layers that recorded flood events and were
464 associated with higher inputs of macrodetritus (Pondell and Canuel, 2020; Pruski et al., 2021). In good
465 agreement with the hypothesis that the relative abundance of LCFA varies with the proportion of OM
466 deriving from plants, palynofacies observations confirm that higher plant remains are heterogeneously
467 distributed in the lobe sediments (Schnyder et al., 2017).

468 Due to their ubiquitous synthesis by different groups of organisms, the contribution of the other
469 subgroups of fatty acids (SCFA, BAFA, MUFA) are not indicative of OM provenance, but their
470 isotopic values may provide some clues. Generally, lipids such as fatty acids are depleted in ¹³C by
471 around 4‰ relative to total OM (Hayes et al., 1990). As C3 land plants have a δ¹³C_{org} value of ~-27.5‰
472 (Hedges et al., 1986; Meyers, 1997), δ¹³C_{org} values of around -31.5‰ would be expected for C3 plant-
473 derived lipids. The light isotopic signature of most fatty acids in the lobe sediments is consistent with a
474 predominantly terrestrial origin for these compounds (90% of values ranged between -33.5 and -
475 26.6‰, Supplementary Table S3).

476

477 *4.1.2. Can we identify marine OM inputs in the terminal lobe complex?*

478 The Congo deep-sea fan is located ~ 5 km below a productive oceanic region characterised by a
479 shallow thermocline, an oceanic upwelling and a river plume, which supply nutrients (Berger, 1989;
480 Schneider et al., 1994). Schefuß et al. (2004) recorded the highest contributions of biomarkers deriving
481 from marine sources in sediments collected about 150–200 km offshore the Congo River mouth. Two
482 PUFA, the dinoflagellate biomarker C_{22:6ω3} and the diatom biomarker C_{20:5ω3}, were found in the surface
483 sediments at the entry of the recent lobe complex (site A channel) despite the depth of 4764 m (Table

484 4). The presence of labile compounds, even in small amounts, is unexpected considering that most
485 marine OM that reaches this region is considered to be heavily degraded (Treignier et al., 2006;
486 Stetten et al., 2015). These results demonstrate that biomarkers deriving from fresh phytoplankton can
487 reach the recent lobe complex. Taking into account the rapid degradation of the POM produced in the
488 euphotic layer during settling (Lee et al., 2004), it seems unlikely that the overlying pelagic production
489 could explain the occurrence of phytoplankton PUFA at the entry of the recent lobe complex (site A).
490 A plausible scenario is that marine POM deposited in the active channel upstream has been caught by
491 turbidity currents and rapidly delivered to the recent lobe complex. A closer look at the fatty acid
492 composition provides further arguments supporting this hypothesis (Table 4). $C_{18:1\omega7}$ and $C_{16:1\omega7}$, which
493 are found in many phytoplankton groups including diatoms and dinoflagellates (Volkman et al., 1989;
494 Mansour et al., 1999), were more abundant in sediments collected along the active channel than at site
495 E and their contributions were significantly correlated with the PUFA content in the sediments
496 (Spearman rank correlation, $\rho = 0.81$ and 0.92 for $C_{16:1\omega7}$ and $C_{18:1\omega7}$, p -value <0.01). Moreover, $C_{16:1\omega7}$
497 in the surface sediments at site F had a $\delta^{13}C$ signature (-21.3‰ , Supplementary Table S2) consistent
498 with an algal origin (Canuel et al., 1997). This observation, however, does not hold when considering
499 the isotopic value of $C_{18:1\omega7}$ and $C_{16:1\omega7}$ in the other samples, whose $\delta^{13}C$ values ranged between -33‰
500 and -26‰ (Supplementary Table S2). These lower values point to a terrestrial origin, while the less
501 negative values point to a mixture of marine and terrestrial OM (Shi et al., 2001). Since these MUFA
502 are also found in bacteria (Parrish, 2013), their presence in the sediments could also at least partly
503 account for the heterotrophic bacteria that break down terrestrial and marine OM (Teece et al., 1999;
504 Wang et al., 2008), and their isotopic values would in this case reflect the source of decomposed OM.

505 Despite the wide array of lipid biomarkers analysed (Méjanelle et al., 2017 and the present study),
506 no specific marker of marine OM was found in appreciable amounts in the lobe sediments, likely due
507 to their degradation in the water column and the strong dilution of any signal by the turbidity inputs.
508 Overall, fatty acid patterns suggest that fluxes of marine POM are rather limited and that their
509 composition is extensively modified before settling on the seafloor. In good agreement with this, (1)
510 bulk $\delta^{13}C_{org}$ signature ($\sim -26.5\text{‰}$), Rock-Eval pyrolysis analysis and palynofacies observations
511 revealed that marine OM represents at most 30% in these sediments, is highly degraded, and is present

512 as amorphous material (Stetten et al., 2015; Schnyder et al., 2017; Baudin et al., 2017b).

513

514 *4.1.3. Transformation of the source signal during transport*

515 The challenge to assess sink to source transformations lies in the difficulty to constrain the original
516 source signatures and the limited knowledge on the many factors that control the chemical
517 composition of the exported OM. The Malebo Pool is recognised as a good sampling location for
518 Congo suspended solids because no major tributary enters the river between Kinshasa and the head of
519 the estuary (~350km downstream), and POM composition remains fairly constant from this point to
520 the mouth of the river (Spencer et al., 2012). Soil-OM from the Congo watershed is deposited in the
521 Malebo Pool wetlands and later exported to the Atlantic Ocean with some local production (Talbot et
522 al., 2014; Spencer-Jones et al., 2015). Sediments from the Malebo Pool displayed OC-normalised
523 concentrations in fatty acids similar to that of river suspended POM (Hemingway et al., 2016)
524 confirming that they are representative of the terrestrial OM exported by the Congo River. The relative
525 enrichment in LCFA is consistent with the integration of the local C3-vegetation signal. Low
526 contribution of unsaturated homologues in permanently submerged and recently exposed sediments
527 are indicative of degraded OM. The different proxies of OM alteration used here and in previous
528 studies agree with this observation and suggest pre-aging of the OM within the watershed prior export
529 to the Congo shelf and deep-sea fan (UI, amino acid based indices DI an RI, Rock-Eval OI and HI,
530 palynofacies, Baudin et al., 2017b; Pruski et al., 2017; Schnyder et al., 2017).

531 Sediments in the active lobe area had a fatty acid composition that closely matches that of the
532 permanently submerged and recently exposed sediments from the Malebo Pool in terms of proportion
533 of major components highlighting the remarkably good preservation of the terrestrial source signal in
534 spite of the distance covered. Fatty acids are considered as relatively labile lipid biomarkers and
535 undergo rapid degradation in the ocean. However, the degradation rate of each fatty acid depends on
536 many factors including its chemical structure, the phase with which it is associated, and the exposure
537 time to O₂ (Bianchi and Canuel, 2011). If the fatty acids exported by the Congo River undergo
538 extensive degradation during their transport, one would expect a marked decrease of the OC-
539 normalised concentrations from the source to the terminal depocenter (site C). This was not the case,

540 either suggesting that fatty acids are degraded at the same rate as total OC or that OM remineralisation
541 is low. Furthermore, sediments from the lobe complex and those from the Malebo Pool had similar
542 fatty acid profiles and comparable values of microbial degradation indices (UI, CPI and ACL_{16-30}),
543 showing limited reprocessing during the 1135 km-length transit to the terminal lobe area. This lack of
544 apparent reactivity may be attributed to the nature of the POM exported by the river, which is mostly
545 associated to soils (Spencer et al., 2012). Fatty acids deriving from both plant materials and
546 microorganisms are vulnerable to decomposition by microbial decomposers, but interactions with
547 mineral surfaces and occlusion in soil aggregates may stabilize and protect them from degradation
548 (Salmon et al., 2000; Lützow et al., 2006; Wakeham et al., 2009). Leaf plant waxes were shown to
549 have a particularly high affinity for the inorganic matrix, higher than that of other plant markers such
550 as lignin phenols (Feng et al., 2013). The interaction of leaf fatty acids with organo-mineral aggregates
551 may limit their degradation and allow the export of pre-aged, but yet reactive, pools of OC.

552 The dynamic of sediment transfer in the Congo turbiditic system is another factor which may
553 contribute to the preservation of fatty acids. Sediment transfer is non-linear with phases of deposition
554 and erosion all along the canyon and the channel, but OM burial is always prevalent (Talling et al.,
555 2022). The speed at which turbidity currents export the terrigenous particles to the terminal lobe area
556 limits the exposure time to O_2 and allows the preservation of recent plant remains in the sediments
557 with limited alteration of their structural lipid content (Schnyder et al., 2017, Talling et al., 2022).

558

559 *4.2. Processes affecting fatty acid preservation*

560 Fatty acid profiles were used to explore post-depositional processes involved with the preservation
561 of these compounds in recent turbidites. To this aim, groups of samples with similar fatty acid
562 composition were determined (Fig. 5) and related to the geochemical proxies determined concurrently
563 from the same cores (Fig. 6). The sediment samples were partitioned into four distinct clusters, each
564 characterised by different biomarker composition, geochemical properties and grain size distribution,
565 providing clues on the factors affecting OM distribution and preservation in the distal reach of the
566 Congo turbiditic system.

567

568 4.2.1. *Post-depositional oxic degradation*

569 When a turbidite settles in the deep ocean, oxygen from the overlying surface water diffuses in the
570 deposit until equilibrium is reached. This controls the evolution of the redox conditions and the extent
571 of oxic degradation (Wilson et al., 1985). Consequently, turbidites have been considered as an
572 interesting in situ model for the study of long term oxic degradation (de Lange, 1998; Hoefs et al.,
573 2002; Huguet et al., 2008), but this approach has not been applied to recent turbidite deposits, such as
574 those in the Congo terminal lobe complex where oxygen diffusion into the surface of the turbidite is
575 restricted to the first centimetre (Pozzato et al., 2017).

576 The nMDS ordination of the samples from the active lobe area confirms that surface sediments
577 (layers 0–0.5 and 0.5–1 cm in cluster 1) had a fatty acid composition distinct from that of the deeper
578 layers (Fig. 6). Higher BAFA contributions in the surface sediments are consistent with an enhanced
579 bacterial degradation near the benthic boundary layer where more electron acceptors are present,
580 especially O₂ (Emerson and Hedges, 2006), whereas lower contributions of MUFA and PUFA show
581 the preferential degradation of unsaturated compounds, which are more labile. These sediments were
582 also characterised by lower OC contents, consistent with increased degradation in oxic conditions, as
583 well as lower values of our amino acid and fatty acid-based proxies of OM quality (UI and DI)
584 indicative of a more advanced alteration of the OM. δ¹³C values of bulk OC were also higher in the
585 surface sediments a trend also observed for many fatty acids (Supplementary Table S2). Diagenesis
586 might explain this positive isotopic shift and could be explained by the selective degradation of ¹³C
587 depleted components, such as lipids (Sun et al., 2004; Pan et al., 2014). Sun et al. (2004) further
588 postulated that ¹³C enrichment of fatty acids during decomposition could be attributed to the dissimilar
589 distribution of ¹³C between carbon sites and the dominant decarboxylation pathway, which removes
590 the isotopically lighter carboxyl group, leading to higher δ¹³C of the residual fatty acids. Surface
591 sediments collected at the entry of the terminal lobe complex (site A) were not clustered with the other
592 upper layers due to a higher contribution of PUFA. Nevertheless, there are also evidences of oxic
593 degradation at this site with (i) a decrease of the OC content by about one fourth between the non-
594 oxidised and the oxidised layers and (ii) lower values of the degradation index (DI) at the surface.

595 The particulate OM resuspended during turbidity events is strongly remineralised before settling on
596 the seafloor (Vangriesheim et al., 2009). The efficient degradation of the material resuspended by
597 turbidity currents and deposited in the fluffy layer was previously demonstrated in the Congo canyon-
598 levee system using alcohol biomarkers (Treignier et al., 2006). A decrease of 62% of the total *n*-
599 alcohols was observed between the material in suspension collected during the turbidite event and 9
600 months later in the surface sediment. To assess the extent of post-depositional degradation on fatty
601 acid concentration in the terminal lobe complex, we calculated preservation factors in a similar way as
602 described by Hoefs et al. (2002) (Table 6). The extent of degradation observed here for fatty acid
603 biomarkers was lower than in the study of Treignier et al. (2006), but only accounts for the oxic
604 degradation taking place in the first upper oxic layer after deposition of the turbidite, as no information
605 on the composition of the material in suspension during the last turbidite event was available. SCFA
606 decreased by 3 to 33% between the non-oxidised (3–5 cm) and the oxidised (0–0.5 cm) layers with
607 strong differences between individual fatty acids. Preservation factors for C_{14:0} were constantly above
608 100%, suggesting post-depositional production of this compound in the oxic layer. MUFA and PUFA
609 were more extensively degraded than SCFA (>40%) apart in the channel at site A, which received
610 additional inputs of phytoplankton biomarkers. The level of alteration of the different fatty acid
611 subgroups followed their known level of resistance to oxidation, with higher plant biomarkers being
612 the less prone to degradation (Wakeham et al., 1997a). Preservation factors for most bacterial
613 biomarkers are higher than 100%, suggesting in situ production of these compounds by aerobic
614 heterotrophs. By contrast, preservation factors above 100% for certain LCFA biomarkers might be
615 indicative of plant detritus heterogeneous distribution (see section 4.2.2).

616 Oxic degradation appears as the principal process affecting fatty acid preservation in the terminal
617 lobe area, but is strictly restricted to the uppermost sediment layer (~ first centimeter), consistent with
618 the depth of oxygen penetration, which never exceeded 1.8 cm (Pozzato et al., 2017). In relict
619 turbidites from the Madeira abyssal plain, dissolved oxygen has been diffusing in sediments for
620 thousands of years, which explains the presence of a marked oxygen front separating OM-depleted
621 surface sediments and OM-well preserved deep sediments (Cowie et al., 1995; Prahl et al., 1997; de
622 Lange, 1998). In these deposits, 80% of the organic carbon and 50% of the nitrogen originally present

623 in the sediment have been degraded under oxic conditions (de Lange, 1998). By contrast, in the recent
624 lobe complex, even if mineralisation rates are exceptional for this depth (Rabouille et al., 2009), OM
625 loss remains limited to the surface sediments and burial clearly outweighs remineralisation processes:
626 ~ 12 to 35% of the OC initially deposited in the upper oxic layer is degraded.

627

628 *4.2.2. Deposition dynamics and lateral sorting*

629 A remarkable feature of the Congo turbidite system is the homogenous composition and
630 distribution of the OM in the channel-levee area and in the terminal lobe complex at different scales,
631 from the single turbiditic event to the entire lobe area (Baudin et al., 2010, 2017b; Stetten et al., 2015).
632 This apparent homogeneity may be explained by the predominant export of fine-grained particles by
633 the Congo River, which limits hydrodynamic sorting by the turbidity currents as well as by post-
634 depositional sediment reworking (Stetten et al., 2015; Baudin et al., 2017b). Multivariate analyses of
635 the fatty acid profiles nonetheless revealed site-differences in the distribution of terrestrial biomarkers,
636 which were related to subtle changes in sediment grain size: the layers 1 to 16 cm of the core collected
637 in the channel of site C were grouped in cluster 2, while the 16–22 cm layers were grouped in cluster 3
638 with the 5–7 and 19–22 cm layers of the other sites. High contributions of terrestrial plant biomarkers
639 (LCFA) and CPI values along with higher C/N ratios and a slightly coarser granulometry in cluster 3
640 are indicative of the preservation of plant detritus. In contrast, lower contributions of LCFA in
641 conjunction with lower ACL values and a higher proportion of clay in cluster 2 point to higher inputs
642 of soil-derived OM in the channel at site C.

643 The density/buoyancy sorting of particles that occurs along the active channel-levee system
644 (Schnyder et al., 2017) may explain the lower proportion of plant debris observed in the main
645 depositional area (channel at site C). Site C, located at the end of the feeding channel, is the terminal
646 depocenter of materials transported by the Congo canyon system (Babonneau et al., 2010; Dennielou
647 et al., 2017). Thus, this site mostly accumulates fine particles from soils, as plant debris form low
648 density aggregates that can be sorted upstream (Remusat et al., 2012; Cotrufo et al., 2015). High UI,
649 DI and OC content associated to these sediments further show the limited diagenetic changes
650 occurring in these anaerobic sediments and underline the good preservation of the OM in the terminal

651 depocenter. A mechanism often proposed to explain OM preservation is its strong association with the
652 mineral matrix (Huguet et al., 2008). As stated earlier, OM is mainly associated with fine silty-clay
653 minerals in the lobe sediments (Stetten et al., 2015). The labile compounds can be adsorbed on
654 mesopores present on the surface of these small particles (Mayer, 1994), which protects the
655 intrinsically labile OM from microbial enzymes (Wakeham and Canuel, 2006). The increased
656 contribution of soils and the exceptionally high accumulation rates (up to 12 cm.y^{-1} at site C; Stetten et
657 al., 2015; Rabouille et al., 2017) very likely account for the higher preservation potential in the
658 terminal depocenter. Besides, physical disturbance is certainly lower due to the loss of confinement,
659 which limits sediment re-exposure to oxygen.

660

661 *4.2.3. Past and actual influence of turbidity currents on the abandoned lobe*

662 The terminal lobe complex of the Congo turbidite system has been formed by the successive
663 progradation of the turbidite deposits. Site E corresponds to an older lobe, which got disconnected
664 after the bifurcation to the south of the active channel between 4000 to 6000 years ago (Picot et al.,
665 2016). Despite this, sediments in the active and abandoned lobes still share some common features. A
666 high OC content compared to the surrounding abyssal plains of the equatorial Atlantic Ocean (Baudin
667 et al., 2017a) and the presence of LCFA along with a BIT value ranging between 0.48 and 0.76 show
668 the past and actual influence of the Congo channel-levee system on the abandoned lobe. Fig. 4b
669 illustrates the changes in the proportion of land derived OM proxies (e.g. proportions of LCFA and
670 terrestrial phytoclasts), reflecting the progressive shift from terrestrial inputs supplied by ancient
671 turbidite events to the present-day hemipelagic sedimentation. The first 7 centimetres of this core
672 formed a distinct cluster characterised by the absence of PUFA, lower MUFA content and higher
673 contributions of SCFA (Fig. 5, cluster 4). These sediments are of marine origin as evidenced by their
674 $\delta^{13}\text{C}_{\text{org}}$ signature, which was significantly higher than the mean $\delta^{13}\text{C}_{\text{org}}$ of all the samples (Stetten et al.,
675 2015). The hypothesis of the hemipelagic origin of OM in the topmost layers of site E is strengthened
676 by the higher $\delta^{13}\text{C}$ values of the fatty acids (Supplementary Table S2). This hemipelagic ooze consists
677 in the sedimentation of marine particles with the admixture of terrigenous material originating from
678 the dispersion and settling of the upper turbid plume of the turbidites deposited ~40 km to the south

679 and/or from the pelagic snow. These inputs explain the presence of terrestrial biomarkers in the
680 surface sediments of the abandoned site (this study and Méjanelle et al., 2017) as well as the
681 occurrence of terrestrial amorphous OM and plant debris (Stetten et al., 2015; Schnyder et al., 2017).
682 Higher OI and lower DI are furthermore associated with these layers, indicative of a strongly oxidised
683 OM (Table 1). This is consistent with the high penetration depth of oxygen (~6 cm on Fig. 4b, Pozzato
684 et al., 2017) and the low sedimentation rate at this site (Rabouille et al., 2017), which provide
685 favourable conditions for the intensive oxidation of the hemipelagic deposit.

686 Below a depth of 7 cm, sediments from the abandoned site displayed a fatty acid composition
687 similar to that of the surface sediments from the active lobe (cluster 1, Fig. 5), suggesting that they
688 correspond to ancient turbidite deposits. The clustering of these sediments with the oxic layers from
689 the active lobe shows that the OM has been subjected to some degradation, but the persistence of fatty
690 acids in these ancient turbidites over millennia is nonetheless remarkable. As already mentioned,
691 LCFA are associated to soil aggregates, mineral particles or plant remains consisting of relatively
692 recalcitrant substances such as lignin or cellulose and may thus be protected from microbial
693 degradation (Wakeham and Canuel, 2006). Such a good preservation of the fatty acid record suggests
694 the progressive burial of the older turbidite deposit under the predominantly hemipelagic
695 sedimentation without any significant reworking or redistribution of the sediments on the abyssal plain
696 over the past few millennia.

697

698 **5. Conclusion**

699 Sediment cores from the terminal lobe complex of the Congo deep-sea fan were investigated to
700 assess the potential of fatty acids as biomarkers of OM origin and processes affecting the composition
701 of the terrestrial material transported by turbidity currents during transit in the channel-levee system
702 and after deposition in the distal depositional area. Fatty acid profiles were interpreted in light of a
703 combination of selected geochemical proxies. Fig. 7 summarises the major outcomes from this study.

704 The close similarity of the molecular composition of sediments from the active lobe with that of
705 samples collected on land at the Malebo Pool suggests that (i) POM delivered by the Congo River is
706 primarily composed of soil-OM deriving from C3 plants, (ii) OM is subjected to limited recycling

707 during transit, and (iii) mixing of riverine inputs with material from the surrounding Angola margin is
708 low. Yet, the unexpected occurrence of undegraded phytoplankton biomarkers at the entrance of the
709 terminal lobe highlights that pelagic inputs deposited upstream in the active channel may be rapidly
710 exported by turbidity currents. Site B located 10 km to the north of the active channel is characterised
711 by lower sedimentation rates ($0.3\text{--}0.4\text{ cm.y}^{-1}$; Rabouille et al., 2017) and only receives material
712 overflowing the levees of the feeding channel. This material is coarser but similar in composition to
713 that deposited in the rest of the active lobe. In the abandoned lobe, located 40 km away from the active
714 channel, the hemipelagic oozes still contain non negligible amounts of terrestrial biomarkers
715 originating from the dispersion and settling of the particles suspended in the upper plume of the
716 turbidity currents or in the surface plume, but these inputs are too low to influence the benthic
717 communities (Olu et al., 2017).

718 LCFA were used to trace inputs from the Congo River at different time scales, from the turbidites
719 recently deposited in the present-day active lobe to the millennial deposition in the remote abandoned
720 lobe. Although changes in the composition of the material delivered by the Congo River cannot be
721 ruled out, the good preservation of the LCFA in the ancient turbidites suggests a conservative
722 behaviour.

723 The fatty acid data were combined with those of several geochemical proxies to gain more accurate
724 insights into the processes affecting fatty acid distribution and preservation in the lobe complex. The
725 preferential degradation of unsaturated fatty acids was reflected by the unsaturation index, while
726 changes in the amino acid composition due to early diagenesis were apparent through the DI. Since
727 about half of the total nitrogen is associated to proteinaceous material in lobe sediments (Pruski et al.,
728 2017), DI values can be considered as representative of bulk OM biochemical alteration. This shows
729 that even though fatty acids only represent $\sim 0.5\%$ of total OC, the extent of PUFA/MUFA oxidation
730 can be used as an OM degradation proxy. However, while compositional changes in amino acid
731 distribution are mostly due to diagenesis, fatty acid profiles are dependent both on OM sources and
732 degradation processes and cannot be summed up in a univariate index. Detailed information can be
733 obtained from the refined interpretation of fatty acid fingerprints, combined with the use of
734 multivariate statistical tools. In the present study, such an approach revealed the different mobilisation

735 pathways for the OM associated to fine soil-derived particles and the coarser plant detritus, likely
736 related with the density/buoyancy sorting taking place in the turbidity currents and the resulting
737 selective delivery. Quantitative estimates of both the soil and plant terrestrial inputs in the Congo lobe
738 complex are still lacking, but the combination of fatty acid and glycerol dialkyl glycerol tetraether
739 biomarkers offers promising perspectives to better deconvolute the soil-derived OM and the plant
740 debris signals.

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1135

1136 **Captions**

1137 Fig. 1. (A) General bathymetric map showing the Congo deep-sea fan with its active channel, and
1138 (B) a EM12 Backscatter sonar image of the terminal part of the Congo deep-sea fan with location of
1139 the sampling sites: A, F, C and B are located in the recent lobe complex; E is located in an abandoned
1140 lobe complex. The orange box in A indicates the study area and the red box the location of the Malebo
1141 Pool at Kinshasa, whereas the dotted orange line in B shows the limit of the terminal lobe complex.
1142 Coordinates of sampling sites are provided in Supplementary Table S1.

1143
1144 Fig. 2: Fatty acid composition of Congo River sediments collected on land (Malebo Pool) and
1145 marine suspended POM recovered in surface waters above the terminal lobe complex. Results are
1146 expressed in percent of total fatty acids (N= 6 for Congo River sediments and 5 for suspended POM).
1147 The bold line represents median value, the box is the mid-spread (including the first and third
1148 quartiles), and the whiskers are the minimum and maximum values. Data beyond the end of the
1149 whiskers are outliers.

1150
1151 Fig. 3. OC-normalised fatty acid concentrations, cumulative biomarker contributions, and OC
1152 content (%) in the surface sediments from the terminal lobe complex of the Congo deep-sea fan (layer
1153 0–0.5 cm) and on land at the Malebo Pool (layer 0–5 cm).

1154
1155 Fig. 4. Downcore evolution of bulk $\delta^{13}\text{C}$, fatty acid subgroup contributions and proportion of
1156 terrestrial phytoclasts in the sediment cores collected in (A) the channel at site C and (B) the
1157 abandoned site E. Values were plotted at the mid depth of the layer (11 layers for fatty acids and $\delta^{13}\text{C}$
1158 values, 9 for palynofacies counts). Long chain fatty acids= LCFA, polyunsaturated fatty acids= PUFA,
1159 bacterial fatty acids= BAFA and monounsaturated fatty acids= MUFA. Palynofacies data are from
1160 Schnyder et al. (2017). The yellow area indicates the oxygen penetration depth (OPD), (Pozzato et al.,
1161 2017). Note the similar vertical distribution of LCFA and terrestrial phytoclasts at site E.

1162

1163 Fig. 5: Fatty acid-based hierarchical cluster analysis of sediments from the terminal lobe complex
1164 of the Congo deep-sea fan (A) and average composition of the 4 clusters (B). Bray-Curtis dissimilarity
1165 index and Ward's minimum variance linkage method were used for clustering. Average composition
1166 for each cluster is expressed as percentages of total fatty acids. Code for sediment samples is: AL (site
1167 A levee), AC (site A channel), CL (site C levee), CC (site C channel), B (site B), F (site F), and E (site
1168 E) followed by sediment layers from 0 for surface layer (0–0.5 cm) to 10 for the deepest sediment
1169 layer (19–22 cm).

1170

1171 Fig. 6: Non-metric multidimensional scaling (nMDS) ordination plot assessing the relationship
1172 between sites, sampling depths, fatty acid biomarkers, and sediment properties in the terminal lobe
1173 area of the Congo deep-sea fan (stress = 0.116). Code for sediment samples is: AL (site A levee), AC
1174 (site A channel), CL (site C levee), CC (site C channel), B (site B), and F (site F) followed by
1175 sediment layers from 0 for surface layer (0–0.5 cm) to 10 for the deepest sediment layer (19–22 cm).

1176 The distance between samples indicates similarity of the fatty acid composition, i.e., the closer, the
1177 more similar. Environmental factors were fitted in the ordination plot as vectors, whereby the arrow
1178 indicates the direction of the increasing gradient of the environmental variable and the length of the
1179 arrow is proportional to the correlation coefficient between the variable and the nMDS ordination.

1180

1181 Fig. 7. Conceptual scheme summarising the principal outcomes of this study. Processes affecting
1182 marine and terrestrial organic matter during transit and after deposition in the terminal lobe area of the
1183 Congo deep-sea fan are presented. The blue box presents the different depositional scenarios in the
1184 recent and abandoned lobe complexes.

1185

1186 Table 1. Principal descriptors used in this study with their interpretation.

Descriptors	Feature	Main diagnostic information	References
C/N	Source/Quality	Marine derived OM (6-9), Soil derived OM (8-20) and higher plants (>20)	1-3
$\delta^{13}\text{C}$	Source	POM Gulf of Guinea (-21‰), POM Congo River ($-26.7 \pm 0.4\text{‰}$), Savannah soils (-26‰), C3 vascular plant from the Angola ($-28.0 \pm 1.8\text{‰}$) and C4 vegetation (-13.6‰)	4-7
DI	Quality	Diagenetic alteration of OM with DI values ranging from -2.2 extensively degraded sediments to 1.5 for fresh algae	8
OI	Quality	Oxygen content of the OM	9
BIT index	Source	Proxie of soil OM with values of 0.91 ± 0.14 for Congo soils and 0.04 for marine OM	10–11
<i>Fatty acids</i>			
SCFA	Source	Mixed origin, but shorter chains predominate in phytoplankton	12–13
LCFA	Source	Terrestrial higher plants, macrodetritus	14
PUFA: 18:2 ω 6 and 18:3 ω 3	Source	Terrestrial higher plants (>2.5%)	16–17
PUFA: all except 18:2 ω 6 and 18:3 ω 3	Source/Quality	Phytoplankton with C _{20:5ω3} specific of diatoms and C _{22:6ω3} specific of dinoflagellates	12,18
MUFA	Source	Mixed origin with C _{16:1ω7} common in diatoms and bacteria and C _{18:1ω7} abundant in bacteria	12–13
BAFA	Source	Bacterial sources: Includes odd saturated (C _{15:0} , C _{17:0}), branched (iC ₁₅ , iC ₁₇ , aiC ₁₅ , aiC ₁₇), and β -hydroxylated fatty acids	13
UI	Quality	OM degradation (<70 old detrital matter)	19
CPI	Source/Quality	Expected to decrease with ongoing degradation (in soils <10 degraded OM)	20
ACL	Source/Quality	Expected to increase with ongoing degradation, higher in plant tissues than in microorganisms or aquatic plants	21–22

1187

1188 1: Moloney and Field (1991), 2: Hedges and Oades (1997), 3: Meyers (1997), 4: Badewien et al. (2015), 5: Delègue et al. (2001), 6: Fischer et al. (1998), 7: Powers

1189 and Schlesinger (2002), 8: Dauwe et al. (1999), 9: Espitalié et al. (1985), 10: Weijers et al. (2006), 11: Schouten et al. (2013), 12: Dunstan et al. (1994), 13: Bianchi
1190 and Canuel (2011), 14: Eglinton and Hamilton (1967), 15: Volkman et al. (1989), 16: Budge et al. (2001), 17: Pruski et al. (2015), 18: Volkman et al. (1998), 19:
1191 Claustre et al. (1992), 20: Angst et al. (2016), 21: Wiesenberg et al. (2010), 22: Wang and Liu (2012).

1192 Table 2: Geochemical and sedimentological properties of the sediments from the terminal lobe complex of the Congo deep-sea fan. Organic carbon (OC), C/N
 1193 (molar ratio), isotopic value of stable carbon ($\delta^{13}\text{C}$), isotopic value of stable nitrogen ($\delta^{15}\text{N}$), oxygen index (OI), Dauwe's degradation index (DI), and percentages of
 1194 clay, silt and sand. The mean, lowest and highest values measured for each core are given. N=4, except for C channel and E abandoned where N= 11. Data are from
 1195 Stetten et al. (2015), except for OI (Baudin et al., 2017b) and DI (Pruski et al., 2017).

1196

1197

Site	OC %			C/N molar			$\delta^{13}\text{C}$ ‰			$\delta^{15}\text{N}$ ‰			OI mg CO ₂ /g OC		
	mean	min	max	mean	min	max	mean	min	max	mean	min	max	mean	min	max
A channel	3.0	2.7	3.7	16.9	15.3	18.2	-26.5	-26.8	-26.1	5.4	4.7	6.2	280.5	269	295
A levee	3.0	2.7	3.5	16.6	14.5	19.9	-26.2	-26.7	-25.7	5.5	4.6	5.9	301.8	262	324
F levee	2.8	2.4	3.4	15.7	14.0	16.7	-25.9	-26.3	-25.2	5.4	5.2	5.6	288.3	278	305
C channel	3.8	3.2	4.1	15.6	14.7	17.1	-26.9	-27.1	-26.5	5.3	4.7	5.8	275.0	258	292
C levee	2.9	2.2	3.4	15.0	13.9	15.8	-26.4	-26.6	-26.1	4.9	4.7	5.0	304.3	276	323
B	2.6	2.2	2.9	17.4	14.1	22.5	-25.9	-26.4	-25.3	5.3	4.8	5.9	265.0	244	295
E abandoned 0-7cm	0.8	0.7	0.9	11.4	11.0	11.7	-23.2	-23.9	-22.8	7.8	7.1	8.2	499.7	447	609
E abandoned 7-22cm	1.9	1.2	2.8	14.0	12.3	15.9	-25.4	-26.9	-24.1	6.4	6.3	6.6	231.0	200	270

1198

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1200

DI			Clay %			Silt %			Sand %		
mean	min	max	mean	min	max	mean	min	max	mean	min	max
-0.2	-0.42	-0.08	19.4	14.8	22.4	75.6	73.2	77.9	4.8	2.5	7.3
-0.1	-0.40	0.18	17.0	12.5	20.1	73.7	70.2	77.1	9.4	4.5	15.6
-0.2	-0.32	0.15	20.1	15.5	22.0	75.7	73.8	78.1	4.3	0.8	8.3
0.1	-0.41	0.61	23.0	20.0	26.0	71.2	69.2	73.5	5.6	2.1	10.4
-0.1	-0.36	0.22	26.6	25.4	28.1	72.4	70.7	74.2	0.9	0.3	2.7
16.5	-0.39	0.15	76.3	14.8	18.9	7.1	74.5	78.5	-0.1	5.7	9.0
-1.1	-1.39	-0.87	24.4	17.7	30.9	71.7	68.2	74.2	3.6	0.9	8.8
-0.1	-0.52	0.24	26.6	23.9	31.1	71.1	67.3	73.8	2.3	1.6	2.7

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1202

1203 Table 3: BIT index values calculated for surface and deep horizons of sediments sampled from the terminal lobe complex. 0–1 cm layers were obtained by pooling
 1204 the 0–0.5 cm and 0.5–1 cm horizons.

Sediment layer	Present-day active lobe complex						Northern lobe complex
	A channel	A levee	F levee	C channel	C levee	B	E abandoned
0-1 cm	0.75	0.76	0.76	0.83	0.81	0.78	0.48
19-22 cm	0.84	0.84	0.83	0.84	0.84	0.82	0.76

1210

1211 Table 4: Fatty acid composition and concentrations in sediments from the terminal lobe complex of the
1212 Congo deep-sea fan. Data are expressed as percentages of total fatty acid concentrations, and concentrations
1213 are in $\mu\text{g}\cdot\text{g}^{-1}$ dw and $\mu\text{g}\cdot\text{g}^{-1}$ OC. Minor compounds (<1%) are not included. Fatty acids are grouped in five
1214 categories: short chain saturated fatty acids (SCFA), long chain saturated fatty acids (LCFA),
1215 monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA) and bacterial fatty acids (BAFA).
1216 UI: unsaturation index, CPI: carbon preference index, ACL_{16-30} : average chain length calculated for saturated
1217 fatty acids in the range $\text{C}_{16}\text{--}\text{C}_{30}$, nd: not determined.
1218

Site Horizon (cm)	A levee				A channel				F levee			
	0-0.5	0.5-1	5-7	19-22	0-0.5	0.5-1	5-7	19-22	0-0.5	0.5-1	5-7	19-22
C_{14:0}	6.1	5.5	3.9	3.8	5.6	5.4	4.1	3.7	5.9	5.0	5.3	4.8
C_{16:0}	17.3	16.2	14.9	16.1	16.3	15.4	17.9	15.3	16.4	15.5	18.7	17.7
C_{18:0}	5.5	5.7	4.4	5.6	5.2	5.2	5.8	5.2	5.4	5.3	6.7	6.0
C_{20:0}	3.4	3.9	3.8	4.7	3.4	3.4	4.4	3.9	3.7	4.1	4.8	4.3
C_{21:0}	0.5	0.6	0.5	0.6	0.5	0.6	0.6	0.5	0.6	0.7	0.7	0.5
C_{22:0}	5.5	6.2	4.9	8.1	5.1	5.4	7.2	6.9	6.3	6.6	7.6	7.1
C_{23:0}	1.2	1.6	1.5	1.6	1.1	1.3	1.5	1.5	1.5	1.7	1.8	1.5
ΣSCFA	41.4	42.2	35.7	42.3	39.5	38.8	43.4	38.7	42.3	41.3	47.9	44.2
C_{24:0}	8.5	9.9	7.8	15.4	7.9	8.8	12.0	12.8	10.1	11.0	11.4	12.3
C_{26:0}	7.5	8.2	21.2	10.2	6.5	7.5	8.3	9.5	9.0	9.8	6.2	9.9
C_{28:0}	6.7	8.5	2.9	6.3	6.5	7.4	5.8	7.3	9.3	9.3	6.4	7.0
C_{30:0}	5.7	7.2	7.5	3.7	5.5	6.4	6.1	8.7	8.1	8.6	5.3	5.7
ΣLCFA	28.4	33.8	39.4	35.5	26.4	30.0	32.3	38.4	36.6	38.7	29.3	34.9
C_{16:1ω7}	3.2	1.7	2.1	2.1	4.4	3.2	3.1	2.6	1.2	1.3	3.3	2.2
C_{18:1ω9 cis}	1.6	0.7	2.7	3.6	2.9	2.8	2.9	2.8	0.7	0.5	1.6	2.5
C_{18:1ω7}	2.8	1.2	3.4	2.5	4.3	3.1	3.7	2.7	0.4	0.5	2.8	2.2
C_{20:1ω9}	0.0	0.0	0.3	0.4	0.2	0.1	0.1	0.4	0.0	0.0	0.2	0.2
ΣMUFA	7.7	3.6	8.6	8.6	11.7	9.2	9.7	8.5	2.3	2.3	7.9	7.1
C_{18:2ω6 cis}	0.2	0.0	0.6	0.8	0.4	0.3	0.5	0.5	0.0	0.0	0.2	0.4
C_{20:4ω6}	0.5	0.0	0.2	0.2	0.6	0.5	0.2	0.2	0.0	0.0	0.2	0.1
C_{20:5ω3}	0.7	0.1	0.5	0.2	0.0	0.0	0.6	0.4	0.0	0.0	0.2	0.2
C_{22:6ω3}	0.7	0.0	nd	nd	1.0	0.8	nd	nd	0.0	0.0	nd	nd
ΣPUFA	2.1	0.1	1.7	1.6	2.9	2.4	1.5	1.3	0.0	0.0	0.6	0.7
C_{15:0}	1.7	1.5	1.1	1.0	1.6	1.5	1.2	1.0	1.6	1.5	1.3	1.1
C_{17:0}	1.4	1.3	1.1	1.0	1.4	1.3	1.1	1.0	1.6	1.3	1.2	1.0
3-OH-C₁₂	0.9	0.9	0.6	0.6	0.9	1.0	0.3	0.5	1.0	0.9	0.4	0.3
3-OH-C₁₄	5.1	5.8	3.3	3.1	5.0	5.1	1.9	3.5	4.9	5.0	1.9	2.3
i C_{14:0}	1.1	1.2	1.0	0.8	1.2	1.1	1.0	0.9	0.8	0.9	1.1	1.1
i C_{15:0}	4.4	4.3	3.3	2.6	4.2	4.1	3.3	2.7	3.6	3.4	3.3	3.0
ai C_{15:0}	2.2	2.0	1.7	0.6	2.1	2.0	1.7	1.4	2.1	1.8	2.0	1.6
i C_{16:0}	1.8	1.7	1.3	1.2	1.6	1.7	1.3	1.1	1.7	1.5	1.4	1.2
i C_{17:0}	1.7	1.6	1.3	1.1	1.6	1.7	1.3	1.0	1.5	1.4	1.5	1.3
ΣBAFA	20.4	20.3	14.6	12.0	19.5	19.5	13.1	13.1	18.9	17.7	14.3	13.0
Tot FAs ($\mu\text{g}\cdot\text{g}^{-1}\text{dw}$)	133.7	133.6	173.3	115.3	135.5	145.4	128.3	149.4	129.4	130.7	116.9	137.3
Tot FAs ($\text{mg}\cdot\text{g}^{-1}\text{OC}$)	5.0	4.8	4.9	3.7	5.1	5.4	3.5	5.0	5.2	5.5	3.7	4.1
UI	17.9	4.1	14.1	12.9	25.6	20.9	15.0	12.7	2.7	2.4	10.0	9.2
CPI	13.4	13.5	16.1	17.5	13.1	13.2	15.8	17.5	13.3	13.7	13.6	16.7
ACL₍₁₆₋₃₀₎	22.0	22.5	22.9	22.1	22.0	22.4	22.0	22.8	22.7	22.9	21.7	22.2

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C levee				C channel				B				E abandoned			
0-0.5	0.5-1	5-7	19-22	0-0.5	0.5-1	5-7	19-22	0-0.5	0.5-1	5-7	19-22	0-0.5	0.5-1	5-7	19-22
6.2	5.6	4.3	5.7	6.1	5.7	5.4	4.4	6.4	6.0	3.7	5.1	10.5	11.0	8.4	4.8
17.4	17.3	16.2	19.9	18.4	18.1	23.1	19.7	18.4	18.5	13.9	19.3	25.6	29.2	18.3	16.4
6.8	7.3	5.5	6.9	6.5	7.0	5.9	5.2	5.9	6.3	4.7	7.1	7.1	8.4	6.9	7.1
4.3	4.3	4.0	4.8	4.7	4.9	3.7	3.6	4.3	4.6	3.9	5.9	3.2	3.1	3.6	4.8
0.7	0.7	0.6	0.7	0.7	0.8	0.5	0.6	0.7	0.8	0.6	0.7	0.7	0.8	1.0	0.6
6.4	6.5	6.5	6.9	7.0	7.9	5.0	5.1	7.1	7.3	6.1	7.5	5.0	5.0	5.7	9.3
1.6	1.6	1.6	1.7	1.6	1.8	1.1	1.3	1.7	1.8	1.4	1.5	1.1	1.0	1.8	1.9
47.3	47.2	40.6	48.7	47.8	48.8	47.1	42.1	46.5	47.9	36.2	49.7	58.3	60.2	48.2	45.8
9.1	9.7	11.8	11.5	9.7	11.2	5.2	11.9	10.9	10.8	26.8	11.1	5.9	5.5	8.3	13.4
6.4	6.7	8.5	7.7	7.2	7.1	4.1	5.7	8.4	8.2	6.9	6.8	4.9	5.0	7.8	11.5
5.6	6.0	6.7	4.1	5.4	4.9	3.6	4.9	6.6	6.3	4.3	4.4	2.5	2.4	6.6	9.4
4.3	3.2	5.7	4.3	3.6	3.9	3.1	4.1	4.6	3.5	2.9	2.9	1.8	0.0	6.8	5.2
25.4	25.6	32.7	27.7	26.0	27.1	15.9	26.6	30.5	28.8	40.9	25.2	15.1	12.8	29.6	39.5
1.8	1.8	3.3	3.1	1.8	1.2	4.3	3.4	1.2	1.2	2.5	2.7	1.1	1.2	1.4	0.8
1.0	1.3	2.5	1.5	1.3	0.8	4.2	3.4	0.6	0.5	2.8	3.1	0.1	0.0	nd	1.5
1.5	1.8	3.8	2.2	1.3	1.0	5.0	4.0	0.6	0.5	2.6	2.3	0.0	0.0	nd	0.5
0.0	0.0	0.4	0.2	0.0	0.0	0.1	0.2	0.0	0.0	0.4	0.4	0.0	0.0	nd	nd
4.3	4.9	10.0	7.0	4.4	3.1	13.7	10.9	2.4	2.3	8.2	8.4	1.2	1.2	1.4	2.8
0.1	0.1	0.5	0.2	0.2	0.0	1.0	0.8	0.0	0.0	0.6	0.5	0.0	0.0	nd	0.2
0.1	0.1	0.3	nd	0.0	0.0	0.4	0.3	0.0	0.0	0.2	nd	0.0	0.0	nd	nd
0.3	0.3	0.5	0.2	0.1	0.0	0.6	0.4	0.0	0.0	nd	nd	0.0	0.0	nd	nd
0.2	0.1	nd	nd	0.0	0.0	nd	nd	0.0	0.0	0.5	nd	0.0	0.0	nd	nd
0.8	0.6	1.6	0.5	0.3	0.0	1.9	1.6	0.0	0.0	1.5	0.5	0.0	0.0	0.0	0.2
1.7	1.6	1.1	1.6	1.7	1.5	1.5	1.3	1.7	1.6	1.0	1.4	2.2	2.8	2.0	1.1
2.4	2.3	1.1	1.4	1.6	1.5	1.5	1.3	1.3	1.4	1.0	1.3	3.8	1.6	1.7	1.1
1.1	1.2	0.6	0.3	1.2	1.1	0.8	0.8	1.1	1.0	0.6	0.4	0.8	0.0	nd	nd
6.0	6.4	3.9	1.4	6.4	6.5	5.2	4.5	5.9	5.8	2.7	3.2	5.7	5.9	6.3	4.0
1.1	1.1	1.0	1.4	1.2	1.2	1.6	1.5	0.9	1.1	0.8	1.3	1.1	1.3	1.5	0.9
4.0	3.8	3.3	4.4	4.0	4.1	4.6	4.0	4.0	4.1	2.6	3.1	4.3	5.3	3.7	2.0
2.0	1.8	1.6	2.1	1.9	1.8	2.3	2.0	2.3	2.3	2.1	2.5	3.9	4.9	3.5	1.0
1.8	1.8	1.3	1.7	1.8	1.7	1.7	1.5	1.8	1.8	1.1	1.4	2.3	2.9	1.4	1.1
1.9	1.7	1.3	1.9	1.7	1.7	1.8	1.6	1.6	1.9	1.1	1.4	1.3	1.1	0.8	0.4
22.3	21.7	15.2	16.1	21.5	21.0	21.3	18.8	20.6	21.1	13.1	16.1	25.5	25.8	20.9	11.7
121.0	140.2	143.3	126.7	133.5	133.0	191.2	210.6	109.1	102.5	168.3	95.5	56.1	38.5	36.8	93.1
5.6	5.3	4.3	3.7	4.1	3.6	5.1	5.3	5.0	4.2	6.0	3.3	6.2	4.4	4.9	3.3
8.0	7.7	15.5	8.5	5.9	3.1	20.0	15.9	2.4	2.3	14.5	9.9	1.2	1.2	1.4	3.1
9.9	10.2	15.3	12.9	11.8	12.1	12.3	13.7	12.8	11.9	17.3	13.5	8.4	10.7	10.2	16.7
21.5	21.4	22.2	21.3	21.4	21.5	20.2	21.4	21.8	21.6	22.3	21.1	19.7	19.1	22.0	22.4

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1228 Table 5: Environmental fitting significance and correlation with nMDS axes of the main geochemical properties. Significant variables are indicated in bold, * p <
 1229 0.05, ** p < 0.01, *** p < 0.001.

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Parameter	nMDS1	nMDS2	r2	p value	
UI	0.98	0.22	0.89	0.001	***
CPI	-0.15	0.99	0.78	0.001	***
ACL	-0.59	0.81	0.63	0.001	***
δ¹³C	-0.98	-0.19	0.59	0.001	***
DI	0.96	0.27	0.47	0.001	***
OC	1	0.02	0.42	0.001	***
C/N	0.13	0.99	0.4	0.002	**
Silt	-0.62	0.78	0.24	0.019	*
Clay	0.55	-0.84	0.19	0.047	*
δ ¹⁵ N	-0.33	-0.94	0.17	0.073	
OI	-0.31	0.95	0.11	0.199	
Sand	-0.32	0.95	0.03	0.675	

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1235 Table 6. Preservation factors (Pf in %) for fatty acids in turbidites from the terminal lobe area of the Congo deep-sea fan. Values are mean for the specific compound

1236 class and, between brackets, minimal and maximal Pf within the compound class.

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	SCFA	LCFA	MUFA	PUFA*	BAFA
Site A channel	95.1 (73.9-144.0)	86.6 (69.7-118.6)	126.1 (104.5-151.5)	210.8	157.3 (124.9-331.5)
Site A levee	75.9 (54.7-101.5)	75.6 (49.8-150.6)	60.4 (38.7-99.2)	78.8	90.8 (70.0-102.9)
Site C channel	70.2 (55.8-98.1)	114.0 (82.2-131.0)	22.6 (18.5-28.5)	10.4	72.1 (53.8-105.1)
Site C levee	95.8 (83.8-124.1)	66.5 (63.6-71.1)	38.4 (33.4-46.6)	42.7	126.0 (94.1-192.4)
Site F	96.6 (85.4-121.8)	137.8 (98.2-167.5)	32.6 (16.8-46.5)	0.0	145.1 (74.8-292.3)
Site B	66.6 (56.2-89.5)	75.5 (61.7-84.2)	15.4 (10.2-25.5)	0.0	80.8 (55.5-113.4)

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1240 Preservation factors were calculated according to Hoefs et al. (2002), but only considered the first unoxidised layer (3–5 cm), as the layer 19–22 cm tended to be

1241 coarser which affected the OM content.

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$$Pf = \frac{[C_{0-0.5cm}]}{[C_{3-5cm}]} \times 100$$
 where Pf: preservation factor and [C]: concentration of specific biomarker in $\mu\text{g.g}^{-1}$ dry sediments.

1243 Pf below 100% are signs of oxic degradation, whereas values above 100% are indicative of a post-depositional enrichment.

1244 * Due to low concentrations Pf were calculated on the sum of all PUFA.