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## Segmentation and kinematics of the North America-Caribbean plate boundary offshore Hispaniola

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1 **Segmentation and kinematics of the North America-Caribbean plate boundary offshore Hispaniola**

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26

27 **Highlights:**

28 • We explored submarine portions of fault systems bounding the Gonâve microplate

29 • Structures are a series of delineated left-lateral strike-slip fault segments

30 • The distinct segments 50 to 100 km-long cut across pre-existing structures

31 • A 16.5km total strike-slip displacement on the northern system estimated since ~1.8 Ma

32

33 **Abstract**

34  
35 We explored the submarine portions of the Enriquillo-Plantain-Garden Fault zone (EPGFZ) and  
36 Septentrional-Oriente Fault zone (SOFZ) along the Northern Caribbean plate boundary using high-  
37 resolution multi-beam echo-sounder and shallow seismic reflection. The bathymetric data shed light  
38 on poorly documented or previously unknown submarine fault zones running over 200-km between  
39 Haiti and Jamaica (EPGFZ) and 300-km between Dominican Republic and Cuba (SOFZ). The primary  
40 plate-boundary structures are a series of strike-slip fault segments associated with pressure ridges,  
41 restraining bends, step-over, and dogleg offsets indicating very active tectonics. Several distinct  
42 segments 50 to 100 km-long cut across pre-existing structures inherited from former tectonic  
43 regimes or bypass recent morphologies formed under the current strike-slip regime. Along the most  
44 recent trace of the SOFZ, we measured a strike-slip offset of 16.5 km that indicates steady activity for  
45 the past  $\sim 1.8$  Ma if its current GPS-derived motion of  $9.8 \pm 2$  mm/yr has remained stable during the  
46 entire Quaternary.

47  
48

## 49 **1 – Introduction**

50

51 Following the 2010 Mw 7.0 Haiti earthquake, an international effort was initiated to investigate the  
52 corresponding fault system and to constrain both the individual fault slip rates and their seismic  
53 history. Such an effort depends critically on knowledge of the detailed geometry of the fault system  
54 delineating the northern boundary of the Caribbean domain (Fig. 1). The Caribbean plate is currently  
55 moving eastward relative to North America and the plate motion is accommodated along a complex,  
56 200 km-wide deformed zone, the Northern Caribbean plate Boundary (NCarB). The NCarB is a  
57 seismogenic zone extending over 3000 km along the northern edge of the Caribbean Sea (Fig. 1) and  
58 a deforming region that includes two large strike-slip fault systems, the Septentrional-Oriente fault  
59 zone (SOFZ) in the north and the Enriquillo-Plantain-Garden fault zone (EPGFZ) in the south (Mann *et*  
60 *al.*, 1991; Calais and De Lépinay, 1995). The SOFZ extends from the Mid Cayman spreading center,  
61 initiated 50 Ma ago (Leroy *et al.*, 2000), runs along the Southern coast of Cuba to cut across the  
62 northern Hispaniola (Calais and Mercier de Lépinay, 1989; Mann *et al.*, 1998). The EPGFZ, the  
63 prolongation to the east of Jamaica of the Walton fault, cuts across the Southern Peninsula in Haiti  
64 and dies out eastwards in the vicinity of the Muertos trough south of Hispaniola, delimiting the  
65 Gonâve microplate (DeMets and Wiggins-Grandison, 2007) (Fig. 1). Between the two strike-slip  
66 systems, the middle to late Eocene East Cayman margin is described offshore Jamaica (Leroy *et al.*,  
67 1996) and the early Miocene to Present collisional wedge of Haiti, well-described onshore (Pubellier  
68 *et al.*, 2000), continues offshore in the Gonâve Gulf (Figs. 1 and 2).

69 Destructive earthquakes are reported along the NCarB both onshore and offshore (Ali *et al.*, 2008;  
70 Fig. 1). The most recent historical earthquakes known to have hit Northern Hispaniola are the 1842  
71 event in Haiti and the 1562 event in Dominican Republic (Prentice *et al.*, 1993). Both events are  
72 commonly ascribed to the offshore portion of the Septentrional fault because paleosismological  
73 studies show that no surface rupture has occurred on the onshore Septentrional fault in central  
74 Dominican Republic in the last 800 years (Prentice *et al.*, 2003). Recent studies of historical  
75 earthquake accounts (ten Brink *et al.*, 2011; Bakun *et al.*, 2012) that have nonetheless assigned  
76 historical earthquakes to the onshore strike-slip faults remain challenged by the available  
77 paleosismological studies (Prentice *et al.*, 2013). The 6-12 mm/yr late Holocene slip rate of the  
78 Septentrional fault derived from the paleoseismological restoration (Prentice *et al.*, 2003) appears in  
79 agreement with the rate of  $9.8 \pm 2$  mm/yr computed from GPS along the Septentrional fault (Benford  
80 *et al.*, 2012, Fig.1). Historical events reported for southern Hispaniola are commonly ascribed to the  
81 Hispaniola onshore portion of the EPGFZ (Ali *et al.*, 2008). The source of the 2010 Haiti earthquake  
82 that remains uncertain (Bilham, 2010; Calais *et al.*, 2010; Prentice *et al.*, 2010; Mercier de Lépinay *et*  
83 *al.*, 2011, Douilly *et al.*, 2013) demonstrates the uncertainty inherent in the assignment of historical  
84 events to particular fault segments in the absence of contemporary observations of surface rupture  
85 or paleoseismic data. Benford *et al.* (2012) computed a  $6.8 \pm 1$  mm/yr GPS-derived horizontal slip rate  
86 for the EPGFZ but the short-term geological slip rate is unknown.

87 Offshore and onshore investigations were performed soon after the 2010 earthquake in the vicinity  
88 of Port-au-Prince to search for the source fault of this event (Hayes *et al.*, 2010; Prentice *et al.*, 2010;  
89 McHugh *et al.*, 2011; Mercier de Lépinay *et al.*, 2011). Here we report the results of two systematic  
90 offshore surveys of the NCarB from Cuba to Hispaniola and from Jamaica to Haiti and our analysis  
91 aimed at deciphering the segmentation of both fault systems. The marine geophysical data we  
92 collected (swath bathymetry from Haiti-sis and Norcaribe cruises, 1.8-5.3 kHz sub-bottom profiles  
93 and seismic reflection from Haiti-sis cruise) allow us to characterize the detailed geometry and  
94 kinematics of these two fault systems as well as to image the most recent cumulative fault trace  
95 disrupting the sea-bottom.

96

## 97 **2 – Geometry and segmentation of the strike-slip fault systems**

98 Multibeam bathymetry data reveal the geometry of the active submarine fault systems between  
99 Cuba and Haiti for the SOFZ, and between Jamaica and the Southern Peninsula of Haiti for the EPGFZ  
100 (Fig. 2). The faults we characterize as active bear by sharp scarps disrupting the sea-bottom and  
101 affect the shallowest unconsolidated sediments on the seismic profiles with suitable resolution to  
102 image the surficial sediments. Older faults bear significantly degraded scarps and the faults reported

103 inactive do not disrupt the uppermost seismic units on the high-resolution seismic profiles. Active  
104 fault traces are very well preserved, especially the youngest strike-slip cumulative fault scarps that  
105 imprint the submarine landscape (Figs. 3, 4). The active fault system is remarkably linear and  
106 comprises a single strand along much of its length (Figs. 3, 4). Both fault systems display notable  
107 bends in their strikes. The strike of the SOFZ changes from N88°E to N100°E at 20°N and 72°50'W,  
108 south of Tortue Island (Fig. 3) and that of EPGFZ changes from N78°E to about EW west of Southern  
109 peninsula at 18°18'N and 74°30'W (Fig. 4). The fault segmentation, key information for seismic  
110 hazard assessment (e.g.; Wells and Coppersmith, 1994), can be defined on the basis of morphological  
111 and structural discontinuities such as fault bends and small jogs.

112 Along the active trace of the SOFZ, four distinct overlapping segments can be mapped from west to  
113 east. The western 90 km-long segment, segment 1 on Figure 3, runs offshore Cuba eastward to the  
114 Punta Caleta high, from 75°W to 74°05'W. From 74°10'W to 73°03'W, a second 125 km-long segment  
115 bends 10° clockwise near longitude 73°40'W, changing strike from N80°E to N90°E and traverses the  
116 no longer active Windward Passage Deep pull-apart. From 73°25'W to 72°25'W, a third 100 km-long  
117 segment trends N95°E west of the south Tortue Island bend and N100°E east of the bend. A fourth  
118 100 km-long segment also trends N100°E and runs from east of Tortue Island eastward to the  
119 Dominican Republic (segment 4 in Fig. 3).

120 Along the EPGFZ, we interpret three distinct, overlapping, offshore segments on the basis of  
121 structural discontinuities (Fig. 4). Each segment has a clear morphologic imprint on the seafloor.  
122 From west to east, the eastern Jamaican segment corresponds to the offshore continuation of the  
123 Plantain Garden Fault described in Jamaica (Burke *et al.*, 1980; Mann *et al.*, 1985; Koehler *et al.*,  
124 2013). The offshore portion of the eastern Jamaican segment is 25 km-long. The boundary between  
125 the Eastern Jamaican segment and the Western segment is defined by a left stepover at longitude  
126 75°58'W (Fig. 4). The Western segment, about 70 km long, is associated with horsetail structures  
127 near the left step (Fig. 5) and traverses the 2800 m-deep Morant basin. Midway across the basin the  
128 active fault trace bisects a small compressional push-up (Fig. 5) and continues eastward to longitude  
129 75°20'W. The Central segment (75°20'W to 75°10'W) is about 50 km long and overlaps the western  
130 segment for about 25 km. North-dipping thrusts, a few km apart of and sub-parallel to the central  
131 segment occur south of the main fault along most of its length (Fig. 4, 6). The eastern segment  
132 extends from 75°10'W, where a series of thrusts splay off the main strike-slip trace, to 74°33'W. The  
133 distance between the strike-slip trace and the thrust traces increases eastwards to reach a maximum  
134 of 15 km in the eastern Matley basin. The boundary between the 40 km-long eastern segment and  
135 the western Haitian segment is marked by a 2 km left-stepover, with both segments overlapping by  
136 20 km. The western Haitian segment continues onshore Southern peninsula of Haiti along the base of  
137 a south-facing cumulative fault scarp (Figs. 1 and 4).

138

### 139 **3. Fault kinematics, offset morphologies and slip-rate estimate**

#### 140 *3.1 – Southern system - EPGFZ*

141 Young submarine morphologies offset by strike-slip faults are rare because passive markers are  
142 unusual on the seafloor or because any such passive markers, if present, are commonly buried by  
143 sedimentation. This is the case for the EPGFZ and one has to rely on unambiguous kinematic  
144 indicators to assess the fault motion, such as in the Morant basin where the western and central  
145 segments overlap (Figs. 4 and 6). There, nearby the western tip of the central segment, *en echelon*  
146 pressure ridges testify for a primary left-lateral motion (Figs. 6 a,b). The *en echelon* ridges are well-  
147 expressed on the seafloor over a length of 7-8 km (Fig. 6b). An extensional horsetail splay by the left  
148 step-over between the western tip of the western segment and the eastern tip of the Jamaican  
149 segment also attests to left-lateral motion (Fig. 5). The regularly spaced normal faults branch from  
150 the master fault to the north where the western and Jamaican segments of the EPGFZ step-over.  
151 Further east, on the floor of the Morant basin, the fault cuts across a prominent structure obvious  
152 both on the reflectivity image and on the bathymetric map. A superficial analysis may induce doubt  
153 regarding the sense of motion of the EPGFZ, as it shows an apparent right-lateral offset (Fig. 6c).  
154 However, a more careful analysis reveals the presence of a restraining bend on the master fault that  
155 is associated with left-lateral motion (Fig. 5). In the Gobi Altai region such features have been  
156 extensively described along gentle bends of the main strike-slip system (Bayasgalan *et al.*, 1999;  
157 Cunningham, 2007). The local restraining bend along the EPGFZ is now bypassed by the main strike-  
158 slip fault in agreement with a primary strike-slip motion at depth.

159 The Navassa basin, located on the central segment at the longitude of 75°15'W, is a 40-km-long and  
160 5km-wide asymmetric basin (Fig. 4). Sub-bottom seismic profiles (1.8-5.3 kHz) show that this basin is  
161 deeper along the master strike-slip fault (Fig. 4 lower right inset). Such asymmetric basins are  
162 typically formed along strike-slip fault systems (Ben-Avraham and ten Brink, 1989; Mann *et al.*, 1995;  
163 Cunningham, 2007; Mann, 2007; Smit *et al.*, 2008). The sedimentary sequence infilling the Navassa  
164 basin is thicker towards the north, where the present-day depocentre is located along the main  
165 strike-slip fault (lower right inset of Fig. 4). A large landslide (4 by 4 km), possibly earthquake-  
166 induced, impinges on the southern flank of the Navassa ridge and moved southward within the  
167 Navassa basin (Fig. 4 upper right inset). Similar mass movement may present a source of tsunami for  
168 the nearby coast of Haiti and Jamaica (Hornbach *et al.*, 2010).

169 The EPGFZ cross cuts pre-existing morphologies and the current deformation stage is superimposed  
170 on older tectonic structures as depicted by the seismic section crossing the Morant basin (Fig. 7). The  
171 sediment layers have been tilted by the previous activity of a normal fault in a large half-graben

172 similar to the ones identified in the northern Jamaica margin (Fig. 1; Leroy *et al.*, 1996). The overall  
173 sedimentary infill has been subsequently folded with unevenly distributed gentle folds and the final  
174 crosscutting by the EPGFZ is associated with very limited adjacent compressive structures.

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176

### 177 *3.2 – Northern fault system - SOFZ*

178 We identified a notable exception to the lack of well-identified offset geomorphic features on the  
179 SOFZ at about 19°50'N-72°14'W. There, the course of a NS channel flowing northward veers abruptly  
180 to the west within the strike-slip furrow (Fig. 8, red arrows) and bends abruptly again to the north to  
181 cross the North Hispaniola Deformed Belt (Fig. 3a). The canyon is 400-800m deep and its  
182 downstream course incises a carbonate platform, which outcrops closely (<~20km) in Dominican  
183 Republic and Haiti (Calais *et al.*, 1992). In between the upstream and downstream courses, there is  
184 no significant canyon south of the fault. However, the upstream part of the channel faces another  
185 channel north of the fault (Fig. 8, green arrow) but the latter is beheaded at the fault precluding a  
186 former continuity of these channels as well as the piracy of the upstream course of the offset  
187 channel. Therefore the 16.5 km-long dogleg offset of the channel has been preserved (Fig. 8, red  
188 arrows).

189 A similar shift of a second canyon occurs toward the west, near the Tortue Island (Fig. 8). The  
190 corresponding offset is more difficult to assess because there are several possibilities of upstream  
191 courses (blue arrows on Fig. 8), the easternmost one pointing to a plausible offset of 16.5 km. The  
192 analysis of the bathymetric profiles (Fig. 9) confirms this estimate although we lack full multibeam  
193 bathymetry coverage of the shallow platform merging with the shore to verify that this largest offset  
194 does correspond to a large canyon merging onland with a significant river. The NGA nautical charts  
195 offshore Cap-Haitien and Tortue Island combined with the new dataset provide some candidates for  
196 the onshore source river system (Fig. 8).

197 In the western part of the SOFZ, the active fault trace crosses the Windward Passage Deep through  
198 the basin (Fig. 3; at the longitude of 73°50W). This 40 km-long, 10 km-wide and 3700 m-deep basin is  
199 described as an early Miocene pull-apart by Calais and De Lépinay (1995), and it is now cross-cut by  
200 the present trace of SOFZ (Fig. 3).

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#### 207 **4 – Discussion and Conclusions**

208 Our work brings to light a hitherto poorly known, 500km-long portion of the offshore active strike-  
209 slip fault systems of the North America-Caribbean plate boundary. The bathymetry and seismic data  
210 delineate multiple left-lateral, 50 to 100 km-long, strike-slip fault segments. The geometry of the  
211 active fault systems does not seem to be controlled by pre-existing tectonic features (rifted basin,  
212 folds). The lengths of the fault segments we have identified along both the EPGFZ and the SOFZ are  
213 capable of producing Mw ~7-7.7 earthquakes (e.g.; Wells and Coppersmith, 1994) that are likely to  
214 trigger prominent submarine landslides in the vicinity of Hispaniola similar to the one we highlight in  
215 Fig. 4.

216 Paleoseismic studies performed along the onshore SOFZ trace in Dominican Republic show that the  
217 most recent ground-rupturing earthquake occurred more than 800 years ago (Prentice *et al.*, 1993;  
218 Prentice *et al.*, 2003), suggesting the 1842 earthquake most likely occurred along the offshore  
219 segment documented here, in tune with the triggering of a tsunami at Cap Haïtien (Lander *et al.*  
220 2002; Prepetit, 2008).

221 On the SOFZ, the 16.5 km dogleg offset of two canyons is not dated, nor is the limestone platform  
222 into which the canyons are incised, ruling out a direct determination of the geological slip-rate of the  
223 SOFZ. Based on the geology of adjacent coast we propose an estimate age of 2 Ma for the upper part  
224 of the carbonate platform which is reefal onshore (Villa Vasquez series; De Zoeten and Mann, 1991;  
225 Calais *et al.* 1992) and with a suggestive karstic morphology offshore (Fig. 8) indicating a low sea level  
226 and subaerially environments, respectively. The occurrence of stepped terraces along the northern  
227 wall fault implies the record of paleo-sealevels, a position above sea surface where waves action  
228 progressively erase the karstic terrain and a progressive uplift of the northeastern block relative to  
229 the southern one. Eastward wedge of stepped terraces indicates a variable uplift along the fault  
230 coeval with the activity of the SOFZ for significant time periods (Fig. 8). If the  $9.8 \pm 2$  mm/yr slip rate  
231 derived from the GPS (Benford *et al.*, 2012) has remained constant, at least during the whole  
232 Quaternary, the 16.5 km offset would yield an age of ~1.8 Ma for its inception. Interestingly, this age  
233 matches that estimate of the upper part of the carbonate platform and of the recent uplift of the  
234 Septentrional Cordillera in the northern Dominican Republic which is bounded on its southern edge  
235 by the onshore portion of the SOFZ (Calais and Mercier de Lépinay, 1989) and of the northwestern  
236 Cordillera of Haiti (Bowin, 1975; Nagle *et al.*, 1979; Prentice *et al.*, 1993; Mann *et al.*, 1995; 1998). ~  
237 1.8 Ma is the likely age for the uplift above sea-level of the erased karst block, the Tortue island and  
238 further west, the windward passage sill (Calais and De Lépinay, 1995). Channels offset and vertical  
239 movements are probably indicative of a southward plate boundary shift along SOFZ (around 2 Ma)



240 that could be driven either by the Bahamas-Hispaniola collision (Dolan *et al.* 1998; Mann *et al.* 2002)  
241 or deeper processes such as Slab Edge Push (Van Benthem *et al.* 2014). Our study does not allow  
242 deciphering between the importance of the two mechanisms. Nonetheless the geometry and  
243 segmentation of the offshore SOFZ and EPGFZ and the primary strike-slip motion highlighted along  
244 the offshore portion EPGFZ are key information for seismic hazard assessment, stress-transfer  
245 calculations and GPS-derived kinematic models.

246

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## 374 **Figures Captions**

375

376 **Figure 1:** Tectonic map of the northern Caribbean plate boundary. Orange dots indicate the  
377 presumed epicenter of Mw>7 historical earthquakes from (Ali *et al.*, 2008), orange dashed lines  
378 indicate imprecisely localized historical earthquakes. Velocities in mm/yr reported from a block  
379 model incorporating the available GPS data (Benford *et al.*, 2012). The studied parts of the fault  
380 systems in this paper are outlined in red. Faults in black are from previous studies (Calais and de  
381 Lepinay *et al.* 1989; Calais, E., and de Lepinay, B.M., 1991; Mann *et al.* 1995; 1998; Leroy *et al.* 1996 ;  
382 Mauffret and Leroy 1997; Granja Buna *et al.* 2014; in Gulf of Gonave from Corbeau *et al.* 2014) **Inset:**  
383 Geodynamic map. NOAM: North American; CAR: Caribbean; GMP: Gonâve microplate. MCSC: Mid-  
384 Cayman spreading center; CT: Cayman trough; D.R.: Dominican Republic; NJAM: North Jamaican  
385 Margin; OFZ: Oriente Fault zone; EPGFZ: Enriquillo-Plantain Garden Fault zone; SFZ: Septentrional  
386 Fault zone; WFZ: Walton Fault zone; SDB: Santiago Deformed Belt; BPF: Bahamas platform; HsB: Haiti  
387 sub-basin; BR: Beata ridge; BF: Bunce Fault, BoF: Bowin Fault, MR: Mona rift.

388

389 **Figure 2:** 50 m resolution bathymetric map of the Hispaniola area from several cruises: Haiti-sis 1&2  
390 (2012, 2013 on R/V L'Atalante), Norcaribe (2013 on R/V Sarmiento de Gamboa), Haiti-OBS (2010; R/V  
391 L'Atalante; (Mercier de Lépinay *et al.*, 2011)) and Seacarib 1 & 2 (1985, R/V Conrad; 1987, R/V J.  
392 Charcot; (Calais and De Lépinay, 1995; Leroy *et al.*, 1996; Mauffret and Leroy, 1997)). Rectangles with  
393 number locate the corresponding figures. Inset: Location of the cruises Haiti-OBS (orange); Seacarib 1  
394 & 2 (purple); Norcaribe (green); Haiti-sis 1 & 2 (blue).

395

396 **Figure 3:** Bathymetric map of the Septentrional-Oriente fault zone (SOFZ) and tectonic  
397 interpretation. Fault segmentation inferred from distinct geometric fault complexities (fault bends  
398 and small jogs). W.P. Deep: Windward Passage Deep. Active fault segments are in red and inactive  
399 one or pre-existing structures from older tectonic events are in black. Onland Hispaniola the main  
400 rivers are shown in blue.

401

402 **Figure 4:** Bathymetric map of the southern system Enriquillo-Plantain Gardain Fault zone (EPGFZ) and  
403 tectonic interpretation (Lower panel). Active fault segments are in red while inactive or older ones  
404 are in black. The eastern Jamaican segment is the offshore continuity of the Plantain Garden Fault  
405 identified onland in Jamaica. The western Haitian segment is the prolongation of the Southern  
406 Peninsula fault observed in Haiti (faults are drawn in green onland). These segments are connected

407 by three hitherto unrecognized, western central and eastern offshore segments. J: Jamaica; H: Haiti.  
408 Lower right Inset is a subbottom seismic profile (1.8-5.6kHz) crossing the EPGFZ in the Navassa basin  
409 (grey line for location). Upper right inset is a close-up of the northern wall of the Navassa basin  
410 showing a large landslide (4x 4 km). The white dashed lines represents the scar of the mass failure  
411 and white arrows point to the corresponding deposits on the basin floor.

412

413 **Figure 5:** Upper panel: Bathymetric map of the western termination of the western segment of the  
414 EPGFZ. See figure 2 for location. Lower panel: Tectonic interpretation with extensional horsetail splay  
415 and restraining bend in the Morant basin. Note the very limited local shortening observed at the  
416 restraining bend ultimately bypassed by the most recent fault trace in the Morant basin, in  
417 agreement with the occurrence of recent releasing bend described onshore crosscut by the Haitian  
418 prolongation of the strike-slip fault system (i.e Clonard pull-apart (Fig. 1) (Mann *et al.*, 1995)).

419

420

421 **Figure 6:** a, 3D-view from the SW of the western offshore portion of the EPGFZ. Two overlapping  
422 segments with linear fault traces (black arrows), 3 km apart, cut across a pre-existing bathymetry.  
423 The dashed line indicates the location of the seismic profile on Fig. 7. b, Detailed bathymetry along  
424 the two parallel fault traces. The western segment to the north is highlighted by a narrow strike-slip  
425 furrow. The central segment to the south displays 1.5 km long, 150 m wide, and 15 m high *en echelon*  
426 pressure ridges. c, Reflectivity image of the active trace of the western segment of the EPGFZ cutting  
427 across a prominent transpressive structure (restraining bend ; see Cunningham & Mann, 2007 for  
428 classification).

429

430 **Figure 7:** Migrated shallow seismic profile across the EPGFZ nearby the Morant basin and  
431 corresponding interpretation (upper panel). Red lines represent recent active trace of the EPGFZ,  
432 clearly identified on the profile. Other faults (black lines) are supposed to be active before and not  
433 during the very recent motion along the EPGFZ. A gentle compressive structure in the north of the  
434 EPGFZ is also crosscut by this seismic profile. Pre-existing southward-tilted series and syn-tectonic  
435 sequence are deformed before the recent motion along the active fault (Corbeau *et al.* 2014).

436

437 **Figure 8:** Map view of the offshore prolongation of the Septentrional Fault (labelled SOFZ), North of  
438 Haiti (see Figs 1 & 2 for location). Note the linearity of the fault trace and fault parallel canyon, and  
439 the downstream and upstream courses of two offset channels (large vertical arrows). Note the 16.5  
440 km dogleg offset of the eastern canyon (red arrows) which upstream course faces a beheaded

441 channel north of the fault (oblique white arrow) and parallels a shallow canyon south of the fault  
442 (vertical orange arrow) For the western dogleg offset canyon, the downstream canyon is beheaded  
443 while the upstream feasible ones merge with the bottom of the fault parallel canyon. The size of the  
444 blue arrows south of the fault increases with that of the resulting offset, the biggest arrow pointing  
445 to the likely 16.5 km offset. The offset channels, 400-800m deep, incise a platform, presumably  
446 carbonated which outcrops in Dominican Republic (Calais *et al.*, 1992). North of the fault, large parts  
447 of the platform display a hummocky pattern with impressive swallow holes, which is suggestive of  
448 drowned karstic terrain. Stepped terraces may indicate a gradual uplift of the northeastern block  
449 relative to the southern wall fault. Onland present-day rivers are indicated (thicked lines are the  
450 major one) and NGA nautical charts available offshore Cap-Haitien and Tortue Island are used to  
451 draw two channels (brawn lines). Note that the large canyon (orange arrow) was already mapped on  
452 the nautical chart but appears unlikely for matching the red arrow canyon with our multibeam data.

453 **Figure 9:** a, Bathymetric profiles parallel to the fault projected on a vertical plane striking N100°E.  
454 Arrows are drawn as in fig. 8 and location of the profile is shown in the inset map. The downstream  
455 offset canyons are 400-800 m wide and 1600-1250 m deep while the downstream-beheaded channel  
456 to the east (oblique green arrow) is less incised. Minimum offset of the eastern channel, shown by  
457 the red arrows, is 16.5km. A smaller offset is ruled out by the absence, south of the fault, of any  
458 significant canyon between the upstream and downstream courses. A larger offset of 24 km (orange  
459 arrow) appears unlikely because, south of the fault, the next channel to the east with an appropriate  
460 width is less incised and too shallow to match the morphology of the downstream offset channel. b,  
461 The profile in the south of the fault (grey) has been displaced by 16.5 km to restore the offset of the  
462 canyon. Note also the restoration of the overall morphology with similar regional slopes on both side  
463 of the main canyon.

464  
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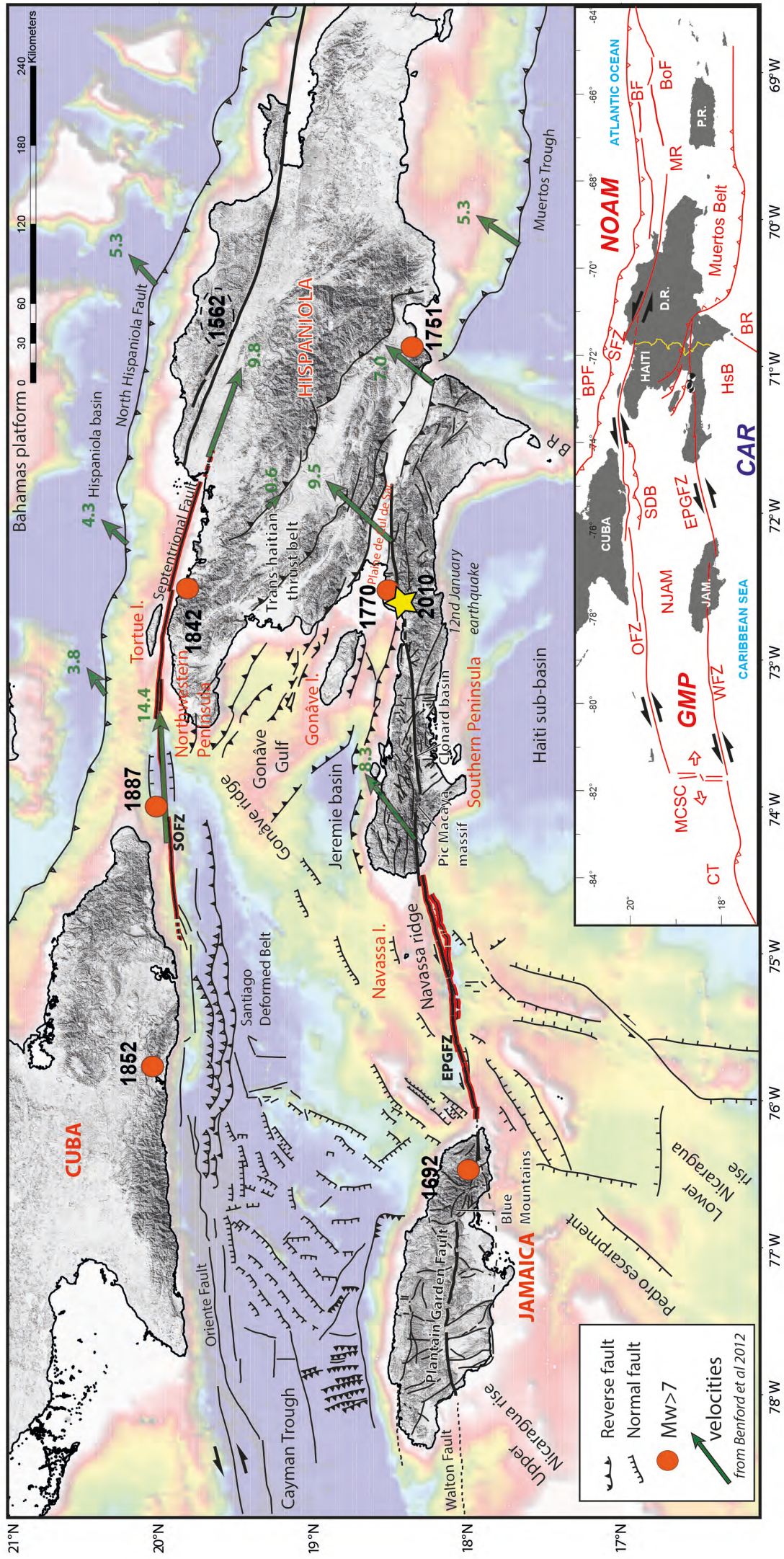


Fig 1

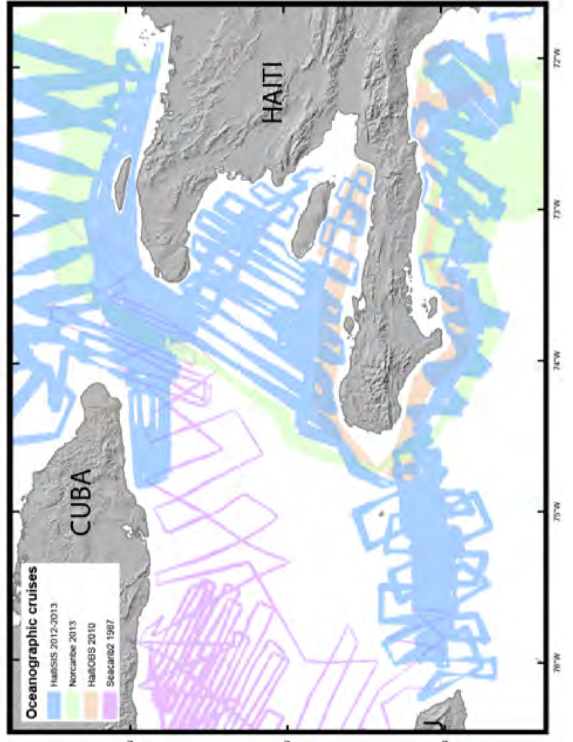
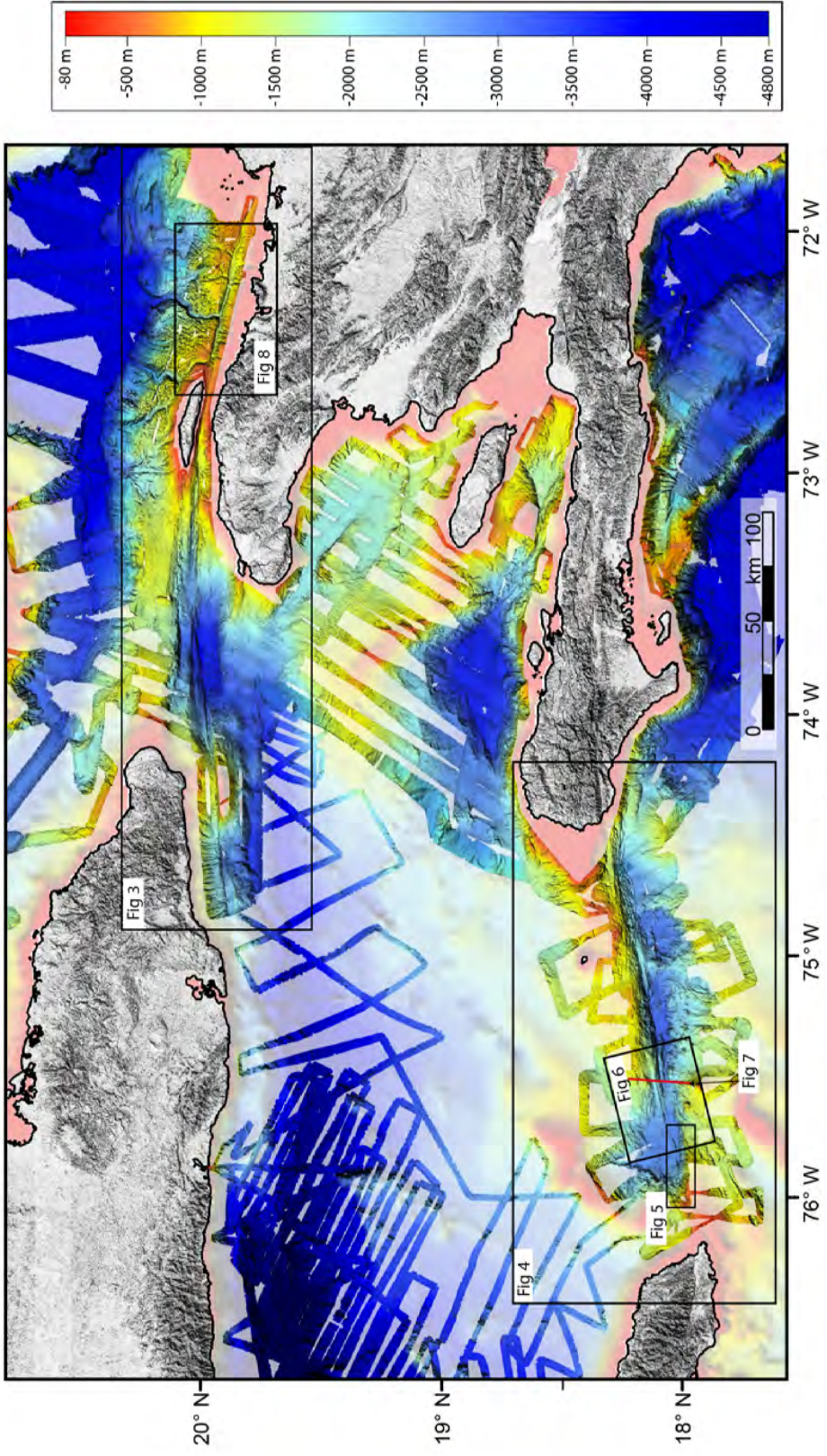


Fig 2



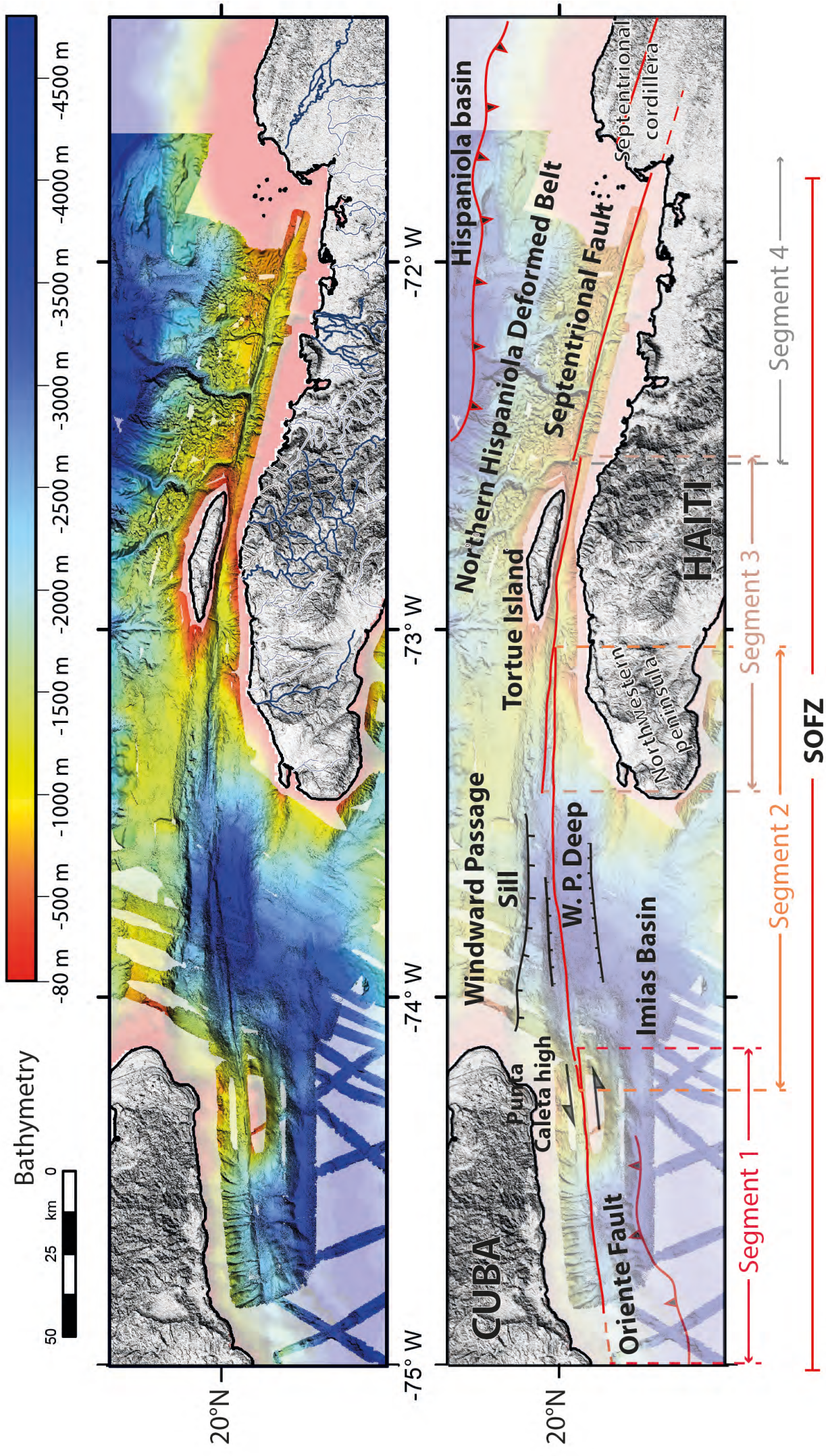


Fig3

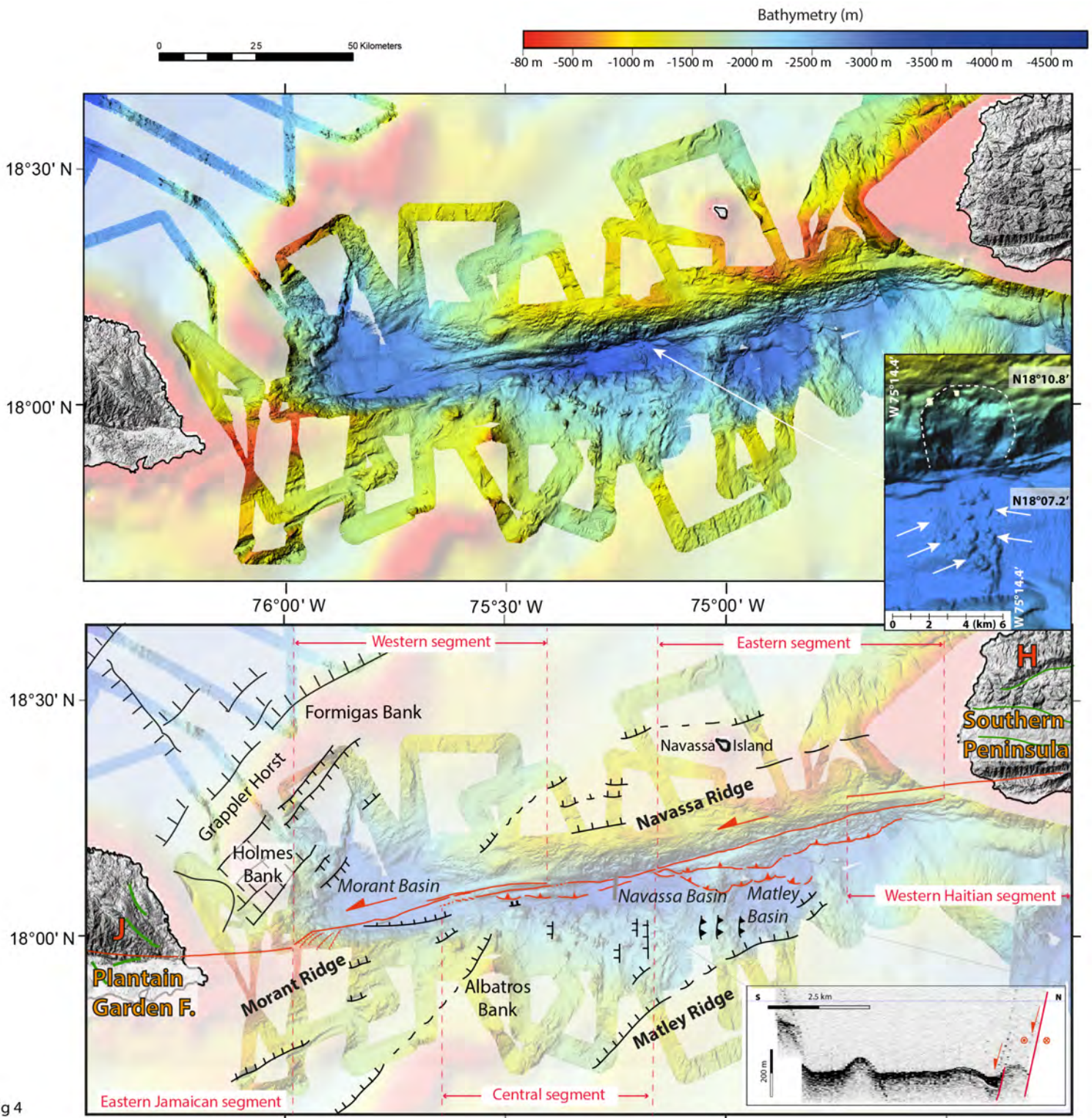
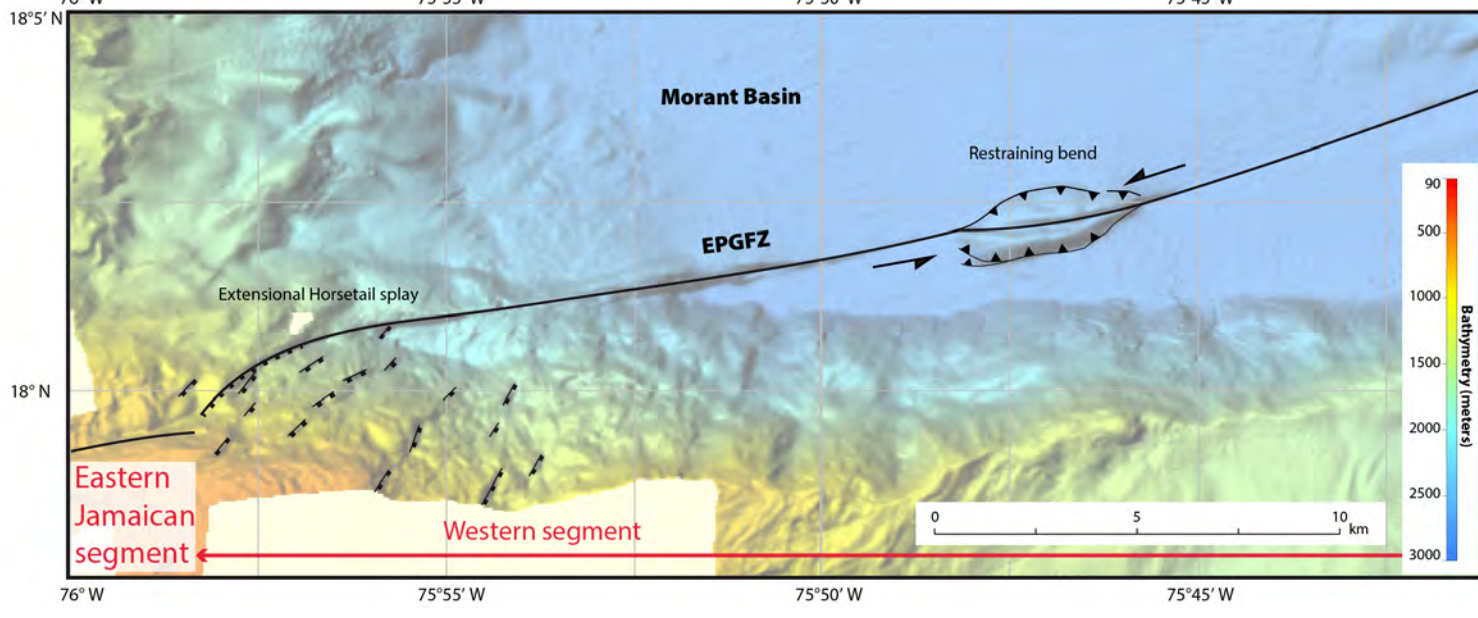
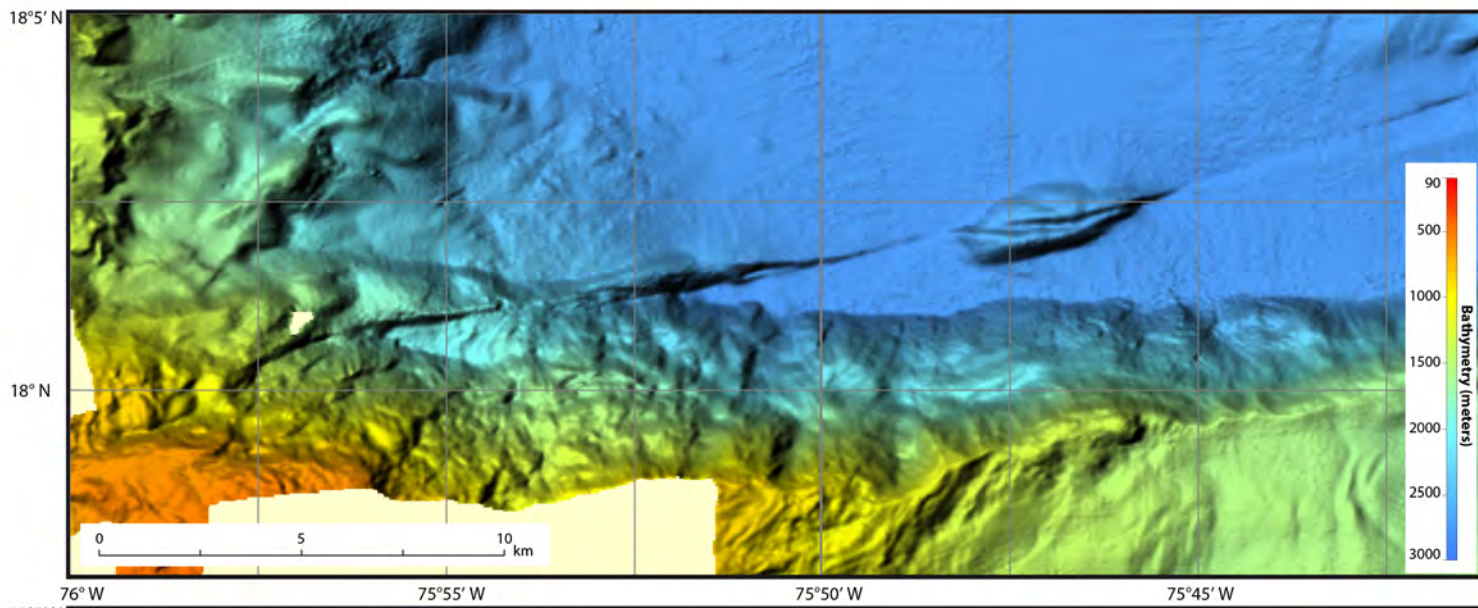


Fig 4



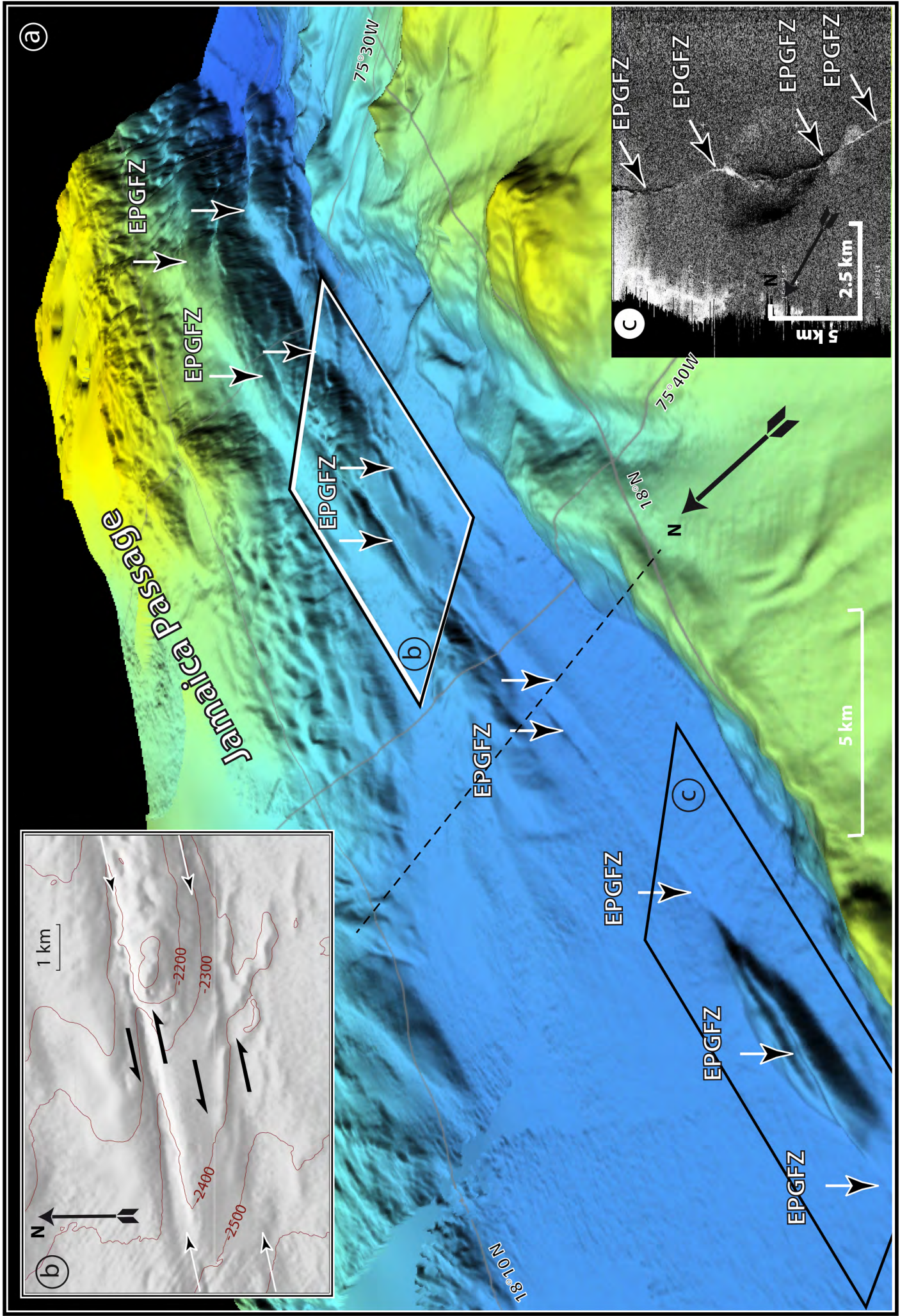


Fig 6

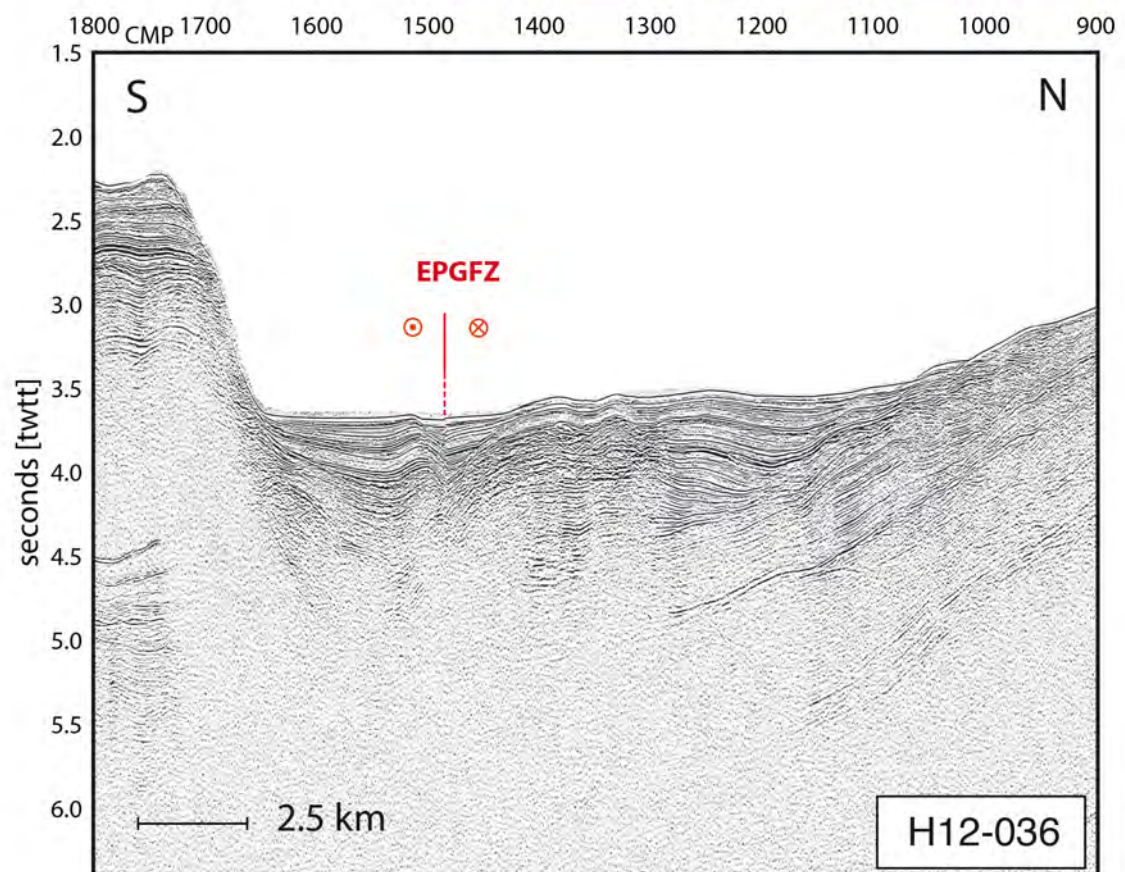
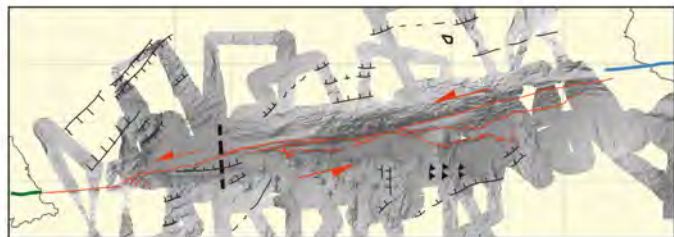
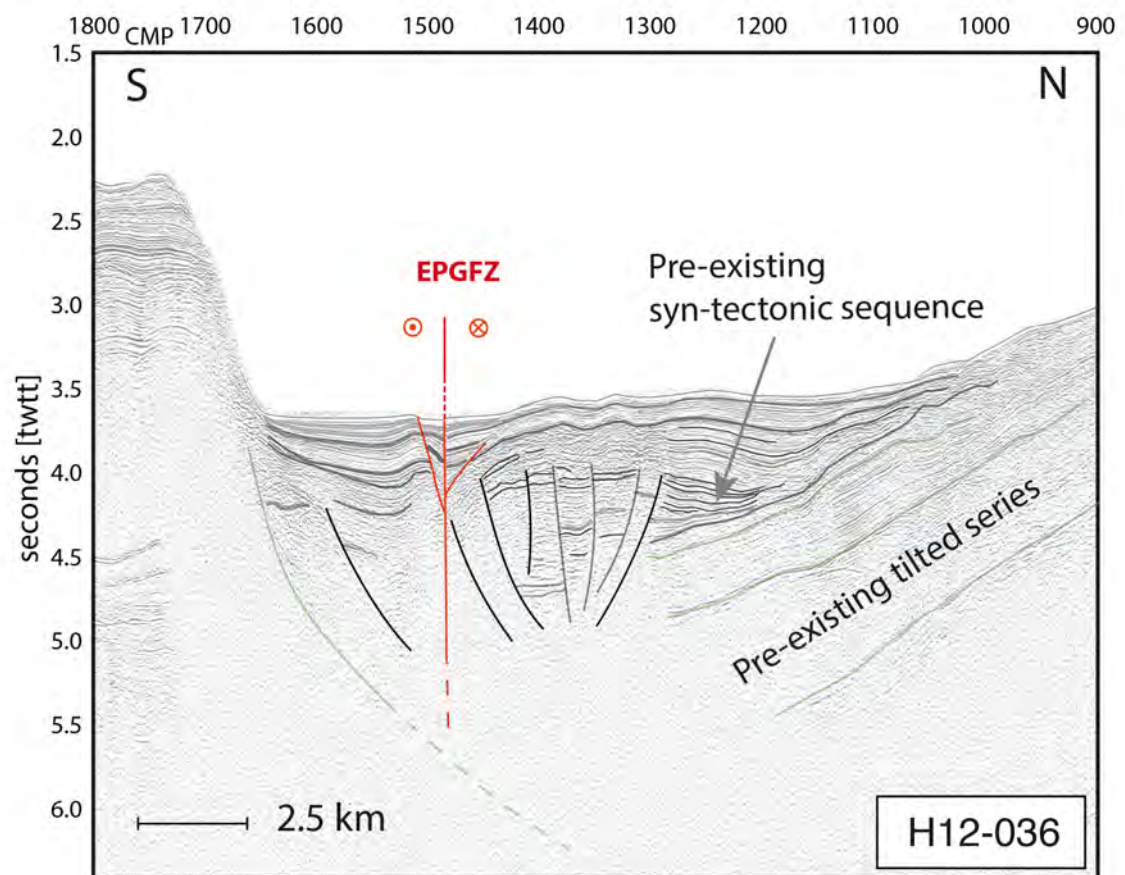


Fig 7

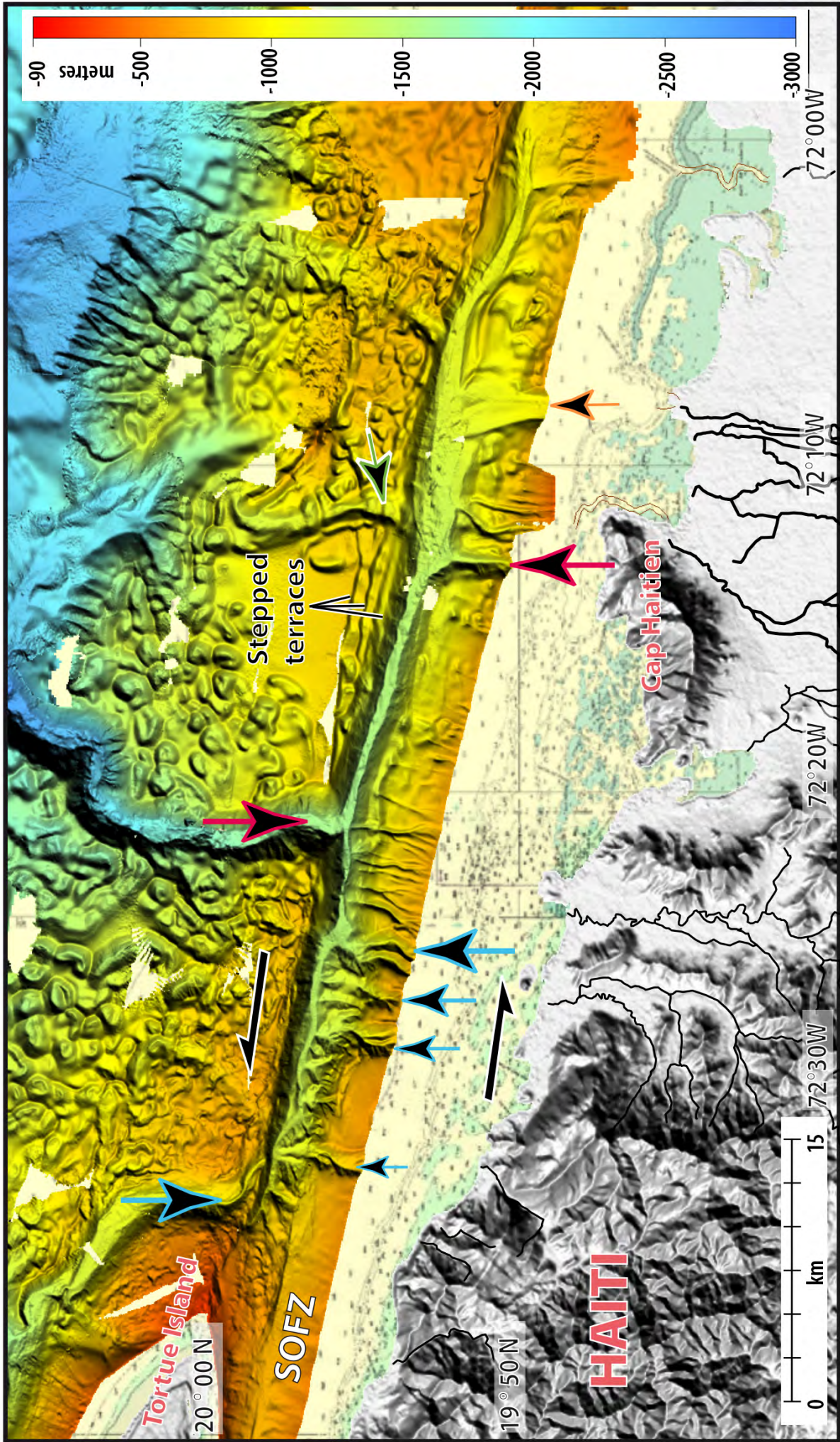


Figure 8

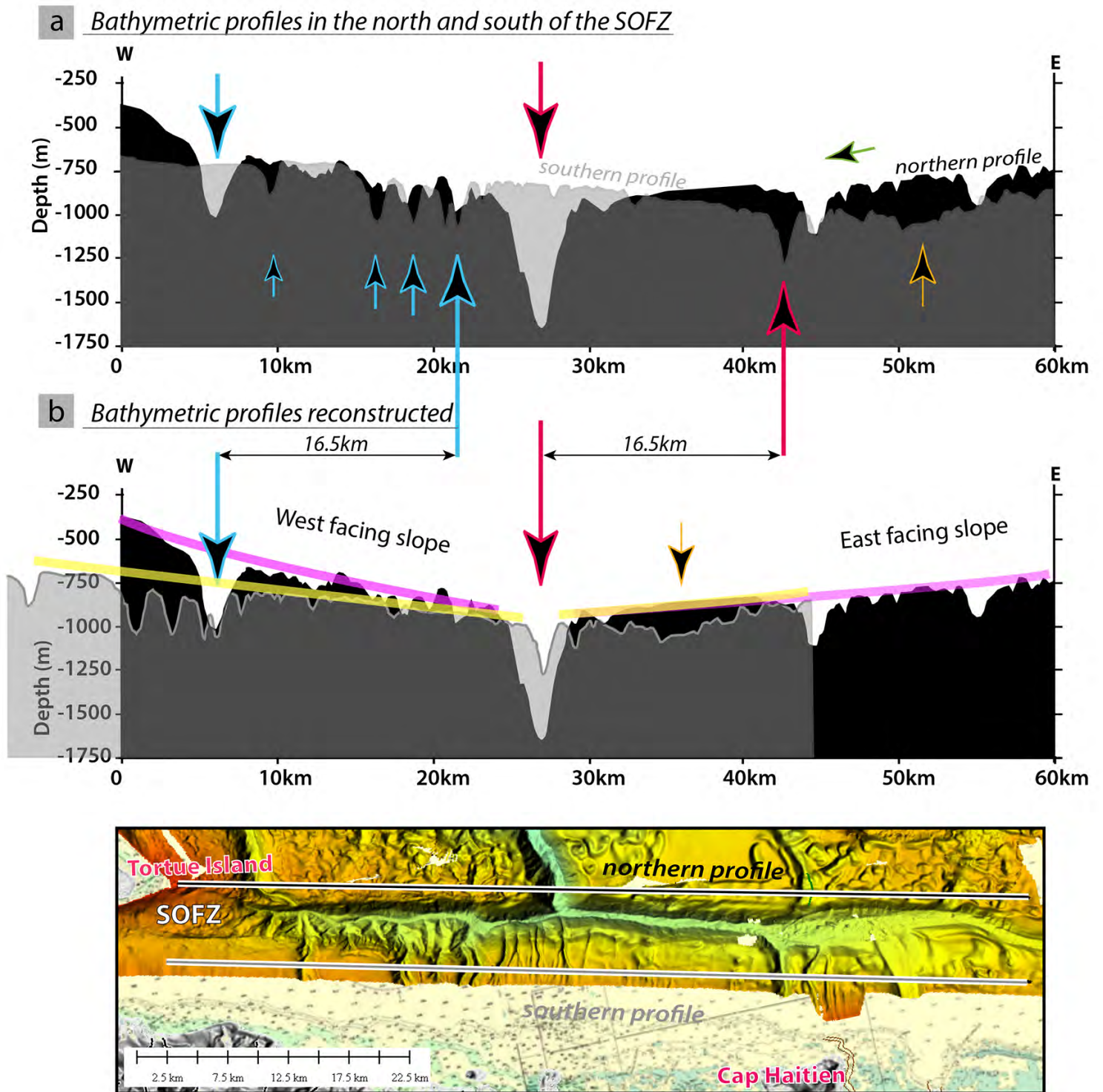


Figure 9