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Interactive comment on "The Ogooue Fan (Gabon): a modern example of deep-sea system on a complex sea-floor topography" *by* Salomé Mignard et al.

Salomé Mignard et al.

mignard.salome@gmail.com

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We are thankful to Dr haugton for his interest in our paper and for his helpful and constructive comments. We have made efforts to answer most of his questions in the revised manuscript. Here, we report below the reviewers' comments answers concerning the main issues.

This paper provides interesting details of a part of the West African margin for which there is limited data currently available in the public domain. It describes a deep-sea fan system related to sediment discharged from the Ogooue River in Gabon (although it is also characterised as an apron on the basis of multiple feeder systems). The area sits between areas where extensive work has already been published so it fills a gap and also demonstrates some features unique to this part of the margin. The focus here on tracing slope canyons and channels down slope across what is a topographically complex slope and basin floor on account of the presence of the Cameroon volcanic line across which the system traverses. The work is based on recent sea floor and shallow echosounder and seismic imaging, as well as an array of shallow cores, some of which have already been published, but not from the perspective of facies distribution and wider system character so there is significant new material here. What will be of particular interest to the deep-water research community is the complex way in which the system is responding to the changing gradients and variable levels of lateral confinement.

The paper includes some spectacular images of a headless valley system that sits mid-way along the transport path (the term distal valley may be a little misleading particularly as there is another confinement further down slope).

The valley is now termed as "mid-system valley" to avoid any misunderstanding.

Unlike deep-sea fans building into open basins, this one has a series of depocenters separated by bypass sectors where gradients are steeper and where flows become more confined. Deep-water systems commonly traverse irregular sea floor topography related to mobile substrates and active or pre-existing structures so this aspect makes the study more than just of regional interest. The set-up in the introduction very much focusses on the west Africa margin but it might be useful to cast it more widely in terms of system response to complex topography and to refer to other examples in the literature – for example the late Bill Normark and colleagues work on headless channels in the California borderland. There has been a lot of work done on stepped slopes and the response of gravity currents to topography, so it is important that the more novel aspects of this system are stressed, and previous work referenced as appropriate.

We agree on this remark and a rewrite of the introduction has been done. As suggested by both reviewers, most information given in the introduction has been placed in the “Context” section, whereas the introduction will focus on the role of complex topographic slopes on depositional processes and fan architecture. This study shows that very subtle gradient changes (less than 0.4°) can have a major impact on the fan construction. These gradients are much lower than the ones previously presented in most of the articles concerning stepped slopes. We have also widened our bibliographic research in order to be able to compare our result with other stepped-slope systems.

One issue that is important in looking at interactions of deep sea systems and topography is whether the topographic is static or dynamic. Some more details on the history of the Cameroon volcanoes and sea mounts would be useful. How young are the volcanoes – is activity continuing in the offshore part of the chain?

All the volcanoes of the Cameroon Volcanic line are more or less of the same age and have been active for at least 65Ma (Lee et al., 1994; Déruelle et al., 2007). Geophysical studies of the line suggest that the volcanic alignment could be related to a deep-mantle hot line (Déruelle et al. 2007). The Bioko island recorded eruption as young as 1923 (Déruelle et al. 1987) whereas Ar/Ar dates realized by Barfod et Fitton (2014) on Sao Tomé volcanic rocks have shown activity as young as 0.036 Ma and proved activity of the volcanic island over much of the Pleistocene. A previous publication from Lee et al. (1994) showed also recent volcanic activity for the Annobon Island (0.2 Ma). This volcanic -and associated seismic- activity could have triggered some down slope processes on the slopes of Sao-Tomé and Annobon. Slump deposits can be seen on the 3.5 kHz seismic lines in the vicinity of these two islands. Unfortunately, we found only limited information in the literature concerning the sea-mounts in our studied area. Emery et al. (1975) described them as part of the basement uplift linked with the Guinea Ridge. Meyers et al. (1998) proposed that these seamounts were primarily composed of old oceanic basement and a thick sediment cover capped with volcanic rocks.

At several points the text mentions mud diapirism – but it is unclear to what extent this is an issue here in terms of sea floor topography. Where are the mud diapirs?

Some mud diapirism appears in the vicinity of Annobon Island. They form small relief on the seafloor (< 20 m high and 100 m of diameter). Their definition is based on morphological characteristics and on the presence of gas in the water column over this structures (Garlan, personal communication). The “small Annobon” is a much larger structure which gathers a large number of smaller mud volcanoes and forms a more than 200 m high and 10 km large mount. Its morphology is very different from the other rocky seamounts of the area which present much steeper slope and a clear pelagic drape.

Given how important pock marks are in the area just to the north, why are these apparently less well developed in the study area? What is different about the Equatorial Guinean margin? Are there any examples of the Jobe et al. depositional canyons and if not why the change along the margin.

According to Pilcher and Argent (2007) who studied the pockmarks in the area north of the Mount Loiret, their presence is due to different processes. Some pockmark trains are related to the presence of abandoned channels buried under hemipelagic sediments (Pilcher and Argent, 2007, Jobe et al., 2010). The pockmarks result from the expulsion of fluid contained the underlying sand after the abandonment of the channel and its filling by fine-grained sediments. This is the case for the pockmark trains located just north of the Cape Lopez lobe that follow the path of buried sinuous channels. The absence of pockmark on the southern part of our studied area where the active channels of the Ogooue fan are settled may be linked with the higher slope gradient that prevents the deposition of thick fine-grained sediments layers. Following the classification of Jobe et al. (2010), the canyons of the Ogouee fan are of two types, some are clearly of “Type I”, they indent the shelf and are pathways for erosive, sand-rich turbidity currents sourced from shallow water. Others are more of “Type II”, they head in deeper water and lack access to coarse-grained sediment. According to Jobe et al., erosive turbidity currents are rare and relatively unimportant in these canyons, favoring their infill by hemipelagic sediments and the formation of pockmarks trains. The development of Type I rather than Type II canyons may be linked with local variations in sediment supply.

Parts of the system apparently show extensive scouring and a range of different features are described, but it is a little hard to see these because they are overlain by the interpretation lines. It would be useful to include a few more un-interpreted sea floor images showing features such as the putative mega flutes.

A new figure showing close-ups of deferent bathymetric features presented in the text has been added. We hope that this figure will allow to better support our interpretations.

Figures 5 and 6 work very well showing one of the leveed channels and the valley feature. It would also be good to see more detail on the 'ponded' lobe associated with the northernmost Cape Lopez canyon – it is currently reproduced at very small scale.

A new figure showing the Cape Lopez intraslope lobe has been prepared and added to the manuscript.

The straight to sinuous channels appear erosional and inset with channel floors well beneath the levees - is this similar to Congo fan? Levees seem to be relatively poorly developed – is this the case?

The channels of the system are indeed deeply incised in the seafloor, below the associated levees, when present. This feature is similar to the Zaire Channel (Babonneau et al., 2002). This incision is observed along most of the channel path and is attenuated only in the distal area. This entrenched morphology prevents extensive overflow of turbidity currents and a low development of external levees. For the Zaire channel it has been proposed that the entrenched morphology of the channel confines the flow and keeps the energy high enough to allow a transport of sediment to very distant areas. This morphology is opposed to the morphology of aggrading channels (such as the Amazon Channel) where the thalweg is perched above the base of the levee system

(Damuth et al., 1995).

I am not quite sure I know what is meant by a secondary channel.

The term “secondary channel” has been replaced by “subsidiary channel” according to the definition of Masson et al. (1995) “channels with no headward connection with an obvious feeder system”

The core data are a very useful compliment to the sea floor and shallow imaging and the age constraints are important in thinking about depositional rates. Are some of the AMS 14C dates new – some have been published already but if the others are new should be properly tabulated with analytical details.

A new table has been added giving details about the new AMS 14C dates, specifying the age reservoir and the calibration curve used.

Only the MIS1/2 boundary is indicated on the core correlation in Fig. 3 but reading Mignard et al (2017) the case is made for penultimate glacial sections as well as last glacial in some of the cores of the basis of stable isotope profiling. It would be useful to indicate this on Fig. 3 where the lower part of KC10 is interpreted previously as MIS6.

We initially didn’t add the older ages for KC 10 to Fig. 3 as only MIS1/2 boundary is discussed in the text. But we understand the reviewer request and the limits of MIS 1 to 6 have been drawn for KC10 on figure 3.

The mid-system incision and valley is a very interesting feature of this system and impressively wide at 15 km, presumably as it collected a number channels. A large volume of sediment has been removed and translated down slope (can you estimate how much?). A significant part of the lower fan system must come from erosion of this valley.

According to our bathymetric data, the volume of sediment removed from the mid-system valley is between 8 to 10 km3. We agree that this important volume of sediments has, in all likelihood, been transported downstream to the most distal lobe. We assumed that these sediments may be preferentially found in the most distal and muddier part of the system. According to the mineralogical composition of the turbidites found in the distal lobe just at the outlet of the valley (KC11) showed that the main source for the sediments in the sandy distal lobe are coming from the Ogooue delta (high density of fresh plant debris).

Channels feeding to it seem better resolved to the north. Presumably during the Holocene (and earlier) transgression, precursors of Manji island may have migrated eastwards, sequentially feeding the various slope canyons ending up at Cape Lopez canyon today.

The development of the Mandji Island started 3,000 years ago (Lebigre, 1883, Giresse, 1975, 1977). The reconstruction of the past positions of the spit showed that it grew north with several successive steps. However, its southern most limit has never changed. It seems thus difficult for us to link its evolution with the feeding of the different canyons of the slope. Nonetheless, it is highly probable that its position change has influenced the feeding of the northernmost canyons. Some of them are currently being infilled with hemipelagic sediment and might have been abandoned due to the growth of the Manji Island.

The shelf/coastal set up is unusual with longshore drift maintaining supply to deep water – comparisons are made with longshore drift in the California margin where longshore drift feeds sand to La Jolla canyon, but the kink in the Ogooue coast sets up a rather different geometry where sand is able to spill downslope at the shelf edge without the need for a canyon to cut back to the modern shoreline.

Currently, the canyons are not fed with sand supply, except for the Cape Lopez canyon. The canyons heads are too far from the coastline to be fed by the littoral drift. The only turbidite recorded during the Holocene highstand (in core KC13) might result from the destabilization of the pre-Holocene sandy deposits found on the continental shelf (Giresse and Kouyoumontzakis, 1973).

One wonders also given the coastal and shelf geometry whether this type of system is partitioned into a contemporaneous sandy supply from the outboard littoral cell (in what is otherwise a sand deficient system) and contemporary mud supply from the extensive bay head delta behind it feeding north towards the Equatorial Guinea margin with its pockmarks and muddy depositional canyons.

The contemporary muddy supply linked with the Ogooue discharge is concentrated north of the Mandji Island. Most of it remains in a mud zone at the mouth of the Ogooue River (Giresse and Odin, 1977). Farther from the shoreline, relict deposit consisting of shelly sand compose the seafloor.

Is that a previous highstand strand plain sitting inboard of the modern bay head delta on Google Earth?

On Google earth the post-Holocene transgression coastline position is clearly visible. It is marked by North-South lineation on the satellite images (Lebigre, 1983).

Specific points lied to line numbers.

Most of these points have been directly corrected in the manuscript. Here are some more specific answers:

Line 23: ‘The most distal depocenters receive only the upper parts of the flows, which are composed of fine-grained sediments’. Why uppermost – does this component not escape to the levees?

The entrenched morphology of the channels prevent an important development of the levees. This feature allow the distal transport of the fine-grained sediments.

Line 25: evidence that the system is active during highstand?

Biscara et al., (2011) showed that the Cape Lopez lobe has recorded recent turbidity currents in the Cape Lopez Canyon proving its current activity.

Line 67: Seems odd Angola Basin lies to north of ridge.

Right, this is a mistake, we were referring to the Guinea Basin, not the Angola Basin.

Line 98: Show backscatter classes on separate figure showing examples.

A new figure has been created to better show the backscatter classes

Line 128: Why no MIS1/2 boundary in KC21 in terms of facies/carbonate content?

Sedimentological study of core KC21 indicates that there has been no important sedimentation change at the MIS1/2 transition. This is in agreement with our scheme of continuous activity of the northern Lobe.

Line 177: source of mass transport deposits – do they have volcanic sand grains or not?

Volcanic sand grains have been found only in core KC01, this is specified in the "sedimentary facies" section of the manuscript.

Line 189: What is a thin incision? Some of detail here hard to see given small scale of seafloor maps – include a blow up?

A new figure has been added and a more precise description of the different canyons is now given in the text.

Line 205: Channel seems to change direction before seamount – why is this? What is bathymetry like between San Tome and seamount? Is there a ridge here?

There is actually a ridge between Sao Tomé and the seamount, this is now better illustrated in Figure 1. We have added some isobaths.

Line 226: How does lobe pass to channels? Provide a more detailed image.

A figure illustrating this part of the system has been added to the manuscript.

Line 248: Any potential for bed waves/cyclical steps?

Some bed waves are seen north of mount Loiret. They are localized on a high gradient part of the slope.

Line 297: is it all delta fed? Components supplied by alongshore transport?

Giresse and Kouyoumontzakis (1973) showed that the Gabon shelf presents a high sandy quartz content due to the successive deposition of the Holocene transgression sediments. These relict sandy deposits might compose some of the turbidite. However, the alongshore drift is localized really close to the coastline creating the sandy spits. This current seems unable to feed the canyons which heads are localized more than 50 km away from the shoreline.

Line 321: Geometry of various scour features are not that well illustrated.

A new figure has been added in the manuscript.

Line 369: Mud volcanoes? Where are these?

We were referring to the “Small Annobon” structure.

All the reference cited here can be found in the revised manuscript

Please also note the supplement to this comment:
https://www.solid-earth-discuss.net/se-2018-99/se-2018-99-AC2-supplement.pdf

Interactive comment on Solid Earth Discuss., https://doi.org/10.5194/se-2018-99, 2018.