Comments Anonymous Referee 1:

Dear authors,

your manuscript presents interpretations of structural geological features in seismic data from two conjugate segments of extended continental margins that formed during the breakup of Gondwana. It contends that the features interpreted, because they are unusual for extended continental margins, must have been contiguous during breakup and that they can therefore be used as tie points for reconstructing the supercontinent. It goes on to use those tie points for the purposes of such a reconstruction, which it describes as defining a two-stage Gondwana breakup history in which an early NW-SE directed phase is followed by a later N-S directed phase.

A two stage history like this is not new, as the text makes clear. Instead, what is new here is the identification and interpretation of unusual structural characteristics, and the dating of the change from NW-SE to N-S directed plate divergence to around chron M38. Earlier studies place the change merely at some time before M25 - around 10-11 Myr earlier. For the manuscript to be taken further, I think it needs to treat its new aspects more strongly and clearly, as follows.

Structural interpretation: Right now, it is unclear how the unusual structural features fit into the proposed breakup history. If I understand the manuscript clearly, these features are interpreted as flower structures, with both transpressional and transtensional segments on the Mozambique margin, and transpressional only on the less well-sampled Riiser-Larsen Sea side. I further understand that motion along these structures should have been occurring until chron M38, after the onset of seafloor spreading in a NW-SE orientation. This set-up requires NE-SW oriented relative motions, parallel to the interpreted COTZs but perpendicular to the NW-SE directed phase of movement that is supposed to have ended with the deformation in the tie-point zones.

Here, our manuscript obviously was not clear. Our interpretation is that there was a rifting and seafloor spreading phase with a NW-SE direction before chron M38. The flower structures developed from M38n on, when transform motion in N-S direction along the Davie Fracture Zone and western flank of Gunnerus Ridge established. This means, the flower structures developed in conjunction with N-S oriented transform motion and that there was no relative motion parallel to the COT. We have modified the manuscript (mainly sections 4 and 5) to explain this better.

The manuscript needs to make clear how NW-SE and NE-SW directed motions can have happened at these margins the same time, or it needs to present an alternative interpretation more clearly.

We apologize that this was not presented clear enough. What we suggest is that there were two consecutive NW-SE and N-S directed motions, these motions were not contemporaneous. There was no movement parallel to the COT. We modified section 5 (Implications on Gondwana breakup) to make this clear.

Timing of the change from NW-SE to N-S directed plate divergence: Although the extrapolations of M41 and M38 onto lines A and C are shown in figures 2 and 4, you do not describe on what basis the extrapolation was done (i.e. was it by noting the distance of M38 from the COTZ further west, or by prolongation of the mapped M38 from further west?) or how accurate the extrapolation is. Figure 8 shows, at least, that the extrapolation has been made over a long distance and that the seismic profile of line A lies sub-parallel to the isochron. This is likely to have made the task of extrapolation difficult, and the result rather inaccurate.

This comment is addressing the accuracy of the extrapolated magnetic chrons. To the west of Profile A (as shown in Figure 1b), there is another profile available in our dataset, that is located directly adjacent to the study area of Müller and Jokat (2017). Our profiles are relatively closely spaced and from the westernmost profile on, the extrapolation was rather simple. We constrained the extrapolation by noting the distance from the COT and are confident that the accuracy of the extrapolation is sufficient for the subject of this manuscript.We added a paragraph in section 4.2 about the extrapolation method.

Regarding the comment concerning Profile A: As it is shown in Figure 8 (now Figure 9), Profile A has the smallest distance from the isochrons defined by Müller and Jokat (2017) and trends NW-SE along the margin, which is not subparallel to the isochrones (that trend NE-SW).

This figure would be easier to use if it were clearly to map the downlap trace of the MJ reflector and its relationship to the extrapolation of the proposed M38 isochron at the Mozambique margin, and if it accompanied a clear description of the extrapolation method in the text. Without these, it is at best difficult for readers to assess what kind of error to expect in your assessment, and at worst likely to leave them actively sceptical of the viability of your results.

We apologize that we missed out to describe the extrapolation method and added a section about it in section 4.2 and in the figure caption of Figure 8 (now Figure 9). We also added the extrapolation line of chron M38n and the downlap locations of the MJ reflector in Figure 8 (now Figure 9). For the RLS, magnetic chrons older than M25 are not available, but we show the downlap location of the MJ horizon in Figure 8b (now Figure 9b).

Some of the following more detailed observations feed back into these two main points, others stand alone:

Line 26: "NE-SW" should be ’NW-SE’. Thanks, this has been corrected.

Line 79: What are the details of this ’considerable debate’? It’s important to describe the details because right now, one of the main new points of your work is a proposal that would end this debate. We added a sentence regarding the discussion about timing and directions of rifting and spreading and rephrased the paragraph.

Line 85-88: The sentence is not clear. Clarify whether the recent studies show older isochrons because they have found new reversal anomalies at marginward locations in new data, or because they have reinterpreted anomalies that were previously assigned to isochron M22. We have revised this paragraph.

Line 117: It is ’Knowledge of’ the crustal nature of Beira High that is required, not the crustal nature itself. Thanks, corrected. We decided to delete this sentence, as the Beira High is not the focus of this manuscript.

Line 119: Why is knowing the location of the COTZ really so important for making pre-rift reconstructions? Is it the only or best route to making such reconstructions?

SECTION 3: Please make clear to readers which profiles are being presented in a publication for the first time here, and which ones have been published elsewhere already. Thanks for the suggestion. We added in the Introduction that we show new and published profiles. In section 3 (Methods) we describe in detail which profiles are new and which profiles are already published.

Line 168: Consider a different descriptor. It is difficult to see how two zones of deformation, one of which (according to figure 8) is around 200 km long, the other a fraction of this length,

can really be considered as tie 'points'. The features as described allow for several tens of kilometres of uncertainty in any pre-rift reconstruction built by uniting them.

The difference in size mainly results from the different strike of the lines. Admittedly, additional variations may be introduced by the less sufficient data quality in the Riiser-Larsen Sea, which hinders a conclusive tracing of this deformation zone to the west. In Figure 8 (now Figure 9), solely those structural features are shown, which are distinct and clearly observed in the seismic data. This does not mean that the structures do not extend to the west, indeed we consider this as very likely. This distinct structural style is very untypical for rifted continental margins and contrasts the widespread used term "passive margin". The margins under discussion clearly have been deformed after formation and therefore, we would like to maintain the descriptor.

Line 179: Give clear reasons for the strong resemblance referred to here. It is difficult to understand, what the reviewer means. We make clear in the manuscript, that both margins are conjugate.

Line 182: How does the faulting increase? Is it the number, spacing, throw, length, or some other descriptor of the faults that changes? The number of the faults increases and the spacing decreases. We corrected this in the text.

FIGURE 8: The figure should map the extents of the compressional and extensional structure interpretations in the deformed basement areas. We added this information in the Figure. Transpressional deformation is marked as yellow hatched area and transtensional areas as rose hatched areas.

Line 223: Remind readers of the start and end times of the JMQZ. We added "Middle to Late Jurassic times", because the exact start and end times of the JMQZ are still under discussion. E.g. Sager et al. for the Pacific oceanic crust.

FIGURE 1 and/or FIGURE 8 (cf Line 290): should show the location of the downlap of reflector MJ. This is added in Figure 8 (Figure 9) as blue dots.

Line 230: Is there an equivalent reflector to MJ in the Riiser-Larsen Sea? If so, how does any date given to it by Leitchenkov et al (2008) compare to that determined from the Mozambique Basin? It is stated in section 4.2 that our interpretation concurs with that of Leitchenkov et al. (2008), who also interpreted the top of the deformed sediments. However, Leitchenkov et al. (2008) suggest that this horizon is the breakup unconformity as they place the COT much more seaward than we do. We discuss this point in section 5.1. However, Leitchenkov et al. (2008) suggest that this horizon is 158 Ma or even older based on the extrapolation of magnetic chrons. This fits very well with results from the Mozambique Basin, where a Late Middle Jurassic age has been derived by e.g. Castelino et al. (2015) and Mahanjane (2014). Our correlation with magnetic data lies well in line with these results and we propose an age of ~164 Ma for horizon MJ.

Are there clear bends in fracture zone traces (for example in the vertical gradient of gravity data from the Mozambique, Riiser-Larsen of West Somalia basins) that can be placed near the M38 isochron and so support your interpretation? Thanks for this suggestion. We believe that the generation of fracture zones commenced after magnetic chron M38n, when the spreading direction changed to N-S. This is also indicated from the interpretation of magnetic anomalies in the West Somali Basin (Gaina et al., 2013). There, the orientation of the chrons changes from NE-SW to E-W, implying a change in spreading direction from NW-SE to N-S. This is well in line with the identification of NW-SE oriented structures identified in the vertical gradient of gravity data and the identification of two phases of deformation affecting basement in the West Somali Basin, near the Davie Ridge (Klimke et al., 2016). We describe

the similarities of the here observed basement deformation with the results in the West Somali Basin (Klimke et al., 2016) in section 5.

SECTION 4.3: this section should clearly state how transform-related motions along the NE-trending COTZs can be reconciled with NW-SE plate divergence and/or N-S directed transform-related motions along the Davie and Gunnerus ridges. See the above section about the consecutive (and not contemporaneous) movements. In our view, there was no NE directed movement along the COT. However, we decided to delete section 4.3, as in our view, this section does not provide additional information to support the results presented in this manuscript.

Line 284: The assertion only applies alongside the assumption of synrift sediment supply. Yes.

Line 357: I think that Mueller and Jokat adjusted the timing of the jump to 164 Ma, which would be more consistent with your scenario. Indeed, we also state that the jump occurred at 164 Ma, based on the downlap of horizon MJ against oceanic crust at magnetic chron M38n. However, Müller and Jokat (2017) merely state that the oldest chron is M38n (164 Ma). They do not propose that this chron is linked to a rift jump or a change of the spreading direction.

FIGURE 9: How are the reconstructions here built (what Euler rotations were used), or which earlier publication are they based on? In the Figure caption of Figure 9 (now Figure 10), we state that the reconstruction is based on Nguyen et al. (2016). We took most of the continents positions out of this publication. However, as is noted in the Figure caption, this is a schematic reconstruction.

Why do the deformation zones shown differ in length from those in Figure 8? We apologize: This was corrected and some features from Figure 8 (now Figure 9) were added as was suggested by Reviewer 2.

Why do the reconstructions shown an untenably large overlap between India and the Napier Peninsula? The reconstruction is based on Nguyen et al. (2016). The position of India, Madagascar and Antarctica have been adopted from Nguyen et al. (2016). However, as India and Napier Peninsula is not the focus of the manuscript, we consider this figure still suitable for this manuscript.

Comments Referee 2 (Carmen Gaina):

This is a well-conceived study, which is demonstrating, based on recently acquired seismic data and other available information, that the Jurassic formation of the Mozambique and Riiser-Larsen Sea basins went through a phase of N-S opening that involved substantial deformation along the Davie fracture zone and conjugate features offshore Antarctica. The authors identify similar deformed structures on conjugate margins and use them as “tie points” for the reconstruction of early opening between Africa and Antarctica. The manuscript is well written and presented, and I have only minor comments.

Detailed suggestions: Lines 54-55: Please specify if any of these seismic lines are unpublished (if not, add “published” to “datasets”) We present some new and some published seismic profiles. In Line 55, we added “new and published” reflection seismic profiles and explain in detail in section 3 (Methods), which profiles are new and which profiles were previously published.

Line 66: We provide evidence “for the first time” (?) Thanks, we deleted “for the first time” and rephrased this paragraph.

Line 86: please add the age of M38n.2n (as this is the first time you mentioned it), and the timescale used to assign this age Thanks, we added the age (~164 Ma) and the timescale used (timescale of Ogg, 2012).

Line 134 – see my comment about new and already published material

We added in this section in detail, which profiles are new and which are reinterpreted.

Figures: Fig. 1 I suggest to describe the background for all panels in the beginning of figure caption, including reference. In this case, you can remove this explanation from "b)" and "c)". Thanks, we adjusted this. We now reference ETOPO 1 in the beginning and removed it from b and c.

Because you have a dark blue, all other elements (flowlines, location of seismic profiles, etc) shown on top can be hardly distinguished. Please use lighter colours for those. This is a very good suggestion. We agree that the figure is very loaded with information and we tried to make it more readable using light colors. We now consistently mark oceanic fracture zones with dashed white lines and magnetic isochrons with solid yellow lines. Seismic profiles shown in this paper are indicated with thick red lines. COT of Leitchenkov et al. (2008) in Figure 1c is now an orange line. Seismic profiles of the surveys remain in thick black lines and (for mbwg00) in orange lines (to distinguish it from the BGR14 dataset). In 1c, we merged the magnetic isochrones and fracture zones from Leinweber and Jokat (2012) and Leitchenkov et al. (2008) to make the figure easier to read.

The "magnetic anomalies" are in fact isochrons (lines of equal age obtained by linking the interpreted magnetic picks). Thanks, this was corrected in the caption.

Figs 2, 4 and 6. Please add inset maps showing the location of these profiles (easier to find them than looking at Fig. 1 where is very difficult to distinguish the red lines). Also, the font used for labels is too small. The labels are enlarged now. We also added inset maps showing the location of the profiles.

Fig. 7 Could you add a zoomed in map showing the faulted oceanic basement? We added a zoomed section of the faulted oceanic basement. This is Figure 8 now.

Fig. 9 Could you plot the same features shown on Fig. 8 in reconstructed position? The deformed basement, SDRs, lavaflows and intrusions are already shown in Figure 9 (now Figure 10). In A), we added magnetic chron M41n. In B), we added the positions of magnetic anomalies M41, M38 and M33n, the COT as interpreted in this study and the COT from Leitchenkov et al. (2008). For the Riiser-Larsen Sea, magnetic chron M25n is the oldest interpreted magnetic anomaly available. We didn't plot the locations of the profiles and the downlap locations of MJ to not overload the figure with too much information.

Also, show the extinct ridge between the Beira Heigh and East African Margin in panel b). As we added all features from Figure 8 (now Figure 9), this panel is already filled with much information and we would like to omit the extinct spreading ridge in B).