Solid Earth Discussions

Solid Earth Discuss., referee comment RC2
https://doi.org/10.5194/se-2020-214-RC2, 2021

Comment on se-2020-214

Thomas Phillips (Referee)

Referee comment on "Complex rift patterns, a result of interacting crustal and mantle weaknesses, or multiphase rifting? Insights from analogue models" by Frank Zwaan et al., Solid Earth Discuss., https://doi.org/10.5194/se-2020-214-RC2, 2021

Review – Zwaan et al – Complex rift patterns, a result of interacting crustal and mantle weaknesses, or multiphase rifting? Insights from analogue modelling

This study uses analogue modelling to investigate the relative, and often competing effects of crustal and mantle weaknesses on rift physiography. The paper addresses an important question in structural geology and tectonics, namely whether multiphase rifting is required to explain non-collinear faults and rift systems, and proposes that such systems may form due to the interplay of crustal and mantle weaknesses during a single phase of rifting.

The paper presents a detailed and comprehensive study of a series of models and thoroughly explores a range of parameters. This study will be of wide interest to people interested in structural geology and tectonics and the model observations will have implications for a wide range of rift systems. I list a few general comments and suggestions on the manuscript below, before giving some more detailed line-by-line comments.

If the authors have any questions or if anything is unclear, feel free to get in touch.

I believe that the manuscript represents a detailed and thorough piece of work and will be of interest to the Solid Earth readership. On that basis I suggest the paper should be accepted for publication after consideration of the following comments:

General comments – these are expanded upon further in the individual comments.

The interactions between the weaknesses and faults should be expanded to discuss more aspects of how the weaknesses/seeds may not reactivate but still segment and block the propagation of faults and rift segments, i.e. they are not reactivated but are also not entirely passive and cross-cut during the rifting. This could be expanded in either the introduction or discussion, but these high-angle structures represent important weaknesses throughout breakup in that they may influence the site of future transfer zones.

The authors provide a detailed and comprehensive comparison to previous modelling studies. However, I think the study would benefit from an increased comparison to rift basins and natural examples, particularly in the discussion. There are a number of parallels here with rift systems in East Africa and the North Sea, amongst other areas. More direct comparisons should be drawn between specific natural examples and the model results.

Heron et al., (2019) use numerical modelling to discuss the relative importance of crustal and mantle weaknesses in the evolution of the Labrador Sea. It would be interesting to see how your observations from an analogue modelling perspective compare to those generated in numerical models.

Line by line comments

L25 – what do you mean by great depth and high temperature here, can you give examples and be more specific?

Paragraph 2 – Worth mentioning the work of Heron et al, looking at the influence of "perennial mantle scars"

L40 – Schiffer et al., (2020) may be relevant here, looking at structural inheritance (including crustal and mantle structures) in the North Atlantic.

Para 2, Line 43 – Can you expand on why crustal structures may not reactivate? – Can these structures still influence the rift, i.e. through segmentation/blocking?

L72 – Throughout the introduction, more emphasis should be given on multiphase rifting as a concept and the ways in which non-collinear fault systems may form through this process, as well as crustal/mantle weaknesses. Reeve et al. (2015) showcase a number of mechanisms that may contribute to non-collinear fault systems, similar to those produced in the models.

Section 2.2 – Can you expand on what the velocity discontinuity is equivalent to in reality? Could this be equated to a thickness change in the lithosphere, akin to the Sorgenfrei-tornquist Zone?

Very detailed explanation of the model setup, and comprehensive descriptions of the scaling properties of the model.

Results section – Would be useful to the reader to briefly outline the different models and the key things that they examine at the start of this section, before delving into the results.

Figure 2 – would be useful to distinguish the pre-cut faults from the weak crustal seeds on the figure. One suggestion would be to change the markers along the sides of the model to allow the two to be distinguished easily.

Line 233 – What is the difference between Models C and D in terms of setup? Are they the same model but ran twice? Would be useful to explain why this is the case. Ah, I see this is related to the CT scanning. Can you make this clearer on the figures to ensure that people are not looking for differences that are not there (Also for Models G and H). Figures would also benefit from a cross-section of the initial setup for each of the models. This is particularly the case for Figure 4 which has a thicker lower crust.

Good exploration of the available parameter space.

Model J – Do you have any information on the displacement along the faults in the model? It would be very interesting to see whether there is a change in displacement as the faults cross the VD.

Line 340, figure 7 – Model K shows some fascinating features and very clear evidence of rift segmentation. Would be interesting to see how this compares to observations of rifts where crustal weaknesses have been proposed to segment rifts (i.e. the Viking Graben in the North Sea, Phillips et al., (2019), Fossen et al., 2016)

Model N – Initial seed-related faults are partitioned by the VD. Is there a switch in polarity occurring across this discontinuity? Would you be able to expand on this slightly?

Discussion

Line 416 – I assume that the right-stepping nature of the en-echelon faults is a symptom of the orientation of the weaknesses rather than a fundamental feature? This should be made clearer.

Figure 11 – Nice, clear summary diagram. Might be worth annotating/labelling key features and observations onto the diagram to make it clearer.

Line 463 – Can you be more specific here, it seems to me that they appear to dip downwards towards the VD. Are you referring to the structures from the bottom up?

Line 490 – Would be interesting to see how this compares to the crustal weaknesses as modelling in Henza et al, 2010, 2011 too

Line 502 – check sentence structure here, seems like something is missing.

Line 509 – Would be good to mention the segmentation aspect of the higher-angle weaknesses at some point here.

Line 568 - See Reeve et al., (2015) for potential mechanisms that may give rise to non-collinear fault systems.

References

Heron et al., (2019) - https://doi.org/10.1029/2019TC005578

Schiffer et al., (2020) - https://doi.org/10.1016/j.earscirev.2019.102975

Reeve et al., (2015) - https://doi.org/10.1016/j.jsg.2014.11.007

Phillips et al., (2019) - https://doi.org/10.1029/2019TC005756

Fossen et al., (2016) - https://doi.org/10.1144/SP439.6

Henza et al., (2010) - 10.1016/j.jsg.2009.07.007

Henza et al., (2011) - 10.1016/j.jsg.2011.06.010