Solid Earth Discussions

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Comment on se-2021-18

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Referee comment on "Looking beyond kinematics: 3D thermo-mechanical modelling reveals the dynamics of transform margins" by Anthony Jourdon et al., Solid Earth Discuss., https://doi.org/10.5194/se-2021-18-RC1, 2021

This study by Anthony Jourdon and colleagues uses high-resolution 3D numerical models to investigate the formation of transform continental margins. It very nicely demonstrates that key strike-slip faults do not originally emerge parallel to the plate motion unless under a highly oblique setting. The authors introduce structural inheritance in a very minimalistic but transparent way, by including weak blocks. This approach sheds new light on the complex fault evolution during rifting and continental break-up and notably on the formation of transform continental margins. The employed numerical software pTatin3D is at the forefront of current code capabilities. I very much enjoyed reading this well-written and illustrated manuscript. I only found some minor points that I think should be improved before final publication of this study.

Minor comments:

title: "dynamic" is an adjective, the noun is "dynamics"

line 26 - "plates boundaries": replace with "plate boundaries"

line 29- "Mélody Philippon & Corti, 2016": first name appearing in reference (please check throughout the manuscript)

line 41 - "plate margins": I think you mean continental margins. The South African margin for instance does not coincide with the closest African plate boundary, which is a mid-ocean ridge.

line 49 - "Whether transform faults originate pre- or syn-rifting or even post-continental break-up is still a matter of debate.": It would be a good addition here to mention that there are transform faults in the East Pacific Rise and at other mid-oceanic ridges, which never evolved from a continental rift. So it is clear that at least some of the transforms must have formed without any continental inheritance.

line 69: I would recommend to also include earlier analog models of oblique rifting. I find that notably Withjack & Jamison (1986) and Clifton et al., (2000) are excellent studies.

line 75 - "models show that the onset of intra-continental deformation always localizes on structures closely orthogonal to the extension direction": This is not correct. In Brune (2014) I show that normal faults emerge at half the angle of obliquity (i.e. the angle between extension-perpendicular direction and rift trend). This is illustrated in Brune (2014), Figs. 5-9 in the upper left corner as the theoretical fault orientation perpendicular to the initial maximal horizontal stress. This orientation is computed following the idea illustrates in Fig.1 of the same paper and analytically based on Withjack & Jamison (1986). According to these theoretical considerations, faults are only perpendicular to far-field extension under zero-obliquity boundary conditions.

line 91 - "rift basins segments": replace with "rift basin segments". This is similar to my comment on line 26. Please check entire manuscript for this little mistake.

line 97 - "This highly oblique deformation regime is rarely simulated": I suggest to add "... except in setups with periodic boundary conditions." I fully agree that the highly oblique regime is where models with periodic boundary conditions like yours (or mine) are particularly useful.

line 193 - "knowing": perhaps rather "known"?

Table 1 - "KJ/mol": tiny detail - for consistency it should be "kJ.mol^-1".

line 390 - "[Modelling experiments] show that strain localization in the continental lithosphere always begins as extensional structures sub-perpendicular to the extension direction for angles between extension direction and the weak zones larger than ~30°.": this is not correct. See comment on line 75.

line 397 - "For angles of obliquity lower than ~30° the models with oblique boundary conditions show that strike-slip deformation dominates": better refer to Withjack & Jamison (1986). They provided the analytical calculation for this statement.

line 410 - "Brune et al., (2018)": I appreciate the many references, but the 2018 paper merely hypothesises about this point. Having said that, Heine & Brune (2014) actually provide complementary evidence in addition to my 2012 paper.

line 420 - "shows that the deformation localizes to progressively form a unique straight shear zone and straight margins.": I was wondering about the same point. My feeling is that the numerical resolution might play a bigger role here than the setup of the weakness.

line 441 - "greater that": replace with "greater than".

line 491 - "Numerical models show that this is precisely during this intra-continental rifting phase that strike-slip": A relevant extreme case of this rotation, namely formation of a rotating continental microplate, has been very recently described in Neuharth et al., (2021).

line 533 - "pull-apart basins": There is a very nice numerical study on pull-aparts that you might want to refer to (van Wijk et al., 2017).

Figures: I find reviewing difficult if figures are not within the text, but at the end of the file. But I find it even more difficult if captions are not next to figures.

Figure 1b: I am a bit confused by the half-headed arrows. Shouldn't they point in the opposite direction or be on the other side of the transform faults?

Figure 2b: There should not be any red arrows on the left and right side of the box. They evoke the impression that you prescribe rift velocities there as well, but in fact you have a periodic boundary condition. Perhaps simply mention "Periodic BC" instead.

Figure 3: Mantle exhumation starts close to your periodic boundaries. Is that because your boundaries are only approximately periodic or because the distance between the neighbouring weak seeds across the periodic boundary is smaller than to the other neighbour?

Figure 4: Is there a reason for the orientation of the cross sections? Wouldn't parallel to far-field extension be a logical direction?

References of this review that are not already included in manuscript:

Clifton, A. E., Schlische, R. W., Withjack, M. O., & Ackermann, R. V. (2000). Influence of rift obliquity on fault-population systematics: results of experimental clay models. Journal of Structural Geology, 22(10), 1491–1509. https://doi.org/10.1016/S0191-8141(00)00043-2

Neuharth, D., Brune, S., Glerum, A., Heine, C., & Welford, J. K. (2021). Formation of continental microplates through rift linkage: Numerical modelling and its application to the Flemish Cap and Sao Paulo Plateau. Geochemistry, Geophysics, Geosystems, e2020GC009615. https://doi.org/10.1029/2020GC009615

Heine, C., & Brune, S. (2014). Oblique rifting of the Equatorial Atlantic: Why there is no Saharan Atlantic Ocean. Geology, 42(3), 211–214. https://doi.org/10.1130/G35082.1

van Wijk, J., Axen, G., & Abera, R. (2017). Initiation, evolution and extinction of pull-apart basins: Implications for opening of the Gulf of California. Tectonophysics, 719–720, 37–50. https://doi.org/10.1016/j.tecto.2017.04.019

Withjack, M. O., & Jamison, W. R. (1986). Deformation produced by oblique rifting. Tectonophysics, 126(2–4), 99–124. https://doi.org/10.1016/0040-1951(86)90222-2

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