

Solid Earth Discuss., referee comment RC2
<https://doi.org/10.5194/se-2021-17-RC2>, 2021
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Comment on se-2021-17

Frank Zwaan (Referee)

Referee comment on "Contribution of gravity gliding in salt-bearing rift basins – a new experimental setup for simulating salt tectonics under the influence of sub-salt extension and tilting" by Michael Warsitzka et al., Solid Earth Discuss.,
<https://doi.org/10.5194/se-2021-17-RC2>, 2021

Review se-2021-17 (Warsitzka et al.)

Contribution of gravity gliding in salt-bearing rift basins – A new experimental setup for simulating salt tectonics under the influence of sub-salt extension and tilting

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General comments

The authors present an interesting experimental set-up to model salt tectonic processes in

a continental rift setting. The set-up allows the simulation of rift development and thermal sag. In addition, different sediment covers and syn-rift sedimentation can be included.

The authors show with a series of simple experiments how structures in rift basins may develop. Firstly, the presence of a salt layer may decouple the subsequent brittle cover from the modeled basement. This destabilizes the "post-basement" units leading to increased deformation. Furthermore, the authors show how sag may increase rift-ward displacement of material. By contrast, when syn-tectonic sedimentation is included, the sediments seem to stabilize the system, more or less locking the post-basement units in place.

The topic is interesting and well-suited for a Solid Earth publication, and I found it a pleasure to read the manuscript. However, I think that there are still a couple of things that could be improved. Please find my general comments below, and more details in the annotated PDF that is also part of my formal review. I hope that the authors will find these helpful.

Frank Zwaan

General comments

- Perhaps this is a bit nitpicking, but the authors present the set-up as a novel method and while it is true that (to my knowledge) this specific set-up has never used before, it is in fact a combination of techniques used in previous models. The authors then go on to test a quite a couple of parameters and do a comparison with natural examples. So I was wondering the focus should really be shifted a bit to the new set-up, or rather on the various parameters tested in the models?

- The set-up itself is very nice I think, and the experimental results very clear and interesting. However, what is really missing is a thorough description with detailed information on the model parameters/set-up. Now there is a lot of info on the scaling and sedimentation (see also next points), but crucial information such as model duration, extension/subsidence rates, thickness of sedimentary infill, angle of the basement faults, inclusion of a post-rift phase etc. are not really mentioned in the text I believe, and only provided in table 3. (NB: I noticed that model durations seem to vary from model to model, and are not always consistently reported.) I think these details should be expanded a bit as it remains a bit vague how the models are actually constructed and colleagues would not be able to reproduce the models.

- Very importantly, it is not 100% clear to me what the initial geometry of the PDMS layer is. Fig. 2 shows a deformed state with a silicone layer that pinches out towards the sides. What is the extent of the salt layer (I noticed that there are static borders in the DIC results), what is the thickness of the salt/silicone layer? In table 3 it says that the layer thickness is between 5 mm and 3 cm. Is this the same in all models? (I would assume so) and what would the distribution of these thicknesses be? The same goes for the brittle layer (ranging between 1 mm and 3 cm?, where fig 2 shows it pinching out to the sides as well). Confusingly, different (the correct?) values are presented in Table 3... It would probably be good to include a figure with the initial layer thicknesses, and please be consistent with these details throughout the manuscript to avoid confusion.

- There is a rather long section on model scaling. Now I agree that this is very important, but this part is not very new I believe (?), and perhaps distracts a bit from the main point: the new set-up/models. It might be better to shorten it a bit or perhaps move part of it to the appendix? (NB: I think it would be good to keep it in the main paper and not in the a supplement)

- There is also a section on sedimentation and using different densities to reproduce (more) realistic sedimentary loading. However, this is not addressed any more in the results or discussion. Only in the conclusion it is mentioned again. If this is indeed an important part of the model series or set-up, I would expect some comparison of the impact of different sediment densities on the models. This is however missing. I also understand that this concept is already tested by previous modellers? (Dooley & Hudec?) Perhaps it would therefore be better to move the detailed description to the appendix as well?

- I think that by moving parts of the scaling and the sedimentary infill to the appendix, there would be a bit more focus on the set-up itself (now, the key parts are really a bit separated by the scaling and sediment description). And as stated before the description of the set-up should really be expanded a bit to include more of the important technical details that I think are missing.

- Extension is forced by the downward moving central block, which pushes apart the "rift shoulders". I assume that this central block is controlled by motors? This is not clearly specified I believe. In the results I also noticed that the motion of the "rift shoulders" is a bit "shaky" (which is addressed in the discussion, but should also be mentioned in the results part I think, it is very obvious). I figured a solution would be to also have motors control the horizontal motion of both rift shoulders, to ensure a smoother deformation?

- Since the rift shoulders are simulated by a bendable plate, does the force of the central block moving down cause flexure? And what kind of materials is used for building the set-up? The type of material surely influences the degree of bending, which would surely affect gravity gliding. I could also imagine the weight of the model materials (and the extra weight of sediments) would affect the bending of the plates. How is this checked?

- A general remark on the thermal sag applied in the models: Would it not be better to first form the rift, and have the sag act after rifting? During rifting, one would expect rift shoulder uplift instead, which would counteract the riftward tilting induced in the models I'd say? Could also the angle of tilting in the models be specified? This might be a rather crucial detail to interpret the results.

- Analysis: perhaps it should be mentioned what the frequency of photography is. It should also be mentioned that sections were made (and how, I assume by simply soaking the sand and cutting by hand?)

- In general the style of writing is very pleasant, but sometimes it is a bit too efficient I think. See for instance the model set-up description I mentioned above. I also think the result section could be expanded a bit. As it is, the authors do not really introduce the models and their general characteristics, but directly describe detailed results. I think there could be a couple of extra sentences to help the reader "get used to" the models. Here and there it would also be good to remind the reader about the parameters used in specific models. Also, it might be nice to spend a bit more attention on the evolution of structures (e.g. the faults, I noticed that these may be moved, i.e. translated downslope, as gravity gliding occurs).

- I felt that it could be useful to finish the results section with a summary figure of the main observations. (perhaps simple section views with the main processes indicated?) This could serve as a key figure and a framework to refer to in the discussion.

- The discussion seems to lack some comparison with previous models (e.g. the ones mentioned in the introduction). Discussion section 5.1 is indeed a bit short. I would suggest adding some as especially the gravity-gliding without sedimentation looks like what one finds in models of passive margin style salt tectonics. Some of the other models have features (e.g. flexure of overburden over a normal fault) that may also be found in analogue modelling studies of rifting? E.g. Withjack & Calloway (2000) in AAPG Bull. or perhaps the work by Tim Dooley.

- The comparison with natural examples was a bit hard to follow. Perhaps such a summary image of the results could help to illustrate the points made there a bit better (e.g. how compressional supra-salt structures can be "hidden" by sub-salt deformation).

Figures:

- I really like the side-by side presentation to show the effects of specific parameters. But would it be possible to systematically include a (final) top view of the models as a first row of each column, to show what each model looks like? The same for sections, these could be easy to add and be very insightful, if available. And surface evolution graphs, or final topography profiles might also be nice to add.

- In some models, strain plots are shown as well. Could these be provided for each model? This could allow a more detailed description. Now it may seem that some models are perhaps not fully explored, which would be a pity.

