Solid Earth Discussions

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Comment on se-2021-135

Anonymous Referee #1

Referee comment on "The topographic signature of temperature-controlled rheological transitions in an accretionary prism" by Sepideh Pajang et al., Solid Earth Discuss., https://doi.org/10.5194/se-2021-135-RC1, 2021

Dear Editor, dear Authors,

This contribution presents new results for the tectonic evolution of accretionary prisms. Using numerical models, the Authors explore the role of temperature, dehydration reactions, rheological transitions, and internal and basal friction, on the topography of fore-arc wedges. An important result of the modelling experiments is that an increased topographic slope may be associated with the onset of viscous deformation, and thus, the brittle-ductile transition in the wedge. Further, the Authors suggest that accretionary prisms consist of four topographically and structurally distinct domains. Two topographically flat domains are associated with either dehydration reactions along the décollement, or with primarily viscous deformation at the back of the wedge. A domain with topographic slope that follows the critical taper theory corresponds to the brittle frontal toe of the wedge. The fourth domain has a topographic slope steeper than what predicted by the critical taper theory. This steep slope is linked with the brittle-viscous transition in the wedge. These results can offer new interpretations on the location of seismogenic zones along subduction systems.

This is an interesting manuscript that I enjoyed reading. My own expertise is in rheology and tectonic evolution of fore-arc wedges, and my review will primarily focus on these two aspects of the manuscript; I am less comfortable with the technical aspects of numerical modelling. The manuscript is generally well-written and illustrated. In terms of language, the Authors need to pay attention to the use of plural versus singular throughout the text. I have provided suggestions for some text improvements in my detailed comments. I believe this work can be of interest to the broader tectonics community, as the results of the models also have implications on the interpretation of field relationships and geophysical data. Below I provide a few comments and suggestions that the Authors could consider addressing.

General comments

1) I found the spatial distribution of viscous and brittle deformation in the brittle-viscous transition zone very interesting. I think that the Authors could provide some more clarity for their interpretations of the observed relationships. Specifically, most models show low strain islands of sand to deform viscously at temperatures between 300°C and 180°C. These islands of viscous deformation are bounded by faults characterised by brittle deformation. Moreover, deformation in the décollement remains brittle while part of the overlying sequence deforms viscously at lower temperatures. I am wondering how the Authors interpret these rheological relationships. Is viscous deformation of quartz-dominated lithologies expected and what could cause the onset of viscous deformation at temperatures between 300°C and 180°C? If all sandstone in the sandstone sequences has the same mechanical properties, what causes the concurrent viscous and brittle deformation at a specific depth and temperature?

2) In D2 deformation phase occurring in the brittle-viscous transition zone, back-thrusts are attributed to the change in the material behaviour from brittle to viscous with depth (e.g., lines 333-334). In Figure 9a, however, the backthrusts are shown to be rooted within or at the top of the brittle décollement. The Authors could consider providing some clarity and additional explanation regarding the processes or conditions that favour the formation of back-thrusts at this part of the wedge.

3) I found the titles of subsections 3.2 and 3.3 not very informative. I do not have any good suggestions of how the titles could be improved, but the Authors could rethink these titles.

4) I found the colour schemes used in the models hard to follow and interpret. Less so in the "current state figure" of each model, where the type of deformation (brittle versus viscous), strain rate, and topographic slope are presented. In the "finite strain figure", I found it hard to discriminate between the colouring describing the amount of brittle strain and the colouring for lithology / sedimentation time. For example, it hard to determine whether there is any brittle strain accumulated in the deposited sediments (i.e. deposited after 0 Ma). I am not sure how easy would be to fix this issue. I leave it to the discretion of the Authors to decide whether they wish to address this issue.

5) The use of the term "strain" is not clear. The text refers to finite strain (e.g., lines 145, 147), the figure legends suggest that it is the brittle strain mapped on the models. Observing the models, however, brittle strain appears in domains where the wedge deforms purely viscously. Also, from a rheological perspective, it might be interesting to show the spatial distribution of stress magnitude in the evolving wedge.

6) I am wondering if the Authors have explored the relationship between the slope of the isotherms and the topographic slope in their models.

Specific comments

Lines 11: Please explain what aspect of the brittle-ductile transition results in increase of the topographic slope (e.g., depth?).

Line 13: Please change to: "Our models, therefore, imply ….".

Lines 37-38: "…, which stability field is controlled mainly by temperature" – Please rephrase this part of the sentence. Something seems to be missing.

Lines 49: Change "complex" to "complexes".

Line 50: Please change "rich" to "reach".

Lines 58-66: It is hard to follow the content of this sentence, primarily because of the large number of citations. Also, the "While" in the beginning of the sentence does not fit to how the sentence evolves. It seems that something is missing. I suggest rewriting the sentence.

Line 68: "…how the introduction temperature evolution…" – Please check the sentence. Something seems to be missing.

Lines 73-74: "We briefly discuss internal deformation the morphology of the wedge and its potential seismic behavior." – Please check the sentence. It may need some rewording.

Lines 127-128: It is not clear to me to what "respectively" refers in this sentence. Does it refer to the two different initial thicknesses of the model? If so, please make it clearer.

Line 144: Do you mean on the right of the panels?

Line 145: Please explain what you mean by "current state". Also, in the text you mention "finite strain" while in the figures you report "brittle strain". Are these considered the same, in your descriptions? Please explain.

Line 183: Change "trust" to "thrust".

Line 193: "…which corresponds to the brittle-ductile transition." – The brittle-ductile transition is present in almost the half length of the model. Do the Authors mean that the topographic slope corresponds to the slope of the 300°C isotherm, taken to correspond to the brittle-ductile transition? If not, please explain as this outcome is important but not clearly presented.

Line 200: Do the Authors mean faults, instead of shear bands and shear zones? Deformation seems to be entirely brittle after 1 Myr.

Line 213: Please elaborate on how strain rate shows information about the thickness of the wedge.

Lines 223-224: I would agree that the brittle-ductile transition in the wedge seems to reach some sort of steady state configuration, but in my view this takes place between 15 and 20 Myr.

Lines 226-229: The text does not flow very well in these lines. Please consider rewriting. For example:

"This phase corresponds to crossing the zone…." - It is not clear to which zone refers, and what crosses the zone.

"…whether they were incorporated in the ramp or not…" - It is not clear what is meant by "they".

"…before being exhumed for large temperature" – again, it is not clear to me what the Authors try to say here.

Line 241: Maybe "run" instead of "ran"?

Lines 248-252: This sentence is long and quite complicate. Also, the last part of the sentence does not flow well. The Authors could consider simplifying the sentence.

Line 255: Please provide the number of kilometres along the models in Figure 5, where the out-of-sequence thrusts appear.

Lines 263-265: This sentence needs to be simplified or broken in two, in my view. It is a long, dense sentence, and it does not read smoothly.

Line 302: "…by reducing both the size of the critical taper…" – Do the Authors mean the size of the critical taper angle? If so, it would be useful to provide the values for models M14 and M13.

Moreover, there are significant differences between models M14 and M13, potentially even more striking from the two mentioned in the text. The Authors could expand on this aspect.

Line 317-318: In Figure 8a, the length of the frontal flat segment decreases between 3.8 and 6.3 Myr. After 6.3 Myr, I do not see any significant change in its length. Especially at 15 Myr, the length of the Frontal flat segment seems to me larger compared to 10 Myr. In ase I am wrong, it might be preferable if the Authors describe quantitatively the change of length over time.

Line 328: Change "Comparision" to "Comparison".

Line 332: "…which corresponds to the start development of…" – Please consider rephrasing.

Line 335: "…or thick incoming sedimentary,…" – Something seems to be missing here.

Line 338: "…by a very vertical back-thrust." – Change to "a vertical back-thrust" or "a steeply-dipping back-thrust".

Line 343: Change to "Forearc basins".

Line 356: Something has gone wrong in this line. Does not make sense.

Line 362: "…it corresponds more or less to the 450°C isotherm" – I think a more accurate description would be that the splay fault roots at the location of the 450°C isotherm along the décollement. Or something similar.

Lines 365-366: Is it possible to provide examples of the velocities recorded at the base of the spay fault, by seismic studies of active margins? It would be useful for comparison with the velocities you report here.

Lines 369-370: For comparison reasons, the Authors may wish to add a figure callout to one of their models where the forearc basin forms on top of the viscous shear domain.

Lines 381 & 383: Please be more specific what is meant by "This" in the beginning of each sentence.

Figure 9a: An explanation for the isotherm lines is missing from the legend.