Response to Topic Editor's comments

Note from authors: Our responses to each comment are provided as bullet points. Line numbers of the reviewers' comments refer to the previous version of the manuscript, while line numbers in our responses refer to our revised manuscript.

Dear authors,

Overall the concept of your contribution (inversion of wide-rifts) is interesting and the manuscript has clearly improved with respect to the original submission.

Based on my own reading, some additional clarifications are needed, particularly on the justification of the material properties and rheological setups when compared to nature (section 2). There, a better justification of your choices how the model material properties reflect the properties of natural systems is needed. The natural example (North Australia Craton) should be leading when it comes to the choice of modelling materials and their properties. Here you follow an unclear logic, where you scale the natural example to the model to match the desired time-scales (eg. L185/186). An important implication of your approach is that you assume unrealistically low (eg. 2900 kg/m3 in table 2) densities for the lithospheric mantle which also vary considerably among models, which provides a flavour of arbitrariness, which you wish to avoid. Some comments of reviewer R#2 were along these lines when questioning the parameter space, you explored.

- We thank the editor for these constructive comments. We acknowledge the need for better justifying how the model material properties reflect the properties of the natural lithosphere, where possible with comparisons with the North Australian Craton. We have added justifications for our choice of scaling properties, for example:
    - In **Lines 127-133**, we explain the choice of crustal thicknesses: "Given the challenge of reconstructing the lithosphere configuration and rifting conditions of the North Australian Craton in the Proterozoic, we used the Basin and Range Province – a well-known example of a wide rift (e.g., Hamilton, 1987; Parsons, 2006) – as a proxy for estimating crustal thicknesses (Gueydan et al., 2008) and the rate of extension for our models. Hence, the thicknesses of the crustal layers in Models R1 and R2 scale to 10 km and 40 km for the upper and lower crust, respectively. After running Models R1 and R2, we found that it would be more representative of the North Australian Craton (Betts et al., 2002; Kennett et al., 2011) to have upper and lower crust layers with the same thickness, which we then implemented in Models R3, R4, and R5 (**Error! Reference source not found.**)."
    - In **Lines 196-199**, we clarified that estimated asthenosphere densities between 3100 kg/m^3 and 3400 kg/m^3 are "consistent with previous lithospheric-scale analogue experiments (e.g., Molnar et al., 2017; Santimano and Pysklywec, 2020; Samsu et al., 2021) and reference asthenospheric densities used in geophysical models (e.g., 3250 kg/m^3 in Lamb et al., 2020)."

- In **Lines 217-220**, we explained that the "layer densities in Models R4 and R5 are the most consistent with those used in geophysical models on the density structure of the lithosphere, where the densities of the upper crust, lower crust, and lithospheric mantle are 2700 kg/m^3, 2940 kg/m^3, and 3350 kg/m^3 respectively (Kaban et al., 2014)."
- Related to the last point, we reiterated in several parts of the text that (1) the initial objective of this experimental series was to identify a reference experiment of wide rifting followed by shortening, to be compared against future, more complex experiments for understanding multistage tectonics in the North Australian Craton [**Lines 97-101**, **634-635**]; and (2) Models R4 and R5 were the most suitable, as "the layer properties and corresponding strength profile are most consistent with previous three-layer models of wide rifting and estimates for the density structure of the natural lithosphere" [**Lines 637-639**].

- We hope that we have provided a clearer explanation on the changes to the scaling parameters between Models R1 and R2, Model R3, and Models R4 and R5 in **lines 205-220**: "For Models R1 and R2, we started out with a natural asthenosphere density ρ_p = 3100 kg/m^3 and viscosity η_p = 1.9 x 10^{19} (following Molnar et al., 2017) and an extension velocity that scaled to 2 mm/year, resulting in an extension duration of 14 hours. For Model R3, the objective was to explore the behaviour of the ductile layers when we extended the model by the same amount but at a faster rate. Therefore, the prototype viscosity was increased by one order of magnitude (to $_p$ = 1.9 x 10^{20}) to achieve an appropriate time scaling factor. This change in the time scaling factor enabled us to apply an extension rate that still scaled to 2 mm/year in nature within a shorter (experimental) extension duration, i.e., around 3 hours. However, additional changes to the ductile materials were still necessary, as the strength contrast between the lower crust and lithospheric mantle (LM1 in Table 2) in Model R3 was too low to simulate natural lithosphere with a strong lithospheric mantle and relatively weak lower crust (Table 1, Figure 2c). Therefore, for Models R4 and R5, we created an improved lithospheric mantle mixture (LM2 in **Error! Reference source not found.**) with the desired viscosity η_m = 2.7 x 10^5 Pa s (approximately ten times greater than the model lower crust), resulting in a low LC:LM strength ratio. As this mixture had a density ρ_m = 1384 kg/m^3, the density scaling factor was changed to 0.42 (using ρ_p = 3400 kg/m^3 for the asthenosphere), otherwise the prototype lithospheric mantle and asthenosphere densities would have both equalled 3100 kg/m^3. This last change did not significantly impact the other scaling factors. The layer densities in Models R4 and R5 are the most consistent with those used in geophysical models on the density structure of the lithosphere, where the densities of the upper crust, lower crust, and lithospheric mantle are 2700 kg/m^3, 2940 kg/m^3, and 3350 kg/m^3 respectively (Kaban et al., 2014)."
- The choice of an initial lithospheric mantle density of 2900 kg/m^3 in Models R1 and R2 (Table 2) was not influenced by the time scaling. Instead, this initial choice was arbitrary, mainly focusing on choosing a prototype lithospheric mantle density that was lower than the asthenosphere to prevent subduction of the model

lithosphere. We realised after running Models R1 and R2 that changes to the scaling parameters were required (see previous point).

The discussion sections would benefit from integrating some key references. For example, with reference to vertical motions related to folding of a weak basin see Dombradi et al., 2010 (doi:10.1016/j.tecto.2009.09.014). Though this paper does not have an extension phase proper, the model mechanical stratigraphy at the onset of shortening is comparable to your models R1 and R2. Other suggestions are provided in particular for sections 4.1 and 4.2 (for details see the annotated manuscript).

- Key references have been added in various parts of the discussion, e.g., in relation to upwelling of viscous material during extension [**Lines 449-451**] and CT-scanning [**Lines 532-533**].
- We added a sentence relating vertical motions to folding [**Lines 442-447**]: "Continued shortening resulted in inversion of the basins, which we interpret to have been driven by anticlinal folding of the ductile layers, based on observations of uplifted lower crust underneath the inverted basins (following the removal of upper crustal material at the end of the experiments). This interpretation is comparable with observations from analogue experiments of continental collision (Sokoutis and Willingshofer, 2011) and intraplate compression (Dombrádi et al., 2010), where strain is accommodated and topography is controlled by folding of pre-existing weak zones."
- All suggestions for Sections 4.1 and 4.2 in the annotated manuscript have been addressed (see comments in the revised manuscript with tracked changes).

Figures: I suggest to remove fig. 2c and 3b and merge what is left of Fig 2 and 3 into one figure, which shows the fundamentals of the experimental setup and rheology. Make sure that all abbreviations in the figures are explained in the captions.

- We have merged the edited versions of the previous Figures 2 and 3 into one figure (now Figure 2) that shows the fundamentals of the experimental setup and rheology.

Please see the annotated manuscript for detailed comments and suggestions.

- All comments and suggestions in the annotated manuscript have been addressed.
- Editor's comment on what was previously Figure 10 (now Figure 9): "Model R3 seems to have a tilt from upper left to lower right corner. Why? Maybe the data need to be corrected for that?"
    - Our response: The tilt that is visible in the oblique 3D view in DaVis was corrected during the strain processing step outlined in Section 3.2. For example, the tilt is no longer visible in Figure 8.

Looking forward to receiving the revised version of the manuscript.

- We thank the editor for the thorough review of the manuscript.

Ernst Willingshofer (Guest Editor)