This review addresses “Strike-slip faulting in extending upper plates: insight from the Aegean”, by Faucher et al. The manuscript uses numerical models of lithospheric deformation to elucidate how normal and strike-slip faults may coexist during multiphase deformation based roughly on the tectonic evolution of the Aegean region.

While the presented models show promising preliminary findings where normal and strike-slip faults are present after an initial phase of pure extension and a second phase of extension + rift perpendicular extension, the modeling effort and manuscript is in a very rough state and a myriad of critical issues exist:

1. There is a vast literature on 3D modeling of continental extension from the past decade, none of which was cited here. At minimum, the authors need to fully review this body of literature and cite relevant studies to this work (there are many). I’ve included a few references for 3D continental rifting studies using the same software as in this paper (ASPECT), and those publications have appropriate referencing for 3D rifting studies from other groups using pTatin3D, Underworld, LaMEM, and SLIM3D.

2. There are quite a few additional regions (Gulf of California, SE Brazilian Margin, etc) that underwent multiphase extension with an initial phase of normal faulting and subsequent oblique deformation where both normal and strike-slip faults persisted. This paper would benefit from a summary of these regions and how the structural observations and broad scale tectonic forces compare with the Aegean.

3. The numerical methods are inadequately described and no link to the underlying input files are provided, preventing further analysis.

4. There are potentially significant issues with the numerical setup, including the model domain size and propagation of deformation to the model edges.

5. The model evolution is insufficiently described and more images, including cross-sectional views and animations (supplementary material) is needed to properly analyze the simulations.

6. The authors should extract relevant structural information from the modeled faults (e.g., offset through time, changes in slip sense, etc) and compare these with any existing structural datasets from the region. Pan et al. (2022, 2023) and Phillips et al. (2023) outline techniques on how this can be accomplished.

Based on these and additional issues outlined below, my recommendation is that the paper is rejected. However, the study's premise and preliminary results are certainly interesting, and I encourage the authors to resubmit after using the comments provided here to improve both the model design and text.

Specific Comments

1. Please compare and contrast the Aegean with other systems that have made a transition from orthogonal to oblique rifting (Campos and Santos basins, Gulf of California, etc).

2. Before getting into the methods, there really should be a discussion of prior 3D modeling work done on rift systems - this is a major flaw and omission from the manuscript. For example, see papers by Sascha Brune, Laetitia Le Pourhiet, Guillaume Duclaux, Dave May, Ritske Huismans, Anne Glerum, etc, etc. References to these papers can be found in a number of 3D rifting studies using ASPECT I am an author on (see below).

3. What assumptions allow one to go from a Moho temperature of 920 C to a lithospheric thickness of 50 km? Perhaps this is defined later, but for a conductive geotherm one would need to assume a given mantle thermal conductivity, radiogenic production, and LAB temperature.

4. Model size - is 100x100 km in map view is much smaller than the spatial extent in Figure 1c? Is the assumption that the deformation patterns at this spatial extent would scale up for a model size of say 400x400 km?

5. I think you have incorrectly stated that material can freely enter from the sides ~ line 75), or at least that is inconsistent with the velocity boundary conditions you stated in the previous line (velocity on vertical wides prescribed)? Do you mean the model base and surface? If yes, what are the specific model constraints (zero stress on surface, fixed pressure on base) that were prescribed?

6. A maximum mesh resolution of 2 km is fairly on the low end for a model of this size. It would be nice to see what happens as the model resolution is increased to 1 and 0.5 km. Also, I would state the resolution as either 2 km or 2x2x2 km, etc.

7. Thank you for citing a number key ASPECT papers that describe the overall code package. Here, I would also cite a number of papers that specifically dealt with lithospheric deformation and extension at the earliest stages of these features development (e.g., Glerum et al., 2018; Naliboff et al., 2020). There are also quite a few additional ASPECT 3D rifting papers to choose from that may also be relevant to cite here or in other sections (Gouiza and Naliboff, 2021; Pan et al., 2022, 2023; Phillips et al., 2023).

8. I would move Table S1 into the main text.

9. There are quite a few details of the numerical methods missing, including the governing equations, constitutive equations, how deformation is initiated, etc. Please see the methods section from papers listed in comment 7 for guidelines on what details should be included. Unfortunately, I did not see a link to any of the parameter files used to

conduct the study, which need to be accessible during the review process in order to make an appropriate analysis.

10. I advise breaking up section 2 into two separate sections - one for methods, and a subsequent one describing the 3D end-member models.

11. Line 100 - Note that Naliboff et al. (2020) also has 3D rifting results (using ASPECT) that highlight normal fault evolution during a wide rifting mode.

12. In all of the models faults are interacting with the edges of the model domain. This is not ideal, and may affect the evolution of different deformation patterns. You should run a series of models where deformation is focused sufficiently far from the domain boundaries, and strategies for how to do this in a computationally efficient manner can be found in Pan et al. (2022, 2023) and Phillips et al. (2023).

13. Does the timing of the transition from pure extension to extension + compression matter? Is the timing and nature of this transition constrained at all by observations?

14. Are you sure the black labeled faults in Figure 2C are normal faults? To my eye, they appear near-vertical at the boundaries? Likewise, why are the models labeled as 1, 4, and 7, rather than 1, 2, and 3. These model numbers are also not referred to in the text.? On a related note, it would help to choose color scales that more clearly highlight the fault zones. This can be done by restricting the color scale to say 10^-16 or 10^-15 /s to 10^-14 /s. (Again, see prior studies for suggestions on how to do this). Additional figures should also be provided that show more temporal snapshots of how deformation evolves, and various cross-sectional views. In general, I really have no sense of how these models are evolving through time or how the kinematics of the modeled faults compares to the abundant structural details of the region.

15. Unfortunately, it is extremely hard to evaluate the conclusions of the study given the issues outlined above.

References

S. Pan, J. Naliboff, R.E. Bell, C.A-L. Jackson (2023), How Do Rift-Related Fault Network Distributions Evolve? Quantitative Comparisons Between Natural Fault Observations and 3D Numerical Models of Continental Extension, Tectonics, 42(1), e2022TC007659, https://doi.org/10.1029/2022TC007659.

T. Phillips, J. Naliboff, K. McCaffrey, S. Pan, J. van Hunen,, and M. Froemchen (2023), The influence of crustal strength on rift geometry and development – Insights from 3D numerical modelling, Solid Earth, 14(4)m 369-388, https://doi.org/10.5194/se-14-369-2023.

S. Pan, J. Naliboff, R. Bell, and C. Jackson, C. (2022). Bridging spatiotemporal scales of normal fault growth during continental extension using high-resolution 3D numerical models. Geochemistry, Geophysics, Geosystems, 23, e2021GC010316. https://doi.org/10.1029/2021GC010316

M. Gouiza, and J.B. Naliboff (2021), Rheological inheritance controls the formation of segmented rifted margins in cratonic lithosphere, Nature Communications, 12, 46453, https://doi.org/10.1038/s41467-021-24945-5.

J.B Naliboff, A. Glerum, S. Brune, G. Péron-Pinvidic, T. Wrona, (2020), Development of 3‐D Rift Heterogeneity Through Fault Network Evolution. Geophys. Res. Lett., 47, e2019GL086611.