Reviewer 1 – Anonymous referee

This manuscript addresses the very interesting question on the effect of along-strike strength variations on fault localisation processes. It uses state-of-the-art 3D numerical models that are complemented by observations from several examples of rifts worldwide but especially by geological observations of the Great South Basin, New Zealand, that features particularly prominent along-strike lithological variations. The results are well discussed and linked to previous insights. I find the interaction of strain localisation processes across terrane boundaries particularly interesting and well balanced. I only have a few minor suggestions that hopefully help to improve this interesting paper even more.

We thank the reviewer for their positive comments and have modified the manuscript accordingly. Please find detailed responses to the individual comments below. Line numbers correspond to the track changes final document.

*** Comments:

Fig. 1: An overview map could provide the reader with the plate tectonic context and the location of the study region relative to New Zealand. It would be useful to annotate New Zealand on the map in panel A. The cross section in panel C should be annotated in the map view of panel A. I suspect it is the black line, but I can't be certain.

We have now added an inset to panel A showing the regional geological setting of New Zealand and the location of the study area. The location of the section shown in Panel C has also been annotated in A, corresponding to the black line.

It would be good to motivate the model setup a bit more with the natural example. It's absolutely fine if some of the employed values are generic, but this should be mentioned. Here are some points that could be addressed:

- Line 85: is the 5 mm/yr extension velocity based on local divergence rates? If yes this would be good to mention here.

The 5mm/yr extension rate used in our models are not based on the chosen example. The concept and geometry of our models are based on the study area, but the extension rate is based on an average of velocities used in other recent 3D models of continental rifts (Naliboff et al., 2020; Gouiza and Naliboff, 2021; Pan et al., 2022) and many previous 2D numerical models. Given insufficient data exists to carefully assess strain rates in the region, we decide it would be best to use an average (or median) velocity used in previous rifting studies and is also close in magnitude to active continental rifts that have experienced similar amounts of extension. A sentence describing this has been added to the text (Line 86-87).

The findings of Pan et al. (2022) suggest that increasing or decreasing the velocity by a factor of 2 is likely to affect second order features of the fault network (i.e., number of faults and displace-offset distributions) but we do not anticipate it would change the key findings of this study in regards to how faults interact with rheological boundaries. However, we anticipate it would affect the timing of when faults in our different model domains (normal, strong, weak) propagate into neighbouring domains. For example, increasing the extension rate would likely promote faster localization onto

fewer faults within the weak zone, accelerated formation of small faults within the strong domains, and subsequent propagation of major faults across the strong domain.

- Line 90: Are layer thicknesses consistent with the chosen example?

We base the map view geometry and the distribution of areas of differing strength on the Great South Basin. Crustal thicknesses in the model are based on general thicknesses of unstretched crust. We have clarified this in the revised manuscript (Line 92).

- Line 101: Why do you choose 5 km^3 blocks?

The choice of 5 km was based on Pan et al. (2022), which found using a block size of at least 2-4x the numerical resolution (1.25 km here) was required to sufficiently localise deformation at the onset of extension (Line 109-111). The findings of a follow up study (Pan et al., In Revision; Preprint https://doi.org/10.31223/X5G65Q) suggests that increasing or decreasing the block size by a factor of 2 is likely to affect fault spacing, but we do not anticipate this would have a first-order control on the results of this study.

*** Minor details:

Abstract and text in general: double check capitalisation of "weak", "strong" and "initial plastic strain".

We have now checked and modified the manuscript to ensure that Weak, Strong, Reference and Initial Plastic Strain are correctly capitalised throughout. Weak, Strong and Reference are capitalised when referring to domains.

Line 16: "extension occurs perpendicular to distinct geological terranes and parallel to terrane boundaries" I find the description of extension "perpendicular to terranes" but "parallel to terrane boundaries" misleading. I suggest to delete "perpendicular to distinct geological terranes and".

Have modified this to say that extension occurs parallel to the boundaries between distinct geological terranes (Line 18).

Fig. 4: Cross sections are vertically exaggerated. It would be useful to note in the caption by how much.

This has now been added to the figure captions where appropriate. The cross-sections in Figure 4 are shown at 2.5x vertical exaggeration, whereas those in Figure 6 show no V.E.

Section 5.1: There is a recently submitted analog/numerical modelling manuscript at Solid Earth Discussion by Schmid et al. (https://doi.org/10.5194/egusphere-2022-1203) that might be relevant to this section.

We agree that this is relevant to this section and have added a sentence on this in the revised manuscript (Line 278).

Some figures contain rather small font that could be enlarged for better readability.

Figures have been modified to ensure that the text is clear and legible.

Citation: https://doi.org/10.5194/egusphere-2022-1278-RC1