Response to Review #3

The study by Froemchen et al. investigated the active tectonics of the Shanxi Rift System using geomorphic indices to 'to identify the impact of structural inheritance on the formation of the Shanxi Rift System'. The geomorphic indices highlight the focusing of active deformation in the rift interaction zones (RIZs) separating the active rift basins: Linfen and Taiyuan Basins are separated by the Lingshi RIZ, and the Taiyuan and Xinding Basin are separated by the Shilingguan RIZ. The Lingshi RIZ shows a through-going fault system, a through-going axial stream with unidirectional southward flow, and a southward down-stepping longitudinal surface relief shape that suggests a recently breached RIZ. The Shilinggian RIZ retains a high relief, lacks a through-going stream, but hosts evolving active faults that suggest a partially Breached RIZ morphology. The authors went further to assess the basement fabric trends across the region, and their relationship between faults bounding the rift basins and those extending into the RIZS, and found that the NE-trending basin-bounding faults follow the basement fabrics indicating structural inheritance control, whereas the RIZ faults form zigzag geometries suggesting strain re-orientation in the RIZs. The authors conclude that 'geomorphic indices might prove useful in the study of the evolution of structural inheritance in other active rifts'.

I think the topic of the paper is of broad interest to the continental rifting community and a good fit for EGU-Solid Earth's audience. However, while I enjoyed reading the manuscript, I have two major criticisms of the paper which I explain below and provide suggestions on how the issues can be fixed.

> *We thank the reviewer for their detailed review and the helpful comments and constructive suggestions. We have addressed the comments and have modified the manuscript accordingly. Below are the more detailed responses to the individual comments with references to the changed parts in brackets:*

1) Drainage and topographic geomorphic indices cannot directly show the impact of structural inheritance on active rift tectonics. In other words, one cannot look at a map of hypsometric integral, local, relief, channel steepness index etc. and interpret that areas with high values are controlled by structural inheritance. Where there is a relationship, it is always indirect. The reason is simply because geomorphic indices of drainage systems are primarily sensitive to surface processes and controlling factors like vertical motions and variability in erodibility of rocks. Whereas structural inheritance is a mechanical process that is controlled by the interaction between the geometry and strength of inherited mechanical anisotropy and the tectonic stress field. Thus, while I think the tectonic geomorphology analysis and structural inheritance investigations in this study are great, the interpretation of a causative relationship between both is problematic. This implied causative relationship weakens the impact of the paper and should be avoided. The main point is that geomorphic indices can highlight the zones of intense active tectonic deformation which in the case of this study are the deforming RIZs within which active breach faulting is influenced by the inherited basement fabrics. However, I think it can be easily fixed by rewording key sections of the texts that alludes to an interpretation of direct causative relationship which includes the manuscript title, the abstract (lines 18-19, 24-25), introduction (lines 92-93), and many sections of the discussion (see my in-text suggested edits).

Yes, we agree that the wording in the manuscript suggesting a causative link between the inheritance and geomorphic analysis was imprecise and misleading. We will reword the outlined sections in line with your comments those of the other reviewers to clarify that we do not imply a causative relationship between inheritance and geomorphic analysis but instead use geomorphic analysis to evaluate the tectonic evolution of the rift and compare this to the mapped inherited structures.

Line 18-19: "Here we use tectonic geomorphological techniques, e.g., hypsometric integral (HI), channel steepness (ksn) and local relief to study the evolution of the Shanxi Rift and identify areas of higher tectonic activity. We found that HI was less sensitive to lithology and more valuable in evaluating the tectonic signal and found that activity is concentrated in two rift interaction zones (RIZ) formed between the basins. We then evaluate the relationship between the active faults and mapped pre-existing structures and found that many faults formed parallel to inherited structures. (17-22)

Line 24-25: removed.

Line 92-93: "By using geomorphic analysis to evaluate the tectonic evolution of the Shanxi Rift, highlighting areas of increased tectonic activity and comparing these with inherited structures, we provide new insights on the influence of inheritance on the evolution of the Shanxi Rift." (99-101)

2) On interpreting mantle anisotropy to represent inherited mantle fabric: Due to a lack of any age constraint on the timing of development of the anisotropy beneath this region, I do not think the interpretation of mantle shear wave anisotropy to be an inherited mantle fabric is appropriate. The mantle underlying active Continental rifts commonly develop anisotropic fabric due to mantle flow induced by the rifting, and this anisotropy is not always parallel to the rift axis (see East African Rift studies e.g., Tepp et al. 2018; doi.org/10.1029/2017JB015409). I don't think there is a need for this interpretation. The study has presented a strong case for the control of crustal inheritance. I think this is sufficient unless there is strong data on the age of the mantle anisotropy.

Thanks for bringing this to our attention. We understand that this discussion part is speculative and mainly based on the map shape of the TNCO and the shear wave anisotropy which as highlighted by you might be dubious evidence. We think that this is still a valuable thought experiment as multilayer inheritance is common in many rift basins and the response of rift evolution to obliquity of crustal and mantle inheritance has been modelled recently (Zwaan et al. 2022; Molnar et al., 2020). However, the evidence for this is thin and therefore perhaps more work needs to be done before highlighting this connection. We added the caveats and limitations to this interpretation highlighted above to make clear that this part of the discussion is speculative. (639-643)

In addition to these two criticisms, I have a lot of minor recommended edits which are mostly typographical errors in the text and missing references. I have attached my in-text comments to this review.

We went through the annotated pdf with the in-text comments and have done our best to address these and correct the errors and missing references. Thanks for highlighting these.

I would note two of the recommended edits:

1) Include some discussion text on the relatively different stages of development of the Lingshi and Shilingguan RIZs, which I think can be explained by their contrasting RIZ geometries. This is well supported by our recently accepted paper Kolawole et al. (2024, AGU Books, in print) where we find that RIZ geometries may influence the pace of breaching of active RIZs as they influence tectonic stress distribution across the interacting RIZ bounding faults. See the ESSOAr preprint: https://www.researchgate.net/publication/370066205_Rapid_Versus_Delayed_Linkage_and_Coalescence_of_Propagating_Rift_Tips

Reference:

Kolawole, F., Xue, L., Dulanya, Z. Rapid Versus Delayed Linkage and Coalescence of Propagating Rift Tips. Accepted, in press at AGU Books: Extensional Tectonics: Continental Breakup to Formation of Oceanic Basins. Preprint: 10.22541/essoar.168167202.29986035/v2.

Thanks for highlighting this fascinating paper, we agree, that the differing geometries of the RIZs in Shanxi may indeed explain the different evolution stages of the RIZs. We included a short section of the discussion on this to refer to the apparent northward progression of the Shanxi Rift which may be connected to the different RIZ geometries. (Line 486-494)

2) Adding a panel to Figure 7 showing the longitudinal elevation profile of the Fen He River itself from the center of the Taiyuan Basin to the center of Linfen Basin. I did a quick plot of the profile, and it shows the very nice 'down-stepping' shape that is typical of 'recently breached RIZs'. I think a plot like this would make this figure stronger.

We have added a longitudinal elevation profile of the Fen He which shows that down-stepping profile typical of recently breached RIZ and have added this to the discussion to strengthen the identification of the Lingshi RIZ as a recently breached RIZ. Thanks for the suggestion! (Fig. 8c)