TEKTONIKA

Review Report

Zwaan et al., Simultaneous Deformation Along the Main Ethiopian Rift and Associated Transversal Lineaments: an Analogue Modelling Perspective, TEKTONIKA, 2025.

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1st Round of Revisions

Decision Letter

Dear Dr Zwaan and co-authors,

Thank you for submitting your work "Simultaneous deformation along the Main Ethiopian Rift and associated transversal lineaments: an analogue modelling perspective" to Tektonika. We have now received comments from two reviewers and the editor. The reviewers raised some concerns about the manuscript, and based on their recommendations and our own assessment, we believe that moderate revisions are needed before the manuscript can be considered for publication. This study employs a series of analogue experiments to investigate whether the Yerrer-Tullu volcano-tectonic lineament (YTVL) could have been active simultaneously with the Main Ethiopian Rift (MER), challenging previous assumptions about the reactivation of structures parallel to the far-field extension direction. The experiments suggest that activation of such crustal weaknesses is possible, contributing to our understanding of how pre-existing structures influence younger deformation. However, this finding appears to contradict previous studies, prompting reviewers to question the applicability of these models to the MER geological setting.

The reviewers recommend several improvements that will strengthen the study's contribution to our understanding of rift dynamics and the influence of pre-existing structures on deformation patterns. We ask that you carefully address and respond to each of the points raised by the reviewers in a response letter, and we ask you to submit a copy of your revised manuscript, with changes clearly marked, and a clean version, during your resubmission.

Specific points we would particularly ask you to address are:

- emphasize the significance and applicability of the findings, particularly in relation to the MER geological context. This could be done, for example, by enhancing illustrations, particularly in Figure 1, to better represent active structures within lineaments.

- provide a clear justification for the modeling approach, specifically the use of weak seeds/notches. The geological features or weaknesses represented by these seeds need to be explicitly defined.

- provide a more detailed explanation of the localization observed in the models.

- define some terms used in this study like "reorientation" which is used in different contexts, and also state how obliquity is calculated.

- expand the interpretations and discussions to highlight the significance of the experimental results, including a comprehensive discussion on the mechanisms behind seed activation, which is currently lacking in the submission.

We hope that you will be able to address the reviewers' concerns and submit a revised manuscript by 17th February 2025. If you require additional time for your resubmission,

please don’t hesitate to get in touch with the editorial team to discuss a revised timeline. Feel free to reach out at any stage if anything is unclear.

Yours sincerely,

Guillaume Duclaux, PhD, Associate Editor - Tektonika

Janine Kavanagh, PhD, Executive Editor - Tektonika

Comments by Reviewer 1

Review of "Simultaneous deformation along the Main Ethiopian Rift and associated transversal lineaments: an analogue modelling perspective" by Zwaan et al., submitted to Tektonika.

The paper aims to investigate the origin of deformation in lineaments almost parallel to the extension direction across the Ethiopian Rift, using analogue models. While I believe all models bring value and should be published, I must note that some crucial aspects need clarification for this study before publication.

The main point is that the paper should better illustrate or map the structures thought to be active within the lineaments (are these the small black lines without kinematic indicators, or the dashed line?). This is central to the study, but from the map, it is not entirely clear, leaving me uncertain as to what strain rates generated by the model's notch should be compared to.

Secondly, the paper should clarify the reasoning behind modeling these lineaments with weak seeds/notches instead of wider slabs or possibly strong heterogeneities. I am unclear about what these seeds represent geologically.

Thirdly, the paper should explicitly explain how obliquity is calculated. The main conclusion states that obliquity is necessary to reactivate the seed, yet Figure 1 does not provide a clear basis for the 45° obliquity chosen for models A1 to A4.

Below, I discuss these three key points in more detail, which I believe need clarification prior to publication. These clarifications should be feasible, though I am uncertain if new models should be run to examine the influence of seed type (strong vs. weak, slabs vs. seeds).

Laetitia Le Pourhiet

Figure 1

Does the map suggest that the main border faults truly terminate at the lineaments? If so, it would be beneficial for the model to capture this primary effect before delving into minor structures.

Setup

I am uncertain about the choice of 45° and 30° VD and how these relate to the Ethiopian Rift. While 30° could be plausible, I don't see the justification for 45°. Observing Figure 1a, I would suggest that the 30° VD mainly arises from the rift trend shifting northward towards Afar in the northern MER.

If we consider an opening direction of N105, the faults in the central and southern MER are nearly perpendicular to the stretching direction, so a VD of 10–15° would better represent obliquity, while 45° is excessive. The only section with 45° is in the northern

MER, but this approach may not be suitable for modeling magmatic activity.

Overall, I disagree that the setup, particularly Series 1, accurately represents the map in Figure 1. If a lower obliquity is applied to be more realistic, then, according to previous studies, the seeds would not be reactivated, which contradicts this paper's conclusions but I will agree that the Serie 2 is probably representative of the 90° extension direction. Would just be nice if you could locate you model compare to the map. Maybe I completely misunderstood the set up and what the basal obliquity means but in any case, it must be clarified in the manuscript.

Seeds

Another point is why the lineaments are represented by 0.5–1 cm diameter silicon putty seeds when, on the map, they appear to be 30–50 km wide. At scale, a notch of 3–5 cm would seem more appropriate, assuming the model's 4 cm height represents the crust. Furthermore, I am uncertain whether these lineaments should represent weaker or stronger crust. I also wonder how the outcome would change if the lineament were positioned on the opposite side or if the authors were to pull the plate situated below the lineaments. All this should be better argued and discussed in the text.

Comments by Reviewer 2

Dear authors and editors,

Please see the review form and annotated manuscript attached. The review form is provided in Word format, so that the authors can directly insert their responses into the document if they so choose.

Thank you for your patience with this review. I hope that the suggestions and comments are helpful.

Best regards,

Anindita Samsu

Section A: Overview of manuscript

A1) Overall evaluation, general comments & summary

A1.1) Reviewer's comments

A1.1.1) General evaluation and publication suggestion – Required:

The submission presents a study investigating whether the Yerrer-Tullu volcano-tectonic lineament (YTVL) could have been active at the same time as the Main Ethiopian Rift (MER). More broadly, the question was posed whether a lineament (interpreted as a crustal weakness) that is almost parallel to the plate divergence direction could be activated or reactivated during rifting, despite previous studies suggesting that this orientation would be unfavorable to reactivation. To answer this question, a series of brittle-ductile analogue experiments of extension was performed, in which the MER was represented by a vertical discontinuity (localizing a rift), and the YTVL was represented by a narrow zone of thinned brittle crust. Based on these experiments, the authors concluded that the YTVL could have been active during the opening and evolution of the MER.

The experiments presented in this submission are interesting and suitable for publication, given that they show that the activation or reactivation of a crustal weakness is possible even when this weakness is parallel to the far-field extension direction, which is another step forward in understanding the range of ways in which pre-existing structures influence younger deformation.

I strongly encourage the authors to develop the interpretations and discussion further, to highlight the significance of the results of these experiments. Several suggestions on how the discussion can be developed are provided in Sections A2.1 and B4.1.

A1.1.2) What does the submission need to be publishable? (select as needed; comment for all cases)

- ☐ No changes required
- ☒ Rewriting
- ☐ Reorganising
- ☐ More data/figures
- ☐ Condensing
- ☒ Reinterpretation
- ☐ Other

Comments:

See Section A2.1.

A1.1.3) Can the submission be improved by reducing/adding any of the following? (select as needed; comment for all cases)

- ☒ Text
- ☐ Table
- ☐ Figures
- ☐ Supplementary material

Comments:

The submission can be improved by adding a deeper discussion of the experiment results (see Sections A2.1 and B4.1).

A1.1.4) Please complete the following section if you recommend that the submission is NOT appropriate for publication (select as needed; comment if a box is selected)

- ☐ Quality is poor
- ☐ Research is not reproducible
- ☐ Other

A2) Summary of main merits and main points of improvement

A2.1) Reviewer's comments

Please describe below in a few sentences (100 to 300 words) the main merits of the submission and suggestions for improvements.

The main merits I have found are...

- The study is well-presented, with a clear and easy-to-follow structure, which made for a pleasant reading experience.
- The figures are suitable and relevant to the text, as are the tables.
- The methods are described in a clear and comprehensive way. The experiments appear to have been conducted in a thorough manner.

The main points of improvement I have found are...

The study could have benefited from a reference experiment in which the crustal weakness (i.e., seed) and VD are 90 degrees to each other. This comment is related to a conclusion presented in the manuscript: that lineaments parallel to the plate divergence direction can be activated when the main rift is sufficiently oblique to the plate divergence direction. To validate this statement, one should in theory run an experiment in which the VD is perpendicular to the plate divergence direction. Alternatively, the manuscript should refer to a previous study in which such an experiment has been conducted.

This submission is missing a thorough discussion on why the seed was activated. The authors propose a local reorientation of the extension direction but do not refer to the presented data (e.g., displacement vectors shown in the Figs. 3 to 6) to explain this. I encourage the authors go a step beyond concluding that the lineament can be activated. Some prompts for this discussion are provided in Section xxx.

A more thorough discussion of similar situations/natural examples could help strengthen the statement on the significance of this study. Where has a situation similar to the YTVL and MER (with “active” lineaments parallel to the plate divergence direction) been observed but not yet explained?

Section B: Detailed evaluation of manuscript

B1) Title and abstract

B1.1) Reviewer’s comments

*These statements are a **guide** to what good* Titles *and* Abstracts include*. Please select YES or NO to the statements below if you wish and detail in the free form box below your reasons for any box checked with NO, or to comment on any other matter.*

The *Title* describes the main topic of the manuscript **accurately** — [YES] / [NO]

The *Title* describes the main topic of the manuscript **succinctly** — [YES] / [NO]

The *Title* includes **appropriate key terms** — [YES] / [NO]

The *Abstract* includes a **clear aim and rationale** — [YES] / [NO]

The *Abstract* supports the rationale with **sufficient background information** — [YES] / [NO]

The *Abstract* includes a **well-balanced description of the methods** — [YES] / [NO]

The *Abstract* describes the **main results sufficiently and adequately** — [YES] / [NO]

The *Abstract* clearly describes the **importance/impact of the study** — [YES] / [NO]

The *Abstract* clearly states the **conclusions of the study** — [YES] / [NO]

The *Abstract* is **clear** and **well structured** — [YES] / [NO]

Comments:

The title could benefit from a slight rewording for accuracy. Specifically, the work “transversal” implies that the lineaments lie across the MER. In Fig. 1, the GBVL appears to maybe cross the MER, and the YTVL terminates at the MER. In addition, “associated transversal lineaments” is vague. What relationship is implied by “associated”? Simply a geometric relationship, or something else?

The abstract is well-written and structured. It could benefit from a more specific statement on the impact of the study. The last sentence is vague and not supported by a discussion on the topic, apart from the final two sentences in the conclusion, which is rather general. See also my comments in Section A2.1.

The authors could define what they mean by “reorientation”, as it is used differently in two different contexts, and/or use the term consistently. In the abstract, the authors use the term “stress reorientation” to describe a possible change or “rotation” in direction of the far-field stress with time, throughout the evolution of the MER. In other parts of the manuscript (e.g., Discussion and Conclusion), “reorientation” seems to refer to local “perturbations” in the local stress or strain field because of another structure. Perhaps the authors could use more precise terminology or wording to distinguish between the two phenomena outlined above.

B2) Introduction

B2.1) Reviewer’s comments

*These statements are a **guide** to what good* Introductions *include. Please select YES or NO to the statements below if you wish and detail in the free form box below your reasons for any box checked with NO, or to comment on any other matter.*

The *Introduction* provides **sufficient background and context** for the study — [YES] / [NO]

The *Introduction* describes the **aim/hypothesis/rationale** clearly, providing **sufficient context** — [YES] / [NO]

The *objective/hypothesis/rationale* **flows logically from the background** information — [YES] / [NO]

The *Introduction* describes the study's **objective and approach** (last paragraph) — [YES] / [NO]

The *Introduction* contains **relevant, suitable citations** — [YES] / [NO]

The *Introduction* is **organized effectively** — [YES] / [NO]

B3) Data and methods

B3.1) Reviewer's comments

*These statements are a **guide** to what good* Method *sections include and good practices for* Dataset *accessibility. Please select YES or NO to the statements below if you wish and detail in the free form box below your reasons for any box checked with NO, or to comment on any other matter.*

The *Methods* are described **concisely and with enough detail** for reproducibility — [YES] / [NO]

Necessary information about **data sources/acquisition/processing** is included — [YES] / [NO]

Data used are accessible via either supplementary files or links in the data availability statement — [YES] / [NO]

The *Dataset and/or Methods* are **organized effectively** — [YES] / [NO]

Comments:

The authors explain that "seeds" represent an inherited weakness caused by the difference in the crust north and south of the YTVL (Lines 130-131). This is incorrect, as such seeds simply locally reduce the strength of the crust along a long, narrow zone. It doesn't represent two blocks of crust with distinct strengths, as the strength profile on both sides is the same. Hence, I suggest rewording this section for accuracy (and potentially adding this point to the discussion on model limitations).

Explain that the different seed diameters mean in nature. Presumably a larger seed diameter represents a thinner brittle crust or wider zone of weakness.

B4) Results

B4.1) Reviewer's comments

*These statements are a **guide** to what good* Result sections *include. Please select YES or NO to the statements below if you wish and detail in the free form box below your reasons for any box checked with NO, or to comment on any other matter.*

The *Results* findings are **supported by data** — [YES] / [NO]

The *Results* findings are presented **clearly and succinctly** — [YES] / [NO]

The text in the *Result* section **cites tables and figures appropriately** — [YES] / [NO]

The *Results* directly **relate to the study objectives** — [YES] / [NO]

The *Results* present **data for all the approaches** described in the *Methods* section — [YES] / [NO]

The *Results* **text belongs to the Results section**, not to *Introduction*, *Methods*, or *Discussion.* — [YES] / [NO]

The *Results* section is **organised effectively** — [YES] / [NO]

Comments:

Lines 203-204, "This localization of deformation is associated with additional displacement between

204 the seed and the main graben": This "additional displacement" in the zone bound by the seed and the VD should be described in more detail, commenting on its magnitude and direction. This has potential implications for how the movement along the YTVL can be interpreted and perhaps explained. The same comment applies to Lines 206-207.

Line 209, "gradual increase in opening": Replace opening with displacement, or describe more clearly what is being opened. Also, it is not clear what is meant by "moving along the seed."

Is a "graben" defined by an area of relatively low topography? If so, please state this.

For models where the angle between the seed and VD is 45 degrees, the seed is activated when it has a diameter of 10 mm (A2 and B4), but not when the seed diameter is 5 mm (A1 and B3). I don't think this observation is explicitly stated anywhere, and it could be integrated into the summary in Fig. 7. For the discussion, perhaps a conceptual model can be presented with the aid of such an observation, which considers the interplay between the angle between the seed and VD and the seed size. This might be more impactful than closing the manuscript with Fig. 8, which is great for showing the similarity between modelling results and the MER map but does not explain the modelling results.

B5) Discussion and conclusions

B5.1) Reviewer's comments

*These statements are a **guide** to what good* Discussions *and* Conclusions *include. Please select YES or NO to the statements below if you wish and detail in the free form box below your reasons for any box checked with NO, or to comment on any other matter.*

The *Discussion* is **focused on the objectives** of the study — [YES] / [NO]

The *Discussion* **addresses all major results** of this study, which are shown in *Results* — [YES] / [NO]

The *Discussion* section makes **comparisons with other studies** that are relevant and informative — [YES] / [NO]

The *Discussion* section properly identifies all **speculative statements** — [YES] / [NO]

The *Discussion* section presents the **implications of the study** persuasively — [YES] / [NO]

The *Discussion* section **highlights novel contributions** appropriately — [YES] / [NO]

The *Discussion* section **addresses the limitations** of the study appropriately — [YES] / [NO]

The *Discussion* section is **organised effectively** — [YES] / [NO]

The *Conclusions* are **consistent** with and **summarise** the rest of the manuscript — [YES] / [NO]

The *Conclusions* are **supported by the data** in *Results* and **follow logically** from the *Discussion* — [YES] / [NO]

The *Conclusions* are **clear and concise** — [YES] / [NO]

Comments:

As mentioned in Section A2.1, I encourage the authors to dive deeper into the discussion of the results and interpretation. The authors may be able to propose some explanations for the lineation activation through asking questions such as: What do the displacement vectors tell us about deformation within the model? Can something be said about the kinematics of movement along the lineament? For example, is the activation of the lineament a result of the “east” or “south”-ward movement of the block between the VD and lineament? Also, see the observation presented in Section B4.1, which could help with developing this discussion.

B6) Figures, tables and citations

B6.1) Reviewer’s comments

*These statements are a **guide** to what good* Figures *and* Tables *include and how they are presented. Please select YES or NO to the statements below if you wish and detail in the free form box below your reasons for any box checked with NO, or to comment on any other matter.*

Tables and *Figures* are **ordered logically** and **numbered sequentially** — [YES] / [NO]

Tables and *Figures* have **captions that explain** all their major features — [YES] / [NO]

Tables and *Figures* have **captions that complement** the information in the main text — [YES] / [NO]

Tables and *Figures* present data that **relate** to the study objective — [YES] / [NO]

Tables and *Figures* present data that are **consistent** with and support the description of results — [YES] / [NO]

Tables and *Figures* have **succinct and informative titles** — [YES] / [NO]

Figures are **accessible** (elements are clearly labelled, accessible colour palettes, colour contrasts, font size legible, etc.…) — [YES] / [NO]
Please, check our [Figure guidelines]

Figures with **maps or cross-sections** contain all **elements to be understood** (north arrow orientation, scale, visible coordinates, sufficient coordinate grid intercepts) — [YES] / [NO]

Figures with **maps** have **sufficient location information** (in the map or caption) — [YES] / [NO]

Cross-sections have clear labels for **scale and coordinates** at ends and within-section kinks — [YES] / [NO] – not applicable

All georeferenced elements are provided in common format (.shp, .geotiff, .kml) [in an open-access repository] — [YES] / [NO] – not applicable

Citations throughout are relevant, suitable, and comprehensive — [YES] / [NO]

Comments:

Fig. 1:

- Symbol for active displacement should be explained or labelled.
- Where are the divergence directions of 90 and 105 degrees taken from? Please provide citations and, if possible, explanations for how these divergence directions were obtained, as they provide the rationale for the study and form the basis of the model setup.

Figs. 3 and 4, “Vectors in the Vx maps indicate the full incremental displacement direction and magnitude”: Add this explanation or label directly on image.

Section C: Additional comments

C1) Minor/line-numbered comments

C1.1) Reviewer's comments

Line 13: I recently attended a talk by Robyn Pickering, where she explained the preferred use of "eastern African Rift System" over "East African Rift System", as the latter carries colonial roots (see Pickering et al. 2023; https://research.vu.nl/files/299856644/How_language_can_be_a_path_away_from_neo-colonialism_in_geoscience.pdf). In sharing this suggestion, I am mindful that East African Rift System or EARS is a widely accepted term in the geoscience community.

Lines 46-48: Explain briefly in which direction the MER opened (i.e., which domain of the rift is older or younger).

Lines 53-56: Please rewrite for clarity.

Line 62: Why is the YTVL considered to be the "most important" of the transverse structures?

Lines 66-68: How can the YTVL experience eastward displacement if it trends E-W? Which part exactly is moving east?

Lines 72-78: What is the evidence for structural inheritance? And what is considered to be the pre-existing structure? The change in crustal thickness or vertical to steeply dipping weak zones (made up of, e.g., shear zones) within stronger crust? The effects of these two distinct "types" of pre-existing structures would be different. What is known about the geometry of the YTVL at depth and it's mechanical properties?

Line 85: What is meant by the "modern rift valley"?

Fig. 1: On the left-hand inset, the displacement vectors increase in length from south to north, implying rotational rifting. Does this rotational movement impact the structures along the MER and the YTVL (and other lineaments of the same orientation)? Whether or not it does should at least be mentioned in the introduction, especially as the focus of this study is to "replicate" rifting along the MER.

References: Erbello is misspelled.

Authors' Reply to Decision Letter

Authors' reply: We kindly thank the editors for organizing the review of our manuscript, and for providing constructive feedback. In the following we provide detailed replies, in a nutshell:

o We have improved the figures to better illustrate the geological context (and put more focus overall in the YTVL, which is the core inspiration of this work, rather than the GBVL)

o We have better clarified the use of seeds and how they represent the natural situation, i.e. the YTVL.

o We now provide a more detailed explanation of the localization observed in the models (via extensional strain reorientation theory pioneered by Withjack & Jamison 1986

o We now made a clear distinction between (1) large-scale changes in plate motion and (2) local extensional strain reorientation, and make sure to not mix terminology. Obliquity is defined as shown in the (revised) figures.

• NB: there were some issues with the track changes option being off during some parts of the revision process. To fully display all revisions, we have included a clean PDF and a PDF compared to the previously submitted manuscript.

Authors' Reply to Reviewer 1

We kindly thank the reviewer for providing constructive feedback. In the following we provide detailed replies.

Figure 1:

The models are (as always) a simplification of the natural case and cannot reproduce al the complexities of the actual MER. Some of the models do show termination of the boundary faults at the transversal lineament; the reactivation of this lineament does not seem to be influenced by the behaviour of the boundary faults, which therefore is not crucial for our findings.

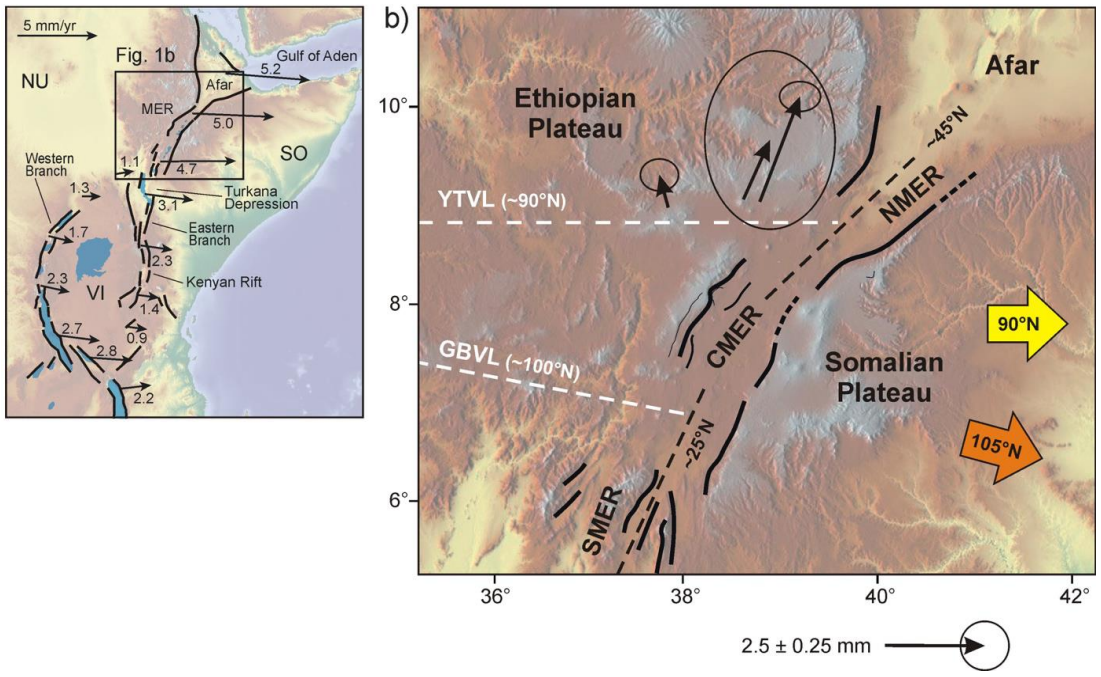
Setup:

o The orientation of the VD reflects the situation along the northern/central MER, which is 45˚N. As such, the 45˚ oblique VD would represent a 90˚N plate motion scenario, whereas the 30˚ oblique VD would represent a 105˚N plate motion scenario. This is clearly explained in section 2.2 (model parameters), and we have drawn it out in the map below. Perhaps the confusion stems from Fig. 8, where we show two models that could fit the situation in nature (i.e. the YTVL and MER)?

- To avoid any future confusion, we have updated the map in the manuscript to clearly indicate the orientation of the rift axis in the northern and central parts of the MER.

o The E-W striking YTVL, which is the main lineament our work is inspired by, interacts with the northern/central part of the MER, so our model set-up is solid.

o It is true that we do not include the magmatism in the MER our model, but we argue that is not a major issue since we do not aim at reproducing the MER itself. Instead, we aim to study how the lineaments outside the rift can be active, even if they are unfavourably oriented with respect to the overall plate tectonic situation. This is addressed towards the end of section 4.1.



Seed:

o We apply the seeds as a means to localize deformation. In the case of the YTVL, they are intended to represent the transition between the thicker crust in the north, and the thinner crust in the south. We assume that this transition represents a rheological contrast that localized deformation in a similar manner as the seeds in our model. This allows us to avoid the rather complex construction of crustal domains with different thicknesses, and present a clear and straightforward modelling study.

o When it comes to the size of the lineaments: The YTVL is vaguely defined in published works, and the width of its volcano-tectonic expressions may vary along its length. As such, the width of the YTVL is poorly constrained. Some researchers indicate it as a broader zone, but most people like to represent it as a simple line on map. Using a seed is the easiest way to simplify this loosely constrained system and reproduce it. As for the relative strength/weakness of the YTVL, this is commonly believed to be a weak zone.

- We have now addressed the uncertainty regarding the extend (width) of the YTVL (and GBVL) in the paper, and clarified that we apply a focusses interpretation of the lineament's extent in our study (i.e., that it is more of a focussed, linear, zone of deformation, rather than a wide one, inherited from Neoproterozoic deformation). As such, we have removed the explanation of crustal thickness differences.
- Keir et al. (2009): https://doi.org/10.1029/2009GC002382

o The placement of the lineaments on one side or the other of the model should not make much of a difference in terms of localization of deformation. See for instance the works by Zwaan et al. 2021, 2022; Bonini et al. 2023, who used seeds on both sides of the VD, which would then both activate. That is, the systems would be more or less

symmetric, so there should be activation on the other side as well (keeping in mind that the seeds must be oriented favourably, or the VD must be oriented sufficiently oblique to allow less favourably oriented sees [as those in our models] to activate).

- We have now addressed this in the text

Authors' Reply to Reviewer 2

A1.2) Author(s) Responses:
Authors' reply: We kindly thank the reviewer for providing constructive feedback. In the following we
provide detailed replies.

A2.2) Author's responses:
We can confidently build upon previous works (e.g., Zwaan & Schreurs 2017, Corti et al. 2018, and Zou et al. 2023, but in particular Maestrelli et al. 2020 and Bonini et al. 2023), who have shown that secondary weaknesses oriented (sub-)parallel to the rift axis (or general extension direction) are not reactivated under overall orthogonal extension. The exception occurs under the conditions we are testing in our models.
o These works (apart from Corti et al. 2018, https://doi.org/10.1016/j.tecto.2018.02.011 and Maestrelli et al. 2020: https://doi.org/10.1029/2020TC006211) were already mentioned in the previous version to make this argument in the introduction, but we have now expanded the text to better clarify the argument and set the stage for our modelling study.
o Moreover, we have run a single control experiment with an orthogonal VD and a 90˚ seed (ø = 10 mm) that shows absolutely no reactivation and is therefore fully in line with previous model results. The results of this experiment are included in the appendix of the new manuscript.

We now have added a more thorough explanation as to how the seeds can be activated, using extensional strain reorientation theory pioneered by Withjack et al. (1986). It follows that the main rift/VD causes a reorientation of the local extension direction, allowing activation of the seeds. Moreover, there may even be a secondary reorientation due to the seed itself being a weak zone.

o We agree that it would be of interest to highlight other examples of such improbable active lineaments. However, we are not aware of any. It may be that this phenomenon is very rare, or that there are simply no present-day examples, given the limited number of active continental rifts in this stage of the global Wilson Cycle. Given that this work is inspired by a local phenomenon, we believe that somewhat forcing a broader scope is beyond the purpose of this study.

- Even so, we hope of course that our new analysis could inspire researchers to rethink other examples of improbable reactivation of structures, either in the present day or perhaps even in the past.

B1.2) Author's responses
We have modified the title as follows:
o *Local strain reorientation explains deformation along rift-oblique tectonic lineaments along the Main Ethiopian Rift*

o “transverse” is indeed vague, we now use “oblique”, as in “oblique lineament” throughout the text (although we use the shorter “rift-oblique” in the new title)

See the other reply on this topic: we don’t have any ready examples at hand and the MER may be a somewhat rare case. But we hope that this study can be of use for the interpretation of other areas. The inclusion of this statement in the conclusion was to sketch some perspective for future research.

o **There are indeed two types of reorientation**, which we now refer to as follows in the revised manuscript:

- changes in plate motion direction and thus regional extensional stresses
- local reorientation of regional extensional strain (itself a result of stress reorientation, but we cannot really account for stress in our analogue models, only for observed strain)

B3.2) Author’s responses

o We use the seed as a practical means to simulate the localizing impact of the rheological contrast due to the contrast in crustal thickness. We have now rephrased the text to better explain that we do not directly apply differences in crustal thickness between two crustal blocks. See also our reply to the comment from reviewer 1 on the same topic.

o A thinner seed, when one-to-one scaled up to nature would be indeed a (locally) thinner and therefore brittle crust. this is how the deformation localization mechanism in the model works. However, we do not aim to directly reflect the natural case (see also previous answer): we aim to implement different degrees and orientations of weaknesses, based on the natural case, to explain the curious activation of such weaknesses.

B4.2) Author’s responses

We have added more details on its direction, which is an important part of the revised discussion. The magnitude itself is important in that there is a gradient, which is also described in the revised text.

o we mean that from west to east, there is an increase in opening / displacement along the seed. We have rephrased the text to avoid confusion.

o Graben is a common geographical/geological term that we believe should be known to the reader.

We have focussed our Fig. 7 on the key points, and the 45˚ angle case seems a minor point. As such, we decided to keep it out. We have included a new schematic figure 8 that explains how strain reorientation can lead to activation of the seed.

B5.2) Author's responses

We have added new discussion and a schematic figure to better address these questions, which was indeed deadly missing in the previous manuscript.

B6.2) Author's responses

o It is not 100% clear what the active displacement symbol that the reviewer refers to is. The arrows (GPS motions) were indicated in the figure, but we have added some moredetails. Note that divergence directions (end members) are after DeMets and Merkouriev (2016; 2021). This was mentioned in the main text, but not in the caption, where it is now added.

o We thank the reviewer for this suggestion, the sentence is added to the caption of both figures

C1.2) Author's responses

o We prefer to stick with established terminology

o There is general agreement that at least in the last few million years the direction of extension has been more or less E-W or ESE-WNW, with no significant changes. As for the age of the different rift domains this is quite complex and there is no clear consensus at the moment. As such, a detailed description of the evolution of the MER is not key to our paper and could distract from the main objective: explaining how the YTLV can be active under the current plate tectonic setting.

o Although the northern part of the MER may in fact be the youngest (see previous reply), the current state of the MER shows a younger rifting stage in the south, whereas the northern MER is close to breakup. We have now rephrased things for better clarity.

o The YTVL is believed to be the most important because it extends larger than the GBVL, and is characterised by more prominent Miocene-recent volcano-tectonic activity.

o We mean that there is a displacement gradient, in that there is more displacement in the east than in the west. The text is now rephrased to avoid confusion.

o See replies to previous comments from both reviewers on this topic: we identify the transition in crustal thickness between north and south as the weakness.
o Moreover, the focus of this study is not to create the exact same structures as found in nature. Instead, we aim to show that deformation in general is possible along lineaments, even if they should be considered unfavourably oriented. We do however generate extensional deformation along the seeds / modelled lineaments, which matches the type of deformation along the YTVL (extensional)

o We mean the present-day MER rift valley. The text is reworded.

o There is indeed increased northward plate divergence along the East African Rift System (EARS) in general, which is linked to the rotation of the Somalian plate (Fig. 1a).However, this rotation occurs at a very large scale. The along-rift plate motion gradient may have had an important effect on the evolution of the EARS (Zwaan & Schreurs 2023 in Solid Earth: https://doi.org/10.5194/se-14-823-2023). However, at a local scale, we should not expect such gradients to have much of an effect on local structures such as the lineaments (Zwaan & Schreurs 2020 in Journal of Structural Geology: https://doi.org/10.1016/j.jsg.2020.104119).
o We have now mentioned this in the introduction

o Thanks for noticing the typo, it is now corrected

C2.2) Author's responses
Replies to comments in annotated PDF (insofar as not already listed in C1.2):
Line 65: Do the faults strike E-W?
• **Authors' reply**: o They do indeed strike E-W, it is not rephrased for clarity
Line 95: Replace with "study" or "explore". Normally, hypotheses can be tested.
• **Authors' reply**: o We now use "study" as suggestedLine 95: Replace with "study" or "explore". Normally, hypotheses can be tested.
• **Authors' reply**: o We now use "study" as suggested
Line 238: Similar to what?
• **Authors' reply**: o Similar to the other models in series 2, as specified in the first part of the sentence. We have reordered the sentence to avoid possible confusion.
Line 320: What is meant by "generic"? Perhaps replace with a more specific description.
• **Authors' reply**: o We now use "previous"
Line 320: What is meant by "generic"? Perhaps replace with a more specific description.
• **Authors' reply**: o We now use "previous"
Line 322: This is vague.
• **Authors' reply**: o We now rephrased the sentence to: "As such, the simultaneous deformation along the MER and YTVL has remained a conundrum."
Line 325: This is also vague.
• **Authors' reply**: o We now rephrased the sentence to: "Our novel analogue modelling study now enables us to propose a solution to this conundrum."

Acceptance Letter

Dear Drs Zwaan, Muluneh, Liu, Khosari, Rosenau, Corti, and Sani,

We are pleased to inform you that both the Associate and Executive editors have reviewed the resubmitted revision of your manuscript, "Local strain reorientation explains deformation along rift-oblique tectonic lineaments along the Main Ethiopian Rift" (ID: 86) and are satisfied with the changes you have made in response to the two reviewers' comments. Your careful attention to their recommendations and response to their questions has greatly improved the quality of the paper.

We are happy to confirm that your manuscript is now accepted for publication in τεκτονικα. The next steps will involve production processing, during which you will receive proofs for final review before publication. Our production team will be in touch to oversee this process.

Thank you for your contribution to τεκτονικα and we hope you will consider publishing with us again. We have greatly appreciated your cooperation throughout the review process and look forward to sharing your work with our readers.

Congratulations, and thank you again for submitting your work to τεκτονικα!

Yours sincerely,

Guillaume Duclaux, PhD, Associate Editor
Janine Kavanagh, PhD, Executive Editor