Solid Earth Discuss.,
https://doi.org/10.5194/se-2020-104-RC2, 2020

Solid Earth
Discussions

Interactive comment on "A systems-based approach to parameterise seismic hazard in regions with little historical or instrumental seismicity: The South Malawi Active Fault Database" *by* Jack N. Williams et al.

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Received and published: 23 August 2020

Title: A systems-based approach to parameterise seismic hazard in regions with little historical or instrumental seismicity: The South Malawi Active Fault Database Manuscript Number: se-2020-104 Authors: Williams et al. ---

This manuscript presents a new systematic approach useful for parametrizing seismic hazards in areas with limited instrumental seismicity. The study was carried out in the

southern part of Malawi, and documents the large faults that are capable of accommodating medium-large magnitude earthquakes in the region, as well as the attributes of these faults that are relevant for the hazard analysis. Also, the study discusses both the seismic hazard and tectonic implications of the results, as well as the uncertainties in the estimates. I believe that this approach is great and useful in active plat boundary settings where there is poor earthquake monitoring infrastructure. Such settings abound in several continents, and seismic instrumentation is expensive; thus, necessitating a need for creative, less expensive approaches as presented in this study. The manuscript is well written and easy to read. I believe that this manuscript contains material fit for publication in EGU Solid Earth. However, I believe this manuscript could appropriate for publication in the journal after moderate revisions to the paper. I'm recommending moderate revision because of the issues I consider to be major flaws in the interpretation of the tectonic domains and associated structural elements in the study area, which directly impact either the input data or specific features of the implementation of the analysis performed in the study. Here below, are the 7 major issues I have with the manuscript, and 2 comments/questions that I think the authors could consider incorporating into the discussion part of the manuscript. Also, I made comments in different parts of the text that are either minor corrections/comments, or are related to the major issues stated below (see attached an annotated pdf).

Regards, Folarin Kolawole

Major Issue 1: The interchanging use of "southern Malawi" and "southern Malawi Rift". These two terms should not be used interchangeably in this text as it can bring confusion. "Southern Malawi" refers to a geopolitical region that hosts rift segments of different tectonic affiliations; whereas, "Southern Malawi Rift" refers to the southernmost segment of the Malawi Rift which includes only the Makanjita Trough & Malombe Graben (bifurcation around the Shire Horst), and the Zomba Graben. This interchanging use occurs at too many parts of the manuscript, so I decided to just mention it here instead of commenting on it in the text (attached pdf). This issue also leads to and is related to my Major Issue 2. . .see below.

Major Issue 2: Definition of principal grabens of the southern Malawi Rift. The authors identified the graben “Lower Shire Graben” as a principal graben of southern Malawi Rift (pg 19 lines 458-459). I have issue with the characterization of this graben as a tectonic element of the Malawi Rift. This is very misleading as this Lower Shire Graben is a sub-basin in the Shire Rift, not the Malawi Rift (Castaing, 1991). I understand that this graben is located within the Malawi geopolitical boundary, whereas most of the other sections of the Shire Rift are located in Mozambique. However, geopolitical location does not automatically make this graben a part of the Malawi Rift. Moreover, the Shire Rift has a distinctly different structure, orientation, and tectonic history from those of the southern Malawi Rift. Shire Rift is a multiphase rift basin (Mesozoic-Cenozoic; Castaing, 1991), whereas, southern Malawi Rift is Late Cenozoic (e.g., Wedmore et al., 2019; Scholz et al., 2020). Infact, exposed basement highs separate the Zomba Graben (which is at the southernmost tip of the Malawi Rift) from this Lower Shire Graben and the other sections of the Shire Rift. Therefore, in order not to confuse a reader, I'll suggest that the authors use the term “southern Malawi” in the context of describing the location of the ‘Lower Shire graben’ (i.e. use geographical description), rather than the term “southern Malawi Rift”.

Major Issue 3: The descriptions of the “Makanjira Graben” in the manuscript and the modelling done in Fig.A3a shows that the authors consider that term to incorporate both the Makanjira Trough and Malombe Graben. The Malawi Rift bifurcates around the Shire Horst into these two segments and further south, they link-up and transition into the Zomba Graben. The Makanjira Trough is bounded to the west by Chirobwe-Ncheu Fault, and to the East by Shire Horst, whereas the Malombe Graben is bounded to the west by the Malombe Fault and to the east by the Mwanjage Fault. The surface+subsurface structure of this section of the Malawi Rift (Lao-Davila et al., 2015) shows that the Malombe Graben has a greater hanging wall subsidence and thus, border fault offset than the Makanjira Trough. Here are the evidences: 1.) the floor of the

Makanjira trough is mostly dominated by exposed basement, whereas, the Malombe Graben is relatively better developed graben structure with a wider-spread sediment accumulation and even a lake development at the foot of its border fault. The zone of sediment accumulation on the northern half of the Makanjira trough is associated with subsidence along the southern extension of the N-S trending eastern border fault of the Nkhotakota Segment of the Malawi Rift (for location of Nkhotakota Segment see Lao-Davila et al., 2015; for the described subsidence and fault location, see Fig.5b of Scholz et al., 2020). 2.) the floor of the Makanjira half-graben is at a higher elevation compared to that of the Malombe Graben, indicating that subsidence is most-likely greater in the Malombe Graben. For reference see the across-rift profiles in Figs.4L-4M of Lao-Davila et al. (2015). I am guessing that the authors consider that because the Chirobwe-Nchue Fault has a higher footwall elevation/escarpment along the rift section, therefore, it must have the largest throw. If that is the consideration upon which the border fault definition and Fig.A3a model are based, I refer the authors to the Rukwa Rift where border fault footwall elevation/uplift is not representative of the subsurface fault throw (Morley et al., 1999). Thus, based on the observed geologic structure, I think the model in Fig.A3a is problematic because it ignores the presence of the fault with the larger offset and hanging wall subsidence at the so-called “Makanjira Graben”. Also, the model assumes the Chirobwe-Ncheu to has the greatest offset/hanging wall subsidence along the profile which is not representative of the distribution of subsidence across this section of the rift (Figs. 4L-4M in Lao-Davila et al., 2015). Therefore, in my opinion, if possible, I think this model needs to be revised. If impossible due to modelling limitations, then it should be stated.

Major Issue 4: Age of the Thyolo Fault and modelling of strain in Lower Shire graben (Fig. A3c and pg 37 lines 895-896, pg 38 lines914-915). The authors suggest that the Thyolo Fault is Karoo age. There is no evidence suggesting that there exists karoo-age sedimentary or volcaniclastic deposits on the hanging wall of the Thyolo Fault (Habgood, 1963; Habgood et al., 1973). Mesozoic activity along the Thyolo Fault would require subsidence of its hanging wall and creation of accommodation space for the deposition of volcanic and sedimentary sequences. Both Habgood (1963) and Castaing (1991) suggested that the Mwanza-Namalmbo Fault system is the eastern border fault of the Mesozoic Shire Rift. Castaing (1991) suggested that the Thyolo Fault is Cenozoic, bounding the currently active eastern domain of the Shire Rift. Therefore, I think this idea of Thyolo Fault being a Karoo fault needs to be revised. . .except the authors provide data showing the presence of Mesozoic deposits on the hanging wall of the Thyolo Fault.

Major Issue 5: Definition of "border fault" in southern Malawi (Fig. 2a). The Lisungwe Fault, Malombe Fault, and Mwanza Faults are excluded from the 'border fault' definition and I am not particularly sure why. This is an issue for me, particularly because the structure of the basins point directly to the essence of these faults. For example, the Malombe Fault is the principal border fault of the Malombe Graben, not the Mwanjage Fault which you've assigned as the main border fault. Even the distribution of the amplitudes and wavelengths of the magnetic fabrics beneath the Malombe Graben in Fig. 2c (Laõ-Dávila et al., 2015) clearly shows that the hanging wall of the Malombe Fault has significantly larger subsidence than that of the Mwanjage Fault. Also, the Mwanza Fault is a major border fault of the NW half of the Shire Rift (as shown in the maps in Figure 2). There is also evidence that the exposed segment of the Mwanza fault has been reactivated in the Cenozoic given by accumulation of Quaternary sediments on its hanging wall (Habgood, 1963).

Major Issue 6: Related to "Issue 4" above, the authors classified Namalambo Fault as an active Fault (e.g., Figs. 1b & 2). Namalambo Fault cannot be classified as an East African Rift System Fault because there is no evidence supporting its Cenozoic reactivation (see Bloomfield, 1958; Habgood, 1963; Castaing, 1991). The mentioned geological reports specifically stated that there is no Quaternary sediment deposition on top of the karoo sedimentary units at the base of its scarp, suggesting it has not been reactivated in the Cenozoic. Also, this fault does not satisfy the criteria stated by the author in Pg11 lines 260-267. Are the authors including it because they're assuming

that it could be reactivated sometime in the future? If yes, I think this should be stated in the relevant figure captions and in the manuscript (particularly because this fault is a prominent fault in the area, and could be confusing to a reader without this additional information).

Major Issue 7 (minor): A 'declaration' that I think is not clearly made in the set-up of the premise of the manuscript is that the parameterization approach focuses on tectonically active continental settings. I do not think that the authors imply that the approach is applicable to relatively more stable intraplate settings where much lower strain rates generally abound and potentially dangerous faults are buried, although some of those areas could be seismically active (e.g., intraplate induced seismicity). Therefore, I'll suggest that the authors state this clearly, at least in the abstract and introduction sections of the paper. I noticed that in different parts of the text, it is subtly implied with phrases relating to plate boundary, interplate setting etc., however, I think it will be beneficial to the reader if this is stated clearer from the onset.

Question/Comment 1: Pg29 lines 703-707. The authors highlighted the anomalously large seismogenic thickness of the southern Malawi area, with continuous 30-60 km-long fault sections. Crustal thickness map of southern Malawi (Njinju et al., 2019a) shows that an unusually thick crust dominates the area. In addition, heat flow map of the same area (Njinju et al., 2019b) shows an anomalous thermal gap in the area. Both of these have been associated it with an eastern extension of the Niassa Craton. Do you think that there is a possibility that these have an impact on the observed seismogenic thickness?

Question/Comment 2: It is well-known that the patterns of seismogenic fault reactivation are influenced by the frictional stability of faults. Asides from strain rate and lithology/mineralogical composition, another important factor that influence the frictional stability is geothermal gradient/heat flow. Well-constrained heat flow & geothermal gradient maps of southern Malawi (Njinju et al., 2019b) show interesting thermal anomalies within the areas analyzed in this study. I am curious as to how the heat flow distribution in the area may affect the results/conclusions of this study.

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Please also note the supplement to this comment:
https://se.copernicus.org/preprints/se-2020-104/se-2020-104-RC2-supplement.pdf

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