Solid Earth Discussions

Solid Earth Discuss., author comment AC2
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Reply on RC2

Christoph Grützner et al.

Author comment on "Holocene surface-rupturing earthquakes on the Dinaric Fault System, western Slovenia" by Christoph Grützner et al., Solid Earth Discuss., https://doi.org/10.5194/se-2021-7-AC2, 2021

RC2

Reviewer comment:

"The authors present a comprehensive paleoseismological study of the Holocene activity of the Dinaric Fault System, which threatens major cities in the region such as Ljubliana or Idrija. They used a large number of methods to obtain their data in a difficult environment with low tectonic activity, in addition to fluvial deposits, forests, intense anthropogenic activity, ... The opportunity for such a study to be undertaken is noteworthy and the use of the several approaches to the topic adopted is mostly appropriate. The paper has a good organization showing a well-organized research work by the authors, providing all kind of information (figures, complementary images, dating samples, ...), for which the authors should be complimented. The writing style is clear and easy to follow. The resulting paper will provide a worthwhile input to the future SHA of the region. However, the manuscript, in its present state, would benefit from further attention and tightening up technically. For my part, the manuscript requires major/moderate revision.

Although the following comments, along with those included in the revised pdf, may appear to be challenging or negative, they are intended to be constructive, as the nature of the topic and how it is being addressed make it worthy of such attention from my pointof-view."

Answer:

Thank you for the very positive and constructive feedback.

Reviewer comment:

"In general terms, further geological description of the sites must be done, especially at Predjama fault : type of sedimentary units, the environment of deposition. A geological map must be included. An adequate description of the sedimentary units exposed on the trenches walls must be also done."

Answer:

Thank you for the suggestion to add more details on the geology. We will add another figure with geological maps of the study area(s), which will have the same extent as Fig. 2 including the two insets. We will also add a more detailed description of the geological units found in the trenches.

Reviewer comment:

"Predjama Fault: My main concern of the interpretation of the trenches in this fault is about the possible pedogenic development on the exposed materials. I am not sure whether the dating is giving the age of a sedimentary deposit or the progressive and continuous process of edaphization. Besides this, the interpretation of unit U6 as sagpond seems to me rather unrealistic. See detailed comments on the pdf."

Answer:

Thanks for the detailed comments here and in the annotated PDF. We will provide more detailed descriptions of the geological units that we encountered in the trench. We interpret units U3 and U4 as weathered calcarenites. Unit U5, however, also contains sand, fine gravels, and charcoal fragments at its base (where it is in contact with U4).

Thus, U5 is not just the product of weathered bedrock, but also involves slope deposits. This lowermost part of U5 parallels U4, which is why we interpret the base of U5 as having been involved in the deformation. Therefore, sample SLO18_BAN3 should pre-date the deformation. However, we agree that non-tectonic processes may have also contributed to the features that we see in the trench, and we realize that we must discuss possible alternative interpretations and processes in more detail. We will therefore discuss these possibilities in the revised manuscript in detail and leave it to the reader to draw the conclusions. Abstract, discussion, and conclusions will be modified accordingly.

We thank the reviewer for pointing out that unit U6 is not likely to be a sag pond deposit. In the revised version, we will remove this interpretation and modify our already included alternative explanation: "We note that unit U6 is not necessarily a sedimentary body, but the distinct pale appearance may be due to post-depositional modification by increased water content, or it may result from compaction due to the occasional use of the track by the farmers."

We will also include the other changes that you suggested in the annotated PDF.

Reviewer comment:

"Idrija Fault: the analysis of the stratigraphic relationship with a potential earthquake is too speculative. The uncertainty of the ages (both, epistemic and methodological) obscure any reliable analysis."

Reviewer comment in the annotated PDF on the same subject:

"The two other samples collected from U10: SLO18_SK13 and SLO18_SK6 give a consistent age around 2300 ka. Taking SLO18_SK11 as representative for the U10 would give an unrealistic young age for the unit and the tectonic activity.

2300 ka is also consistent with the age of the fissure filling. The last tectonic event must occur before that date, and maybe after 2645."

"An alternative dating method as OSL would have been valuable (U10 looks really adecuate sediment for that method)"

Answer:

We agree that the dating results are not as straight forward as we would have wished, and indeed we cannot narrowly bracket the tectonic deformation. We did not take OSL samples, because we found abundant charcoals in the trench. Unfortunately, most of the charcoal samples that we took turned out to be of insufficient quality after pre-treatment in the lab.

Sample SLO18_SK11 gives a very young age of 492-315 cal BP. This contrasts all other samples, which cluster around 2-2.5 ka. (An exception is SLO18_SK8, which yielded ca. 1.5 ka, but it is also a bulk age and not a charcoal age.) One possibility is that the young age of sample SLO18_SK11 is simply wrong. However, it is a charcoal sample and not bulk, and there is no indication of technical difficulties with the sample. It could have been brought into its position via bioturbation, but we checked carefully and did not find any evidence for burrows etc. It is easily possible to deposit an older charcoal in younger sediments, but not vice versa. Therefore, we must assume that the age is valid. There is practically no way to find out how long it took to deposit unit U10, because the samples SK6, SK11, and SK13 are not in stratigraphic order, but sample SK11 indicates that the deposition cannot pre-date 492-315 cal BP. However, we do agree that the clustering around 2-2.5 ka raises the question if something is wrong with sample SK11 (although, as mentioned above, there is no hint for that). The only way to solve this issue is to raise this possibility in the discussion section of the manuscript. In any case we would like to stress that we are not trying to sell a very young rupture, e.g. in the 1511 Earthquake. This is reflected in the title of our manuscript and we also very carefully discussed the pros and cons in the first version. For us, the important message is that the fault ruptured in the last 2.5 ka. Our study does not aim to find the 1511 rupture. Even if the features in the Idrija trench were not due to primary rupture, but due to seismic shaking as suggested by reviewer 1, this means that a strong earthquake occurred very close to the trench site, and perhaps on the Idrija Fault. However, we think that many arguments are in favour of a rupture on the Idrija Fault, despite the trench not showing a textbook rupture with a sharp fault.

Reviewer comment:

"Geomagnetic and georadar surveys could be removed from the paper, as they do not show any valuable results."

Answer:

Thanks for this suggestion. We would like to mention these geophysical surveys for two reasons. (i) It may be a valuable information for other researchers attempting to use GPR or magnetics in a similar setting for active fault studies. (ii) The data set is huge and freely available for everyone via the PANGEA repository (Grützner, 2020). Thus, it can be used for any kinds of scientific studies or other purposes. We would like link the data with the trenching results for the sake of completeness. Also, the methodological description is very short and does not unnecessarily lengthen the paper a lot.

Reviewer comment:

"The analysis of the earthquake magnitude on both faults is completely speculative. The authors cannot make any reliable estimation with their data. Remove these sections.

Please also note the supplement to this comment:
https://se.copernicus.org/preprints/se-2021-7/se-2021-7-RC2-supplement.pdf"

Answer:

Thank you very much! We agree that discussing magnitudes weakens the paper. Accordingly, we will remove this part from the manuscript. We will also happily incorporate all the other comments raised in the annotated PDF, which mainly refer to clarifications, more precise wording, and some changes to the figures.

Reviewer comment in the annotated PDF:

"As you describe later, Sava Ft. and Periadriatic F. accommodate part of this deformation. In the way that it is written, seems like all the motion were accommodated only by DFS. Could even some other not studied faults take part in this motion, also?"

"I do not understand what is the objective of this discussion. Trying to find some correlation between recurrence interval and slip rate? Please, rewrite it."

Answer:

Yes, that is right. In our thought experiment, we therefore wrote "If the entire northward motion of Adria were accommodated by the right-lateral motion on the DFS …" Thank you for pointing out that this is misleading. We will add the information for the Sava and the Periadriatic Ft. and make clear that we talk about the absolute maximum cumulative slip rate that can be expected for the DFS. The entire reason for this paragraph is to make the point that the faults must be slow given the overall slow Adria-Europe convergence, and that the recurrence interval of strong earthquakes must, therefore, necessarily be long.

We will also incorporate all the minor suggestions made in the annotated PDF.

References

Buser, S.: Geological Map of Slovenia – 1:250.000. Ljubljana, Geološki zavod Slovenije, 2009.

Copley, A., Grützner, C., Howell, A., Jackson, J., Penney, C. and Wimpenny, S.: Unexpected earthquake hazard revealed by Holocene rupture on the Kenchreai Fault (central Greece): Implications for weak sub-fault shear zones. Earth and Planetary Science Letters 486, 141-154, 2018.

Grützner, C., Aschenbrenner, S., Krämer, A., Reicherter, K., Saifelislam, N., Ustaszewski, K., Viscolani, A. and Welte, J.: Geophysical survey (GPR, ERT, magnetic) on active faults in Slovenia and Italy. PANGAEA, https://doi.org/10.1594/PANGAEA.922902, 2020.

Lin, A., Rao, G., Jia, D., Yan, B., and Ren, Z.: Co-seismic strike-slip surface rupture and displacement produced by the 2010 Mw 6.9 Yushu earthquake, China, and implications for Tibetan tectonics. Journal of Geodynamics, 52(3-4), 249-259, 2011.

Moulin, A., Benedetti, L., Rizza, M., Jamšek Rupnik, P., Gosar, A., Bourles, D., Keddadouche, K., Aumaître, G., Arnold, M., Guillou, V., and Ritz, J. F.: The Dinaric fault system: Large□scale structure, rates of slip, and Plio□Pleistocene evolution of the transpressive northeastern boundary of the Adria microplate. Tectonics, 35(10), 2258-2292, doi:10.1002/2016TC004188, 2016.

Quigley, M., Van Dissen, R., Villamor, P., Litchfield, N., Barrell, D., Furlong, K., ... and Pedley, K.: Surface rupture of the Greendale Fault during the Darfield (Canterbury) earthquake, New Zealand. *Bulletin of the New Zealand Society for Earthquake Engineering*, *43*(4), 236-242, 2010.

Shirahama, Y., Yoshimi, M., Awata, Y., Maruyama, T., Azuma, T., Miyashita, Y., ... and Miyakawa, A.: Characteristics of the surface ruptures associated with the 2016 Kumamoto earthquake sequence, central Kyushu, Japan. Earth, Planets and Space, 68(1), 1-12, 2016.

Best regards on behalf of all authors
Christoph Grützner