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Discussions

Interactive comment on "Implications from palaeoseismological investigations at the Markgrafneusiedl Fault (Vienna Basin, Austria) for seismic hazard assessment" *by* Esther Hintersberger et al.

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In this study, the authors present new paleoseismic trenching results from three sites along the Markgrafneusiedl fault, which is a normal fault splay within a releasing bend along the Vienna Basin Transfer Fault system. On the basis of their mapping and constraints from luminescence dating, they report evidence for 5-6 >M6.5 earthquakes since ∼140 ka. They construct two models to correlate earthquakes between their sites, with one model consistent with periodic earthquake recurrence and the other appearing clustered. The study is important, as it represent some of the first paleo-

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seismic constraints on earthquake occurrence within the Vienna Basin. I find that the authors do a terrific job of outlining the evidence for earthquakes at each site. The results should be of broad interest to the neotectonic community within Austria and the bordering region. It should also lead to improved constraints on seismic hazard models constructed for the region.

I think there are some critical issues that need to be addressed to fully flesh out the study. The most significant of these comments are as follows. First, the authors should present their earthquake timing results in a probabilistic framework, using a tool like OxCal. This is a standard approach within the paleoseismic community. Second, I encourage the authors to calculate the coefficient of variation (COV) for their two earthquake models ("event lines 1 and 2"), as a way to statistically distinguish/represent periodic vs clustered earthquake behavior. Third, detailed site maps should be presented, showing the context for the trench sites, along with topographic profiles. This information is essential to guide readers' understanding of the interpretation of the earthquake history at these sites.

In summary, after addressing the issues I have raised, I think that this dataset and the manuscript will be an important contribution to the neotectonic and seismic hazard communities. It is well suited for publication in NHESS. I hope that the detailed comments I have provided, below and in the manuscript PDF document (attached, nhess-2017-126-supplement.pdf), are found to be clear and useful to the authors.

Sincerely, Ryan Gold

MAJOR COMMENTS:

1. Probabilistic framework – I recommend that the authors calculate and present earthquake timing in a probabilistic framework, using a tool like OxCal, which is standard in the paleoseismological community. Sample ages and the resulting model earthquake timing can then be reported on a typical Oxcal-style figure (e.g., Figure 2 in Personius et al., 2012, BSSA - doi: 10.1785/0120110214). One major advantage of this

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approach is that earthquakes can be reported with an age and associated uncertainty, rather than a range that comes from the luminescence ages from the bracketing units (e.g., range with uncertainty on both ends…which is confusing). This will also help with event correlation between sites, because earthquake timing can be refined by using age control from multiple sites. Check out a recent publication by DuRoss et al. (2016, JGR, doi:10.1002/2015JB012519) for some ideas on to graphically represent earthquake correlation between multiple sites in a probabilistic framework. You might also consider combining earthquake timing information using the product PDF combination method, also described by DuRoss et al. (2016).

2. Earthquake correlation between sites – I found the discussion of event correlation between sites confusing (Section 5). One problem is that the earthquake ages are presented as ranges – preparing an OxCal model to calculate event timing will help to address this issue. A second issue is confusion over the number of events. The two models proposed yield either six ("event line 1" or five ("event line 2") earthquakes. However, in the text and in table 3, a total of eight events (E1-E8) are reported. I recommend coming up with a different way of presenting the two models and the associated events, so that you don't confuse readers with a possible interpretation that there are eight earthquakes documented for the MF.

3. Clustered vs periodic – While I think that the question of whether earthquake recurrence is periodic or clustered is quite interesting, I'm concerned that given the uncertainty in earthquake timing it's difficult to discriminate between these two end-member earthquake modes. On a related note, I'd encourage the authors to cast recurrence intervals in terms of the coefficient of variation (COV), which is the statistical evaluate of periodic vs clustered earthquake recurrence. Check out a study by Scharer et al. (2010, Geology, doi: 10.1130/G30746.1) or Berryman et al. (2012, Science, doi: 10.1126/science.1218959) to see how to employ this type of calculation.

4. Characteristic vs Super-Cycle – In the introduction, the authors place their study in the context of debate between "characteristic" and "super-cycle" recurrence. I think

they are using mistaken definitions of these terms and would suggest that they instead frame their study in terms of periodic vs clustered earthquake behavior. In more detail, "characteristic," comes loaded with a wide range of meanings, but basically means similar slip-per-event – the dataset presented in this study clearly demonstrates that slip varies between earthquakes. I think the authors instead mean periodic or quasi periodic recurrence. A better way to state the behavior you're getting at might be "quasi-periodic." Similarly, I'm not sure "super-cycles" is the correct terminology. Sieh's idea of "supercycles" (Sieh et al., 2008, Science) is based on observations of the Sumatran subduction zone in which it is quiescent for several centuries and then ruptures in a series of earthquake along the length of the arc at short intervals. Thus, it is that ruptures in different nearby areas occur in a short period of time, not that ruptures in the same area occur in a short amount of time. The bottom line is that "clustered" earthquake recurrence is probably the better descriptor. Âă 5. Unit ages – There is a missing step in the logic of the study, where event ages are calculated without describing the age of the units from which the luminescence samples were collected. It may be useful to restructure presentation of the data in the manuscript, where ages are introduced with the description of the deposits (section 3, trenching results).

6. Linkage to the Vienna Basin Transfer Fault (master strike-slip fault) – Some discussion of how faulting events on the MF might correlate/link to the Vienna Basin Transfer Fault would be useful. For example, do events on the MF correlate to known earthquakes on the VBTF? Do the authors think that the MF is an independent seismic source, or might earthquakes on the MF be correlated to larger strike-slip faulting events on the VBTF (e.g., 1957 Gobi-Altay earthquake which involved reverse faulting with strike-slip faulting)? Exploring this topic shouldn't require too much additional work, but would be nice for readers not familiar with the setting and geologic investigations in the region.

7. Site maps and topo profiles – The study would benefit from the presentation of detailed site maps, showing the trench locations in the context of the local site geomor-

phology. This information is essential to help readers understand the context for the trench studies. On a related note, topographic profiles in the area where the trenches were excavated are another essential set of data, which will facilitate readers' understanding of the trench exposures.

MODERATE/GENERAL COMMENTS:

1. Event lines – "Event lines" is a non-standard description of the combination of earthquake timing and slip-per-event. As an alternative, I recommend "slip history" or "slip model" or "time-displacement history."

2. Subjective word choice – I encourage the authors to search for subjective words in their manuscript (e.g., "major", "completely") and to delete and/or replace with quantitative descriptions.

3. Mmax for Vienna Basin – Authors propose an Mmax for Vienna Basin of M7.0. But this Mmax assessment does not include the possibility of rupture of both the MF and the Vienna Basin Transfer Fault, which would rupture a larger fault area and thus produce a larger magnitude earthquake.

4. Luminescence dating – I encourage the authors to condense the luminescence methodology, especially since it's previously been covered by Weissl et al. (2017). A paragraph should be sufficient.

5. Uncertainty – An explicit description of uncertainty needs to be provided (e.g., luminescence sample ages). Specifically, are ages presented at 1-sigma uncertainty level?

6. Methods section – I think that the text would benefit from a methods section, prior to getting into trenching results. A methods section would provide an opportunity to introduce the basic framework for the investigation: size + depth of trenches, methodology for generating photomosaics, logging, sampling strategy, luminescence dating (and uncertainty), etc..

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7. Haiti Earthquake (Line 4, pg 2): The Haiti earthquake occurred in 2010, not 2009. Also, it occurred in along a previously mapped and known strike-slip fault system (Enriquillo Plantain Garden fault) with known geodetic strain accumulation (Manaker et al., 2008, GJI, doi: 10.1111/j.1365-246X.2008.03819.x). This conflicts with the presentation in the introduction.

TABLES/FIGURES

Table 1: Nice table. Did you also used buried soils as a criterion for distinguishing earthquakes?

Table 2: Presumably, ages are reported at 1-sigma uncertainty? Be explicit, to avoid confusion here and in text.

Table 3: I'm not a fan of reporting 8 events, which I think is unlikely. It's also not supported by the text. Perhaps you could use an a,b,c nomenclature. e.g., E1, E2, E3a, E3b, E4a, E4b, E5 or something else, which more clearly communicates that possibility of a range of event correlations.

Figure 1: -delineation of the bounds of the Vienna Basin would be useful -what does "PDZ" mean (e.g., PDZ of strike-slip fault) in legend? -Add "N" to major latitude and "E" to major longitude marks -What does "Acorn (2004)" in legend refer to? Source for seismicity? I think it'd be less confusing to include in caption and remove from legend.

Figure 2: -figure has a funky gray background in reviewer version. Make sure that doesn't propagate to publication. Make sure you use the vector file. -Highlight the location of the MF, which isn't immediately obvious. -Show location of profile on Figure 1, as indicated in legend.

Figure 3a -highlight location of VBTF -Add "N" to major latitude and "E" to major longitude marks

Figure 3b -report magnitude of vertical exaggeration.Âă

Figure 3c -report magnitude of vertical exaggeration.Âă -label y axis (depth? m) -label VBTF

Figure 4 -Show uninterpreted version of photomosaic at same scale as mapped version -Close polygons in mapped version. E.g., what are units in hanginwall interfingering with colluvial deposits A5, A4, and A3. -Avoid using red for a unit color (e.g., A1) because it's easily confused with fault zone. -Add a legend clarifying unit labels. -Use linework to show outline the trench (e.g., surface and floor of trench). -Show topographic profile at same scale as trench, to illustrate geomorphology. -What do letter labels mean (e.g., H, G, F, E, and D)? -There's a big jump from the overview figure (Fig 3) to the detailed trench log (Fig 4). Compendium site maps to the trench logs are essential to establish site geomorphology, etc.

Figure 6 -Show uninterpreted version of photomosaic at same scale as mapped version -Add a legend explaining unit labels. -Use linework to show outline the trench (e.g., surface and floor of trench). -Show topographic profile at same scale as trench, to illustrate geomorphology. -What do letter labels mean (e.g., H, G, F, E, and D)? Presumably vertical level in trench? -There's a big jump from the overview figure (Fig 3) to the detailed trench log (Fig 6). Compendium site maps to the trench logs are essential to establish site geomorphology, etc.

Figure 10: -Super interesting figure!Âă -I recommend that age control and event times should be presented in a probabilistic framework using a Bayesian treatment (e.g., OxCal). There are some really good recent examples in the literature (e.g., DuRoss et al., 2016, JGR). -How about model 1 and model 2, instead of "event line"

Figure 11 – -label the min/max bounds on the slip history and consider shading the polygon within. To avoid too much shading, you could remove shading between min/max slip rate bounds from geomorphology.

Figure 12 -nice figure! -add N, W labels to lat/lon

SUPPLEMENTAL MATERIAL

Photo mosaics: Uninterpreted and large-scale photomosaics should be included as an online supplement.

Please also note the supplement to this comment:
http://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2017-126/nhess-2017-126-RC1-supplement.pdf

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