

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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The authors present new paleoseismic data for three sites along the Markgrafneusiedl Fault in the Vienna Basin, Austria. This is one of several normal fault splays within

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a releasing bend along the Vienna Basin Transfer Fault (VBTF). Evidence for seismic disturbance at each site is thoroughly and meticulously documented, demonstrating a definite seismic hazard. The data are then combined to derive two possible event chronologies for $M \sim 6.2$ - 6.8 earthquakes on the MF involving 5-6 events over the past ~ 120 ka. The finding that multiple large earthquakes have occurred within the Vienna Basin has the potential to constrain future seismic hazard assessments, and so is of great interest to researchers constructing seismic hazard models for the region, and emergency managers. Researchers of neotectonics more generally will also find the results interesting.

However, I have concerns with the method by which events were correlated between trenches. For paleoseismological investigations with the richness of data that this one possesses, it is common practise to estimate event ages and their uncertainties using a probabilistic framework such as OxCAL (Lienkaemper & Ramsey, 2009). Without such a rigorous framework, the confidence that can be placed in the event chronology derived, and the slip models proposed, is significantly diminished. For example, such a treatment may invalidate or provide support for either a periodic or a clustered slip model, significantly simplifying the discussion. Given the complex linkages between splay faults and the VBTF, it is intuitive to suspect some fault interaction that might lead to clustering behaviour. This possibility could be more fully explored if a re-analysis supported it as a probable mechanism.

Following revision, I think the manuscript will be an important contribution to the seismic hazard community and might drive greater awareness of the potential seismic hazard in the Vienna Basin relating to the splay faults of the VBTF (and to the VBTF itself). As such the study is well suited for publication in NHESS.

GENERAL COMMENTS:

• The labelling of ‘events’ (e.g. A1-A5, B1-B5 etc) on the trench logs is a bit confusing. Consider labelling the colluvial units (in your unit notation), or event horizons.

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Combination of age data between trenches (Section 5). Section 5 is perhaps more complex/convoluted than it needs to be. For paleoseismological investigations with the richness of data that this one possesses, it is common practise to estimate event ages between trenches, and their uncertainties, using a probabilistic framework such as Ox-CAL (Lienkaemper & Ramsey, 2009). The people working on the Wasatch Fault in Utah have taken this to the next level (DuRoss et al., 2016; Personius et al., 2012). A rigorous analysis of this kind will lead to a clearer understanding of what range of event timings are possible within the uncertainties of your data. The conclusions regarding recurrence interval and slip model (periodic or clustered) may then be more boldly stated. Recurrence model. It's hard to get a good understanding of whether a periodic (with a calculated coefficient of variation) or clustered recurrence model might be more appropriate to describe rupture on the MF until the above analysis is completed. However, Figures 1 and 2 present some possibilities worth consideration/discussion. The figures imply that all of the faults shown on Figure 1 are connected, either at the surface, or at depth. Excellent potential exists for fault interaction throughout the slip history of individual faults, and stress triggering between faults in individual ruptures. Figure 1 shows concentrations of epicentres where the normal splays branch from the VBTF. The first question is then how do events on the MF relate to events on the Vienna Basin Transfer Fault? Does any data exist (or could an average recurrence on the VBTF be calculated using its slip rate)? Does rupture on the VBTF trigger rupture on the splays, do the splay faults rupture individually or with only a small segment of the VBTF, bound by the intersections? A potentially much larger rupture area than you have considered bit result from such an interaction (for example, the smaller displacement of your most recent event could relate to rupture 'leaking' from a VBTF event). Does sharing of slip between the splay faults result in what appears to be a clustered slip history for the MF when considered in isolation?

SPECIFIC COMMENTS:

Page 2, line 23: there seems to be interchanging between the terms 'periodic be-

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haviour' and 'characteristic behaviour'. They are not alike. A fault characterised by a periodic slip distribution (or a clustered slip distribution for that matter) need not rupture characteristically. Page 4, line 16: "Whether this apparently slowly moving fault can produce larger earthquakes or it is aseismically creeping, is the key question of our study". The potential for creep has not been discussed. What light does the observations in the trenches shed on this question?

Page 4, lines 23-30: It would be helpful to provide some contextual detail of the trench sites for the reader not familiar with Vienna Basin stratigraphy and fluvial evolution. In particular, a few words regarding Gaenserndorf terrace. It would also help set context to provide figures showing the geomorphology of the trenching sites. Perhaps these could be provided in supplemental information? Also, the mentioned towns are not marked on the Figure 3.

Page 12 line 10: Your displacement estimates for the most recent event relate to just the displacement across the active fault trace. In each case the far field displacement may be much more (e.g. the vertical separation of the red horizon in Figure 4). How do you explain this? Does it relate to pre-existing topography, is there a near surface slip deficit on the fault, or may there be afterslip, or interseismic creep on the fault?

Page 14, line 13: "It seems that the colluvial wedges associated with the larger earthquakes conceal or even erase evidences for offsets formed by smaller earthquake". A related question here is what is the threshold for surface rupture and the threshold for discoverability of a surface rupture in this area? An interesting article where thresholds have been assessed is found here: <http://gfzpublic.gfz-potsdam.de/pubman/faces/viewItemOverviewPage.jsp?itemId=escidoc:691901:3>

Page 14, line 25: The aperiodicity of the 'event line 1' (and 'event line 2') could be quantified by calculating a coefficient of variation.

Page 14, line 7: or they don't break the surface.

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Page 17, line 8: I would suggest that you express your results in terms of minimum magnitude events based upon your displacements. e.g. the Mmax should be considered to be at least X. This accounts for the potential that the events you see on the MF might be part of a larger, mainly strike slip, rupture on the VBTF.

Page 17, point 3. The splay to the southeast of the MF appears to have a larger Quaternary throw. Does this imply that it is more active than the MF?

Page 17, line 15. This is the first mention of data for the Aderklaa-Bockfliess fault. What is this data and how can it be interpreted in terms of fault interaction/clustering etc?

TABLES/FIGURES

Table 2: are the stated uncertainties one sigma or otherwise? Figure 1: Parts A and B are not marked on the Figure. "PDZ" is not explained. ACORN (2004) in the legend is not in the reference list. - It is interesting that there are concentrations of historic epicentres apparent where the mapped releasing bend normal faults splay off the main VBTF trend. I wonder if this association could be used for a proxy to assess activity on each splay, or segmentation behaviour? - As for Figure 12, please mark the names of the other faults. Figure 2: Location of this cross section should be marked on Figure 1. Figure says "for location see Figure 2". MF and VBTF should be marked for clarity. What does NCA stand for? What is the white material uppermost in the section? Figure 3: It is not easy to reconcile the fault scarps that are marked in the inset box on Figure 1 with the scarps shown on Figure 3A. At least mark the features that are shown on Fig. 1 on Fig. 3A. Do parts B and C have a vertical exaggeration? Figure 4: It is good practice to present interpreted and uninterpreted trench photomosaics (or an uninterpreted photomosaic and an interpretation with patterned fill) side by side for comparison. Using line work in the interpreted version would assist with developing and explaining the interpretation. For example, the uppermost (darker) unit thickens significantly across the F2 fault trace. Could this be interpreted to mean that although the discrete fault

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displacement relating to the A1 event is small, the far field displacement was significantly more (and taken up by distributed deformation). It's a bit confusing that 'events' are labelled on the trench wall, rather than units, or event horizons. Perhaps mention in the figure caption that the 1 m square trench grid is lettered on the vertical axis and numbered on the horizontal axis (this would make it easier for the reader to orient on Figure 5). The scale bar in the figure seems to be twice the size as the grid. Figure 5: Most of the parts of this figure are not cited in the text. Are they necessary? Figure 6: present uninterpreted and interpreted parts as per suggestion for Figure 4. Figure 7: the parts of this figure are not cited in the text. Figure 9A: there should be consistency between Figures 8 and 9A as to which horizons and faults are indicated with the arrow heads. Figure 10: While it is good to see all the data in one figure, there are perhaps more rigorous ways to analyse event timing. Consider developing an Oxcal model, and combining event probability density functions. Figure 12: perhaps these faults could be labelled on Figure 1 also?

SUPPLEMENTAL MATERIAL

It would be valuable to include detailed site maps for the trench locations to support your interpretations of site geomorphology. There is a big jump from the scale of Figure 3 to the trench log scale.

Note that an annotated version of the manuscript has been provided with grammatical etc corrections suggested.

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