

## Specific Comments to NHESS MS

“Implications from palaeoseismological investigations at the Markgrafneusiedl Fault (Vienna Basin, Austria) for seismic hazard assessment” by Esther Hintersberger et al.

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### COMMENTS:

In general, well written. The writing is concise and clear. Well organized as well. It could be improved in Topic sentences are included at the beginning of some sections, providing a summary of what it is coming. For instance, section 3.1.1.

English grammar and usage. I found is pretty correct but I am not really good in english. I detect some minor errors which I marked in the commented MS pdf.

Structural data are reported following the convention (dip direction/dip: 116/69). I suggest to specify this the first time one fault plane orientation is given (henceforth dip direction/dip, in this case: 116/69) and do not include the explanation in the following text, just include the values.

### ABSTRACT,

1) you state that:

*Trench observations*

*also show that structural and sedimentological records of strong earthquakes with small surface offset have only low conservation potential.*

It is really showed and discussed in the text? Because as an idea, it's quite reasonable, expected. But perhaps not derived from the data discussed here.

2) you state that:

Magnitude estimates from fault dimensions suggest that the largest earthquakes observed in the trenches activated the entire fault surface of the MF including the basal detachment that links the normal fault with the VBTF.

I don't see how the Magnitude estimates can tell about the rupture length by themselves. The M is estimated from length, so cannot be indicative of it.

### GEOLOGICAL SETTING

- Historical seismicity. Even if some moderate EQ (not rupturing the surface) nucleates in the fault splay, its location would be rough. So, with the uncertainties associated to the epicentral locations, some of the historical EQ assigned to the VBTF could have been produced by the splay faults, don't you think? They are too close, compared to epicentral

errors of pre-instrumental Eqs.

- At the end of section 2.2, you suggest that someone can think of the MF as a creeping fault. But some sentences above, you talk about small earthquakes. I would rather highlight that there are small Eqs associated to the fault (so, it is seismically visible). Include references, even if no-one did that correlation between small Eqs and the MF, just the data base of those  $M < 1.0$  Eqs.
- Is this fault moving along? For a reader from abroad, a short summary of the number of active faults characterized by paleoseismology in the region is necessary, also to appreciate how these data are unique.

## TRENCHING RESULTS

### SDF1

line 28 (page 4). Please follow an easier structure. The trenches expose: 1) a fluvial terrace (description is lacking) in the MF footwall; 2) a different fluvial terrace or flood deposits (??) (include here your description) in the MF hanging wall.

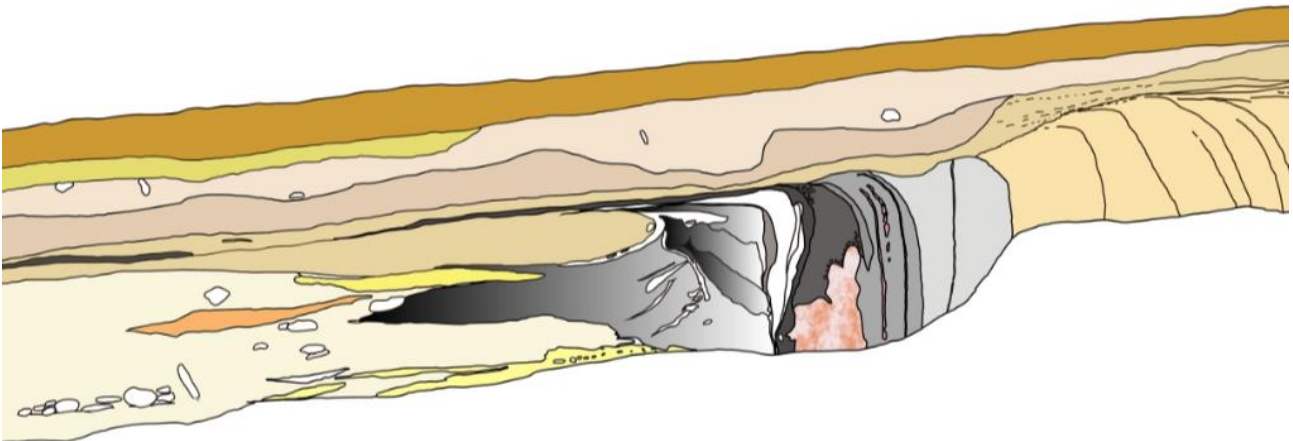
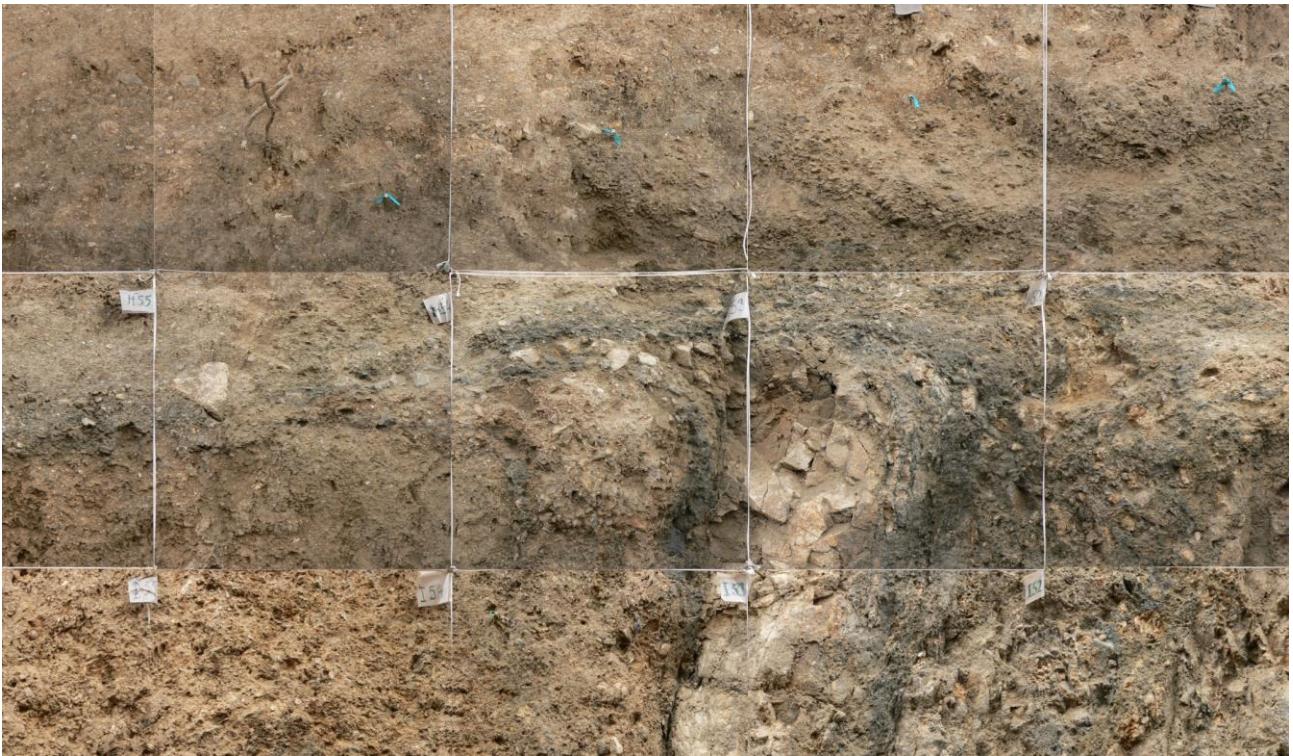
SDF1 trench.

-You mention a “dry valley”. It is an intermittent creek?? Please provide a geomorphological sketch (it doesn't have to be complicated, just simple, showing the scarp and the terraces). It could be a general sketch for SDF1 and 2, and WAG.

-Deformation bands. I guess we can refer to them as “foliation”. They are sub-vertical, so you can also say that, then they are identified more easily. Otherwise I could tend to think of the sub-horizontal bands within the tails of the wedges, for instance.

-Tension cracks. You refer to them as “filled fissures” in the next section (I guess). Please homogenize terms. Also, In the log, there are not so evident. Please mark and describe better. Is the infill distinctive?

-Geometry of the colluvial wedges. The “flux like” geometry of these wedges is really distinctive. We saw similar geometries at Vila Boda site (in the Suddetic Frontal Thrust, leaded by Petra Štěpančiková). In those trenches, we were considering the action of solifluxion -criofluxion? Gelifluxion? motivated by ice creep (check some of the abstracts from Petra S., or I provide some sketches below). I found later in you text that hypothesis (line6 page 9) for trench SDF3 wedge-like bodies, which made me more confident with this explanation. Why don't you consider this also for this trench?



Figures taken from studies by Štěpančíková et al.

For instance:

Štěpančíková, P., Rockwell, T., Hartvich, F., Tábořík, P., Stemberk, J., Ortuño, M., Wechsler, N. (2013). Late Quaternary Activity of the Sudetic Marginal Fault in the Czech Republic: A signal of Ice Loading? 4th International INQUA Meeting on Paleoseismology, Active Tectonics and Archeoseismology, 259-262 October 2013, Aachen, Germany. 259-263. ISBN: 978-3-00-042796-1

Štěpančíková P., Rockwell T., Nývlt D., Hartvich F., Stemberk J., Rood D. H., Hók J., Ortuño M., Myers M., Luttrell K., Wechsler N. (2014): A signal of Ice Loading in Late Pleistocene Activity of the Sudetic Marginal Fault (Central Europe). Eos Trans. AGU 2014, Fall Meet., Abstract T41C-4631. San Francisco 15-19 December 2014.

I am not sure if these 5 wedges in SDF1 can all be interpreted as tectonic colluvial wedge *sensu*

*stricto* by a number of observations:

- 1) They show lamination. The pebbles in the wedges (or at least at some of them) are well organized and follow the same general orientation than pebbles in the terraces. The pebbles, do not display chaotic orientations (as it would be expected from a sudden collapse).
- 2) Thee wedge shaped geometry could result from the modification of a rectangular block fault-bounded, i.e., they could be a “pieces” of the terrace that are fault bounded and then the part to the SE has been reworked. It seems that these features display sub-vertical foliation, so I would think they are involved in the fault zone (i.e., a fault would be missing in the SE parth of the “wedges”, but it would have been modified by the creep.
- 3) It is strange to me that the sequence of colores of these wedges is so similar to the sequence of layers within the terrace in the hanging wall.

As you mention, the long tail invokes some kind of creep (you said slump) that is oposite to the idea of a sudden collapse or the pebbles where redeposited down the scarp. I don't think fluvial processes are involved, probably some local process (just colluvial processes smoothing the scarp).

This does not mean that the wedges are not telling us about episodic movement of the fault. Episodic generation of fault scarps from which pebbles (tail parts) are transported to the downthrown bolck could be inferred as well. Tectonic wedges in trench SDF3 are more clear, and do not seem fault bounded.

**I would be able to have a more clear “judgment” if photologs were provided as supplementary materials.**

-Please give letters or numbers to the units and subunits. One cannot follow the discussion just by the description in the text. For instance, sand layers 2 and 3 (line 14 page 6). I cannot locate them. Are these the colluvial wedges?

- You only refer to photopgraph in Figure 5E. Reference to the other photographs through the text would help to follow descriptions.

### SECTION 3.1.1

Need some reorganization. I would also give some more detail here. For instance, the single event displacement and the bracketting units for each of the events. I think this is the section to provide with those data.

IMPORTANT: Number of events. If each “colluvial wedge” is an event, and the younger one is affected, then 6 (and not 4) surface ruptures should be inferred.

### SDF3

### SECTION 3.2.1

line 31 page 8. I guess you want to say that not all fault branches were active during successive events. And that this has led to a thinning of the fault zone upwards. That's quite expectable, yes. But I would rather say “abrupt changes in width of the fault zone” and not “reduction of thickness (=thinning)”. For instance, the fact that fault branch 2 is not so vertical but tilted leads to a “thickenning” of the fault zone with respect to the lower section, so what you are discussing has more to do with the number of fault branches than with the width of fault zone, I guess.

Please include the fault numbers (F2, F2', etc) in the log of Fig. 6 and refer to them in the text (in the structural description, previous section).

### **WAG trench**

line 19 page 9 (evidence is? Are? I think it should be singular)

Please consider to re-interpret the exposure as a fold-scarp, affected by later faulting. The layers in the footwall are folded and form part now of the “deformational bands” that you describe in the text, as part of the fault zone. In a way, it is not so different from a fault zone *sensu stricto*, but the materials affected do not rupture, are not cut and displaced. This might tell us that this site in the termination of a fault segment. In latter stages, the fold scarp is cut by faults.

At the SE most part of the fold-scarp, layers are indeed cut, as you mention: a fault, affecting the unit underlying unit C, is clear. Other faults affecting the thinned layers (that you call “deformational bands”) are also evident. But they seem to have been originated only at the most recent events.

Please provided the units and faults with unit/fault numbers in the log and in the text. Otherwise the discussion is almost impossible to follow.

The section analyzing the events is missing here! Expected section 3.3.1. I wonder why...

### **SECTION 4. LUMINESCENCE DATA.**

The title of section 4 in my opinion should be “**Dating of events based on luminescence age results**” or some alternative title. Then, I would refer to the methodological steps (in an appendix) and some other details in an introductory subsection 4.1 about dating procedure and results. (Now, section 4.1 It is not a “sedimentary and tectonic context”).

As stated above, I would move most part of this section to an appendix (“protocol followed for luminescence dating”). I would leave here the discussion of the dating results, which could include the section 4.2 and addressing clue issues such as uncertainties:

Could you at least constrain how much underestimation could be reflected in the results?

### **SECTION 5. EVENT CORRELATION**

-Introduction paragraph: To properly locate the reader in what is coming..I would also include in this introduction that 2 possible rupturing scenarios are discussed, implying up to 6 surface ruptures in the area during the last 140 ka.

You said 5 possible common Eqs but you have 6 common Eqs in line (scenario) 1.

**EXPECTED MAGNITUDE:** I suggest to include this in sub-section 6.2 (about Seismic parameters). Just move there the discussion about the magnitude expected from surface displacement, referring to the average, minimum and maximum values observed. The data observed in 3 trenches are indicative and should give an idea of the maximum event displacement, but nowadays most of the paleoseismological research use the scaling of the surface rupture length. See the recommendation done by Stirling et al. (2013), perhaps some other equations are more suitable than Wells and Coopersmith.

**Stirling, M., Goned, T., Berryman, K., and Litchfield, N., 2013. Selection of earthquake scaling relationships for seismic-hazard analysis: Seismological Society of America Bulletin, v. 103, p. 2993–3011, doi: 10.1785/0120130052**

**Caution!** You should explain first (for instance in section 3 or here but in a brief sub-section) the sequence of events not based in ages, but in constraining units. For that, you need to give names to the subunits. There is no place in the Manuscript where you explain that events A2 and A3 are defined by different bracketing units (the same with B2 and B3). Then, you comment that although different, your age constraints are limited, and are the same for A2 and 3 (B2, B3). But in your figure 10, the younger limit of event A3 (and B3) is a little older than A2 (A3). This is not based in rigorous age results. I would rather reflect the real time constrain, but would state that defining units are different.

For instance. In SDF3, event B2 is constrained by unit 3 and the younger CW (let's say CW, you need to give names to the Cws). But B3 is constrained by CW1 and unit 4. They are different events. However, since you don't have more dating results, you cannot constrain it in a finer way, just can say that both events (B2 and B3) should have happened between the minimum age of unit 5 (I guess, although not in the log);  $32.9 \pm 4.1$  ka and the oldest possible age of unit 3;  $70.8 \pm 8$  ka.

**Caution!** Your representation of Common events (E), light grey, is not consistent with your definition in years in Figure 10. For instance, which is the criteria to propose (in the graphical representation) that E3 younger bracket is near 37 ka. I guess you used the  $32.9 + 4.1$  ka (as inferred from the location of the sample) but you cannot do that, it does not fit with the event definition.

## SEISMOTECTONIC IMPLICATIONS

Please discuss a little more the problem of variable slip. You just mentioned it very quickly (line 11 page 14) and I think is relevant for recurrence and magnitude estimations. You refer to the “incompleteness” as related to the fact that larger events erase evidence of the smaller events. If you had a finer stratigraphy and units that you could correlate both sides of the fault, you would probably be able to detect minor events. So it is not only the “fault” of the large colluvial wedges.

Relating the “clear” periodicity of line 1, I honestly don't think that the events are defined in a sufficiently fine way as to infer periodic behavior. Also, their definitions (light gray rectangles) should be revised, as I comment above. Even if they are well located (perhaps the problem is only with E3), I can envisage an EQ distribution matching with line 1 and completely irregular (or clustered). This is the problem we have (I have it in all my studies) when working with rough stratigraphy, which would be overpassed if all trenches were in lake sediments with annual layers!!.

When comparing line 1 and line 2, the implications have not only to do with recurrence. Also with EQs being recorded (for the case of E3) in a different way (or just not being recorded). That this means that E3 only affected trench SDF1? Or if present also in SDF3, might be this event E3 implicit in the next event? (this is, E3 is “hidden” in the deformation assigned to B2?). It would be good to explain which is your preferred scenario, and if you consider that rupture in E3 could have stopped between trenches (they are at both sides of a bend in the trace!).

### SECTION 6.1

I think that figure 11 should be better explained in the text. It contains a nice representation of the 2 scenarios, with sub-scenarios implying maximum-minimum ruptures. So it needs further explanation if you decide to keep it in the paper. If kept, it might be used to justify the preferred scenario.

-Why is event E6 not having any associated displacement in figure 11 line 1, minimum slip? It is confusing because it seems you have 5 events (but in line 1, you have 6, if I understand well figure

10 and information in section 5).

I guess that the estimates from paleoseismology...0.03-0.04 mm/yr should be explained here. I cannot find them along the text, only in the concluding section (7).

And discuss which slip rate you think

-It would be helpful that you give some judgment about which slip rate value you consider more robust, i.e., to take into account in calculation of the seismic hazard.

SECTION 6.3 (note 6.2 is lacking).

I suggest to include (move) here an additional the data about expected magnitudes, taking it from the former section 5 (from each subsection).

Perhaps is this section where you should explain why you think MF is a primary source of earthquakes. Its geometry and relation to the VBTF would also lead to consider that it might move as a secondary fault. I would expect that from the tail/spay geometry of faults. That possibility doesn't mean it is not a valuable source of paleoseismic information. Perhaps is it a better fault for paleoseismic studies than VBTF due to the more complete sedimentary record.

See for instance Beanland et al. 1990 to see an example of how large the secondary slip can be.

Beanland, S., Berryman, K.R., and Blick, G.H., 1989, Geological investigations of the 1987 Edgecumbe earthquake, New Zealand: New Zealand Journal of Geology and Geophysics, v. 32, p. 73–91, doi: 10.1080/00288306.1989.10421390.

Finally.... The EQ chronology, does it fit with data in surrounding faults? Perhaps it is the only EQ chronology available and that question does not make sense. Although GPS data indicate the fault system (VBTF) is active, I wonder if the seismogenic events seen here are related with the unloading after the Glaciers retreated in repeated glaciations, leading to “pulses” of enhanced activity. That question is of first order for the seismic hazard. Perhaps no large events are expected to occur at Present?

SECTION 7.

It is a good summary. If changes are done in the former sections, it just should be updated.

FIGURES:

Fig 1. A and B are lacking.

Fig 1A. which time span covered by the seismicity represented? Source of data? same than in figure 1B?

Fig. 2 mentioned in the caption is not a map... Perhaps the box indicated the location of Figure 3? Please clarify.

It would be nice to locate Eastern Alps and Western Carpathians in the Figure, since they are mentioned in the text. Also the name of the hills right to the NE and SW of the sViena Basin. Someone from South Spain (me) is not so familiar with that local relief.

Fig. 2. It is a section (not a map). So the box in fig. 1A should be replaced by the location of the section.

Remove the text that says “for location see Fig. 2” and provide the meaning (or remove if not referred in the text) the acronyms (e.g., NCA, TWT).

Fig. 3. Please locate this Figure in Fig. 1. If the VBTF is evident in the seismic profile (as mentioned in the figure caption), include it in the figure (Fig.3C at least).

The Gaenserndorf terrace is not indicated in the figure but mentioned in the text.

I highly recommend to modify this figure, including an orthophoto (or aerial photo or a simple sketch) and a few more lines interpreting the geomorphology. The DEM image is insufficient to understand the setting.

Figures 4, and Fig. 8. At least for logs of SDF1 and SDF3 (only lacking in footwall), please include the sub-units. Including the name of the trench in the figure (for instance, at the top of the log) would also help, but if it is clear at the beginning of the figure caption, it is also ok.

Fig 5. Please include a picture of the trenching site. A general picture, so that someone that has not been there can have an idea of how it looks like. It is the fault scarp easy to detect in a field survey?

Fig. 10. Please include the units in this graph. I think it would help to understand the EQ chronology. In general, this graph is useful but I think it should be largely modified to reflect precise definition of events. This figure could be improved if you remark the EQ used in the different correlations. For instance, for E4, I would mark with a distinctive filling (for instance with tilted lines or dots) B3 (just the lower part of it, overlapping with A4) and A4 (in this case, the upper part, overlapping with B4)