



Comment on se-2021-97

Lucilla Benedetti (Referee)

Referee comment on "Onset of Aegean-style extensional deformation in the contractional southern Dinarides documented by incipient normal fault scarps in Montenegro" by Peter Biermanns et al., Solid Earth Discuss., <https://doi.org/10.5194/se-2021-97-RC2>, 2021

The authors have found two normal faults in the Montenegro that they interpreted as active while the active tectonics of the area is dominated by active compression according to the instrumental seismicity (focal mechanisms). The authors studied in the paper the seismic history of those faults using ^{36}Cl dating on fault scarps and morphological observations of the fault planes. They deduce slip-rate, recurrence interval, and suggest those faults could generate Mw6 normal faults events.

The question of the surface expression of the faults affecting an area and how those are interpreted in terms of kinematics and seismotectonic of an area is crucial. However the authors somehow avoid to thoroughly discuss this question, and very quickly interpret those faults as active and as the surface expression of an active extension, however normal faults have been observed also in compressional context (see my last comments). The tone of the paper somehow provocative and assertive is disturbing because it does not allow to really appreciate the quality of the observations and of their interpretations. There are several major points that I listed below that I think should be addressed before this paper can be published.

On Figure 4, the colour are difficult to distinguish but the normal faults appear to correspond to the contact between Mesozoic carbonates and Eocene or Paleocene. This is puzzling since if there is activity over the Quaternary there should be some Quaternary deposits on the hanging wall attesting for the hanging wall subsidence. In all the active faults of Italy or Greece that the authors cite that were mapped as active this observation is verified. Moreover I have not seen in the paper a mention about the bedding of the carbonates. It is important since hanging valleys could appear as such if the bedding is vertical and not be related to the recent fault activity. Is it possible that those are exhumed features due to active folding ?

The assumption that the fault scarps are 18 ± 3 kyr supposed that all faults started to resume activity at that time which is not correct since some faults could have started to resume a seismic activity later for example 10 or 12ka ago, with a long quiescence time between 15 and 20 ka ago. The ^{36}Cl dating is an absolute dating of the scarp exhumation whatever the cause for this exhumation, seismic or others. So I don't think the comparison brings anything to the paper and does not make the slip-rate calculation convincing to me. You can use the assumption that those scarps are post-glacial if you

have no dating but if you have an absolute dating you can discuss this assumption by mentioning that the yielded ages for the fault scarp are in agreement with an hypothesis of post-glacial exhumation but note use an age based on an hypothesis to compare a result you yield with an absolute dating. Moreover the LGM in the Apennines is probably closer to 21 kyr ago and this could be different in the Dinarides (see recent papers by Hughes et al. for example this one and references there in Hughes, P. D., & Woodward, J. C. (2017). Quaternary glaciation in the Mediterranean mountains: a new synthesis. *Geological Society, London, Special Publications*, 433(1), 1-23.)

The identification of earthquake slip is based on qualitative observations that are very difficult to interpret in my opinion. The pictures presented do not allow the reader to actually reproduce those observations or appreciate their quality. The authors do not discuss their origin at all and interpret them as seismic exhumation. This is very discutable and should not be presented as straightforward. How are those ribbons oriented in comparison to the slope ? Could snow or others processes of erosion produced similar features ? how the 5 horizons were distinguished ? Moreover, the way they are presented in the abstract is misleading because it suggests that the slip amount and age is deduced from the ³⁶Cl profile. While it is not possible to retrieve event on a 8 m-high scarp with such low resolution (5 samples). The way the age of the event is retrieved is not clear. Did the authors introduce the slip yielded from the ribbons observations and injected those values in the model as a direct model to yield the ages ? This has to be much better explained in the text.

In the introduction the relations between the normal faults identified and the present day kinematic of the area is problematic to me. The presence of normal faults in the Apennines and in Albania is in agreement with the seismotectonic of the area while geodesy and focal mechanisms support no active extension in the Dinarides. So mixing those aspects in the introduction is misleading. Even more that the authors have not yet shown their observations and discuss the origin and the mechanisms underlying their observations. So I would present all this with much more caution, saying that while in the Dinarites active tectonics is driven by compression, the presence of those two normal faults is puzzling and the purpose of your pape is to understand how those features can be interpreted. First by answering the question, are those faults active or not ? The fault potential activity should be thoroughly discussed, after reading the paper as it is I am not convinced that those are active normal faults. Second, if we assume those faults have been active over the Quaternary, they could be the surface expression of flat and ramp fold as it has been described during the El Asnam earthquake in 1980. The mechanical processes is explicitated in this paper Avouac, J. P., Meyer, B., & Tapponnier, P. (1992). On the growth of normal faults and the existence of flats and ramps along the El Asnam active fold and thrust system. *Tectonics*, 11(1), 1-11. Such possible explanation should be added in the discussion and the bibliography concerning surface expression of folding should be thoroughly studied and discussed in that paper. It could make the paper much more appealing. If those faults are actually the surface expression of the fold an thrust affecting the Dinarides they could indeed be use to retrieve the seismic history of compressional events.

Specific remarks:

-line 23-26: all those aspects are purely speculative and should not be in the abstract, you have not proven or provide strong evidence for a kinematic change and no evidence of geophysical observations showing the upper plate of the slab is affected.

- line 41: you probably mean instrumental earthquakes and not historical ?

- line 47-49: please look carefully in the litterature about normal faults in active fold and thrust belt, they can also be the surface expression of contraction (see my comments

below but there are probably more examples now since El Asnam).

- line 56: Extension in the Apennines is also attributed to Adria microplate rotation (see papers by D'Agostino et al. 2008, Nocquet 2012), please also cite those papers.

- line 63: it is not a view, this is based on evidences and before considering them obsolete you should at least present your evidence and discuss the previous published ones. The tone is problematic to me, it is not an opinion paper, it is a scientific paper.

- line 87: what do you mean ? ^{36}Cl dating is not affected by vegetation. Maybe you mean for ^{36}Cl sampling ?

- line 91: where does the date 18 ± 3 kyr come from ? please cite papers or discuss this date.

- line 131-133: what do you mean ? not clear to me.

- line 176-178: the radial pattern suggest landslide feature, why not discussing it ? could it be related to bedding slip ?

- line 184: five horizons are very speculative, please discuss what could be their origin besides seismic slip.

- line 257: really not convincing, how is the bedding ? if it is perpendicular to the fault plane it is more convincing, please discuss that.

- line 265-268: what do you mean ? it is not clear whether you suggest those faults are an effect of the contractional regime and it appears in contradiction with what you said in the introduction.