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Solid Earth
Discussions

Interactive comment on "Large-wavelength late Miocene thrusting in the North Alpine foreland: Implications for late orogenic processes" *by* Samuel Mock et al.

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Article Review – Solid Earth

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Title reviewed ms: Large-wavelength late Miocene thrusting in the North Alpine foreland: Implications for late orogenic processes

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MS No.: se-2019-158 MS Type: Research article

General comment

This paper documents the thrust-related exhumation of the Subalpine Molasse during the late Miocene made by interpreting the thermochronometry results of 13 apatite (UTh-Sm)/He, contextualizing them into the regional structural geology and trying to make an upscale comparison with the broader geodynamics at the disputed transition between the western and eastern sector of the European Alps. As far as I know, the manuscript has not been published previously. The title is conforming with the contents of the Ms and the approach and results and conclusions intelligible from the abstract alone. I have proposed some changes in the text organization and minor changes in figures. The manuscript presents an interesting topic, which should catch the attention of the readers of Solid Earth. It is based on some fieldwork and it is quite well structured although field evidences would deserve a to be more deeply described. I found the results too short with respect to the discussion and the Introduction part. If the aim is the attribution to the large-wavelength deformation style as responsible of exhumation in the Alpine thrust front, solving the upscaling problem is crucial. In that case, the authors could consider in their review to contextualize their study area on broader regional map and make considerations on the structures that have allowed exhumation. So far, they are not well documented in this paper. I found interesting the mentioned change of deformation with the lithotype involved in the Molasse units (i.e. conglomerates, sandstones, pelites), but it was not shown as it is in the field or tightly described as referred to the figures. In reinforcing the results section, this topic would be easily solved by the authors that have a great knowledge of the area and could possibly be strengthen in the discussion as associated to the exhuming structures (see later in the detailed comments). I found the geodynamic part not so essential for the general implications of the paper that would anyway fit, without it, a large public when the thermochronometric interpretation will be presented with a reinforced documentation of the thrust-related exhuming structures. After all, the general slab dynamics are still so debated as they nicely reported. The regional role of their structure is to me more interesting and could provide general information on how exhume at a thrust

front a proximal molassic deposit affected by lateral facies changes. Notwithstanding these potential limitations, and considering that addressing these would lie beyond the intended scope of the manuscript, I feel that the paper needs some more work to have that detail for making an informative and well-balanced account that deserves publication in Solid Earth.

Major points of strength/weakness

There are some points where a revision is necessary. In general, the Ms needs just some iteration to enrich a few aspects of the text in the results and shorten the geological setting, updating the literature with respect to the recent works (see detailed comments). The references are quoted finely although lacking of an update on some of the more recent works on the Pennine and Helvetic nappe emplacement recently reported in the Swiss literature and Alps). I found only a reference to check, the rest should be fine. The upscaling to faultâĂŘfault and regional (and eventually) geodynamic setting relationships at map scale needs to be somewhat better shown. That could be due by following the more detailed suggestions and if possible including additional changes to figures combining simplified crossâĂŘsections, mostly in the results. I have suggested some minor changes in the rest of the text. I believe that length is fine at this first review. Tables and figures look fine. Supplementary Data are used appropriately.

Technical points

Suggestions for improving technical points have been provided with detailed comments that will help preparing the next version of the manuscript.

Page 1 – Abstract. Line 20. tectonic forces: you can be more specific; This resulted in a change: you may wish to specify what change you imply (i.e; time and space?) Introduction. Line 26. Davies and von Blanckenburg, 1996 in the reference list Line 28. To consider eventually further on, you may wish to consider as well the implications related to asymmetric slap polarity with respect to the westward drift of the lithosphere

(e.g. Carminati and Doglioni, 2012) in the frame of changes in the subduction polarity across the alps. Carminati, E., & Doglioni, C. (2012). Alps vs. Apennines: the paradigm of a tectonically asymmetric Earth.ÂăEarth-Science Reviews,Âă112(1-2), 67-96.

Page 2 – line 3. considering the relevance of this concept and that you have it also in the title, you may consider to shortly describe what is large-wavelength deformation and to what is usually referred to. Line 4. North Alpine foreland basin - eg. citation Pfiffner 1986 Line 12. have a look at Egli 2017, 2019 and Cardello et al. 2019 JSG on the nappe emplacement during Oligocene to Miocene time. In the latter, you can find also some more references if you find them interesting. Line 15. You may cite who was directly the first stating the link between ECM exhumation and Jura thrusting. Line 25. You can cite a few works here who have so far the attempted to fulfil this aim? and why they did not succeed completely.

Page 3 – Line 6. which at a larger scale is also due to the curvature of the Alpine arc.

Page 4 – Line 8. more recent studies to mention would be appreciated. You can find a summary of previous works in Cardello et al. 2019 (journal of structural Geology) Line 16. You can possibly mention the role of the Pennine nappes. You can find references in the Matzenauer's thesis http://doc.rero.ch/record/32247/files/MatzenauerE.pdf and in the work of Jon Mosar. Line 18. see also Glotzback et al. 2008..., Mancktelow and Seeward, Campani (Simplon), Cardello and Mancktelow 2014, Egli et al. 2016, 2017. Line 25. you mean prism growth? orogen-parallel to perpendicular stretching: have a look at Mancktelow's work on the Simplon Fault in the Central Alps. Line 28. isn't this a repetition from above?

Page 5 – line 2. they are deposits derived from the prgoressive erosion of the Alps since... Line 5. is this a distinction from Sinclair et al. 1991? Line 12. you may find interesting reading this thesis of Tobias Ibele, where you can find useful references and some fine detailed work on the high angle faults and structures of the Swiss Molasse https://doc.rero.ch/record/28382 Line 21. due to tear faulting or? Line

26. Have a look at Fox's works http://www.ajsonline.org/content/316/6/505.short https://pubs.geoscienceworld.org/gsa/geology/article/43/5/379/131816/Rapid-exhumation-in-the-Western-Alps-driven-by Line 28. paleomagnetic indications from Cardello et al. 2016 have shown similar indications in that sense, being the most recent ones associated with the Rhone-Simplon faulting in the ECM rear.

Page 6 – line 16. As so far you were mentioning time in Ma, you can help the reader by providing the age constraints in Ma to the the two corresponding megasequences.

Page 7 – Line 3. Why there are only 12 samples on the map of Fig. 3 and on Fig. 4 and here 13 samples? Line 4. some are strangely positioned within the crystalline basement with no displacement associated to them. You may also consider about drawing the basal thrust trajectory as it is widely accepted that the basal thrust of the Jura is branching off the Alps thus at the base of the Mollasse mesozoic cover. Further please have a look at the cross-sections B-B' and C-C' for the upper thrust and explain why, in your interpretation, is not propagating in this sections as in the A-A' cross-sections. Line 28. Very minor question: can the Saxon genitive be used in Solid Earth?

Page 9 – line 25. notice of little importance, would you choose Aar or Aare? Please consider if it should be called Aar valley and Aar Massif consistently.

Secondly, there are stike slip fault traces which could help partitioning the deformation at the edge of the Pennine Salient. You may consider mentioning them as one of the causes of different styles of deformation at the thrust front. By the way, in the block diagram they are not dashed but they are a continuous line crossing different structural units also in the more external part of the basin in the map. Possibly you have them in an en-echelon disposition and they have recorded right-lateral kinematics. If you have some measurements to add on that it would be great although not extremely necessary for the purpose of this work.

Page 10 – line 1 and 9. Aare valley Line 8. would that fit with a lateral ramp similar to

what experienced at the sw edges of the Molasse basin on the NNE-striking Vuache Mountains (see Charollais works), where you find a traspressive ramp overthrusting the carbonates on top of the Aquitanian sandstones of the Rumilly Basin? Line 12. This is more of a result and would be nice to show if there is any space and if it is useful to support discussion. Line 16. constant through part of the dataset (specify please the samples you want to point at). Line 17. can you please explain a little more on the relationship between deformation style and exhumation pattern, why should, in your case, one influence the other? Considering this is a crucial point of the paper you could show them as they are in the field and make a schema that shows this relationship (optional) and decide to put it here or in the introduction, depending if you want to make it a starting hypothesis or a proven outcome of your work. Line 29. 's genitive Saxon, as above a very minor comments: can that be used in Solid Earth?

PAGE 11 – line 14. what type of association? Line 15-16. is that a repetition? Line 19. is that implying that the backthrust was longer active and that was occurring over 16 Ma? Line 25. In the next section, you dig some more into this concept but maybe this statement occurs too early here Line 30. please add some more references from Pfiffner et al. 2011, Egli et al. 2016, 2017 and the model of Cardello et al. 2016 and 2019. And more references more to the east?

Page 12 line 14. you may find interesting having a look also at more recent findings ot out-of-sequence thrusting of the Pennine Nappes over the European foreland and the flip back to in-sequence thrust propagation in this time frame. Line 21. you may have a look also at recent papers on the Helvetic alps (2016 geological society of london) Line 24 genitive Saxon Line 26. indeed, Megathrust reactivation (Cardello et al., 2019) corresponds with the convergence rate deceleration from about 1.6 cm/a to âĹij0.9 cm/a at âĹij28 Ma reported by Stampfli et al. (2002) and recently discussed in the Journal of Structural Geology. Line 30. specify here please if related to strike-slip and/or reverse kinematics

Page 13 – line 6. How is that fitting with AlpArray tomographic results? Line 12. is

that your observation or needs a citation? Line 22. You may wish here to specify what what you mean as individual tectonic pulses? Why should have a broader implication related to plate tectonics or slab dynamics? Line 25. wouldn't be the other way around: the segmentation in the thrust front being the result of a change in the slab retreat dynamics.

Page 14 – line 20. well you have structures accomodating doming and stretching paralellel to the orogen and with similar role also in the Simplon area and to some extent as well in the Engadine and Rawil depression, but if and how that is affecting the foreland evolution during collision, is to argue a little deeper. Line 23. tectonic processes such as.. try to link better this discussion with your data that may work as an example for... Line 25. you mean mantle-related slab dynamics vs. lateral extrusion of the eastern alps in the upper crust?

Page 15 – line 7-9. you can stress on how it is influenced, saying where salient and recesses occur with respect to the dominant lithology occurrence in the Molasse lithotypes. Line 13-14. Isn't that a repetition from second bullet point here above (line 7-9)? Line 16. sentence to rearrange Line 17. upper crustal signal - You may wish to say to what you refer to (i.e., the decollement at the base of the mesozoic cover deposits? or rather deeper into the crystalline and carbonate deposits? Maybe already in the block-sheme of Fig. 5 you can highlight what is the most relevant structure allowing the large-wavelength deformation Line 18. As it is put here, it seems more a point of discussion rather than a concluding remark. In case you wish to leave it here, as it is relevant to the title, you may wish to explain the reason of this interpretation. Line 21. I would suggest you here to simplify and reinforce what you mean as tectonic pulses in the first bullet point of the concluding remarks. Line 24. this is a major outcome of your work that should be more reinforced in the discussion (maybe reducing somewhat the geodynamic relevance and increasing the documentation on the lithotypes involved and their geometry and associated tectonics).

Page 30 Fig. 1 Periadriatic is not correct being the name Periadriatic firstly used in

literature as referred to main thrust in Friuli. Best would be to say Insubric (as you do for the Insubric Fault) or simply Tertiary Intrusions. Fig. 3 see comments in the text referred to the basal decollement and the role of tear faults

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