

Solid Earth Discuss., referee comment RC2
<https://doi.org/10.5194/se-2021-49-RC2>, 2021
© Author(s) 2021. This work is distributed under
the Creative Commons Attribution 4.0 License.

Comment on se-2021-49

Laurent Jolivet (Referee)

Referee comment on "Orogenic lithosphere and slabs in the greater Alpine area – interpretations based on teleseismic P-wave tomography" by Mark R. Handy et al., Solid Earth Discuss., <https://doi.org/10.5194/se-2021-49-RC2>, 2021

This paper presents a new interpretation of the mantle structure underneath the Alpine arc based on a recent tomographic model. The goal of this work is perfectly clear and the outcome are potentially important given the current debate of the geometry of slabs below this well-known orogen. The attribution of the hanging pieces of slab seen in tomographic model beneath the Alps, European or Adriatic, is indeed debated and this has obviously major consequences for understanding the geodynamic evolution of this emblematic belt. Rightly stating that the long-established geological knowledge of the Alps has to be taken in consideration when interpreting deep structures illuminated by seismic rays, the authors conclude that there is only one main slab beneath the Alps and that it is European. Its geometry is precisely described and the implications of its detachment along most its length are discussed. This is thus potentially a major paper.

BUT, the question of the nature of slabs is mixed up with considerations about the thickness and rheology of the subducting lithosphere with emphasis on a "tectosphere" instead of "lithosphere". While the authors state at some stage that the so-called tectosphere almost equals lithosphere in terms of rheology, they also say that it is entirely different and changes the interpretation of tomographic images. I have two main comments on this question, which really undermines the whole paper and makes it far from convincing:

- "Tectosphere" is by no way a new concept and I do not see why it is useful here. In my

recollection, tectosphere was first discussed by Elsasser in 1967. In that paper it was used as the major stress-guide controlling plate motion in subduction zones. It is also behind the earlier models of Hess of a "tectogene" that was the early understanding of what we now call subduction. I do not really understand why it is useful to go back to this concept when lithosphere is a perfectly adaptable concept with the current corpus of knowledge on mantle and crustal rheology.

- It is extremely difficult to understand which observations allow the authors to place the base of the so-called tectosphere at a given depth below Europe or, else, decide that it is much thinner below the Eastern Alps. At some stage (figure 7) two alternative interpretations of one of the profiles are shown. One has the thick European tectosphere (7B) and the other does not (7C). But, in these alternative interpretations, the authors also show opposing interpretations of the nature of the slabs, either European or continental. Because the interpretation with a detached European slab (7B) seems more realistic (and I fully agree with this conclusion) they then conclude that the interpretation with a tectosphere is also more likely, when the two questions are, in my understanding, totally independent.

The authors should (1) first clearly show why they draw the based of the "tectosphere" at a given depth on tomographic images (in some images the basal limit goes through anything, blue or red and one does not know why) and then, (2) once this is clearly established, discuss the consequences for the tectonic interpretation of images. They should also clearly say the differences between tectosphere and lithosphere. In my understanding there is no difference whatsoever. I do not see why you need this "new" concept (which is not new) for your interpretation. It blurs the whole paper and makes reading unconvincing.

The other major problem with this paper is that it is extremely difficult to follow. The description of the 3D structure is really not well organized and the connection between the text and figures is not clear, at least to me. At one stage, I stopped reading and moved directly to the discussion. There is a major effort to make for clarifying the presentation of the tectonic interpretation based on the tomographic images.

Detailed remarks:

- Line 58: OK for Jordan but you should also refer to Elsasser (1967) or Morgan (1968).
- Line 61: Jordan's definition of tectosphere is exactly what is meant nowadays by lithosphere.
- Line 64 ...: you cannot pretend using tectosphere in a purely kinematic sense when you draw arbitrary limits of the base of your tectosphere on the images. One does not know why you put them there. You also discuss the pre-Alpine history of these pieces of tectosphere, thus implying different chemical, lithological characteristics. Tomographic images shown velocity anomalies, not kinematic entities, and thus certainly not plates.
- Lines 255-260: how do you define a plate boundary at this scale ? A simple thrust is not a plate boundary, especially in a region like the Alps where deformation is widely distributed. Plate boundaries should be used for kinematic purposes not for geological description of small orogen like the Alps.
- Line 282-295: this paragraph is incomprehensible. Please help the reader. Many parts of the paper are similar, so difficult to read.
- Figure 3 and all similar figures: please enlarge the numbers associated with the profiles on the map inset.
- Line 312: how do you recognize a tectosphere on tomographic images. You see velocity anomalies, you do not see rheology nor lithologies. If you do not explain what makes you decide to draw the base of the tectosphere here or there, the reader cannot understand your point.
- Figure 4: same. Why do you decide to draw the base of the European tectosphere there ? What is so special at that depth ? On section 2, the line crosses the red patch below the blue patch, why there ?
- In general, this part is too difficult to read.
- Figure 5: please add the number of the profile (16) in the caption of panel C
- Figure 6: the base of the European tectosphere seems just to go through anything, this is annoying.
- Line 420: why are "classical" sections of the Alps only those published by Schmid et al. ? Same for seismological interpretations of the deep structure those of Pfiffner ?
- Lines 423-463: this part is highly speculative and the reader is not given any hints about why it should be as you say. I do not mind speculations, but they should be presented in the discussion, not here, and you should better explain how you see anything about composition on these images.
- Line 462: what do you call collision in the Alps ? 40-32 Ma is an important period but continental units have been subducted earlier.
- Figure 7: see my point in the general considerations in the first part of this review. The interpretation of the European vs Adriatic nature of the slab does not say anything about tectosphere vs lithosphere.
- Line 526: no, this is certainly not "evident" on the images.

Here I gave up and jumped directly to the discussion ...

- Line 838: what do you mean by "equilibration of the slab" ? This is unclear.
- Lines 880-890: what are the precise arguments here to say that water content rather than temperature is more likely to influence seismic velocities. I have nothing against it, by what is the point .
- Lines 894-895: here, this is circular reasoning. The sink rate of van der Meer et al. can only be taken as average values, it certainly cannot be used for a given region without a long discussion. In the upper mantle, flow rates of the mantle have to be highly variable, and they can be much higher than 1.2 cm/year. And flow is certainly not only vertical.
- Section 6.4 in general: you discuss the influence of slab detachment on the tectonic evolution of the Alps. Fine. But you do not mention slab retreat (or delamination, which is equivalent) that may have partly very similar consequences. Focusing of slab detachment only is misleading, I think. And this becomes very important when you discuss the ages of magmatism. Retreat and detachment can also go together, the discussion should be somehow more subtle here.
- Line 943: please avoid using words like "exciting".

Laurent Jolivet