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Comment on se-2021-49

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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-RC1, 2021

In contrast to large convergence zones such as the Himalayas or the Andes where large lithospheric plates are involved in the thickening process, the Alps-Mediterranean domain is very small involving continental micro blocs separated by small oceanic domains with important plate tectonic rotation during convergence from the Late Cretaceous to present-day. Another parameter complicates the situation: an important Variscan heritage on the western part of Europe with a generalized extension during the Permo-Carboniferous that has thermically eroded the lithosphere and the Liassic extension that has thinned the continental crust. It is in this particular, incredibly 3D context that a better knowledge of the geometry and anomalies in the upper mantle will help to better understand the processes involved at the plate scale.

Based on new results of AlpaArray and presented in a companion paper (Paffrath et al., Solid Earth, 2021), Andy and co-authors give an interpretation of the teleseismic data of the upper mantle of the Alpine domain between ca. 50 and 500 km depth. As I am not a sismologist, it is not my responsibility to judge the validity of the tomographic data presented, I note however two important elements for the further discussion: the fact that the tomographic model is very dependent on the initial crustal model which results in a rather poor resolution of the tomographic model in the very upper part and according to Paffrath et al (2021), the fact that the tomographic model is poorly defined in the range 175-210 km.

All the interpretation that follows in the manuscript is based on the concept of European

Tectosphere (which by the way is in the title of the paper). So this will be my first and more important remark, if the concept of Tectosphere is well explained in the introduction of the paper, the attribution of Tectosphere for the European plate is based between lines 434 and 438 by the fact that the negative anomaly follows the superior positive anomaly, this is the only argments for a Tectosphere rather than a Lithosphere below the European plate.

On the seismological side, as noted in the paper, many European groups (Waldhauser et al., 2002, Lipptsch et al., 2003, Spada et al. 2013) and more recently an uncited paper on absolute S-wave velocities (Lyu et al., 2017) have defined the LAB at about 100-110 km depth; these data are not discussed in the paper. Why?

Moreover, the notion of coherence between the fast and slow velocity anomalies that would imply that the two anaomalies are driven in the same way and thus would define a single plate is undermined by the SKS data. In fact, shear wave splitting measurements (Barruol et al., 2004, 2011; Salimbeni et al., 2008, 2013; Link et al., 2020) show that the crustal contribution is minor and reflect the anisotropy in the upper mantle between 100 and 200 km. Interestingly, the orientation of the anisotropy data in the upper mantle is oblique to the direction of pre-oligocene convergence with an E-W direction in the central Alps becoming progressively N-S in the western Alps and turning to the SE in the direction of the Appenines, driven by the slab retreat. In other words, it notes a very strong decoupling between the crust and the very shallow mantle (high velocity zone) and the mantle below which excludes the notion of kinematic coherence between the high speed zone (0-100 km) and the low speed zone (100-200 km). Thus, It is likely that some of the anistropy in the upper mantle was inherited from the Variscan period, however, there is good agreement between these data and recent kinematics of the Alps that suggest that the anisotropy in the mantle is recent, post Oligocene, and therefore implies a strong decoupling between the slabs visible in the tomography and the upper, asthenospheric, mantle, which goes against the notion of a Tectosphere.

By the way, it is interesting to note that on figure 11, it is the lithosphere that is drawn so this figure, which is not consistent with what is discussed before in the manuscript.

Similarly on figure A3 and A8, why the Tectosphere thins towards the south while on figure A16 and A17 we talk about lithosphere and not Tectosphere with a normal and coherent thickness of the lithosphere and its extension in the mantle

Thus, to conclude, I agree that the upper mantle signature is inherited from the late Variscan event, which is marked by the thinning of the lithosphere and the upwelling of the asthenosphere (Malavieille et al., 1993; Schullman et al., 2015 : VanderHaegue et al., 2020) and finally, why put a limit around 200 km which is very poorly defined when the strongest velocity contract with a passage from +3 to -3 is rather around 80-110 km deep which is perfectly compatible with the geological inheritance suggesting a thin European lithosphere and a relatively shallow asthenosphere and incompatible with the concept of Tectoshere

Then If you consider that the boundary between +3 and -3 anomalies are the LAB, it becomes more easy to interpret the deep high velocity anomaly you observed in the mantle and you don't have to cross cut the contours of the anomaly as you did in the figure 3, figure 4 , Figure 5, Figure 6 and Figure 7.

The data presented is this paper are very important and have to be published, but I consider that the interpretation based on the existence of a Tectosphere is incorrect and it will be difficult to convince the geophysical and geological community. The only convincing figure is the Figure 11 in where the Tectosphere is not considered at all.

I propose that the authors reflect on this concept. If they persist in their interpretation then a stronger argument seems necessary and in particular to explain why in an arbitrary way, the contours of the anomalies in the mantle would be cut in the interpellation. The other solution which for me would be more convincing would be to consider the +3/-3 limit as the LAB and reinterpret the figures accordingly. I would be please to review a

revuised version of this manuscript.

Specific points

Concerning the Adriatic slab, a comparison with the paper of Sun et al. (2019, EPS) is required

Concerning the hydrated mantle, please refer to the paper of Malusa et al. (2021, G3) and refrences therien

in where this point is thoroughly discussed

the Zhao et al. (2015, Geoloy) is not referenced