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Comment on se-2021-9

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Referee comment on "Basin inversion: reactivated rift structures in the central Ligurian Sea revealed using ocean bottom seismometers" by Martin Thorwart et al., Solid Earth Discuss., https://doi.org/10.5194/se-2021-9-RC2, 2021

This manuscript is a short paper presenting seismic activity in the Ligurian Sea, detected by the recently deployed AlpArray seismic network (offshore component LOBSTER), and therefore fits very well with this special edition of Solid Earth. The data and results are very interesting as it shows clusters of compressive earthquakes in the center of the Ligurian Basin, suggesting inversion of this part of the basin, and at intriguing high depths (10-16 km; lower crust - upper mantle). However, the authors need to better present/discuss the uncertainties of the method applied and their results, and improve the discussion of their results in terms of rift-related structures and strength of the lithosphere (see main comments below). Therefore, I suggest major revision.

Main comments:

- **Section 3 - Data, methods & results:** Section 3 lacks information on the uncertainties of the method applied and the results, especially regarding the depth of earthquakes and the orientation of the fault planes, which are essential to assess/support the interpretation in terms of rift-related structures and rheology that follows in section 4. Table 1 provides uncertainty range on the depth of each event but it is not explained how this was estimated?

- **Section 4.2 – Orientation pre-existing rift-related faults**: the title of section 4.2 should be changed. This studies provides insight on the present-day seismic activity of the basin but not on the rifting history. The authors discuss here the orientation of the faults obtained from the focal mechanisms of the earthquakes and that they interpret to be inverted, pre-existing rift-related faults. I agree, a change of strike from c. SW-NE to more SSW-NNE may reflect (not 'mimic') the rotation of normal faults formed during rifting during the CCW rotation of Corsica-Sardinia towards the SE relative to Europe. But this paragraph needs rephrasing and more information should be given, e.g. the exact strike (and dip?) of the fault planes obtained from the focal mechanisms. The authors should also quote papers concerning the evolution of continental rifting that shows

younging of rifting-related structures towards the center of the basin (e.g. Brune et al. 2014, Nature communications) to support their interpretation. Also, the rotation of Corsica-Sardinia, was not only between 21-16 Ma but started with continental rifting at about 35-30 Ma, as indicated by the age of syn-rift sediments (e.g. Séranne 1999, J. Geol. Soc. London; Jolivet et al. 2015, Tectonics; note the total amount of rotation between 35-0 Ma is estimated to a minimum of c. 53°, Le Breton et al. 2017). The phase between 21-16 Ma is often interpreted as the phase of oceanic spreading in the Liguro-Provencal Basin (e.g. Speranza et al. 2002; Le Breton et al. 2017), as suggested by the age of post-rift sediments along the margin of Gulf of Lion (e.g. Séranne 1999; Jolivet et al. 2015) and Sardinia (e.g. Sowerbutts and Underhill, 1998, J. Geol. Soc. London).

- **Section 4.3 – Rheology of the lithosphere**: This section is important as the depth and location of the earthquakes in the upper mantle, in the middle of the basin is indeed quite intriguing. First, the author should better present the uncertainty on the nature of the crust and depth of crystalline basement (CB on Figure 5) in this part of the basin. Then, they discuss the seismicity in terms of strength of the lithosphere. However, Handy & Brun (2004, EPSL) discussed that seismicity is an ambiguous indicator of strength and proposed that earthquakes are more reasonably interpreted as a manifestation of transient mechanical instability within shear zones and may be used to locate active weak zones within the continental lithosphere. This should be mentioned and discussed here, as shear zones commonly form through lower crust-upper mantle during continental rifting (see for example Naliboff et al. 2017, Nature communications). Finally, when discussing the strength of the lithosphere, temperature is indeed an important parameter but the discussion here is not clear. Why does stretching of the lithosphere would cause "lower" temperature at the crust-mantle boundary (l. 229)? Stretching involves thinning of the lithosphere thus increasing of the geotherm, which is reflected by higher heat flow, as mentioned later in the text (l.248-253). This is contradictory and should be clarified.

Specific comments:

Abstract (lines 20-22) and Conclusions (lines 259-263) need to be improved/rephrased (see main comments above). For example, I would not say 'away from the abandoned rift' but away from the center of the rift basin; 'mimic' -> 'may reflect'

Line 35: the entire basin might be under compressive stress but the inversion is mostly observed along the margins of the Tyrrhenian Basin

Line 45: 8 months – precise 2017-2018

Line 52: rollback of the Apennines, Calabrian *and Gibraltar* subduction zones

Lines 53-54: *south*-eastward migrating (or retreating) Apennines-*Calabrian* arc (Frizon de Lamotte et al.)

Line 56: Alboran Basin: c. 25 – *8 Ma* (see for example Comas et al. 1999, Proceedings of the Oceanic Drilling Program, Scientific Result, Vol. 161)

Lines 62-63: I would call it Liguro-Provencal Basin (SW part), not Balearic Sea. Gailler et al. 2009; Afilhado et al. 2015; Moulin et al. 2015 are geophysical studies between Gulf of Lion – Sardinia, which is the southwest part of the Liguro-Provencal Basin. And they mentioned "atypical" oceanic crust, it should be mentioned.

Line 70: Gattacceca et al. (2007, EPSL) should be also mentioned here.

Lines 73-75: please add time constraints here, since when the opening of the Tyrrhenian Sea ceased?

Lines 75-76: today

Lines 180-181: The uncertainty on the depth of the crystalline basement (CB on Figure 5), especially for this part of the profile where the distinction between sediments and thinned continental crust cannot be done (Dannowski et al. 2020), should be mentioned and discussed (here and/or in section 4).

Line 191: How does the counter-clockwise rotation of Adria would generate regional compression in the Ligurian Basin? Larroque et al. (2016) discuss the southward propagation of the deformation from the Alps-Ligurian basin junction to the southern margin of the basin, for me this goes in (1) Africa-Europe convergence.

Lines 193-194: Le Breton et al. (2017) and van Hinsbergen et al. (2020) are not really relevant here. Our plate reconstructions do not indicate where the Europe-Adria convergence is accommodated today, but provide information on the long-term plate motion and kinematics. They would be more relevant in geological setting, when presenting the geodynamic evolution of the area over the last 35 Ma.

Line 195-196: what about the inversion of the northern margin of the Ligurian Basin? (as mentioned in section 2, see also Billi et al. 2011, Bulletin de la Société Géologique de

France 182).

Sentences lines 182-183, 200-201 and 203-204: This is not very clear, do the authors suggest that these earthquakes occur along one fault plane (as projected in their profile AB, l. 200-201) or along different fault planes (as mentioned l. 182-183; 203-204)? And why (based on what arguments/observations)? The rupture lengths/areas must be small, as indicated by the low magnitude of these earthquakes, and may explain why the post-rift sediments are not affected. But how does it tell more information on the location of theses earthquakes along one or more fault plane(s)?

Line 200-201: 'push' direction -> slip direction (?)

Line 204: 'can be taken up by these remaining' -> could reactivate pre-existing ; 'rifting structures' -> rift-related structures (check throughout the text); 'enabling' -> suggesting ongoing

l. 216: 'turned' -> inverted

l. 224: water in the formation of ?

l. 234: interpreted to reflect *inversion along* pre-existing normal faults

Figures

Figure 2: I would remove Ba**l**earic Sea and keep only Liguro-Provencal Basin (the authors could add the North Balearic Transform Zone, e.g. van Hinsbergen et al. 2014, Tectonics, as a delimitation between the Liguro-Provencal Basin and the Algerian Basin). I suggest also to add on this map the (inferred) location of oceanic crust (or atypical crust) vs exhumed mantle, and zones of basin inversion described in previous work and mentioned in the text.

Figure 5: It would be interesting to plot the clusters of earthquakes directly on the seismic velocity model (e). At about 30 km distance, the velocity contour 5.5 km/s deepens, does the location of cluster C1 coincides with this change in velocity?

References

Bethoux 1992: Quaternaire (not quate)

Maggi et al. 2000: Journal (Geology) is missing