Solid Earth Discussions

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Comment on se-2021-71

Jeremy Rimando (Referee)

Referee comment on "Impact of Timanian thrust systems on the late Neoproterozoic–Phanerozoic tectonic evolution of the Barents Sea and Svalbard" by Jean-Baptiste P. Koehl et al., Solid Earth Discuss., https://doi.org/10.5194/se-2021-71-RC2, 2021

I found this paper very thought-provoking. They propose an alternative mechanism and timing for the accretion of basement terranes in Svalbard and the Barents Sea. They propose that these basement terranes were accreted by top-to-the SSW thrusts faults during the Neoproterozoic 'Timanian Orogeny,' rather than by displacement along N–S-striking strike-slip faults during the Paleozoic Caledonian Orogeny. This paper really demonstrates the authors' breadth of knowledge of the previous work on the structures which they suggest belong to "continuous (undisrupted), hundreds–thousands of kilometers long, Timanian thrust systems."

However, I think that the paper will require a bit more work to convince readers of the presence of a laterally continuous system of Timanian thrust faults throughout Spitsbergen, Storfjorden, and the Norwegian Barents Sea. As it is, I am not convinced that the authors' interpretations of a few seismic profiles, including correlation of these interpreted structures with lineaments on gravity, magnetic, and slope direction maps, comprise compelling evidence for the lateral continuity of these WNW-ESE-striking and NNE-dipping Timanian thrusts. Ideally, they should have inspected multiple perpendicular seismic profiles from west to east and correlated these. It might help to include additional representative seismic profiles at different longitudes (and incorporate these in the supplementary file at the very least) to bolster their argument for a continuous thrust system.

The lineaments in the gravity and magnetic anomaly maps that the authors claim to be the continuation of the thrust faults could be anything. Even if these were faults, these might display different fault styles, kinematics, and/or timing of deformation. Granted that observing other kinematics on these WNW-ESE-striking faults does not rule out the possibility that these are the prolongation of the Timanian thrusts (i.e., overprinting may have happened), interpreting more seismic profiles and including a discussion similar to the section 'Devonian–Carboniferous normal overprint–reactivation' should help clarify this. In short, I do not think the spatial coverage of the data and the amount of analysis conducted is sufficient to suggest the presence of such a large, continuous thrust system.

The authors could either do additional analyses or at least describe their level of confidence in their mapping of different portions of the fault system, and be clear about which traces are speculative and which traces are certain.

In some instances, it's difficult to follow their line of reasoning for describing a lateral continuous Timanian thrust fault system. They claim that the structures they observed in the northwestern Norwegian Barents Sea are comparable to structures observed onshore and offshore in other areas, but it is unclear how some of their descriptions support such claims. For instance, the Vimsodden–Kosibapasset Shear Zone (VKSZ) is dominantly strike-slip. It is not clear how this is proof that the VKSZ displays similar configuration and kinematics and, consequently, represents the westward continuation of the Kinnhøgda–Daudbjørnpynten fault zone. They describe associated map view folds and they explain the VKSZ's strike-slip kinematics, albeit much later in the text, through strong overprinting by the Caledonian Orogeny. What is the scale and timing of the folds that are observed in map view along the VKSZ? Is there proof that these are Timanian and not folding related to the Caledonian ductile shear zone? While later paragraphs seem to clarify the nature of this folding, the manner in which the VKSZ example is presented as proof does not seem convincing. Instead, it creates confusion. I only cite one example, but I suggest that the authors review how they presented their other arguments for an extensive Timanian thrust system.

As noted by Tony Doré (Reviewer 1), I am also not convinced with why these major thrust systems in Svalbard went unnoticed before. They argue that strong overprinting of the VKSZ by Caledonian Orogeny explains why such thrust systems were not identified before, but in an earlier paragraph they describe folds in map view (which are presumably large and obvious) as proof of the onshore continuation of this thrust system. I would expect to see more exposures of the Timanian thrusts onshore, despite 'deep burial' since, as they themselves claim, these areas onshore would have been intensely deformed, and most likely experienced high uplift and exhumation due to their proximity to the Caledonian collision zones.

On its own, this paper doesn't really provide definitive evidence of the presence of hundreds-thousands of kilometers long Timanian thrust systems and I think this issue should be addressed before they even consider exploring the impact of the existence of Timanian thrust systems on the tectonic evolution of the region. Besides, considering that they discuss the impact of these thrust systems on the tectonic evolution of the region, the authors should include schematic diagrams, or better yet, time-lapse images of their proposed plate reconstruction model.

Overall, the paper is well written. A few stylistic changes, including tweaks to figures and consistency in using in-text citation of figures and figure labels, will significantly improve the readability of this paper. Below are a few minor technical comments to consider:

1) Please make sure that all features/places (e.g., Baltica, Caledonides, Norway, Laurentia, Pearya, Sassendalen, Hornsund) you described are included in your maps. In all of the sections, figures (and panel letters) should be cited consistently in the text right

after the feature being described to make it easier for readers who are not familiar with the area to locate the features you are referring to. Please also make sure that the labels on the maps are big enough and easy to read. Some of the text might need to be outlined in another color to provide a contrast to the background and some may have to be brought to the topmost layer items on your figure to prevent them from being blocked by other lines/shapes.

2) I suggest indicating the ages of these 'Timanian fingerprints' on the map to emphasize the contemporaneity of structures and citing the corresponding references on the figure captions as well.

3) Indicate the abbreviations of geologic features and places in the text, similar to how you did in the figures (e.g., BAFZ for the Baidaratsky fault zone), so that it is easier to locate them on the maps.

4) Please include a north arrow, a scale bar, and northing and easting labels around the map frame. It's difficult to visualize some descriptions of fault lengths in the text since you did not put any scale bars on your map in fig 1.

5) The authors plot the other seismic profiles that belong to the DISKOS database on a map, which is good, but these should be labeled and cited in the text alongside citations of previous studies that inspected these particular seismic lines. If there are other previous studies that look into seismic profiles that are not part of the DISKOS database, these should be included as well. The locations of previous studies which were discussed to provide evidence of the lateral extent of these Timanian thrusts should also be plotted.

6) Rippington et al. (2010), and the lead author himself in Koehl (2018), cast doubt on the existence of an 'Ellesmerian Orogeny' due to the lack of compelling evidence from cross-cutting relationships and age constraints, but 'Ellesmerian Orogeny' is mentioned several times in the text.

7) Is 'top-SSW', 'top-E', or 'top-S' standard notation? Why not use 'top-to-SSW'/ 'top-to-the-SSW', 'top-to-east'/'top-to-the-east', or 'top-to-south'/ 'top-to-the-south' instead?

8) I think it is necessary to outline the approximate extent of the Precambrian basement terranes on a map.

9) In the section geologic setting, can you describe the orientation of the structures (e.g., N-S-striking BFZ and LFZ) as well as the direction of the maximum horizontal stress (and changes thereof) associated with each major tectonic event, to provide context for the

kinematics of the structures you describe?

10) Is there a specific reason for using ‘interpret basement-seated structures’ instead of 'basement-structures?' It seems like a combination of 'basement-structures' and 'deep-seated.'

11) Double check the labelling of figures, especially of the seismic profiles on the map (figure 1).

12) In figure 2, what do you mean by main tectonic stress? Do you mean direction of maximum horizontal stress?

13) I don't think yellow is the best color to outline reflectors in the pink and purple units in your seismic profile interpretations.

14) Indicate the location of the potential field data in figure 5 on the map (figure 1) using a box.

15) 2D seismic profiles only give you the vertical component of displacement, and don't really give a complete picture of the kinematics of faulting. I wonder if the faults you describe as thrust could be oblique or dominantly strike-slip?

16) The authors cite the paper Koehl et al (in review) a lot. Please refer to the guidelines of EGU (Copernicus Publications) on citations of unpublished work.

17) Check completeness/accuracy of descriptions of different figure panels and features on figures. Figure 5b shows a slope direction map, but the caption says it’s a gravity map.

18) The authors write in the passive voice too much. I think it's fine to write in the active voice to avoid making sentences too wordy and difficult to understand.

19) Please make sure if saying "The complete seismic study is also available from the corresponding author upon request" complies with Copernicus Publications' commitment to the 'Coalition on Publishing Data in the Earth and Space Sciences' (COPDESS) and the 'Enabling FAIR (findability, accessibility, interoperability, and reusability) Data Commitment Statement in the Earth, Space, and Environmental Sciences.'

It was a pleasure reviewing your interesting work! I believe the paper is worthy of being published in Solid Earth after addressing the issues I raised. I look forward to hearing your thoughts and I'd be happy to a look at a revised version of this manuscript.

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