Solid Earth Discussions

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Reply on RC1

Jean-Baptiste P. Koehl et al.

Author 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-AC1, 2021

Dear Prof. Doré,

thank you very much for your input on the manuscript, it is highly appreciated. Here is our reply to your comments. We hope the changes we implemented improve the shortcomings of the manuscript highlighted by your comments and suggestions. Please do not hesitate to contact us shall this not be the case for some comments.

- **Comments from Prof. Doré**

Comment 1: This very interesting paper should certainly be published in Solid Earth, not because it provides a definitive solution to the Barents Sea tectonic mosaic, but because it provides a bold and well-argued alternative to the current basement models. In essence, the model would glue the pieces of the Barents Sea (and specifically Svalbard) together in the Neoproterozoic, thus eliminating the idea of later Caledonian assembly from different terranes. It would also put paid to the concept of "Barentsia", the putative microcontinent including Svalbard, formed between two supposed sutures representing arms of the Caledonian orogen.

Comment 2: So how convincing is the interpretation of the Timanian grain extending across from Russia to Svalbard? The idea has to some extent been "out there" for a while, based on the distinct cross-cutting trend of the Tiddlybanken Basin, and the offshore extension of the Trollfjord-Komagelv fault (not strictly Timanian, and actually contested by the lead author elsewhere). But my first reaction on seeing the seismic lines in Fig. 3 was scepticism that such detailed interpretations of deep basement structure could be made from such difficult data. Having to look at the seismic lines with my neck at a right-angle didn't help..... Yes I can see what might be thrust stacks, but I can see lots of other patterns too. That's what happens when you look at noisy data. However, it's good that this is an open review. Others can also take a look and tell me whether I'm being fair or not. Also in the interests of being fair, the authors have looked at a lot more seismic than I have, and for longer - plus the local panels shown in Figure 4 are more convincing.

Comment 3: A significant weakness in the paper's argument, acknowledged by the

authors, is the non-observation of these Timanian structures on Svalbard despite the existence of a few apparently Timanian metamorphic dates. You would really think such a pervasive and dominant tectonic regime, actually not very deeply buried on the seismic lines, would be expressed onshore. The reasons given for the absence are depth of burial and obscuring by later superimposed tectonic events. The latter argument, in particular, is pretty thin based on what the seismic leads us to expect.

Comment 4: Despite these reservations, i think this one can get by with minor revision only. It is very well-written (thanks!) and the illustrations are mainly of good quality. I suggest the following improvement:

1) The multi-panel figures (particularly 3 and 4) are confusing, particularly in online formal. Why not simply call all the different panels different figures? It would make things so much easier.

Comment 5: 2) In any case, the seismic sections are wrongly labelled on Fig. 1. Unless I've got it badly wrong, they should read 3a, 3b etc., (not "2"). The first three sections need readable direction indicators (N-S etc.).

Comment 6: 3) The paper badly needs its own plate tectonic reconstruction (not just the one that is being challenged, Fig. 2). What is your alternative? How was the Barents basement assembled?

Comment 7: Pushing the Iapetus suture even farther west is OK, but where specifically?

Comment 8: And what is the implication for Caledonian assembly, and supposed Laurentian affinity of parts of Svalbard?

Comment 9: How does this idea fit with Caledonian thrust sheets extending as far east as (south of) the Varanger Peninsula? A few simple sketches would suffice to show what you are thinking.

Comment 10: Although these are comparatively minor changes, i look forward to seeing what others say. I'm happy to take a quick look at any revisions. I'm still not sure whether I agree with the idea, but I strongly believe it should be out there and part of the debate.

- **Author's reply**

Comment 1: agreed.

Comment 2: agreed, though the data the authors investigated for the present study did not include much noise. The authors of the present manuscript emphasize that high-resolution versions of the figures are available on DataverseNO to evaluate the work presented (https://dataverse.no/dataset.xhtml?persistentId=doi:10.18710/CE8RQH).

Comment 3: Seismic sections in Figure 3a–c show Timanian portions of the thrust systems (i.e., not related to Caledonian and post-Caledonian brittle overprints, e.g., listric brittle faults and offsets of the seafloor) are buried under at least 2.0–2.5 seconds (TWT; i.e., several kilometers thick) successions of Phanerozoic sediments in the Barents Sea and Storfjorden. In its shallowest segment in Nordmannsfonna where it is folded into an anticline, the Kongsfjorden–Cowanodden fault zone is still buried under at least 1.0 second (TWT) of sediments (Figure 3d–e), which still corresponds to a depth of at least 2.5–4.5 kilometers based on seismic velocities for Pennsylvanian to Cretaceous sediments from

Gernigon et al. (2018). The authors of the present manuscript do not argue that Timanian fault systems are buried everywhere in the Svalbard Archipelago, especially because they were uplifted and exhumed in western Spitsbergen due to strong Caledonian contraction (and subsequent Eurekan contraction). Based on the arguments presented by previous workers for the Vimsodden–Kosibapasset Shear Zone in southern Spitsbergen (e.g., Bjørnerud, 1990; Bjørnerud et al. 1991; Majka et al., 2008, 2012; Mazur et al., 2009), it is highly probable that this major fault zone formed during the Timanian Orogeny as a top-SSW thrust, thus generating the observed regional unconformity between Neoproterozoic and latest Neoproterozoic metasedimentary rocks in the area. In addition, recent dating by Faehnrich et al. (2020) along the Vimsodden–Kosibapasset Shear Zone and other related minor fault zones in southern Spitsbergen further illustrate the point of the authors of the present manuscript about the overprinted character of Timanian thrusts in Spitsbergen. The Vimsodden–Kosibapasset Shear Zone yielded exclusively Caledonian ages (their sample 16-62A), whereas related parallel minor shear zones were only mildly reactivated–overprinted by later Caledonian contraction and preserved partly their Timanian signal (their samples 16-25A and 16-73A). This is discussed in the present manuscript lines 878–887.

Comment 4: the authors of the present manuscript understand the reviewer's perspective here, but changing the labels of Figure 3a–e may not be ideal. At the moment, when reading the manuscript, the reader will only need to remember number "3" to know that the referred "Figure 3" (a–e) refers to seismic data (and will therefore most likely not have to interrupt his/her reading to double check). However, if these labels were to be changed into Figures 3 to 7, the reader will have to remember 5 numbers and may have to disrupt her/his reading more often.

Placing the seismic lines together also aids comparison. Setting Figure 3a–e as separate figures will likely mean that they appear on different pages in the paper, meaning that readers will have to keep flipping back and forth to compare observations from different lines. As such, the authors of the present manuscript would therefore prefer to keep Figure 3a–e together. Nonetheless, the authors of the present manuscript are open to changing the labels and therefore await further instructions from both referees and from the editor.

Comment 5: agreed. However, the labels of the seismic sections are as large as they can be and, should it be necessary, they are possible to read better from the high-resolution of the figures on DataverseNO (doi.org/10.18710/CE8RQH).

Comment 6: agreed.

Comment 7: agreed. Based on the present manuscript's findings, the only natural location for the Iapetus suture is in western Spitsbergen where blueschist and eclogite of Caledonian age are recorded (Horsfield, 1972; Dallmeyer et al., 1990a; Ohta et al., 1995). This is discussed lines 1048–1053 in the present manuscript.

Comment 8: agreed. The present findings have implications both for Caledonian assembly and for the affinity of northeastern Spitsbergen with Greenland. The present manuscript does briefly discuss the tectonic implications of the presented findings in the final sub-section of the discussion. However, in order to keep the manuscript focused and to a reasonable length, these issues will be discussed in a future short manuscript, which will also integrate further datasets (e.g., paleontology) to infer a geodynamic evolution. Points of emphasis will include the use of paleontology to infer terrane separation in plate tectonics reconstructions (e.g., thousands of kilometers separation of northeastern Svalbard from Baltica based on differences in Ordovician trilobites; Fortey and Cocks, 2003).

Comment 9: agreed, although the authors of the present manuscript think that this is beyond the scope of the present study, which focuses on advancing the idea that Timanian thrust systems are present across Svalbard and the Barents Sea. Several papers are currently under development that consider the geodynamics implications of the presented findings more broadly, including one in which implications for Caledonian tectonics are considered. For examples, the idea of deep Timanian thrust systems crosscutting the whole Barents Sea and Svalbard fit well with the presence of Caledonian thrust sheets as far as southwest of the Varanger Peninsula since these represent the shallow portion of the crust. If Timanian thrusts are present at depth > 2–3 kilometers in Svalbard and the northwestern Barents Sea, it is therefore conceivable that such thrust systems are present at depth in northern Norway too. However, the commonly accepted Timanian front being the Trollfjorden–Komagelva Fault Zone on the Varanger Peninsula, it is therefore not required to discuss the impact of the present manuscript's findings on Caledonian nappes south of the Trollfjorden–Komagelva Fault Zone and of this fault's western continuation. A key element in the upcoming years will be to further constrain the nature and location of its extent offshore onto the Finnmark Platform. The lead author has attempted to address this issue during his Ph.D. (Koehl et al., 2018, 2019). It is the lead author's belief that the models presented in both Ph.D. manuscripts are (partly to completely) wrong and need updating, especially in the light of the geometry and attitude of Timanian thrust systems in Svalbard and the Barents Sea.

Comment 10: agreed.

- **Changes implemented**

Comment 1: none required by the reviewer.

Comment 2: none required by the reviewer.

Comment 3: none.

Comment 4: awaiting further instructions from the editor and reviewers.

Comment 5: changed the labels of the seismic sections in Figure 1 to "3a–e".

Comment 6: added the proposed plate tectonics alternative as Figure 8.

Comment 7: none.

Comment 8: none.

Comment 9: see reply to comment 6.

Comment 10: none required by the reviewer.

- **Additional changes implemented**

-Lines 80–81: added ", and imply that the Norwegian Barents Sea and Svalbard basement may contain Timanian structures overprinted during later (e.g., Caledonian) deformation events" for clarity.

-Lines 94–100: split the sentence into two and partly rewrote it to make it easier to read.

-Line 103: added “by future research” for clarity.

-Lines 1004–1005: split the sentence into two and added “. If correct, a Timanian origin for these structures would” to make it more readable.

-Lines 1055 and 1064: added reference to the new Figure 8 as a consequence to Prof. Doré comment 6.

-Lines 1079–1080: added “We interpret these thrust systems as being related to the Neoproterozoic Timanian Orogeny.” for clarity.