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Solid Earth
Discussions

Interactive comment on "High resolution reflection seismic profiling over the Tjellefonna fault in the Møre-Trøndelag Fault Complex, Norway" *by* E. Lundberg et al.

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Please view the attached figures when reviewing our response. The new Figure 1 and a new figure showing topography in the study area are submitted. Response to all referee comments are written in this document. Thank you for your constructive review and we hope you find our response acceptable and will encourage a revised manuscript to be submitted.

Response to Anonymous Referee #1

Regarding the main concern about one of the objectives of the paper: In lines 11 to 15 in page 244 we mention a conclusion made from the results. This was not meant

to be a main objective of the paper. We will remove this unfortunate formulation. The main objective of the paper is to reveal the Tjellefonna fault geometry at depth. The Tjellefonna fault was previously recognized based upon several fault rocks outcropping along a strong topographic lineament, namely the Langfjorden. However, towards north-east the topographic low seems to deviate from the fault based on outcrops and regional scale potential field analysis (Nasuti et al., 2012). We will include a map of the topography with the seismic and resistivity profiles on top and outline the suggested fault to show this more clearly. The conclusion that the topographic low follows a secondary fracture system towards north-east will be removed. The conclusion is simply that the Tjellefonna fault appears to deviate from the main topographic low towards the northeast. The seismic result is consistent with results based on outcrops and regional scale potential field analysis (Nasuti et al., 2012).

- Figure 1 will be changed to a new Figure showing a larger portion of southern Norway. Important features such as WGR, Børgefjell and Møre and Vøring Basins will be marked.

1. The study area will be clearly located within the WGR with the new Figure 1. References to Figures 1 and 2 will be used in the Geological setting section.

2. Contour lines on Figure 2 might be too much information for this figure. We prefer to make one more Figure showing the topography with the seismic and resistivity profiles marked and also the suggested fault outlined.

3. We will consistently adopt the nomenclature suggested S.P. X (seismic profile X) and R.P. X (resistivity profile X).

- We will include the reference to Figure 2 when we explain the 2D resistivity profiles at the end of the Data Acquisition section. We will also remove the reference to Figure 3 in line 22 page 246.

- The merged stack consists of two stacks that were merged. The first stack used a stacking velocity that better images subhorizontal reflectivity. Steeper reflections must be stacked with a higher stacking velocity. Usually a dip moveout (DMO) correction is applied so that all reflections can be stacked using the same stacking velocity. Our data showed significantly reduced quality after applying DMO, probably due to large fold variations along the profile and the large spread of midpoints for each CMP bin. Therefore, we produced two stacks using different stacking velocities and merged the data.

- We will expand the discussion on the traveltime modeling. The modeling is 3D and there are other solutions that could fit the data equally well. We used a constant velocity for the subsurface, but certainly the velocity is not constant. We can give an estimate of approximately how close to the true strike and dip our solutions are and what are the uncertainties.

- The sentence: "The antiform indicated in the geological map (fig 2) is also marked on Fig. 4 for comparison" (line 26, page 248) will be removed. The reference to Figure 2 will be added in the next sentence. Label indicating Antiform axis will be added to Figure 4b.

- Fig 6 will be a) raw shot-gather. b) processed without modeled travel-times. c) processed with travel-times.

- Reference to Figure 12 will be added at the end of the first sentence in line 1, page 251.

- Nomenclature will be changed.

- Page 255 line 20. The word concordant will be changed to related.

- In Figure 14: The important features are that the fold hinge line (interpreted from seismics) and the fault is parallel, and that the interpreted fault only crosses one of the resistivity profiles (7). Since the resistivty profiles are very short compared to the seismics it will be very difficult to see them in detail in this figure.

Response to P. Ayarza (Referee)

Regarding changing the dip of the fault from NW to SE:

The Tjellefonna fault geometry was previously not known, so we do not change the dip of the fault. Most onshore fault segments of the MTFC have been assumed to be NW dipping normal faults because it is easier to fit this with the different known stages of development of the MTFC and with the fact that the topography is higher to the SE and levels off towards NW.

In lines 13 – 15, page 243, "Based on apatite fission track data, Redfield et al. (2005) indicated possible kilometer scale vertical offsets across the Baeverdalen lineament (here Baeverdalen fault, BF, in Figure 1) and/or the Tjellefonna fault TF." It was not stated that the TF was a NW dipping fault with km scale offset, but it was a possibility and therefore a very interesting target. A SE dipping Tjellefonna fault needs to be accommodated into future interpretations, but it is beyond the scope of this paper. More regional scale data have to be used for such an interpretation.

Regarding the offset between CMP 1200 and 1300:

The offset between CMP 1200 and 1300 in Figure 4, could be a potential candidate for a NW dipping or subvertical fault. However, it seems that the folded structure, at about 0.5 s, is continuous across the suggested fault and the lower reflectivity on the NW flank may be due to poor illumination, because the fold flank is dipping out from the profile. Also, the SE dipping reflectivity at about 0.7 s (CMP 1100-1200) seems to be continuous across the suggested fault location. The weaker reflectivity may be due to the strong reflection above is reflecting most energy back to the surface and therefore weakening the reflections below. Although lineaments can be found correlating with a fault between CMP 1200 and 1300, regional data indicates a fault trace close to CMP 1500-1600 (Nasuti et al. 2012).

Regarding the interpretation of the antiform:

We will include also the possibility that this antiform represents the folded lenses that we see on the surface in the discussion. The dimensions of the structure both in width and thickness, however, led us to believe it could represent something else. The lower eclogitic crust is a possibility. If it would outcrop towards NE as suggested by plunge it is probably covered by younger rocks (see new Figure 1). This interpretation was not included in the conclusion. We will rephrase the interpretation to include also the amphibolite lens interpretation in the abstract.

As you mention it is not possible to see from seismic data if the fault cuts the antiform or not because the profile is too short towards SE.

Regarding the minor comments:

1) I'd like that figure 1 had a geological map of southern Norway, where we could see the boundaries of the WGR and if possible, some outcrops of the eclogitized lower crust. Also, it could be added to Figure 2.

- Figure 1 will be changed to a new Figure showing a larger portion of southern Norway. Important features such as WGR, Børgefjell and Møre and Vøring Basins will be marked.

2) In page 248, line 13, you say the used bedrock velocity is constant and 5200 m/s and in page 249 you say velocity is 5.5 km (add per second and use SI units, i.e. m/s). Which was the velocity used?

- 5200 m/s was used in the modeling. We will recalculate depth conversion using 5200 m/s

3) Electric profile 4 shows a subvertical or highly NE dipping fault that divides a conductive zone to the N from a resistive zone to the S. Shouldn't that be the best candidate for TF?

- The suggested fault trace based on outcrops and regional geophysics (Nasuti et al., 2012) will be added to Figure 2, then it will be more clear.

4) The seismic profiles, shot gathers and the resistivity profiles should be oriented all the same: Preferably N to the left and S to the right. It is difficult to follow the dip of events when you change the orientation.

- Figures will be plotted NW to SE.

5) Shots/stacks should be shown without the modeled travel times first so we can judge how good is the fitting and the amplitude and frequency of reflectors (Figures 6, 7 and 9).

- Fig 6 will be a) raw shot-gather. b) processed without modeled travel-times. c) processed with travel-times. And in Figure 9 we will add a figure without modeling. Figure 7 already shows the data with and without modeling.

6) Also, ortography must be revised. There are some errors (e.g. pag 251, line 23, has instead of have? Line 25, a instead of an? shows instead of show? line 26, correlates instead of correlate?)

- Will do!

Response to Anonymous Referee #3

1. Through the whole, the logical presentation should be check. It was hard to understand the logical presentation of this paper. The explanation of each part is good. But it was little bit hard to understand the logical flow of this paper totally.

- We believe that the logical flow will be more clear with the combined changes made along the recommendations from all referees. Especially a more clearly stated objective of the study and the outline of the suggested fault trace in Figures 1 and 2. Also a consistent nomenclature for the seismic and resistivity profiles should help.

2. The reflected waves of the R1 – R5 in figure 6 were not so clear. It is better to show the reflected waves of several record sections. The travel time line did not fit to the observed signals in the case of R3 and R4, in figure 7.

- We will add a new figure to Figure 6 where we show the processed data without the modeling results. This will make it easier to judge the quality of the modeling. We believe showing more sections is not better since all sections still have a rather low signal/noise ratio. We will expand the discussion of the modeling results and uncertainties. The modeling assumes planar surfaces and a constant velocity, therefore violations of these assumptions can lead to misfit in the data. Reflection R3 and R4 fit best in the near surface data of the shot-gather, but in the stacked section in Figure 7, the reflections are not clear in the near surface.

3. Regarding to the interpretation of the S-1, it is little bit difficult that this phase is a P-S converted wave based on the results of Figs. 9 and 10. More detail description is required.

- We will expand and/or rephrase this section to make it more clear.

4. In discussion, the authors wrote the interpretation of the observed data. The data is very good. It is much better to mention the tectonics and forming process of the fault zone in Discussion.

- The tectonics and forming processes require a more regional approach and is beyond the scope of this paper. The first step is to know the geometry of the fault at depth, which is the main objective of this paper.

Interactive comment on Solid Earth Discuss., 4, 241, 2012.

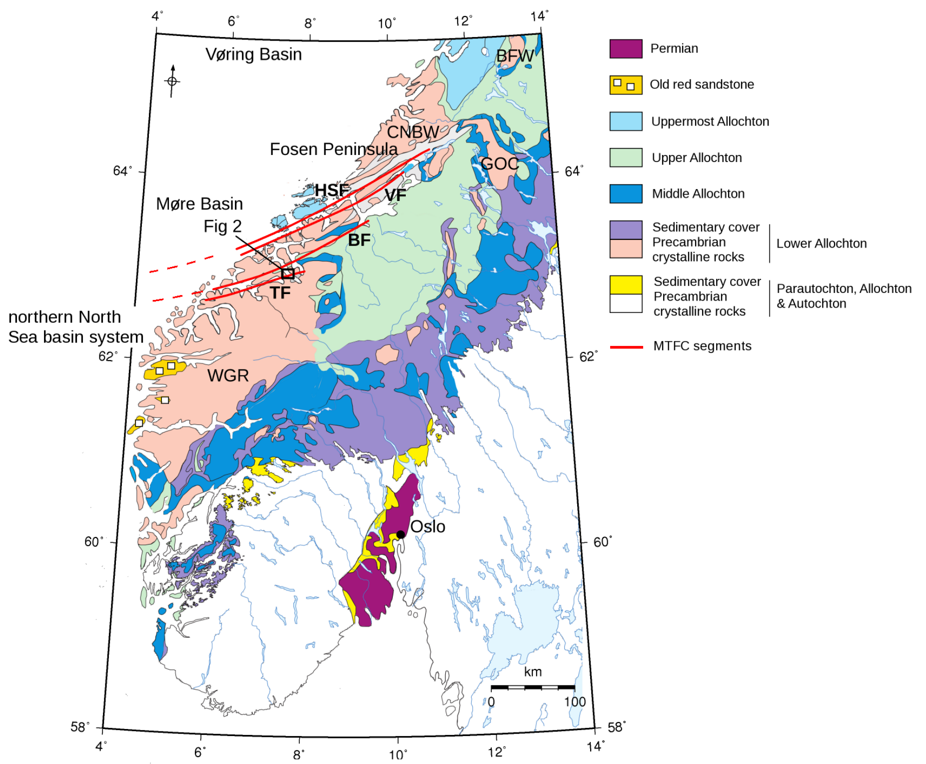

Fig. 1. Replacing Figure 1

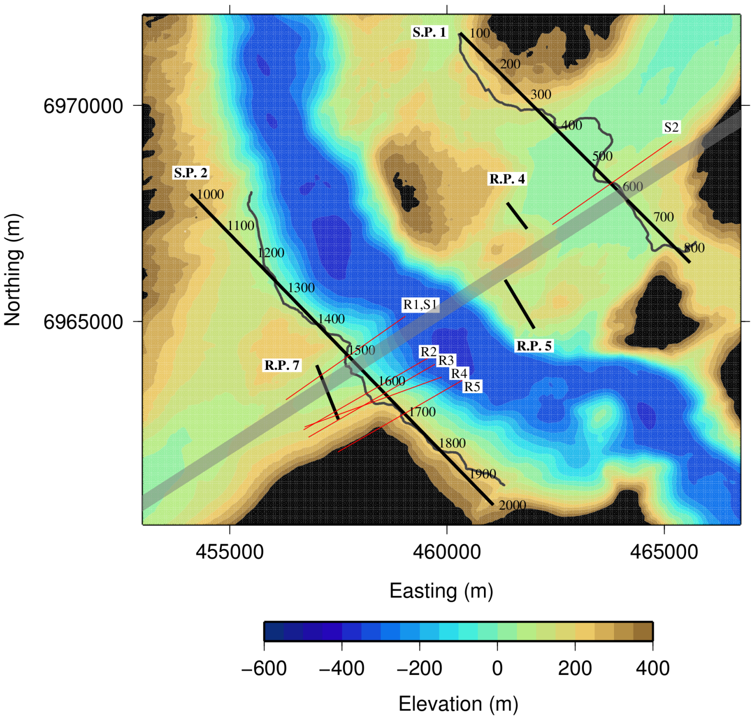

Fig. 2. New figure, not replacing Figure 2