Oblique reactivation of lithosphere-scale lineaments controls rift physiography – The upper crustal expression of the Sorgenfrei-Tornquist Zone, offshore southern Norway

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Solid Earth

MS No.: se-2017-97

Short comment 1 – Alexander Peace

Original comment

This paper presents a thorough analysis of seismic reflection data offshore southern Norway in order to investigate the role of pre-existing structures in the development of the region. Overall, I found the paper to be very well written, organised and insightful. The methods used are suitable for this investigation and the conclusions appear to be supported by the results. The figures depicting seismic lines are well presented, particularly when both the interpreted and uninterpreted sections are shown. The conclusion that a new phase of deformation across the North Sea occurred is arguably this contributions most significant finding. I would therefore like to recommend publication in Solid Earth if the relatively minor points suggested here are considered. These minor points should not be too onerous on the authors, but I believe that they will improve the manuscript, and in particular the legibility of the figures.

First, the fault profiles are very informative and should be commended. However, they have been constructed for throw rather than offset (or heave), and thus do not account for any horizontal displacement. This seems both reasonable and inevitable, given the nature of the data. However, if there are any caveats associated with this approach then they should be stated or discussed in the manuscript potentially by expanding section 3.2.

The profiles shown here only measure the vertical component of deformation (i.e. throw) associated with faulting; as stated in the main body of the text we make no inferences regarding the mode of displacement from these plots (Line 237-239). Additional information on the generation and interpretation of these fault profiles is available in Appendix A and B.

For example would the same conclusions have be drawn from analysis of fault heave, rather than throw?

The width of the fault polygons shown in the figures (i.e. Figure 3, 6) provides a first-order approximation of fault heave, a point now expanded on in the text (Line 222-224). However, we believe that fault heave is unable to provide more information than that provided by throw, particularly regarding the fault geometry and kinematics. Furthermore, for extension, throw is typically much greater than heave; therefore, by measuring throw we are able to minimise any errors associated with our measurements, making our interpretations more robust (Line 225-227).

Furthermore, given that some spatial variation in velocity will be inevitable within the basin and that throw is measured in time, rather than depth, is a throw measured in time on one section of a fault comparable to a throw measured in time elsewhere on the fault (which could be > 40 km away)? Essentially, it would be beneficial to add a few lines to the methodology clarifying why the approach is reasonable.

Although the absolute values of the throw may change we believe that the overall patterns and locations of major throw changes would remain the same after depth conversion. Unfortunately, there is limited well-log data or seismic velocity analyses for us to determine the velocity structure in this manuscript. Within the 3D volume the overall overburden is relatively homogeneous along the fault and therefore velocity is likely to be relatively constant along-strike of the faults. Furthermore, the faults are roughly at the same depth from east to west, thus burial related changes in velocity are also not expected to greatly effect depth conversions. In order to test the difference that depth conversion would make to our throw profiles we depth converted structural measurements made at various points along the fault using limited velocity information (checkshot data) from regional wells (Line 200-201). The overall throw patterns and our interpretations are very similar after depth conversion to those made in the time domain.

My final points relate to the figures, which on the whole compliment the text very well but could undergo some minor amendments that would significantly improve the overall quality of the manuscript. First, the text on most of the figures is very small. For example the labels on Figs. 1 and 10, in addition to all the annotations on the interpreted seismic lines will be difficult to read at publication size. On Figs. 2, 4, 5, 9, 11 and 14, the insert of the location map that includes the seismic line location is too small and the white line is difficult to see against the grey background. Also a colour bar is missing from Fig. 13 and the colour bars on Fig. 6 are too small to read. A horizontal scale is missing from Fig. 2 and it would also be helpful to include the approximate location of the schematic cross section shown in Fig. 1D on one of the location maps.

All annotations and labels on figures are now of a size that will be visible when published full size and adhere to the Solid Earth guidelines. The colour bar for Figure 13 is the same as in Figure 12, this has been added to the caption. The colour bars in Figure 6 have been enlarged. A horizontal scale is already included in Figure 2 (right of figure). Information regarding the approximate location and orientation of the schematic cross-section (Fig. 1D) has been added to the figure caption. In addition, this figure has been modified to more accurately reflect the nature of the lithosphere-scale nature of the lineament, and the link between upper- and sub-crustal components as emphasised in the text (Line 271-276).