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Discussions

Interactive comment on "Oblique reactivation of lithosphere-scale lineaments controls rift physiography – The upper crustal expression of the Sorgenfrei-Tornquist Zone, offshore southern Norway" *by* Thomas B. Phillips et al.

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The manuscript presents a detailed analysis of the geometry and the kinematic evolution of major structures controlling the geometry of the Farsund Basin, offshore southern Norway. The study relies on the interpretation of borehole-constrained 3D and 2D seismic reflection data, the development of isochron and thickness maps of key stratigraphic horizons, and the development of throw-length and backstripped profiles for the major interpreted structures. The authors recognize major N-S and E-W upper crustal fault populations that they relate in depth to the Sorgenfrei-Tornquist lithospheric

lineation. From the tectono-stratigraphic and the structural analysis, the authors document a polyphase activity of these faults which were reactivated in a broad range of tectonic styles during succesive stages governed by a distinctive stress field. Based on all these observations, the authors discuss the evolution and the role of long-lived pre-existing structures during subsequent rift events and debate the main geodynamic implications into the regional tectonic framework. The study is well-supported by the available data and the methods and the workflow used are appropriate for this investigation. Overall, the manuscript is well writen and follows a clear layout; the title reflects the content of the paper and the abstract provides a complete summary of the work. The text explanations are well supported by the figures, which are of a high quality. I find this study very interesting and insightful due not only to the scientific backgroung but also because of the methodology; the work drove to major conclusions that allows advances in the understanding of the studied area. The multiphase activity and the structural link between different fault systems in the Farsund Basin and the discovering of a previously undocumented Early Jurassic period of sinistral strike-slip activity are the most significant findings. In a more general sense, this work provides new insights to comprehend the constraints imposed by inherited lithospheric structures on the development of upper crustal faults during subsequent rift events, depending on the regional stress field. I would therefore highly recommend this manuscript to be published at Solid Earth. Hovewer, I find that including some additional information and some minor modifications, in addition to other reviewers and readers comments, can improve the readability and the high quality of the manuscript. âĂć In the abstract, I would propose presenting the intepreted link between the upper crustal faults and the STZ after addressing the detailed analysis of the upper crustal faults, which is the basis of the study. Thus, I would move information from lines 17-18 to line 28, just before denoting the inferred evolution of the STZ from the analysis of upper crustal faults. âĂć Line 89, figure 1a and c? and Line 90, figure 1a and c (Varnes Graben not in figure 1c). âĂć I would put the regional geological history as section 2.1. I think it could be helpful to contextualize the evolution of the STZ. âĂć I would define a section: 2.2) The

Farsund Basin and I would move the STZ to a section 2.3. I think that a section dealing with the structure and the tectonic evolution of the Farsund Basin would be neccesary to set up the context of this work. I would move lines 164 to 169 to this section and I would include in this 2.2 section an explanation about the geometry of the main faults controlling the architecture of the Farsund Basin (i.e., including the information now in lines 212 to 215, line 220; if these structures were defined by previous works, what is known about these structures from these works?, what is the length of these structures?, explained now in sub-section 4.2, supported by the detailed structural map provided in figure 1c, in case this map was developed from the intergration of previous maps). I think this could be helpful to follow the detailed analysis of the upper crustal fault population provided later by the authors. âĂć Line 98, the Carpathian orogenic front and the Ronne Graben are not labelled in figure 1a. âĂć Lines 108 and 109, Palaeozoic terranes belonging to Central and Western Europe, figure 1D. This cannot clearly be inferred from the figure. âĂć Line 114, Tornquist Fan is not labelled in the referenced Figure 1A. âĂć I would move line 119 to 122 to line 116, after explaining that the STZ is defined as a change in litospheric thickness. Then, I would explain the expression of this structure at shallow crustal levels. âĂć Line 125, "the STZ acted?", line 165, Central Graben is not labelled in Figure 1A. âĂć Lines 170 to 173, this information could be more suitable for a discussion. âĂć In the data section, I think it would be necessary indicating some information about the boreholes and the seismic data (date of acquisition, adquired by oil companies, adquisition and processing parameters,...). Or providing a reference in case this information has been provided in another publication. âĂć I find useful adding some references to supoport the description of the quality of the seismic records (e.g. line 184). âĂć I would define a section 3.2) Methodoly, including the information from line 185 to line 205. I would remove the section quantitative fault analysis (if this section is preserved, I would define a previous section in the same level, explaining the seismo-stratigraphic and structural seismic interpretation, supported by the figures displaying interpreted seismic profiles, borehole analysis and isochron and thickness maps; this information is now explaining in the section dealing

with the available dataset). I would be convenient to introduce in this section what figures support each method (e.g., figure 3 after (...) isochrons between them (...) in line 190, figure 7 and 8 for the throw-length and backstripping techniques,...). âĂć Do the intrinsic geometric uncertainties in time domain and the spatial variations of velocity values affect throw measurements? It would be convenient adding in the methodology section some lines to further explain this limitations. âĂć Lines 207 to 210, section 4.1 should be explained before section 4.2. âĂć I would suggest the definition of a section 4.1 dealing with the stratigraphic architecture and the supported by the figures showing the interpreted seismic profiles. I would explain in this section the main interpreted key horizons, the main units, and its seismic expression (the paragraph included now lines 237 to 240, paragraph between lines 271 and 274). I think that some seismic to well ties should be displayed in the figures to support time constraints of the major seismic horizons for the entire seismo-stratigraphic sequence. In the same way, the authors provide in most cases depth estimations for some horizons, faults displacements and surfaces, so any seismic to well ties and velocity models developed from the checkshots should be displayed to support this information. For instance, Figure 1B is of a very good quality and it has not been referred and explained within the text. I think this figure should not be part of the "tectonic setting" figures. For sure, seismic to well ties and seismo-stratigraphic analysis has been a really important part of the analysis. This is a time-consuming and toughful work but of a great interest to support the analysis of the tectonic evolution. The crustal-scale faulting analysis provided by the authors now as section 4.1 can be included in this section. I think it could be suitable providing a description about the seismic imaging and interpretation of the main faults (if the faults are introduced in the tectonic setting, the authors can describe straighforward these faults using the seismic interpretation (depth, dip, fault links... as it has been interpreted on the seismic profiles). I would suggest to keep the regional description based on isochron maps in section 4.2. âĂć Line 215, Varnes Graben is not labelled in Figure 1c. âĂć Line 216, the Fjerritslew North and South merge with the Farsund Fault between 6 and 8 s (TWT)?. âĂć Line 225-228, the Moho-related reflectivity across the

Fjerritslev Fault system can be inferred in figure S2 provided as supplementary material. Where is this profile located?. Has this feature been observed on several seismic profiles and/or previoysly proposed by noted references? (if this is the case this should be explained in the setting and overcome in the discussion to debate the link between the upper crustal faults and the STZ as deduced from this study and what has been previously proposed). Do the link between the STZ and the upper crustal faults is deduced from the lack of Moho reflections beneath the Farsund Basin, from the offset of Moho reflections by the Fjerritslev Fault System and from the distinctive trend of the upper crustal faults within the Farsund Basin when compared with the trend of the structure delineating the North Sea rift? âĂć Line 256-257, the authors suggest that the Fjerritslev North and South faults merge south of the 3D dataset as indicated by 2D seismic data. A figure displaying a 2D seismic line should be provided as a reference to support this interpretation?. âĂć Line 260, HF2 is not labelled in the isochron maps showing the structure of the supra-salt levels. âĂć Line 304, the NS1 and NS2 faults are not labelled in figure 6b. âĂć Line 322, although slip=fault activity?? âĂć Lines 332 to 334, for the methodology section? After explaining the main developed isochron maps and before explaining the throw-length and backstripping profiles?. âĂć I would suggest including a discussion section dealing with polyphase fault activity. I find the kinematic evolution of these faults described in section 6 from direct observations very suitable. However, some other aspects as the discrete Triassic activity along some segments of E-W faults (included between lines 368 and 389) or the geometric evolution of these faults during the Late Jurassic-Early Cretaceous oblique reactivation (lines 431 to 440, 445 to 447, 452 to 457 and 478 to 484) are discussed together with the previous interpretations and theoretical concepts so I find that these parts could be more appropriate for a discussion section. âĂć Line 397, Figure 10c? âĂć Line 482, the eastern part of the Fjerritslev South Fault? âĂć Line 625-630, do the authors mean that the STZ accomodated most of the deformation allowing the preservation of the cratonic lithosphere of Baltica almost undefformed?.

Figures Figure 1 âĂć It would be useful including the meaning of STZ, TTZ and RFH in

the figure caption of figure 1A. The rectangle delineating the extend of figure 1C seems to be too large taking into account the intersection of Fjerritslev Faults. âĂć Figure 1B is not cited and explained in the text. âĂć Figure 1C does not have a north arrow; It would be useful including boreholes in Figure 1C together with the 2D seismic profiles. What is the red dot in figure 1c? a well location?. âĂć The fault network across the Farsund Basin showed in Figure 1c. Taking into account some references provided in the text, I supposse that it comes from previous studies, but was this map developed from previous studies or was this map developed relying on seismic interpretions made in this study? If the fault trends come from previous studies, these references should be added in the figure caption. If the map was developed during this study it is a new outcome and it should be included in other figure to support the analysis of upper crustal faults. Figures 2,4,5,9,10 and 14 âĂć Salt diapirs should be labelled or included in the legend. âĂć 2D seismic lines: this should be included in the figure caption. âĂć The inset map should include the scale; the maps are too small and the seismic lines displayed in white are difficult to see against the grey background. Figure 3, 6 and 12 âĂć Isochron maps showing thickness variations and associated faults for the main interpreted horizons; A) Triassic; B) Jurassic; C) Lower Cretaceous. âĂć It could be useful adding latitudes and longitudes labels and using them as a reference to describe some of the observed features within the text. âĂć It should also useful adding some key contour values. Figure 15 âĂć It could be useful adding fault names.

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