

Interactive comment on “Mid/Late Devonian-Carboniferous collapse basins on the Finnmark Platform and in the southwesternmost Nordkapp basin, SW Barents Sea” by Jean-Baptiste Koehl et al.

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Received and published: 31 January 2018

Dear Dr. Phillips, Thank you very much for your comprehensive review of our manuscript. Please find our response to your comments organized in three sections: (1) Comments from Dr. Thomas Phillips, (2) Authors' response, (3) Changes implemented. We hope you find it satisfactory and comprehensive.

1. Comments from Thomas Phillips Major comment Comment 1: The authors state that they identify a NE-SW trending “zone of weakness” on seismic reflection data (LINE

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200). Based on the seismic data alone, no inference can be made as to the lithological properties of the structure, rather; what is imaged is a package of prominent inclined reflectivity. As this reflection package does not directly correlate to any structures as observed onshore, more evidence is required before the authors can state with confidence that this represents a shear zone or a zone of weakness. Comment 2: In addition, the authors state that “km-thick layers bearing strong basement fabrics: :” may be resolvable at seismic scale (LINE 438-443). References to shear zones as previously imaged and modelled in seismic data need to be included at this point to back up the, in my view correct, interpretation that this reflection package represents a shear zone. Such references include : Phillips et al. (2016); Reeve et al. (2013); Fountain et al. (1984). Comment 3: LINE 456-457 – Can you speculate as to what the minor mylonites and shear zones may correspond to? Could they correspond to fabrics within Caledonian allochthons? Or potentially thrusts between allochthons? Comment 4: The authors propose a model of core complex exhumation along with excisement and incisement to explain the bowed portions of the SISZ and the exhumation of basement ridges (i.e. Figure 10; Section 5.4). Whilst I agree that the faults appear to merge down with the shear zone structures at depth, what remains unclear is the mechanism by which the bowed portion of the SISZ forms at deeper levels. What causes the SISZ, which then influences faults in the overlying sedimentary sequence, to be uplifted and bow at a particular location at depth? During core complex exhumation, bowed portions would be expected to form towards the surface, but I am unsure as to what would drive the uplift at deeper level (i.e. red arrow in Figure 10b, c) Would it be possible that the fault forms first leading to the passive uplift of the shear zone in its footwall? A more detailed description of this mechanism is required, potentially with more detailed applied to figure 10. Comment 5: LINE 570-571 – I think that you need to first confirm that the observed changes in thickness along the structure are real and not related to variable imaging quality of the shear zone along strike and at depth. For example, the mylonites/fabrics generating the reflections may destructively interfere in some instances. More information is required on the data used in this study and the coverage

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provided (LINE 404). What is the data coverage across the area, which areas are covered by 3D seismic data? What is the typical spacing between 2D lines? Comment 6: LINE 316-319 – does this imply that the faulting pre-dates the dyke emplacement, or is this able to provide any constraints on the exact dating of the faulting? It needs to be made clearer if these dykes are associated with the faulting or just place an upper bound on the age of dyke emplacement.

Minor comments figures Comment 7: Figure 1 appears very cluttered, with a large number of structural elements labelled on the same figure. As such it can often be difficult to identify specific figures referred to in the text (i.e. the locations of the star symbols, LINE 364; Lofoten-Vesteraleen margin, LINE 285). In addition, it is difficult to distinguish between those structures that are fundamental to the text and analysed in detail from more minor structures. Perhaps it would be worth distinguishing the key structural elements. Furthermore, the southwesternmost Nordkapp basin and the area focussed on in the study could be outlined to draw the readers attention. Comment 8: The regional map shown in figure 1 currently offers little information. This should be changed to a slightly more regional version of that shown in 1A (i.e. northern Norway), allowing some regional structures to be labelled on this map instead. Comment 9: Figure 2 – Would it be possible to show the location of this figure on Figure 1 (same as orange in comment 8) Comment 10: Figure 5 – Details of the seismic sections are not clear on both printed and online versions of the manuscript, making it difficult to identify some of the interpretations made in the text. Would benefit from being split over two pages with each section made larger. Comment 11: Figure 6 – These sections appear better quality than those shown in figure 5, with structures and interpretations clearly visible. However, sections in this figure would still benefit from being made larger. Comment 12: Figure 6c – the relationship between the shear zones and the later rift-related faults shown here appear similar to the exploitative fault interactions of Phillips et al 2016, where we suggest that the fault exploit mechanical anisotropies represented by the mylonitic layers. Also applicable to LINE 725-729. Comment 13: Figure 9 – Label each of the individual isochrons with the stratigraphic interval. Comment 14:

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Figure 11 - The different shades of red used in the figure can be difficult to make out.

Minor comments text Comment 15: LINE 1824 (Figure caption) – spelling mistake “0and” Comment 16: LINE 49-51 – Sentence doesn’t make grammatical sense as it stands currently Comment 17: LINE 69-70 – the authors state the Senja Shear Zone and the Fugloya Transfer Zone parallel the Trollfjord-Komagelv Fault Zone, this does not appear to be the case in Figure 1, with the SSZ and FTZ appearing almost perpendicular to the TKFZ. Comment 18: LINE 155 – what differentiates between previous studies that map the TKFZ as a discrete structure and this study, where it is mapped as a series of discrete strands? Comment 19: LINE 427 – The dykes mentioned are not shown in the magnetic map shown in figure 4 Comment 20: LINE 455-461 – It may be useful to compare with the seismic facies observations of Fazlikhani et al. 2017 based on observations from the northern North Sea. Comment 21: LINE 469 – Spelling of occasional Comment 22: LINE 463-467 – I am unable to make out such seismic stratigraphic relationships due to the imaging of the seismic sections shown in figure 5. Comment 23: LINE 563 – Clarify whether you mean ‘curved’, in map view or in cross-section? Comment 24: LINE 575 – I’m slightly confused by this statement, it seems that the causation should be the opposite way around. The correct phrasing and causation is given on LINE 635. The way it is phrased currently implies that the SISZ merges with the TFFC rather than the later-formed TFFC merging with the pre-existing SISZ? Comment 25: LINE 588 – noteworthy needs to be changed to notably Comment 26: LINE 609-615 – Good interpretation of the relationship between the two. Comment 27: LINE 862-870 – Also link to additional examples earlier on to add more weight to the interpretation of the reflection package as a shear zone

2. Author’s response Comment 1: we agree with the suggestion of the referee, the sentence should be changed accordingly. Comment 2: agreed with and updated. Comment 3: agreed with and updated. Comment 4: we do not think brittle faults formed first. Instead, we propose that progressive crustal thinning due to extensional reactivation of the SISZ and extensive erosion are the triggering and driving mechanisms

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for the bowing of the SISZ. First near surface (figure 10a), and gradually along deeper portions of the SISZ now exhumed to shallower crustal level due to crustal thinning and erosion (figure 10b and c). The location of the bowing is far less obvious because seismic data do not allow to see much deeper than the SISZ but perhaps the bowing localized along pre-existing Paleoproterozoic fabrics/heterogeneities (but too speculative to be included in the paper). We agree though that more information must be provided in the figure (10) caption and in discussion section 5.4. Comment 5: agreed with and added relevant information in Methods chapter. The typical spacing for the 2D survey BSS01 was not provided and is therefore not included in the paper. In addition, thickness variations along the SISZ are based on the interpretation of multiple seismic surveys (not shown in our study) of variable quality (the best being survey BSS01). We agree with the comment of Dr. Phillips in which he mentions “mylonites/fabrics generating the reflections may destructively interfere in some instances”. Such phenomenon was actually observed on part of the presented seismic survey (BSS01) but none of these seismic sections is showed in the paper because of the low quality of the SISZ reflections on these sections. We argue that showing such a low-quality section may not add much weight to our argumentation and increase the length of the paper, which is already very long. Comment 6: agree with and updated Comment 7: agreed and adjusted. Comment 8: agreed with and changed. Comment 9: agreed with and updated. Comment 10: agreed with and updated. Comment 11: agreed with and updated. Comment 12: too hard to tell from our seismic data. The fault could be either “exploitative” or “merging” according to the nomenclature used in Phillips et al. (2016). Thus, we would rather leave this out of figure 6c and line 725-729. Comment 13: agreed with and implemented. Comment 14: agreed with and color scheme updated. Comment 15: agreed with and changed. Comment 16: agreed with and changed accordingly. Comment 17: agreed with and re-written. Comment 18: clarified. Comment 19: agreed with and updated. Comment 20: agreed with and updated. Comment 21: agreed with and changed. Comment 22: agreed with and corrected. Comment 23: agreed with. Comment 24: agreed with and changed. Comment 25: agreed with

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and changed. Comment 26: agreed with. Comment 27: agreed with and updated (cf. comments 8 and 21).

3. Changes implemented Comment 1: “zone of weakness” in LINE 200 was replaced by “package of [...] seismic reflections” as suggested by Dr. Phillips. Comment 2: addition of suggested references “Fountain et al., 1984; Reeve et al., 2013; Phillips et al., 2016”. Comment 3: the sentence line 456-457 was updated as follow: “We interpret these pronounced internal fabrics as widespread mylonitic foliation separated by internal thrusts within a large-scale shear zone”. Comment 4: emphasized that erosion and extensional reactivation of the SISZ are the triggering factor for the bowing of the SISZ. Modification of the figure caption as follow: “a) Extensional reactivation (thin red arrow) of the SISZ in Early Devonian times. Rapid crustal thinning and possible erosion along the upper part of the SISZ triggers exhumation of basement rocks near the coasts of NW Finnmark (thick red arrow); b) In the Early-Middle Devonian, continued extension and erosion further thin the crust and exhume basement rocks in the footwall of the SISZ, leading the upper part of the SISZ to bow. Incremental crustal thinning due to continued extensional reactivation of the SISZ and continental erosion triggers exhumation of basement rocks along lower portions of the SISZ (left-hand side, thick red arrow); c) In Mid/Late Devonian times, bowed portions of the SISZ become inactive and excisement (i.e. upwards splaying; cf. Lister & Davis 1989) of the SISZ into its hanging-wall leads to thickening of the upper portion of the SISZ. Continued extension and erosion (i.e. crustal thinning) trigger bending of the lower part of the SISZ (thick red arrow) above which brittle normal faults may have formed and localized the deposition of Devonian sedimentary deposits (orange)”. In addition, multiple minor text modifications were made from line 1049 to line 1063 to emphasize erosion and extension as the trigger mechanisms for bowing of the SISZ. Comment 5: Methods chapter updated as follow: “The seismic interpretation shown in this study is based on publicly available 2D and 3D data from the DISKOS database, thus providing reasonably tight 2D data coverage. However, only one seismic 3D survey was available in the study area”. Addition of the following sentence: “In addition,

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we analyzed two time-slice from 3D seismic survey MC3D-MFZ02 to constrain fault interaction in map-view". Comment 6: dolerite dyke provide a minimum estimate of the age of the latest faulting event along the TKFZ. The sentence was updated to "Roberts et al. (1991) and Lippard & Prestvik (1997) presented indirect evidence of early Carboniferous dolerite dykes emplaced along and cementing WNW-ESE trending brittle fault segments of the TKFZ onshore Magerøya, thus providing a minimum estimate for the latest stage of faulting along this fault." Comment 7: we deleted useless abbreviations and adjusted the font of the remaining ones so that important faults and basins appear in bold (e.g. southwesternmost Nordkapp basin - sNB). In addition, we added the different parts of the Norwegian continental shelf we refer to in the regional map, including e.g. Lofoten-Vesterålen. Comment 8: changed regional map into zoom in Norwegian shelf showing western Norway, Lofoten-Vesterålen, the North Sea and the Barents Sea. Comment 9: addition of a dashed black frame showing the location of figure 2 in figure 1. The following sentence was added to the caption of figure 1: "Dashed black frame locates Figure 2". Comment 10: the seismic sections of figure 5 were split into 3 to enlarge each section. Comment 11: enlarged seismic sections of figure 6. Comment 12: no changes. Comment 13: in figure 9, each map was labelled with corresponding stratigraphic interval. Comment 14: in figure 11, light red color (inactive core complexes) was replaced by grey. Comment 15: typo corrected. Comment 16: the sentence was changed into "This suture and possibly related deep-seated shear zones, which accommodated e.g. thrust nappe emplacement during the Caledonian Orogeny, are now covered by late Paleozoic to Cenozoic sedimentary basins that formed during multiple episodes of extension." Comment 17: the phrase was changed to "by margin-oblique, NNW-SSE to WNW-ESE trending transfer fault zones, e.g. Senja Shear Zone and Fugløya transfer zone (Indrevær et al., 2013), which may represent analogs of the onshore, Neoproterozoic, WNW-ESE trending Trollfjord-Komagelv Fault Zone (TKFZ)", thus suppressing the erroneous "sub-parallel" adjective. Comment 18: the sentence was rewritten as follow: "The Timanian Orogeny produced major NW-SE trending folds

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(Roberts & Siedlecka, 2002) and WNW-ESE trending fault complexes like the TKFZ (Johnson et al., 1978; Herrevold et al., 2009). The TKFZ was mapped as a narrow, single-segment fault strand all the way along the Kola Peninsula in Russia in the east, where it merges with the Sredni-Rybachy Fault Zone (Roberts et al., 1997; Roberts et al., 2011), to the Barents shelf in the west (Gabrielsen, 1984; Gabrielsen & Færseth, 1989; Gabrielsen et al., 1990; Roberts et al. 2011)". In addition, we added the following sentence to show the reader in which way our study of the TKFZ differs from previous works: "We present an alternative model in which the TKFZ splays into multiple fault segments and dies out between the Varanger Peninsula and the Barents shelf". Comment 19: dolerite dykes added to figure 4 as dotted black lines. In addition, an explanatory sentence was added to the figure caption: "Dolerite dykes intruded along WNW-ESE trending fault segments of the TKFZ are shown by dotted black lines." Comment 20: addition of suggested reference: "Fazlikhani et al., 2017". Comment 21: typo corrected. Comment 22: we agree with the comment and forgot to refer to the appropriate seismic zoom in the Base Devonian reflection. Thus, we added a reference to figure 6b and c. Comment 23: added "in cross-section". Comment 24: sentence changed into "where the listric TFFC merges with the shear zone". Comment 25: "Noteworthy" changed into "Notably". Comment 26: no changes. Comment 27: cf. comments 8 and 21 for changes.

Please also note the supplement to this comment:

<https://www.solid-earth-discuss.net/se-2017-124/se-2017-124-AC1-supplement.pdf>

Interactive comment on Solid Earth Discuss., <https://doi.org/10.5194/se-2017-124>, 2017.

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