Reply to all comments

Dear Dr. Marin, Phillips and Roberts,

Thank you very much for your input on the manuscript. Please find a summary of our reply to your comments and the changes implemented to a revised version of the manuscript. We hope you find our correction satisfactory.

1. Comments from the referees

Comment from Dr. David Roberts

Comment 1: mix-ups of British and American spellings, even in the same paragraph (e.g. p.4 Archaean (Brit) vs Archean (Am).

Comment 2: The spelling of the TKFZ by the way is Trollfjorden-Komagelva Fault Zone.

Comment 3: In Figs. 1 & 2 the positioning of the acronym TKFZ is quite wrong. Put it on the Varanger Peninsula (type locality) in Figure 1. It certainly isn't in Laksefjord. However, there are, as you know, very many TKFZ-parallel faults in this part of northern Finnmark (ref my 250K and 500K map-sheets, and the Lippard/Roberts papers); and I have walked across or along most of them in the late-70s, 80s, early-90s. They are mostly normal faults, with this component of movement likely to be Early Carboniferous (see the Nasuti/Rob/Gern mafic dykes paper).

Comment 4: In Fig. 1 the Nordkapp Basin is spelled incorrectly.

Comment 5: On p. 5 line 146 -- there is no such thing as the Tanafjord-Varangerfjord Group.

Comment 6: On line 150 the Timanian foreland basin is in the pericratonic 'Gaissa Basin' realm, not the Barents Sea Group (see Zhang et al. 2015 – attached pdf).

Comment 7: On p.6 under 2.1.2, the idea (Kirkland) that the Kalak strata were exotic and originated on Laurentia, and now lie above an inter-continental suture zone (base of Middle Allochthon) has been shown to be groundless (see e.g. Zhang et al. 2016 – attached pdf). The Kalak rocks are most definitely Baltican (see also my NJG V.87 paper from 2007).

Comment 8: I have always been very sceptical about the notion of late-Caledonian orogenic collapse in Finnmark. This was really dramatic in western & central Norway, following c. 200 km of subduction with eclogites, coesite and microdiamonds, but diminishes in intensity northwards. In Finnmark we have inferred late-Scandian extensional microstructures only on the western flank of the Repparfjord window. In Porsangerfjord, there are late-Scandian, brittle, ESE-directed contractional structures dated to c. Mid

Devonian time. So the sandstones beneath the Carboniferous strata in wellcores are likely to be Late Devonian in age (which fits with the evidence of rifting in Late Dev time in NE Varanger and in large areas of NW Russia).

Comment from Dr. Dora Marin

Comment 1: Although the manuscript is a good contribution to the understanding of the geology of the SW Barents Sea, it lacks a more global impact. Why should researchers that do not work in the SW Barents Sea read this paper? You can include a paragraph that highlights this issue. But please be concise, as the paper is already very long.

Comment 2: The length of the paper should be substantially reduced. Very few people will read the entire paper with such length. In order to do this, I have the following suggestions: -Avoid repetition: you mention three times that the easternmost Hammerfest Basin should be renamed southwesternmost Nordkapp basin, and at least three times you discuss the origin of the Serpukhovian unconformity. Just mention these things once and proceed to the point. -Geological setting: You can reduce this section considerably if you only include what is relevant for your study. A figure with a stratigraphic column could probably help you summarize sections 2.1 and 2.3 into a single paragraph. The geological setting is a little unorganized. For example, in section 2.1.1 you are writing about Precambrian rocks, but suddenly you start describing faults (Lines 155–166, page 6). I suggest that you divide the geological setting in section 2.1, where you only write about lithology, and section 2.2 where you can write about the structural geology. Lines 199–200, page 7 do not belong to the geological setting, it is part of the results. Lines 233–236, page 8; 273–278, pages 9–10 do not belong to geological setting. -Section 5.6 is a summary of what you already have said. You can consider removing this section.

Comment 3: Methods: be more specific about the description of your well-seismic tie. Did you make a synthetic seismogram? Which parameters did you use?

Comment 4: You need to clarify the meaning of your seismic unit's tops: are they sequence boundaries (if so, what type?), formations tops or just key reflectors with stratigraphic meaning? Because in your results you sometimes write about groups, sequences or ages. Be consistent and do not mix nomenclatures. In the figure of the stratigraphic column, you can also add your seismic unit's tops.

Comment 5: Results: descriptions and interpretations are mixed. You can split each section of the results into a description and an interpretation part, in order to make the results chapter easier to read. And please try also to summarize this section.

Comment 6: Discussion: I have a problem with your alternative interpretation of the TKFZ. First you said that the TKFZ dies out before the Finnmark Platform (page 1 line 27; page 37, line 1128; page 38, line 1144), but in your alternative (contradictory) interpretation you suggest that the TKFZ could have been partially eroded in the Finnmark Platform, but it might be possible to find its prolongation in the Loppa or even in the Veslemøy High. To support your interpretation, you mention some WNW–ESE faults in Veslemøy High, referring to Kairanov et al., 2016. First, the figures of this reference are not easy to find for the readers (since this was a conference presentation). Second, what is the timing of the faults in the Veslemøy High compared to the TKFZ? Are they even the same type of faults? You are not showing data that supports your alternative interpretation of the propagation of the TKFZ to the W.

Comment 7: Figure 1: the font size of your abbreviations is different. Why do the BSFC and BKFC have a bigger font? Why are the TKFZ and TFFC abbreviations bold?

Comment 8: Figure 2: some of your fonts are bold. Why?

Comment 9: Figure 4: this figure does not have scale or coordinates. It does not have a color scale. What is the meaning of the red dotted line?

Comment 10: Figure 5: seismic sections are very small, and it is very difficult to see any details (e.g seismic character, amplitude, geometries). You need to make them bigger. It is difficult to agree with your descriptions and interpretations if I can not properly see the data. The sections do not have horizontal scale. You should provide the uninterpreted seismic lines (this can be in supplementary material, if there are any restriction on the number of figures). Sometimes you do not interpret the tops in the entire seismic line. Why? Is it because there is a lot of uncertainty (in that case you could use question marks).

Comment 11: Figure 6: fix the order of the figures. After A comes B, not D. Add horizontal scales.

Comment 12: Figure 8: it shows a time slice near the mid-Carboniferous. That applies probably only for the hanging wall. Add scale.

Comment 13: Figure 9a shows a thickness map of the Devonian–lower Carboniferous, including areas as the sNB. In the seismic lines 5c, d neither the base of the Devonian or the basement are interpreted. How did you make this thickness map? Which reflectors did you use? The Mid- Carboniferous and the SISZ? Also try to make these maps bigger.

Comment 14: There are many paragraphs that need a figure as a reference. If not, they are difficult to understand or visualize, ex: page 3, line 69; page 9, line 250; page 10, line 301; page 38, line 1159.

Comment 15: Some sentences are very long, for example: page 3, lines 67–73; page 12, lines 360–364; pages 16–17, lines 490–498. Try to split them to make the paper easier to read.

Comment 16: Be consistent between the names that you use in the text and the figures. Is the Senje fracture zone in line 285, the same as the Senje Shear Zone in figure 1? Page 19, line 576 says basement highs, but in figure 1 it says basement ridges.

Comments from Dr. Thomas Phillips

Comment 1: The authors state that they identify a NE-SW trending "zone of weakness" on seismic reflection data (LINE 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 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.

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-Vesteralen margin, LINE 285). In addition, it is difficult to distinguish between those structure 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: Figure 11 - The different shades of red used in the figure can be difficult to make out.

Comment 15: LINE 1824 (Figure caption) – spelling mistake “0and”

Comment 16: LINE 49-51 – Sentence doesn’t make grammatical sense as it stands currently

<u>Comment 17:</u> 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.

<u>Comment 18:</u> 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?

<u>Comment 19:</u> LINE 427 – The dykes mentioned are not shown in the magnetic map shown in figure 4

<u>Comment 20:</u> 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.

<u>Comment 21:</u> LINE 469 – Spelling of occasional

<u>Comment 22:</u> 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.

<u>Comment 23:</u> LINE 563 – Clarify whether you mean 'curved', in map view or in cross-section?

<u>Comment 24:</u> 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?

<u>Comment 25:</u> LINE 588 – noteworthy needs to be changed to notably

<u>Comment 26:</u> LINE 609-615 – Good interpretation of the relationship between the two.

<u>Comment 27:</u> 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

Response to comments from Dr. Roberts

<u>Comment 1:</u> agreed, we noticed these inconsistencies and made changes where necessary.

<u>Comment 2:</u> agreed and updated.

<u>Comment 3:</u> agreed with and updated figure. We fully agree with you to say that there are many WNW-ESE trending faults and that they accommodated a presumably early Carboniferous component of normal/strike-slip faulting as shown by the dating of Lippard & Prestvik (1997).

<u>Comment 4:</u> agreed with and corrected.

<u>Comment 5:</u> agreed with and corrected.

<u>Comment 6:</u> agreed with and updated/modified using Siedlecka & Roberts (1992; excursion guidebook) as key reference instead of the suggested Zhang et al. 2015 reference.

Comment 7: we most definitely agree that the following references addressing the provenance of rocks of the Kalak Nappe Complex should be cited in the geological setting chapter of our paper: Roberts 2007, Zhang et al. 2016.

Comment 8: the conclusions of our paper is not incompatible with your comment, i.e. it may still have occurred to a lesser extent than in southern and mid-Norway. There are strong indications of Devonian inversion of basement-seated shear zones in Lofoten-Vesterålen (cf. Steltenpohl et al. 2011) and of Late Devonian-early Carboniferous faulting in Troms (Laksvatn and Vannareid faults; Davids et al., 2013) and Finnmark (Kvenklubben, Markopp and Talvik faults; Torgersen et al. 2014; Koehl et al. 2016). We are also aware of the Middle/Late Devonian extensional event in Russia (Pease et al., 2016), e.g. Kontozero Graben (Kramm et al. 1993) and dolerite dykes (Roberts & Onstott 1995).

Response to comments from Dr. Marin

Comment 1: agreed with and added appropriate phrase to the Introduction chapter.

Comment 2:

-Avoid repetitions: deleted one sentence referring to the change of name of the easternmost Hammerfest basin. Shortened sentence line 899. Deletion of sentence line 899-901. Deletion of sentence line 1087-1091 and addition of the following phrase to the previous sentence ", and in agreement with eustatic sea-level fluctuations at that time (Saunders & Ramsbottom, 1986)".

-Geological setting: we agree this section should be updated, including the addition of a simplified stratigraphic chart. The geological setting chapter, though relatively long, is organized chronologically. First, we approach Precambrian basement rocks, then Precambrian faults (e.g. TKFZ; lines 155–166, page 6). Second, we address Caledonian nappe thrusting in North Norway and, third, we review existing studies about post-Caledonian sedimentary basins and faults. We believe it is important to address Precambrian faults (e.g. TKFZ) together with associated rocks and deformation events to indicate that these faults correspond to long-lived, basement-seated faults that may have experienced several episodes of reactivation. Thus, we would prefer to keep the geological setting organized as it is now (chronological order) rather than to split it into lithology and structural geology as suggested. Nonetheless, we understand that the length of the geological setting chapter may partly impact negatively the manuscript and we have proceeding to a partial shortening of this chapter.

-Section 5.6: we agree that this section repeats what has already been argued for in previous discussion chapters. However, we believe that this section is essential to our contribution since it links all the faults and basins addressed in previous discussion chapters by providing a chronological evolution of the study area. We would therefore prefer to keep section 5.6.

Comment 3: agreed with and updated.

Comment 4: agreed with and mostly addressed with the addition of a stratigraphic chart (figure 3; cf. comment 2). We also restricted the use of the term “sequence” to intra-unit/succession reflections, e.g. dotted white lines in Devonian sedimentary unit in figure 5 & 6.

Comment 5: the authors agree that distinguishing description from interpretation is important to keep the manuscript clear for the reader. Dr. Marin, herself, judiciously uses “description” and “interpretation” sub-headings in a recent manuscript (Marin et al., 2017). We, however, feel that adding supplementary sub-headings to our manuscript will only lengthen and segment a text already split in multiple chapters and sub-chapters. We therefore prefer not to use the suggested additional sub-headings.

Comment 6: to clarify: the fault-tip process zone model is from Koehl et al. submitted. Our model in the present contribution is that the TKFZ may partly be preserved in pre-Devonian basement rocks and observable on seismic data across basement highs. Indeed, the reference support we use (Kairanov et al., 2016) is from a conference presentation, which makes it difficult but not impossible to the reader to check our argumentation. The faults observed on the Veslemøy High are sub-vertical, WNW-ESE to NW-SE trending and, thus, geometrically similar to the fault segments of the TKFZ. Further, WNW-ESE trending faults on the Veslemøy High (Kairanov et al., 2016) do not propagate into Mesozoic-Cenozoic sediments and are constrained to basement rocks, hence suggesting that they may represent analogs or even the westwards continuation of the Neoproterozoic TKFZ.

Comment 7: agreed with and adjusted.

Comment 8: agreed with and corrected.

Comment 9: agreed with and corrected/updated.

Comment 10: agreed with and updated.

Comment 11: agreed with and fixed.

Comment 12: agree that the figure needs a scale-bar. However, we believe it is no need to specify that “Intra-Permian” in (a) and “Mid-Carboniferous” in (b) refer to the hanging-wall of the TFFC and MFC since we already mention “in the southwesternmost Nordkapp basin” for both (a) and (b). We furthermore argue that changing “in the southwesternmost Nordkapp basin” into “in the hanging-wall of the TFFC and MFC” would minimize the attention of the reader to the footwall portion of the seismic cube, which is actually the most important portion of the figure showing that the inferred linkage between the TFFC and TKFZ probably does not exist.

Comment 13: the SISZ and adjacent basin-bounding fault complexes were used as base Devonian. We added an explanatory sentence to the figure caption.

Comment 14: agreed with and updated with appropriate references, apart from page 9, line 250 where we believe sufficient figure references were used to highlight specific structures.

Comment 15: agreed with and changed.

Comment 16: agreed with the lack of consistency. The term Senja Shear Zone shall not be used. Instead, we now consistently use "Senja Shear Belt" for the onshore Precambrian belt and "Senja Fracture Zone" for the offshore prolongation of the Senja Shear Belt. Page 19, line 576, "basement highs" should be changed for more consistency.

Response to comments from Dr. Phillips

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 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 and changed.

Comment 26: agreed with.

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

3. Changes implemented

Changes based on comments from Dr. Roberts

Comment 1: line 111, "Archaean" becomes "Archean".

Comment 2: lines 25, 27, 41, 42-43, 71, 1102. 1296 and 1706, "Trollfjord-Komagelv" was changed into "Trollfjorden-Komagelva".

Comment 3: location of "TKFZ" acronym changed to the Varanger Peninsula.

Comment 4: in figure 1, "Norkapp Basin" becomes "Nordkapp Basin".

Comment 5: the sentence erroneously referring to the "Tanafjord-Varangerfjord Group" was modified as follow: "A thin cover of Neoproterozoic to Cambrian (para-) autochthonous metasedimentary rocks occurs on top of Paleoproterozoic basement rocks in Finnmark (Siedlecki, 1980; Ramsay et al., 1985; Andresen et al. 2014; Corfu et al., 2014). Other Neoproterozoic-Ordovician units in eastern Finnmark include metasedimentary rocks of the Barents Sea and Tanafjorden-Varangerfjorden regions (Siedlecki, 1980; Siedlecka & Roberts, 1992) which are exposed on the Varanger Peninsula (Figure 1)."

Comment 6: cf. comment 5 for implemented changes.

Comment 7: the sentence referring to the hypothesis of Kirkland et al. (2008) and addressing a potential exotic origin of the Kalak Nappe Complex was updated as follow: "The Kalak Nappe Complex was previously considered to represent an exotic terrane accreted on the Laurentian margin of Rodinia prior to the rifting of the Iapetus Ocean, and to have later been thrusted over Baltica during the Caledonian Orogeny (Kirkland et al., 2008). However, paleocurrent and geochronological data suggest these rocks to be of Baltican origin (Roberts, 2007; Zhang et al., 2016)." In addition, the two references were added to the reference list.

Comment 8: no changes.

Changes based on comments from Dr. Marin

Comment 1: we highlight the regional impact of our contribution on Arctic regions as follow: "The goal of this paper is to contribute to the understanding of tectonic and sedimentary processes in the Arctic in the Late Devonian-Carboniferous. To achieve this, we demonstrate the presence of an overall NE-SW trending, NW-dipping, basement-seated, low-angle shear zone on the Finnmark Platform, the Sørøya-Ingøya shear zone (SISZ; Figure 1), and to discuss its role played in shaping the SW Barents Sea margin during late/post-orogenic collapse of the Caledonides in late Paleozoic times and its influence on the formation and evolution of Devonian-Carboniferous collapse basins."

Comment 2:

-Avoid repetitions: deletion of the following sentence: "This basin was named the "easternmost Hammerfest basin" by Omosanya et al. (2015). We find this name inappropriate and tentatively rename this basin the "southwesternmost Nordkapp basin", as argued for later in the text".

-Geological setting: addition of a stratigraphic chart for the study area. Deletion of lines 152-153, 158-160, 212-217, 351-353, 384, 392-397 and 410-415. In addition, we proceeded to partial shortening of the results and discussion chapter as follow: deletion of lines 520-521, 645-647, 971, 1109-1112, 1178-1179 and 1245-1247.

-Section 5.6: no changes.

Comment 3: the following sentence from the methods chapter was updated to "The present study uses ties to wells 7120/12-4, 7128/4-1 and 7128/6-1 and 7124/3-1 based on publicly available well data (www.npd.no) and private well-tie seismograms". Well-tie seismogram used in the present study are private data and cannot be published. We hope the explanatory sentence is satisfactory as it is now.

Comment 4: addition of a simplified stratigraphic chart of late Paleozoic successions and restricted use of the term "sequence".

Comment 5: no changes.

Comment 6: the final paragraph of section 5.5 was largely modified and now includes the geometrical similarities of faults on the Veslemøy High and fault segments of the TKFZ: "However, if the TKFZ ever extended westwards, portions of its western prolongation might be preserved in offshore basement highs such as the Loppa and Veslemøy highs (Figure 1). More work is needed on this hypothesis, but a possible insight is the recent observation of subvertical, WNW-ESE trending brittle faults analog to the TKFZ in basement rocks of the Veslemøy High (Kairanov et al., 2016)".

Comment 7: bold fonts in figure 1 now correspond to the most important faults and basins dealt with in the present contribution. Font size of BSFC and BKFC are now the same as other structural elements.

Comment 8: bold fonts now highlight the main faults and basins dealt with in the paper.

Comment 9: addition of an arrow pointing northwards, a color-scale from the original publication, of a scale bar and of an explanatory sentence regarding dashed red lines (from the original publication; Gernigon et al. 2014) in the figure caption: "Dashed red lines represent faults inferred by Gernigon et al. (2014)."

Comment 10: seismic sections of figure 5 were split to enlarge them and horizontal scale were added. In addition, uninterpreted versions of the sections will be submitted as supplements.

Comment 11: order of figures changed as suggested and addition of a scale-bar in (a).

Comment 12: scale-bar added to the figure and decapitalizing of "Intra-Permian", which becomes "intra-Permian".

Comment 13: added explanatory sentence: "Note that in this part of the margin, the SISZ and basin-bounding faults were used as base Devonian reflections." In addition, the three maps were enlarged as suggested.

Comment 14: page 3, line 69, we added a reference to figure 1. Page 9, line 250, nothing was changed. Page 10, line 301, a reference to figure 1 was added. Page 38, line 1159, reference to figure 1 and Koehl et al. (submitted) were added.

Comment 15: Page 3, lines 67–73, the sentence was shortened into “The SW Barents Sea margin off Western Troms and NW Finnmark is segmented by margin-oblique, NNW-SSE to WNW-ESE trending transfer fault zones, e.g. Senja Fracture Zone and Fugløya transfer zone (Indrevær et al., 2013), which may represent analogs of the onshore, Neoproterozoic, WNW-ESE trending Trollfjorden-Komagelva Fault Zone (TKFZ) in eastern Finnmark (Siedlecki, 1980; Herrevold et al., 2009) and to the Kokelv Fault on the Porsanger Peninsula (Figure 1; Gayer et al., 1985; Lippard & Roberts, 1987; Rice, 2013)” and the following sentence was added later in the same paragraph: “Onshore-nearshore, margin-parallel fault complexes include the Langfjord-Vargsund fault (LVF; Figure 1) trending NE-SW and possibly representing an analog to the TFFC and MFC”. Page 12, lines 360–364, the sentence was split into two as follow: “Devonian sedimentary rocks are yet to be reported in North Norway and along the SW Barents Sea margin. However, Devonian sedimentary deposits are present in western Norway (Osmundsen & Andersen, 2001) where they represent a several km-thick succession made up with clastic deposits that notably include rhythmic sandstone and coarse-grained conglomerate units. These were deposited in the hanging-wall of a major, low-angle extensional shear zone, the Nordfjord-Sogn Detachment Zone (Séranne et al., 1989; Wilks & Cuthbert, 1994; Osmundsen & Andersen, 2001)”. Pages 16–17, lines 490–498, the sentence was shortened and split as follow: “On the Finnmark Platform (Figure 1 & 2), the base of upper Carboniferous sedimentary sequences is difficult to identify (cf. “mid-Carboniferous” reflection in figure 5). In places, it appears as a linear, moderate to low amplitude seismic reflection that separates subparallel reflections of lower and upper Carboniferous sedimentary rocks, whereas in other places this reflection is irregular and truncates high-amplitude coal-bearing sedimentary deposits of the Billefjorden Group, and/or high-amplitude reflections produced by basement rocks (figure 6a), and/or low-amplitude reflections in Devonian sedimentary strata (figure 6b & c)”.

Comment 16: minor changes include lines 69-70 where “Senja Shear Zone” becomes “Senja Fracture Zone”, figure 1 where “SSZ” becomes “SFZ” and line 1705 where “SSB = Sørøy sub-basin” becomes “Senja Shear Belt” and “SFZ = Senja Fracture Zone” was added. In addition, page 19 line 576, “basement highs” was changed into “basement ridges”.

Changes based on comments from Dr. Phillips

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, 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 (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-Rybachi 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.

Mid/Late Devonian-Carboniferous collapse basins on the Finnmark Platform and in the southwesternmost Nordkapp basin, SW Barents Sea

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Abstract. The SW Barents Sea margin experienced a pulse of extensional deformation in the Middle-Late Devonian through the Carboniferous, after the Caledonian Orogeny terminated. These events marked the initial stages of formation of major offshore basins such as the Hammerfest and Nordkapp basins. We mapped and analyzed three major fault complexes, i) the Måsøy Fault Complex, ii) the Rolvsøya fault, iii) the Troms-Finnmark Fault Complex. We discuss the formation of the Måsøy Fault Complex as a possible extensional splay of an overall NE-SW trending, NW-dipping, basement-seated Caledonian shear zone, the Sørøya-Ingøya shear zone, which was partly inverted during the collapse of the Caledonides and accommodated top-to-the-NW normal displacement in Mid/Late Devonian-Carboniferous times. The Troms-Finnmark Fault Complex displays a zigzag-shaped pattern of NNE-SSW and ENE-WSW trending extensional faults before it terminates to the north as a WNW-ESE trending, NE-dipping normal fault that separates the southwesternmost Nordkapp basin in the northeast from the Finnmark Platform west and the Gjesvær Low in the southwest. The WNW-ESE trending, margin-oblique segment of the Troms-Finnmark Fault Complex is considered to represent the offshore prolongation of a major Neoproterozoic fault complex, the Trollfjorden-Komagelva Fault Zone, which is made of WNW-ESE trending, subvertical faults that crop out on the island of Magerøya in NW Finnmark. Our results suggest that the Trollfjorden-Komagelva Fault Zone dies out to the northwest before reaching the Finnmark Platform west. We propose an alternative model for the origin of the WNW-ESE trending fault segment of the Troms-Finnmark Fault Complex as a possible hard-linked, accommodation cross-fault that developed along the Sørøy-Ingøya shear zone. This brittle fault

decoupled the Finnmark Platform west from the southwesternmost Nordkapp basin and merged with the Måsøy Fault Complex in Carboniferous times. Seismic data over the Gjesvær Low and southwesternmost Nordkapp basin show that the low-gravity anomaly observed in these areas may result from the presence of Mid/Late Devonian sedimentary units resembling Middle Devonian, spoon-shaped, late/post-orogenic collapse basins in western and mid Norway. We propose a model for the formation of the southwesternmost Nordkapp basin and its counterpart Devonian basin in the Gjesvær Low by exhumation of narrow, ENE-WSW to NE-SW trending basement ridges along a bowed portion of the Sørøya-Ingøya shear zone in the Mid/Late Devonian-early Carboniferous. Exhumation may have involved part of a large-scale metamorphic core complex that potentially included the Lofoten Ridge, the West Troms Basement Complex and the Norsel High. Finally, we argue that the Sørøya-Ingøya shear zone truncated and decapitated the Trollfjorden-Komagelva Fault Zone during the Caledonian Orogeny and that the western continuation of the Trollfjorden-Komagelva Fault Zone was mostly eroded and potentially partly preserved in basement highs in the SW Barents Sea.

1. Introduction

The SW Barents Sea margin is located near the Iapetus suture zone that formed when Laurentia collided with Fennoscandia to produce the Caledonian Orogeny (Ramberg et al., 2008; Gernigon et al., 2014). This suture and possib~~le,~~ly related deep-seated shear zones, which accommodat~~ing~~ed 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. These repeated extension events led to the breakup of the North Atlantic Ocean and formation of a transform plate margin at the boundary between the Mid-Norwegian and SW Barents Sea margins (Faleide et al., 1993, 2008; Blystad et al., 1995; Doré et al., 1997; Bergh et al., 2007; Hansen et al., 2012; Gernigon et al., 2014). The rift-margin along the SW Barents Sea, offshore Western Troms and NW Finnmark (Figure 1~~Figure 1Figure 1~~), consists of the Finnmark Platform and an adjacent, glacial sediment-free strandflat, and of deep offshore basins such as the Hammerfest and Nordkapp basins (Gabrielsen et al., 1990). These basins are bounded by major NE-SW trending extensional faults such as the Troms-Finnmark Fault Complex (TFFC; Gabrielsen et al., 1990; Smelror et al., 2009; Indrevær et al., 2013), the Måsøy Fault Complex (MFC; Gabrielsen et al., 1990; Gudlaugsson et al., 1998), and potential basement-seated ductile

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detachments (Figure 1). The study area also includes a deep Paleozoic basin that is located southwest of the Nordkapp Basin and east of the Hammerfest Basin, and which is bounded to the southwest by the WNW-ESE trending segment of the TFFC and to the southeast by the MFC (Figure 1~~Figure 1Figure 1~~).~~ This basin was named the "easternmost Hammerfest basin" by Omosanya et al. (2015). We find this name inappropriate and tentatively rename this basin the "southwesternmost Nordkapp basin", as argued for later in the text.~~

~~In addition, t~~The SW Barents Sea margin off Western Troms and NW Finnmark is segmented by margin-oblique, NNW-SSE to WNW-ESE trending transfer fault zones, e.g. Senja Fracture ~~Shear~~ Zone and Fugløya transfer zone (Indrevær et al., 2013), which ~~are both sub-parallel~~may represent analogs of ~~to~~ the onshore, Neoproterozoic, WNW-ESE trending Trollfjorden-Komagelva Fault Zone (TKFZ) in eastern Finnmark (Siedlecki, 1980; Herrevold et al., 2009) and to the Kokelv Fault on the Porsanger Peninsula (Figure 1~~Figure 1Figure 1~~; Gayer et al., 1985; Lippard & Roberts, 1987; Rice, 2013)~~ while the coastal Langfjord-Vargsund fault (LVF) trends NE-SW, parallel to the TFFC (Figure 1)~~. The TKFZ is believed to continue farther west, off the coast, where it is thought to interact with and merge into the WNW-ESE trending fault segment of the TFFC (Gabrielsen, 1984; Vorren et al., 1986; Towsend, 1987; Gabrielsen & Færseth, 1989; Gabrielsen et al., 1990; Roberts et al., 2011; Bergø, 2015; Lea, 2015). Onshore-nearshore, margin-parallel fault complexes include the Langfjord-Vargsund fault (LVF; Figure 1) trending NE-SW and possibly representing an analog to the TFFC and MFC. The geometric interaction, timing and controlling effects of the TFFC, MFC, TKFZ and LVF, and adjacent offshore basins and ridges are not yet resolved. In particular, the presence of potential Caledonian structures in the deeper portion of the Finnmark Platform, e.g. in the footwall of the TFFC (cf. Johansen et al., 1994; Gudlaugsson et al., 1998) is further explored in the present contribution.

The goal of this paper is to contribute to the understanding of tectonic and sedimentary processes in the Arctic in the Late Devonian-Carboniferous. To achieve this, we demonstrate the presence of an overall NE-SW trending, NW-dipping, basement-seated, low-angle shear zone on the Finnmark Platform, the Sørøya-Ingøya shear zone (SISZ; Figure 1~~Figure 1Figure 1~~), and to discuss its role played in shaping the SW Barents Sea margin during late/post-orogenic collapse of the Caledonides in late Paleozoic times and its influence on the formation and evolution of Devonian-Carboniferous collapse basins. We mapped and analyzed basin-bounding brittle faults on the Finnmark Platform and in the southwesternmost Nordkapp basin (named the easternmost

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Hammerfest basin in Omosanya et al., 2015), such as the TFFC and the MFC (Figure 1~~Figure 1Figure 1~~), to evaluate the impact of the SISZ on post-Caledonian brittle faults. We aim at showing the importance of structural inheritance by examining the relationship between Precambrian-Caledonian structural grains, post-Caledonian fault trends and offshore sedimentary basin geometries. Minor Carboniferous grabens and half-grabens on the Finnmark Platform (e.g. the Sørvær Basin; Figure 1~~Figure 1Figure 1~~), which are thought to have formed during early stages of extension shortly after the end of the Caledonian Orogeny (Lippard & Roberts, 1987; Olesen et al., 1990; Johansen et al., 1994; Bugge et al., 1995; Gudlaugsson et al., 1998; Roberts et al., 2011), are of particular importance to the present work. We further investigate the presence of possible Devonian sedimentary deposits on the Finnmark Platform and in the southwesternmost Nordkapp basin and tentatively interpret them as potential analogs to Middle Devonian basins in western Norway (Séranne et al., 1989; Chauvet & Séranne, 1994; Osmundsen & Andresen, 2001) and mid-Norway (Braathen et al., 2000). In this context, NE-SW to ENE-WSW trending basement ridges in the footwall of the TFFC and on the northern flank of the southwesternmost Nordkapp basin are described and analyzed, and we compare them to adjacent basement highs such as the Norsel High (Figure 1~~Figure 1Figure 1~~; Gabrielsen et al., 1990; Gudlaugsson et al., 1998), the West Troms Basement Complex (Zwaan, 1995; Bergh et al., 2010) and the Lofoten Ridge (Blystad et al., 1995; Bergh et al., 2007; Hansen et al., 2012). Finally, we propose a model of exhumation of these ENE-WSW to NE-SW trending basement ridges as a metamorphic core complex (cf. Lister & Davis, 1989) using shear zones in Lofoten-Vesterålen as onshore analogs for the SISZ (Steltenpohl et al., 2004; Osmundsen et al., 2005; Steltenpohl et al., 2011).

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2. Geological setting

The bedrock geology of the SW Barents Sea margin (Figure 1~~Figure 1Figure 1~~) consists of (i) an Arch~~a~~ean to Paleoproterozoic basement suite, the West Troms Basement Complex (Zwaan, 1995; Bergh et al., 2010), (ii) locally preserved autochthonous Neoproterozoic cover sequences (Kirkland et al., 2008), (iii) a series of Caledonian thrust nappes (Andersen, 1981; Ramsay et al., 1985; Corfu et al., 2014), and (iv) late Paleozoic to Cenozoic sedimentary sequences offshore (Faleide et al., 1993, 2008; Gudlaugsson et al., 1998; Worsley, 2008; Smelror et al., 2009; Figure 1~~Figure 1Figure 1~~). Archean to Paleoproterozoic basement rocks are mostly exposed in major horsts and ridges in Western Troms (Bergh et al., 2010; Indrevær et al., 2013; Indrevær & Bergh,

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2014), whereas Neoproterozoic and Caledonian rocks dominate in the eastern part of Troms and in NW Finnmark (Kirkland et al., 2008; Corfu et al., 2014; Indrevær & Bergh, 2014; Figure 1~~Figure 1Figure 1~~). In offshore areas adjacent to Western Troms and NW Finnmark, extensive post-Caledonian normal faulting led to the formation of large sedimentary basins that are filled with thick, late Paleozoic to Cenozoic deposits related to the post-orogenic collapse of the Caledonides and to the opening of the NE Atlantic Ocean (Faleide et al., 1993, 2008; Gudlaugsson et al., 1998; Worsley, 2008; Smelror et al., 2009). Late Paleozoic-Cenozoic sedimentary units are missing in onshore areas of Troms and Finnmark likely due to erosion and/or non-deposition (Ramberg et al., 2008; Smelror et al., 2009).

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2.1. Onshore Precambrian and Caledonian geology

2.1.1. Precambrian basement rocks

The Western Troms margin is characterized by Archean to Paleoproterozoic basement rocks of the West Troms Basement Complex (Bergh et al., 2010) that are preserved and exposed in a horst block formed during post-Caledonian extension (Indrevær et al., 2013). The West Troms Basement Complex consists of tonalitic, trondhjemitic and granitic gneisses, metasupracrustal rocks and mafic and felsic igneous rocks (Corfu et al., 2003; Bergh et al., 2010). These rocks were deformed during the Svecofennian orogeny, which resulted in the formation of NW-SE trending steep foliation, ductile shear zones and upright and vertical macrofolds, only weakly reworked during the Caledonian Orogeny (Corfu et al., 2003; Bergh et al., 2010).

In NW Finnmark, Paleoproterozoic basement rocks occur in several tectonic windows of the Caledonides, e.g. Repparfjord-Komagfjord and Alta-Kvænangen tectonic windows (Zwaan & Gautier, 1980; Pharaoh et al., 1982; 1983; Bergh & Torske, 1988; Figure 1), and consist of low-grade supracrustal metavolcanics and metasedimentary rocks of the Raipas Group. These Greenstone belts formed ~~in~~ as NW-SE trending rift basins in the Archean?-Paleoproterozoic during the opening of the Kola Ocean (Bergh & Torske, 1986; 1988), although more recent studies tentatively reinterpret these rocks as foreland basin deposits derived from the Svecokarelian Orogeny (Torske & Bergh, 2004). A thin cover of Neoproterozoic to Cambrian (para-) autochthonous metasedimentary rocks occurs on top of ~~the~~ Paleoproterozoic basement rocks~~windows. This unit is correlated with the autochthonous Tanafjord-Varangerfjord Group~~ in

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~~eastern~~ Finnmark (Siedlecki, 1980; ~~), as well as with the Lower Allochthonous Gaissa and Laksefjord Nappes (~~Ramsay et al., 1985; Andresen et al. 2014; Corfu et al., 2014).

~~Another~~ Other Neoproterozoic-Ordovician units in eastern Finnmark~~,~~ include metasedimentary rocks of the Barents Sea and Tanafjorden-Varangerfjorden regions ~~Group~~ (Siedlecki, 1980; Siedlecka & Roberts, 1992)~~,~~ ~~is~~which are exposed ~~in the outer part of~~on the Varanger Peninsula (Figure 1~~Figure 1Figure 1~~). ~~The rocks of the Barents Sea Group were deposited in a large-scale foreland basin during the Timanian Orogeny (Andresen et al., 2014) and a Cryogenian depositional age was inferred from fossil-bearing assemblages (Corfu et al., 2014),.~~

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The Timanian Orogeny produced major NW-SE trending folds (Roberts & Siedlecka, 2002) and WNW-ESE trending fault complexes like the TKFZ (Jonhson et al., 1978; Herrevold et al., 2009). The TKFZ was mapped as a narrow, single-segment fault strand all the way ~~from~~ along the Kola Peninsula in Russia in the east, where it merges with the Sredni-Rybachi 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) ~~to the east of the Kola Peninsula in Russia (Roberts et al., 1997). Between these areas, the TKFZ is traced along the Kola Peninsula as the Sredni-Rybachi Fault Zone (Roberts et al., 2011)~~. 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. On the Varanger Peninsula, the TKFZ is well displayed on satellite and DEM images, but is generally poorly exposed. In map view, the TKFZ is irregular, with different structural segments and branching subsidiary faults both across- and along-strike, locally showing duplex structures (Siedlecka & Siedlecki, 1967; Siedlecka, 1975). The TKFZ formed along the southwestern boundary of the Timanian Orogeny in the late Cryogenian-Ediacaran (Roberts & Siedlecka, 2002; Siedlecka et al., 2004), and was later reactivated as a strike-slip fault during the Caledonian Orogeny when it accommodated significant lateral displacement constrained to 200-250 km of dextral strike-slip movement (Bylund, 1994; Rice, 2013).

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2.1.2. Caledonian ~~rocks~~nappes

Coastal areas of NW Finnmark are dominated by Caledonian thrust sheets of the Kalak Nappe Complex and Magerøy Nappe (Ramsay et al., 1985; Ramberg et al., 2008; Corfu et al., 2014), formed in the Neoproterozoic through Silurian (Figure 1~~Figure 1Figure 1~~). The Kalak Nappe Complex is composed of amphibolite facies schists, metapsammites and paragneisses, and

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comprises several allochthonous thrust sheets with Proterozoic basement rocks, clastic metasedimentary rocks, and plutonic rocks of the Seiland Igneous Province (Corfu et al., 2014). A major thrust defines the contact with the underlying pre-Caledonian basement (Ramsey et al., 1985). Dominant structures include a gently NW-dipping foliation, NNE-SSW trending, east-verging, asymmetrical recumbent folds and low-angle thrusts that accommodated top-to-the-ESE shortening (Townsend, 1987a; Kirkland et al., 2005). The Kalak Nappe Complex was previously considered to represent ~~likely corresponds to~~ an exotic terrane ~~that was~~ accreted on the Laurentian margin of Rodinia~~,~~ prior to the rifting ~~linked to the opening~~ of the Iapetus Ocean, and to have later been thrusted over Baltica during the Caledonian Orogeny (Kirkland et al., 2008). However, paleocurrent and geochronological data suggest these rocks to be of Baltican origin (Roberts, 2007; Zhang et al., 2016).

The Seiland Igneous Province corresponds to a large, late Neoproterozoic mafic and ultramafic intrusion linked to the early-mid rifting stages of the Iapetus Ocean (Elvevold et al., 1994; Corfu et al., 2014). Recent geophysical studies by Pastore et al. (2016) show that the base of the Seiland Igneous Province defines two deep-reaching roots located below the islands of Seiland and Sørøya constraining the thickness of the Kalak Nappe Complex in this area to a maximum of 10 km. On the Porsanger and Varanger Peninsula, ENE-WSW to NNE-SSW trending, Ediacaran metadolerite dyke swarms are particularly common, and they are as well associated to the rifting of the Iapetus Ocean (cf. Roberts, 1972; Siedlecka et al., 2004; Nasuti et al., 2015).

The Kalak Nappe Complex is structurally overlain by the Magerøy Nappe, which consists of Late Ordovician to early Silurian greenschist facies metasedimentary and metaplutonic rocks (Andersen, 1981; 1984; Corfu et al., 2014) that crop out on the island of Magerøya (Figure 1~~Figure 1Figure 1~~). The Magerøy Nappe is characterized by asymmetrical, NNE-SSW trending, east-verging folds and low-angle, NW- and SE-dipping thrusts similar in trend to those observed within the Kalak Nappe Complex (Andersen, 1981), and is intruded by granitic and gabbroic plutons, e.g. the Silurian Honningsvåg Igneous Complex (Corfu et al., 2006) and the Finnvik Granite (Andersen, 1981). Remnants of the Magerøy Nappe thrust units are also found in northeastern Sørøya and on the Porsanger Peninsula (Kirkland et al., 2005; 2007; Corfu et al., 2014; Figure 1~~Figure 1Figure 1~~).

~~In nearshore areas of NW Finnmark, along the coasts of Sørøya and Ingøya, we identified on seismic sections a large NE-SW trending, dominantly NW-dipping zone of weakness below~~

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~~post-Caledonian basin and faults that we tentatively interpret as a major Caledonian shear zone, which we name the Sørøya-Ingøya shear zone (Figure 1). This large weakness zone has not been described in scientific literature and we therefore proceed by describing its geometry and potential kinematics based on offshore seismic data.~~

2.2. Post-Caledonian brittle faults and basins

2.2.1. Post-Caledonian offshore basins

The SW Barents Sea margin was subjected to multiple episodes of extensional faulting after the end of the Caledonian Orogeny, starting with the collapse of the Caledonides in the Mid/Late Devonian-early Carboniferous, ~~and~~ lasting until the early/mid Permian, although evidence of this stage is only preserved onshore western and mid-Norway (Séranne et al., 1989; Chauvet & Séranne, 1994; Braathen et al., 2000; Osmundsen & Andresen, 2001). During this period, basement ridges in Lofoten-Vesterålen (Klein & Steltenpohl, 1999; Klein et al., 1999; Steltenpohl et al., 2004; 2011; Figure 1) and in mid-Norway (Osmundsen et al., 2005; Figure 1) were exhumed as metamorphic core complexes, synchronously with the development of large half-graben basins such as the Vøring and Møre basins in mid-Norway (Blystad et al., 1995) and the Hammerfest, Nordkapp and Ottar basins in the SW Barents Sea (Gabrielsen et al., 1990; Breivik et al., 1995; Gudlaugsson et al., 1998; Indrevær et al., 2013; Figure 1~~Figure 1Figure 1~~). The main rifting events occurred in the Late Jurassic and peaked in the Early Cretaceous, when major offshore basins such as the Tromsø and Harstad basins formed. The rifting ended with full breakup of the North Atlantic Ocean and formation of a transform plate margin in the SW Barents Sea at the Paleocene-Eocene transition (Faleide et al., 1993; 2008).

Off the coasts of Western Troms and NW Finnmark, the SW Barents Sea margin is characterized by a relatively shallow area, the Finnmark Platform (Gabrielsen et al., 1990; Figure 1~~Figure 1Figure 1~~), which is thought to have remained relatively stable since late Paleozoic times. For example, the inner part of the Finnmark Platform, here referred to as the Finnmark Platform east (Figure 1~~Figure 1Figure 1~~), was only affected by the formation of minor Carboniferous, ENE-WSW to NE-SW trending half-graben and graben structures (Bugge et al., 1995; Samuelsberg et al., 2003; Rafaelsen et al., 2008; Figure 1~~Figure 1Figure 1~~). In the hanging-wall of the MFC on the western part of the Finnmark Platform, the Finnmark Platform west (Figure 1~~Figure 1Figure 1~~),

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shows a prominent gravity low, the Gjesvær Low, which was ascribed to the presence of low-density Caledonian rocks (Johansen et al., 1994; Gernigon et al., 2014). We explore and argue for an alternative explanation, i.e. the presence of Devonian collapse basin deposits draped against a low-angle extensional detachment of the SISZ, similar to the Nordfjord-Sogn Detachment Zone, a late-orogenic shear zone that bounds the Middle Devonian Hornelen, Kvamshesten and Solund sedimentary basins onshore western Norway (Séranne et al., 1989; Chauvet & Séranne, 1994; Wilks & Cuthbert, 1994; Osmundsen & Andersen, 2001). Ductile detachment surfaces of comparable size, showing analog kinematics and contemporaneous timing of activity as the Nordfjord-Sogn Detachment Zone are documented as far north as the Lofoten-Vesterålen Margin (Klein & Steltenpohl, 1999; Klein et al., 1999; Steltenpohl et al., 2004; 2011), but Devonian collapse basin sedimentary rocks and extensional detachments have not yet been reported along the margins of Western Troms and NW Finnmark.

2.2.2. Post-Caledonian faults~~ and fractures trends~~

Multiple studies have reported post-Caledonian brittle faults onshore coastal areas in Lofoten-Vesterålen, Western Troms and NW Finnmark (Roberts, 1971; Worthing, 1984; Lippard & Roberts, 1987; Townsend, 1987a; Rykkelid, 1992; Lippard & Prestvik, 1997; Roberts & Lippard, 2005; Bergh et al., 2007; Hansen et al., 2012; Indrevær et al., 2013; Davids et al., 2013). A common feature is the presence of rhombic, zigzag-shaped fault trends similar in geometry to offshore basin-bounding faults. Dominant fault-fracture trends of the margin strike NNE-SSW, ENE-WSW and NW-SE, respectively (Bergh et al., 2007; Eig, 2008; Eig & Bergh, 2011; Hansen et al., 2012; Hansen & Bergh, 2012; Indrevær et al., 2013). Typical examples are basin-bounding, NNE-SSW and ENE-WSW trending brittle normal faults that are part of the Vestfjorden-Vanna Fault Complex, which bounds the offshore Vestfjorden Basin southeast of the Lofoten islands and which can be traced northward to Western Troms (Indrevær et al., 2013; Figure 1~~Figure 1Figure 1~~), whereas the NNW-SSE to WNW-ESE trend typically reflects ~~the~~ margin-oblique, transform fault trends (Faleide et al., 2008). An analog to the onshore Vestfjord-Vanna f~~F~~ault c~~C~~omplex in NW Finnmark is the Langfjorden-Vargsundet fault (Figure 1~~Figure 1Figure 1~~), described by Zwaan & Roberts (1978) and Worthing (1984) as a major NE-SW trending, NW-dipping normal fault where rocks from the Kalak Nappe Complex and the Seiland Igneous Province in the

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northwest are juxtaposed against Precambrian basement rocks of the Repparfjord-Komagfjord and Alta-Kvænangen tectonic windows in the southeast (Figure 1~~Figure 1Figure 1~~).

The NW Finnmark margin is located along the northeastward prolongation of the Lofoten-Vesterålen and Western Troms segments of the Norwegian continental shelf (Figure 1~~Figure 1Figure 1~~). Similar fault sets and trends as in Lofoten-Vesterålen exist in Finnmark and their interaction is thought to partly have controlled the rhombic geometry of many offshore sedimentary basins (Bergh et al., 2007; Indrevær et al., 2013). A typical example along the Western Troms and NW Finnmark margins is the NW-dipping TFFC, which bounds the Harstad Basin to the east and the Hammerfest Basin to the southeast (Gabrielsen et al., 1990; Indrevær et al., 2013). The TFFC defines a system of irregular branching faults trending NNE-SSW and ENE-WSW and terminating as a WNW-ESE trending fault zone northwest of the island of Magerøya where it merges with the NE-SW trending, NW-dipping MFC at the southeastern boundary of the Nordkapp Basin (Gabrielsen et al., 1990) and of the triangular-shaped southwesternmost Nordkapp basin (Omosanya et al., 2015; Figure 1~~Figure 1Figure 1~~). We address a possible genetic relationship and structural inheritance of the post-Caledonian MFC with the Caledonian SISZ and argue that the MFC may have initiated as an extensional splay during the reactivation of the SISZ as an extensional detachment during the late/post-orogenic collapse of the Caledonides. Furthermore, we tentatively link basement ridges such as the Norsel High in the footwall of the Nysleppen Fault Complex (Gabrielsen et al., 1990) to bowed segments of the SISZ (Figure 1~~Figure 1Figure 1~~).

2.2.3. Post-Caledonian transfer zones

The Norwegian continental shelf is segmented by transfer fault zones of which the largest is the offshore De Geer Zone (Faleide et al., 1984; 2008; Cianfarra & Salvini, 2015), which main fault segment is the Hornsund Fault Zone, an offshore NNW-SSE trending fault that runs parallel to the west coast of Spitsbergen and separates the SW Barents Sea margin from the Lofoten-Vesterålen Margin (Figure 1~~Figure 1Figure 1~~). In the south, the De Geer Zone proceeds through the Senja Fracture Zone and into the Senja Shear Belt onshore the island of Senja (Figure 1~~Figure 1Figure 1~~). Olesen et al. (1993; 1997) suggested shifts of polarity of the Vestfjorden-Vanna Fault Complex along the Senja Fracture Zone, and they argued that the formation of the Senja Fracture Zone offshore was controlled by a major onshore basement weakness zone, the Bothnian-Senja Fault Complex (Figure 1), which provided suitably oriented basement heterogeneities for the

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development of a transfer zone (e.g. Doré et al., 1997). Similarly, Indrevær et al. (2013) proposed the existence of a fault array termed the Fugløya transfer zone to explain offsets and shifts of polarity along the Vestfjorden-Vanna Fault Complex farther northeast in WesternTroms (Figure 1). The Fugløya transfer zone trends N-S/NNW-SSE and continues onshore Western Troms, where it merges with the NW-SE trending Bothnian-Kvænangen Fault Complex, and offshore where it is thought to merge into the TFFC and the Ringvassøy-Loppa Fault Complex (Indrevær et al., 2013; Figure 1~~Figure 1Figure 1~~).

Analogously in NW Finnmark, the WNW-ESE trending TKFZ seems to merge into a basin-bounding fault, in this case the WNW-ESE trending, NE-dipping fault segment of the TFFC (Gabrielsen, 1984; Gabrielsen & Færseth, 1989; Roberts et al., 2011). In nearshore areas of NW Finnmark, the TKFZ is thought to proceed offshore and seems to correlate with a large escarpment north of Magerøya and into the Barents Sea (Vorren et al., 1986; Townsend, 1987b). In the area where it terminates, it merges and links up with the TFFC to form triangular-shaped mini-basins (Gabrielsen, 1984; Gabrielsen & Færseth, 1989; Roberts et al., 2011). We explore an alternative origin for the WNW-ESE trending fault segment of the TFFC and further examine its interaction with the onshore-nearshore TKFZ, which potentially acted as a transfer fault after the Caledonian Orogeny and contributed to offset the LVF onshore Magerøya and in adjacent coastal areas (Koehl et al., submitted; Figure 1~~Figure 1Figure 1~~). Other major WNW-ESE trending faults exist offshore, northeast of the Varanger Peninsula, and these bound the Tiddlybanken Basin, a large WNW-ESE trending basin that formed in Carboniferous times (Mattingsdal et al., 2015; Figure 1~~Figure 1Figure 1~~).

2.2.4. Absolute age dating of post-Caledonian faultings

The absolute age of post-Caledonian brittle faults onshore NW Finnmark is poorly constrained although a few contributions provide valid insights (Lippard & Prestvik, 1997; Davids et al., 2013; Torgersen et al., 2014; Koehl et al., 2016). Torgersen et al. (2014) performed K/Ar dating of brittle fault gouge in the footwall of the LVF and obtained dominantly Carboniferous to early Permian ages, as well as a subsidiary Early Cretaceous age for one of the faults. 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

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this fault. These dykes produce high positive aeromagnetic anomalies (Nasuti et al., 2015) and may be used to further identify brittle faults in NW Finnmark. Late Devonian dolerite dykes emplaced along brittle faults that trend NE-SW and N-S have been identified and dated in eastern Varanger Peninsula (Guise & Roberts, 2002) and on the Kola Peninsula (Roberts & Onstott, 1995). By comparison, Davids et al. (2013) obtained Late Devonian-early Carboniferous ages from K/Ar dating of illite clay minerals for early extensional faulting along the Vestfjorden-Vanna Fault Complex and related faults in Lofoten-Vesterålen and Western Troms.

2.3. Offshore sedimentary successions and well-ties

Deep fault-bounded basins formed along the SW Barents Sea margin during successive extension events in late Paleozoic-early Cenozoic times, and~~–~~ these basins contain important sedimentary successions for hydrocarbon exploration. We particularly focus on the late Paleozoic succession (Figure 3~~Figure 3~~) which sedimentary rocks were deposited on top of eroded Precambrian and Caledonian basement rocks (cf. Townsend, 1987a; Johansen et al., 1994; Bugge et al., 1995; Zwaan, 1995; Gudlaugsson et al., 1998; Samuelsberg et al., 2003; Bergh et al., 2010). Late Paleozoic sedimentary deposits in the study area were penetrated by only a few exploration wells to which we tied our seismic interpretation (Figure 2)~~. These wells include exploration wells 7120/12-4, 7124/3-1, 7128/4-1 and 7128/6-1, and shallow drill-cores 7127/10-U-2 and 7127/10-U-3 from Bugge et al. (1995; Figure 2)~~. Overlying Mesozoic to Cenozoic sedimentary units were not investigated and are better described in Omosanya et al. (2015).

The nature and age of basement rocks along the SW Barents Sea margin remain relatively complex to resolve since only a handful of wells drilled through the thick post-Caledonian sedimentary cover. Nevertheless, wells 7128/4-1 and 7128/6-1 penetrated quartzitic metasedimentary rocks on the Finnmark Platform east (Figure 2~~Figure 2Figure 2~~) and these are believed to correlate with upper Proterozoic rocks involved in Caledonian thrusting in northern Finnmark (Røe & Roberts, 1992).

Devonian sedimentary rocks are yet to be reported in North Norway and along the SW Barents Sea margin (Figure 3~~Figure 3~~). However, Devonian sedimentary deposits ~~however~~ are present in western Norway (Osmundsen & Andersen, 2001) where they represent a several km-thick succession made up with clastic deposits that notably include rhythmic sandstone and coarse-

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grained conglomerate units. These ~~that~~ were deposited in the hanging-wall of~~ a~~ major, low-angle extensional shear zones, e.g. the Nordfjord-Sogn Detachment Zone (Séranne et al., 1989; Wilks & Cuthbert, 1994; Osmundsen & Andersen, 2001).

Lower Carboniferous sedimentary rocks of the Billefjorden Group directly overlie basement rocks on the Finnmark Platform east ~~-~~as evidenced by exploration wells 7128/4-1 and 7128/6-1 (Larssen et al., 2002; Figure 2~~Figure 2Figure 2~~ & Figure 3~~Figure 3~~). These rocks mostly correspond to fluvial clastic deposits interbeded with coal-bearing sedimentary rocks that correlate with contemporaneous deposits onshore Bjørnøya (Cutbill & Challinor, 1965; Gjelberg, 1981, 1984) and Spitsbergen (Cutbill & Challinor, 1965; Cutbill et al., 1976; Gjelberg, 1984). The total thickness of Billefjorden Group sedimentary deposits evidenced by exploration wells on horst-blocks on the Finnmark Platform east ranges from 350 m to 450 m. However, in the hanging-wall of a minor normal fault interpreted by Bugge et al. (1995) near the coast of northern Finnmark (Figure 2~~Figure 2Figure 2~~), shallow drill-cores 7127/10-U-2 and 7127/10-U-3 indicate that the thickness of lower Carboniferous sedimentary rocks reaches a thickness > 600 m within a NE-SW trending mini-basin on the Finnmark Platform east near the coast of the Nordkinn Peninsula (cf. star symbol in Figure 1~~Figure 1Figure 1~~ & Figure 2~~Figure 2Figure 2~~). In the Serpukhovian, fluvial sediments of the Billefjorden Group were gradually replaced by shallow marine sediments of the Gipsdalen Group from which they are generally separated by a mid-Carboniferous (Serpukhovian) unconformity (Cutbill et al., 1976; Gjelberg, 1984; Bugge et al., 1995) potentially related to a global sea-level fall (Saunders & Ramsbottom, 1986).~~ This unconformity was recognized on the Finnmark Platform east by Bugge et al. (1995).~~

Shallow marine sedimentary deposits of the Gipsdalen Group are widespread along the SW Barents Sea margin and have proven prolific for hydrocarbon exploration (Larssen et al., 2002; Figure 3~~Figure 3~~). Thus, this sedimentary succession benefits from a relatively high number of well penetrations and, as a result, its lateral facies and ~~lateral~~ thickness variations are well-constrained (Gjelberg & Steel, 1981, 1983; Samuelsberg et al., 2003; Rafaelsen et al., 2008). The Gipsdalen Group was notably penetrated by wells 7128/4-1 and 7128/6-1 on the Finnmark Platform east, by well 7120/12-4 on the Finnmark Platform west and by well 7124/3-1 on the northern flank of southwesternmost Nordkapp basin (Larssen et al., 2002; Figure 2~~Figure 2Figure 2~~). ~~Sedimentary strata of the Gipsdalen Group were tied to their stratigraphic equivalent onshore Bjørnøya and Spitsbergen (Gjelberg & Steel, 1981, 1983; Gjelberg, 1984; McCann & Dallmann, 1996).~~ This

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succession consists of alluvial clastic sedimentary rocks ~~deposited on top of lower Carboniferous sedimentary deposits of the Billefjorden Group (McCann & Dallmann, 1996). In the upper part of the Gipsdalen Group, alluvial clastic sedimentary rocks~~ that are progressively replaced upwards by shallow marine platform carbonates interbedded with clastic and evaporite deposits (McCann & Dallmann, 1996). In well 7124/3-1 (Figure 2~~Figure 2Figure 2~~), Asselian evaporite deposits typically include thin layers of anhydrite and gypsum, but thicker, halite-rich end-members are found along the flanks of the Nordkapp Basin and southwesternmost Nordkapp basin where large pillows of upper Carboniferous~~- and~~ lower Permian salt were observed (Gabrielsen et al., 1992; Jensen & Sørensen, 1992; Koyi et al., 1993; Nilsen et al., 1995; Gudlaugsson et al., 1998; Koehl et al., 2017). In the Nordkapp Basin, pre-Permian deposits may in places reach a thickness of up to 7-8 km (Gudlaugsson et al., 1998). These deposits are composed of thick clastic sedimentary rocks and of upper Carboniferous to lower Permian evaporite deposits characterized by mobile salt that was involved in salt tectonism in the southwesternmost Nordkapp basin (Gudlaugsson et al., 1998; Koehl et al. 2017) and in the Nordkapp Basin (Gabrielsen et al., 1992; Jensen & Sørensen, 1992; Koyi et al., 1993; Nilsen et al., 1995).

~~In the present work, we renamed the sedimentary basin located at the intersection of the TFFC and MFC (Figure 1) as the "southwesternmost Nordkapp basin" instead of the "easternmost Hammerfest basin" as proposed by Omosanya et al. (2015). The reason is that this basin shows more geometric similarity to the Nordkapp Basin than the Hammerfest Basin and must be treated as a separate basin (see further arguments later).~~

3. Methods & databases

3.1. Seismic data and well-ties

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. The interpretation of seismic data aims at providing good constraints for the extent and geometry of offshore brittle faults and for offshore stratigraphy on the Finnmark Platform and in the southwesternmost Nordkapp basin. The present study uses ties to wells 7120/12-4, 7128/4-1 and 7128/6-1 and 7124/3-1 based on publicly available

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well data (www.npd.no) and private well-tie seismograms ~~(Henningsen, pers. comm.)~~ and to shallow drill-cores 7127/10-U-2 and 7127/10-U-3 from Bugge et al. (1995; Figure 2). Seven seismic profiles from the BSS01 2D seismic survey were used to analyze and describe offshore basin and fault geometries and provide the basis for discussion about the late Paleozoic evolution of the SW Barents Sea margin. Note that none of the seismic profiles used was depth-converted. Therefore, all relevant estimates of fault offsets and stratigraphic seismic unit thicknesses will be described in seconds (s) two-way time (TWT). In addition, we analyzed two time-slice from 3D seismic survey MC3D-MFZ02 to constrain fault interaction in map-view.

3.2. Aeromagnetic anomaly data

The offshore aeromagnetic data used in this study correspond to a compilation of the BASAR project of the Geological Survey of Norway (NGU) published by Gernigon & Brönner (2012) and Gernigon et al. (2014; Figure 4~~Figure 4Figure 3~~). The dataset is composed of tilt derivatives of aeromagnetic data and has been used to delineate possible magmatic intrusions (dykes) emplaced along brittle faults (cf. Nasuti et al., 2015) and abrupt changes of lithology generally recorded across major faults, thus, contributing to the mapping of post-Caledonian offshore brittle faults along the SW Barents Sea margin. However, data uncertainties arise from the fact that significantly different rock types may yield similar aeromagnetic responses. A crucial example in northern Finnmark is the similar high positive narrow aeromagnetic anomalies produced both by sub-vertical folded beds of metasedimentary rocks (Roberts & Siedlecka, 2012; Roberts & Williams, 2013) and dolerite dykes intruded along brittle faults (Nasuti et al., 2015; Figure 4~~Figure 4Figure 3~~). In order to distinguish such features, we carefully analyzed onshore geology in coastal areas of NW Finnmark and the results of exploration wells on the Finnmark Platform and adjacent offshore basins.

4. Results

4.1. Seismic interpretation of offshore basins and faults

4.1.1. Seismic units and stratigraphy

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On seismic data (Figure 5~~Figure 5Figure 4~~), basement rocks typically show chaotic internal reflection patterns, which complicate the task of identifying intra-basement structures and basins, and individualize layered sedimentary sequences. However, km-thick layers bearing strong basement fabrics such as widespread gently dipping foliation or pronounced mylonitic fabric commonly found along large shear zones may turn out to be resolvable at seismic scale (see chapter 4.1.2.; Fountain et al., 1984; Reeve et al., 2013; Phillips et al., 2016; Fazlikhani et al., 2017). For instance, we observed a several km-thick, curved, shallow-dipping layer that is characterized by moderate-amplitude reflections, which are parallel to the layer's upper and lower boundaries (see "Sørøya-Ingøya shear zone" reflections in Figure 5~~Figure 5Figure 4~~c-g). We interpret these pronounced internal fabrics as widespread mylonitic foliation separated by internal thrusts within a large-scale shear zone. Numerous smaller basement shear zones may be present below late Paleozoic-Cenozoic sedimentary rocks on the Finnmark Platform west, and these correspond to steeply to moderately dipping fabrics made of sub-parallel, moderate- to high-amplitude reflections (cf. Figure 5~~Figure 5Figure 4~~b, e, f, g & Figure 6~~Figure 6Figure 5~~a-c).

Potential Devonian sedimentary deposits along the SW Barents Sea are sparse and as a result their seismic character is not well constrained (Figure 3~~Figure 3~~). This sedimentary succession has not been drilled, which makes its interpretation on seismic data rather speculative. However, we believe that the best two candidates to represent Devonian sedimentary deposits analog to those in western and mid-Norway (Braathen et al., 2000; Osmundsen & Andersen, 2001; Fazlikhani et al., 2017) are located at the base of the southwesternmost Nordkapp basin and on the Finnmark Platform west near the Gjesvær Low (Figure 1~~Figure 1Figure 1~~). In the southwesternmost Nordkapp basin, possible Devonian sedimentary strata are located at a deep level (below 4 seconds TWT) and their seismic signature is thus largely masked by overlying sedimentary successions (Figure 5~~Figure 5Figure 4~~c & d). By contrast, on the Finnmark Platform west (Figure 5~~Figure 5Figure 4~~e), potential Devonian sedimentary rocks are relatively shallower, which makes their seismic pattern easier to distinguish from underlying basement rocks, and from overlying Carboniferous sedimentary deposits and seismic artifacts (Figure 5~~Figure 5Figure 4~~e). Devonian sedimentary rocks on the Finnmark Platform west display relatively low seismic amplitudes, partly similar to analog deposits in the North Sea (cf. seismic facies 1 in Fazlikhani et al., 2017). The internal reflection pattern is rather chaotic apart from a few discrete, shallow-dipping, moderate-amplitude reflections that converge towards each other upwards and that we

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interpret as major sedimentary sequence boundaries (cf. dotted white ~~“Base Devonian”~~ reflections in Figure 5~~Figure 5Figure 4~~e & Figure 6~~Figure 6Figure 5~~b & c). Furthermore, Devonian sedimentary deposits are likely separated from underlying basement rocks by an angular unconformity that appears as arcuate, high-amplitude seismic reflections (“Base Devonian” reflection in Figure 5~~Figure 5Figure 4~~e and Figure 6b & c). We interpret these arcuate, high-amplitude seismic reflections as an erosional unconformity.

Lower Carboniferous sedimentary deposits of the Billefjorden Group, composed of thick clastic sedimentary deposits interbedded with occasional coal-bearing sedimentary rocks (Figure 3~~Figure 3~~), may produce high-amplitude seismic reflections related to their organic-rich content (Figure 5~~Figure 5Figure 4~~a & b). Such sedimentary strata are present on the Finnmark Platform east, where they appear to thicken to the southeast near the coasts of NW Finnmark (Figure 6~~Figure 6Figure 5~~d), whereas they are rather sparse on the Finnmark Platform west, i.e. eroded or never deposited (Figure 5~~Figure 5Figure 4~~e & f). On the Finnmark Platform east, the transition from basement rocks (cf. “Top basement” reflection in Figure 5~~Figure 5Figure 4~~a & b) to lower Carboniferous sedimentary rocks is difficult to interpret on seismic sections. This is attributable to the strong similarities between high seismic amplitudes displayed locally both by basement rock fabrics such as major shear zones (cf. yellow dotted lines in Figure 5~~Figure 5Figure 4~~b) and by lower Carboniferous coal-bearing sedimentary deposits. Low amplitude reflections also show identical chaotic patterns in both basement rocks and clastic sedimentary rocks of the Billefjorden Group (Figure 5~~Figure 5Figure 4~~a & b). In the southwesternmost Nordkapp basin, lower Carboniferous sedimentary strata are believed to be present although their seismic signature certainly appears to be affected by overlying upper Carboniferous evaporite deposits (Figure 5~~Figure 5Figure 4~~c & d). The boundary between lower Carboniferous sedimentary deposits and potential underlying Devonian sedimentary rocks was not identified in the southwesternmost Nordkapp basin. Nevertheless, ~~since~~ the maximum thickness of Billefjorden Group sedimentary strata ~~is ca. 600 m~~ on the Finnmark Platform east is ca. 600 m (Bugge et al., 1995), and this suggests that the several km-thick succession below the mid-Carboniferous reflection and above a thick shear zone in the southwesternmost Nordkapp basin is composed of lower Carboniferous sedimentary rocks probably complemented by thick Devonian sedimentary deposits (Figure 5~~Figure 5Figure 4~~c & d). Alternatively, sedimentary deposits of the Billefjorden Group directly overlie basement rocks.

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On the Finnmark Platform (Figure 1~~Figure 1Figure 1~~ & Figure 2~~Figure 2Figure 2~~), the base of the upper Carboniferous sedimentary ~~sequences~~ succession is difficult to identify (cf. “mid-Carboniferous” reflection in Figure 3~~Figure 3~~ & Figure 5~~Figure 5Figure 4~~). ~~because it often~~In places, it appears as a linear, moderate to low amplitude seismic reflection that separates subparallel reflections of lower and upper Carboniferous sedimentary rocks, whereas in other places the~~is~~ reflection is irregular and truncates ~~either~~ high-amplitude coal-bearing sedimentary deposits of the Billefjorden Group, and/or high-amplitude reflections produced by basement rocks (Figure 6~~Figure 6Figure 5~~a) ~~similar to those of the km-thick shear zone below the Finnmark Platform west and the southwesternmost Nordkapp basin (see Figure 4c-g)~~, and/or low-amplitude reflections in Devonian sedimentary strata (Figure 6~~Figure 6Figure 5~~b & c). Nevertheless, this reflection generally corresponds to an angular unconformity (e.g. Figure 6~~Figure 6Figure 5~~a-c & e) and is therefore interpreted to correspond to a regional erosion surface.

In the southwesternmost Nordkapp basin, the base of upper Carboniferous sedimentary deposits (cf. “mid-Carboniferous” reflection in Figure 3~~Figure 3~~ and Figure 5~~Figure 5Figure 4~~c & d) ~~is relatively easy to interpret as it mostly~~ appears as a clear, discrete high-amplitude reflection. The strong acoustic impedance contrast producing the high seismic amplitude for the mid-Carboniferous reflection most likely arises from the presence of upper Carboniferous evaporite deposits partly composed of mobile salt (halite), which is significantly less dense than regular sedimentary rocks, (cf. “Top upper Carboniferous evaporites” reflection in Figure 3~~Figure 3~~ and Figure 5~~Figure 5Figure 4~~c & d). This evaporite succession was identified by Gudlaugsson et al. (1998) and is restricted to basinal areas located northwest of the MFC and north of the TFFC (Figure 1~~Figure 1Figure 1~~ & Figure 2~~Figure 2Figure 2~~). It is characterized by a highly variable thickness, which is due to the presence of lensoidal bodies bounded to the top and bottom by high-amplitude reflections on the basin edges and to the occurrence of thick bodies made of chaotic reflection patterns near the center of the basin (Figure 5~~Figure 5Figure 4~~c). We interpret the lensoidal bodies on the basin edges as pillows of mobile salt and the chaotic bodies near the basin center as small salt diapirs based on similarities with large salt diapirs and evaporite deposits observed in the Nordkapp Basin (Gabrielsen et al., 1992; Jensen & Sørensen, 1992; Koyi et al., 1993; Nilsen et al., 1995). We consider that the presence of analog, late Paleozoic evaporite deposits in the southwesternmost Nordkapp basin and in the Nordkapp Basin (Jensen & Sørensen, 1992; Koyi et al., 1993; Gudlaugsson et al., 1998) and the absence of such deposits in the

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Hammerfest Basin constitute strong ~~enough~~ arguments to justify ~~the proposed~~ a change of name for the “easternmost Hammerfest basin” (Omosanya et al., 2015) into the “southwesternmost Nordkapp basin”. However~~Nonetheless~~, this~~e southwesternmost Nordkapp~~ basin shows large amount of normal displacement along its southern boundary fault, the NW-dipping MFC, which is opposite to the Nordkapp Basin where basin subsidence was dominantly accommodated along the SE-dipping Nysleppen Fault Complex (Figure 1~~Figure 1Figure 1~~). Hence, despite their similarities, the Nordkapp Basin and the southwesternmost Nordkapp basin should be treated as two separate basins.

Non-evaporitic, upper Carboniferous and Permian sedimentary deposits are characterized by subparallel, flat-lying to shallow-dipping, homogeneous, moderate to low-amplitude seismic reflections (see Figure 5~~Figure 5Figure 4~~). Permian deposits are relatively thin on the Finnmark Platform and are sometimes difficult to distinguish from upper Carboniferous deposits (Figure 5~~Figure 5Figure 4~~a, b, e, f & g). In the southwesternmost Nordkapp basin, however, late Paleozoic sedimentary deposits are ~~reasonably~~ thicker and individual units are therefore easier to identify at seismic scale. Thus, ~~and~~ we interpreted a thin unit characterized by high-amplitude reflections (cf. “Base Asselian” and “Top Asselian evaporites” reflections in Figure 3~~Figure 3~~ and Figure 5~~Figure 5Figure 4~~c & d) as Asselian (earliest Permian) evaporite deposits that were evidenced by exploration well 7124/3-1 on the northern flank of the southwesternmost Nordkapp basin (Figure 2~~Figure 2Figure 2~~, Figure 5~~Figure 5Figure 4~~c & d). Where present, this thin Asselian evaporite succession defines the base of the Permian sedimentary succession and therefore serves as an upper boundary for the Carboniferous succession (cf. “Base Asselian” reflection in Figure 5~~Figure 5Figure 4~~c & d). However, Asselian evaporites are too thin and too discontinuous to be seismically resolvable on the Finnmark Platform (Bugge et al., 1995). Occasionally, Asselian evaporites are truncated by chaotic reflections of small salt diapirs sourced from deeper upper Carboniferous evaporites in the southwesternmost Nordkapp basin (Figure 5~~Figure 5Figure 4~~c).

The Base Triassic reflection (see Figure 5~~Figure 5Figure 4~~) defines the (near-) top of the late Paleozoic sedimentary succession and is easily interpreted through the whole Barents Sea as it corresponds to a high-amplitude reflection that represents the top of a regionally widespread carbonate unit (Bugge et al., 1995). Other important seismic reflections interpreted in the present study include the Base Cretaceous, Base Paleocene, the Upper Regional Unconformity (URU), which corresponds to a major erosional unconformity and represents the base of Quaternary sediment cover (Solheim & Kristoffersen, 1984), and the seabed reflection (Figure 5~~Figure 5Figure 4~~). These reflections are penetrated by a large number of exploration wells and shallow drill-cores both on the Finnmark Platform and in the southwesternmost Nordkapp basin, where they all display consistently high seismic amplitudes (Faleide et al., 1984; Bugge et al., 1995; Gudlaugsson et al., 1998; Omosanya et al., 2015).

4.1.2. Structural architecture of the Finnmark Platform and of the southwesternmost Nordkapp basin

In this section, we describe the most important structural elements of the Finnmark Platform and of the southwesternmost Nordkapp basin (cf. Figure 1~~Figure 1Figure 1~~ & Figure 2~~Figure 2Figure 2~~) based on interpreted key seismic sections (Figure 5~~Figure 5Figure 4~~). We also highlight the most dominant fault trends and their interaction with major structures such as the TFFC, MFC, TKFZ and SISZ to form offshore sedimentary basins.

Faults and shear zones within basement rocks

We identified a several km-thick, curved (in cross-section), shallow-dipping layer of moderate-amplitude reflections that we interpreted to represent a large-scale basement-seated shear zone, which we name the SISZ. The upper boundary surface of the SISZ (Figure 7~~Figure 7Figure 6~~) appears to be relatively shallow in coastal areas on the Finnmark Platform west. On the Finnmark Platform west, the SISZ dominantly dips to the NW but switches to a dominant dip to the northeast on the Finnmark Platform east. In the footwall of the MFC and in the southwestern part of the Finnmark Platform west, the SISZ occurs at relatively shallow depth (< 1.5 s TWT). ~~and~~ There it is believed to have been deeply eroded and is now overlain by a very thin sedimentary cover (cf. Figure 5~~Figure 5Figure 4~~c-f & Figure 6~~Figure 6Figure 5~~d). The SISZ shows significant lateral thickness variations that range from 2.0-2.5 seconds (TWT) near the coastline and in the footwall of the TFFC to 0.5 second (TWT) below the MFC and the TFFC (Figure 5~~Figure 5Figure 4~~f). The SISZ deepens to the northwest towards the center of the Finnmark Platform west before bending upwards in the footwall of the TFFC (Figure 5~~Figure 5Figure 4~~e & f). The SISZ then curves down where ~~and merges with~~ the listric TFFC merges with the shear zone at depth, thus delineating an elongated, NE-SW trending ridge in the footwall of the TFFC (cf. “basement ~~highs~~ridges” in Figure 1~~Figure 1Figure 1~~ and Figure 5~~Figure 5Figure 4~~e &f). A similar pattern is observed in the

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southwesternmost Nordkapp basin where the SISZ deepens to the northwest before curving up near the center of the basin and merging with the N-boundary fault of the southwesternmost Nordkapp basin, the Rolvsøya fault, hence giving this basin a characteristic "U" shape in cross-section (Figure 5~~Figure 5Figure 4~~c & d). The SISZ also curves down in the footwall of the Rolsøya fault and defines a second elongated, ENE-WSW trending ridge (cf. "basement highs" in Figure 1~~Figure 1Figure 1~~). Importantly, the two basement ridges located in the footwall of the TFFC and of the Rolvsøya fault ("basement highs" in Figure 1~~Figure 1Figure 1~~), respectively, are separated by a narrow trough that is bounded to the southwest by the WNW-ESE trending segment of the TFFC (Figure 7~~Figure 7Figure 6~~). Apart from this narrow trough, the attitude of the SISZ is uniform along NE-SW transects on the Finnmark Platform west and within the southwesternmost Nordkapp basin with a gentle dip to the northeast (Figure 5~~Figure 5Figure 4~~g).

Notably~~Noteworthy~~, the spoon-shaped geometry of the SISZ, with asymmetric, NE-SW trend, northeastwards-broadening, NE-plunge (Figure 7~~Figure 7Figure 6~~) appears to coincide with a basement gravity low on the Finnmark Platform west: the Gjesvær Low (Johansen et al., 1994; Gernigon et al., 2014; Figure 1~~Figure 1Figure 1~~) The geometry of the SISZ also matches the trend and shape of the southwesternmost Nordkapp basin (Figure 1~~Figure 1Figure 1~~ & Figure 7~~Figure 7Figure 6~~). Farther south, along the coasts of Western Troms and westwards below the Hammerfest Basin, the low quality of available seismic data did not allow us to trace the SISZ more precisely (Figure 7~~Figure 7Figure 6~~). On the Finnmark Platform east, the SISZ bends from NE-SW into a more WNW-ESE trend and changes dip from gentle to steep to the northeast (Figure 7~~Figure 7Figure 6~~), and as a result, the SISZ becomes too deep to interpret on seismic data in the northeastern part of the Finnmark Platform east (Figure 7~~Figure 7Figure 6~~). The multiple changes of trend, dip direction, dip angle and thickness of the SISZ gives the shear zone a spoon-shaped geometry (Figure 7~~Figure 7Figure 6~~).

On the Finnmark Platform west, subsidiary steep, SE-dipping high-amplitude reflections occur in basement rocks and these are truncated by the mid-Carboniferous reflection and the Base Devonian erosional unconformity in the footwall of the TFFC (see yellow dotted lines in Figure 5~~Figure 5Figure 4~~e-g). Despite dipping southeast, these reflections resemble the dominant reflection pattern observed within the SISZ (Figure 5~~Figure 5Figure 4~~e & f). Thus, we interpret them as SE-dipping, mylonitic shear zones (yellow dotted lines in Figure 5~~Figure 5Figure 4~~e-g). The upper boundary of one of these SE-dipping shear zones coincides with an abrupt seismic facies change on the Finnmark Platform west, from moderately dipping, moderate-amplitude reflections in the west to gently dipping/sub-horizontal, low-amplitude seismic reflections in the east (Figure 5~~Figure 5Figure 4~~g). This change also coincides with a ca. one second (TWT) deepening of the upper boundary of the SISZ towards the northeast (Figure 5~~Figure 5Figure 4~~g), and with a small normal offset of a lensoidal, eastwards-thickening layer of sub-horizontal reflections located above the SISZ (cf. dotted black lines in Figure 5~~Figure 5Figure 4~~g). We interpret these changing attributes to be related to the presence of a NNE-SSW trending, ESE-dipping brittle fault that flattens and soles into the SISZ and which may have developed along a pre-existing, steep ductile shear zone (yellow dotted lines in Figure 5~~Figure 5Figure 4~~g).~~ This fault is likely early Carboniferous in age since it is truncated by the "mid-Carboniferous" refection and does not propagate through overlying late Paleozoic–Cenozoic sedimentary rocks (Figure 4g).~~

Similar NE-SW trending but NW-dipping shear zones may exist in basement rocks on the Finnmark Platform east, for example in the form of steeply dipping, high-amplitude seismic reflections truncated by the mid-Carboniferous reflection (cf. yellow dotted lines in Figure 5~~Figure 5Figure 4~~b and Figure 6~~Figure 6Figure 5~~a). These reflections differ from gently dipping, high-amplitude reflections of lower Carboniferous coal-bearing sedimentary deposits (Figure 6~~Figure 6Figure 5~~a) and rather resemble the SISZ reflection pattern, though these are located well above the presumed continuation of the SISZ (Figure 5~~Figure 5Figure 4~~e & f). We therefore interpret these steep reflections as a NE-SW trending, NW-dipping shear zone similar to the SISZ (Figure 5~~Figure 5Figure 4~~b).

Faults within late Paleozoic sedimentary successions

Faults ~~that structured the~~bounding Paleozoic sedimentary strata and basins include the major TFFC and MFC and numerous faults on the Finnmark Platform. The TFFC is made of alternating ENE-WSW and NNE-SSW trending, NW-dipping, listric fault segments that form a zigzag pattern and that separate the Hammerfest Basin in the northwest from the Finnmark Platform west in the southeast (Figure 1~~Figure 1Figure 1~~ & Figure 5~~Figure 5Figure 4~~e & f; Gabrielsen et al., 1990; Indrevær et al., 2013). Seismic data below ENE-WSW and NNE-SSW trending fault segments of the TFFC show that these fault segments merge with and sole into shallow-dipping reflections of the SISZ at depth (Figure 5~~Figure 5Figure 4~~e & f). At the northeast termination of the Hammerfest Basin, the TFFC bends 90 degrees clockwise and continues to the southeast as a

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WNW-ESE trending, NE-dipping, listric fault (Figure 1~~Figure 1Figure 1~~, Figure 2~~Figure 2Figure 2~~ & Figure 5~~Figure 5Figure 4~~g). At depth, this fault merges with the SISZ (cf. Figure 5~~Figure 5Figure 4~~g) near a narrow trough in the top surface of the SISZ, separating two elongated NE-SW to ENE-WSW trending basement ridges in the footwall of the TFFC and of the Rolvsøya fault (cf. “basement highs” in red in Figure 1~~Figure 1Figure 1~~ & Figure 7~~Figure 7Figure 6~~). In map-view, the WNW-ESE trending, NE-dipping fault segment of the TFFC bends anticlockwise into the main fault segment of the MFC, which corresponds to a linear, NE-SW trending, NW-dipping fault (Figure 1~~Figure 1Figure 1~~, Figure 2~~Figure 2Figure 2~~ and Figure 8~~Figure 8Figure 7~~a & b). The interaction of these two faults in map-view gives the Finnmark Platform west and the southwesternmost Nordkapp basin triangular shapes (Figure 2~~Figure 2Figure 2~~ & Figure 8~~Figure 8Figure 7~~a & b). The main fault segment of the MFC defines the southeastern boundary of the southwesternmost Nordkapp basin (Figure 1~~Figure 1Figure 1~~, Figure 2~~Figure 2Figure 2~~ & Figure 5~~Figure 5Figure 4~~c & d) and of a ca. 25-30 km wide graben structure on the Finnmark Platform west that is believed to be partly filled with Devonian sedimentary deposits (Figure 1~~Figure 1Figure 1~~, Figure 2~~Figure 2Figure 2~~ & Figure 5~~Figure 5Figure 4~~e & f). Northeastwards, the main segment of the MFC (Figure 5~~Figure 5Figure 4~~c-f) is replaced by several minor fault segments of the MFC with limited vertical throw (Figure 5~~Figure 5Figure 4~~a & b) that defines the southeastern boundary of the Nordkapp Basin (Figure 1~~Figure 1Figure 1~~ and Figure 5~~Figure 5Figure 4~~a & b). The southwesternmost Nordkapp basin is bounded to the north by an E-W to ENE-WSW trending, south-dipping, listric normal fault, the Rolvsøya fault, which flattens at depth and merges into gently dipping reflections of the SISZ (Figure 5~~Figure 5Figure 4~~c & d). The Rolvsøya fault separates the southwesternmost Nordkapp basin from the Ottar Basin to the northwest and from the Nordkapp Basin to the northeast (Figure 1~~Figure 1Figure 1~~ & Figure 2~~Figure 2Figure 2~~).

Late Paleozoic grabens on the Finnmark Platform east display fault patterns that are analogous to those that shape the southwesternmost Nordkapp basin and the Finnmark Platform west (Figure 1~~Figure 1Figure 1~~ & Figure 2~~Figure 2Figure 2~~). Numerous steeply dipping, listric normal faults made of alternating, zigzag-shaped, ENE-WSW and NNE-SSW trending fault segments bound relatively narrow, few km-wide graben and half-graben structures that are filled with wedge-shaped, late Paleozoic sedimentary ~~sequences~~ successions (Figure 2~~Figure 2Figure 2~~ & Figure 5~~Figure 5Figure 4~~a & b). In particular, one of these zigzag-shaped faults trends NE-SW to NNE-SSW, dips to the northwest and can be traced for about 60 km from the northern coast of

Magerøya onto the Finnmark Platform east (Figure 1~~Figure 1Figure 1~~ & Figure 2~~Figure 2Figure 2~~). Southwestwards, this fault roughly aligns with a similarly shaped and oriented, NW-dipping onshore-nearshore fault complex syntethic to the TFFC described as the LVF (Figure 2~~Figure 2Figure 2~~ & Figure 5~~Figure 5Figure 4~~a & b; Zwaan & Roberts, 1978; Lippard & Roberts, 1987; Roberts & Lippard, 2005; Koehl et al., submitted). We tentatively interpret the ca. 60 km-long, zigzag-shaped brittle fault on the Finnmark Platform east, northeast of Magerøya, as the northeastward continuation of the LVF on the Finnmark Platform east (Figure 1~~Figure 1Figure 1~~, Figure 5~~Figure 5Figure 4~~a & b and Figure 6~~Figure 6Figure 5~~a).

Below the minor northern fault segments of the MFC, we identified a large NE-SW trending, SE-dipping fault that is antithetic to the MFC (Figure 5~~Figure 5Figure 4~~a & b). Due to the rather low quality of seismic data at large depths, the interaction of the northern fault segments of the MFC with the antithetic SE-dipping fault is difficult to evaluate. Our data indicate that the northern fault segments of the MFC crosscuts the NE-SW trending, SE-dipping fault in the southwest (Figure 5~~Figure 5Figure 4~~b), whereas farther northeast, along strike, the northern fault segments of the MFC seem to sole into upper Carboniferous evaporite deposits (Figure 5~~Figure 5Figure 4~~a).

4.1.3. Fault-controlled thickness variations

In the following chapter, fault offsets and thickness variations in the sedimentary successions across brittle faults will be described as a basis to infer timing and sense of shear for brittle faults on the Finnmark Platform and in the southwesternmost Nordkapp basin. Regional stratigraphic thickness maps (Figure 9~~Figure 9Figure 8~~a-c) show that late Paleozoic sedimentary strata on the Finnmark Platform east thicken from < 0.1 second (TWT) in the southeast to a maximum thickness of ca. 2 seconds (TWT) in the footwall of the MFC (see also Figure 5~~Figure 5Figure 4~~a & b). This gradual thickness increase contrasts with the abrupt thickness increase of Devonian-Carboniferous sedimentary strata in the hanging-wall of major normal faults, e.g. the WNW-ESE trending segment of the TFFC and the main segment of the MFC (Figure 9~~Figure 9Figure 8~~a-b), thus separating depositional versus tectonic thickness changes.

Intra-basement thickness changes

The dominant shear zone system within basement rocks on the Finnmark Platform west is the SISZ (Figure 5~~Figure 5Figure 4~~c-g, Figure 6~~Figure 6Figure 5~~b-c & e-f and Figure 7~~Figure 7Figure 6~~). A pronounced intra-basement unit made of sub-horizontal, high-amplitude reflections occurs above the SISZ (Figure 5~~Figure 5Figure 4~~g).The top reflection of the SISZ and the overlying intra-basement unit are offset by a NNE-SSW trending, gently east-dipping fault, which is accompanied by thickness increase of the intra-basement unit across the east-dipping fault (cf. black dotted line in Figure 5~~Figure 5Figure 4~~g & Figure 6~~Figure 6Figure 5~~e). This fault is interpreted to have a top-to-the-E, normal sense of shear (cf. dotted black lines in Figure 5~~Figure 5Figure 4~~g & Figure 6~~Figure 6Figure 5~~e), and is itself truncated by the subhorizontal mid-Carboniferous reflection, which constrains its activity to the Mid/Late Devonian-early Carboniferous (Figure 5~~Figure 5Figure 4~~g).

Fault-controlled thickness changes in Devonian-Carboniferous strata

In the southwesternmost Nordkapp basin, the Devonian-lower Carboniferous sedimentary succession (Figure 5~~Figure 5Figure 4~~c & d) appears to be thickest at the intersection of the TFFC and MFC (Figure 9~~Figure 9Figure 8~~a), where vertical displacement along the MFC and TFFC is estimated to be ca. 1.5 second (TWT), based on offset of the mid-Carboniferous reflection (cf. Figure 5~~Figure 5Figure 4~~d). The overlying upper Carboniferous succession displays a similar attitude as shown by the broad thickening of similar sedimentary strata at the intersection of the TFFC and MFC (Figure 9~~Figure 9Figure 8~~b). These observations suggest that the WNW-ESE trending segment of the TFFC and the main segment of the MFC potentially formed simultaneously in Devonian times and acted as syn-sedimentary normal faults that contributed to the thickening of Devonian-lower Carboniferous and upper Carboniferous sedimentary deposits within the southwesternmost Nordkapp basin (Figure 5~~Figure 5Figure 4~~c & d). In this scenario, the Rolvsøya fault likely limits the extent of thickened Devonian-lower Carboniferous and upper Carboniferous sedimentary strata to the north. If we consider the thickness of the seismic package limited upwards by the mid Carboniferous reflection and downwards by the top reflection of the SISZ in the footwall of the Rolvsøya fault, the maximum thickness of Devonian and lower Carboniferous sedimentary rocks on the northern flank of the basin does not exceed ca. 1 second (TWT). This thickness estimate is significantly thinner than what is observed within the southwesternmost Nordkapp basin, where the Devonian-lower Carboniferous succession reaches a maximum thickness of ca. 2-

2.5 seconds (TWT; see Figure 5~~Figure 5Figure 4~~c & d). By analogy, the thickness of upper Carboniferous sedimentary strata on the northern flank of the southwesternmost Nordkapp basin decreases from ca. 1.5 seconds (TWT) to ca. 0.5-1 second across the Rolvsøya fault (Figure 5~~Figure 5Figure 4~~c & d and Figure 9~~Figure 9Figure 8~~b). Hence, the Rolvsøya fault was active and largely contributed to sediment thickening within the southwesternmost Nordkapp basin during the Mid/Late Devonian-Carboniferous.

On the Finnmark Platform west, potential Devonian sedimentary rocks are characterized by low-amplitude, chaotic reflections within which we observed distinct, shallow-dipping, moderate-amplitude reflections that we interpreted as major sedimentary sequence boundaries (cf. white dotted lines in Figure 5~~Figure 5Figure 4~~e and Figure 6~~Figure 6Figure 5~~b & c). These shallow-dipping reflections diverge from each other downwards and define gently dipping, wedge-shaped layers of low-amplitude, chaotic reflections that thicken downwards against arcuate, high-amplitude basement reflections that represent an erosional unconformity (cf. "Base Devonian" reflection in Figure 5~~Figure 5Figure 4~~e), and to the northwest against an ENE-WSW trending, SE-dipping normal fault (Figure 5~~Figure 5Figure 4~~e and Figure 6~~Figure 6Figure 5~~b & c). We interpret these sedimentary sequences separated by shallow-dipping, moderate-amplitude reflections to represent growth strata deposited along an active ENE-WSW trending, SE-dipping normal fault, which is parallel to SE-dipping basement shear zones (Figure 5~~Figure 5Figure 4~~e and Figure 6~~Figure 6Figure 5~~b & c). In addition, the main fault segment of the MFC shows decreasing amount of vertical displacement to the southwest, accompanied by a simultaneous thickness decrease in the upper Carboniferous succession along strike~~the main segment of the MFC~~ (Figure 9~~Figure 9Figure 8~~b), before the MFC eventually dies out on the Finnmark Platform west (Figure 1~~Figure 1Figure 1~~, Figure 2~~Figure 2Figure 2~~ & Figure 5~~Figure 5Figure 4~~e & f). Analogously, upper Carboniferous sedimentary deposits on the Finnmark Platform west display a wedge shape that is thickest in the southeast, near the MFC, and gradually thins towards the TFFC in the northwest (Figure 5~~Figure 5Figure 4~~e & f, Figure 9~~Figure 9Figure 8~~b). This upper Carboniferous sedimentary wedge likely formed by syn-tectonic sedimentary growth along the main fault segment of the MFC.

On the Finnmark Platform east, the offshore portion of the LVF (cf. Figure 1~~Figure 1Figure 1~~ & Figure 5~~Figure 5Figure 4~~a & b) downthrows the mid-Carboniferous reflection by ca. 0.5 second (TWT) to the northwest (Figure 5~~Figure 5Figure 4~~b) and bounds a NE-SW trending graben structure filled with thickened lower Carboniferous and upper Carboniferous sedimentary strata (cf. Figure 5~~Figure 5Figure 4~~a & b). In this graben structure, the lower Carboniferous and upper Carboniferous sedimentary successions thicken against the LVF (Figure 5~~Figure 5Figure 4~~b), while thickness variations become negligible farther north where the LVF dies out (Figure 1~~Figure 1Figure 1~~ & Figure 5~~Figure 5Figure 4~~a). Consequently, similar thickness increases of lower Carboniferous and upper Carboniferous sedimentary strata elsewhere within graben and half-graben structures on the Finnmark Platform east suggest that syn-tectonic sediment deposition ~~occurred in Carboniferous times~~ along the LVF and analog ENE-WSW to NNE-SSW trending faults mostly occurred in Carboniferous times. Furthermore, in the footwall of the northern fault segments of the MFC, we recorded anomalously thick upper Carboniferous succession (Figure 9~~Figure 9Figure 8~~b) with a thickness comparable to what is observed within the southwesternmost Nordkapp basin (Figure 9~~Figure 9Figure 8~~b). This succession shows a half-ellipsoid shape in map-view with a NE-SW trending major axis parallel to the MFC (Figure 9~~Figure 9Figure 8~~b). We therefore argue that this thickness change on the Finnmark Platform east is the result of syn-tectonic sediment deposition in the hanging-wall of a NE-SW trending, SE-dipping fault antithetic to the MFC (Figure 5~~Figure 5Figure 4~~a & b). We suggest that the half-ellipsoid shape of the thickened upper Carboniferous sedimentary deposits on the Finnmark Platform east reflects large offset near the center of ~~a~~ the SE-dipping fault, and decreasing vertical throw towards the fault-tips, a feature characterizing syn-sedimentary, rift-related normal faults (Figure 9~~Figure 9Figure 8~~b).

By contrast, depositional sediment wedges may as well occur on the Finnmark Platform east, and they differ from fault-controlled thickness changes. One example is the ca. 600 m-thick lower Carboniferous succession evidenced by shallow drilling between the Nordkinn Peninsula and Magerøya (cf. “star” symbol in Figure 1~~Figure 1Figure 1~~; Bugge et al., 1995), which we re-interpreted as a prograding Carboniferous sedimentary system (Figure 6~~Figure 6Figure 5~~d). The apparent thickening of the lower Carboniferous succession near the coasts of NW Finnmark is more likely to be related to sedimentary processes during the formation of large clinoforms in a prograding sedimentary system (Figure 6~~Figure 6Figure 5~~d) than to syn-tectonic deposition in the hanging-wall of a NE-SW trending, NW-dipping fault.

Fault-controlled thickness changes in Permian strata

In the southwesternmost Nordkapp basin and on the Finnmark Platform east and west, the Permian sedimentary succession is thin and shows a relatively constant thickness compared to the

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underlying Devonian-lower Carboniferous and upper Carboniferous successions (Figure 5~~Figure 5Figure 4~~a-d and Figure 9~~Figure 9Figure 8~~a-c). However, the Base Asselian and Base Triassic reflections marking the lower and upper boundary of the Permian succession show some offsets across the main fault segment of the MFC, WNW-ESE trending segment of the TFFC and Rolvsøya fault, thus accounting for minor thickness variations in the Permian succession across th~~i~~ese faults (Figure 5~~Figure 5Figure 4~~c, ~~&~~ d & g and Figure 9~~Figure 9Figure 8~~c). We interpret these small offsets and thickness variations as the product of minor faulting activity in the Permian and mild Mesozoic reactivation of these faults, thus ~~This~~ suggesting~~s~~ that the main tectonic activity along these ~~Rolvsøya~~ faults was essentially restricted to the Mid/Late Devonian-late Carboniferous (Figure 5c, d & g). Moreover, on the Finnmark Platform west and east, most brittle faults die out within the upper Carboniferous succession and only a few faults crosscut the Permian succession with limited amount of offset (Figure 5~~Figure 5Figure 4~~a, b, e, & f). ~~Across the TFFC and the MFC, the Base Asselian and Base Triassic reflections display small offsets, which we interpret as mild Mesozoic reactivation of these faults (Figure 4c, d & g).~~

Fault-controlled thickness changes in Mesozoic-Cenozoic strata

Most faults observed within the late Paleozoic succession on the Finnmark Platform east and west and in the southwesternmost Nordkapp basin die out in the upper part of the succession before reaching the Base Triassic reflection (Figure 5~~Figure 5Figure 4~~). A few exceptions exist where the MFC and the WNW-ESE trending segment of the TFFC show small offsets of Mesozoic sedimentary strata (Figure 5~~Figure 5Figure 4~~c-g). The weak influence of these faults compared to offsets observed within late Paleozoic successions (Figure 5~~Figure 5Figure 4~~c-g) suggests that, at least some major faults were mildly reactivated in Mesozoic times but, in general, most brittle faults on the Finnmark Platform east and west and in the southwesternmost Nordkapp basin remained inactive after Carboniferous times.

4.2. Offshore aeromagnetic data

To better verify our 2D interpretation of faults and basin architectures on the Finnmark Platform and in the southwesternmost Nordkapp basin, we compare and tie our results using high-resolution, offshore aeromagnetic data from Gernigon et al. (2014; Figure 4~~Figure 4Figure 3~~).

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Aeromagnetic anomalies, when combined with seismic interpretation, may provide useful results allowing to identify brittle faults and offset patterns (cf. Indrevær et al., 2013).

On the Finnmark Platform east, offshore aeromagnetic data (Figure 4~~Figure 4Figure 3~~; Gernigon et al., 2014) show multiple narrow, NNE-SSW trending, high-positive aeromagnetic anomalies that bend into NW-SE/NNW-SSE orientations near the center of the Nordkapp Basin, which Gernigon et al. (2014) interpreted as arc-shaped prolongations of Caledonian nappes. A more detailed analysis of these aeromagnetic data reveals a set of triangular to rhomboidal, high-negative aeromagnetic anomalies, the largest of which was observed northeast of the island of Magerøya (dashed white lines in Figure 4~~Figure 4Figure 3~~). This high-negative anomaly is bounded to the northeast and to the northwest by narrow, linear, NNE-SSW to NE-SW trending, high-positive aeromagnetic anomalies (dashed white lines in Figure 4~~Figure 4Figure 3~~). On seismic data, the locations of these linear, high-positive aeromagnetic anomalies coincide with SE-dipping normal fault for the northwestern anomaly, and the NW-dipping, zigzag-shaped LVF for the southeastern anomaly (cf. black arrows in Figure 5~~Figure 5Figure 4~~a & b). These two faults bound a triangular-shaped basin filled up with thickened Carboniferous sedimentary deposits (cf. Figure 5~~Figure 5Figure 4~~a & b), which shape and extent mimic those of the triangular, high-negative anomaly observed on aeromagnetic data northeast of Magerøya (Figure 4~~Figure 4Figure 3~~). Such triangular-shaped, high-negative aeromagnetic anomaly may thus be indicators of offshore Carboniferous sedimentary basins.

Similarly, on the Finnmark Platform west, a large NE-SW trending, linear, high-positive aeromagnetic anomaly is observed in the footwall of the TFFC (dotted white lines in Figure 4~~Figure 4Figure 3~~), where it extends northeastwards into the footwall of the Rolvsøya fault (Figure 4~~Figure 4Figure 3~~). This NE-SW trending, high-positive aeromagnetic anomaly coincides with a NE-SW trending basement ridge in the footwall of the TFFC on the Finnmark Platform west and with the location of an ENE-WSW trending basement ridge in the footwall of the Rolvsøya fault (Figure 1~~Figure 1Figure 1~~ and Figure 5~~Figure 5Figure 4~~c-f). We interpret this NE-SW trending, high-positive aeromagnetic anomaly to highlight a significant compositional difference between highly-magnetic basement rocks in NE-SW and ENE-WSW trending basement ridges and poorly magnetic, adjacent basement rocks on the Finnmark Platform west and in the southwesternmost Nordkapp basin (Figure 1, Figure 4 and Figure 5~~Figure 5Figure 4~~c-f).

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5. Discussion

Our regional and detailed seismic studies of basin-boundary faults such as the TFFC, MFC, Rolvsøya fault and TKFZ on the Finnmark Platform and adjacent southwesternmost Nordkapp basin show multiple links and interactions. We focus the discussion on the interaction of these faults and associated minor faults on Late-Devonian-Carboniferous (half-) graben basins. We specifically discuss how deep-seated ductile Caledonian shear zones, i.e. the Sørøya-Ingøya shear zone and basement ridges may have been exhumed and thus enabled to control post-Caledonian brittle faulting and formation of Late-Devonian-Carboniferous basins as collapse basins. In combinaison, the structural architecture, timing of faulting and fault-controlled thickness variations on the Finnmark Platform and in the southwesternmost Nordkapp basin provide the framework to discuss the evolution of the SW Barents Sea margin from the Mid/Late Devonian to the Permian.

5.1. Interaction of the main segment of the Måsøy Fault Complex with the Sørøya-Ingøya shear zone

The linear, NE-SW trending geometry of the main segment of the MFC in map-view (Figure 1~~Figure 1Figure 1~~ & Figure 2~~Figure 2Figure 2~~) strongly differs from the dominant ENE-WSW to NNE-SSW trending, zig-zag pattern typically observed for post-Caledonian faults in Mid-Norway (Blystad et al., 1995), Lofoten-Vesterålen (Bergh et al., 2007; Eig, 2008; Hansen et al., 2012), Western Troms (Indrevær et al., 2013) and NW Finnmark (Koehl et al., submitted). Notably, the anomalously linear fault segment of the MFC trends fully parallel to and soles into high-amplitude, NW-dipping seismic reflections of the SISZ on the Finnmark Platform and in the southwesternmost Nordkapp basin (Figure 5~~Figure 5Figure 4~~c-f). This obvious merging of main segment of the MFC into the basement-seated SISZ (Figure 5~~Figure 5Figure 4~~c-f) suggests it formed as a brittle splay fault along an inverted portion of the SISZ, likely during the collapse of the Caledonides in the Mid/Late Devonian (Gudlaugsson et al., 1998). We suggest a similar interpretation for the Rolvsøya fault, which also flattens and merges into a bowed portion of the SISZ (Figure 5~~Figure 5Figure 4~~c & d), and for the northwest-boundary fault of the Devonian graben on the Finnmark Platform west soling into a minor, SE-dipping shear zone (Figure 5~~Figure 5Figure 4~~e & Figure 6~~Figure 6Figure 5~~b & c). These faults are thought to have remained active through the late Carboniferous as suggested by potential syn-tectonic sediment thickening within

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the upper Carboniferous succession (Figure 9~~Figure 9Figure 8~~b) but most likely ceased before the Permian as supported by the relatively constant thickness of Permian sedimentary strata throughout the study area (Figure 9~~Figure 9Figure 8~~c).

By analogy, in the ~~central~~ North Sea, Phillips et al. (2016) successfully tied the southernmost onshore occurrence of the Karmøy Shear Zone, a major Caledonian shear zone, to a thick seismic unit made up with sub-parallel, high-amplitude reflections similar to those ascribed to the SISZ in the footwall of the main segment of the MFC (Figure 5~~Figure 5Figure 4~~d-f). Phillips et al. (2016) argue that the Åsta Fault, a large N-S trending, W-dipping, post-Caledonian fault in the North Sea, formed during a phase of extensional reactivation of the Karmøy Shear Zone. Similarly, in western Norway, Wilks & Cuthbert (1994) proposed that the Hornelen Basin formed along a brittle fault that splayed upwards from the Nordfjord-Sogn Detachment Zone during Middle Devonian late-orogenic extension.

5.2. Formation of the WNW-ESE trending fault segment of the Troms-Finnmark Fault Complex as a hard-linked accommodation cross-fault

Our data (Figure 9~~Figure 9Figure 8~~a & b) show abrupt fault-controlled thickening of the Devonian-lower Carboniferous and upper Carboniferous sedimentary successions just northeast of the WNW-ESE trending segment of the TFFC into the southwesternmost Nordkapp basin. On the Finnmark Platform west, potential Devonian sedimentary rocks are truncated upwards by the mid-Carboniferous reflection~~, which we interpret as a major angular unconformity~~ (Figure 5~~Figure 5Figure 4~~e & f). ~~This unconformity may have been caused by a major eustatic sea-level fall in mid-Carboniferous (Serpukhovian) times that exposed large areas to coastal erosion (Saunders & Ramsbottom, 1986).~~ We propose~~, for example,~~ that the absence of high-amplitude, coal-bearing sedimentary deposits of the Billefjorden Group (lower Carboniferous) on the Finnmark Platform west is related to ~~this~~ a major episode of eustatic sea-level fall in the Serpukhovian (Saunders & Ramsbottom, 1986), which may have contributed to expose lower Carboniferous sedimentary rocks in this area to coastal erosion. Hence, part of the thickening of the Devonian-lower Carboniferous succession across the WNW-ESE trending segment of the TFFC might be related to extensive erosion of the Finnmark Platform west in mid-Carboniferous times. In addition, the clear deepening (plunge) to the northeast of the spoon-shaped trough formed by the three-

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dimensionally folded and bowed geometry of the SISZ (Figure 7~~Figure 7Figure 6~~) suggests that the thickening of Devonian-lower Carboniferous sedimentary strata into the southwesternmost Nordkapp basin (Figure 9~~Figure 9Figure 8~~a) is also partly controlled by the shape and attitudes of the underlying SISZ. Finally, the thickened sediment depocenter observed in the southwesternmost Nordkapp basin at the intersection of the TFFC and the MFC (Figure 9~~Figure 9Figure 8~~a & b) is at least partly related to syn-sedimentary normal faulting along the WNW-ESE trending fault segment of the TFFC and along the main segment of the MFC. This most likely indicates that the TFFC and the MFC had already merged and acted as a single fault zone during sediment deposition in the southwesternmost Nordkapp basin from the end of the Serpukhovian and potentially from Devonian times. We propose that the WNW-ESE trending fault segment of the TFFC acted as an accommodation cross-fault, as defined in Sengör (1987), that transferred displacement between the NNE-SSW trending segment of the TFFC and the main segment of the MFC, defining a step synthetic with the deepening direction of the spoon-shaped trough formed by the geometry of the SISZ (Figure 7~~Figure 7Figure 6~~). This interpretation is based on the dominant dip-slip kinematic of the WNW-ESE trending segment of the TFFC and on its sub-parallel strike to the dominant WNW-ESE trending extension direction inferred along the SW Barents Sea margin during late Paleozoic times (Bergh et al., 2007; Eig & Bergh, 2011; Hansen & Bergh, 2012). Further, we infer that the strike and location of the WNW-ESE trending segment of the TFFC was controlled by the geometry of the underlying SISZ (see below), which dips gently to the northeast on the Finnmark Platform west and in the southwesternmost Nordkapp basin and may therefore have favorized the formation of a NE-dipping fault at this location (Figure 5~~Figure 5Figure 4~~g & Figure 7~~Figure 7Figure 6~~).

Alternatively, Lea (2016) proposed that the WNW-ESE trending fault segment of the TFFC corresponds to a breached relay-ramp fault between the NNE-SSW trending fault segment of the TFFC and the MFC. However, this model implies that this portion of the TFFC would have accommodated significantly fewer displacement than the two faults it links (i.e. the NNE-SSW trending segment of the TFFC and the MFC), which is clearly not the case. The offset of the mid-Carboniferous reflection and the thickness increase both of the Middle/Upper Devonian-lower Carboniferous and upper Carboniferous sedimentary successions across the WNW-ESE trending segment of the TFFC are comparable to the offset and thickness increase observed across the main

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fault segment of the MFC (Figure 5~~Figure 5Figure 4~~c, d & g), and the TFFC and MFC seem to have evolved synchronously in the late Paleozoic.

5.3. Devonian collapse basins on the Finnmark Platform west (Gjesvær Low) and in the southwesternmost Nordkapp basin

~~Our seismic interpretation has shown that~~ Devonian sedimentary rocks in the SW Barents Sea may exist on the Finnmark Platform west and in the southwesternmost Nordkapp basin (Figure 5~~Figure 5Figure 4~~c-g). The most probable occurrence is on the Finnmark Platform west, in the hanging-wall of the main segment of the MFC (Figure 1~~Figure 1Figure 1~~, Figure 5~~Figure 5Figure 4~~e). The presumed Devonian seismic unit corresponds to a suite of low-amplitude reflections crosscut by a few, moderate-amplitude reflection that dip gently to the northeast (Figure 5~~Figure 5Figure 4~~e). The main argument for a Devonian ~~sequence~~ succession is that these reflections are remarkably different from the typical seismic patterns observed for lower Carboniferous sedimentary deposits and basement rocks. Lower Carboniferous sedimentary deposits of the Billefjorden Group are characterized by high-amplitude reflections produced by coal-bearing sedimentary rocks (Figure 5~~Figure 5Figure 4~~a & b and Figure 6~~Figure 6Figure 5~~a), while basement rocks are mostly associated with thick packages of chaotic seismic reflections (Figure 6~~Figure 6Figure 5~~a-c) and thick layers of moderate- to high-amplitude, sub-parallel seismic reflections that we interpreted as basement-seated shear zones (e.g. the SISZ; Figure 6~~Figure 6Figure 5~~f). Another argument in favor of Devonian sedimentary deposits is the presence of a NE-SW trending gravimetric low on the Finnmark Platform west: the Gjesvær Low (Johansen et al., 1994). Devonian sedimentary rocks in Svalbard show an average density of ca. 2.4 g.cm^{-3} associated to depths of 0-8 km (i.e. average depth of 4 km; Manby & Lyberis, 1992), which is less dense than metamorphosed Caledonian rocks (2.6-3.0 g.cm^{-3}) and Carboniferous sedimentary rocks on the Finnmark Platform west (< 2.5 g.cm^{-3}; Johansen et al., 1994). However, taking into account the effect of burial up to a depth of 5-6 km on the Finnmark Platform (Johansen et al., 1994) and the resulting density increase for Devonian sedimentary deposits with an approximate rate of ca. 0.15 g.cm^{-3}.km^{-1} (cf. “all rocks density-depth gradient” in table 3 in Maxant 1980), Devonian sedimentary rocks on the Finnmark Platform may reach densities 2.55-2.7 g.cm^{-3}. Thus, the occurrence of the Gjesvær low can be explained by the presence of intermediate-density Devonian

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sedimentary rocks below the mid-Carboniferous reflection (Figure 5~~Figure 5Figure 4~~e & Figure 6~~Figure 6Figure 5~~b & c). This is as well in accordance with density variations and related estimates of Johansen et al. (1994) in the Gjesvær low.

In addition, the discrete, moderate-amplitude, NW-dipping reflections observed within the presumed Devonian sedimentary strata on the Finnmark Platform west may represent syn-tectonic sedimentary growth strata (Figure 5~~Figure 5Figure 4~~e & Figure 6~~Figure 6Figure 5~~b & c). These strata are located above and thickened against arcuate, high-amplitude reflections that we interpreted as a major erosional unconformity that truncates SE-dipping Caledonian basement shear zones subparallel to the SISZ (dotted yellow lines in Figure 6~~Figure 6Figure 5~~b & c). We consider the Devonian sedimentary rocks on the Finnmark Platform west to have been deposited in wedge-shaped late/post-Caledonian extensional basins due to reactivation of a set of partly eroded, exhumed, SE-dipping Caledonian shear zones (dotted yellow lines in Figure 5~~Figure 5Figure 4~~e & Figure 6~~Figure 6Figure 5~~b & c). In mid-Norway, Braathen et al. (2000) reported a similar setting of Middle Devonian sedimentary basins located above Caledonian shear zones and folded nappe stack, and proposed that Middle Devonian basins in western and mid-Norway formed during extensional reactivation of these Caledonian shear zones. Such a model is further supported by the similar geometry of the Devonian sedimentary growth strata on the Finnmark Platform west to the highly tilted geometry of sedimentary strata in Middle Devonian basins in western Norway (cf. Séranne & Seguret, 1987; Séranne et al., 1989; Wilks & Cuthbert, 1994; Osmundsen & Andersen, 2001). Moreover, the Devonian sedimentary basins on the Finnmark Platform west (Figure 5~~Figure 5Figure 4~~e and Figure 6~~Figure 6Figure 5~~b & c) and in the southwestermost Nordkapp basin (Figure 5~~Figure 5Figure 4~~c & d) define NE-SW trending graben structures with comparable, < 50 km-wide sizes to those of the Middle Devonian Hornelen, Kvamsheten and Solund basins in western Norway (Séranne & Seguret, 1987; Osmundsen & Andersen, 2001).

In the southwesternmost Nordkapp basin, the presence of Middle/Upper Devonian sedimentary rocks is more speculative and is mostly based on the maximum thickness of lower Carboniferous sedimentary deposits registered in the SW Barents Sea, which is ca. 600 m on the Finnmark Platform east (Bugge et al., 1995; Figure 6~~Figure 6Figure 5~~d). Assuming a seismic velocity < 6 km.s^{-1} for lower Carboniferous coal-bearing sedimentary deposits, a thickness of 600 m would account for only part (maximum~~.~~ 0.2 s) of the 2-2.5 second-thick (TWT) seismic unit observed below the mid-Carboniferous reflection in the southwesternmost Nordkapp basin (Figure

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5~~Figure 5Figure 4~~c & d). If basement rocks were present at the base of the southwesternmost Nordkapp basin, they would most likely produce a seismic reflection pattern similar to that of the sub-parallel, high-amplitude reflections of the underlying SISZ (Figure 5~~Figure 5Figure 4~~c & d) or potentially form an unconformity to the overlying late Paleozoic sedimentary rocks. We therefore believe that the southwesternmost Nordkapp basin, which is bounded below by the SISZ, ~~which~~ giving~~es~~ the basin a peculiar "U" shape in cross-section (Figure 5~~Figure 5Figure 4~~c & d), ~~and~~ is composed of thick Middle/Upper Devonian sedimentary deposits overlain by lower Carboniferous sedimentary strata below the mid-Carboniferous reflection. ~~From these arguments, i.e.~~Based on the brittle extensional reactivation, bowed geometry and controlling effect of the basement-seated SISZ (Figure 7~~Figure 7Figure 6~~), we suggest deposition of Devonian sedimentary rocks within a late/post-Caledonian, spoon-shaped, collapse basin formed along bowed, inverted portions of the Caledonian SISZ (Figure 5~~Figure 5Figure 4~~c-f), thus representing analogs to Middle Devonian collapse basins in western and mid-Norway (Séranne et al., 1989; Wilks & Cuthbert, 1994).

5.4. Formation of NE-SW to ENE-WSW trending basement ridges as exhumed metamorphic core complexes

We have argued for an upward-bowed seismic geometry of the SISZ (Figure 5~~Figure 5Figure 4~~c-fFigure 7~~Figure 7Figure 6~~) into which major fault complexes such as the TFFC, the MFC and the Rolvsøya fault merge and sole into (Figure 5~~Figure 5Figure 4~~c-f). In map-view (Figure 7~~Figure 7Figure 6~~) and cross-section (Figure 5~~Figure 5Figure 4~~c-f), the bowed geometry of the SISZ defines two, ENE-WSW to NE-SW trending ridges of basement rocks on the northwestern flanks of presumed Devonian basins. These basement ridges correlate well by displaying high-positive gravimetric (fig. 5 in Olesen et al., 2010 and fig. 5 in Gernigon et al., 2014) and high-positive aeromagnetic anomalies (Figure 4~~Figure 4Figure 3~~; Gernigon et al. 2014) that suggest these ridges are made of basement lithologies significantly different from adjacent basement rocks on the Finnmark Platform west and in the southwesternmost Nordkapp basin. These basement ridges seem to align with high-positive gravimetric anomalies that coincide with the NE-SW trending Norsel High (Gabrielsen et al., 1990) along the northwestern flank of the Nordkapp Basin in the northeast. Farther southwest, these basement ridges coincide with the NE-SW trending West Troms Basement Complex in Western Troms (Bergh et al., 2010; Figure 1) and

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the NE-SW trending Lofoten Ridge in Lofoten-Vesterålen (Bergh et al., 2007; Figure 1), among which at least the Lofoten Ridge was exhumed as a metamorphic core complex (Klein & Steltenpohl, 1999; Klein et al., 1999; Steltenpohl et al., 2004; 2011) along inverted Caledonian shear zones such as the Eidsfjord and Fiskefjord shear zones (Steltenpohl et al., 2011). By comparison, the SISZ seems to coincide with high-positive aeromagnetic anomalies on the Finnmark Platform west that follow the trace of the MFC (Indrevær et al., 2013) and continue past the southwestern fault-tip of the MFC (Gernigon & Brönner, 2012). The aeromagnetic anomalies visible on the dataset Gernigon & Brönner (2012) appear to line up with aeromagnetic anomalies onshore the island of Vannøya, in the northeasternmost part of the West Troms Basement Complex (Figure 1), and these onshore anomalies correlate with NE-SW trending, SE-dipping basement shear zones that were reactivated as extensional brittle faults (Paulsen et al. pers. comm.~~; Figure 1~~).

These data indicate that SE-dipping portions of the SISZ propagated southwest of the MFC fault-tip on the Finnmark Platform west and possibly merged onshore Vannøya in Western Troms with a suite of NE-SW trending, SE-dipping shear zones. As a consequence, the basement ridges observed on the FinnmarkPlatform west and along the northern flank of the southwesternmost Nordkapp basin may have formed as part of a large metamorphic core complex, which included the Lofoten Ridge, the West Troms Basement Complex and possibly also the Norsel High (Figure 1~~Figure 1Figure 1~~), exhumed along inverted Caledonian shear zones, e.g.~~ such as the~~ SISZ on the SW Barents shelf and the analogous Eidsfjord and Fiskefjord shear zones in Lofoten-Vesterålen (Steltenpohl et al., 2011).

The timing, nature of uplift and processes of core complex exhumation can be inferred from thickness variations of the SISZ in cross-section, for example, thickest in the footwall of the MFC and TFFC and thinnest below these two fault complexes (Figure 5~~Figure 5Figure 4~~f). We link these thickness variations to excisement and incisement processes (cf. Lister & Davis, 1989) along the SISZ during core complex exhumation, after the embrittlement of the SISZ (Figure 10~~Figure 10Figure 9~~). A model of Devonian late/post-orogenic extension is proposed, when inversion of the SISZ ~~was inverted~~ as a low-angle, top-to-the-NW extensional detachment and extensive erosion of the Caledonides ~~that~~ contributed to crustal thinning~~ through top-to-the-NW tectonic transport~~ (Figure 10~~Figure 10Figure 9~~a). R~~elatively r~~apid thinning through extension and erosion above the upper part of the SISZ may have triggered early exhumation of basement rocks on the Finnmark

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Platform west and along the northern flank of the southwesternmost Nordkapp basin (Figure 10~~Figure 10Figure 9~~a), causing the upper part of the SISZ to bow upwards (Figure 10~~Figure 10Figure 9~~b). Continued crustal extension and continental erosion further enhanced exhumation of basement rocks below the upper part of the SISZ, leading the bowed portion of the SISZ to become unsuitably oriented to accommodate top-to-the-NW extensional displacement and ~~therefore~~ thus become inactive (dashed black line in Figure 10~~Figure 10Figure 9~~c). Further extension likely ~~led~~ triggered ~~the SISZ to splay~~ upwards splaying of the SISZ into its hanging-wall, becoming suitable again to accommodate top-to-the-NW extension displacement (Figure 10~~Figure 10Figure 9~~c). This upward splay-faulting process is referred to as excisement by Lister & Davis (1989) and we tentatively apply this process to explain the observed thickening of the SISZ in the footwall of the MFC (Figure 5~~Figure 5Figure 4~~f). Further extension/erosion-related crustal thinning along the SISZ may have initiated~~triggered the~~ exhumation of basement rocks along progressively deeper parts of the SISZ (Figure 10~~Figure 10Figure 9~~b & c), causing bend-up of the SISZ at ~~even~~ deeper crustal levels (Figure 10~~Figure 10Figure 9~~d). Extreme bowing of lower portions of the SISZ led to opposite top-to-the-SE transport direction on the Finnmark Platform west and in the southwesternmost Nordkapp basin (Figure 10~~Figure 10Figure 9~~d), which contributed to exhume NE-SW to ENE-WSW trending ridges of basement rocks in the footwall of the NNE-SSW trending segment of the TFFC (Figure 5~~Figure 5Figure 4~~e & f) and in the footwall of the Rolvsøya fault (Figure 5~~Figure 5Figure 4~~c & d), thus forming a large spoon-shaped trough where Devonian sedimentary rocks deposited (Figure 7 and Figure 10d & e). Incisement (downward splaying; cf. Lister & Davis, 1989) may have occurred below the basement ridges during continued top-to-the-NW extension along the SISZ (Figure 10~~Figure 10Figure 9~~e) and possibly contributed to thicken the SISZ in the footwall of the TFFC (Figure 5~~Figure 5Figure 4~~e & f) and of the Rolvsøya fault (Figure 5~~Figure 5Figure 4~~c & d), resulting in the current geometry of the SISZ (Figure 10~~Figure 10Figure 9~~f). ~~We believe that extreme bowing of lower portions of the SISZ and associated local top-to-the-SE displacement contributed to form the spoon-shaped trough in which Devonian sedimentary rocks are thought to be deposited on the Finnmark Platform west and in the southwesternmost Nordkapp basin (Figure 6 & Figure 9d & e).~~

By comparison, in northeast Greenland, Sartini-Rideout et al. (2006) and Hallett et al. (2014) proposed that ultra-high pressure (UHP) basement rocks were exhumed along large, mylonitic, Caledonian shear zones in Late Devonian-early Carboniferous times (ca. 370-340 Ma).

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The study of Sartini-Rideout et al. (2006) also shows that the last stages of exhumation were accommodated by steep, brittle normal faults that strike parallel to major Caledonian shear zones, i.e. similar to the main segment of the MFC ~~that strikes~~striking parallel to the SISZ along the SW Barents Sea margin (Figure 1~~Figure 1Figure 1~~). In addition, results from sediment provenance and geochronological studies by McClelland et al. (2016) in Carboniferous basins in northeast Greenland showed that the exhumation of UHP basement rocks as elongated ridges could have formed a regional Serpukhovian erosional unconformity, ~~i.e.~~ contemporaneous with the mid-Carboniferous (Serpukhovian?) unconformity observed on the Finnmark Platform east (Figure 5~~Figure 5Figure 4~~a & b and Figure 6~~Figure 6Figure 5~~a; Bugge et al., 1995) and on the Finnmark Platform west (Figure 5~~Figure 5Figure 4~~e-g & Figure 6~~Figure 6Figure 5~~b & c), and in agreement with eustatic sea-level fluctuations at that time (Saunders & Ramsbottom, 1986). ~~These observations are compatible with the results of Saunders & Ramsbottom (1986) who argued that major eustatic sea-level fluctuations occurred in Serpukhovian times and that these fluctuations included an episode of sea-level fall and continental erosion around 330 Ma in the early Serpukhovian, and an episode of sea-level rise at ca. 325 Ma at the end of the Serpukhovian.~~ In late Paleozoic times, the northeast Greenland margin was located close to its conjugate counter-part of the SW Barents Sea margin and these two areas were most likely subjected to similar regional stresses and closely related sea-level fluctuations. Therefore, we suggest that the mid-Carboniferous unconformity reflection observed in the SW Barents Sea (cf. Figure 5~~Figure 5Figure 4~~ & Figure 6~~Figure 6Figure 5~~a-c; Bugge et al., 1995), formed as a response to major eustatic sea-level fall in the early Serpukhovian (Saunders & Ramsbottom, 1986) and due to large-scale exhumation of basement rocks in Late Devonian-early Carboniferous times. Exhumation occurred along inverted Caledonian shear zones (e.g. SISZ) and brittle splay faults such as the main segment of the MFC, the NNE-SSW trending segment of the TFFC, the Rolvsøya fault and the NNE-SSW trending, SE-dipping fault that bounds potential Devonian sedimentary strata on the Finnmark Platform west ~~to the northwest~~ (Figure 5~~Figure 5Figure 4~~). The timing of exhumation ~~can be~~ is constrained to the end of the Serpuhkovian based on deposition of thick alluvial and shallow marine upper Carboniferous sedimentary deposits of the Gipsdalen Group (Figure 3~~Figure 3~~) on top of the mid-Carboniferous unconformity in the SW Barents Sea (Figure 5~~Figure 5Figure 4~~)~~, associated with~~ during an eustatic sea-level rise near ~~in~~ the end of the Serpukhovian (Saunders & Ramsbottom, 1986).

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In Lofoten-Vesterålen, Steltenpohl et al. (2004) inferred a Late Devonian age for the exhumation of metamorphic core complexes and this age was refined by recent ^{40}Ar/^{39}Ar isotopic results (Steltenpohl et al., 2011), which constrained extensional reactivation of the Eidsfjord shear zone to the Early Devonian. In the SW Barents Sea, much work is needed to better constrain the timing of late/post-Caledonian extension and collapse basin formation. Nonetheless, we believe that the Early Devonian age obtained in Lofoten-Vesterålen (Steltenpohl et al., 2011) represents a reasonable estimate for the onset of crustal thinning in the SW Barents Sea (Figure 10~~Figure 10Figure 9~~a-c). Additionally, Late Devonian-early Carboniferous timing of exhumation for basement rocks in northeast Greenland and formation of a regional mid-Carboniferous (Serpukhovian) unconformity (Sartini-Rideout et al., 2006; Hallett et al., 2014; McClelland et al., 2016) corresponds to a realistic approximation for the final stages of late/post Caledonian extension, ending with the formation of Devonian-Carboniferous collapse basins along exhumed, NE-SW to ENE-WSW trending basement ridges (Figure 10~~Figure 10Figure 9~~d-f).

5.5. Interaction of the Trollfjorden-Komagelva Fault Zone with the Troms-Finnmark and Måsøy fault complexes

The prolongation of the TKFZ from onshore areas in eastern Finnmark to offshore areas of the SW Barents Sea has been a matter of debate. Most studies tend to connect the onshore TKFZ with the offshore WNW-ESE trending fault segment of the TFFC (Gabrielsen, 1984; Gabrielsen & Færseth, 1989; Roberts et al., 2011; Bergø, 2016; Lea, 2016). Our data, however, suggest that the TKFZ dies out near the coasts of NW Finnmark (present contribution and Koehl et al., submitted), and in this section we review and discuss new evidence obtained from the interpretation of offshore seismic and aeromagnetic data.

First, the TKFZ was described onshore eastern Finnmark as a major sub-vertical fault that accommodated dominantly strike-slip movement (Roberts, 1972; Rice, 2013). Farther west, the TKFZ crops out onshore Magerøya, where it is made of numerous, high-frequency, subparallel, subvertical, WNW-ESE trending faults and fractures that accommodated at least small-scale post-Caledonian, strike-slip to oblique-slip displacement (Koehl et al., submitted). By contrast, seismic interpretation of the WNW-ESE trending fault segment of the TFFC shows that this fault exhibits a typical, high-angle (ca. 70°) normal fault geometry and accommodated significant amount of

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post-Caledonian normal dip-slip displacement (Figure 5~~Figure 5Figure 4~~g),~~.~~ ~~T~~thus~~,~~ contrasting significantly with the geometry~~ies~~ of the TKFZ~~ and of the WNW-ESE trending segment of the TFFC contrast significantly with each other~~. Second, the imaginary prolongation of the TKFZ from the island of Magerøya to the WNW, onto the Finnmark Platform, would crosscut the Finnmark Platform west nearly 23 km southwest of the observed trace of the WNW-ESE trending segment of the TFFC (Figure 5~~Figure 5Figure 4~~g). This represents a~~n~~ significant mismatch that is far too important to represent minor dextral strike-slip offset of the TKFZ across the main fault segment of the MFC, which dominantly accommodated normal dip-slip motions (Figure 5~~Figure 5Figure 4~~c-f). Third, the interpretation of 3D seismic data at the intersection of the MFC and TFFC reveals that the footwall of the MFC is largely intact and~~or~~ seismically unaffected by brittle faults (Figure 8~~Figure 8Figure 7~~). There is ~~rather ~~no~~t~~ ~~any ~~evidence of intense fracturing as typically observed along the TKFZ onshore Magerøya (Koehl et al., submitted). We therefore believe that the TKFZ and the WNW-ESE trending fault segment of the TFFC represent two distinct faults. This~~ese data more likely~~ suggests that the TKFZ dies out instead of propagating onto the Finnmark Platform~~, and that the WNW-ESE trending fault segment of the TFFC does not continue through the MFC~~. This ~~interpretation ~~is also supported by the absence of ~~other ~~WNW-ESE trending ~~offshore ~~faults offshore (Figure 1 & Figure 2)~~., such as~~ For example, the Austhavet fault previously interpreted near the coasts of Finnmark (Townsend, 1987b; Lippard & Roberts, 1987; Roberts et al., 2011)~~.~~ ~~We ~~was re-interpreted~~ the Austhavet fault~~ as seismic artifacts related to the Djuprenna trough, a large glacial trough that trends parallel to the northeastern coast of Finnmark (Ottesen et al., 2008; Rise et al., 2015). ~~Such a~~ This re-interpretation~~conclusion~~ is supported by shallow drillings on the Finnmark Platform east, which show~~ing~~ no sign of fault-related offset ~~o~~in this part of the Finnmark Platform east (cf. fig. 4 in Bugge et al., 1995). Similarly, our mapping and regional analysis of brittle faults on the Finnmark Platform show very few occurrences of WNW-ESE trending faults (Figure 1~~Figure 1Figure 1~~ & Figure 2~~Figure 2Figure 2~~).

O~~ur o~~nshore studies (Koehl et al., submitted) show an increased number of large-scale WNW-ESE trending fault segments and splays along the TKFZ, varying from a single-segment fault onshore the Varanger Peninsula in eastern Finnmark ~~(Figure 1) ~~to multiple segments onshore and nearshore Magerøya (Figure 1)~~.~~ ~~This ~~suggesting~~s~~ that the island of Magerøya is located near the fault-tip process zone (Shipton & Cowie, 2003; Braathen et al., 2013) of the TKFZ, and that the TKFZ therefore dies out to the west before reaching the Finnmark Platform and the

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southwesternmost Nordkapp basin (Figure 1; Koehl et al. submitted). Nearby Magerøya and the Nordkinn Peninsula, high-resultion aeromagnetic data reveal the presence of highly magnetic dolerite dykes along WNW-ESE trending fault segments of the TKFZ (Roberts et al., 1991; Nasuti et al., 2015; Koehl et al., submitted). These narrow, high-positive aeromagnetic anomalies also die out westwards (Gernigon & Brönner, 2012; Gernigon et al., 2014), therefore supporting that the dolerite dykes and, thus, the TKFZ ~~may~~ die out before reaching the Finnmark Platform (Koehl et al., submitted).

~~-~~We explore ~~consider~~ an alternative model to the fault-tip process zone of Koehl et al. (submitted)~~.~~ in which ~~W~~we argue that~~, during the Caledonian Orogeny,~~ the Precambrian, orogen-parallel, WNW-ESE trending TKFZ was ~~oriented subparallel to the dominant top-to-the-SE transport direction of Caledonian thrusts in northern Norway (Townsend, 1987a) and thus~~ not suitably oriented to be reactivated as a major thrust or strike-slip fault during the Caledonian Orogeny. ~~Instead, o~~Our data indicate that if the TKFZ extended farther west~~ onto the Finnmark Platform west~~ prior to the onset of Caledonian deformation, it was certainly ~~and was~~ truncated and decapitated by large-scale, top-to-the-SE movement along the SISZ and associated NE-SW trending, Caledonian thrusts and shear zones~~ during top-to-the-SE thrusting,~~. This is supported by dominant top-to-the-SE transport direction inferred along Caledonian thrusts onshore NW Finnmark (Townsend, 1987a). Thus, we propose that the western continuation of the TKFZ ~~on~~ below the Finnmark Platform may have been ~~transported/~~thrusted southeastwards along the SISZ and is now ~~most likely~~ eroded. However, if the TKFZ ever extended westwards, portions of ~~the~~ its western prolongation ~~of the TKFZ~~ might~~ay~~ ~~have~~ be~~en~~ preserved ~~offshore~~ in offshore basement highs such as the Loppa and Veslemøy highs (Figure 1~~Figure 1Figure 1~~)~~, assuming that the TKFZ extended west of Magerøya into the SW Barents Sea prior to the Caledonian Orogeny~~. More work is needed on this hypothesis, but a possible insight is ~~This is supported by~~ the recent observation of subvertical, WNW-ESE trending brittle faults analog to the TKFZ ~~on~~ in basement rocks of the Veslemøy High (Kairanov et al., 2016).

5.6. Late Paleozoic evolution of the SW Barents Sea margin

Based on the seismic data and discussions from previous chapters we now address the tectonic evolution of the Finnmark Platform and the southwesternmost Nordkapp basin in the late

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Paleozoic (Figure 11~~Figure 11Figure 10~~). The main structural element discussed in our model is the SISZ and we link its influence on (i) the development of the southwesternmost Nordkapp basin, (ii) the geometry of the TFFC and MFC, (iii) the deposition of Mid/Late Devonian sedimentary rocks in the southwesternmost Nordkapp basin and on the Finnmark Platform west, (iv) transfer faults such as the TKFZ and (v) the deposition of syn-tectonic sedimentary wedges along steep normal faults that bound triangular-shaped, Carboniferous basins~~ in the Carboniferous~~.

~~We have demonstrated the presence of major, basement-seated, Caledonian shear zones on the Finnmark Platform west and below the southwesternmost Nordkapp basin. The largest of these shear zones is the SISZ, which strikes NE-SW and dips to the northwest (Figure 4c-g & Figure 5f).~~ The trend and dominant northwestern dip of the SISZ (Figure 5c-g & Figure 6f) ~~is shear zone~~ suggest that it formed as a large thrust that accommodated top-to-the-SE tectonic transport during the Caledonian Orogeny. The SISZ has a bow-shaped, three-dimentionally folded geometry that coincides with basement ridges in the footwall of the TFFC and of the Rolvsøya fault (Figure 5~~Figure 5Figure 4~~c-f, Figure 7~~Figure 7Figure 6~~ and Figure 11~~Figure 11Figure 10~~). We propose that the SISZ and potential other Caledonian shear zones along the SW Barents Sea margin were inverted as low-angle extensional shear zones during late/post-Caledonian orogenic extension and subsequent collapse. This is based on analog examples in northeast Greenland (Sartini-Rideout et al., 2006; Hallett et al., 2014; McClelland et al., 2016), western Norway (Séranne & Seguret, 1987; Séranne et al., 1989; Wilks & Cuthbert, 1994; Osmundsen & Andersen, 2001), mid-Norway (Braathen et al., 2000) and Lofoten-Vesterålen (Klein & Steltenpohl, 1999; Klein et al., 1999; Steltenpohl et al., 2004; 2011; Osmundsen et al., 2005). Extensional reactivaton of such ductile shear zones along the Barents Sea margin may~~ight~~ have initiated in the Early Devonian, as in Lofoten-Vesterålen (Steltenpohl et al., 2011), through ~~by crustal thinning and~~ orogenic collapse ~~through~~ dominated by ~~dominant~~ top-to-the-NW ~~displacement~~ movement along the SISZ.~~ and later~~

~~e~~

Exhumation of the SISZ and underlying basement ridges as a metamorphic core complex was probably triggered by extensional reactivation of the SISZ combined to continental erosion, leading to crustal thinning. Reactivation of these exhumed basement ridges occurred by normal faulting along new, steep, brittle faults such as the main segment of the MFC and the NNE-SSW trending fault segment of the TFFC (cf. Figure 5~~Figure 5Figure 4~~f), likely due to incisement and excisement processes (Figure 10~~Figure 10Figure 9~~; Lister & Davis, 1989). These processes also

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contributed to ~~a~~ the progressive exhumation of ~~basement rocks as~~ ENE-WSW and NE-SW trending basement ridges along bowed portions of the SISZ (cf. Figure 5~~Figure 5Figure 4~~c-f and Figure 11~~Figure 11Figure 10~~a & b). We believe that these ridges were part of a larger-scale NE-SW trending metamorphic core complex that included the Norsel High and the two basement ridges located in the footwall of the TFFC and the Rolvsøya fault. Farther south, this core complex may be linked to the West Troms Basement Complex (Bergh et al., 2010) and the Lofoten Ridge (Blystad et al., 1995; Figure 11~~Figure 11Figure 10~~). Such a regional link is favored by the alignement of NE-SW trending, high-positive gravimetric anomalies that characterize these ridges (Olesen et al., 2010; Gernigon et al., 2014). The timing of final core complex exhumation can be constrained to Mid/Late Devonian-early Carboniferous and possibly linked to the regional Serpukhovian unconformity on the Finnmark Platform (cf. Figure 5~~Figure 5Figure 4~~a, b, e, f & g and Figure 6~~Figure 6Figure 5~~a-c; Bugge et al., 1995), in accordance with Sartini-Rideout et al. (2006) and Hallett et al. (2014) in northeast Greenland.

The exhumation of basement ridges as metamorphic core complexes along the inverted SISZ and subsequent normal faulting along the MFC and TFFC created a deep, spoon-shaped topographic depression on the Finnmark Platform west and in the southwesternmost Nordkapp basin (Figure 5~~Figure 5Figure 4~~c, d, e & g, Figure 6~~Figure 6Figure 5~~b & c and Figure 11~~Figure 11Figure 10~~a). These depressions were filled with thick Devonian clastic deposits analog to those observed in Middle Devonian collapse basins in western Norway (Séranne et al., 1989; Osmundsen & Andersen, 2001), and with lower Carboniferous coal-bearing and clastic sedimentary rocks of the Billefjorden Group (Figure 3~~Figure 3~~) deposited unconformably above Devonian strata (cf. Figure 11~~Figure 11Figure 10~~b). These collapse basins are also likely responsible for the gravimetric low observed on the Finnmark Platform west,~~:~~ the Gjesvær Low (Figure 4~~Figure 4Figure 3~~).

On the Finnmark Platform west, the final stages of core complex exhumation and a major phase of eustatic sea-level fall in the Serpukhovian (Saunders & Ramsbottom, 1986) led to extensive erosion of Devonian and lower Carboniferous sedimentary rocks, therefore explaining the absence of lower Carboniferous sedimentary deposits and the erosional truncation of Devonian sedimentary strata along this part of the margin (Figure 5~~Figure 5Figure 4~~e-g & Figure 6~~Figure 6Figure 5~~b & c). On the Finnmark Platform east, lower Carboniferous sedimentary rocks are preserved as minor syn-tectonic sedimentary wedges within small triangular grabens and half-grabens that correlate with aeromagnetic lows (dashed white line in Figure 4~~Figure 4Figure 3~~).

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These grabens are bounded by zigzag-shaped, Late Devonian-Carboniferous normal faults such as the LVF (Figure 5~~Figure 5Figure 4~~a & b and Figure 6~~Figure 6Figure 5~~a; Koehl et al., submitted), which coincide with narrow, high-positive aeromagnetic anomalies (cf. Figure 4~~Figure 4Figure 3~~ and black vertical arrows in Figure 5~~Figure 5Figure 4~~a & b). In addition, triangular basins like the graben bounded by the LVF and the southwesternmost Nordkapp basin were partly offset and segmented by WNW-ESE trending transfer faults that accommodated small amount of strike-slip ~~displacement~~motion. Examples include the TKFZ onshore NW Finnmark, which may offset~~s~~ the LVF in a right-lateral fashion (Koehl et al., submitted), and accommodation cross-faults (Sengör, 1987) that accommodated large amount of orogen-parallel extension through normal dip-slip movement, ~~for example~~e.g. the WNW-ESE trending fault segment of the TFFC (Figure 5~~Figure 5Figure 4~~g and Figure 9~~Figure 9Figure 8~~a).

In the late Serpukhovian, a regional episode of eustatic sea-level rise (Saunders & Ramsbottom, 1986) flooded the Finnmark Platform east and west and allowed the deposition of sedimentary rocks of the upper Carboniferous Gipsdalen Group (Figure 3~~Figure 3~~). These rocks occur as syn-tectonic sedimentary wedges that thicken in the hanging-wall of basin-bounding normal faults such as the LVF on the Finnmark Platform east and the main segment of the MFC on the Finnmark Platform west (Figure 5~~Figure 5Figure 4~~a, b, e & f and Figure 11~~Figure 11Figure 10~~c). Similarly, in the southwesternmost Nordkapp basin, which may have remained flooded through the entire phase of eustatic sea-level fall and core complex exhumation, thick, partly evaporitic, upper Carboniferous sedimentary rocks were deposited in the basin and these are thickest at the intersection ~~between~~ of the TFFC and the MFC (Figure 5~~Figure 5Figure 4~~c, d & g and Figure 9~~Figure 9Figure 8~~b). Thus, the thickening of upper Carboniferous strata probably reflects significant syn-sedimentary normal faulting along these two faults, which may have acted as a single fault during in the final stage of extension in the late Carboniferous (Figure 11~~Figure 11Figure 10~~c).

Most faults on the Finnmark Platform east and west and in the southwesternmost Nordkapp basin appear to die out below the Base Asselian reflection and those that propagate through the Base Asselian reflection show limited amount of offset within Permian and Mesozoic-Cenozoic sedimentary strata (Figure 5~~Figure 5Figure 4~~). Moreover, the Permian sedimentary succession shows a rather constant thickness through the entire study area (Figure 5~~Figure 5Figure 4~~ & Figure 9~~Figure 9Figure 8~~c). Thus, we argue that late/post-Caledonian extensional faulting linked to the collapse of the Caledonides essentially took place in the Mid/Late Devonian-Carboniferous and came to a halt towards the end of this Period~~e late Carboniferous~~ (Figure 11~~Figure 11Figure 10~~d). This presumed timing is consistent with recent K/Ar radiometric dating of brittle fault gouges in Western Troms (Davids et al., 2013) and in NW Finnmark (Torgersen et al., 2014; Koehl et al., 2016), as well as with radiometric dating of dolerite dykes in NW Finnmark (Lippard & Prestvik, 1997), eastern Finnmark (Guise & Roberts, 2002) and on the Kola Peninsula in Russia (Roberts & Onstott, 1995), which constrain significant extensional faulting activity onshore northern Norway and adjacent areas in Russia to the Late Devonian-early/mid Permian. Minor reactivation of major fault complexes occurred in the Mesozoic-Cenozoic and are most likely associated with the rifting of the NE Atlantic (Faleide et al., 2008).

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6. Conclusions

1) The atypically linear, NE-SW trending, main fault segment of the Måsøy Fault Complex formed as a brittle splay of the inverted Caledonian Sørøya-Ingøya shear zone through excisement processes during the collapse of the Caledonides in the Mid/Late Devonian-early Carboniferous and was active until the end of the late Carboniferous.

2) The WNW-ESE trending fault segment of the Troms-Finnmark Fault Complex developed as a hard-linked, accommodation cross-fault that accommodated orogen-parallel, late/post-orogen extension in the Mid/Late Devonian-Carboniferous. This fault merged with the main fault segment of the Måsøy Fault Complex and the two faults acted as a single fault at least during the late Carboniferous, but potentially from Devonian-early Carboniferous times, and accommodated the deposition of thick Devonian-lower Carboniferous and partly evaporitic upper Carboniferous deposits in the southwesternmost Nordkapp basin before faulting came to a halt towards the end of the late Carboniferous.

3) Low-gravity anomalies in the Gjesvær Low and southwesternmost Nordkapp basin may result from the presence of a thick, Mid/Late Devonian, spoon-shaped sedimentary basin that developed along an inverted, bowed portion of the Sørøya-Ingøya shear zone during the collapse of the Caledonides and that display a geometry similar to those of Middle Devonian, late/post-orogenic collapse basins in western and mid-Norway.

4) The ENE-WSW and NE-SW trending basement ridges in the footwall of the Troms-Finnmark Fault Complex and on the northern flank of the southwesternmost Nordkapp basin formed through incisement processes and were exhumed along a bowed portion of the Sørøya-Ingøya shear zone during the collapse of the Caledonides in the Mid/Late Devonian-early Carboniferous. These basement ridges are thought to be part of a large-scale, margin-parallel, NE-SW trending, metamorphic core complex that includes a succession of aligned basement highs such as the Lofoten Ridge, the West Troms Basement Complex and the Norsel High. Core complex exhumation is believed to have stopped by the end of the Serpukhovian when a major eustatic sea-level rise flooded the Finnmark Platform, leading to the deposition of widespread upper Carboniferous sediments.

5) The Sørøya-Ingøya shear zone is thought to have truncated and decapitated Precambrian faults such as the Trollfjorden-Komagelva Fault Zone through top-to-the-SE thrusting during the Caledonian Orogeny and subsequent late/post-orogenic extension. We nevertheless believe that preserved segments of these Precambrian faults might be preserved offshore on basement highs such as the Loppa and Veslemøy highs. However, more work is required in order to map and evaluate the impact of these WNW-ESE trending, subvertical Precambrian faults on the SW Barents Sea margin.

Data availability

The seismic data analyzed in this study are part of the DISKOS database and are publicly accessible from any Norwegian academic institution. Aeromagnetic data discussed in the present contribution are from Gernigon et al. (2014).

Author contribution

Jean-Baptiste Koehl interpreted the seismic and aeromagnetic data and is the main contributor to the writing process (work-load ca. 45 %). Professor Steffen Bergh provided significant input to the “Introduction” and “Geological Setting” sections as well as detailed critical reviews of the whole manuscript (work-load ca. 30 %). Tormod Henningsen helped initiating the project and provided help with seismic well-ties and regional seismic interpretation (work-load ca.

15 %). Professor Jan-Inge Faleide provided help with the writing process and helped improve the margin evolution model (work-load ca. 10 %).

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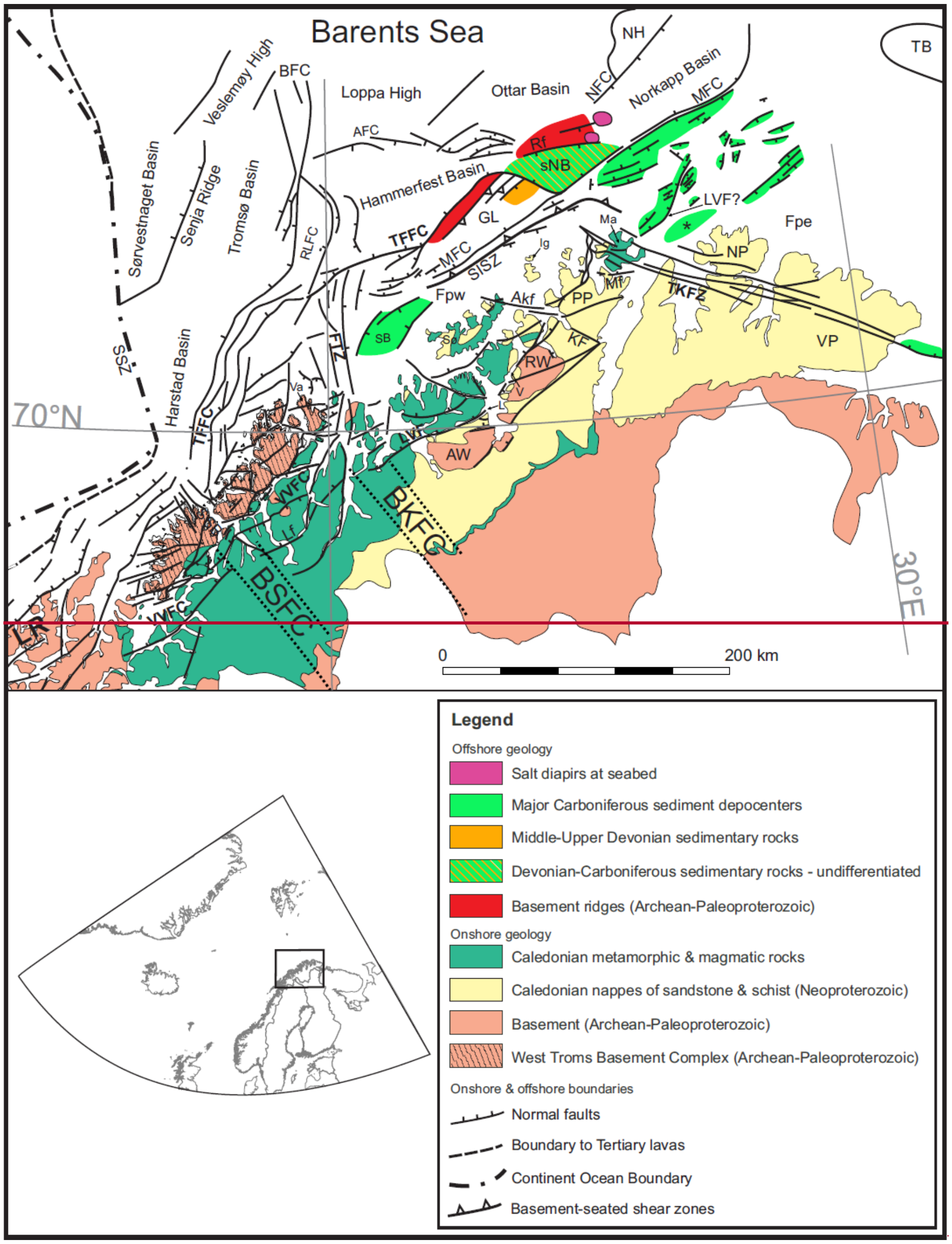
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Loppa High
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Norkapp Basin
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Hammerfest Basin
GL
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LVF?
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Sørvestnaget Basin
Senja Ridge
Tromsø Basin
RLFC
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Harstad Basin
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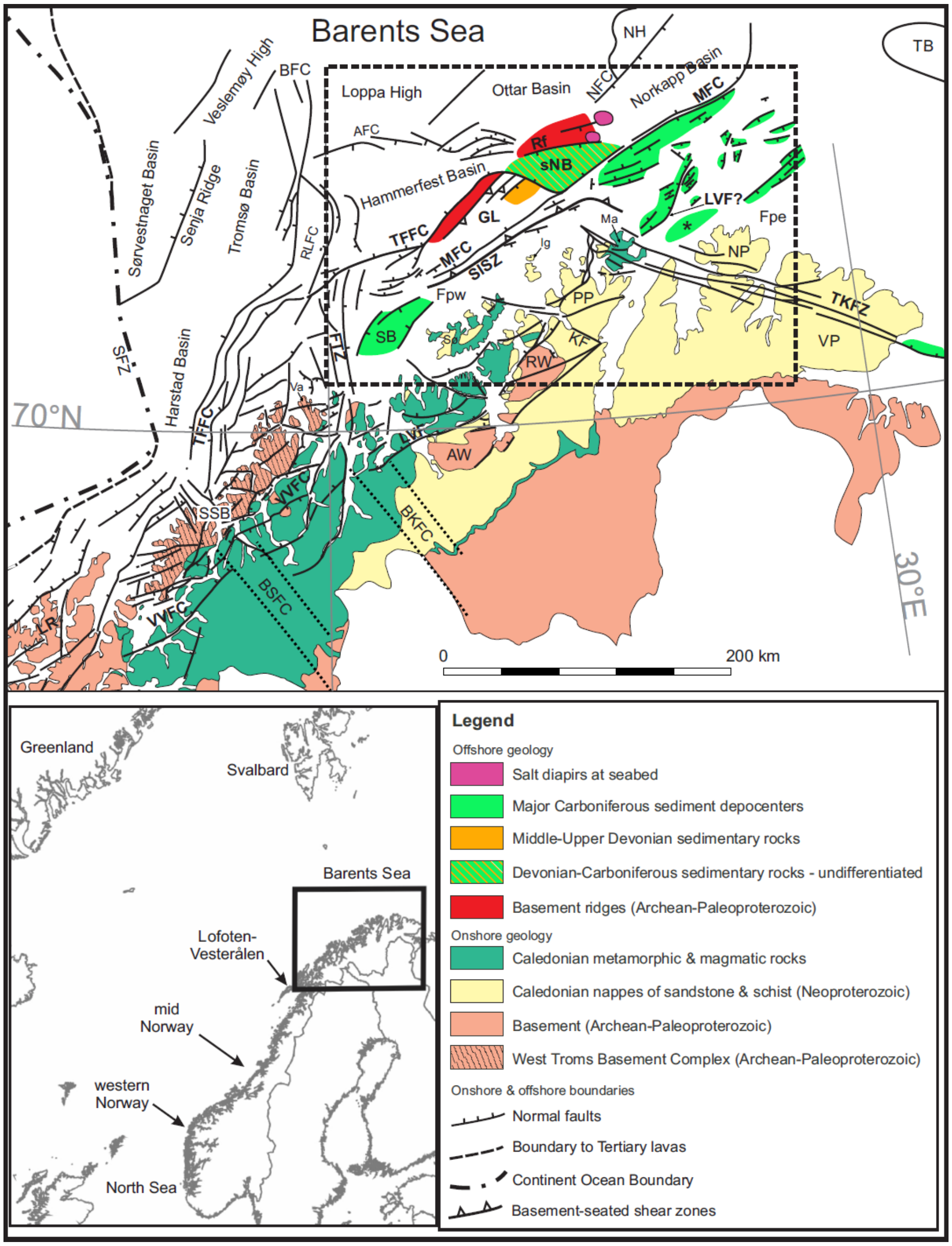
Legend
Offshore geology
Salt diapirs at seabed
Major Carboniferous sediment depocenters
Middle-Upper Devonian sedimentary rocks
Devonian-Carboniferous sedimentary rocks - undifferentiated
Basement ridges (Archean-Paleoproterozoic)
Onshore geology
Caledonian metamorphic & magmatic rocks
Caledonian nappes of sandstone & schist (Neoproterozoic)
Basement (Archean-Paleoproterozoic)
West Troms Basement Complex (Archean-Paleoproterozoic)
Onshore & offshore boundaries
Normal faults
Boundary to Tertiary lavas
Continent Ocean Boundary
Basement-seated shear zones



Barents Sea
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RW
Sørvestnaget Basin
Senja Ridge
Tromsø Basin
RLFC
SFZ
Harstad Basin
FTZ
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SSB
WFC
BKFC
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VVFC
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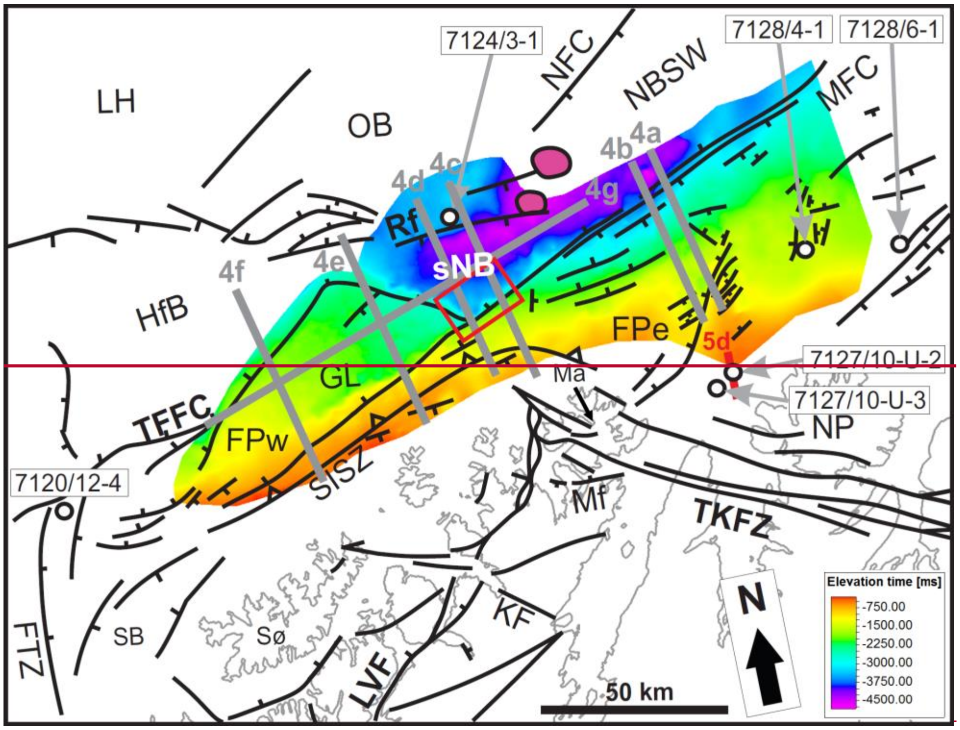
Greenland
Svalbard
Barents Sea
Lofoten-Vesterålen
mid Norway
western Norway
North Sea
Legend
Offshore geology
Salt diapirs at seabed
Major Carboniferous sediment depocenters
Middle-Upper Devonian sedimentary rocks
Devonian-Carboniferous sedimentary rocks - undifferentiated
Basement ridges (Archean-Paleoproterozoic)
Onshore geology
Caledonian metamorphic & magmatic rocks
Caledonian nappes of sandstone & schist (Neoproterozoic)
Basement (Archean-Paleoproterozoic)
West Troms Basement Complex (Archean-Paleoproterozoic)
Onshore & offshore boundaries
Normal faults
Boundary to Tertiary lavas
Continent Ocean Boundary
Basement-seated shear zones

Figure 1: Regional structural map of the SW Barents Sea margin (based on Bergh et al. 2007, Faleide et al. 2008, Hansen et al. 2012 and Indrevær et al. 2013 and Koehl et al. submitted). The onshore geology is from the NGU and Ramberg et al. (2008). Dashed black frame locates Figure 2~~Figure 2~~. The black star marks the location of the speculated half-graben structure described in Bugge et al. (1995), which we reinterpret as a prograding sedimentary system unconformably resting on basement rocks. Location of the Barents Sea shown as a black frame in lower left inset map. Abbreviations: AFC = Asterias Fault Complex; ~~Akf = Akkarfjord fault;~~ AW = Alta-Kvænangen tectonic window; BFC = Bjørnøyrenna Fault Complex; BSFC = Bothnian-Senja Fault Complex; BKFC = Bothnian-Kvænangen Fault Complex; FPe = Finnmark Platform east; FPw = Finnmark Platform west; FTZ = Fugløya transfer zone; GL = Gjesvær Low; Ig =Ingøya; KF = Kokelv Fault; ~~L = Langfjorden; Lf = Laksvatn fault;~~ LR = Lofoten Ridge; LVF = Langfjord-Vargsund fault; Ma = Magerøya; ~~Mf = Magerøysundet fault;~~ MFC = Måsøy Fault Complex; NFC = Nysleppen Fault Complex; NH = Norsel High; NP = Nordkinn Peninsula; PP = Porsanger Peninsula; Rf = Rolvsøya fault; RLFC = Ringvassøya-Loppa Fault Complex; RW = Repparfjord-Komagfjord tectonic window; SB = Sørvær Basin; SFZ = Senja Fracture Zone; SISZ = Sørøya-Ingøya shear zone; sNB = southwesternmost Nordkapp basin; SSB = S~~ørøy sub-basin~~enja Shear Belt; ~~SSZ = Senja Shear Zone;~~ Sø = Sørøya; TB = Tiddlybanken Basin; TFFC = Troms-Finnmark Fault Complex; TKFZ = Trollfjorden-Komagelva Fault Zone; ~~V = Vargsund;~~ Va = Vannøya; VP = Varanger Peninsula; VVFC = Vestfjorden-Vanna fault complex.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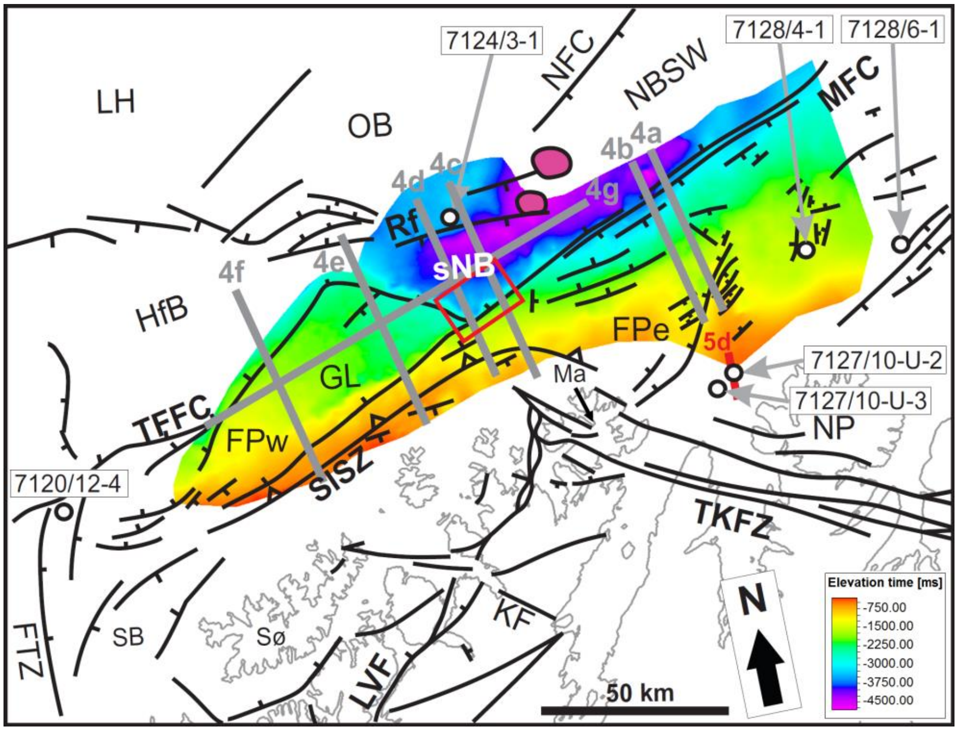

Figure 2: Regional structural map summarizing the architecture of the Finnmark Platform east (FPe) and west (FPw) and of the southwesternmost Nordkapp basin (sNB). The figure includes a time map of the interpreted mid-Carboniferous reflection. Grey lines show the location of seismic profiles displayed in Figure 5~~Figure 5Figure 4~~a-g, the red line displays the location of the seismic section shown in Figure 6~~Figure 6Figure 5~~d and the red frame indicates the location of seismic Z-slices described in Figure 8~~Figure 8Figure 7~~. White dots show the location of exploration wells and shallow drill-cores while purple blobs represent major salt diapirs in the southernmost part of the Nordkapp Basin (NBSW). See Figure 1~~Figure 1Figure 1~~ for abbreviations.

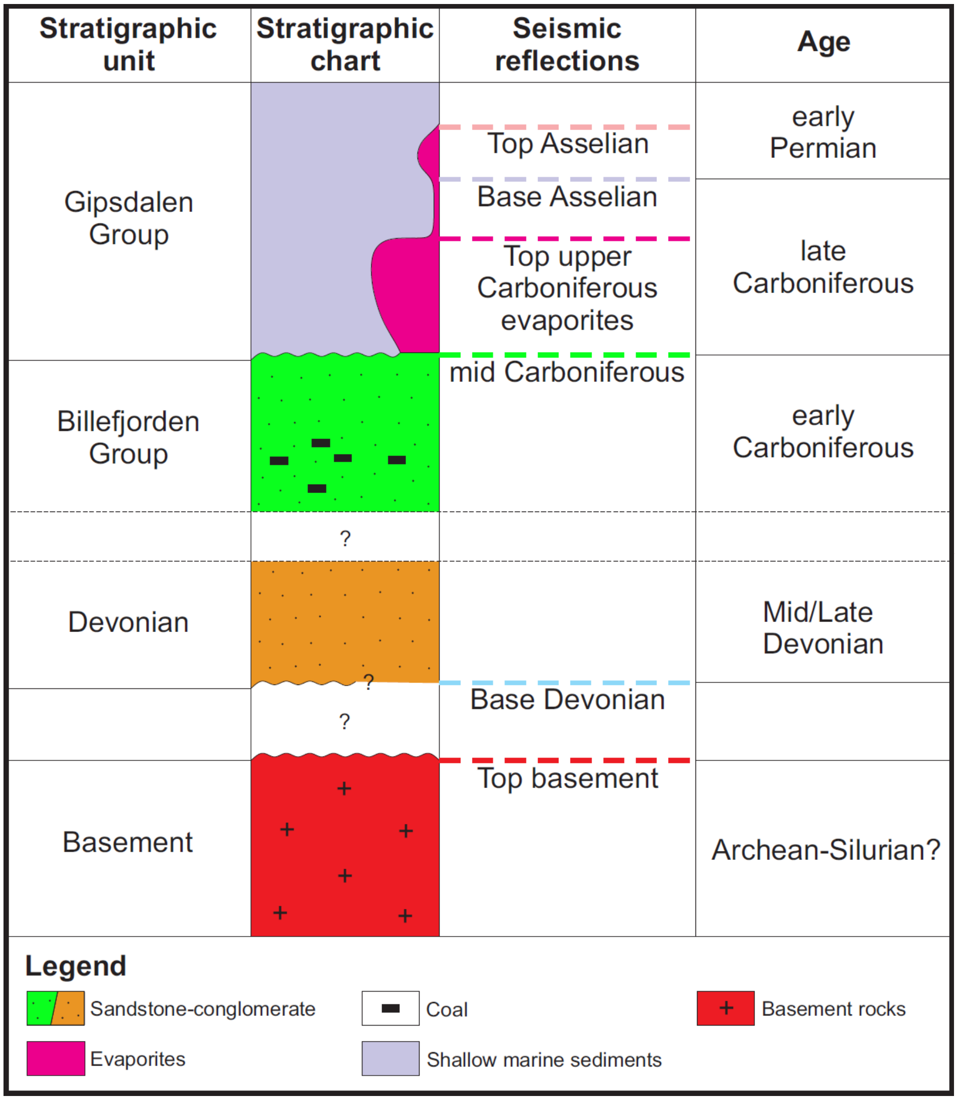

Figure 3: Simplified stratigraphic chart of late Paleozoic sedimentary successions on the Finnmark Platform and in the southwesternmost Nordkapp basin. From left to right, columns indicate the unit name, the the successions dominant lithologies and types of succession boundaries (undulating lines = erosional unconformity; straight line = conformity; dashed lines = uncertain), interpreted seismic reflections (cf. Figure 4~~Figure 4~~ & Figure 5~~Figure 5~~) and the units age. Lithological legend at the bottom.

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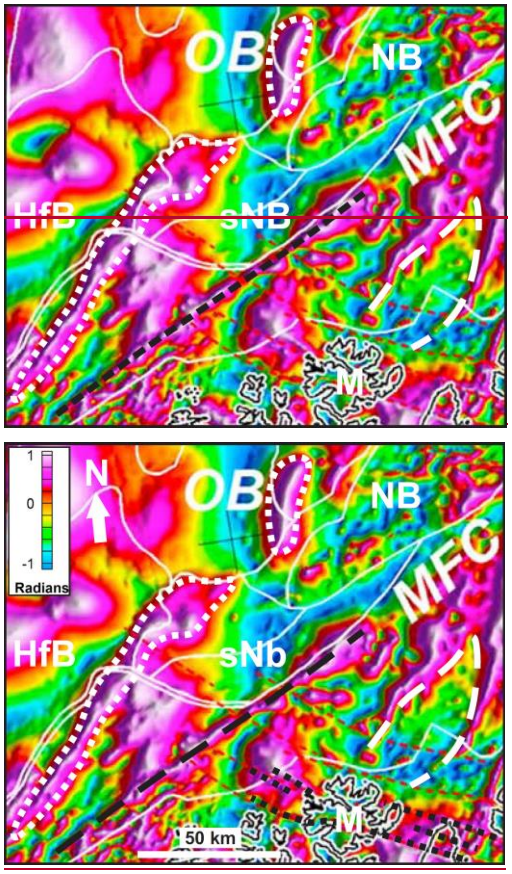
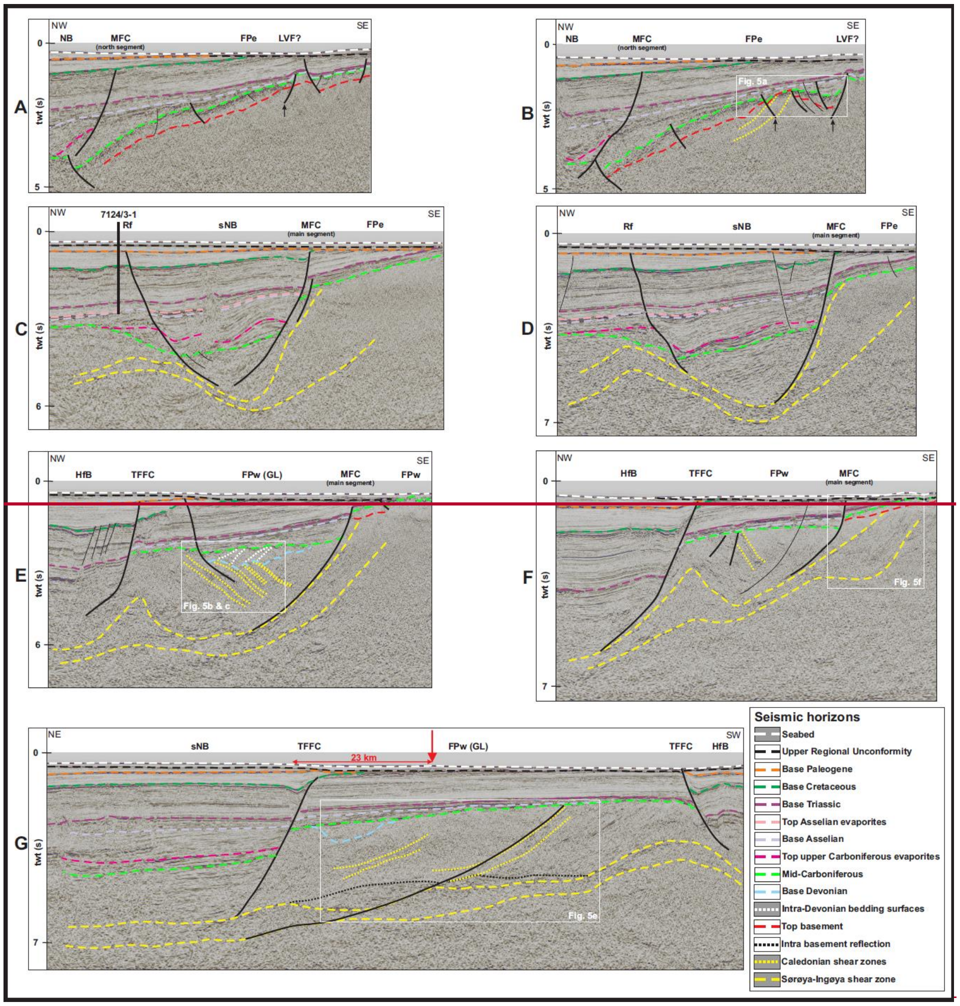


Figure 4~~43~~: Zoom in offshore tilt-derivative aeromagnetic data published by Gernigon et al. (2014). The white dashed line on the Finnmark Platform east represents a triangular- to rhomboid-shaped aeromagnetic low that coincides with a Carboniferous basin bounded by zig-zag-shaped brittle faults (e.g. LVF). The dotted white lines on the Finnmark Platform west and on the northern flank of the southwesternmost basin represent ENE-WSW to NE-SW trending ridges of magnetic basement rocks. The dashed black line represents a linear, NE-SW trending, high positive aeromagnetic anomaly that has been tied to the occurrence of the main segment of the MFC (cf. Indrevær et al. 2013). Dolerite dykes intruded along WNW-ESE trending fault segments of the TKFZ are shown by dotted black lines. Dashed red lines represent inferred from Gernigon et al. (2014). See Figure 1~~Figure 1Figure 1~~ for abbreviations.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Seismic horizons
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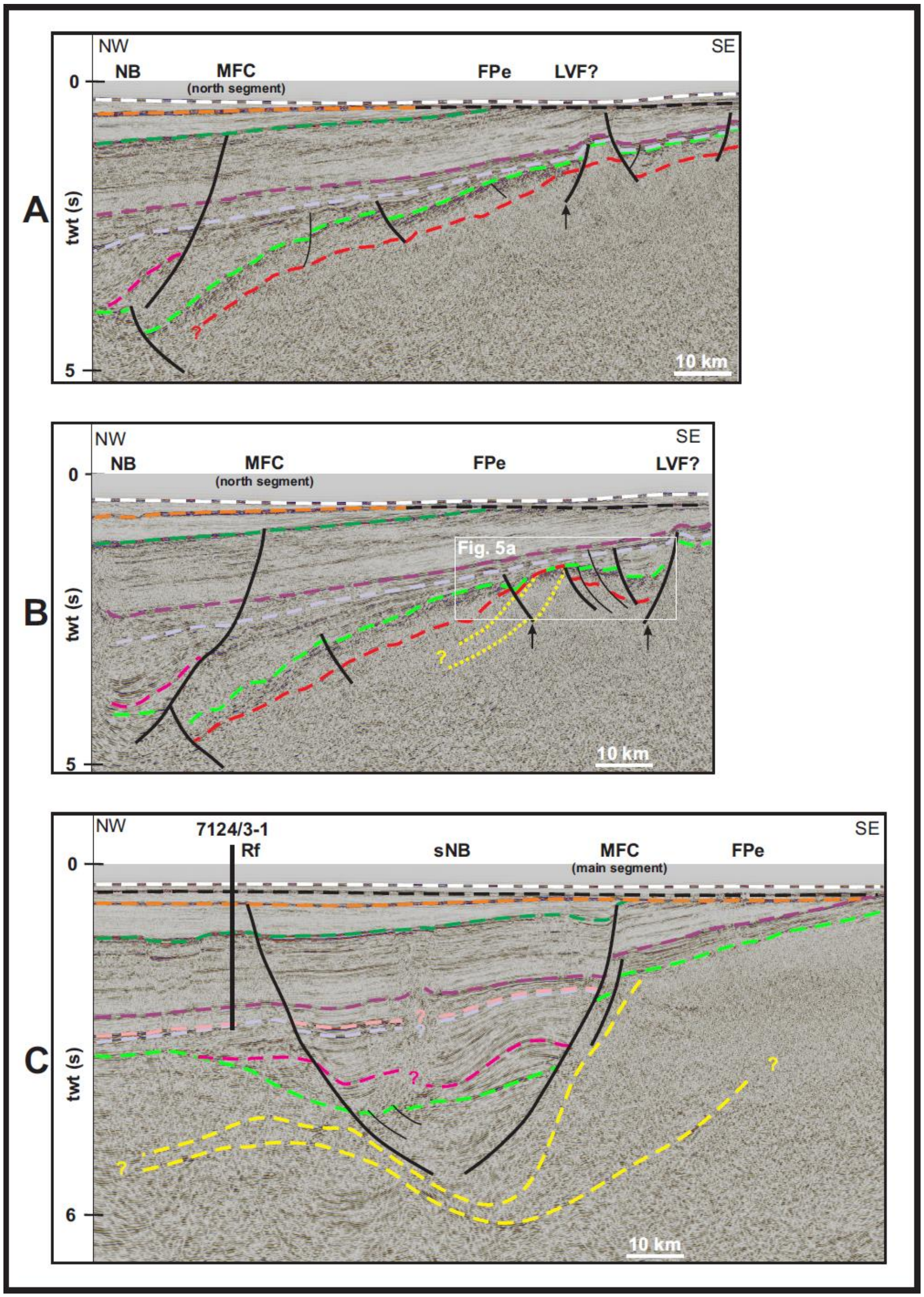
Base Cretaceous
Base Triassic
Top Asselian evaporites
Base Asselian
Top upper Carboniferous evaporites
Mid-Carboniferous
Base Devonian
Intra-Devonian bedding surfaces
Top basement
Intra basement reflection
Caledonian shear zones
Sørøya-Ingøya shear zone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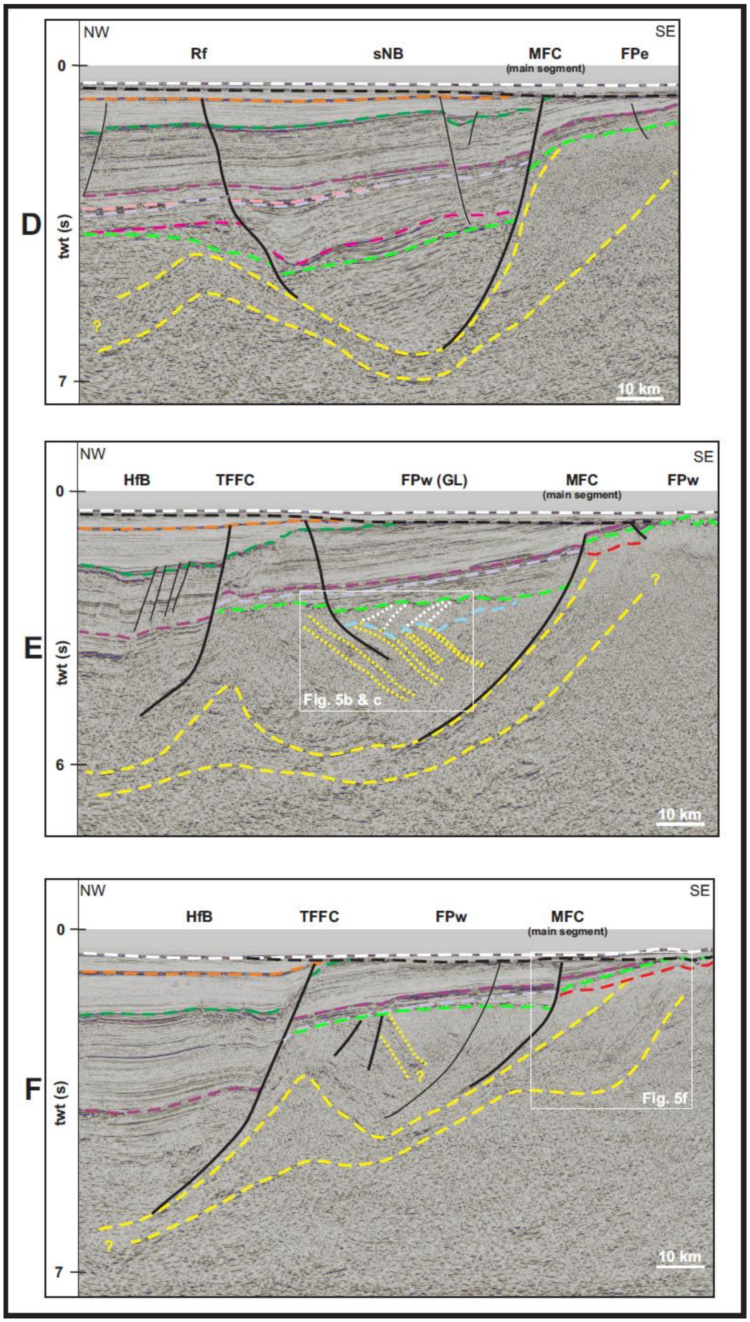
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7
10 km

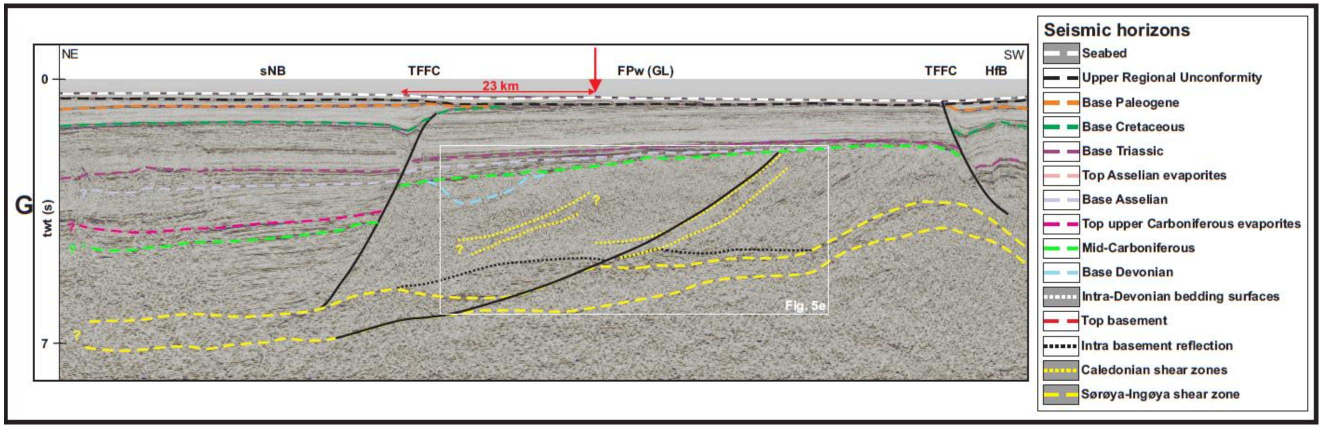
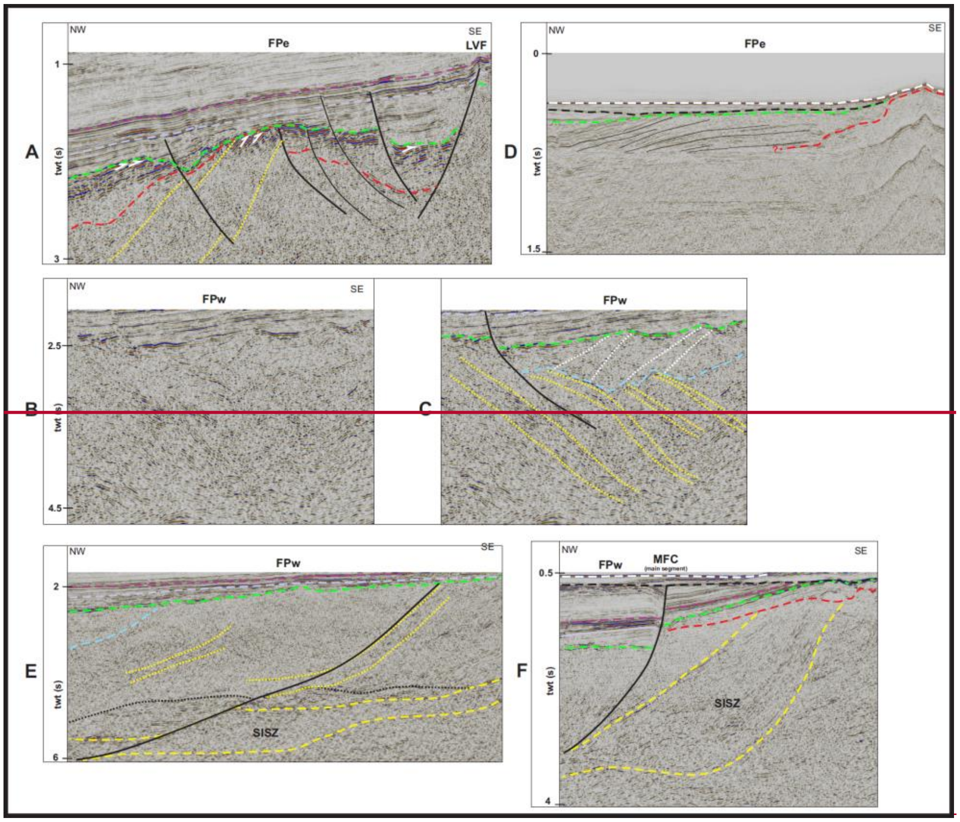
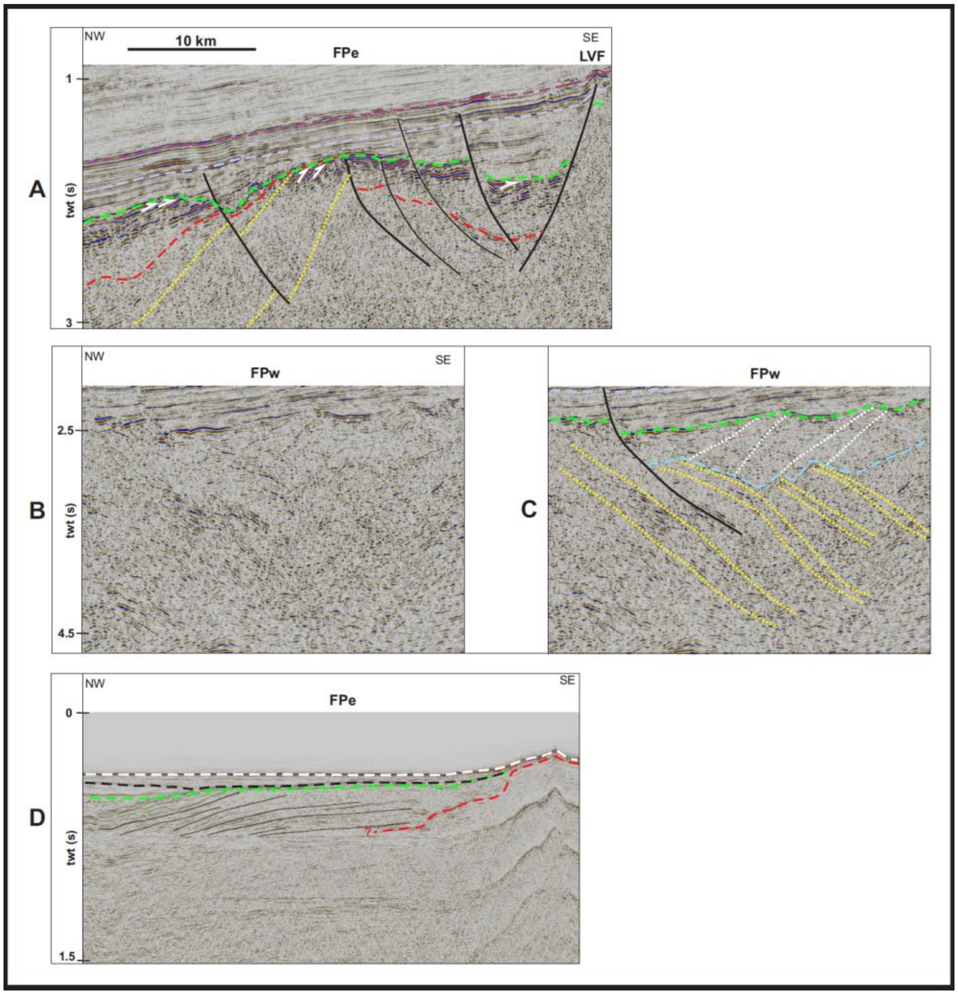

G
NE
SW
sNB
TFFC
FPw (GL)
TFFC
HfB
23 km
twt (s)
0
7
?
Fig. 5e
Seismic horizons
Seabed
Upper Regional Unconformity
Base Paleogene
Base Cretaceous
Base Triassic
Top Asselian evaporites
Base Asselian
Top upper Carboniferous evaporites
Mid-Carboniferous
Base Devonian
Intra-Devonian bedding surfaces
Top basement
Intra basement reflection
Caledonian shear zones
Sørøya-Ingøya shear zone

Figure 55~~4~~: Examples of interpreted seismic profiles from the BSS-01 survey (2D) which locations are displayed in Figure 2~~Figure 2Figure 2~~. Brittle faults are shown in black and depth is in seconds (s) TWT. See Figure 1~~Figure 1Figure 1~~ for abbreviations; a) Interpreted seismic section that shows a system of Carboniferous horst-graben structures on the Finnmark Platform east; b) Seismic profile showing increased normal displacement across the NW-dipping LVF compared with (a) and thickening of the Carboniferous sedimentary succession within the graben bounded by the LVF. Note the insignificant amount of the displacement accommodated by the northern segment of the MFC in (a) and (b). Black arrows mark brittle faults that bound a triangular-shaped, negative aeromagnetic anomaly (cf. dashed white line in Figure 4~~Figure 4Figure 3~~); c) Seismic profile showing a highly thickened Carboniferous succession and potential Devonian-lower Carboniferous sedimentary rocks in the southwesternmost Nordkapp basin. Note the large offset accommodated by the main segment of the MFC and the peculiar "U" shape of the southwesternmost Nordkapp basin. Also displayed is a lateral projection of exploration well 7124/3-1; d) Interpreted seismic section that shows the listric geometries of the main segment of the MFC and of the Rolvsøya fault; e) Seismic section showing potential Devonian sedimentary rocks deposited in a NE-SW trending graben above a set of minor, SE-dipping shear zones on the Finnmark Platform west; f) Seismic section showing the listric geometries of the TFFC and MFC, which both seem to sole into the SISZ; g) NE-SW trending seismic cross-section across the Finnmark Platform west and the southwesternmost Nordkapp basin showing the gentle dip of the SISZ to the northeast and a gradual thinning of the upper Carboniferous sedimentary succession towards the southwest. A major NNE-SSW trending, SE-dipping brittle fault seems to offset the SISZ and an intra-basement reflection on the Finnmark Platform west before being truncated by the mid-Carboniferous reflection. The vertical red arrow shows the location of the imaginary prolongation of the TKFZ on the Finnmark Platform west as a comparison with the actual location of the WNW-ESE trending fault segment of the TFFC, which are separated by a distance of ca. 23 km.


A
NW
FPe
SE
LVF
1
twt (s)
3
D
NW
FPe
SE
0
twt (s)
1.5
?
B
NW
FPw
SE
2.5
twt (s)
4.5
C
FPw
E
NW
FPw
SE
2
twt (s)
6
SISZ
F
NW
FPw
MFC
(main segment)
SE
0.5
twt (s)
SISZ
4


A
NW
10 km
FPe
SE
LVF
1
twt (s)
3
B
NW
FPw
SE
2.5
twt (s)
4.5
C
FPw
D
NW
FPe
SE
0
twt (s)
1.5

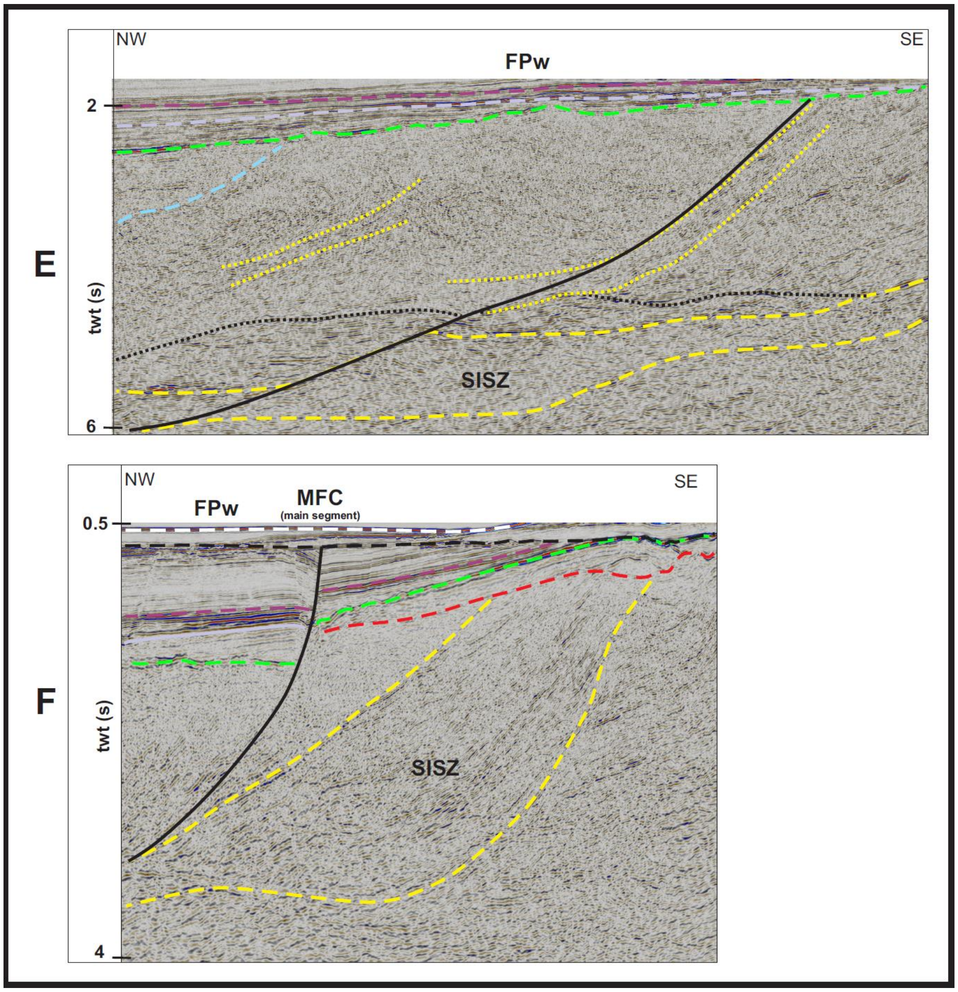
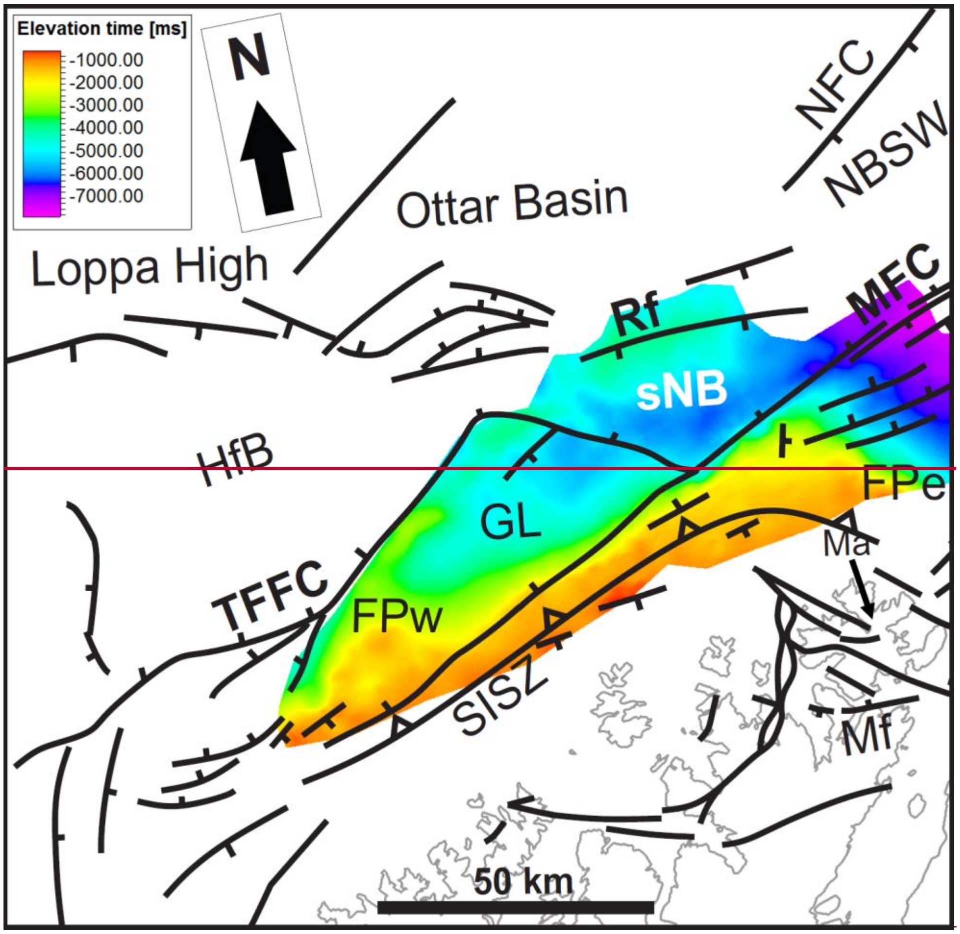


Figure 66~~5~~: Zoom in seismic sections on the Finnmark Platform east and west. The locations of (a), (b), (c), (e), & (f) are displayed as white frames in Figure 5~~Figure 5Figure 4~~ and the location of (d) is shown as a red line in Figure 2~~Figure 2Figure 2~~. See Figure 1~~Figure 1Figure 1~~ for abbreviations and Figure 5~~Figure 5Figure 4~~ for seismic reflection legend; a) Interpreted seismic section across the Finnmark Platform east. White arrows represent high-amplitude lower Carboniferous and basement seismic reflections that are truncated upwards (toplaps) by the mid-Carboniferous reflection. Note the contrast between low-amplitude upper Carboniferous-Permian reflections, gently dipping, high-amplitude lower Carboniferous reflections and steeply dipping, high-amplitude basement reflections that possibly belong to a basement-seated shear zone (yellow dotted lines); b) uninterpreted and c) interpreted seismic zoom of a section across presumed Devonian sedimentary rocks and SE-dipping basement shear zones (yellow dotted lines) on the Finnmark Platform west; d) Interpreted seismic section from the IKU-87-BA (2D) survey showing a thick lower Carboniferous succession made up of large clinoforms (thin black lines) on the Finnmark Platform east (location in Figure 2~~Figure 2Figure 2~~). Note the presence of seismic artifacts in the southeast, including several multiples and NW-dipping diffraction rays; e) Interpreted seismic section across the Finnmark Platform west that displays NE-dipping basement shear zones (yellow dotted lines) including the SISZ (yellow dashed lines); f) Seismic zoom in the SISZ in the footwall of the main segment of the MFC on the Finnmark Platform west.

The SISZ is composed of NW-dipping, moderate- to high-amplitude reflections that dip more gently than the MFC but that are steeper than basement reflections in the southeast. Note the significant thickness variations of the SISZ, thick in the footwall of the MFC and thin below the MFC.


Elevation time [ms]
-1000.00
-2000.00
-3000.00
-4000.00
-5000.00
-6000.00
-7000.00
N
NFC
NBSW
Ottar Basin
Loppa High
Rf
MFC
sNB
HfB
FPe
GL
Ma
TFFC
FPw
SISZ
Mf
50 km

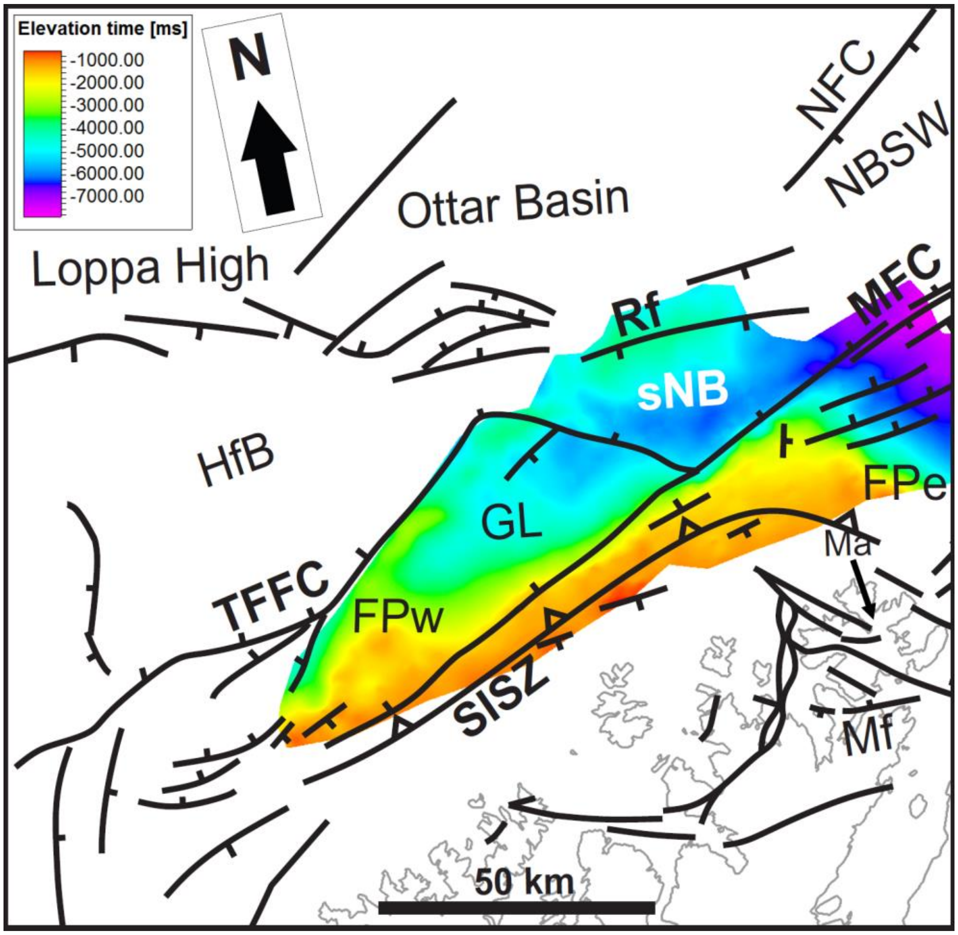
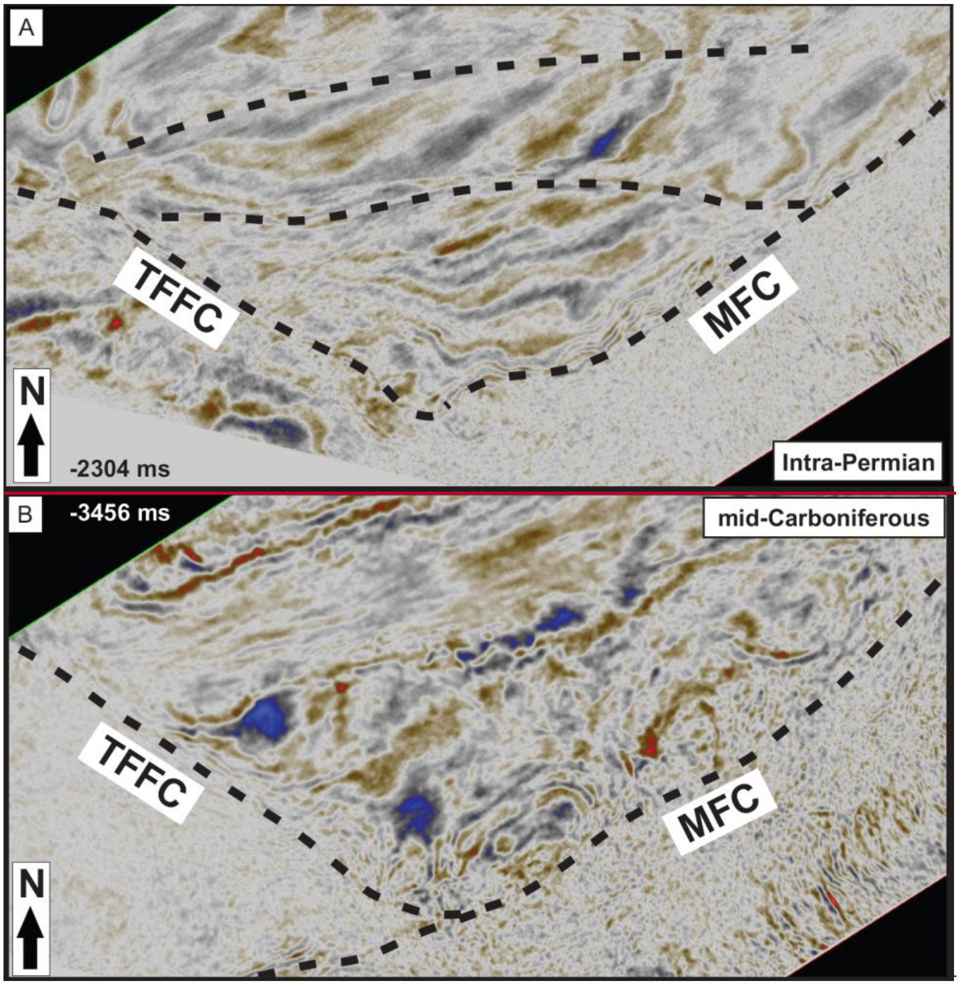


Figure 7~~76~~: Time surface map of the top reflection of the SISZ and major brittle faults in the SW Barents Sea. Note the spoon-shaped depression formed by the SISZ on the Finnmark Platform west and southwesternmost Nordkapp basin, the abrupt change to a northeastward dip on the Finnmark Platform east, and the two narrow, NE-SW and ENE-WSW trending ridges in the footwall of the TFFC and of the Rolvsøya fault.


A
TFFC
MFC
N
-2304 ms
Intra-Permian
B
-3456 ms
mid-Carboniferous
TFFC
MFC
N

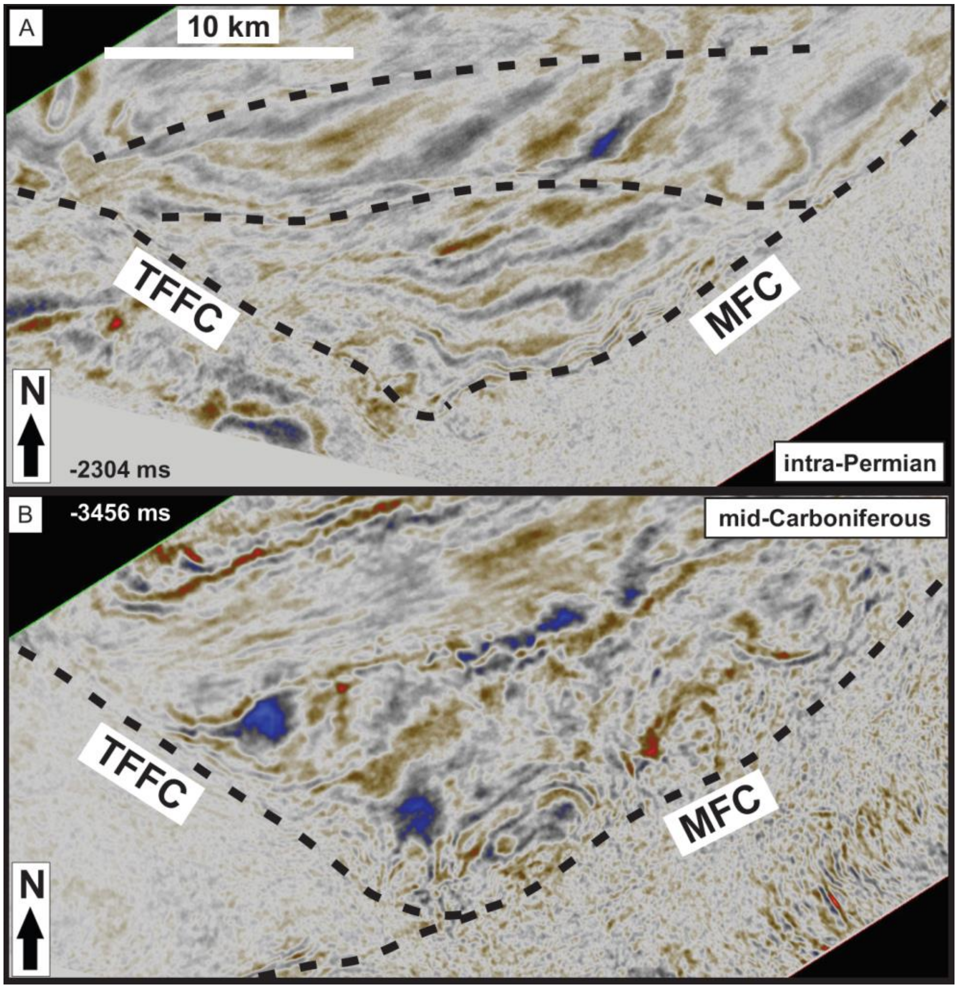
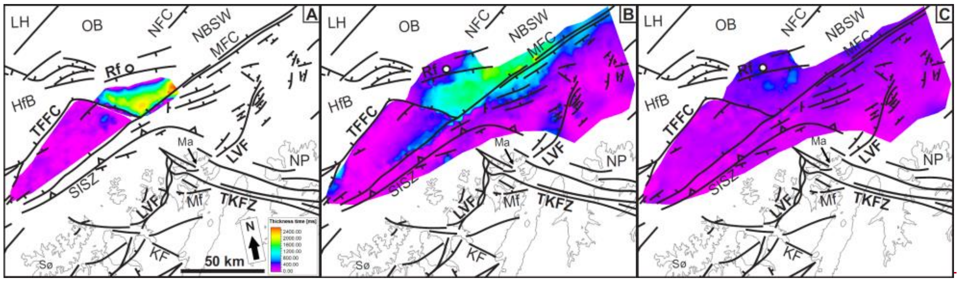


Figure 8~~87~~: (a) Intra-Permian seismic time-slice within 3D seismic survey MC3D-MFZ02 in the southwesternmost Nordkapp basin. Dashed black lines correspond to interpreted brittle faults; (b) Seismic time-slice within 3D seismic survey MC3D-MFZ02 near the interpreted mid-Carboniferous reflection in the southwesternmost Nordkapp basin. Black dashed lines represent interpreted brittle faults. See Figure 2~~Figure 2Figure 2~~ for location.


A
LH
OB
NFC
NBSW
MFC
Rf
HfB
TFFC
Ma
LVF
NP
SISZ
LVF
Mf
TKFZ
Sø
KF
50 km
N
Thickness time (ms)
2400.00
2000.00
1600.00
1200.00
800.00
400.00
0.00
B
C

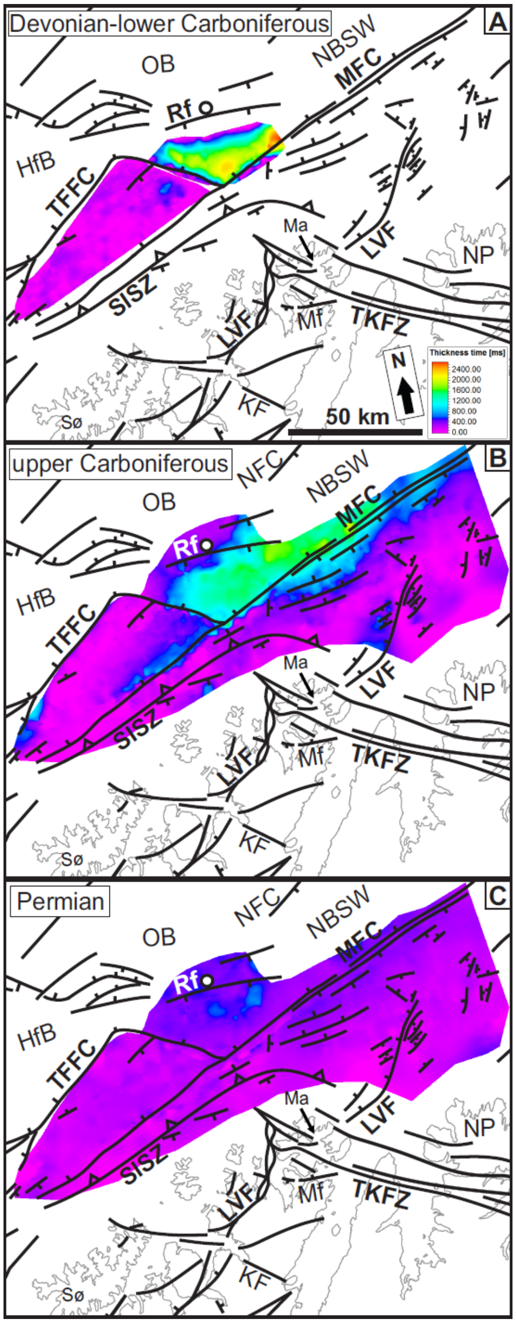

A
Devonian-lower Carboniferous
OB
NBSW
MFC
Rf
HfB
TFFC
Ma
LVF
NP
SISZ
LVF
Mf
TKFZ
N
Thickness time [ms]
2400.00
2000.00
1600.00
1200.00
800.00
400.00
0.00
50 km
KF
Sø
B
upper Carboniferous
NFC
NBSW
OB
MFC
Rf
HfB
TFFC
Ma
LVF
NP
SISZ
LVF
Mf
TKFZ
KF
Sø
C
Permian
NFC
NBSW
OB
MFC
Rf
HfB
TFFC
Ma
LVF
NP
SISZ
LVF
Mf
TKFZ
KF
Sø

Figure 9~~98~~: Thickness maps in milliseconds (ms) two-way time (TWT) of late Paleozoic sedimentary successions on the Finnmark Platform and in the southwesternmost Nordkapp basin. Color scale in (a); a) Thickness map of the Devonian-lower Carboniferous succession on the Finnmark Platform west and in the southwesternmost Nordkapp basin. The succession is thickest in the southwesternmost Nordkapp basin and represents the thickest sedimentary unit of the basin. Note that in this part of the margin, the SISZ and basin-bounding faults were used as base Devonian reflections. On the Finnmark Platform west, lower Carboniferous sedimentary rocks are missing but Devonian sedimentary deposits are possibly preserved in an ENE-WSW trending graben adjacent to the southwesternmost Nordkapp basin and bounded to the southeast by the MFC; b) Thickness map of the upper Carboniferous sedimentary succession showing gradual thickening of upper Carboniferous sedimentary rocks in the southwesternmost Nordkapp basin, on the Finnmark Platform west in the hanging-wall of the MFC, and on the Finnmark Platform east in the hanging-wall of the LVF and of a SE-dipping fault that parallels the MFC; c) Thickness map of the Permian succession showing very thin Permian sedimentary deposits and very mild thickness variations within the Permian sedimentary succession throughout the study area.

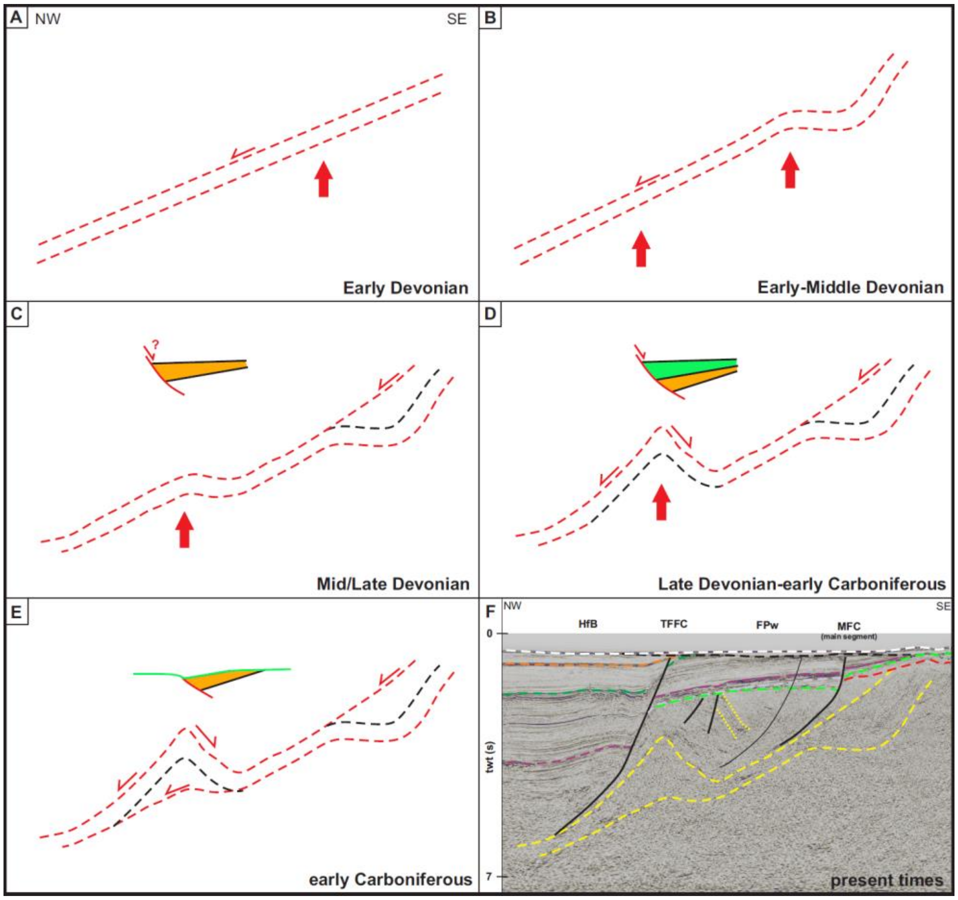
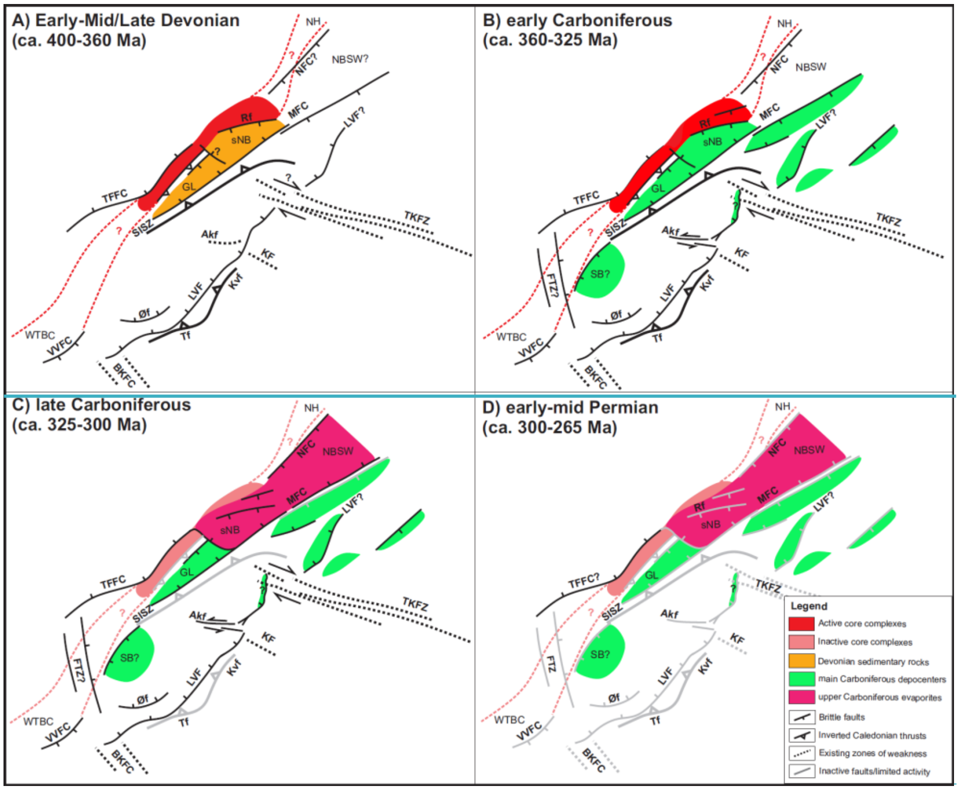


Figure 10~~109~~: Evolutionary model ~~that tentatively~~ explaining~~s~~ thickness variations along the SISZ. Note that the timing of (a) to (e) is tentative. Dashed red lines in (a) to (e) correspond to tectonically active portions of the SISZ whereas dashed black lines show inactive portions. Red lines in (c), (d) & (e) show presumed normal faults. Thick vertical red arrows indicate exhumation of basement rocks along the SISZ. The model is adapted to the geometry of the SISZ observed below the Finnmark Platform west (see f); 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 ~~crustal thinning~~ and ~~basement~~ exhume~~ation~~ basement rocks in the footwall of the SISZ, leading the upper part of the SISZ to bow. ~~Further~~ 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~~s~~ 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); d) Further exhumation of basement rocks along lower portions of the SISZ in the Late Devonian-early Carboniferous leads to extreme bending of the SISZ, to antithetic top-to-the-SE extensional faulting, and to early Carboniferous syn-tectonic sedimentation (green); e) Towards the end of the early Carboniferous, the lower portion of the SISZ is thickened due to incisement (i.e. downward splaying; cf. Lister & Davis 1989) of the SISZ into bow-shaped portions in its footwall. Core complex exhumation ceased in the Serpukhovian and a major sea-level fall exposed the Finnmark Platform to continental erosion (green line representing

the mid-Carboniferous reflection); f) Present times seismic expression of thickness variations along the SISZ (dashed yellow) on the Finnmark Platform west. See Figure 5~~Figure 5Figure 4~~ for seismic reflections color schemes.


A) Early-Mid/Late Devonian
(ca. 400-360 Ma)
NH
NFC?
NBSW?
Rf
MFC
sNB
LVF?
GL
TFFC
SISZ
TKFZ
Akf
KF
LVF
Kvf
Øf
Tf
WTBC
VVFC
BKFC
B) early Carboniferous
(ca. 360-325 Ma)
NH
NFC
NBSW
Rf
MFC
sNB
LVF?
GL
TFFC
SISZ
TKFZ
Akf
KF
FTZ?
SB?
LVF
Kvf
Øf
Tf
WTBC
VVFC
BKFC
C) late Carboniferous
(ca. 325-300 Ma)
NH
NFC
NBSW
MFC
LVF?
sNB
GL
TFFC
SISZ
TKFZ
Akf
KF
FTZ?
SB?
LVF
Kvf
Øf
Tf
WTBC
VVFC
BKFC
D) early-mid Permian
(ca. 300-265 Ma)
NH
NFC
NBSW
Rf
MFC
LVF?
sNB
GL
TFFC?
TKFZ
SISZ
Akf
KF
FTZ
SB?
LVF
Kvf
Øf
Tf
WTBC
VVFC
BKFC
Legend
Active core complexes
Inactive core complexes
Devonian sedimentary rocks
main Carboniferous depocenters
upper Carboniferous evaporites
Brittle faults
Inverted Caledonian thrusts
Existing zones of weakness
Inactive faults/limited activity

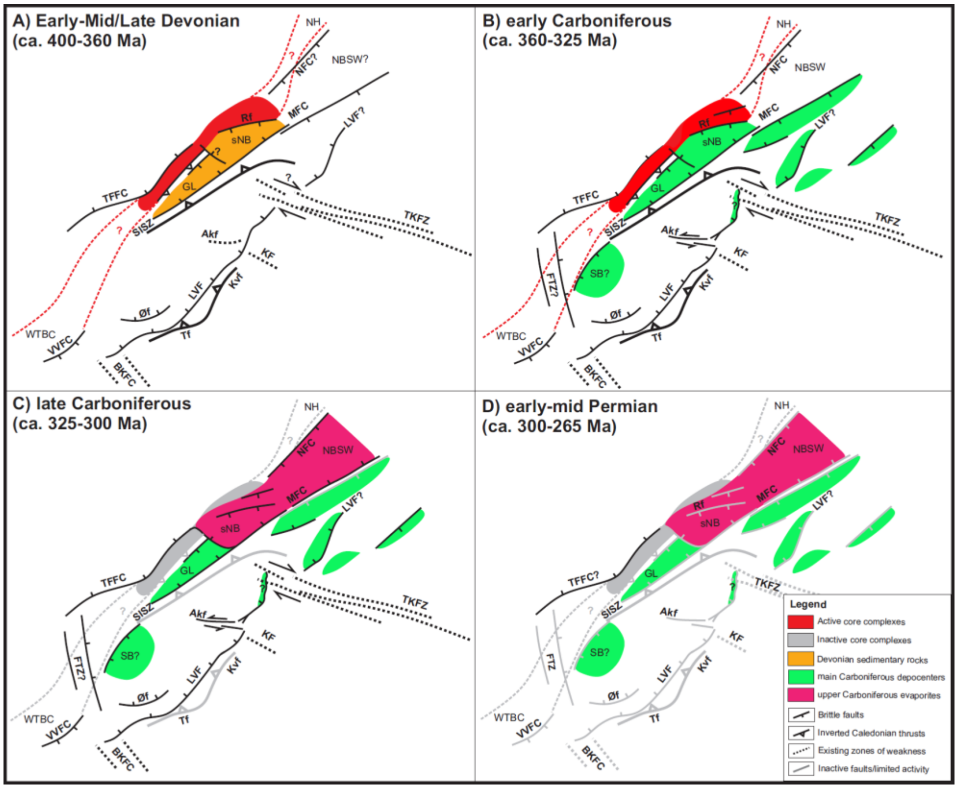


Figure 11~~1110~~: Map-view figures summarizing the late Paleozoic tectono-sedimentary evolution of the Finnmark Platform and southwesternmost Nordkapp basin (sNB). The tectonic evolution of onshore and nearshore faults in NW Finnmark is from Koehl et al. (submitted). Abbreviations as in Figure 1~~Figure 1Figure 1~~. a) In the Early to Mid/Late Devonian, major Caledonian thrusts (e.g. SISZ) were inverted as low-angle extensional shear zones and exhumed metamorphic core complexes in the footwall of the TFFC and of the Rolvsøya fault. Thick Devonian sedimentary rocks were deposited within a spoon-shaped trough created by the geometry of the SISZ; b) Core complex exhumation continued through the early Carboniferous, though mostly accommodated by high-angle normal faults, which formed as brittle splays along Caledonian thrusts and shear zones (e.g. MFC, TFFC, Rolvsøya fault and LVF). Core complex exhumation ceased by the end of the Serpukhovian and the WNW-ESE trending fault segment of the TFFC formed as an accommodation cross-fault that decoupled the Finnmark Platform west from the southwesternmost Nordkapp basin, thus contributing to preserve thick Devonian and lower Carboniferous sedimentary successions in the southwesternmost Nordkapp basin while these sedimentary rocks were almost completely eroded on the Finnmark Platform west. Minor graben and half-graben structures formed on the Finnmark Platform east. Precambrian, WNW-ESE to NNW-SSE trending fault zones such as the TKFZ segmented the margin and acted as minor transfer faults that accommodated limited amount of lateral displacement. Lateral movements along these faults ceased in the early Carboniferous; c) In the late Carboniferous, inverted Caledonian thrusts and shear zones became inactive and were truncated by high-angle splay-faults that accommodated the deposition of syn-tectonic sedimentary wedges on the Finnmark Platform east ~~0~~and west, and of thick, partly evaporitic deposits in the southwesternmost Nordkapp basin; d) By the end of the Carboniferous, active brittle faulting came to a halt and the Finnmark Platform and the southwesternmost Nordkapp basin are believed to have remained tectonically quiet.