

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 Sørøya-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 possibly related deep-seated shear zones, which accommodate 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), 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). ~~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,~~ 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 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). ~~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; Townsend, 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), 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 1, Figure 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 1, Figure 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 1, Figure 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).

2. Geological setting

The bedrock geology of the SW Barents Sea margin (Figure 1, Figure 1, Figure 1) consists of (i) an Archean 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 1, Figure 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
125 NW Finnmark (Kirkland et al., 2008; Corfu et al., 2014; Indrevær & Bergh, 2014; ~~Figure 1~~
~~Figure 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;
130 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).

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
140 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).

145 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
150 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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155 ~~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).~~

160 ~~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 1, Figure 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).~~

165 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-Rybachy Fault Zone~~
~~(Roberts et al., 1997; Roberts et al., 2011), to the Barents shelf in the west (Gabrielsen, 1984;~~
~~Gabrielsen & Færseth, 1989; Gabrielsen et al., 1990; Roberts et al. 2011) to the east of the Kola~~
170 ~~Peninsula in Russia (Roberts et al., 1997). Between these areas, the TKFZ is traced along the Kola~~
~~Peninsula as the Sredni Rybachy 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
175 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).

180 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 1, Figure 1). The Kalak
185 Nappe Complex is composed of amphibolite facies schists, metapsammites and paragneisses, and

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190 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 thrust over Baltica during the Caledonian Orogeny (Kirkland et al., 2008). However,
195 paleocurrent and geochronological data suggest these rocks to be of Baltican origin (Roberts, 2007;
Zhang et al., 2016).

200 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).

205 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 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
210 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 1
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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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220 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

225 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., 230 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; 235 Gudlaugsson et al., 1998; Indrevær et al., 2013; Figure 1, Figure 1, Figure 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).

240 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 1, Figure 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 1, Figure 1), was only affected by the formation of minor Carboniferous, ENE- 245 WSW to NE-SW trending half-graben and graben structures (Bugge et al., 1995; Samuelsen et al., 2003; Rafaelsen et al., 2008; Figure 1, Figure 1, Figure 1). In the hanging-wall of the MFC on the western part of the Finnmark Platform, the Finnmark Platform west (Figure 1, Figure 1, Figure 1),

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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 1, Figure 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 1, Figure 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 1, Figure 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 1, Figure 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 1, Figure 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 1, Figure 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 Western Troms (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 1, Figure 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 1, Figure 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 1, Figure 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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340 [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
345 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

350 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 [\(Figure 3Figure 3\)](#) which sedimentary rocks were deposited on top of eroded
Precambrian and Caledonian basement rocks (cf. Townsend, 1987a; Johansen et al., 1994; Bugge
355 et al., 1995; Zwaan, 1995; Gudlaugsson et al., 1998; Samuelsen 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
360 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 [\(Figure 2Figure 2Figure 2\)](#) and these are
365 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 [\(Figure 3Figure 3\)](#). ~~However,~~ Devonian sedimentary deposits ~~however~~ are
present in western Norway (Osmundsen & Andersen, 2001) where they represent a several km-
370 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 2~~~~Figure 2~~ & ~~Figure 3~~~~Figure 3~~). These rocks mostly correspond to fluvial clastic deposits interbedded 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 2~~~~Figure 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 1~~~~Figure 1~~ & ~~Figure 2~~~~Figure 2~~~~Figure 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~~; Samuelsen 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 2~~~~Figure 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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405 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), 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).

420 ~~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

425 3.1. Seismic data and well-ties

430 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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435 [well data \(www.npd.no\)](http://www.npd.no) and [private well-tie seismograms \(Henningesen, pers. comm.\)](#) and to
440 [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

445 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 & Brønner (2012) and
Gernigon et al. (2014; [Figure 4](#)~~Figure 4~~[Figure 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
450 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 4~~[Figure](#)
455 [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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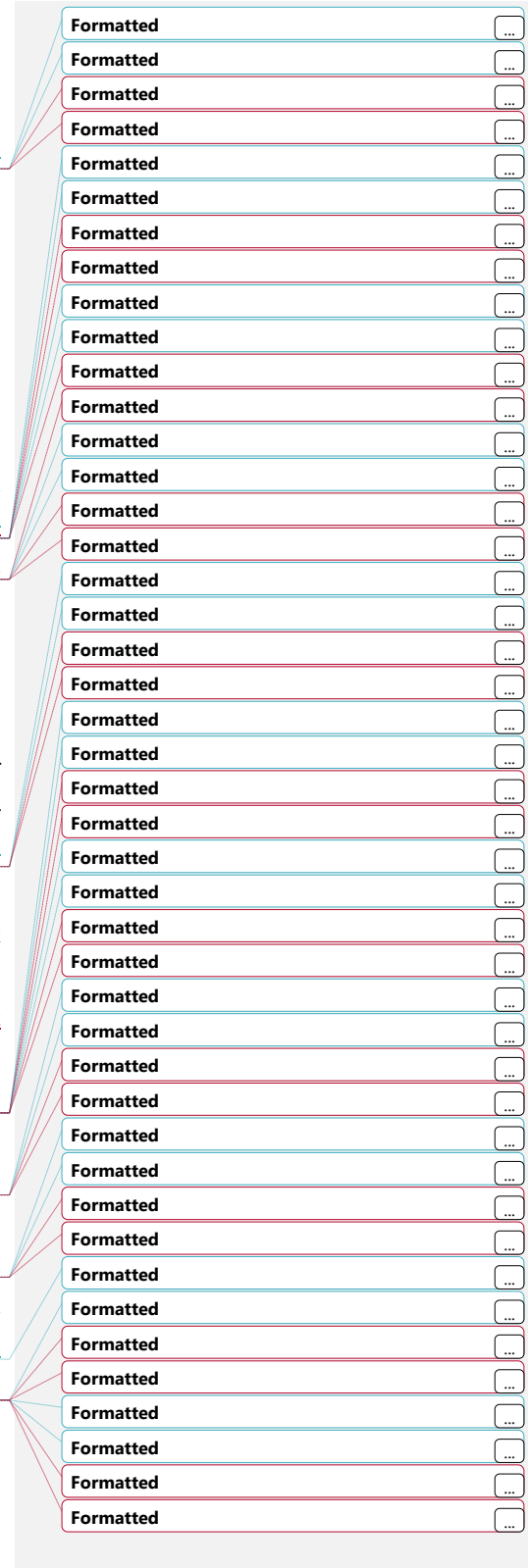
sediment cover (Solheim & Kristoffersen, 1984), and the seabed reflection (Figure 5Figure 5Figure 4). These reflections are penetrated by a large number of exploration wells and shallow drill-cores both on the Finnmark Platform and in the southwesternmost Nordkapp basin, where they all display consistently 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 1Figure 1Figure 1 & Figure 2Figure 2Figure 2) based on interpreted key seismic sections (Figure 5Figure 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 7Figure 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 5Figure 5Figure 4c-f & Figure 6Figure 6Figure 5d). 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 5Figure 5Figure 4f). The SISZ deepens to the northwest towards the center of the Finnmark Platform west before bending upwards in the footwall of the TFFC (Figure 5Figure 5Figure 4e & 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 highridges” in Figure 1Figure 1Figure 1 and Figure 5Figure 5Figure 4e & f). A similar pattern is observed in the



(cf. [Figure 5Figure 5Figure 4a & b](#)). In this graben structure, the lower Carboniferous and upper Carboniferous sedimentary successions thicken against the LVF ([Figure 5Figure 5Figure 4b](#)), while thickness variations become negligible farther north where the LVF dies out ([Figure 1Figure 1Figure 1](#) & [Figure 5Figure 5Figure 4a](#)). 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 9Figure 9Figure 8b](#)) with a thickness comparable to what is observed within the southwesternmost Nordkapp basin ([Figure 9Figure 9Figure 8b](#)). This succession shows a half-ellipsoid shape in map-view with a NE-SW trending major axis parallel to the MFC ([Figure 9Figure 9Figure 8b](#)). 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 5Figure 5Figure 4a & 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 9Figure 9Figure 8b](#)).

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 1Figure 1Figure 1](#); Bugge et al., 1995), which we re-interpreted as a prograding Carboniferous sedimentary system ([Figure 6Figure 6Figure 5d](#)). 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 clinofolds in a prograding sedimentary system ([Figure 6Figure 6Figure 5d](#)) 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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835 underlying Devonian-lower Carboniferous and upper Carboniferous successions ([Figure 5Figure 5Figure 4a-d](#) and [Figure 9Figure 9Figure 8a-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 [these faults](#) (840 [Figure 5Figure 5Figure 4c, d & g](#) and [Figure 9Figure 9Figure 8c](#)). 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 suggestings](#) that the main tectonic activity along [these Rolvsøya-faults](#) was essentially restricted to the Mid/Late Devonian-late Carboniferous (845 [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 5Figure 5Figure 4a, 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).~~

850 *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 5Figure 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 (855 [Figure 5Figure 5Figure 4c-g](#)). The weak influence of these faults compared to offsets observed within late Paleozoic successions ([Figure 5Figure 5Figure 4c-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.

860 **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 4Figure 4Figure 3](#)). 865

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 combination, 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 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 4c-f). This obvious merging of main segment of the MFC into the basement-seated SISZ (Figure 5 & Figure 4c-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 4c & 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 4e & Figure 6 & Figure 5b & 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 9Figure 9Figure 8b) but most likely ceased before the Permian as supported by the relatively constant thickness of Permian sedimentary strata throughout the study area (Figure 9Figure 9Figure 8c).

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 5Figure 5Figure 4d-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-Finmark Fault Complex as a hard-linked accommodation cross-fault

Our data (Figure 9Figure 9Figure 8a & 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 5Figure 5Figure 4e & 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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960 dimensionally folded and bowed geometry of the SISZ ([Figure 7](#)~~Figure 7~~[Figure 6](#)) suggests that
the thickening of Devonian-lower Carboniferous sedimentary strata into the southwesternmost
Nordkapp basin ([Figure 9](#)~~Figure 9~~[Figure 8a](#)) 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 9~~[Figure 8a & b](#)) is
965 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
970 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 7~~[Figure 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
975 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 favored the
980 formation of a NE-dipping fault at this location ([Figure 5](#)~~Figure 5~~[Figure 4g](#) & [Figure 7](#)~~Figure 7~~[Figure 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
985 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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1085 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 & Brönnner, 2012). The aeromagnetic anomalies visible on the dataset Gernigon & Brönnner (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 4](#)).

1095 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 Finnmark Platform 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 4](#)), 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).

1105 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 4f](#)). 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 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 9a](#)). ~~Relatively rapid 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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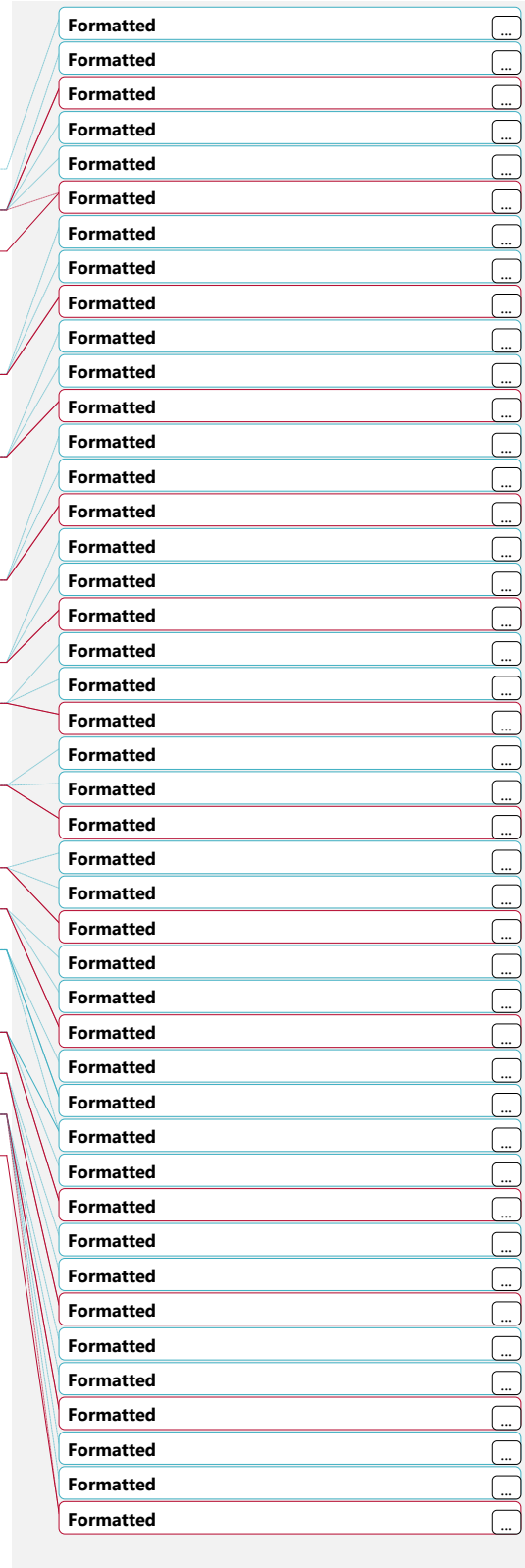
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Platform west and along the northern flank of the southwesternmost Nordkapp basin (Figure 10Figure 10Figure 9a), causing the upper part of the SISZ to bow upwards (Figure 10Figure 10Figure 9b). Continued crustal extension and continental erosion further 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 10Figure 10Figure 9c). 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 10Figure 10Figure 9c). 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 5Figure 5Figure 4f). 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 10Figure 10Figure 9b & c), causing bend-up of the SISZ at even deeper crustal levels (Figure 10Figure 10Figure 9d). 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 10Figure 10Figure 9d), 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 5Figure 5Figure 4e & f) and in the footwall of the Rolvsøya fault (Figure 5Figure 5Figure 4c & 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 10Figure 10Figure 9e) and possibly contributed to thicken the SISZ in the footwall of the TFFC (Figure 5Figure 5Figure 4e & f) and of the Rolvsøya fault (Figure 5Figure 5Figure 4c & d), resulting in the current geometry of the SISZ (Figure 10Figure 10Figure 9f). 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).



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 $^{40}\text{Ar}/^{39}\text{Ar}$ 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 10, Figure 9a-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 10, Figure 9d-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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1240 southwesternmost Nordkapp basin (Figure 1; Koehl et al. submitted). Nearby Magerøya and the Nordkinn Peninsula, high-resolution 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 & Brönnner, 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).

1245 -We ~~explore consider~~ an alternative model to the fault-tip process zone of Koehl et al. (submitted); ~~in which~~ ~~We~~ 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~~ thrust 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 have been~~ preserved ~~offshore~~ in offshore basement highs such as the Loppa and Veslemøy highs (Figure 1; ~~Figure 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).

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1265 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

1270 Paleozoic (Figure 11Figure 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.

1275 ~~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 4e-g & Figure 5f). The trend and dominant northwestern dip of the SISZ (Figure 5c-g & Figure 6f) is shear zone~~
1280 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-dimensionally folded geometry that coincides with basement ridges in the footwall of the TFFC and of the Rolvsøya fault (Figure 5Figure 5Figure 4c-f, Figure 7Figure 7Figure 6 and Figure 11Figure 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 reactivation of such ductile shear zones along the Barents Sea margin ~~may~~ 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~~
1285 ~~e~~

1290 ~~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 5Figure 5Figure 4f), likely due to incisement and excisement processes (Figure 10Figure 10Figure 9; Lister & Davis, 1989). These processes also
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collapse of the Caledonides essentially took place in the Mid/Late Devonian-Carboniferous and came to a halt towards the end of this ~~Period~~ ~~late Carboniferous~~ (Figure 11, Figure 11, Figure 10d).

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).

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.

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- 1395 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
1400 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.
- 1405 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.

1410

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).

1415

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
1420 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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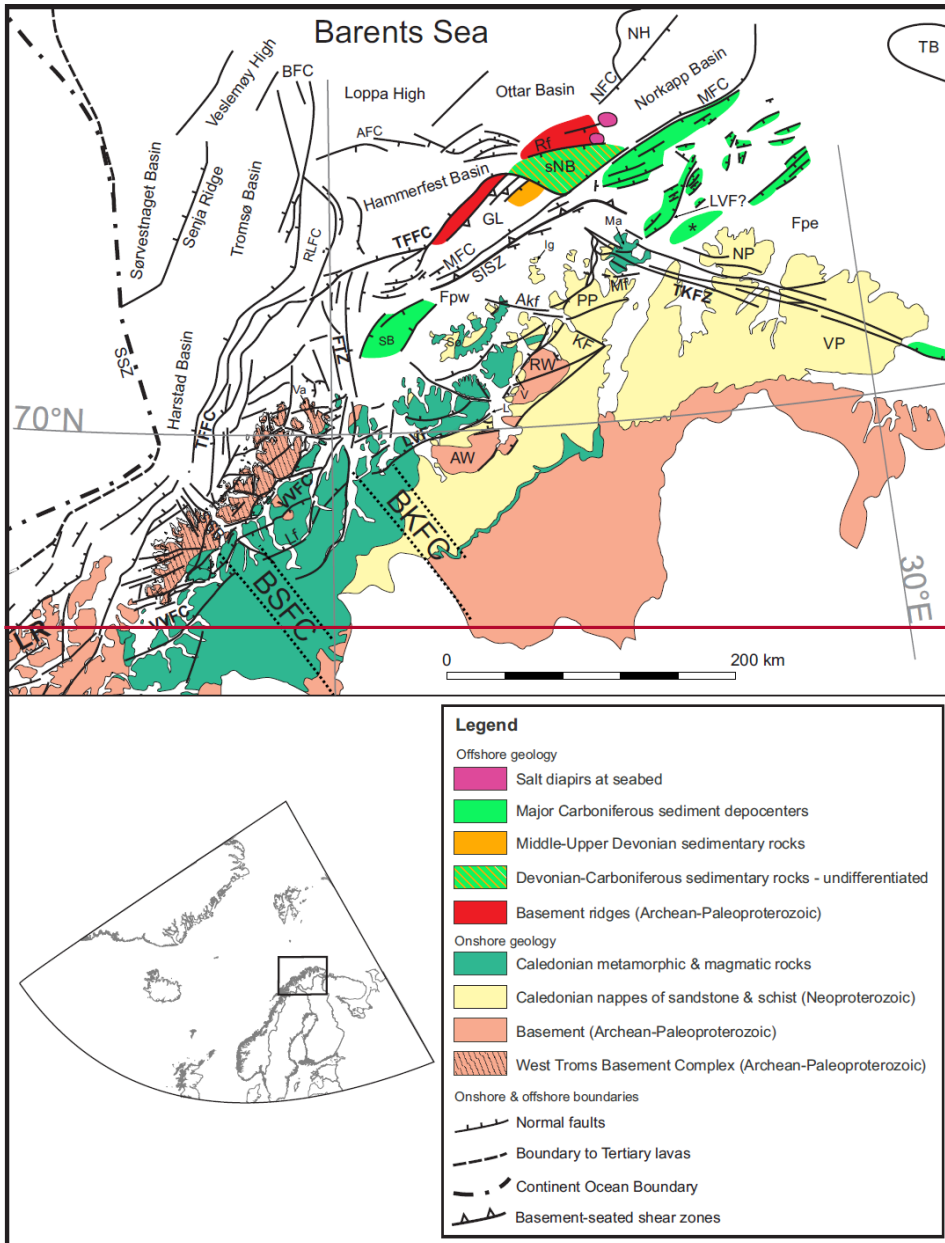
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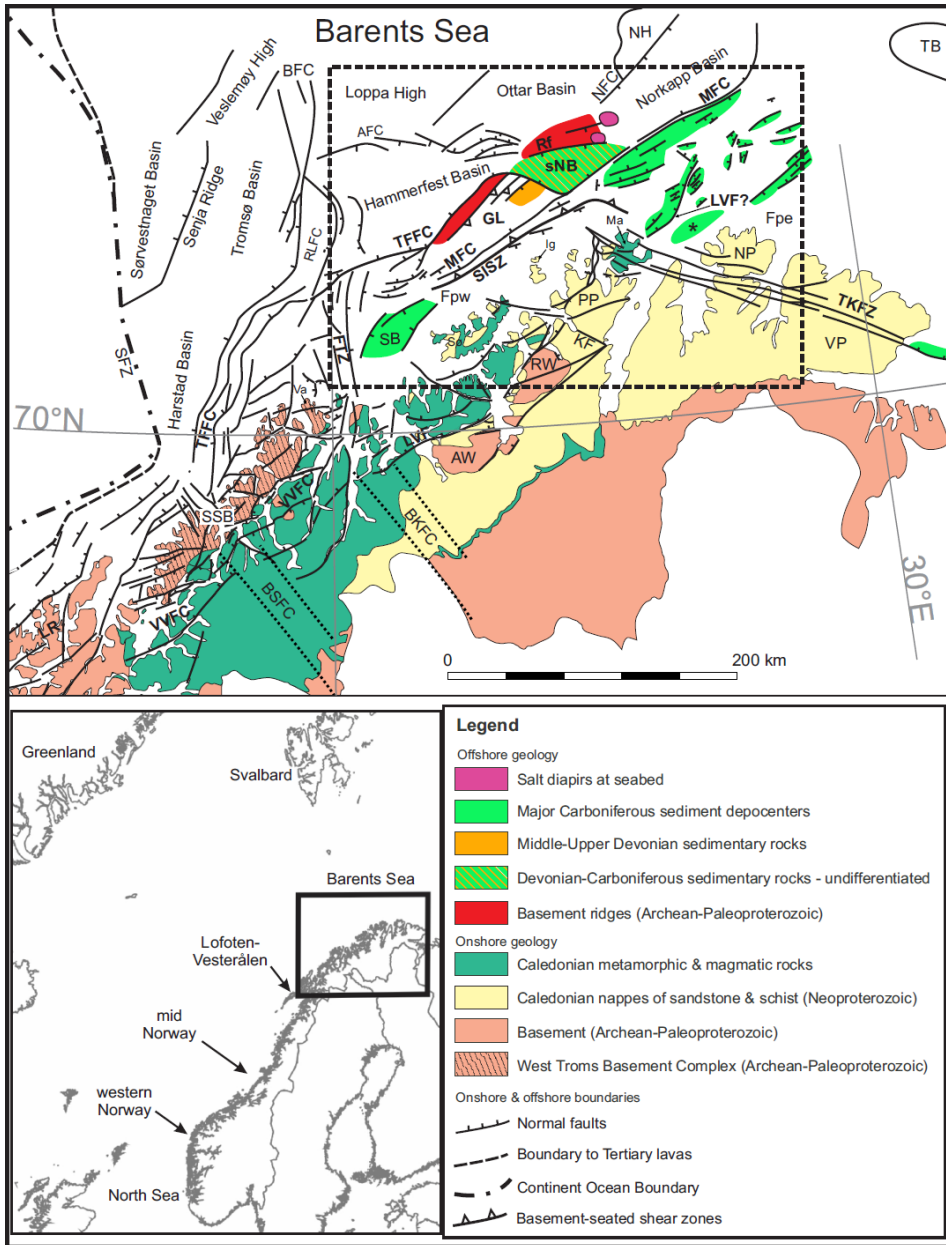
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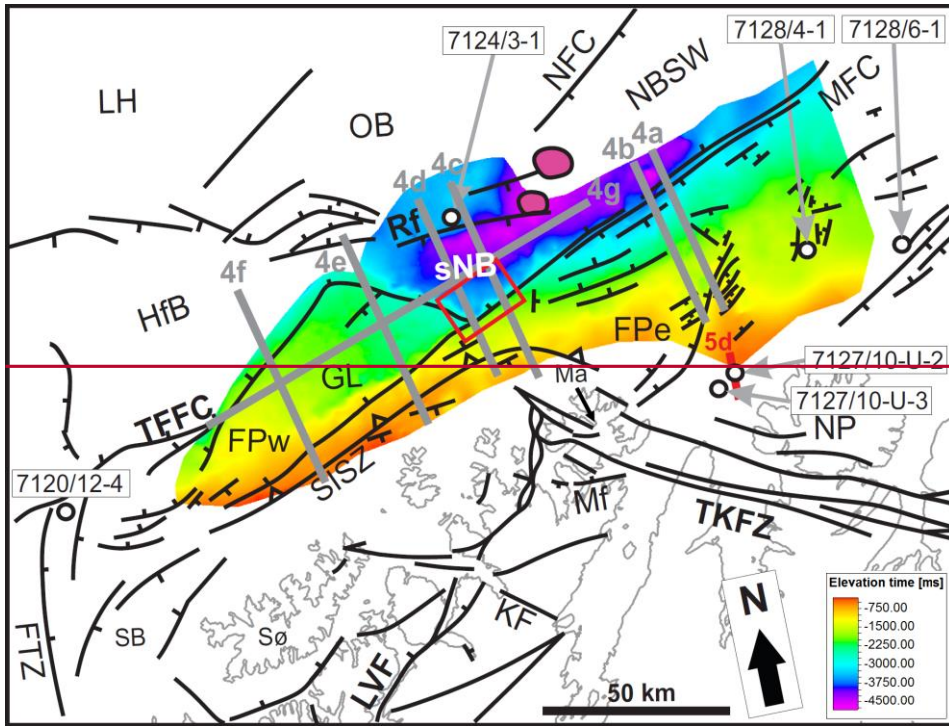
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1820 Figure 1: Regional structural map of the SW Barents Sea margin (based on Bergh et al. 2007, Faleide et al. 2008, Hansen et
al. 2012 and Indrevær et al. 2013 and Koehl et al. submitted). The onshore geology is from the NGU and Ramberg et al.
(2008). ~~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 =
1825 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 = Fugløy 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~~
1830 ~~= 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 = Sørøy sub-basin~~ Senja Shear Belt; ~~SSZ = Senja Shear Zone~~; SØ = Sørøya; TB =
Tiddlybanken Basin; TFFC = Troms-Finnmark Fault Complex; TKFZ = Trollfjord en-Komagelva Fault Zone; ~~V =~~
~~Vargsund~~; Va = Vannøya; VP = Varanger Peninsula; VVFC = Vestfjorden-Vanna fault complex.



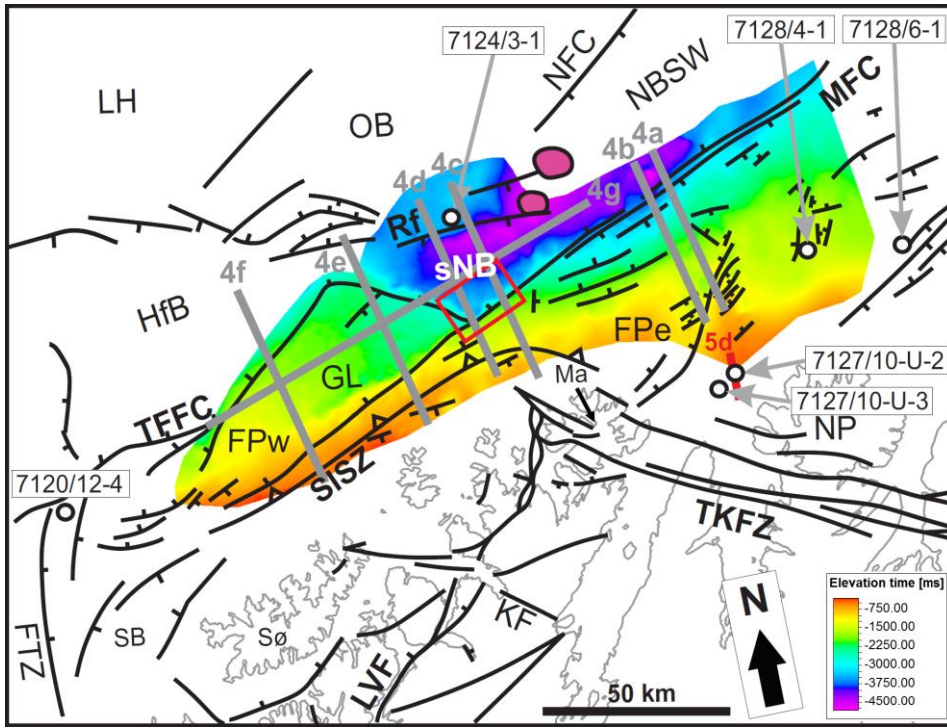
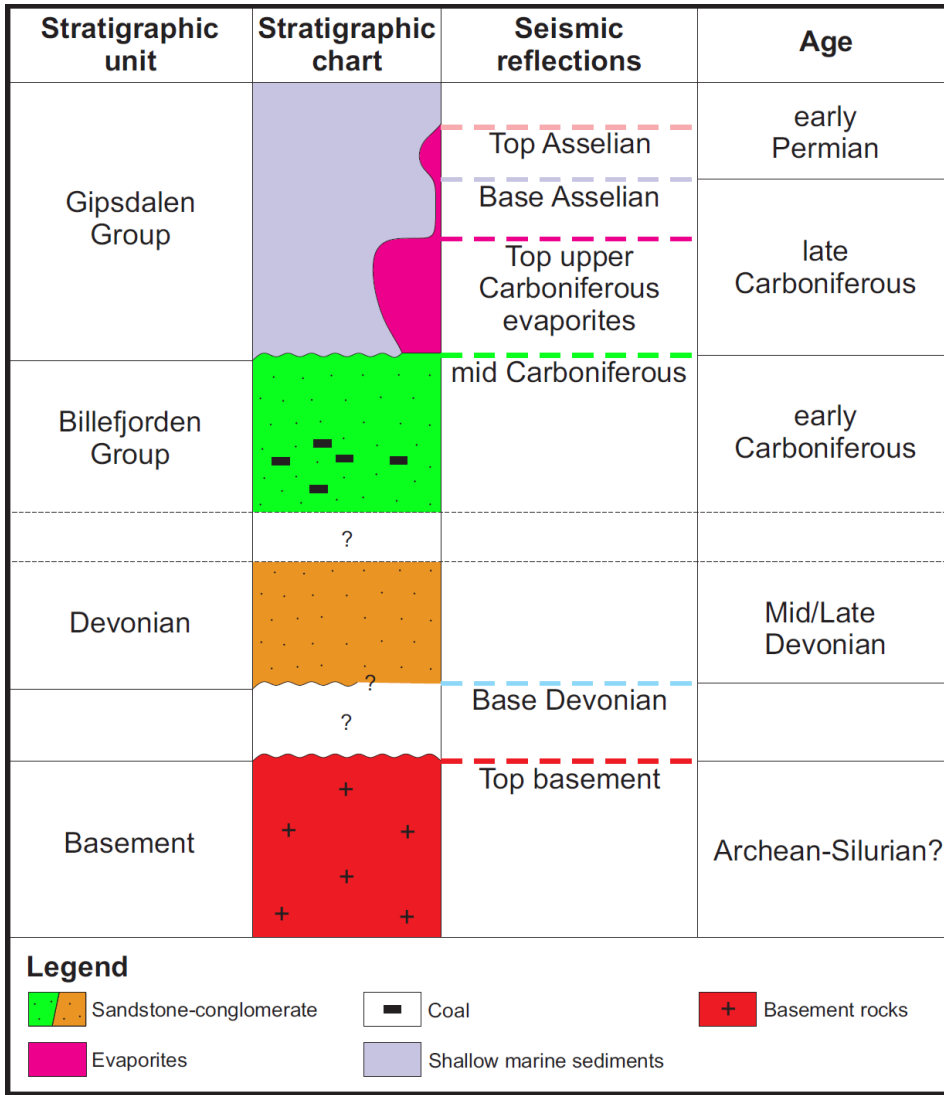


Figure 2: Regional structural map summarizing the architecture of the Finnmark Platform east (FPe) and west (FPw) and of the southwesternmost Nordkapp basin (sNB). The figure includes a time map of the interpreted mid-Carboniferous reflection. Grey lines show the location of seismic profiles displayed in Figure 5 Figure 5 Figure 4a-g, the red line displays the location of the seismic section shown in Figure 6 Figure 6 Figure 5d and the red frame indicates the location of seismic Z-slices described in Figure 8 Figure 8 Figure 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 1 for abbreviations.

1840



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1845 **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 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 5) and the units age. Lithological legend at the bottom.**

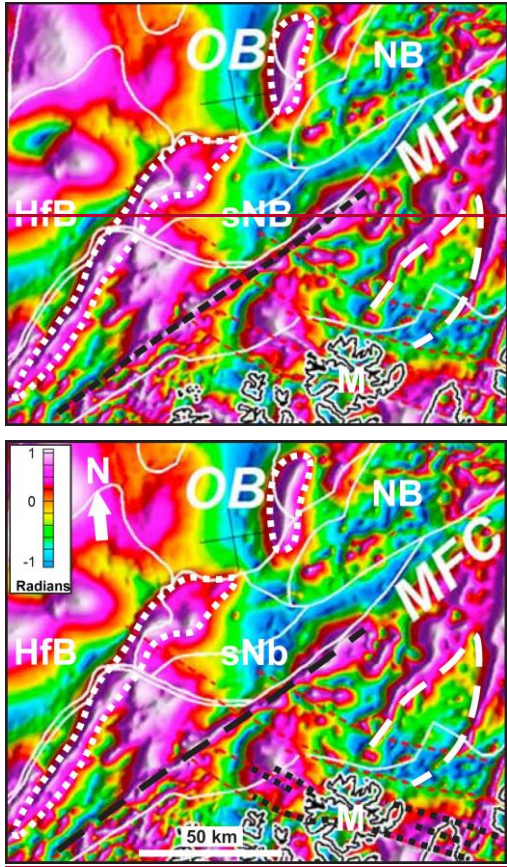
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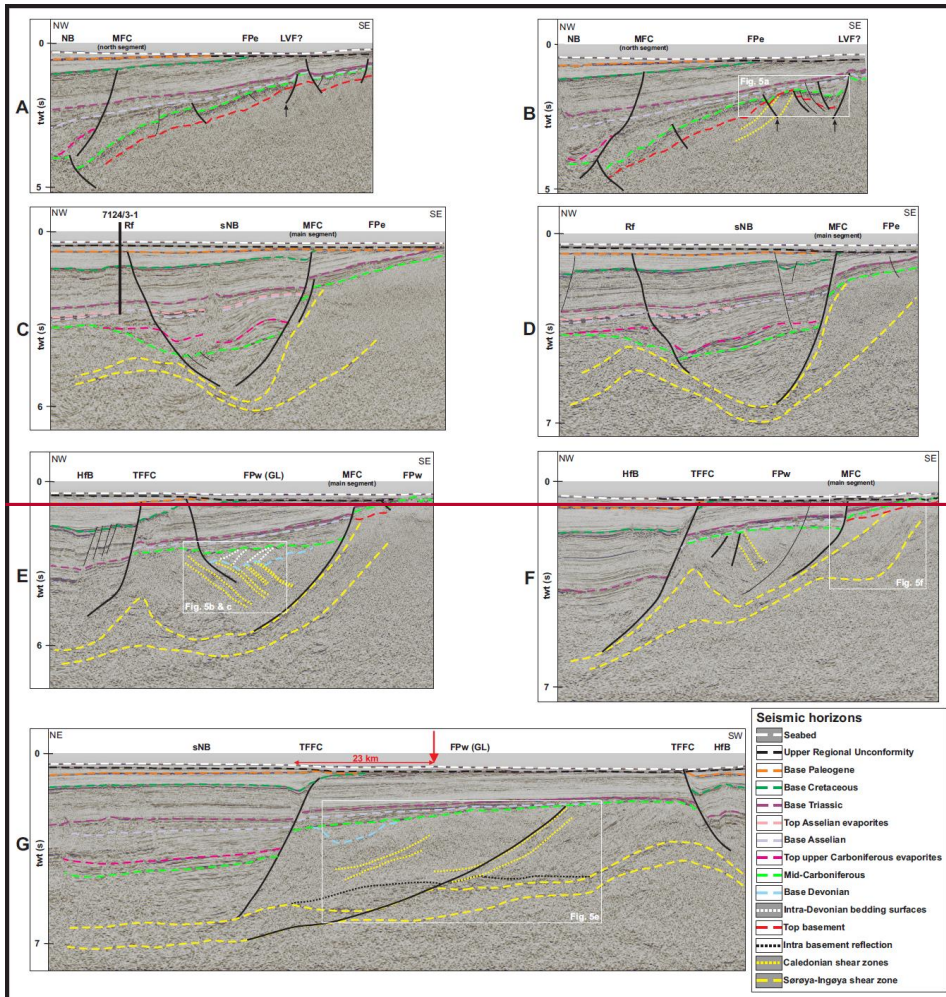
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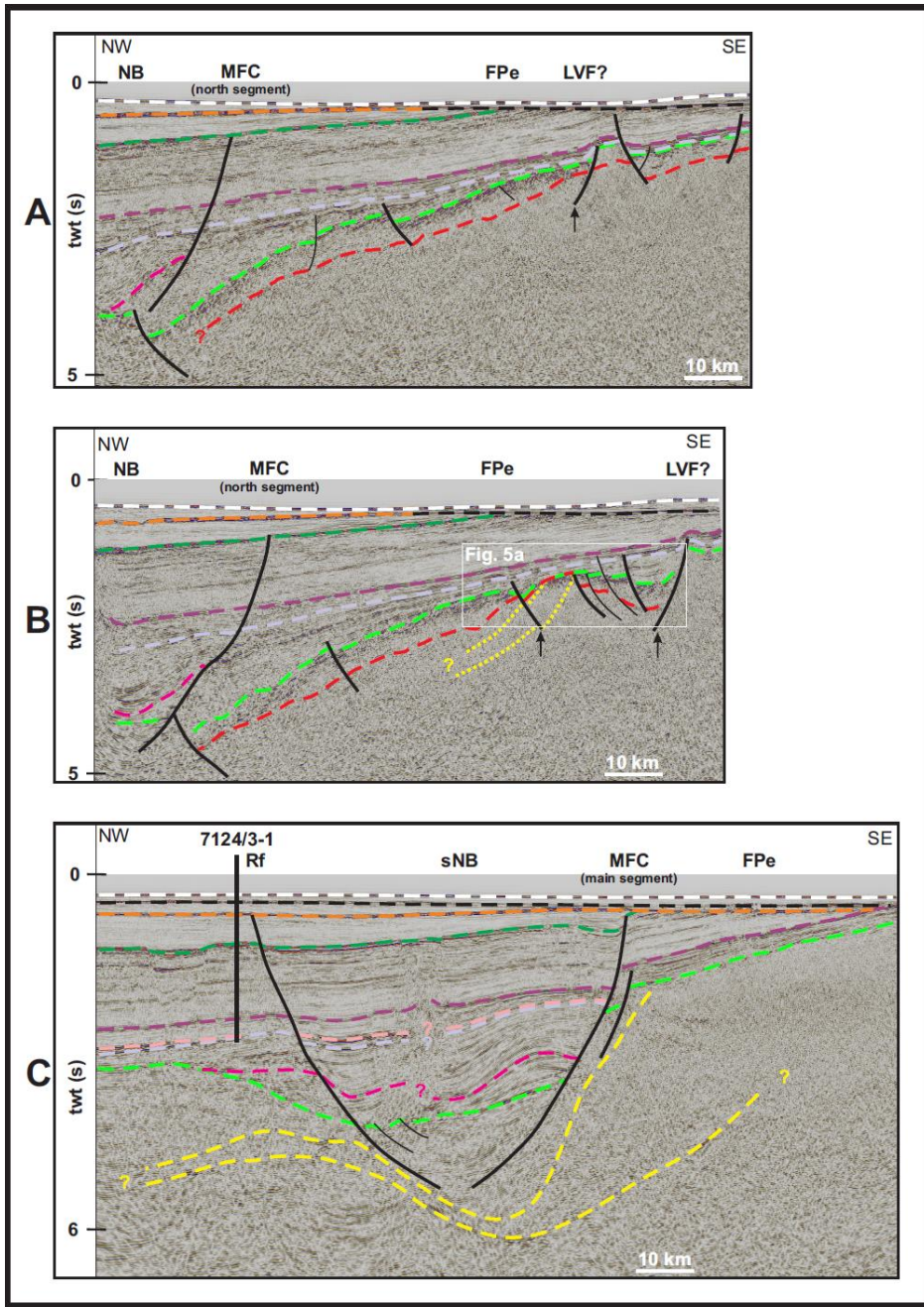


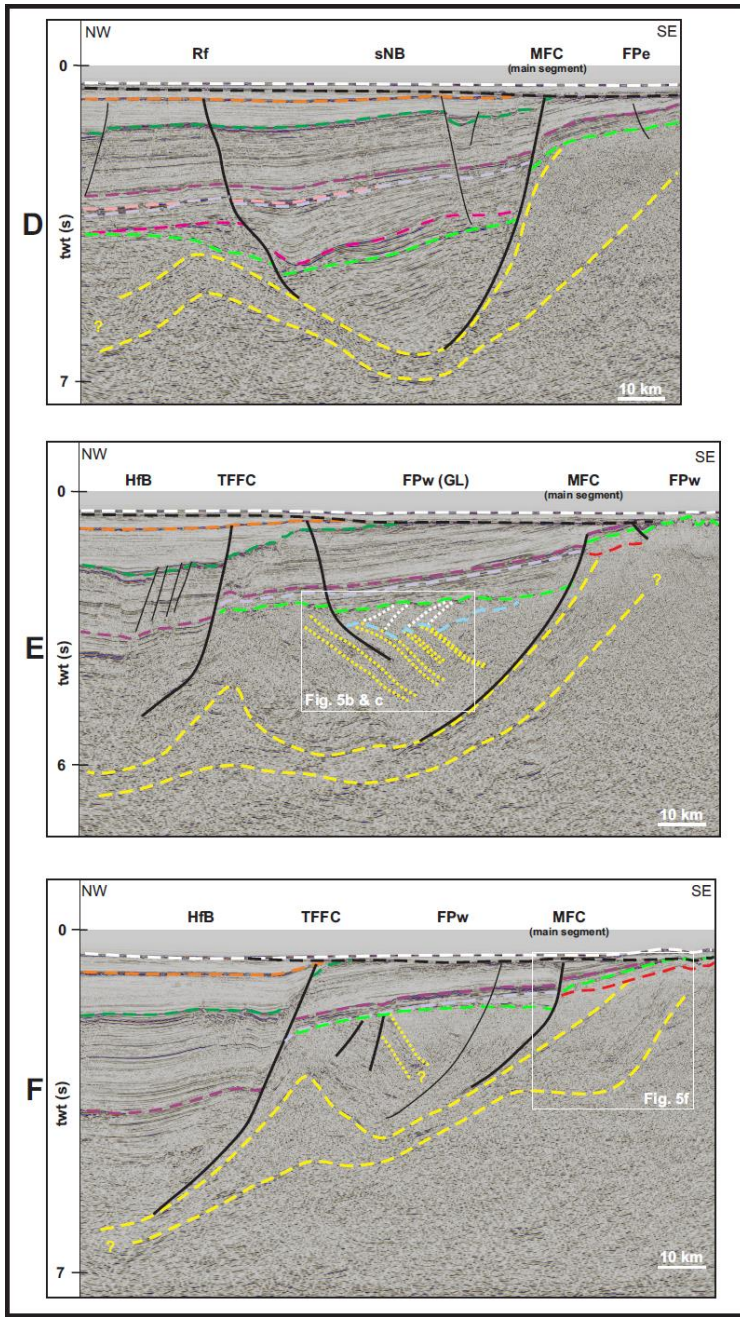
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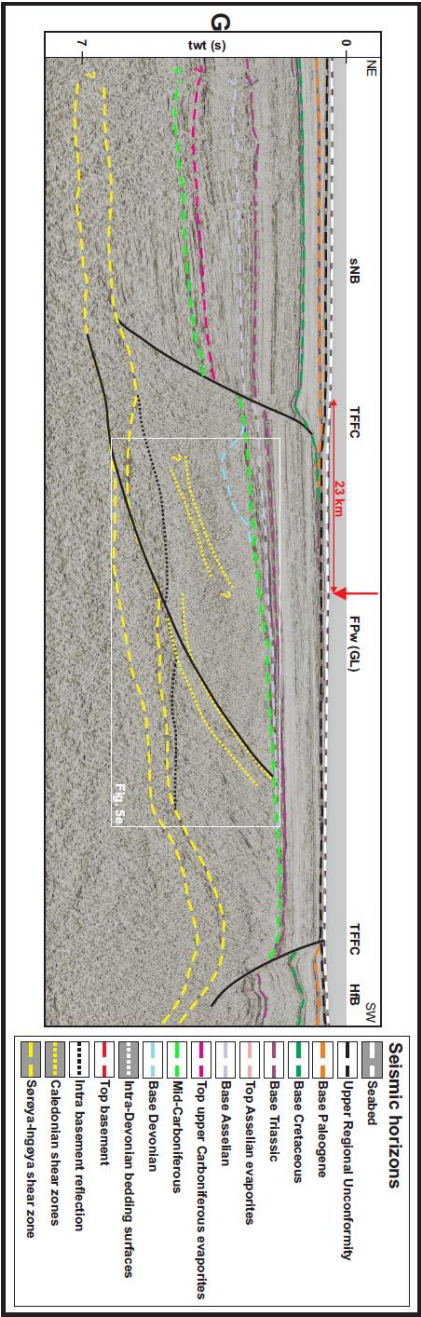
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Figure 443: Zoom in offshore tilt-derivative aeromagnetic data published by Gernigon et al. (2014). The white dashed line on the Finnmark Platform east represents a triangular- to rhomboid-shaped aeromagnetic low that coincides with a Carboniferous 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](#) for abbreviations.

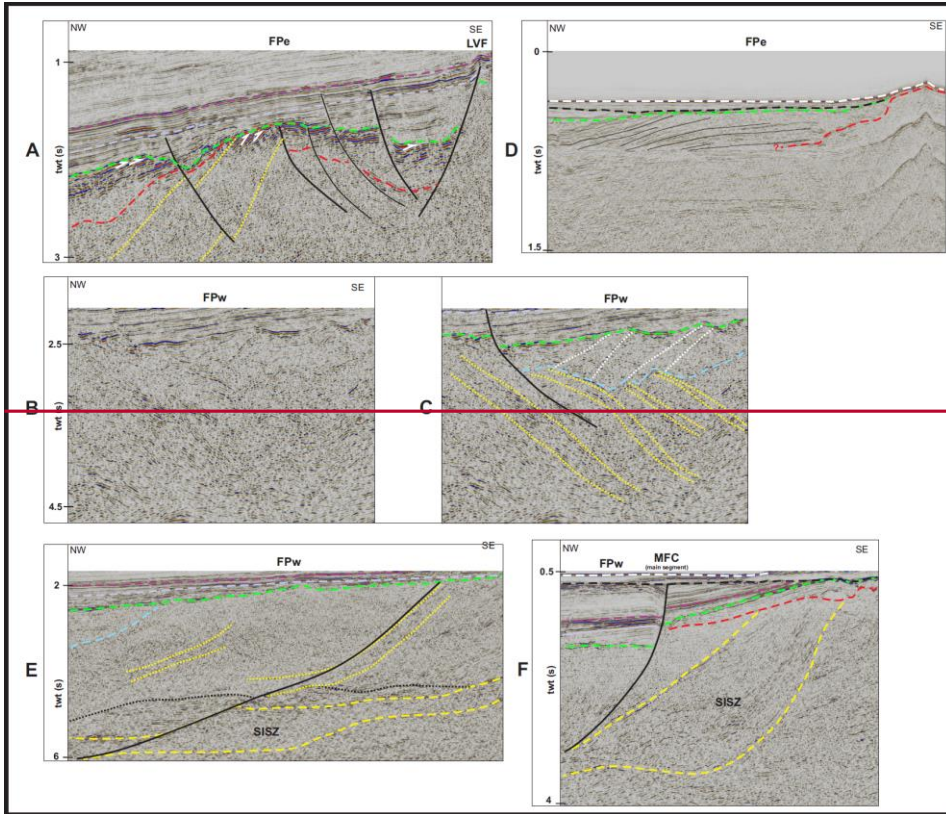


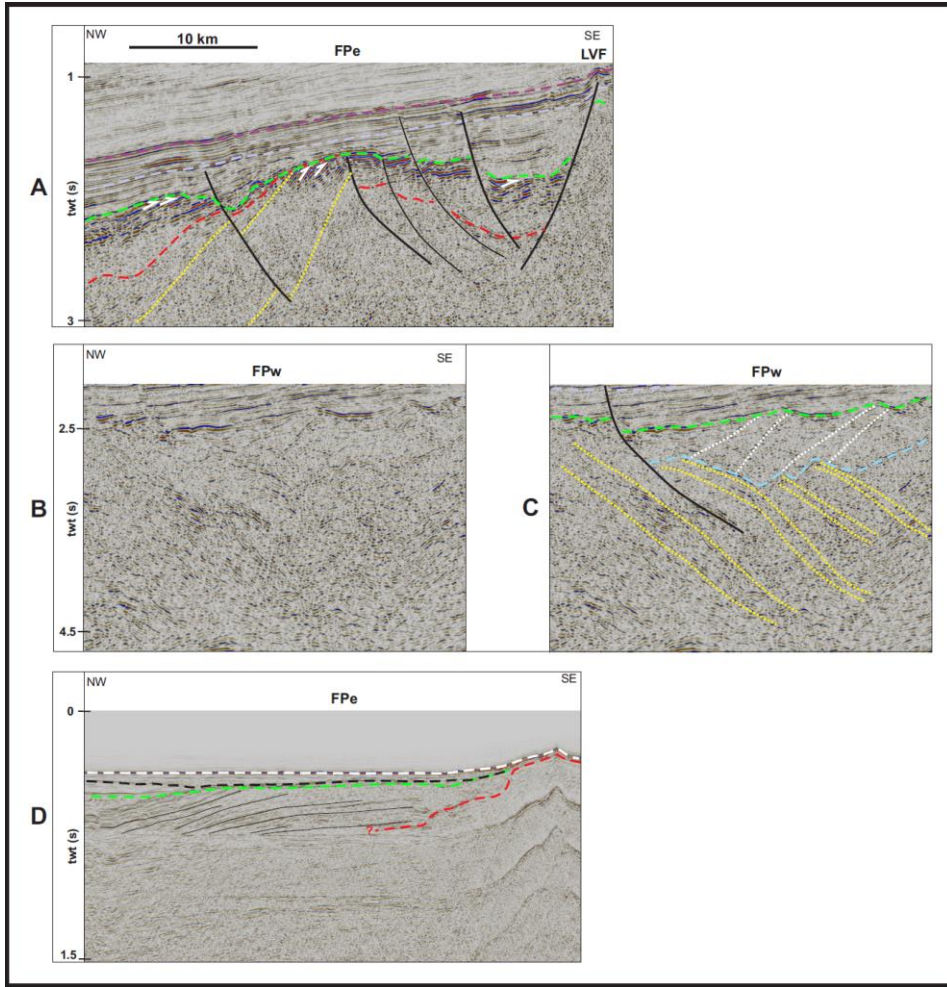






1865 Figure 5.4: Examples of interpreted seismic profiles from the BSS-01 survey (2D) which locations are displayed in Figure
2. Brittle faults are shown in black and depth is in seconds (s) TWT. See Figure 1 for
1870 abbreviations; a) Interpreted seismic section that shows a system of Carboniferous 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
1875 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);
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
1880 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.





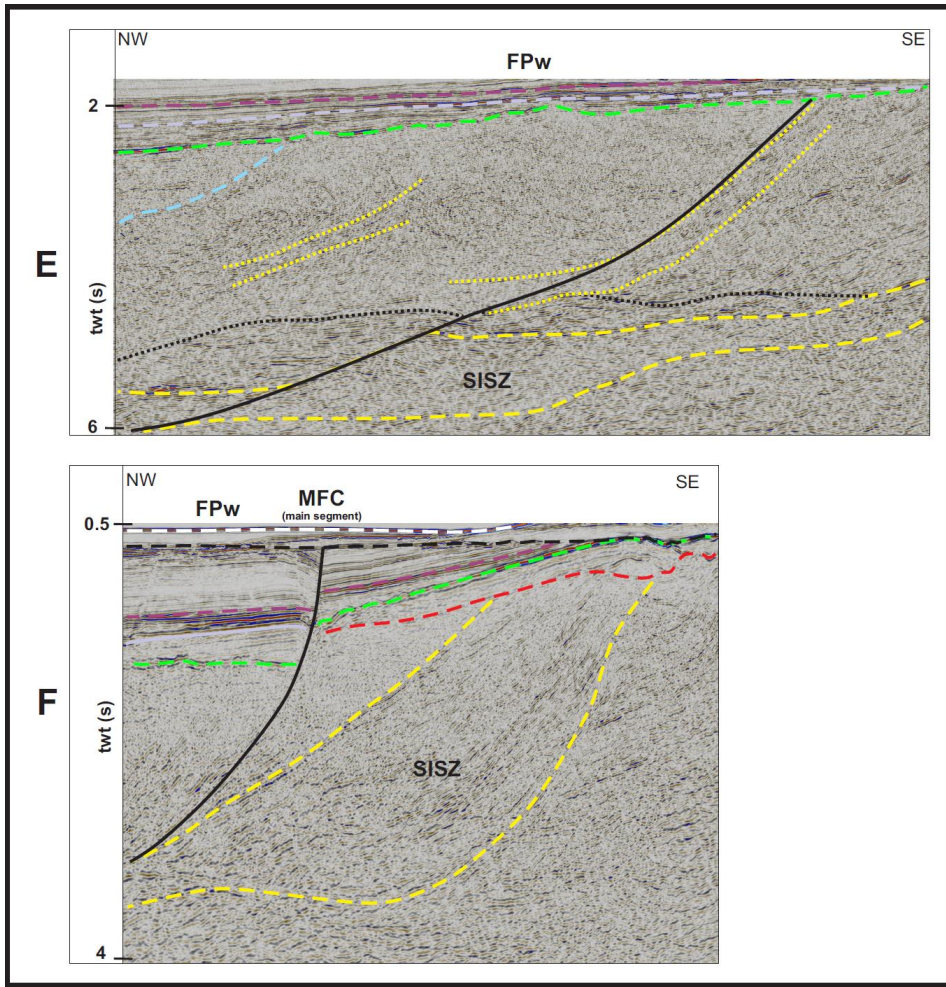
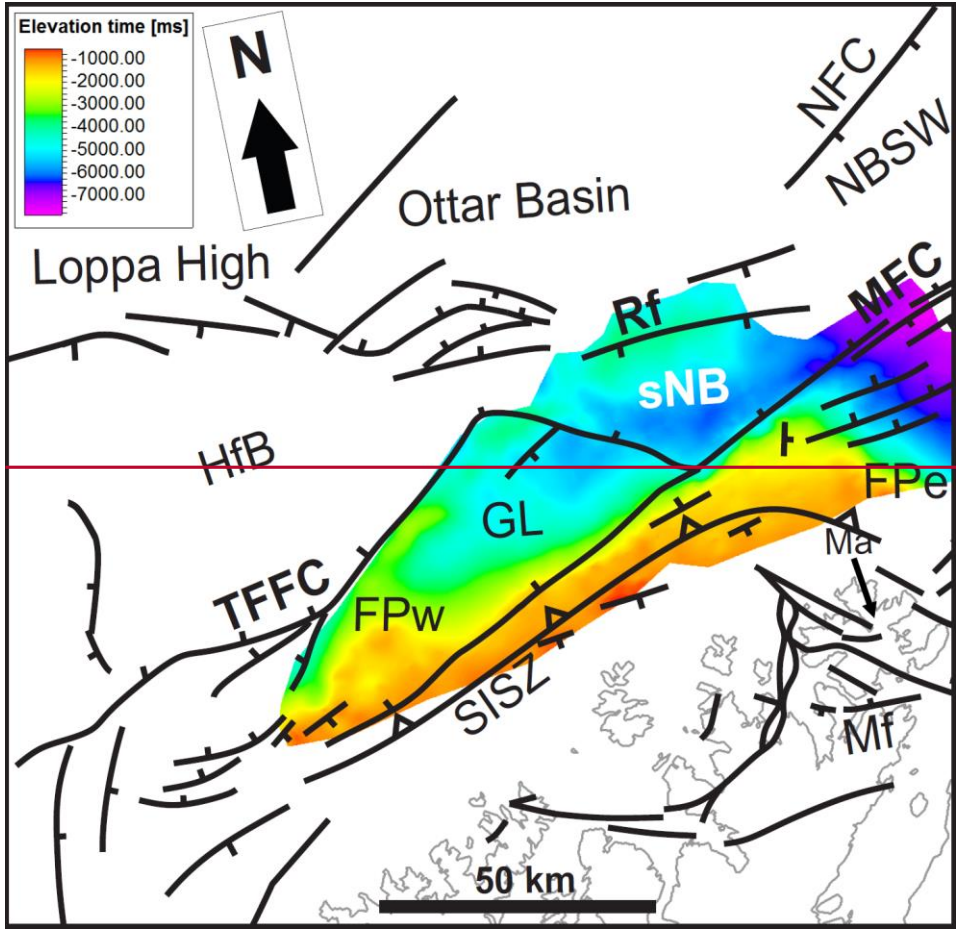


Figure 665: Zoom in seismic sections on the Finnmark Platform east and west. The locations of (a), (b), (c), (e), & (f) are displayed as white frames in Figure 5Figure 5Figure 4 and the location of (d) is shown as a red line in Figure 2Figure 2Figure 2. See Figure 1Figure 1Figure 1 for abbreviations and Figure 5Figure 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 clinofolds (thin black lines) on the Finnmark Platform east (location in Figure 2Figure 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.

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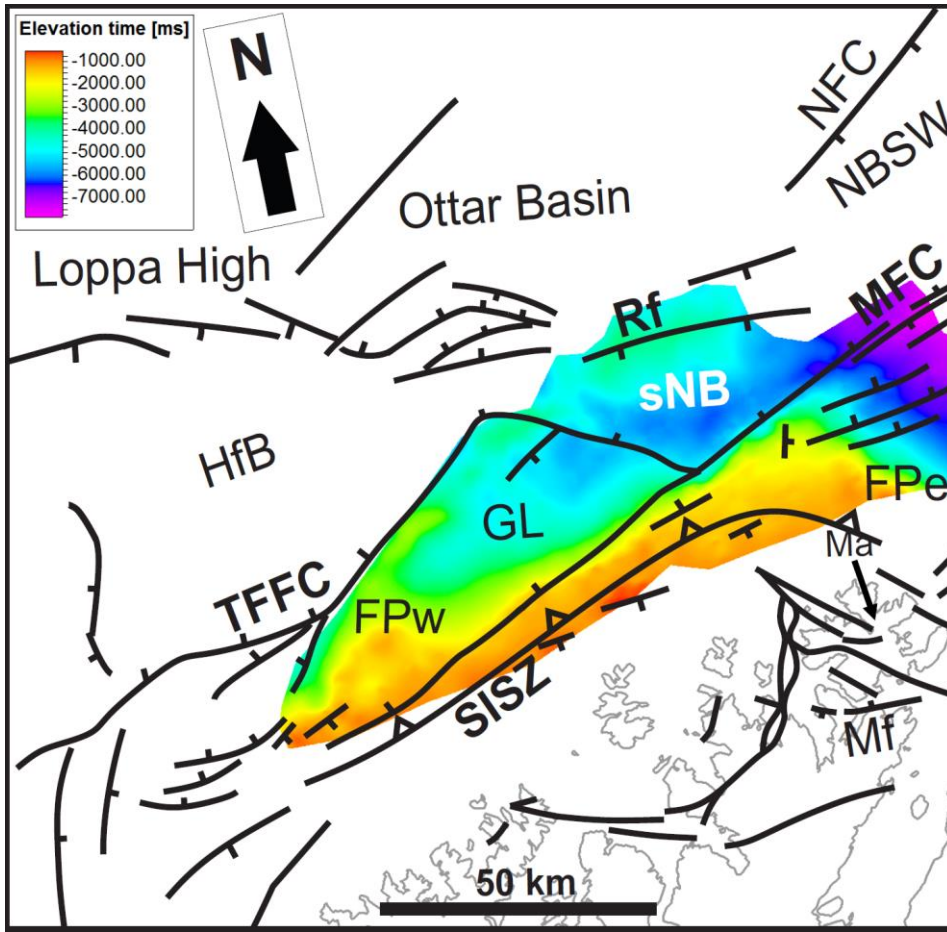
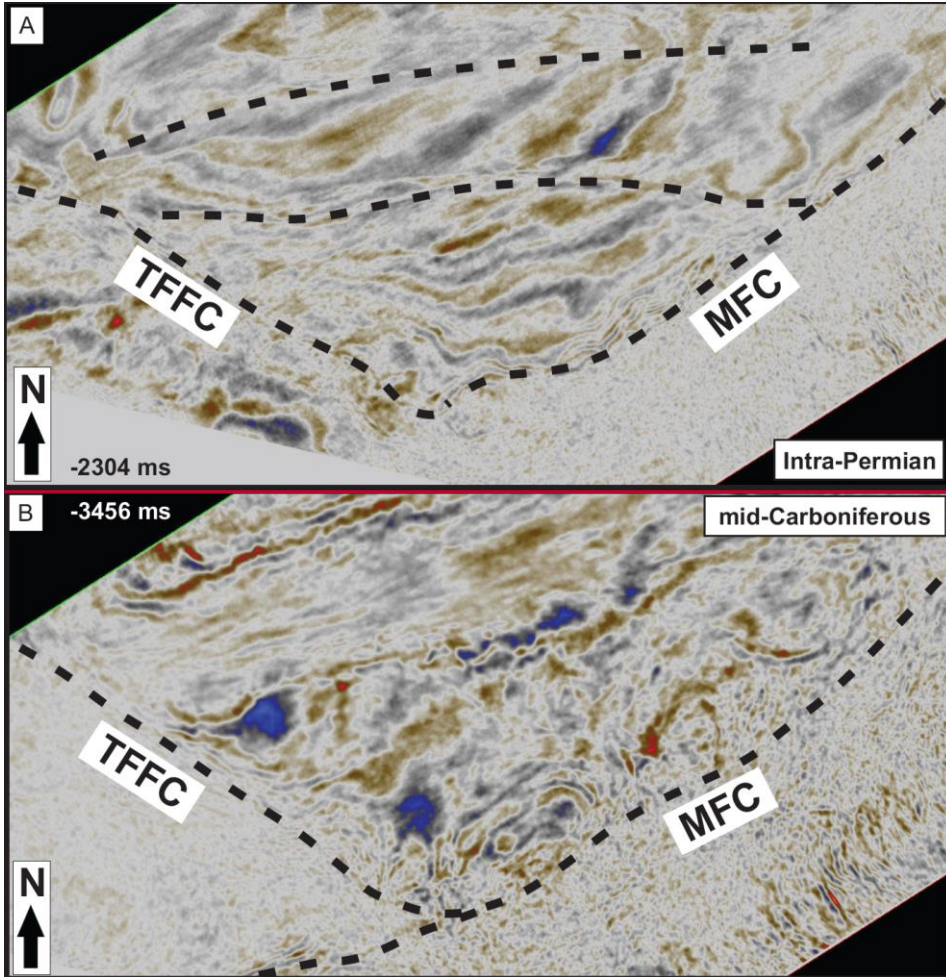


Figure 7.6: Time surface map of the top reflection of the SISZ and major brittle faults in the SW Barents Sea. Note the spoon-shaped depression formed by the SISZ on the Finnmark Platform west and southwesternmost Nordkapp basin, the abrupt change to a northeastward dip on the Finnmark Platform east, and the two narrow, NE-SW and ENE-WSW trending ridges in the footwall of the TFFC and of the Rolvsøya fault.

1910



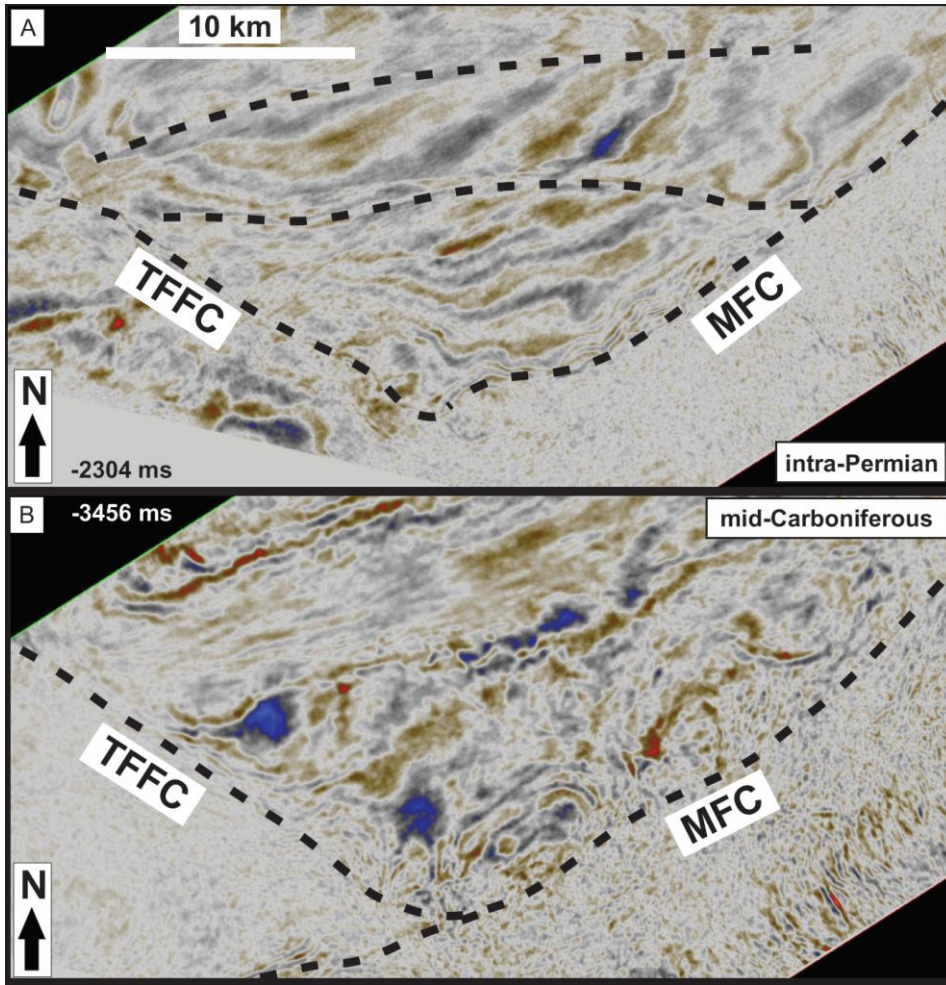
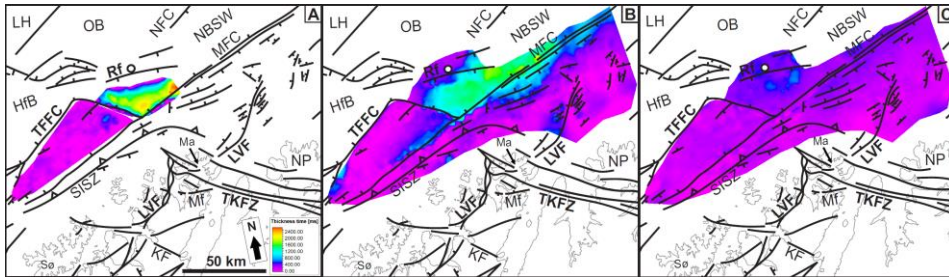
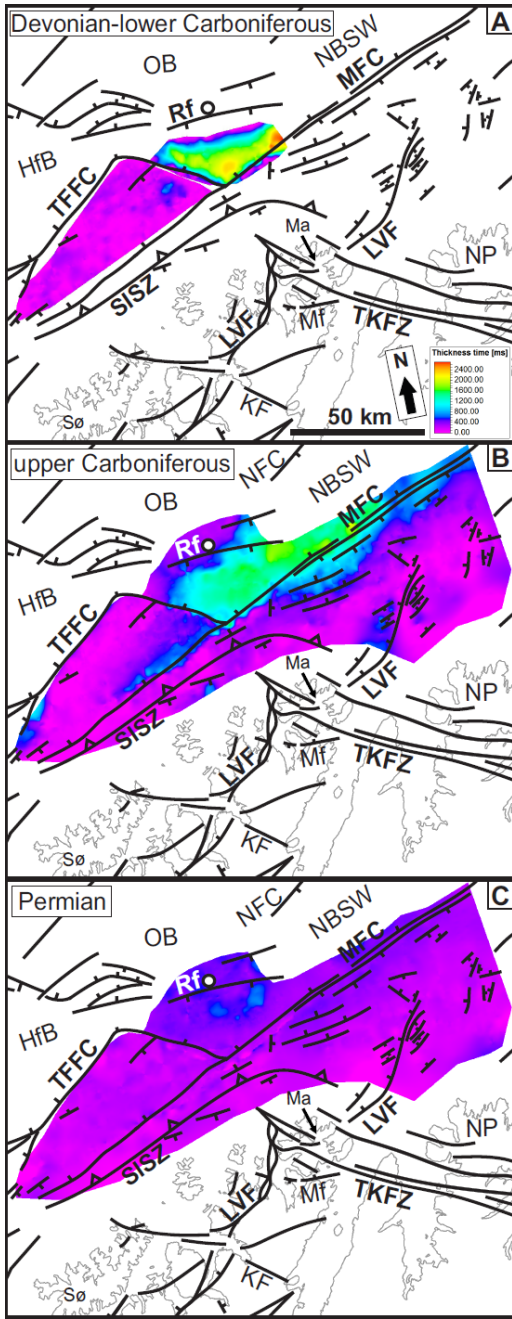


Figure 887: (a) Intra-Permian seismic time-slice within 3D seismic survey MC3D-MFZ02 in the southwesternmost Nordkapp basin. Dashed black lines correspond to interpreted brittle faults; (b) Seismic time-slice within 3D seismic survey MC3D-MFZ02 near the interpreted mid-Carboniferous reflection in the southwesternmost Nordkapp basin. Black dashed lines represent interpreted brittle faults. See [Figure 2](#) for location.

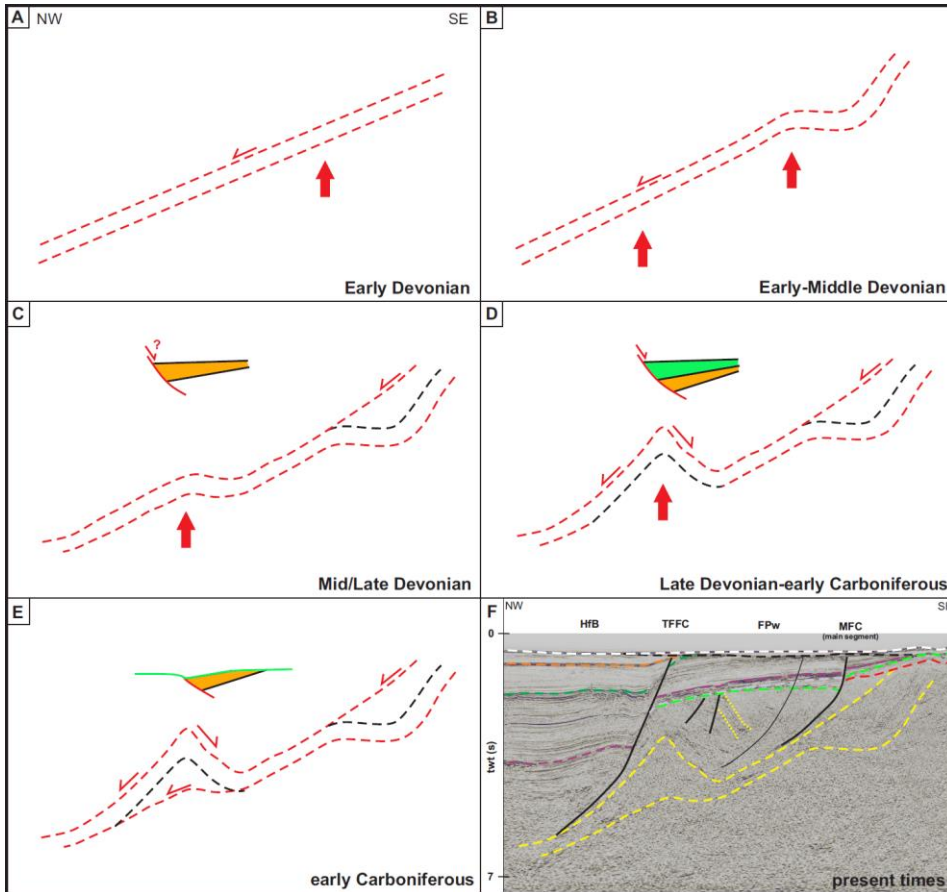




1920 | Figure 998: Thickness maps in milliseconds (ms) two-way time (TWT) of late Paleozoic sedimentary successions on the Finnmark Platform and in the southwesternmost Nordkapp basin. Color scale in (a); a) Thickness map of the Devonian-lower Carboniferous succession on the Finnmark Platform west and 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.

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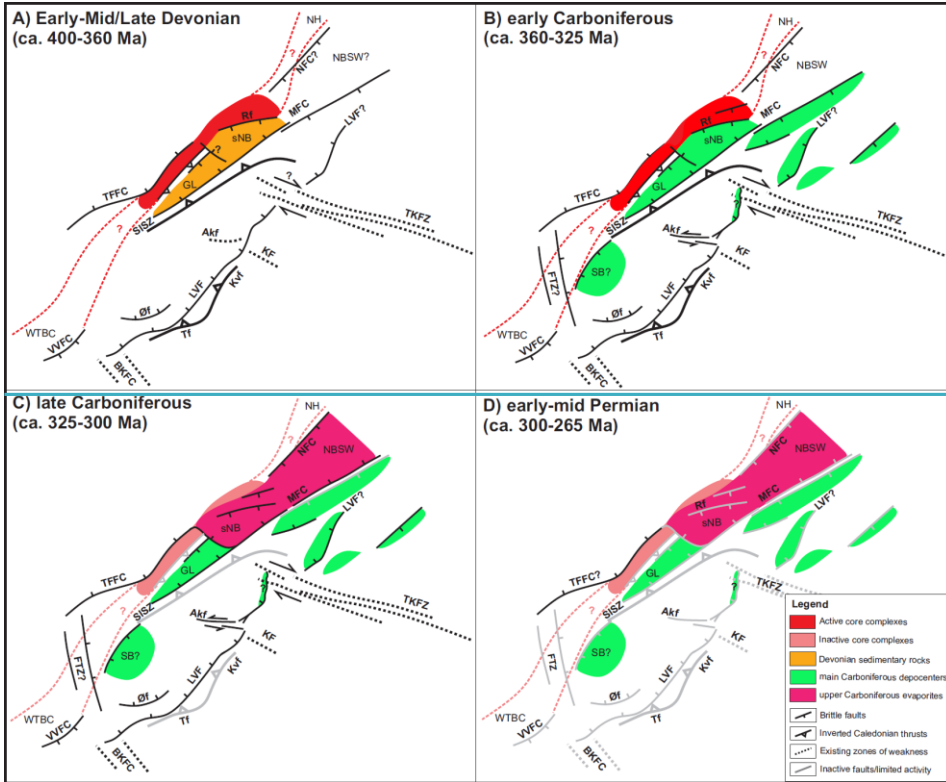
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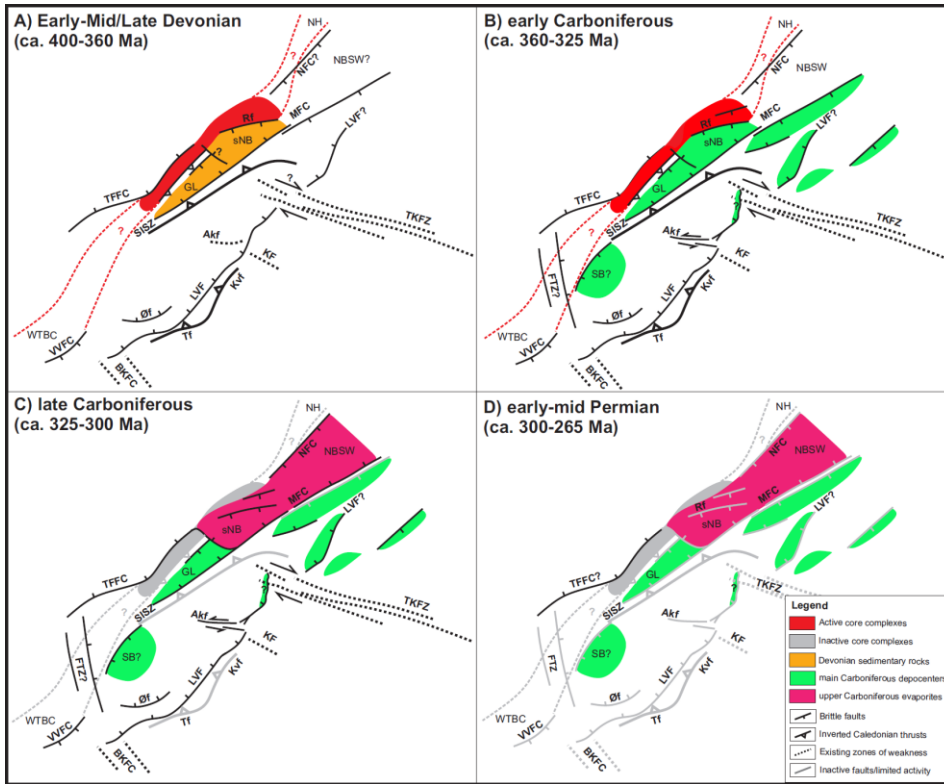


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Figure 10109: Evolutionary model that tentatively explains thickness variations along the SISZ. Note that the timing of (a) to (e) is tentative. Dashed red lines in (a) to (e) correspond to tectonically active portions of the SISZ whereas dashed black lines show inactive portions of the SISZ. 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 exhumation 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 excision (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) triggers 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 incision (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 5~~[Figure 4](#) for seismic reflections color schemes.





1955 Figure 11110: 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 11110-1. 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 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.

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1970