North Barents Composite Tectono-Sedimentary Element

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Abstract: The North Barents Composite Tectono-Sedimentary Element could represent a prosperous petroleum province in the Arctic, with several large basins, platforms and highs identified. The sedimentary succession ranges from the Late Paleozoic and continues throughout most of the Mesozoic. Terrestrial sediments of the Billefjorden Group (Famennian–Visean) are likely to be present, and are overlain by evaporites and carbonates of the Gipsdalen Group (Serpukhovian–Late Artinskian). Most of the Triassic is dominated by deposits from a huge prograding deltaic system building out from the south, SE and east, becoming successively younger towards NW. The system was primarily sourced from the Urals but also partly from mainland Norway and, most probably, from Taimyr. The progradation started in the Late Permian and reached Svalbard in the Early Carnian. The entire delta system was flooded during the regional Early Norian transgression, resulting in the deposition of marine shales of the Flatsalen Formation (Svalbard) and the time-equivalent Akkar Member of the Fruholmen Formation (Barents Sea). The Cretaceous and the Paleogene are, respectively, comprehensively and completely eroded. During the Pliocene–Pleistocene, the entire Barents shelf was a site of repeated glaciations, resulting in extensive erosion. Hydrocarbon source rocks occur at several stratigraphic levels from the Carboniferous to the Jurassic, of which the most important is assumed to be the Lower–Middle Triassic Steinkobbe/Botneheia Formation. The Upper Jurassic Hekkingen Formation, where present, is likely to be immature across the whole area. Potential reservoir rocks are Permian carbonates and siliciclastic rocks of Carboniferous and Mesozoic age.

The North Barents Composite Tectono-Sedimentary Element (CTSE) is regarded as a potential high-resource petroleum province in the Arctic. The province, however, is not currently open to petroleum activities, and is underexplored except for scientific expeditions and data acquisition by the Norwegian Petroleum Directorate (NPD). The content of this chapter is primarily based on the NPD report 'Geological Assessment of Petroleum Resources in Eastern Parts of Barents Sea North' (NPD 2017). It is also based on unpublished reports from stratigraphic boreholes drilled by the NPD, and on the interpretation of non-commercial, NPD regional seismic data.

Age

Confirmed ages of sedimentary successions range from the Late Pennsylvanian (Gzhelian) to the Early Cretaceous (Barremian); however, Late Devonian (Famennian) and Mississippian strata are also assumed to be present. The Jurassic and Cretaceous rocks are eroded in large parts of the area, while Paleogene and Neogene are absent over the entire area (e.g. Grogan *et al.* 1999; Knies *et al.* 2009; Lasabuda *et al.* 2018*a*, *b*). On several platforms and highs, strata down to Olenekian age crop out at the seafloor. The age is estimated from seismic interpretations tied to exploration wells in the southern Barents Sea and NPD stratigraphic boreholes within the area, as well as stratigraphic correlations to equivalent successions onshore Svalbard as described by, for example, Mørk *et al.* (1999), Dallmann *et al.* (2015) and Olaussen *et al.* (2022).

Geographical location and dimension

The North Barents CTSE is situated between approximately 74° N and 80° N, and is delimited to the east by the East Barents Sea CTSE. To the north, it stretches towards the Northeastern Basement Province. To the NW, it is delimited by the Svalbard CTSE, to the west by the West Barents Rifted Margin CTSE and the Stappen High–Bjørnøya CTSE, and to the south by the Tromsø–Bjørnøya and the South-Central Barents Sea CTSEs. It covers an area of *c.* 175 000 km^2 (Fig. 1; Enclosures A and E).

Principal datasets

Wells

Shallow stratigraphic boreholes drilled by the NPD, with the Continental Shelf Institute (IKU) and SINTEF Petroleum Research as the operators, and one drilled by IKU are the only core data in this area. During the period 1985–2015, a total of 29 boreholes were drilled and cored (Fig. 2). The cores provide important information on the depositional environment, age, provenance, geochemistry and reservoir properties of the sediments. Consequently, they provide the information required for assessing petroleum systems, and the presence of source, reservoir and cap rocks. The depth of the boreholes was limited to 200 m below the seabed. Drilling was conducted where seismic reflectors crop out at the seabed, usually at an angle that allows coring of the mostly continuous and deep parts of the stratigraphy. The cored succession ranges in age from the latest Carboniferous (Gzhelian) to the Early Cretaceous (Barremian), and the cores provide an excellent basis for regional correlation and increased understanding of the geological development. An overview of the technical core data from the stratigraphic boreholes are shown in Table 1.

Seismic data

The NPD acquired around 70 000 km of 2D regional seismic lines in the North Barents CTSE during the period 1973–96 (Fig. 2). Despite the poor quality of many of these datasets, they still provide useful and complementary information, especially when combined with new surveys. During the period 2012–17, the NPD acquired nearly 50 000 km of new 2D seismic data, primarily in the eastern parts of the area. In 2019, 1000 km^2 of 3D seismic data were acquired on the easternmost part of the Sentralbanken high.

The quality of the new datasets is considerably improved compared to the older datasets but there are still limitations with the seismic resolution in the deeper parts of the sedimentary basins. Seismic multiples from the seabed and shallow reflectors in the sedimentary succession also cause mapping

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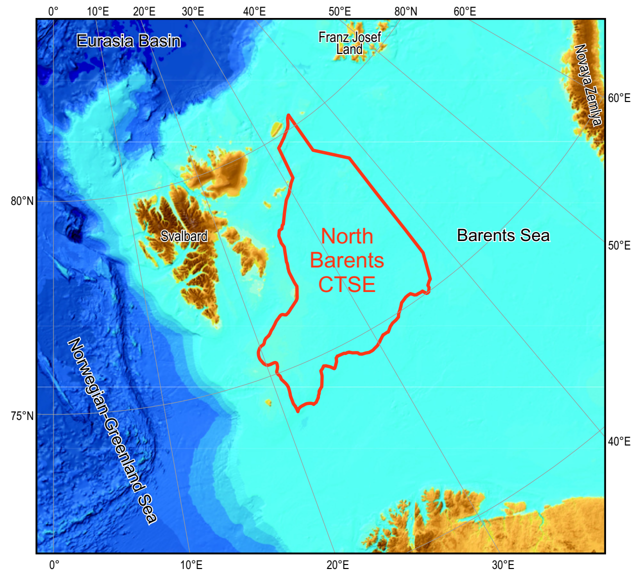

Fig. 1. Overview and location of the North Barents Composite Tectono-Sedimentary Element (CTSE).

challenges. The data quality in general decreases towards the west due to water depth and sub-cropping layers with different and changing acoustic properties.

Tectonic setting, boundaries and main tectonic/erosional/depositional phases

The boundary of the North Barents CTSE is defined by the outer boundaries of updated structural elements and the delimitation line between Norway and Russia (Fig. 3). To the north and NW it is delimited by the boundary of the Svalbard TCSE, which includes all the islands and shelf areas in between. The main structural elements in the North Barents CTSE are assumed to be controlled primarily by the underlying Timanian and Caledonian basement, and by reactivation of older zones of weakness during compressional phases in the Late Jurassic–Early Cretaceous, Late Cretaceous and Eocene (Grogan *et al.* 1999; Faleide *et al.* 2017; Kairanov *et al.* 2018; Gac *et al.* 2020; Enclosure D). During the Late Paleozoic and most of the Mesozoic, the northern Barents Sea was a tectonically relatively quiet area where regional subsidence was the main driving factor for sedimentation (Mørk *et al.* 1982). Five important tectonosedimentary events that affected the North Barents CTSE are described below and summarized in Figure 4.

Regional extension, which resulted in rifting and block faulting, occurred from the Famennian to the Bashkirian and defines the TSE 1, which corresponds to the TSE 1 and lower part of TSE 2 in the Svalbard CTSE. Areas where growth faults associated with this rifting are clearly visible include the graben on the Sentralbanken high. A period of tectonic stability was initiated in the Moscovian and lasted throughout the Permian, leading to the development of a carbonate platform that was subsequently succeeded by the deposition of spiculitic and calcareous shales (Gjelberg 1981, 1987; Brekke and Riis 1987; Stemmerik and Worsley 2005), which define the TSE 2, and correspond to the upper TSE 2 and TSE 3 and 4 in Svalbard.

Regional subsidence started in the latest Permian and lasted until the Early Norian, when a huge deltaic system originating in the Urals prograded gradually northwestwards and reached Svalbard in the Carnian (Riis *et al.* 2008; Glørstad-Clark *et al.* 2010; Lundschien *et al.* 2014; Klausen *et al.* 2015, 2016, 2019), constituting the TSE 3 and corresponding to the lower TSE 5 in Svalbard.

Following the Early Norian regional transgression (Bergan and Knarud 1993; Mørk *et al.* 1999; Worsley 2008), the Realgrunnen Subgroup of Norian–Bajocian age (Mørk *et al.* 1999) was deposited and comprises the TSE 4, which corresponds to the upper TSE 5 in Svalbard. The uppermost part is differentially eroded due to syndepositional uplift (Worsley *et al.* 1988) and draped by the condensed Brentskardhaugen Bed (Parker 1967), marking a new transgression (e.g. Birkenmajer *et al.* 1982; Dypvik *et al.* 1991), onto which the Adventdalen Group developed, which encompasses the TSE 5, corresponding to the TSE 6 in Svalbard.

During the Late Jurassic and Early Cretaceous regional compression formed structural traps within the TSE 2, 3, 4 and 5 (Grogan *et al.* 1999).

Compressional movements in the Late Cretaceous and Cenozoic that caused uplift and erosion, as well as subsequent repeated Quaternary glacial erosion, removed most of the Jurassic and Cretaceous in large parts of the area, and the Paleogene–Neogene across the entire area (e.g. Vorren *et al.* 1989; Knies *et al.* 2009; Lasabuda *et al.* 2018*a*, *b*) (Fig. 4).

A general summary of the main tectonic events (Figs 3–5; Enclosure D and E) includes:

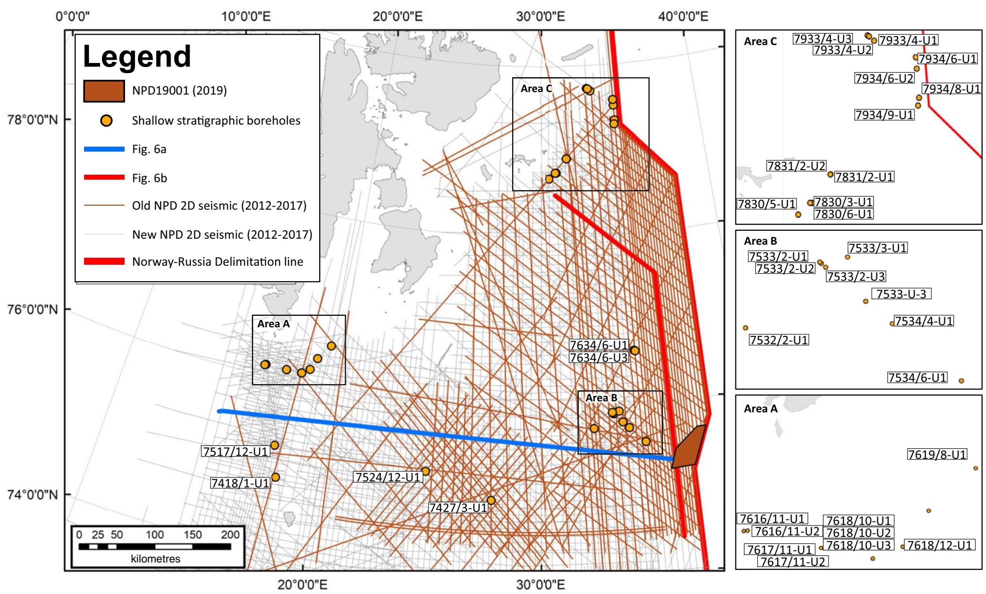

Fig. 2. Overview of shallow stratigraphic boreholes and regional seismic data coverage including vintage (grey) and new (orange) 2D surveys in the North Barents CTSE. The brown-filled polygon marks a 3D survey.The regional geoseismic profiles in Figure 6 are also indicated.

Table 1. *Overview of technical core data from shallow stratigraphic boreholes in the North Barents CTSE*

Core no.	Structural element	Water depth (m)	Core depth from seabed total depth (TD) (m)	Pre-Quaternary/ Quaternary thickness (m)	Core recovery (%)	Age of cored sediments
Sentralbanken high and Storbanken high (1990, 1995, 1998)						
7533/2-U1	Sentralbanken high	274.70	200.45	198.30/2.15	95.96	Late Triassic
7533/2-U2	Sentralbanken high	267.50	88.12	87.12/1.00	99.70	Late Triassic
7533/2-U3	Sentralbanken high	256.00	26.68	25.68/1.00	97.87	Early Jurassic
7533/3-U7	Sentralbanken high	232.40	201.00	199.80/1.25	99.20	Late Triassic
7534/4-U1	Sentralbanken high	201.60	120.10	111.60/9.60	93.70	Early–Middle Triassic
7534/6-U1	Sentralbanken high	167.30	233.60	232.60/1.00	98.10	Early–Middle Triassic
7634/6-U1	Storbanken high	187.00	122.27	120.27/2.00	99.68	Middle Jurassic–Early Cretaceous
7634/6-U3	Storbanken high	195.70	40.93	37.93/3.00	74.23	Middle Jurassic
Northern Edgeøya platform (1994, 1995)						
7616/11-U1	Northern Edgeøya platform	329.00	69.25	67.25/2.00	94.20	Early Cretaceous
7616/11-U2	Northern Edgeøya platform	325.50	47.80	16.35/31.50	75.4	Early Cretaceous
7618/10-U1	Northern Edgeøya platform	226.50	28.80	15.70/13.10	82.10	Early Cretaceous
7618/10-U2	Northern Edgeøya platform	226.00	13.60	0.60/13.00	N/A	Early Cretaceous
7618/10-U3	Northern Edgeøya platform	226.00	22.40	8.70/13.70	88.70	Early Cretaceous
7618/9-U1	Northern Edgeøya platform	270.40	158.30	133.20/5.50	99.60	Late Jurassic–Early Cretaceous
7618/12-U1	Northern Edgeøya platform	235.20	198.50	185.30/13.20	99.90	Early Cretaceous
7619/8-U1	Northern Edgeøya platform	245.90	138.70	158.30/12.30	98.20	Late Jurassic
Kong Karl platform (2005)						
7830/3-U1	Kong Karl platform	208.90	199.60	196.46/3.20	98.60	Late Triassic
7830/5-U1	Kong Karl platform	252.00	144.77	127.00/<19.00	98.50	Late Triassic
7830/6-U1	Kong Karl platform	195.30	52.85	49.35/<3.50	96.70	Late Triassic
7831/2-U1	Kong Karl platform	132.40	27.95	20.95/<6.00	87.60	Middle–Late Triassic
7831/2-U2	Kong Karl platform	130.40	18.85	13.30/<5.50	92.60%	Middle Triassic
Offshore Kvitøya (2015)						
7934/8-U1	Kong Karl platform	231.00	196.05	N/A	N/A	Late Triassic
7934/9-U1	Kong Karl platform	252.00	164.70	N/A	N/A	Late Triassic
7934/6-U1	Kong Karl platform	319.00	200.00	N/A	N/A	Late Triassic
7934/6-U2	Kong Karl platform	333.00	182.30	N/A	N/A	Late Triassic
7933/4-U1	Kong Karl platform	359.00	134.10	N/A	N/A	Middle–Late Triassic
7933/4-U2	Kong Karl platform	252.00	15.50	N/A	N/A	Early Triassic
7933/4-U3	Kong Karl platform	348.00	199.85	N/A	N/A	Late Permian–Early Triassic
8034/5-U1	Kong Karl platform	252.00	52.00	N/A	N/A	Late Permian–Eocene(?)

- Regional extension from the Famennian to the Bashkirian, resulting in rifting and block faulting (TSE 1);
- tectonic quiescence, leading to the development of a carbonate platform in the Moscovian and throughout the Permian (TSE 2);
- regional subsidence from the latest Permian until the early Norian, when a huge delta system originating in the Urals prograded gradually northwestwards (TSE 3);
- deposition of the Realgrunnen Subgroup following the early Norian transgression (TSE 4);
- syndepositional uplift, causing an erosional unconformity on top of the Realgrunnen Subgroup, onto which the Adventdalen Group developed (TSE 5);
- Late Jurassic and Early Cretaceous compression formed structural traps within the TSE 2, 3, 4 and 5; and
- compression in the Late Cretaceous and Paleogene–Neogene and subsequent repeated Quaternary glacial erosion removed most of the Jurassic and overlying sediments.

Underlying and overlying rock assemblages

Age of underlying basement (consolidated crust) or youngest underlying sedimentary unit

Parts of the preserved Late Paleozoic–Mesozoic succession are likely to rest on Caledonian basement rocks of Ordovician–Early Devonian age. These are probably of the same composition as the basement rocks in Svalbard, as described by Dallmann *et al.* (2015) and Olaussen *et al.* (2022), and those drilled by exploration wells in the south Barents Sea, as described by Henriksen *et al.* (2021) and Brunstad and Rønnevik (2023) (Enclosure D). Large parts of the area covering the Gardarbanken high, Sentralbanken high, Olga basin, Storbanken high and Kong Karl platform probably also have Timanian basement rocks of Neoproterozoic age (Klitzke *et al.* 2019).

Age of oldest overlying sedimentary unit

The sedimentary succession sub-crops across the entire area with Mesozoic strata directly beneath a thin layer of Quaternary, mainly glacial deposits.

Subdivision and internal structure

The division of the principal structural elements in the North Barents CTSE is based on the NPD Bulletin *Structural Elements of the Norwegian Continental Shelf; the Barents Sea Region* (Gabrielsen *et al.* 1990). After this publication, the NPD and others extended the mapping in the region (Grogan *et al.* 1999; Anell *et al.* 2016; NPD 2017; Klitzke *et al.* 2019), and it has been necessary to make some adjustments and to introduce new terms to properly describe all of the main structural elements in the study area. The names used for structural

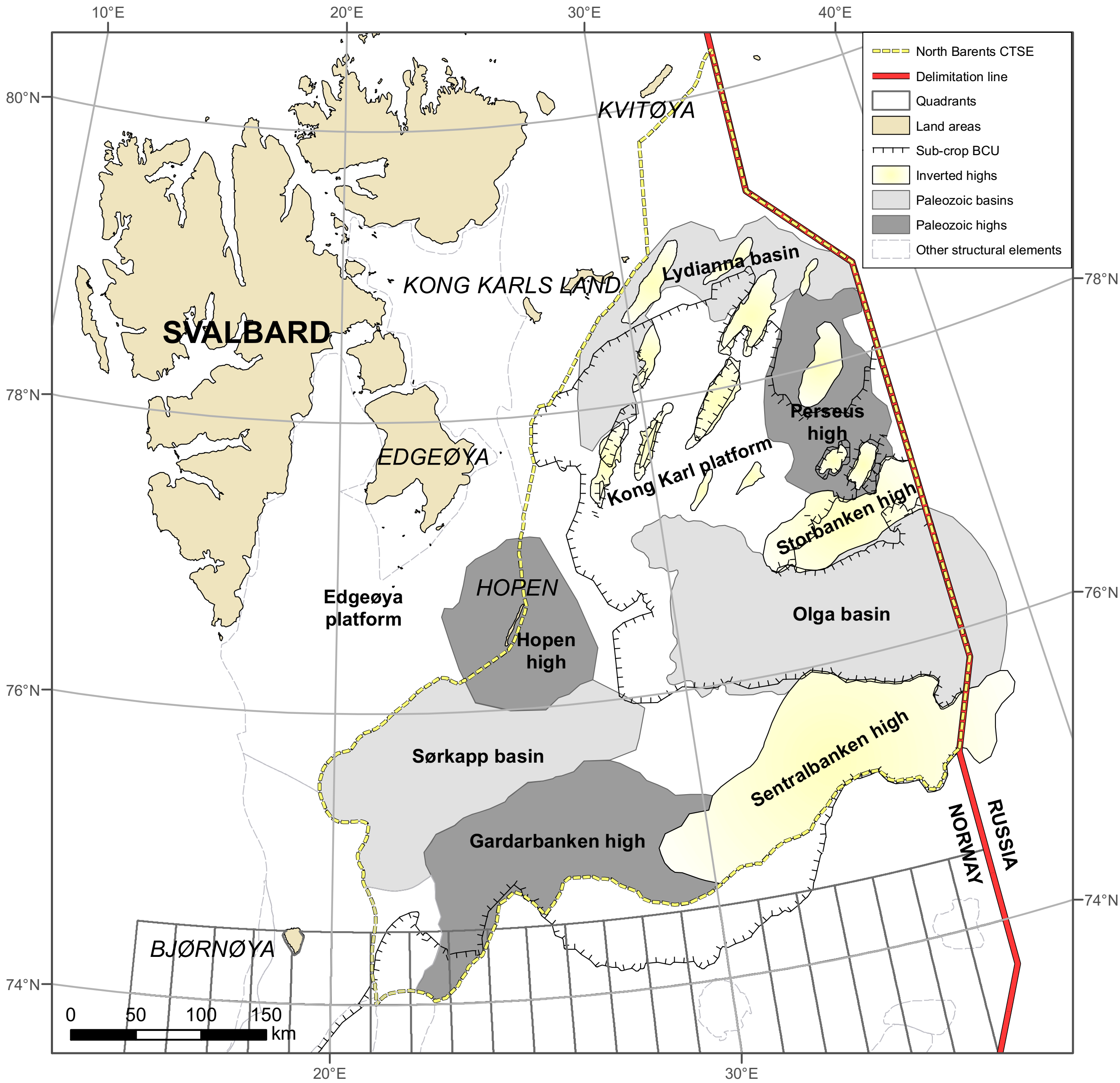

Fig. 3. The structural elements within the North Barents Composite Tectono-Sedimentary Element.

elements in the text are still not formally approved and, hence following the rules of the Norwegian Committee on Stratigraphy (Nystuen 1989), names are indicated by using a lowercase initial letter in the descriptive part of the name (e.g. the Sentralbanken high). The structural elements are defined based on large faults and structural time maps of the Top Permian, Top Mississippian and Base Cretaceous Unconformity (BCU: Fig. 5), and are shown in Figure 3.

Sentralbanken high

The structure is a SW–NE- to west–east-orientated high fragmented by Paleozoic normal faults reactivated as reverse faults by Late Jurassic and younger compression (Fig. 6a). The northern boundary is primarily defined by a prominent reverse fault, its southern flank by other prominent faults and the eastern parts by the sub-crop of the BCU (Figs 3 & 5). Most of the Sentralbanken high contains a Paleozoic sedimentary succession with several horst and graben structures that were formed in the Mississippian (Grogan et al. 1999).

Olga basin

This basin is an east–west-orientated large syncline confined by the Sentralbanken high in the south and the Storbanken high in the north (Figs 3 & 6b). The uppermost Jurassic and the Lower Cretaceous successions thin out towards both highs and are confined to the basin. It has sub-basins extending NW towards the Kong Karl platform (see the ‘Kong Karl platform’ subheading) and SW towards the Gardarbanken high. The NW-orientated sub-basin might have a continuation westwards to the north of Hopen (Klitzke et al. 2019). The Olga basin was a profound basin in the Paleozoic, and is assumed to have formed in the Mississippian or earlier. Subsidence ceased during the Triassic and most of the Jurassic, before continuing during the latest Jurassic and Early Cretaceous.

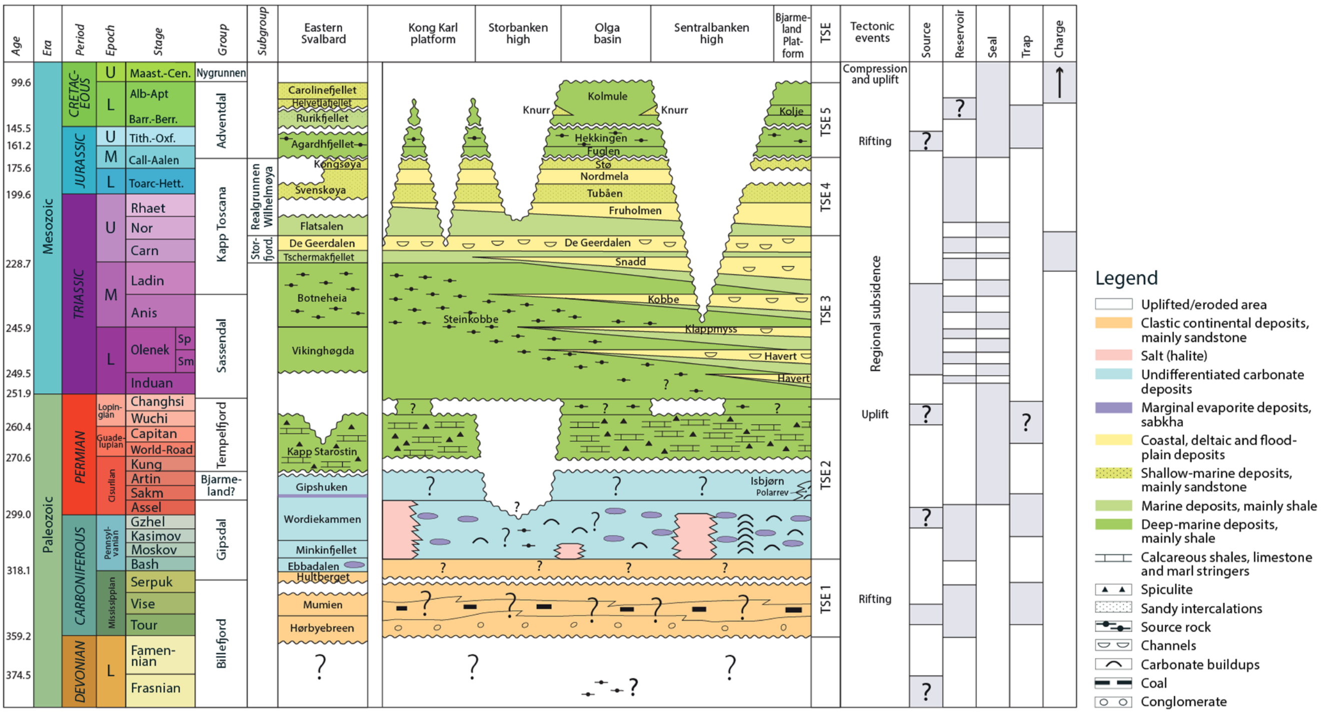

Fig. 4. Tectonostratigraphic chart, orientated SE–NW from the northeastern Bjarmeland Platform to eastern Svalbard, with key geological events. Adapted from NPD (2017). Note that the timescale is non-linear in order to highlight the development of the Triassic succession.

The orientation of the Olga basin axis is situated in the prolongation of Neoproterozoic Timanian trends from the Barents Sea and the Pechora Sea, suggesting that the Olga basin region might be underlain by Timanian basement rocks (Klitzke *et al.* 2019).

Perseus high

The Perseus high is a basement high (Marello *et al.* 2013) (Fig. 3). It is draped by a thin package of Pennsylvanian–Permian sediments overlain by a thin and condensed Lower and Middle Triassic section, suggesting that parts of the high might have also been subaerially exposed during the Late Permian and the earliest Triassic. The Carnian succession is very thick, and the uppermost Triassic and most of the Jurassic sediments are either eroded or sub-crop at the seafloor on large parts of the high. The high has previously been referred to as the Storbanken high, which herein is a name used for the inverted high on the southern flank of the Perseus high.

Storbanken high

The Storbanken high initially formed in the latest Jurassic as an inverted structure on the northern flank of the Olga basin (Fig. 6b). Most of the Jurassic succession is either eroded or sub-crops at the seafloor along the outline of the high. The structure is dissected by a large east–west-orientated fault zone from the Upper Paleozoic to the seafloor. The Storbanken high is an area where Early–Middle Triassic shelf-break clinoform sequences developed over time without prograding far

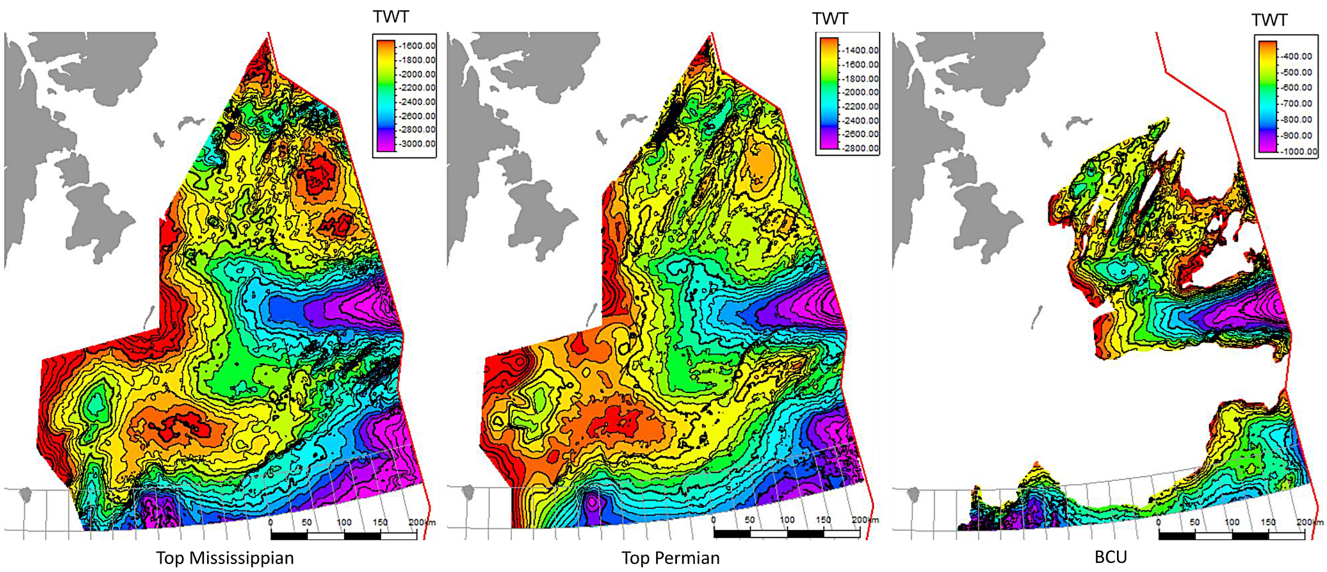

Fig. 5. Structural time maps for the Top Mississippian, Top Permian and Base Cretaceous Unconformity (BCU) in the North Barents Composite Tectono-Sedimentary Element. TWT, two-way travel time (ms).

until the Carnian. This structure has previously been erroneously referred to as the Hopen high on NPD maps.

Kong Karl platform

The structure is herein generally defined by the area where the BCU and Lower Cretaceous sediments are preserved north of the Olga basin and east of the Perseus high. It is dominated by NE–SW-orientated compressional anticlines of various dimensions, the largest ones being more than 100 km long (Fig. 5). The formation of the anticlines started in the latest Jurassic, with the relief being enhanced during later tectonic episodes, and locally the Jurassic succession is eroded or subcropping at the seafloor. The seismic image below the Middle Carboniferous reflector is characterized by poor reflectivity and could indicate that much of the platform area is part of a basement plateau (Fig. 6b). The platform has a very thin package of Lower and Middle Triassic deposits. Parts of the northern area are characterized by lavas and intrusions from the High Arctic Large Igneous Province (HALIP) event (Senger *et al.* 2014), mostly located in the Upper Jurassic shales.

Lydianna basin

The Lydianna basin is a distinctive, previously unnamed, Paleozoic basin area NNE of the Kong Karl platform and north of the Perseus high (Gabrielsen *et al.* 1990). Seismic observations suggest the presence of evaporite sequences that are several hundreds of metres thick, with several salt-related anticlines; the largest being located just SE of Kong Karls Land (Fig. 3). The geological history post-dating the Late Triassic is mostly unknown due to the erosion of younger stratigraphy.

Gardarbanken high

The Gardarbanken high is a complex structure with a gradual transition to the Sentralbanken high (Figs 3 & 5). Towards the Sørkapp basin to the north and west, and towards the Bjarmeland Platform to the south, it is bounded by large normal faults. It is an old basement high, probably of Timanian (Neoproterozoic) age (Klitzke *et al.* 2019), draped by a thin package of Pennsylvanian–Early Permian sediments. Sediments of Middle–Late Triassic age sub-crop at the top of the structure.

Sørkapp basin

The Carboniferous Sørkapp basin is a fault-bounded syncline, delimited by Paleozoic normal faults in the west against the palaeo-Stappen High and by younger Mesozoic faults towards the Gardarbanken high (Grogan *et al.* 1999; Anell *et al.* 2014) (Fig. 6a). It has been suggested that the orientation of the basin axis is situated in the prolongation of Timanian trends from the SE Barents Sea and the Pechora Basin, suggesting that the Sørkapp basin region is underlain by Timanian basement rocks (Klitzke *et al.* 2019). Upper Paleozoic sediments are onlapping towards the palaeo-Stappen High on the western flank of the basin.

Hopen high

The Hopen high is a structural high on which the island of Hopen is situated (Fig. 3). The outline of this Paleozoic structural element is primarily along major faults. Along the southern side of the high, long-lived bounding faults are orientated east–west with significant offset around the mid-Carboniferous. The high is bounded by basins to the NE and NW, and most likely by a gentle undulating slope towards the east (Anell *et al.* 2016).

Edgeøya platform

The Edgeøya platform is an offshore extension of the relatively flat-lying eastern province of the Svalbard archipelago (Fig. 3), where the sub-cropping strata is dominated by Triassic rocks that dip gently eastwards towards the Kong Karl platform. The southern margin is defined by a series of ENE-trending faults that delimit terraces stepping down to the Sørkapp basin (Grogan *et al.* 1999).

Sedimentary fill

Total thickness

The current understanding of the total thickness of the sedimentary fill in the North Barents CTSE is somewhat limited but, based on modelling of potential field data, the depth to basement is assumed to vary in the order of 2–12 km (Marello *et al.* 2013).

Lithostratigraphy/seismic stratigraphy

The Devonian–Early Carboniferous TSE 1 represents a period dominated by extension and rifting (Gjelberg 1981; 1987; Brekke and Riis 1987; Stemmerik and Worsley 2005). The lower part (Famennian–Tournaisian) is assumed to consist of sandstones and conglomerates representing braided river systems. It is supposed to be overlain by alternating thin sandstones, silt, clay and coal (Visean) representing dominantly floodplain depositional environments. The upper part (Serpurkhovian–Bashkirian) elsewhere in the Barents Sea is characterized by limestones and dolomite passing upwards into lower shoreface silt shales, representing a flooding event, and topped by semi-arid to arid terrestrial sandstones and conglomerates (Bugge *et al.* 1995; Larssen *et al.* 2002).

The Moskovian–Permian TSE 2 is characterized by continued rifting during the Late Pennsylvanian followed by relatively tectonic stability. It contains shallow shelf carbonate build-ups and evaporites (Moskovian–Gzhelian) overlain by deep shelf mudstones (Artinskian–Wuchiapingian) observed in 7933/4-U-3.

The Triassic (Induan–Early Norian) TSE 3 represents regional subsidence, and comprises alternating mudstones and sandstones within an overall northwestward-prograding deltaic system. Organic-rich shales were deposited in front of each progradational sequence (Riis *et al.* 2008; Glørstad-Clark *et al.* 2010; Lundschien *et al.* 2014; Klausen *et al.* 2015).

The Late Triassic–Middle Jurassic (Norian–Bajocian) TSE 4 developed in response to the Early Norian regional transgression (Bergan and Knarud 1993; Mørk *et al.* 1999; Worsley 2008), starting with shallow shelf, near-shore shale and siltstone, and developing into coastal plain and shallow Marin sandstones.

A hiatus due to uplift and differential erosion in the Bathonian (Worsley *et al.* 1988) marks the transition to the Middle Jurassic and Cretaceous (Callovian–Albian) TSE 5, including shelf deposits, both open shelf and anoxic, and scattered turbidites.

Depositional environment and provenance

The only detailed information about depositional environment and provenance in the North Barents CTSE is data from NPD stratigraphic boreholes. A summary is presented in the subheadings below.

Devonian and Early Carboniferous (Mississippian). Devonian or Lower Carboniferous rocks have not been proven by any stratigraphic borehole in the North Barents CTSE, and thus the development of these periods east of Svalbard is uncertain. However, Devonian rocks may be present in deeper parts of the area, such as the Olga and Sørkapp basins (Anell *et al.* 2016; Klitzke *et al.* 2019).

On Spitsbergen, large thicknesses of clastic sediments, including conglomerates of the Billefjorden Group, have been observed in the Mississippian Billefjorden graben system (Johannessen and Steel 1992; Bælum and Braathen 2012; Smyrak-Sikora *et al.* 2019; Olaussen *et al.* 2022). Based on the regional setting and seismic observations, similar graben systems are also likely to be present in the North Barents CTSE (Fig. 6).

Late Carboniferous (Pennsylvanian) and Permian. Rifting continued in the Pennsylvanian, and the North Barents CTSE was dominated by an open-marine environment. A dry climate combined with frequent oscillations in sea level led to the deposition of evaporites such as gypsum/anhydrites and halite in the central parts of the graben structures (Fig. 6b). Carbonate build-ups developed laterally to the deepest evaporite basins, and on platforms and highs (Gipsdalen Group).

During the Pennsylvanian, the North Barents CTSE was in the northern dry climatic belt. Globally, an ice age prevailed, known as the Gondwana glaciations (Stemmerik 2000, 2008), causing high-amplitude and high-frequency glacio-eustatic sea-level fluctuations that resulted in the frequent subaerial exposure of carbonates and possibly causing karstification in elevated areas.

Carbonates of Gzhelian–Sakmarian age deposited in a shallow shelf environment were cored in borehole 7933/4-U-3, offshore Kvitøya, and assigned to the Ørn Formation. These are overlain by deep shelf silicified mudstones and dolomites of the Kapp Starostin Formation, dating from the Artinskian to the Wuchiapingian.

Triassic (Induan–Early Norian). Almost the entire Triassic period, from the Induan to the Early Norian, was dominated by the deposition of a large delta system that prograded northwestwards towards Svalbard from the Urals in the SE (Riis *et al.* 2008; Lundschien *et al.* 2014; Klausen *et al.* 2019),

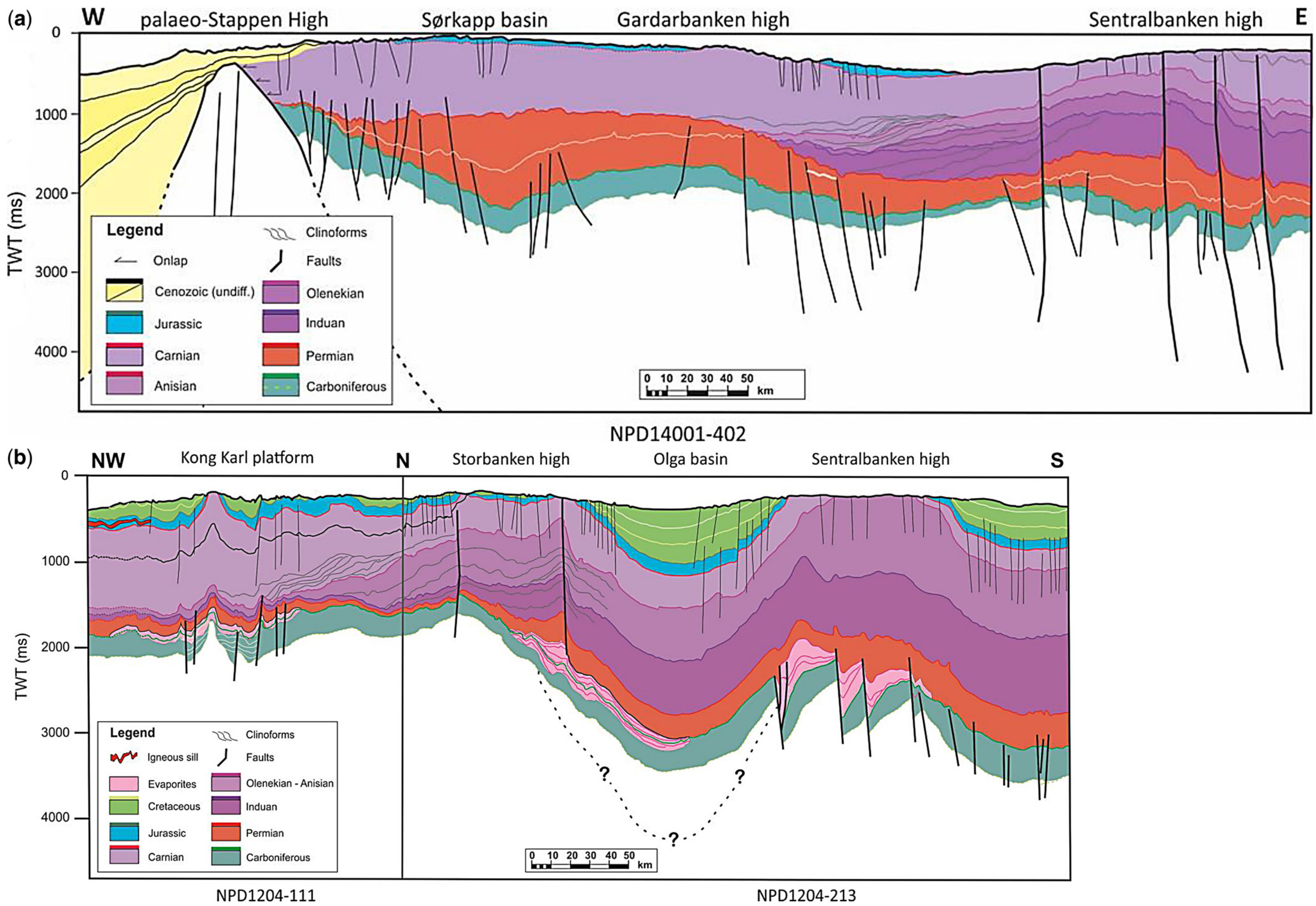

Fig. 6. (**a**) Regional east–west-orientated geoseismic profile across the Sentralbanken high, Sørkapp basin and palaeo-Stappen High. Note the westwards thinning of the Lower–Middle Triassic clinoform sequences and the onlapping of the Upper Triassic succession towards the palaeo-Stappen High. The Sentralbanken high is characterized by a Paleozoic core with horst and graben structures formed in the Mississippian, and small- and large-scale faults that extend towards and crop out at the seafloor. The Sørkapp basin is dominated by a thick succession of Carboniferous and Permian sediments, and the westernmost part of the profile is dominated by a thick Cenozoic succession. The location of the profile is shown in Figure 2. (**b**) Regional south–north- and NW-orientated geoseismic profiles across the Sentralbanken high, Olga basin, Storbanken high and Kong Karl platform. The Paleozoic successions consist mostly of carbonates and evaporites that form salt anticlines and bodies, and are faulted close to the Sentralbanken high. On the Storbanken high, large faults detach into the salt structure. The Triassic consists of clinoform sequences that become gradually thinner and younger towards the NW. The Jurassic succession is thin and thoroughly faulted. Note also the thinning of the Cretaceous succession towards the highs and deepening into basins, which suggests that these were structural highs during the formation of the Olga basin. The approximate base of the Olga basin is also indicated. The location of the profile is shown in Figure 2. TWT, two-way travel time.

possibly with some contributions from Taimyr (Pózer Bue and Andresen 2014; Fleming *et al.* 2016; Harstad *et al.* 2021). This delta system is evident from regional seismic data that show prograding clinoform belts becoming successively younger towards the NW (Riis *et al.* 2008; Glørstad-Clark *et al.* 2010; Høy and Lundschien 2011). Lundschien *et al.* (2014) described a clinoform belt as a set of prograding clinoforms constituting seismic sequences, which they named 'clinoform sequences'.

Observations from stratigraphic boreholes on the Sentralbanken high (7533/2-U-2) and off Kvitøya (7934/8-U-1) confirm that the supply of clastic sediments continued until Early Norian and was terminated by the Early Norian regional transgression, which is also the case for the equivalent succession in Svalbard.

Late Triassic (Norian–Rhaetian) and Jurassic. Late Triassic and Jurassic sediments have been cored in boreholes 7618/9-U-1 and 7619/8-U-1 on the Edgeøya platform, 7533/2-U-2, 7533/2-U-3 and 7533/3-U-1 on the Sentralbanken high, 7634/6-U-1 and 7634/6-U-3 on the Storbanken high, and 7934/8-U-1 offshore Kvitøya (Figs 2 & 3).

The Early Norian transgression led to the deposition of a characteristic condensed bed, equivalent to the Slottet Bed (Mørk *et al.* 1999) in Svalbard, succeeded by open-shelf silty shales, time equivalent with the Flatsalen Formation in Svalbard and the Akkar Member of the Fruholmen Formation in the southern Barents Sea, as observed in the boreholes 7533/2-U-2 (Sentralbanken high) and 7934/8-U-1 (off Kvitøya). The shale interval is overlain by shoreface or fluvial sandstones of Norian–Rhaetian age, assigned to the Svenskøya Formation in Svalbard, displaying a development very similar to that seen on Hopen, as described by Lord *et al.* (2019).

In borehole 7533/2-U-3 (Sentralbanken high), Sinemurian–Middle Pliensbachian-aged low-angle, cross-bedded and ripple-laminated fine-grained deltaic sandstones succeeded by bioturbated very-fine-grained shallow-marine sandstones, assigned to the Svenskøya and Stø formations respectively, were cored.

On top of the Stø Formation, another characteristic condensed stratum, equivalent to the Brentskardhaugen Bed (Parker 1967), marks a new transgression. Above this bed, open-shelf and anoxic shales of the Fuglen and Hekkingen formations, respectively, were deposited as seen in boreholes 7619/8-U-1 (Edgeøya platform), 7634/6-U-1 and 7634/6-U-3 (Storbanken high). The same development is well known from Svalbard, on top of the Wilhelmøya Subgroup (Mørk *et al.* 1999; Olaussen *et al.* 2019).

Cretaceous. The Cretaceous is comprehensively eroded in the North Barents CTSE, except in the Olga basin and in parts of the Storbanken high and the Kong Karl and Edgeøya platforms (Figs 5 & 6b). A succession dating from the Berriasian to the Early Barremian was cored in boreholes 7533/3-U-1 (Olga basin), 7618/9-U-1, 7618/10-U-1, 7618/10-U-3, 7618/12-U-1 (Edgeøya platform) and 7634/6-U-1 (Storbanken high: Figs 2 & 3).

The succession comprises dominantly silty shale and mudstone deposited in open to partly restricted shelf conditions with scattered turbidites and debris flows in basin areas. They are assigned to the Rurikfjellet and Helvetiafjellet formations (Svalbard), and the Knurr and Kolje formations (Barents Sea). Condensed carbonate sections of the Klippfisk Formation (Smelror *et al.* 1998) occur in platform areas (e.g. boreholes 7618/9-U-1, 7533/3-U-1 and 7618/12-U-1).

Cenozoic. Paleogene sediments are eroded across the entire North Barents CTSE, and during the Neogene and Quaternary the area was subject to repeated glaciations. Erosion related to glaciation was extensive throughout the Barents Sea, and total erosion was greatest on northern platform areas and the areas around Svalbard. Approximately 2–3 km of sediments are estimated to have been removed on Svalbard (Knies *et al.* 2009; Smelror *et al.* 2009; Henriksen *et al.* 2011*a*; Lasabuda *et al.* 2018*a*, *b*, 2021).

Magmatism

Extensive volcanic and igneous activity occurred in the North Barents CTSE for a short period during the Early Cretaceous, and it belongs to the HALIP (Senger *et al.* 2014). The intrusions can be mapped at multiple stratigraphic levels in the Permian, Triassic, Jurassic and Early Cretaceous strata (Grogan *et al.* 2000; Senger *et al.* 2014). Radiometric dating by Corfu *et al.* (2013) suggested an Aptian age for the intrusions in Svalbard and in large parts of the North Barents CTSE. On Kong Karls Land, similar igneous rocks are developed both as basaltic lava and intrusions (Olaussen *et al.* 2019). The intrusions are easily visible on regional seismic lines in the northern Barents Sea shelf, and they occur as both vertical dykes and horizontal sills in units assumed to be dominated by mud-rich lithologies (Fig. 7).

Heat flow

Heat-flow information in the North Barents CTSE is based on geothermal data acquired during an expedition by the Russian R/V *Akademik Nikolai Strakhov* in the area west of Franz Josef Land and east of the northern Barents Sea in the Russian–Norwegian cooperation project 'Late Mesozoic–Cenozoic Tectono-Magmatic History of the Shelf and Slope of the Barents Sea as a Key to Paleogeodynamic Reconstruction in the Arctic Ocean' (Khutorskoi *et al.* 2009; Zayonchek *et al.* 2009). Khutorskoi *et al.* (2009) reported an anomalously high heat flow of 300–520 mW m^{-2} based on 20 heat-flow measurements in the northern part of the North Barents CTSE. A regional heat-flow level of 75 mW m^{-2} is known from west of 35° E according to Sundvor *et al.* (2000), who also noted anomalously high heat-flow values in the same area.

Bugge *et al.* (2002) reported temperature gradients of 31.1 and 35.6°C km^{-1} from the shallow stratigraphic boreholes 7227/07-U-1 and 7230/08-U-1, respectively, close to the Nordkapp Basin in the southern Barents Sea. These values were derived from heat-flow measurements of 49.4 and 54.2 mW m^{-2}. Heat-flow measurements on Quaternary age samples from the northern Edgeøya platform indicate a heat flow of 66 mW m^{-2}.

Petroleum geology

Discovered and potential petroleum resources

The North Barents CTSE is not open for petroleum activity and, accordingly, there are currently no hydrocarbon discoveries in the area.

The somewhat unexplored nature of the North Barents CTSE suggests that continuous seismic mapping and evaluation will be important in petroleum assessment. Seismic anomalies have been observed in a number of anticlines at several stratigraphic levels on the Kong Karl platform, within rotated Jurassic fault blocks on the flanks of the Storbanken high, in parts of the western Olga basin and related to Triassic intervals on the Sentralbanken high. Multiple flat spots in Lower–

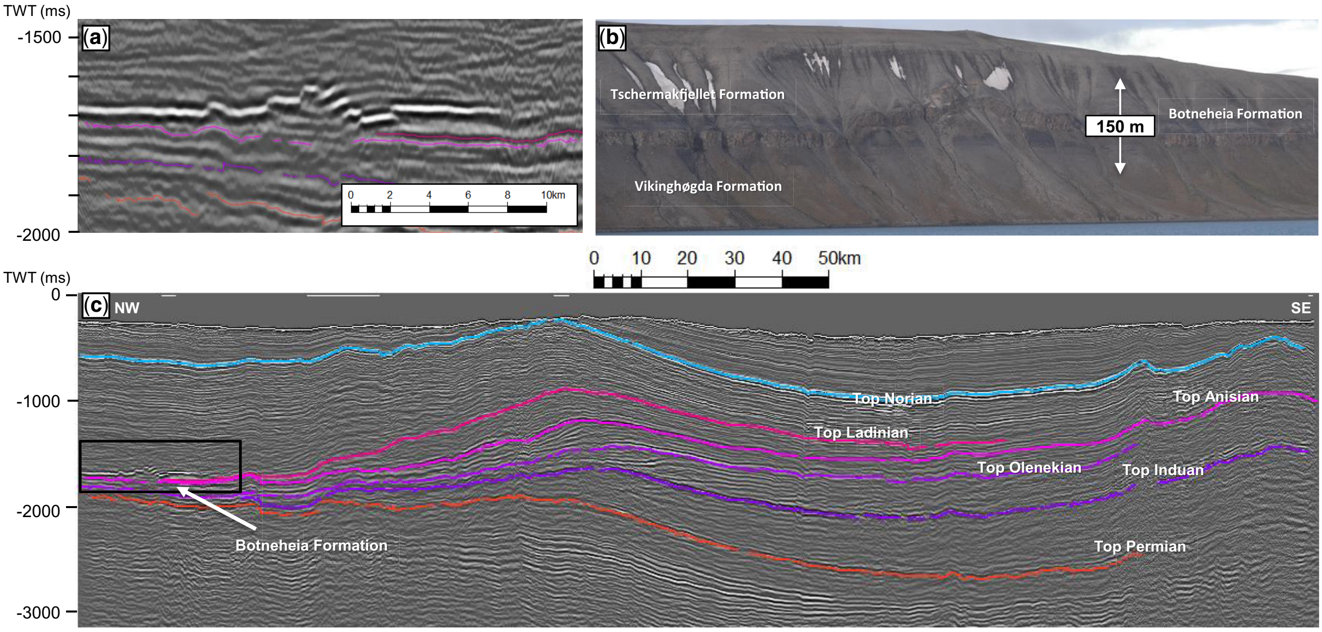

Fig. 7. Igneous intrusions in the North Barents CTSE. The igneous sills occur on the downslope part of clinoform bottomsets where organic-rich shales are assumed to be present. Outcrops on the northwestern Edgeøya on Svalbard, where a sill penetrates the soft shales of the Middle Triassic Botneheia Formation, have a similar configuration. Note the similar geometry of the cropping-out intrusion compared to the seismic example. The regional seismic interpretation indicates the presence of clinoform sequences in the Triassic succession.

Middle Jurassic rocks have also been mapped, indicating the presence of hydrocarbons (Fig. 8). Oil shows have been observed in several of the shallow stratigraphic boreholes, suggesting an active petroleum system in the area.

In addition to seismic data and interpretation, the presence of an active petroleum system is supported by large amounts of natural gas seeps at the seafloor, observed in several areas of the northern Barents Sea using water-column data from multibeam echosounders (Andreassen *et al.* 2017; Mau *et al.* 2017; Serov *et al.* 2017, 2022; Sokolov *et al.* 2017; Nixon *et al.* 2019).

The seeps are geologically controlled by vertical migration along faults (e.g. Waage *et al.* 2019, 2020), and by horizontal migration along reservoir beds, evidenced by seepage where reservoirs sub-crop at the seafloor. Migration through the sedimentary layers might also be related to glacial unloading and erosion (Chand *et al.* 2012). Synthetic aperture radar (SAR) satellite data over, for example, the western parts of the Sentralbanken high (Ivanov 2019; Serov *et al.* 2022) display convincing evidence for natural oil seepage in the form of large persistent perennial oil slicks (Fig. 9).

Current exploration status

As the area is not open for petroleum activity, neither current exploration activity nor past exploration history exist.

Hydrocarbon systems and plays

Source rocks. Petroleum systems in the southern Barents Sea comprise possible source rocks at several stratigraphic levels (Fig. 4) (Ohm *et al.* 2008; Lerch *et al.* 2016*a*, *b*), some of which is assumed to also have potential in the North Barents CTSE.

Devonian and Early Carboniferous (Mississippian). Klitzke *et al.* (2019) documented a Precambrian Timanide origin for the Olga and Sørkapp basins, which could allow these to contain source rock such as the Frasnian Domanik Formation that is present in the Russian Arctic. Visean coal and carbonaceous shale (the Billefjorden Group) are regarded potential source rocks. These are, however, likely to have

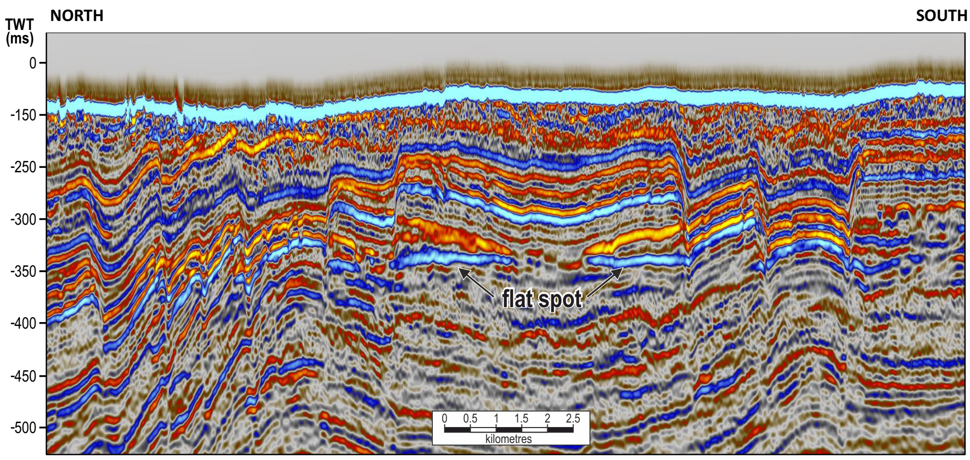

Fig. 8. Seismic line NPD1301R17-HR-222 showing a prominent flat spot in Jurassic reservoirs in several shallow fault blocks on the Storbanken high.

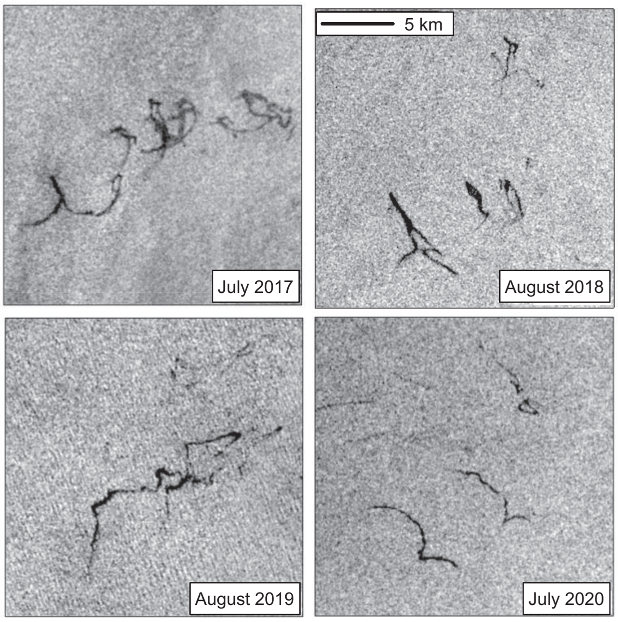

Fig. 9. Large oil slicks visible on SAR satellite images over the same area of the Sentralbanken high in 2017, 2018, 2019 and 2020. Source: Copernicus Sentinel data 2017–20, processed by the European Space Agency.

been deeply buried and are assumed to be mostly gas generating.

Late Carboniferous (Pennsylvanian) and Permian. Upper Carboniferous and Lower Permian organic-rich mudstones of the Gipsdalen Group, and possibly Upper Permian marine shales of the Tempelfjorden Group, may also offer source-rock potential. These rocks have also probably been deeply buried and are thus expected to mostly generate gas.

Early–Middle Triassic. The bottomsets of an Induan–Smithian clinoform belt may represent a source rock (Lundschien *et al.* 2014; Eide *et al.* 2017).

The most important source rock in the North Barents CTSE is assumed to be the organic-rich Spathian–Ladinian shales of the offshore/onshore equivalent Steinkobbe/Botneheia Formation (Mørk and Elvebakk 1999).

The presence of the Steinkobbe/Botneheia Formation in the North Barents CTSE was proven by borehole 7831/2-U-2 on the Kong Karl platform (Riis *et al.* 2008; Lundschien *et al.* 2014) and by borehole 7933/4-U-1 off Kvitøya (Figs 2, 3 & 10a). The total organic carbon (TOC) content in these cores are in the range 3.2–10.8 and 0.5–11.2 wt%, respectively, and both cores contain oil-prone type II kerogen. Comprehensive analysis at three localities on the Edgeøya platform concluded a dominantly type II kerogen, except for the lowermost part (Abay *et al.* 2014; Wesenlund *et al.* 2021, 2022).

Compositional and stable carbon isotope signatures of bound gases from near-surface sediment samples in the Olga basin show a thermogenic origin from source rocks of oil window maturity. Together with 1D basin and petroleum systems modelling, this indicates that Early–Middle Triassic source rocks reached oil window maturity (Weniger *et al.* 2019; Lutz *et al.* 2021).

Late Triassic (Norian–Rhaetian) and Jurassic. The organic-rich Late Jurassic shales (the Hekkingen Formation in the Barents Sea) have been proved to be immature in borehole 7634/6-U-1 at the northern margin of the Olga basin (Figs 2 & 3). They are located at shallow depths in the North Barents CTSE and are most likely to be immature over the entire area (Fig. 6b).

Reservoirs. Four stratigraphic levels with reservoir-rock potential are defined and described below.

Devonian and Early Carboniferous (Mississippian). Clastic sediments, including conglomerates, filling in well-defined graben systems from the Famennian–Mississippian, as observed on Spitsbergen, might represent potential reservoirs. The Perseus high and the Gardarbanken high, which are both old basement highs and where the maximum burial depth is assumed to have been less than 4000 m, are areas where reservoirs of this age might have preserved reservoir properties.

Late Carboniferous (Pennsylvanian) and Permian. Carbonate build-ups of Pennsylvanian and Early Permian age could potentially form reservoir rocks, especially where karstified due to subaerial exposure. Upper Carboniferous–Permian carbonates are expected to be situated at shallower depths in the North Barents CTSE compared to most of the southern Barents Sea, which is favourable for preserving reservoir properties.

Triassic (Induan–Early Norian). Potential reservoir rocks in the Triassic succession are most likely to be found in shallow-marine and deltaic depositional environments. The Lower Triassic is regarded to have limited reservoir potential, while the Middle–Upper Triassic has a moderate–high potential. Sandstones representing shallow-marine to deltaic depositional environments of the De Geerdalen/Snadd Formation have been cored on the Sentralbanken high and offshore Kvitøya, with porosities and permeabilities as specified in Table 2. Sandstones interpreted as a channel complex with good reservoir properties are shown in Figure 10b.

Late Triassic (Norian–Rhaetian) and Jurassic. The Early–Middle Jurassic sandstone hydrocarbon reservoirs of the Realgrunnen Subgroup, which are prolific elsewhere, are eroded over large parts of the area. However, north of the Sentralbanken high and east of Svalbard (Fig. 6b), this stratigraphic interval is preserved and represents shallow plays at depths ranging from *c.* 200 to 1000 m below seafloor. From Kong Karls Land, east of Spitsbergen, the time-equivalent Wilhelmøya Subgroup is represented by lateral continuous unconsolidated sandstones. In the North Barents CTSE, reservoirs have been proven in the Svenskøya and Stø formations on the Sentralbanken and Storbanken highs, and off Kvitøya (Figs 2 & 3), with reservoir properties as given in Table 2.

Seals. The cap rocks in the southern Barents Sea are generally regarded as good. The potential sealing rocks in the North Barents CTSE are considered to be the same, and generally hold the same properties as those found in areas to the south. The 7324/8-1 (Wisting) discovery, at a depth of 264 m below seafloor, proves that adequate seals can be developed even at shallow levels.

Traps. A large number of structural traps have been mapped at different stratigraphic levels (Figs 5 & 6). Several of these are very large with substantial rock volumes. Anticlines and fault blocks dominate but stratigraphic traps may also be present. In the Lower Carboniferous succession, stratigraphic traps could occur locally in fluvial channel systems surrounding and adjacent to highs, and as clastic fans inside graben. In the Upper Carboniferous and Permian successions, stratigraphic traps can be represented by carbonate reefs. During the Triassic, combined traps could potentially occur in shoreface/delta-front settings on the shelf-break edges of the northwestward-prograding clinoform sequences, and

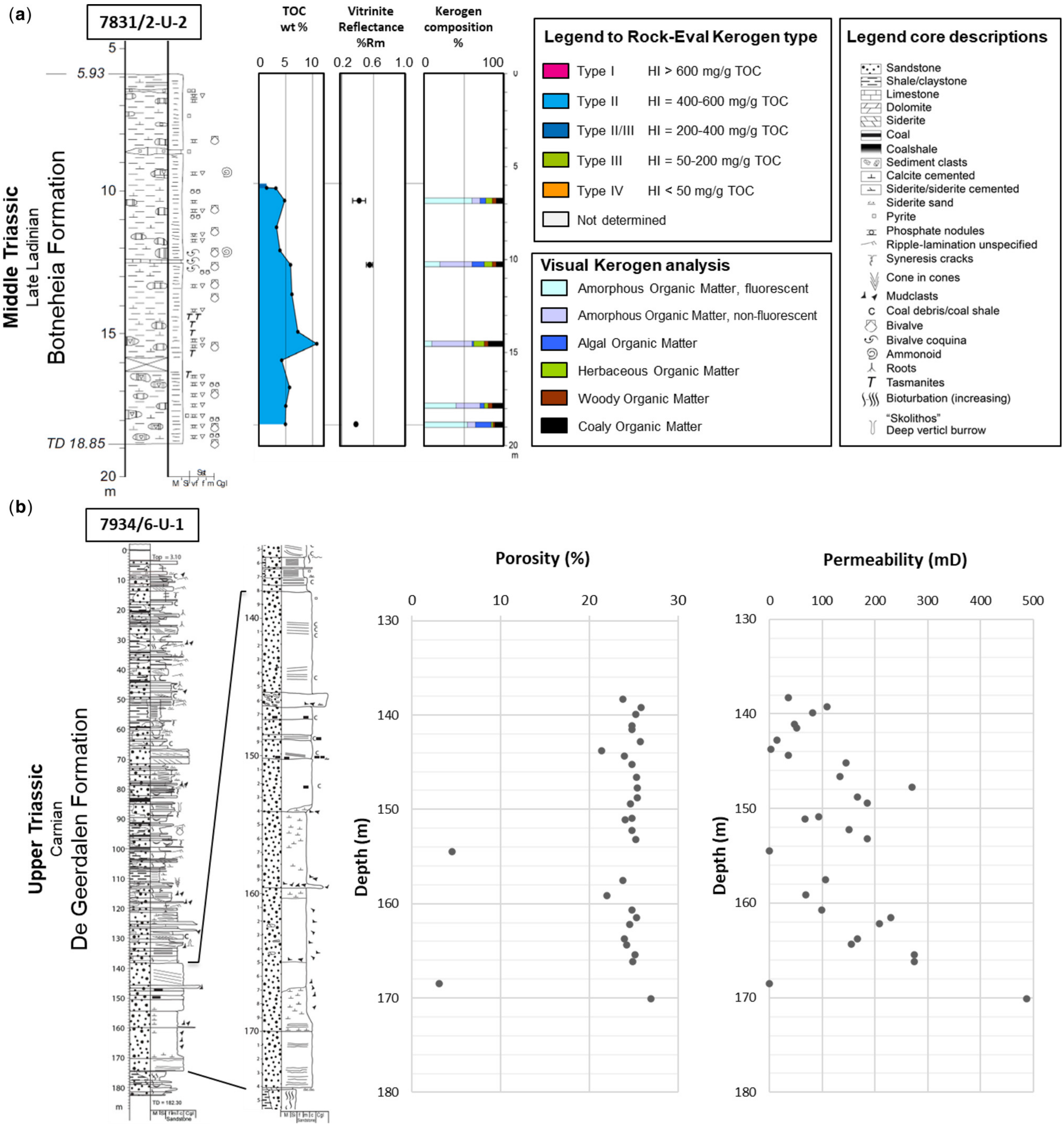

Fig. 10. (**a**) The organic-rich source rock assigned to the Steinkobbe/Botneheia Formation in 7831/2-U-2 on the Kong Karl platform. (**b**) Channel sandstones with good reservoir properties in core 7934/6-U-1 offshore Kvitøya.

stratigraphic traps could be developed by distributary/fluvial channel systems in the delta-plain depositional environment further behind. Structural traps defined by anticlines and fault blocks dominate in the Lower and Middle Jurassic succession. Trap types within the Cretaceous have not been documented to date and Paleogene is lacking throughout the entire area.

Retention of hydrocarbons in traps. Hydrocarbon exploration in the southern Barents Sea has shown that proven discoveries are not filled to spill but have residual oil below the present oil–water contact. Shows of both oil and gas have also been found in multiple dry wells (Ohm *et al.* 2008; Lerch *et al.* 2016*b*), indicating that petroleum has leaked out. Erosion and faulting through and over the structures constitute a risk of increased leak rates (Henriksen *et al.* 2011*a*; Lasabuda *et al.* 2021). Erosion across large parts of the Barents Sea during the Cenozoic is estimated to have been 1000–1500 m or more and up to 3000 m in some areas. The processes behind the erosion are suggested to be compression and uplift in the Paleogene, and later glaciations in the Neogene (Riis and Fjeldskaar 1992; Henriksen *et al.* 2011*a*, *b*; Lasabuda *et al.* 2021). Uplift and subsequent erosion resulting in pressure reduction may have led to the reactivation of faults and fracturing in the cap rocks and, thereby, to leakage. Erosion and pressure reduction from the load removal may have led to a release of associated gas in the oil zones and caused expanding gas caps that pushed the oil out of the traps (Ohm *et al.* 2008; Lerch *et al.* 2016*a*).

Table 2. *Porosity and permeability related to depositional environment in stratigraphic cores in the North Barents CTSE sorted by ascending age*

Core no.	Structural element	Age of cored sediments	Formation	Depositional environment	Core depth (m)	Porosity (%)	Permeability (mD)
Late Triassic and Jurassic							
7634/6-U-3	Storbanken high	Late Toarchian–Late Aalenian	Stø	Shoreface	29	30.4	
					34	23.6	50
7634/6-U-1	Storbanken high	Late Toarcian	Stø	Shoreface/delta front	74	31.6	
					79	31.8	850
					83	23.9	
					86	24.3	20
				Distributary channel	119	24.6	
					121	31.7	
					122	29.3	595
7533/2-U-3	Sentralbanken high	Pliensbachian	Stø	Shoreface/delta front	14	22.6	135
					18	25.7	
					24	24	
7533/2-U-2	Sentralbanken high	Norian–Rhaetian	Svenskøya	Shoreface/delta front	5	23.1	145
					11	26.6	
					19	24.2	
7934/8-U-1	Kong Karl platform	Norian	Svenskøya	Channel complex	14	32.2	
					18	32.7	
Triassic							
7533/2-U-2	Sentralbanken high	Late Carnian	Snadd	Bayhead delta	76	12.1	
7533/2-U-1	Sentralbanken high	Middle Carnian	Snadd	Distributary channel	40	24.5	107
				Crevasse splay	62	16.9	
				Distributary channel	98	20.1	
				Distributary channel	124	16.1	
				Distributary channel	151	16.4	
				Crevasse splay	198	20	
7934/9-U-1	Kong Karl platform	Early–Middle Carnian	De Geerdalen	Distributary channel	94	25.3	30
					99	27.2	183
				Distributary channel	143	23.1	9
				Shoreface	150	27.6	473
					154	28.6	417
7934/6-U-2	Kong Karl platform	Early–Middle Carnian	De Geerdalen	Crevasse splay	23	11.7	
				Shoreface	147	23.5	
				Shoreface	158	27.4	93
				Shoreface	194	26.8	116
					199	27.5	204
7934/6-U-1	Kong Karl platform	Early - Middle Carnian	De Geerdalen	Tidal channel	13	20.5	
				Tidal channel	28	20.4	
				Shoreface	70	22.2	43
				Tidal channel	129	24.1	44
				Channel complex	148	25.4	271
					166	24.9	274
7830/5-U-1	Kong Karl platform	Early Carnian	Snadd	Shoreface	50	14.1	
					55	15.5	
					56	16.6	
7830/3-U-1	Kong Karl platform	Early Carnian	Snadd	Delta front	18	14	
					23	12.8	
				Shoreface	112	15	2
					113	17.1	3
					115	12.8	
7533/3-U-7	Sentralbanken high	Early Carnian	Snadd	Crevasse splay	4	18.5	1
				Crevasse splay	8	18.3	
				Crevasse splay	46	19.6	
				Distributary channel	57	18.7	
					60	16.6	2
				Channel complex	112	17.1	
					135	16.6	
					138	20.3	21
7534/4-U-1	Sentralbanken high	Late Ladinian	Snadd	Distributary channel	8	15	
					10	13.6	
				Crevasse splay	41	17.3	
				Lacustrine shore	78	10.3	
				Lacustrine shore	89	11.6	
				Foreshore	100	12.6	
				Shoreface	106	17.3	
					111	16.3	
					120	14	
				Channel complex	139	10.6	
					150	10.6	

Uplift and erosion will have to be considered when assessing the petroleum potential of the area, and the retention of hydrocarbons in the identified traps could constitute a (significant) risk in the North Barents CTSE.

Hydrocarbon plays

Early Carboniferous (Mississippian) play. The Mississippian play consists of sandstones and conglomerates deposited in alluvial, fluvial and deltaic environments. The play is confined to the Gardarbanken and Storbanken highs, where the maximum burial is assumed to have been less than 4000 m and where the rocks may have retained their reservoir properties.

The trap type comprises anticlines and fault blocks. In addition, stratigraphic traps could occur in fluvial channel systems adjacent to the highs. Potential source rocks are assumed to be Lower Carboniferous coal and carbonaceous shales (Billefjorden Group), and, possibly, Devonian Domanik-type source rocks. The source rocks are generally deeply buried, leading to gas as the most likely hydrocarbon phase.

Late Carboniferous (Pennsylvanian)–Permian (Guadalupian) play. This play consists of limestones (*Palaeoaplysina* reefs) and dolomites in warm-water carbonates (Gipsdalen Group), calcite-dominated cold-water carbonates (Bjarmeland Group), and silicified carbonates and spiculite flint (Tempelfjorden Group). On the eastern Sentralbanken high, new 3D seismic indicates that the play is present in the area (Fig. 11). The play is extensive in the area but is not regarded as relevant in the deeper parts such as the Olga and Sørkapp basins. Excellent reservoir properties have been proven in analogue settings on the Loppa High, in the development processes of the 7220/11-1 (Alta) discovery and are also observed in Svalbard (Stemmerik and Worsley 2005).

The trap types comprise anticlines and fault blocks. Stratigraphic traps could also have developed in isolated carbonate accumulations throughout the area.

Source rocks for the play are Lower Carboniferous coal and carbonaceous shale (Billefjorden Group), Upper Carboniferous and Lower Permian organic-rich mud (Gipsdalen Group), and, possibly, Upper Permian marine shales (Tempelfjorden Group). These source rocks have been deeply buried, leading to gas as the most likely hydrocarbon phase. The Lower–Middle Triassic Steinkobbe/Botneheia Formation may also have fed traps on the Gardarbanken, Perseus and palaeo-Stappen highs, as it has on the Loppa High, in the 7220/11-1 (Alta) and 7120/1-3 (Gohta) discoveries (Brunstad and Rønnevik 2023).

Triassic plays. The Triassic succession comprises three plays, the Early Triassic (Induan) Havert Formation play, the Early–Middle Triassic (Olenekian–Anisian) Klappmyss and Kobbe formations play, and the Middle–Late Triassic (Ladinian–Norian) Snadd Formation play.

Trap types comprise dominantly anticlines and fault blocks; however, in the shoreface/delta-front settings, combined stratigraphic and structural traps may be present. Stratigraphic traps related to distributary and fluvial channel systems may occur in delta-plain settings in the southeastern parts of the plays.

Potential source rocks for the Early Triassic play are Visean coal, and organic-rich shales in the Pennsylvanian and Permian. Organic-rich Induan shales may also offer source-rock potential (Eide *et al.* 2017). These source rocks are at considerable depths in most of the area and thus are most likely to be gas generating.

The Olenekian–Ladinian-aged Steinkobbe/Botneheia Formation is regarded the most important source rock for the Early–Middle and Late Triassic plays; however, the Induan shales, and the Mississippian coal and Pennsylvanian–Permian organic-rich shales, may also contribute.

As all three plays are superimposed transgressive–regressive (T–R) sequences within one overall northwestward-prograding depositional system, they have different extents in the progradational direction. Seismic interpretation indicates that the Early Triassic (Induan) clinoform belt reached the Sentralbanken high, defining the northwesterly extent of this play. The Early–Middle Triassic (Olenekian–Ladinian) clinoform belt prograded further northwestwards to the Storbanken high, defining the extent of this play, and the Late Triassic (Carnian–Norian) prograded beyond Svalbard, covering the entire North Barents CTSE (Fig. 4).

Early–Middle Jurassic play. The play comprises shallow-marine sandstones that correlate with the Wilhelmøya Subgroup in Svalbard and the Realgrunnen Subgroup in the southern Barents Sea. The source rock will be the same as that for the Triassic plays.

The play will generally be at shallow depths, and analogous plays in the south Barents Sea have been proven for both oil and gas in the 7324/8-1 (Wisting), 7324/7-2 (Hanssen) and 7435/12-1 (Korpfjell) discoveries.

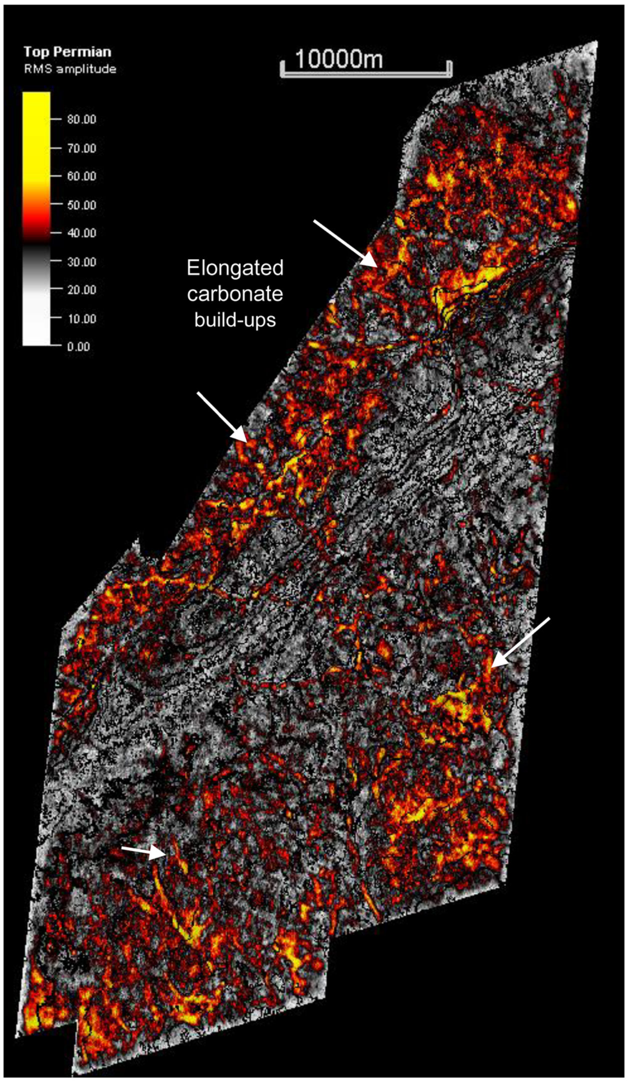

Fig. 11. RMS amplitude map from the Top Permian surface on the eastern parts of the Sentralbanken high, showing a network of elongated carbonate build-ups. The location of 3D seismic survey NPD19001 is shown in Figure 2.

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