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The Mesozoic of Western Scandinavia and East Greenland

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Thick Mesozoic sediments are found off-shore Norway and Denmark, and Mesozoic rocks are present and well exposed in Denmark, along the coast of East Greenland and on the arctic islands of Svalbard.

During the Mesozoic, Scandinavia and Greenland were subject to major extension in the Late Permian–Early Triassic and Late Jurassic–Early Cretaceous, prior to Cenozoic opening of the North Atlantic. Deep basins developed along the rift zones of the North Sea and between East Greenland and Norway, and were filled with sediments derived from mainland Scandinavia and Greenland. The marginal areas bordering the rift zones suffered less subsidence, as did the epicontinental Barents Sea.

Introduction—structural setting

In Late Paleozoic times, northern Europe and Baltica were located on the rim of the supercontinent Pangaea, bounded in the north, where Svalbard and the Barents Sea are located today, by the Boreal Sea. During the Triassic (Figure 1), Pangaea started to fragment and the Tethys Ocean opened in a westerly direction from the present-day Middle East and separated the new Europe from Africa (Ziegler, 1988; Torsvik et al., 2002). In the North Sea and Norwegian Sea, crustal movements that had begun in the Late Permian continued into the Early Triassic (Ziegler, 1982). Crustal extension and the formation of rift basins between Norway and Greenland attempted to divide Pangaea along a zone of weakness where the ancient Iapetus Ocean had closed at the end of the Silurian, resulting in formation of the Caledonian mountain belt.

During Early and Middle Jurassic times, the rift axis propagated progressively northwards, with formation of the central Atlantic Ocean. Following the intense rift tectonics of the Permian and Triassic, however, the North Atlantic and areas between Scandinavia and East Greenland were subject to a period of reduced tectonic activity. In the Late Jurassic, seafloor spreading in the Mid-Atlantic progressed north-eastwards, leading to major rifting between East Greenland and Norway, and with a branch extending southwards into the North Sea. An elongate and continuous rift was formed extending from the North Sea

to the Barents Sea. Late Jurassic rifting was superimposed on the older Permian–Triassic rift structure, after a period of quiescence of some 50 million years. Late Jurassic rifting resulted in deeper subsidence, and was localised within a narrower zone, in contrast to the much broader Permian–Triassic rift. Whereas the Permian–Triassic rift was essentially continental, Mid-, and especially Late Jurassic rifting thinned the crust to such an extent that the rift became submerged beneath the sea.

The Cretaceous was characterized by the transition from prolonged fragmentation of Pangaea to seafloor spreading, and formation of the Atlantic Ocean. Following the earliest Cretaceous South Atlantic opening, break-up and seafloor spreading progressed into the North Atlantic between Europe and North America in the Late Cretaceous, and culminated with continental separation and formation of the Norwegian and Greenland Seas in the Early Cenozoic. The break-up of Pangaea during the Mesozoic put an end to the last of the Earth's great supercontinents.

Palaeodrift and climate

At the onset of the Triassic, Baltica was situated in the sub-tropical zone between 25° and 40° north (Figure 1). In southern Baltica, the climate was arid and, at higher latitudes, there was probably more rain and more permanent vegetation cover (Scotese, 2001). During the Triassic, Pangaea drifted northwards and, at the same time, break-up of Pangaea and formation of the Tethys Ocean in the south led gradually to changes in patterns of global atmospheric circulation and climate. Humid air masses encroached further onto the continents, resulting in the break-up and shrinkage of the arid climatic zone that had covered most of Pangaea throughout the Permian.

The break-up in the central and southern Atlantic Ocean was associated with extensive volcanism, which released large volumes of CO₂ and SO₂. This promoted global warming which dramatically altered the basis for survival both on land and in the oceans, to the extent that it may have been a main cause for the mass extinction that occurred at the end of the Triassic. Some estimates suggest that up to 20% of the marine animals became extinct, and on land the great amphibians were almost wiped out, together with a major floral extinction. This event opened the way for the dinosaurs, which were eventually to dominate the terrestrial faunas during the remainder of the Mesozoic.

Baltica had drifted to between 45° and 60° north in the Middle Jurassic, but in the late Jurassic a change in pole of rotation caused it to rotate slightly southwards, to between 40° and 55° north. The climate was

Figure 1 Global reconstructions of the Mesozoic (From Torsvik et al., 2002).

Figure 2 Plate reconstructions at 170 Ma and 75 Ma, based on total post Mid-Jurassic and pre-Cenozoic break-up stretching estimates. The Rockall Trough probably has a complex Late Paleozoic and/or mid-Cretaceous origin. RT = Rockall Trough, NS = North Sea, MM = Møre margin, VM = Vøring margin, LI = Lofoten Islands, BS = Barents Sea (Modified from Skogseid et al., 2001).

warm and humid, in the warm-temperate zone. This resulted in denser vegetation cover on land, increased chemical weathering, and the production of increased volumes of clay and quartz sand that were transported into the sedimentary basins. Minor seasonal variations allowed a diverse animal and plant life to stabilize during the Early Jurassic, somewhat after the mass extinction at the end of the Triassic. The combination of high temperature and elevated sea levels also resulted in increased biological productivity in the oceans. Superimposed on an irregular basin floor topography, with deep half-grabens, extensive water mass stratification and anoxia, this led to the formation of widely distributed, organic-rich mudstones in the Late Jurassic. Upper Jurassic mudstones form source rocks for oil and gas and represent some of the most organic-rich sediments ever deposited. Late Jurassic algae and plant remains have thus provided the source for some 25% of the Earth's oil and gas resources.

During the Cretaceous, Baltica drifted slowly northwards, to between 50° and 65°, in the temperate zone. In the Early Cretaceous, the Polar Regions had snow and ice during the winter months, but at no time were there permanent ice caps at the poles. Temperatures rose in the Late Cretaceous and remained above freezing throughout the year. In addition, cold, oceanic waters were not formed at the poles. As a result, there was very little density-driven exchange between the polar and equatorial water masses, and very little exchange vertically within the water column. This caused ocean-bottom temperatures to approximate those at the surface. No major ocean currents flowed from the poles as they do today, resulting in periodic oxygen deficiencies over large areas of the deep oceans.

Geological evolution

Very few Mesozoic rocks are found onshore Norway, Sweden and Finland, mainly as a result of Baltica being a stable craton undergoing erosion during much of this period and due to Late Pleistocene and Pliocene glaciations and erosion. Below the bordering North Sea, Norwegian Sea and Barents Sea to the south, west and north, however, a complete record of the Mesozoic is preserved (Figure 2). Mesozoic rocks are present and well exposed in Denmark, along the coast of East Greenland, and on the arctic islands of Svalbard (Figure 3).

Triassic

During the Triassic the central and northern North Sea became separated from the southernmost North Sea by the Mid-North Sea High. In the central-northern North Sea, crustal extension that had begun at the end of the Permian continued (Ziegler, 1982). Most of the Triassic faults are oriented approximately north-south and the structural grain is well demonstrated in the coastal regions of south-western Norway. The basins were commonly half-grabens, 20–30 km wide and several tens of kilometres long. Basins and highs combined to form a rift valley between Norway and Britain that was up to 400 km wide (Figure 2). It was bounded to the west by the present-day Shetland Islands and to the east by the great Øygarden Fault, following the coast of south-western Norway. At the beginning of the Triassic the two basins were distinct, but towards the end of the Triassic they subsided to form a broad, continuous alluvial plain. The Danish Basin, covering most of present Denmark, was bordered to the south by the Ringkøbing-Fyn High, which is the eastwards continuation of the Mid-North Sea High.

Permian rifting between Norway and Greenland also continued into the Triassic (Ziegler, 1988; Seidler et al., 2004). During the Early Triassic, several deep marine rift basins were formed as a result of crustal extension and subsidence across these lowlands. During the earliest Middle Triassic, the rift zone became less active.

Triassic rifting did not affect the Barents Sea area. The Boreal Sea bordering the northern margin of Pangaea was already established during the Late Carboniferous and Permian, and was throughout the Triassic affected by global sea-level changes as a result of lithospheric plate movements. Islands emerged as a result of the crustal movements and served as major obstructions for westward sediment transport from the young Uralian mountain belt.

During the Triassic, continental conditions prevailed in the central-northern North Sea and the rift basins were filled with close to 2 km of alluvial sand, gravel and mud of the Hegre Group (Figure 4) (Steel, 1993; Fisher and Mudge, 1998; Goldsmith et al., 2003; Lervik 2006). Thick Permian salt deposits in the central North Sea became mobilized as a result of the Triassic overburden and faulting, and formed salt pillows and diapirs. These structures caused the sea floor to bulge upwards and controlled sediment distribution and depositional patterns within the basin. In the Danish Basin to the east, deposition, mainly of redbeds, took place in extensive flood-plains in an arid desert. The Triassic succession in the basin is very

Figure 3 Geological maps of Svalbard (Dallman, Norwegian Polar Institute) and East Greenland (Surlyk and Ineson, 2003). Note that the map subdivision in Svalbard is based on stratigraphic groups (see Figure 4). Lower-Middle Triassic = Sassendalen Group, Upper Triassic-Middle Jurassic = Kapp Toscana Group, Upper Jurassic-Cretaceous = Adventdalen Group.

thick, reaching more than 6 km adjacent to the Fjerritslev Fault in northern Jylland. The Lower Triassic Bacton Group may reach up to 800 m in thickness. In the Middle Triassic the basin was flooded repeatedly by the sea and some 2,500 m of halite, anhydrite and clay of the Lolland and Jylland Groups were deposited in shallow coastal environments. In the Late Triassic a shallow brackish sea transgressed the low-lying area and sandy deltas of the Mors Group were formed along the north-eastern basin margin.

In the Norwegian Sea area and in East Greenland, the Early Triassic rift basins were largely marine and filled with marine sand and mud (Figures 3, 4) (Brekke et al., 2001; Seidler et al., 2004; Nystuen et al., 2006). The Triassic succession in East Greenland ranges from 1–1.7 km in thickness. The Boreal Sea gradually encroached southwards, forming an elongated arm between Norway and Greenland that extended to the northern boundary of the North Sea basin. Some faults blocks became elevated and emerged as elongated islands. The cessation of rifting in the Middle Triassic led to filling of the basins and an alluvial plain where sand and mud redbeds were deposited between Norway and Greenland. In the Late Triassic, crustal movements caused uplift in parts of mainland Norway, resulting in increased sediment transport to the Norwegian Sea basin. The area again became a shallow sea, and the lowermost Upper Triassic succession comprised marine mud and salt. These deposits were overlain by a thick mud succession, deposited in a vast lake. The Triassic ended with large parts of the present Norwegian continental shelf from north to south becoming dry land.

Lower Triassic deposits in the Barents Sea consist largely of mudstones belonging to the lower Sassendalen Group, varying from a few hundred metres to 1 km in thickness (Figures 3, 4) (Mørk et al., 1999). Sand was deposited along the basin margins, as observed in the eastern Barents Sea and on Spitsbergen (Mørk et al., 1982; Steel and Worsley, 1984). In the Nordkapp Basin, Permian salt began to move early in the Triassic, in the same way as in the southern North Sea area. It pierced into the overlying Triassic succession to form pillows and diapirs, which strongly influenced sediment distribution and deposition in the basin. Middle Triassic mudstones of the upper Sassendalen Group in the Barents Sea and Svalbard islands contain high proportions of organic material, up to 12% (Mørk et al., 1982; Nøttvedt et al., 1992). They form a very good source rock for oil and are also rich in phosphate. Middle Triassic source rocks contribute to the overall hydrocarbon play potential in the Barents Sea. During the Late Triassic, the Boreal Sea became shallower over large areas. In the southern Barents Sea, alternating beds of sand and mud were deposited in coastal plain and shoreline environments, reaching almost as far west as to the Loppa High. Sea-level changes caused the coastline periodically to retreat, resulting in deposition of well-sorted sand sheets. In the deepest parts of the northern Barents Sea and on Svalbard, the supply of mud continued unabated during the Late Triassic. The Upper Triassic sandstones and mudstones make up the Kapp Toscana Group, which is some 400 m thick on Svalbard and up to 2 km thick in the Barents Sea. Triassic deposits in the Russian sector of the Barents Shelf reach up to 7–8 km in thickness.

Jurassic

In many of the continental shelf basins the lowermost Jurassic succession is characterised by sandstones and mudstones with thick coal units, deposited on vast coastal plains (Figure 4). During the Early Jurassic sea level rose, however, and large parts of the North Sea, as well as the North Atlantic, East Greenland and Barents Sea regions, were flooded. The Shetland Platform, which had formed the margin of the Permian-Triassic rift basin, remained dry land during much of the Jurassic. The sea-level rise in the North Atlantic region eventually resulted in the development of a marine seaway between Greenland and Norway connecting the northern Boreal Sea and the southern Tethys Ocean. The Hammerfest Basin was the dominant basin in the Barents Sea during the Early Jurassic, and Lower Jurassic deposits are not found east of the Hammerfest Basin.

At the transition to the Middle Jurassic, the southern North Sea Basin drifted across a mantle hot-spot, resulting in thermal uplift of a

Figure 4 Mesozoic stratigraphy of Denmark, offshore Norway, East Greenland and Svalbard. The names denote geological groups (vertical text) and formations. (Modified from Clemmensen, 1980; Surlyk and Noe-Nygaard, 2001; Michelsen et al., 2003; Surlyk, 2003; Brekke and Olaussen, 2006; Johannessen and Nøttvedt, 2006; Lervik, 2006; Nystuen et al., 2006; Nøttvedt and Johannessen, 2006).

greater part of the southern North Sea area and the Ringkøbing-Fyn High of the Danish Basin. The uplift, which is commonly referred to as the North Sea Dome, became subject to significant erosion during the Middle Jurassic. As a result, Lower Jurassic sediments are today almost entirely absent from the southern part of the northern North Sea.

Jurassic rifting commenced in the North Sea in the late Middle Jurassic, but accentuated during the Late Jurassic. It resulted in the formation of the Viking Graben in the north and the Central Graben in the south (Figure 2). The rift is characterised by an axial, though discontinuous, rift valley. At some locations, the rift is defined along single faults or zones, comprising a few major faults. Elsewhere, the rift margin comprises fault terraces, like the Tampen and Oseberg terraces, consisting of series of rotated fault blocks. Fault blocks are typically several kilometres across and tens of kilometres long, and have their roots deep in the crust. Initially, the terraces were sloping very gently towards the axis of the rift valley. The present-day configuration, in which the terraces are tilted so that they link the shallow platforms with the deep rift valley, is a result of later thermal subsidence. The rift structure was largely submerged, but at some locations fault blocks emerged above sea level and formed narrow, elongate islands.

Between Greenland and Norway, the Late Jurassic rift structure is divided into the Halten-Dønna Terrace on the Norwegian side and the basins of East Greenland in the west (Figures 2, 3) (Blystad et al., 1995; Surlyk, 2003). The Nordland Ridge forms the northeastern extension of the Halten-Dønna terrace. The Trøndelag Platform is located east of the rift, together with the Helgeland and Froan Basins, and these all combine to form the eastern rift shoulder. The rift axis to the west lies deeply buried beneath several kilometres of Cretaceous deposits within the Rås Basin, and cannot be clearly resolved by seismic data. In the Wollaston Forland area in northern East Greenland, Late Jurassic rifting resulted in the formation of halfgrabens, whereas the wide Jameson Land platform in southern East Greenland was not broken up and was only gently tilted.

The rift structure extends into the Hammerfest and Bjørnøya Basins of the southern Barents Sea. From here it is linked to an embryonic spreading centre in the Arctic Ocean via a transverse fault separating Svalbard from North Greenland. The structure dies out in the eastern Barents Sea and the northern Barents Sea was mostly unaffected (Gabrielsen et al., 1990). Rifting in the Barents Sea commenced in the latest Jurassic, and intensified in the Early Cretaceous. The rifting typically led to fragmentation of the earlier Middle Jurassic basins of the entire shelf from the North Sea to the Barents Sea,

and the faulted terrace provinces evolved into vast seas with elongated islands. Late Jurassic erosion of the fault blocks occasionally continued into the Early Cretaceous and resulted in the formation of a pronounced unconformity surface, the so-called "Base Cretaceous Unconformity".

The Lower Jurassic succession in the northern North Sea consists of fluvial sandstones and mudstones of the Statfjord Group, overlain by alternating coastal deltaic and shallow marine sandstones and mudstones of the Dunlin Group (Figure 4) (Steel, 1993; Husmo et al., 2002). The erosion of the North Sea Dome and Ringkøbing-Fyn High in the Middle Jurassic led to transport of large volumes of sand and mud towards the north, forming the great Brent delta and the deposits that now constitute the Brent Group (Graue et al., 1987; Helland-Hansen et al., 1992), as well as to the east, into the Danish Basin (Michelsen et al., 2003). The Lower and Middle Jurassic succession varies from less than 1 km along the basin margins to more than 2 km in the basin centre, as a result of compaction driven subsidence above the Permian–Triassic rift system. As the Late Jurassic seas encroached and eventually flooded the Middle Jurassic coastal plains of the North Sea, sedimentation changed into fine-grained, organic-rich mud. The resulting mudstones belong to the Viking Group, which may reach up to 1 km in thickness. Sandstones occur locally, however, resulting from deltaic progradation, such as across the Troll field, as well as from local sedimentation around emergent islands, such as in the northern Tampen area, and from submarine fan deposition along the rift structure (Nøttvedt et al., 2000; Fraser et al., 2002). The elevated inner shelf areas acted as sinks for the coarser sediments supplied from the Norwegian mainland. Similar processes were active on the rift's western flank where sands and gravels were trapped in smaller, marginal, rift basins. Consequently, the central rift provinces were supplied only with mud.

During the Early Jurassic, the coastal plains of the mid-Norwegian shelf were transgressed, resulting in a succession of fluvial to shallow marine mudstones and sandstones belonging to the 700 m thick Båt Group (Figure 4) (Gjelberg et al., 1987; Johannessen and Nøttvedt, 2006). Also parts of the East Greenland margin were flooded during the Early Jurassic, following a long interlude with lacustrine deposition across the Triassic–Jurassic boundary (Kap Stewart and Neill Klintner Groups) (Dam and Surlyk, 1993, 1998; Surlyk and Ineson 2003). As in the North Sea, associated coastal-deltaic sand wedges built out from mainland Norway and East Greenland. Early Jurassic marine basins in the North Sea and Norwegian Sea were shallow, commonly tidally influenced and rarely more than 100 m deep. However, continued subsidence across the underlying Permian–Triassic rift structure resulted in sediment thicknesses of several hundred metres, occasionally up to 1,000 metres above the rift axis. The Upper Triassic–Lower Jurassic Kap Stewart and Neill Klintner Groups in East Greenland reach up to 900 m in thickness in the central part of the Jameson Land Basin (Figures 3, 4). Along the basin margin of the Mid-Norwegian shelf, Middle Jurassic deposits reach only some few hundred metres in thickness. Middle Jurassic deposits in the Norwegian Sea and in East Greenland are very sand-rich as a consequence of advancing coastal plains and great delta systems, first on the Mid-Norwegian shelf, and later in East Greenland. Uplift, similar to that of the North Sea Dome, but slightly later, took place in East Greenland and was succeeded by onset of rifting, subsidence and influx of enormous amounts of pure quartz sand deposited in shallow marine, tidally influenced embayments (Surlyk, 2003). The Upper Jurassic succession of the mid-Norwegian shelf reaches up to 1 km in thickness and comprises mostly organic rich mudstones belonging to the Viking Group, but sandstones were deposited locally and around emergent islands such as the Frøya High. The halfgrabens in Wollaston Forland of East Greenland were filled with up to 3 km of deep marine boulder conglomerates, pebbly sand and mud, constituting the Wollaston Forland Group. In contrast, sedimentation in Jameson Land comprised about 300 m of marine coarse sandy high-angle clinoform beds of the Scoresby Sund Group, overlying and passing laterally into some 800 m of submarine sand and mud deposits of the Hall Bredning Group.

The alluvial plains of the Hammerfest Basin were flooded during the Early Jurassic, but with time, the deltaic coastline re-advanced into the western part of the Hammerfest Basin. This resulted in deposition of shallow marine sheet sandstones overlying fluvial mudstones and sandstones of the Realgrunnen Subgroup, some 500 m thick, in the western Hammerfest Basin (Figure 4) (Gjelberg et al., 1987; Mørk et al., 1999). A sea-level rise during the Middle Jurassic resulted in flooding of land areas in the eastern Barents Sea, including the Nordkapp Basin. Lower to Middle Jurassic deposits are preserved in Kong Karls Land in the east, and comprise interbedded tidal sandstones and mudstones, whereas they are very poorly developed and condensed on Spitsbergen (Figures 3, 4) (Johannessen and Nøttvedt, 2006). Widespread deposition of some few hundred metres of organic-rich mudstones belonging to the Adventdalen Group characterises the Upper Jurassic successions of the Barents Sea and Svalbard (Dypvik, 1985; Nøttvedt and Johannessen, 2006).

Cretaceous

Rifting in the North Sea ceased at the onset of the Cretaceous and the Cretaceous period was characterised by crustal cooling and thermal subsidence following the earlier periods of extension and crustal thinning. This process involved burial of the block-faulted terrace provinces along the rift margins, and continuous infilling of the extensive basins located along the rift axis (Figure 2). Within the platforms there are minor, restricted, saucer-shaped depressions such as the Farsund, Egersund, Stord and Helgeland Basins. It is possible that these basins represent an adaptive response to tensional crustal forces beyond the margins of the major rift structures, after the latter became inactive during the Early Cretaceous.

Rifting in the region between Greenland and Norway continued into the Early Cretaceous, along the extension of the Rockall Trough and sea-floor spreading took place in the Mid-Atlantic. The focus of rifting was transferred from the Halten-Dønna Terrace and out into the Møre and Vøring Basins. The magnitude of extension in these basins was great and beneath the Møre Basin, crystalline crust was reduced in thickness to only a few kilometres, corresponding to between 20 and 25% of its original thickness (Brekke, 2000; Skogseid et al., 2000). This suggests that the area came very close to the onset of seafloor spreading and formation of new oceanic crust. Deep, regional depressions such as the Møre, Vøring, Harstad, Tromsø and Sørvestsnaget Basins formed along the main rift axis where the crust was subjected to maximum extension and thinning. The extreme degrees of crustal thinning promoted several kilometres of thermal subsidence during the Late Cretaceous, while continuous sediment infilling from the basin margins kept pace with this subsidence. In East Greenland several phases of rifting and block faulting took place during the Cretaceous and were associated with deposition of coarse-grained gravity flow deposits which can be correlated with similar but larger deep-water sandstone bodies in the Vøring Basin (Surlyk and Noe-Nygaard, 2001; Fjellanger et al., 2004).

In the Barents Sea, rifting in the Hammerfest and Bjørnøya Basins accentuated during the Early Cretaceous (Gabrielsen et al., 1990). These basins represent two divergent rift arms, adjacent to the deep basins in the Norwegian Sea. On the marginal platforms in the Barents Sea, shallow depressions like the Sørkapp and Olga Basins developed. They resemble wave-like undulations of the platform interiors, but their exact formation mechanism is unclear, in that none of the smaller basins are superimposed on older clearly-defined rift structures. In the Late Cretaceous, isolated islands and large parts of the northern Barents Sea became uplifted, causing widespread erosion.

The Cretaceous was accompanied by a continuous global rise in sea level. Lowlands were progressively submerged and, in the Late Cretaceous, sea levels became higher than they have ever been, before or since, and more than half the continental landmasses were submerged, including large parts of mainland Scandinavia. High sea levels and low topographic relief resulted in extensive, shallow epicontinental shelf seas, which were completely different from our present-day marginal seas.

The Lower Cretaceous succession in the North Sea varies from a few hundred metres up to 1 km in thickness and is dominated by mudstones and marls of the Cromer Knoll Group (Figure 4) (Oakman and Partington, 1998; Copestake et al., 2003; Brekke and Olaussen, 2006). Adjacent to highs or close to prevailing coasts local deposition of sand occurred. In the Late Cretaceous, the sea-level rise resulted in drowning of much of mainland Scandinavia resulting in progressive cut-off of terrestrial sediment supply, leading to deposition of more than 1 km of mudstones and limestones of the Shetland Group. The southern North Sea and the Danish Basin received more than 2 km thick deposits of calcareous coccolith ooze forming the Chalk Group (Surlyk et al., 2003). The chalk deposits serve as major reservoirs for oil and gas, especially over salt structures.

On the mid-Norwegian shelf, some 700 m of shallow marine mudstones belonging to the Cromer Knoll Group were deposited during the Early through Late Cretaceous (Figure 4). In the Norwegian Sea, the deep Vøring and Møre Basins contain sedimentary successions between 6 and 9 km thick, and similar thicknesses are recorded in the Harstad, Tromsø, and Sørvestsnaget Basins further north (Skogseid et al., 2000; Brekke, 2000; Færseth and Lien, 2002). The Lower Cretaceous stratigraphy of the deep basins is not known, as no wells have been drilled through the succession, but sand-rich deltaic and fluvial deposits occur along the basin margins. East Greenland was the major source area for the sediments infilling the Early Cretaceous Norwegian Sea basins, notably the outer Vøring Basin. During the Late Cretaceous, thick units of marine mud were deposited in most of the Møre Basin and the southernmost part of the Vøring Basin, whereas in the northern part of the Norwegian Sea thick Late Cretaceous deep-water sandstones are encountered (Fjellanger et al., 2004; Lien, 2005). In East Greenland the Cretaceous succession comprises up to 1,300 m of marine mudstones of the Traill Ø Group, but with sandstone wedges occurring along the basin margins (Figures 3, 4). The warm Cretaceous ocean periodically became stagnant, or anoxic, resulting in the formation of organic-rich mudstones and fine-grained limestones. In the latest Cretaceous, anoxic conditions became much less common.

Early Cretaceous rifting in the Hammerfest and Bjørnøya Basins, led to increased subsidence and deposition of between 1–2 km of calcareous marine mud of the upper Adventdalen Group (Figures 3, 4) (Nøttvedt et al., 1992; Brekke et al., 2001). Sandy fans occur locally along the fault escarpment at the southern margin of the Loppa High. Some few hundreds metres of Cretaceous sediments are preserved in shallow, saucer-shaped, intra-platform depressions such as the Olga and Sørkapp Basins. In the Barents Sea, Upper Cretaceous rocks have been removed over large areas following uplift and subsequent erosion. Even though much of the erosion results from uplift of the entire Barents Sea during the last 2.5 million years, significant uplift and erosion also occurred during the Cretaceous. On Spitsbergen, a Lower Cretaceous succession, some 1.5 km thick, is exposed on land. At the onset of the Cretaceous, marine mud was deposited across the Svalbard area. Uplift and gentle tilting of the basin margin along the northwestern Barents Sea Platform led to erosion and progressive coastal advance from north to south, followed by relative sea-level rise and deposition of a transgressive fluvio-deltaic sandstone overlain by shallow marine sandstones and mudstones (Gjelberg and Steel, 1995). Volcanism associated with the opening of the Amerasian Basin led to eruption of lavas in the area from Franz Josef Land to Svalbard.

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