DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 1997/70

Structural mapping of the Upper Jurassic - Lower Cretaceous in the Danish Central Graben

- a contribution to the EFP-92 project: Jurassic sequence stratigraphy of the Danish Central Graben

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GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF ENVIRONMENT AND ENERGY

G E U S

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Abstract

Rifting in the central and southern North Sea, largely during the Late Jurassic, resulted in a complex of grabens which form the North Sea Central Graben. Cenozoic post-rift subsidence aligned over the former grabens created the North Sea Basin. We suggest that the term 'Central Graben' is also used in a geographical sense to refer to the area in the central and southern North Sea that is characterized by major pre-mid Cretaceous extensional faulting.

Structural depth maps of *Top Jurassic* and *Base Upper Jurassic* and the isochores of the Upper Jurassic in the Danish Central Graben are presented. The maps are simplified and reduced versions of recently published maps (1:200,000) based on all 1994 public domain seismic and well data. Similar versions of the isochore and structural element maps of the Early Cretaceous Cromer Knoll Group are shown to clarify the distinction between the structural development during the Late Jurassic and the Early Cretaceous.

The depth to the *Top Jurassic* reaches 4800 m in the northern parts of the Central Graben, while the depth to *Base Upper Jurassic* reaches 7500 m in the Tail End Graben, where the Upper Jurassic attains a maximum thickness of 3600 m. The Tail End Graben, stretching for about 90 km along the Coffee Soil Fault, is the dominant Late Jurassic structural feature in the Danish Central Graben. During the Early Cretaceous, the development was characterized by a more even distribution of minor basins, whereas the Tail End Graben ceased to exist as a coherent element.

Introduction

The Central Graben was recognized as one of the main geological provinces in Denmark by Rasmussen (1978) based on seismic mapping by J.C. Baartman. A first structural outline of the Danish Central Graben was presented by Andersen *et al.* (1982). The structural evolution of the Danish and Norwegian parts of the Central Graben was later discussed by Gowers and Sæbøe (1985). A detailed analysis of the structural development and a definition of the structural nomenclature for the Danish Central Graben was presented by Møller (1986) for the Middle and Upper Jurassic and by Vejbæk (1986) for the Lower Cretaceous. The structure of the Central Graben in the Norwegian and northernmost Danish part was further discussed by Gowers *et al.* (1993). Four two-way time maps of the Jurassic in the Danish Central Graben were published by Møller (1986): *Near base Middle Jurassic/Top pre-Jurassic, Oxfordian-Kimmeridgian boundary, Late Kimmeridgian marker* and *Near top Jurassic/Base Cretaceous* (1:500,000). In addition, a map (1:800,000) was presented showing the thickness in metres of the Middle and Upper Jurassic.

The maps presented here are reduced and simplified versions of published maps at a scale of 1:200,000 covering up to 13,000 km^2 in the western part of the Danish North Sea sector. The maps are part of the results of an integrated mapping project. The aim of this project was to model and map interval velocities and depths of the main mappable units in the Danish Central Graben. This mapping project has resulted in the publication of a series of map sets containing a total of 15 maps (Britze *et al.*, 1995a, b, c, d). The study is based on well data and time structure maps of four well-defined marker horizons illustrating both

the syn-rift and post-rift phases which have affected the area. The four key horizons interpreted are *Base Upper Jurassic, Base Cretaceous*, *Base Chalk* and *Top Chalk*.
Based on isochore maps of the Late Jurassic and the Early Cretaceous successions, the nomenclature of the structural elements of these periods in the Danish Central Graben is revised (Table 1). The structural elements of these periods have often been confused and it is stressed that the dominant Late Jurassic structural feature in the study area is the Tail End Graben, stretching for about 90 km along the Coffee Soil Fault (Gowers and Sæbøe, 1985). During the Early Cretaceous, the structural development was characterized by a more even distribution of minor basins within the area, whereas the Tail End Graben ceased to exist as a coherent element.

Data base

The mapped area covers the Danish Central Graben and part of the eastern foot-wall block, the East North Sea Block, which forms part of the Ringkøbing-Fyn High system of elevated basement blocks. All 1994 public domain petroleum industry seismic and well data acquired on Danish territory were available for the study. Where data are available, adjacent parts of Norwegian, British, and German waters are included to define structural trends. The well data base comprises 96 released exploration and appraisal wells drilled, as a minimum, into the Late Cretaceous - Danian Chalk Group (Lieberkind *et al.*, 1982). The lithostratigraphic subdivision of most of the wells is presented in Nielsen and Japsen (1991).

The seismic data base varies in quality from 1979 2D sections to 1988 3D data. A selection of public domain 2D data is shown on the time structure maps for reference (Britze *et al.*, 1995a, b, c, d). This selection comprises regional speculative surveys acquired during the early and mid 1980s and proprietary surveys acquired by Mærsk Oil and Gas. Data from these surveys form the basis of the regional interpretation. The seismic interpretation of a number of fields is based on 3D data (e.g. Rasmussen, 1994; Kristensen et al., 1995).

Seismic interpretation and mapping

In basinal areas, the *Top Jurassic* marker is an easily identified seismic event marking the top of the low-velocity Farsund Formation of mainly Late Jurassic age (Jensen *et al.*, 1986). Towards basin margins, the marker is characterized by basal onlap. Locally the marker is expressed as a structural unconformity with truncated Upper Jurassic sediments below.

In the eastern part of the Central Graben the Upper Jurassic graben fill conformably overlies the Middle Jurassic. Here the *Base Upper Jurassic* seismic sequence boundary is picked in a trough above a strong peak of usually rather high lateral continuity. This trough-peak relationship is believed to be generated by interference of alternating sandstones, shales and coal beds in the uppermost part of the Middle Jurassic. Further westwards, where the Upper Jurassic overlies a pre-Jurassic substratum, the seismic marker is often recognized as a pronounced unconformity. The *Base Upper Jurassic* surface is by far the most complicated of the four horizons mapped. This is due to the great depth of burial (up to 6 seconds two-way time), the structural complexity, and local interference of multiples caused by thick, overlying high-velocity chalk deposits.

Four horizons were mapped as part of the project to illustrate the evolution of the area and to make layer-cake depth conversion possible. The four horizons mapped are '*Top Chalk*' - base of the Tertiary deposits (excluding the Danian), '*Base Chalk*' - base of the post-Early Cretaceous deposits, '*Base Cretaceous*' - base of the post-Jurassic deposits and '*Base Upper Jurassic*' - base of the post-Middle Jurassic deposits. The inverted commas indicate that the names are used in a general sense. The name of the surface in general referres to a mapped unit. When the unit is absent the map represents the continuation of the isochronous level along the lacuna replacing the unit in question. A surface defined in this sense becomes defined at any location.

The *Top Jurassic* and *Base Upper Jurassic* depth maps (Figures 1 and 2) show the depth-converted images of two structural traveltime maps: '*Base Cretaceous*' (Britze *et al.*, 1995c) and '*Base Upper Jurassic*' (Britze *et al.*, 1995d). The depth maps shown are only defined where the Upper Jurassic is present in the Central Graben, whereas the original maps at a scale 1:200,000 are defined throughout the area.

The '*Base Cretaceous*' time map is an extension and a revision of the *Near top Jurassic/Base Cretaceous* time map, published by Møller (1986). The '*Base Upper Jurassic*' time map is an extension and a revision of the *Near base Middle Jurassic/Top pre-Jurassic* time map (Mpller, 1986). The map was merged with the *Top Middle Jurassic* structure map of the Søgne Basin/northern Tail End Graben by Korstgård *et al.* (1993). Both time maps were incorporated with unpublished, regional interpretations and detailed field mappings undertaken by the DGU.

The drafts of the time structure maps were compiled manually at a scale of 1:100,000. The final maps were produced digitally with the ZMAP Plus mapping system using a 200 m griding interval.

Depth conversion

The depths to the surfaces are calculated by multi-layer depth conversion. *Top Jurassic* depth is found by adding the thicknesses of the Chalk Group and of the Cromer Knoll Group (Deegan and Scull, 1977) to the *'Top Chalk'* depth (Britze *et al.*, 1995b, c, a). The thickness of the Post Chalk Group (Cenozoic excluding Danian, Nielsen & Japsen, 1991) is calculated by subdividing this layer into two at the mid-Miocene unconformity which represents the top of the overpressured zone. The thickness of each of these units are calculated by velocity-anomaly depth conversion (Japsen, 1993; 1994). In velocity-anomaly depth conversion, the thickness of each layer is calculated sequentially from the top downwards from the seismic traveltime thickness by assuming that the velocity of the layer increases linearly with depth. Laterally, however, velocity is calibrated to match well data. The deviations, or the velocity anomalies, between the linear velocity-depth functions and well-derived interval velocities, represent the lateral velocity variation of the layer when the influence of depth is removed. The velocity-anomaly map, the seismic traveltime maps, and the linear velocity parameters for each layer constitute input for velocity-anomaly depth conversion. The output is depth and interval-velocity maps.

The depth to *Base Upper Jurassic* is calculated by adding the thickness of the Upper Jurassic to the *Top Jurassic* depth. The depth to *Base Upper Jurassic* is in total based on a five-layer depth conversion. No easily applied relationships between velocity and depth or traveltime were found that could be used to predict the interval velocities of the Upper Jurassic (Japsen, 1994). This is believed to be due to the complex geological and physical conditions as well as the restricted well data base for this interval. The thickness of the Upper Jurassic (Figure 3) is consequently calculated by multiplying the traveltime-thickness and the interval velocity of the layer.

The interval-velocity map of the Upper Jurassic represents contoured data from 54 wells of which 10 encountered more than 400 m of Upper Jurassic strata without penetrating the entire succession (Britze *et al.*, 1995d). The latter wells are included to define the velocity field of the thick Upper Jurassic sequence in the Tail End Graben (see Figure 4). Of the estimated maximum thickness of 3600 m, only 1421 m has been drilled (the G-1 well).

The interval velocity of the Upper Jurassic is very low relative to depth in the Tail End Graben: 2556 m/sec in the Nora-1 well, which drilled through the Upper Jurassic interval in the depth range from 3488 to 4381 m below sea level. A minimum value of 2374 m/sec was recorded in the North Jens-1 well. Velocities are relatively high in wells towards the west of the mapped area and adjacent to parts of the eastern border fault where fan delta-sands originating from the East North Sea Block are found in the uppermost part of the Jurassic (Damtoft *et al.*, 1992). The maximum interval velocity was recorded in the Ugle-1 well (4046 m/sec). Low velocities (< 2600 m/sec) recorded in the northern part of the Tail End Graben are believed to be due to extreme overpressure caused by gas generation (Japsen, 1994, cf. Buhrig, 1989).

Results

Reduced and modified versions of four full-scale maps are presented here (1:880,000): *Top Jurassic* depth, contour interval 200 m, *Base Upper Jurassic* depth, c.i. 400 m, Upper Jurassic isochore, c.i. 400 m, and Cromer Knoll Group isochore, c.i. 100 m (Figures 1,2,3 and 5). Maps of the structural elements for the Late Jurassic and the Early Cretaceous are shown in Figures 4 and 6. Among the original full-scale maps, six reflect the Jurassic deposits in the Danish Central Graben (1:200,000, 78,5 cm x 80 cm): '*Base Cretaceous*' time structure map, c.i. 50 msec, and depth structure map, c.i. 100 m (Britze *et al.*, 1995c); '*Base Upper Jurassic*' time structure map, c.i. 100 msec, and depth structure map, c.i. 200 m, Upper Jurassic - interval-velocity map, c.i. 100 m/sec, and isochore map, c.i. 200 m (Britze *et al.*, 1995d). The Cromer Knoll Group isochore map, c.i. 100 m, is included in Britze *et al.* (1995c).

The full-scale maps have annotated values of the well-measurements of the parametres in question - two-way time, depth, interval velocity and thickness - on the respective maps for each well. The status of a well with respect to hydrocarbons encountered in a given stratigraphic interval is expressed by the well symbol shown on the maps. The presence of hydrocarbons in Upper Jurassic sediments is indicated on the '*Base Cretaceous*' structure maps and on the Upper Jurassic interval-velocity and isochore maps, while hydrocarbons encountered in pre-Upper Jurassic strata are shown on the '*Base Upper Jurassic*' structure maps. The location of commercial hydrocarbon discoveries in the Upper Jurassic is given on the '*Base Cretaceous*' depth map, while those with the main reservoir in the Middle Jurassic are indicated on the '*Base Upper Jurassic*' depth map. The major

Late Jurassic and Early Cretaceous structural features are named on the Upper Jurassic and the Cromer Knoll Group isochore maps, respectively.

Structural elements of the Late Jurassic

The major Late Jurassic structural features (Figure 4) should be compared to the Upper Jurassic isochore map (Figure 3). The terminology generally follows that of Møller (1986). The dominant Late Jurassic structural element is the Tail End Graben. It is a halfgraben where up to 3600 m of Upper Jurassic sediments accumulated along the NW-SE trending segments of the Coffee Soil Fault for about 90 km; thicknesses in excess of 2000 m are estimated to cover an area from the Gulnare-1 well in the north to the G-1 well in the south. Towards the north, the Tail End Graben grades into the Piggvar Terrace, separated by the Mandal High from the N-S oriented Danish part of the Søgne Basin. In the southern part of the graben, the Tail End Graben extends into the narrow N-S oriented Rosa Basin (new name) and grades into the Salt Dome Province, a region dominated by halokinetic features. The Poul Plateau with a reduced thickness of Upper Jurassic, is situated adjacent to a shift in direction of the Coffee Soil Fault.

The Feda Graben, which continues north into Norwegian waters, is the most prominent feature in the northwestern part of the mapped area. It is separated by the narrow Gert Ridge from the Gertrud Graben which dips in the opposite direction, i. e. to the east. Towards the south, these depocentres grade into the Heno Plateau, characterized by intermediate thicknesses of Upper Jurassic sediments. To the south, the Heno plateau is dominated by a mosaic of minor fault blocks. To the east, the plateau is bounded by the Arne-Elin Graben, a structurally complicated hinge-zone to the Tail End Graben. Only a thin veneer of Upper Jurassic sediments is present on the flank of the Mid North Sea High in the area west of the Inge and Mads Highs. The Mid North Sea High is characterized by a large number of minor, basement-attached faults.

Upper Jurassic sediments are present throughout the main part of the Danish Central Graben except over the Inge, Mads and Mandal highs and a number of salt diapirs: East Rosa (the Dagmar Field), John, Middle Rosa (the Rolf Field), Nils (the Regnar Field), North Arne (the Svend Field), Ruth (the Skjold Field), Tove and Vagn (see Figure 6). Upper Jurassic sediments are missing on the East North Sea Block. A thin sequence of late Jurassic age was encountered in the L-1 well located on the edge of the Norwegian-Danish Basin. The thickness of this sequence is included in the Cromer Knoll isochore (Figure 5).
Depth to *Top Jurassic* ranges from 1661 m in the John Flank-1 well to 4800 m at the base of several Early Cretaceous depocentres in the northern parts of the Central Graben. Depth to *Base Upper Jurassic* ranges from 2059 m in the John Flank-1 well to 7500 m in the deepest parts of the Tail End Graben, where the Upper Jurassic attains a maximum thickness of 3600 m.

Structural elements of the Early Cretaceous

The major Early Cretaceous structural features (Figure 6) should be compared to the Cromer Knoll Group isochore map (Figure 5). These maps of the Lower Cretaceous are included here to emphasize the differences in the structural development between the Late Jurassic and the Early Cretaceous. The terminology generally follows that of Vejbæk

(1986). In the western part of the mapped area, the Ål Basin and the Outer Rough Basin separate the Mid North Sea High from the early development of the Lindesnes Ridge, the Inge High, and the Mads High. The Outer Rough Basin and the Ål Basin mainly developed during the Cretaceous, as pointed out by Møller (1986). These basins are thus only included on the map of Late Cretaceous structural elements. The Ål Basin was referred to as the Grensen Nose (Gowers and Sæbøe 1985) by Møller (1986) and Vejbæk (1986)). The Grensen Nose is a structural spur protruding from the Mid North Sea High (Gowers *et al.*, 1993) and is mainly located in Norwegian waters. The Heno Plateau with no or reduced thickness of Lower Cretaceous sediments grades northwards into the NW-SE trending depocentres of the Feda Graben and the Gertrud Graben separated by the narrow Gert Ridge. The Heno Plateau is bounded to the east by the Arne-Elin Graben, a pull-apart basin, related to left-lateral oblique-slip movements according to Vejbæk (1986) and Korstgård *et al.* (1993). The northern parts of the Late Jurassic Tail End Graben developed in Early Cretaceous times into two separate depocentres: the Iris Basin and the Gulnare Basin (new names). Salt withdrawal is believed to have played a role in the formation of these depocentres (Korstgård *et al.*, 1993). The E-W trending Pollerne Ridge separates these basins from the Roar Basin (new name) farther to the south. Only a rather thin development of the Cromer Knoll Group is found in the Salt Dome Province. To the north the Mandal High was an elevated feature and probably experienced erosion during Early Cretaceous times.

The maximum thicknesses of the Cromer Knoll Group are found in the Outer Rough Basin (1100 m). Thicknesses of more than 800 m are estimated in the Ål, Iris and Roar Basins and in the Feda, Gertrud and Arne-Elin Grabens. Lower Cretaceous sediments are absent on the uplifted footwall of the East North Sea Block. A thin cover of Lower Cretaceous sediments extends from the Norwegian-Danish Basin into the northeastern part of the mapped area.

Discussion

Rifting in the central and southern North Sea, largely during the Late Jurassic, resulted in a complex of grabens which form the North Sea Central Graben. Cenozoic post-rift subsidence aligned over the former grabens created the North Sea Basin (Ziegler, 1990). We suggest that the term 'Central Graben' is also used in a geographical sense to refer to the area in the central and southern North Sea that is characterized by major pre-mid Cretaceous extensional faulting. It is, however, stressed that the area has undergone a complex poly-phase tectonic development, which since Mid Jurassic times has included segmentation due to faulting, subsidence, block rotation, and localized inversion followed by regional subsidence.

The term 'Central Graben' has gained wide acceptance, in preference to 'Central Trough' as suggested by Rønnnevik *et al.* (1975). Their argument for the term Central Trough for the "graben system of Permian-Cretaceous age" has not been accepted by the majority of subsequent workers: "The tectonic axis of the graben system does not coincide with the deepest part of the depocentre and this is the reason why the name trough is preferred over graben" (Rønnevik *et al.*, 1975). Adding to the terminological confusion, Gowers and Sæbøe (1985) stated that "the Central Trough should be treated as a broad NW trending zone of subsidence with some local highs only when discussing post mid-

Cretaceous geology". When considering the pre mid-Cretaceous geology, the recommendation of Gowers and Sæbøe (1985) was to refer to the individual structural elements within the area of the Central Trough.

The main rifting episodes in the Danish Central Graben occurred during the Middle and Late Jurassic. The graben consists of a system of generally NNW-SSE trending half-grabens bounded by the Coffee Soil Fault towards the footwall block of the East North Sea Block to the east, and by the Mid North Sea High to the west. The rifting, which involved high rates of crustal stretching (Vejbæk 1992), commenced during the Bajocian (Johannessen and Andsbjerg, 1993). The syn-rift sedimentary fill is mudstone-dominated and is very rich in organic matter at certain levels (Damtoft *et al.*, 1992). The early development was characterized by fault controlled subsidence and deposition in the eastern part, especially along N-S trending segments of the Coffee Soil Fault (e.g. Korstgård *et al.*, 1993). During the Kimmeridgian, the dominant tectonic trend shifted from the N-S fault direction inherited from the pre-Jurassic to a dominant NW-SE direction; the depocentres shifted westwards and deposition gradually covered larger areas. Despite the overall extensional tectonic regime, compressional features caused by oblique-slip movements between different graben segments or by re-adjustments at boundaries between opposite-dipping fault blocks, have been recorded locally (Sundsbø and Megson, 1993, Rasmussen, 1995).

The extensional tectonic regime of the Late Jurassic continued in the Early Cretaceous with much reduced subsidence rates. Subsidence occurred to some extent in the same areas which subsided during the Late Jurassic, however, with a westward shift, as new depocentres developed west of the Inge and Mads Highs. The Lower Cretaceous deposits were separated into local depocentres, partly as a result of reduced sediment supply and partly due to accentuation of ridges and structural highs separating the sub-basins. Block faulting gradually ceased after the Hauterivian, giving way to regional subsidence and mild inversion movements (Vejbæk 1986).

Conclusion

Rifting in the central and southern North Sea, largely during the Late Jurassic, resulted in a complex of grabens which form the North Sea Central Graben. The extensional tectonic regime continued during the Early Cretaceous, but later in the Cretaceous it was replaced by a regime characterized by regional subsidence and mild inversion. Cenozoic post-rift subsidence aligned over the former grabens created the North Sea Basin. We suggest that the term 'Central Graben' is also used in a geographical sense to refer to the area in the central and southern North Sea that is characterized by major pre-mid Cretaceous extensional faulting.

Fifteen maps (1:200,000) of the Danish Central Graben have been prepared based on well data and interpretation of four well-defined seismic horizons illustrating both the syn-rift and post-rift phases which have affected the area. Presented here are reduced and simplified versions of the depth maps of *Top Jurassic* and *Base Upper Jurassic* and of the Upper Jurassic and Cromer Knoll Group isochores. The structural nomenclature in use for the Late Jurassic and the Early Cretaceous in the Danish Central Graben is discussed based on a comparison of the two isochore maps.

The Tail End Graben is the dominant Late Jurassic structural feature in the Danish Central Graben. Up to 3600 m Upper Jurassic of sediments accumulated in the Tail End Graben, where deposits in excess of 2000 m that are encountered for about 90 km along the NW-SE trending Coffee Soil Fault. The Rosa Basin (new name) is a narrow N-S oriented element which forms a south-western extension of the Tail End Graben. The Tail End Graben ceased to exist as a coherent structural element during the Early Cretaceous and developed into three separate depocentres: the Iris, Gulnare and Roar Basins (new names). The Early Cretaceous saw a shift from the asymmetric subsidence along the Coffee Soil Fault during the Late Jurassic to a more even distribution of minor basins within the Danish Central Graben.

Extreme pressure induced by gas generation within the Upper Jurassic section is believed to cause the very low seismic velocities in the Tail End Graben (less than 2600 m/sec at depths below 3500 m).

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Table 1. Suggested structural names for the Danish Central Graben.

Structural element	Reference	Stratigraphic level	
		Late Jur.	Early Cret.
Arne-Elin Graben	Møller (1986), Vejbæk (1986)	x	x
Central Graben	Rasmussen (1978)	x	x
East North Sea Block	Rasmussen (1978)	x	x
Feda Graben	Gowers and Sæbøe (1985)	x	x
Gert Ridge	Møller (1986), Vejbæk (1986)	x	x
Gertrud Graben	Møller (1986), Vejbæk (1986)	x	x
Gulnare Basin	new name	-	x
Heno Plateau	Møller (1986), Vejbæk (1986)	x	x
Inge High	Møller (1986), Vejbæk (1986)		x
Iris Basin	new name	-	x
Lindesnes Ridge	Gowers *et al.* (1993)	-	x
Mads High	Møller (1986), Vejbæk (1986)	x	x
Mandal High	Rønnevik *et al.* (1975)	x	x
Mid North Sea High	Rasmussen (1978)	x	x
Outer Rough Basin	Gowers and Sæbøe (1985)	-	x
Piggvar Terrace	Gowers *et al.* (1993)	x	-
Pollerne Ridge	Vejbæk (1986)	-	x
Poul Plateau	Møller (1986)	x	x
Ringkøbing-Fyn High	Rasmussen (1978)	x	x
Roar Basin	new name	-	x
Rosa Basin	new name	x	-
Salt Dome Province	Møller (1986), Vejbæk (1986)	x	x
Spgne Basin	Gowers and Sæbøe (1985)	x	-
Tail End Graben	Andersen *et al.* (1982)	x	-
Ål Basin	Gowers *et al.* (1993)	-	x

Figure 1. *Top Jurassic* structural depth map. Modified after Britze *et al.*, 1995c.

Figure 2. *Base Upper Jurassic* structural depth map. Modified after Britze *et al.*, 1995d.

Figure 3. Upper Jurassic isochore. Modified after Britze *et al.*, 1995d.

Figure 4. Late Jurassic structural elements (Britze *et al.*, 1995d). Modified after Møller, 1986.

Figure 5. Cromer Knoll Group isochore. Modified after Britze *et al.*, 1995d.

Figure 6. Early Cretaceous structural elements (Britze *et al.*, 1995d). Modified after Vejbæk 1986.

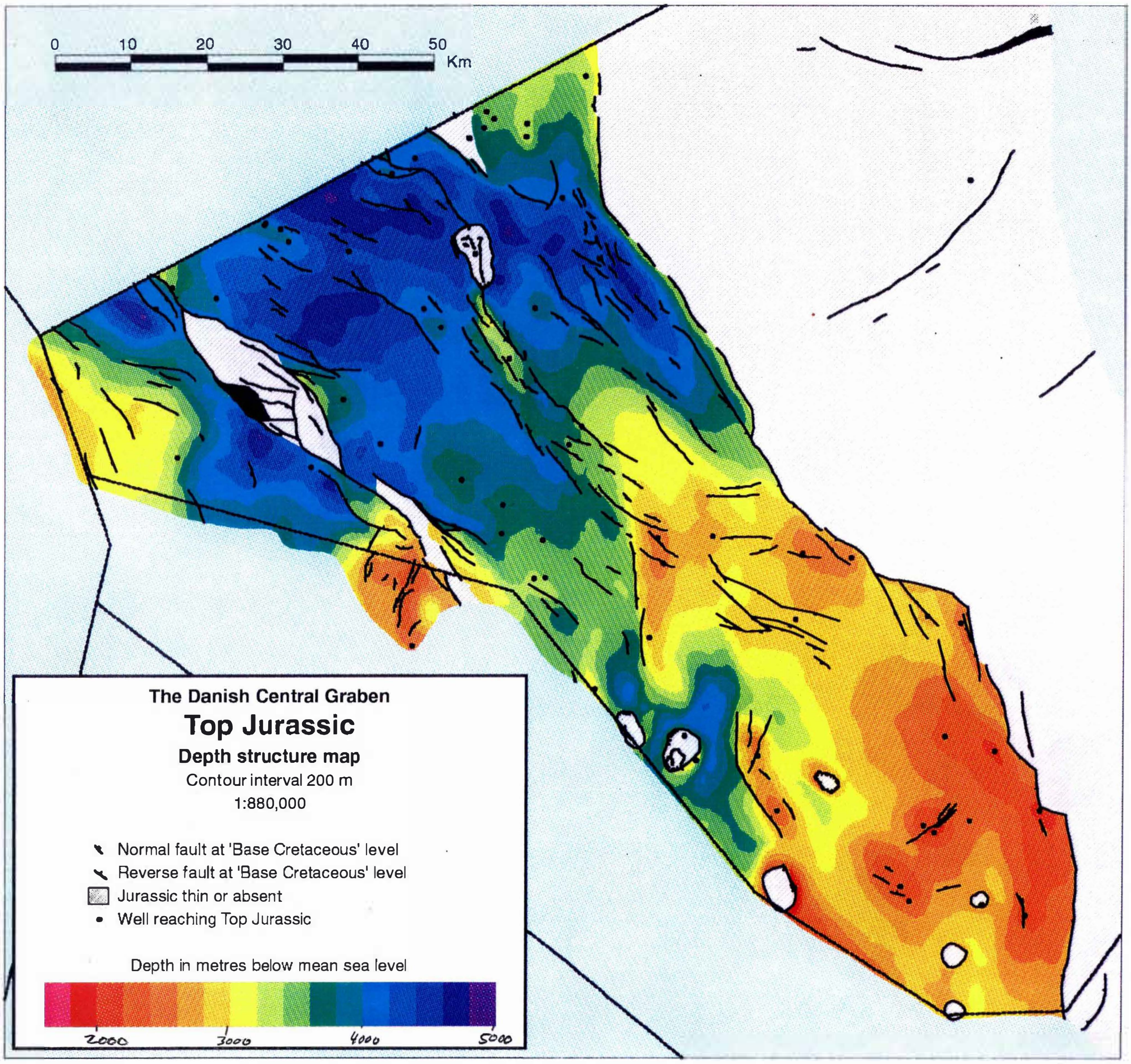

0 10 20 30 40 50
Km
The Danish Central Graben
Top Jurassic
Depth structure map
Contour interval 200 m
1:880,000
Normal fault at 'Base Cretaceous' level
Reverse fault at 'Base Cretaceous' level
Jurassic thin or absent
Well reaching Top Jurassic
Depth in metres below mean sea level
2000
3000
4000
5000

Fig. 1

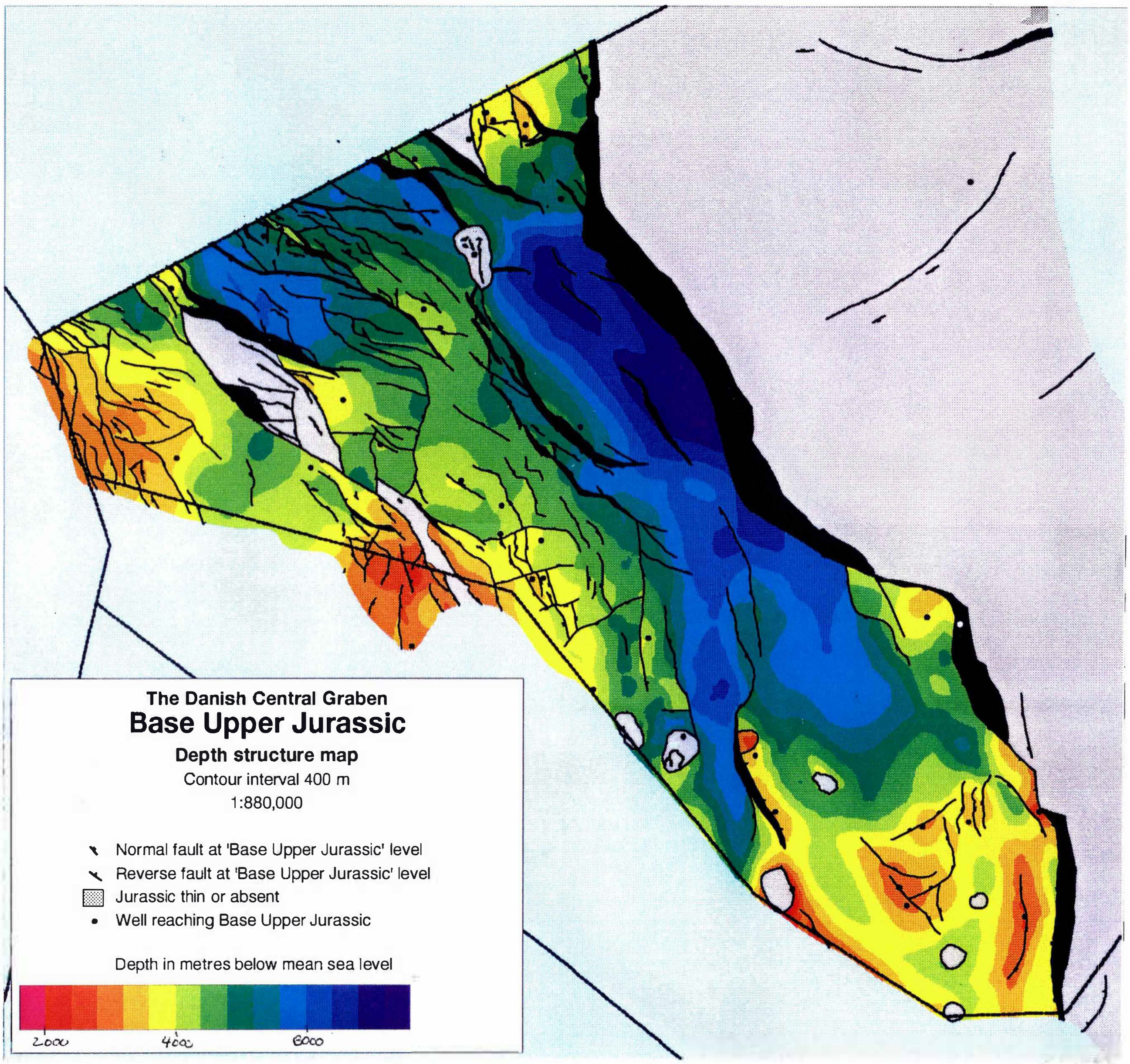

The Danish Central Graben
Base Upper Jurassic
Depth structure map
Contour interval 400 m
1:880,000
Normal fault at 'Base Upper Jurassic' level
Reverse fault at 'Base Upper Jurassic' level
Jurassic thin or absent
Well reaching Base Upper Jurassic
Depth in metres below mean sea level
2000
4000
6000

Fig.2

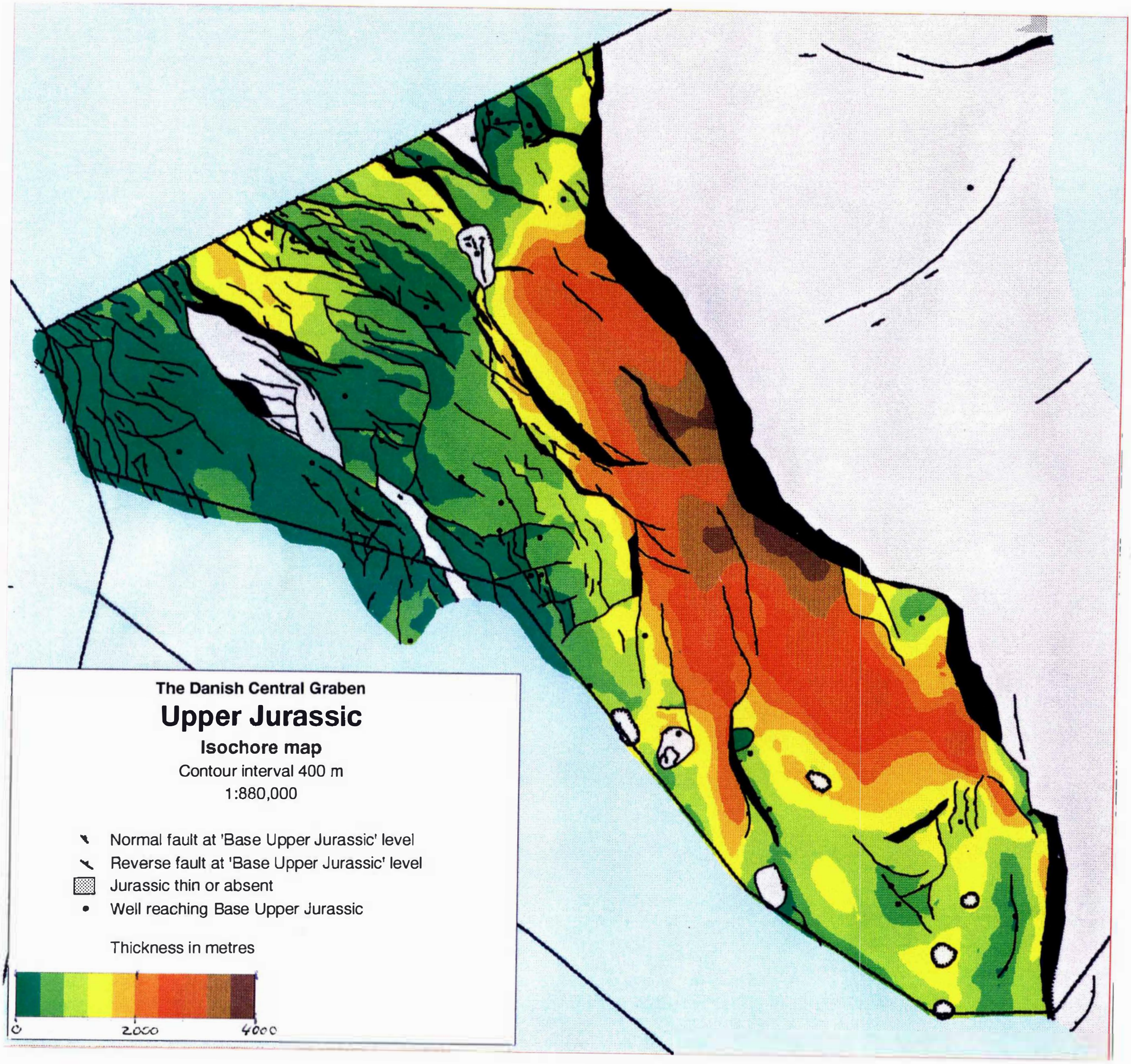

The Danish Central Graben
Upper Jurassic
Isochore map
Contour interval 400 m
1:880,000
Normal fault at 'Base Upper Jurassic' level
Reverse fault at 'Base Upper Jurassic' level
Jurassic thin or absent
Well reaching Base Upper Jurassic
Thickness in metres
0
2000
4000

Fig.3

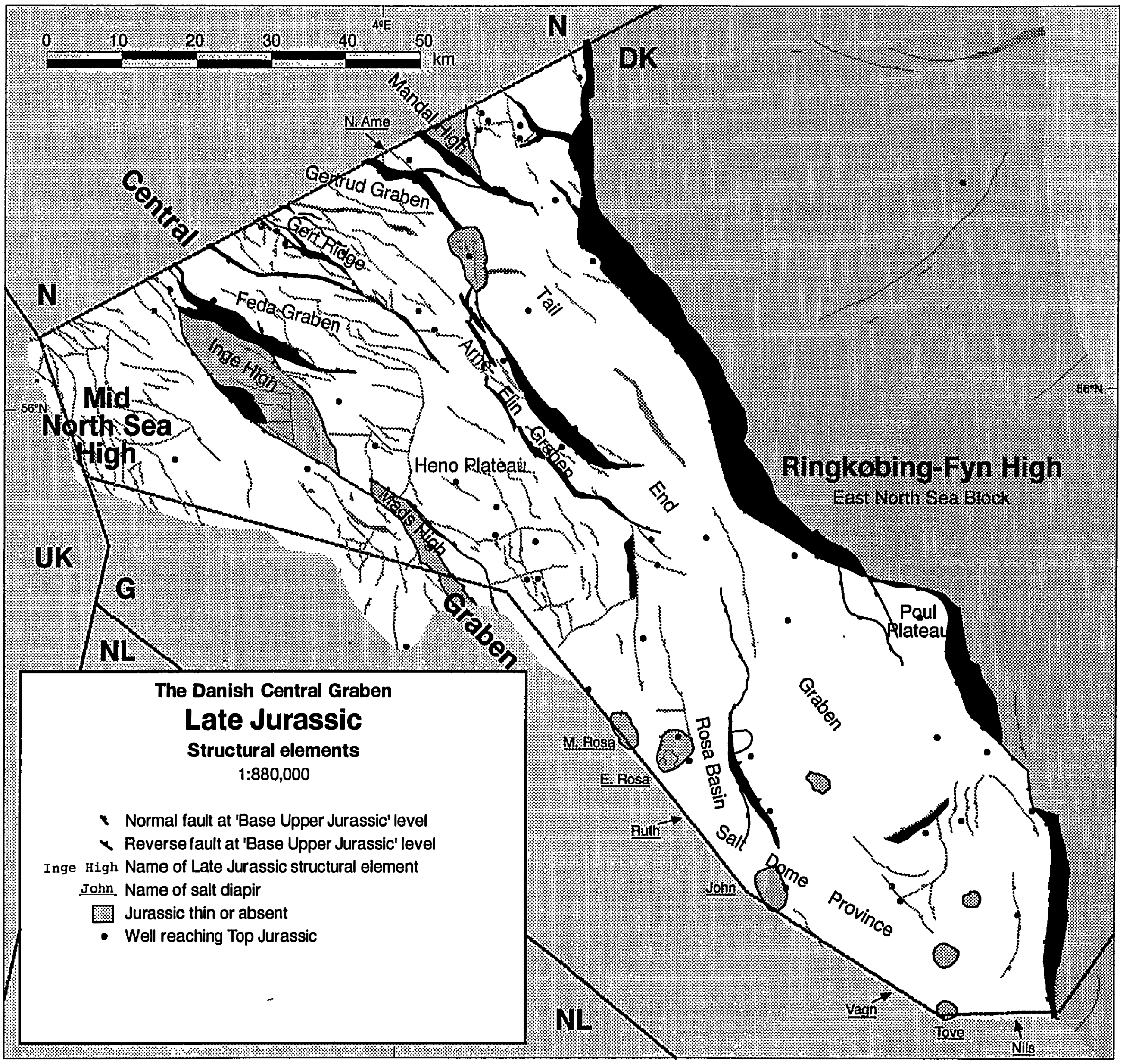

The Danish Central Graben
Late Jurassic
Structural elements
1:880,000
Normal fault at 'Base Upper Jurassic' level
Reverse fault at 'Base Upper Jurassic' level
Inge High Name of Late Jurassic structural element
John Name of salt diapir
Jurassic thin or absent
Well reaching Top Jurassic
0 10 20 30 40 50 km
4°E
56°N
N
DK
Central
Graben
Mid North Sea High
UK
G
NL
Ringkøbing-Fyn High
East North Sea Block
Mandal High
N. Ame
Gertrud Graben
Gert Ridge
Feda Graben
Inge High
Heno Plateau
Mads High
Tail
End
Arne
Elin
Graben
Poul Plateau
Rosa Basin
Salt Dome Province
M. Rosa
E. Rosa
Ruth
John
Vagn
Tove
Nils

Fig.4

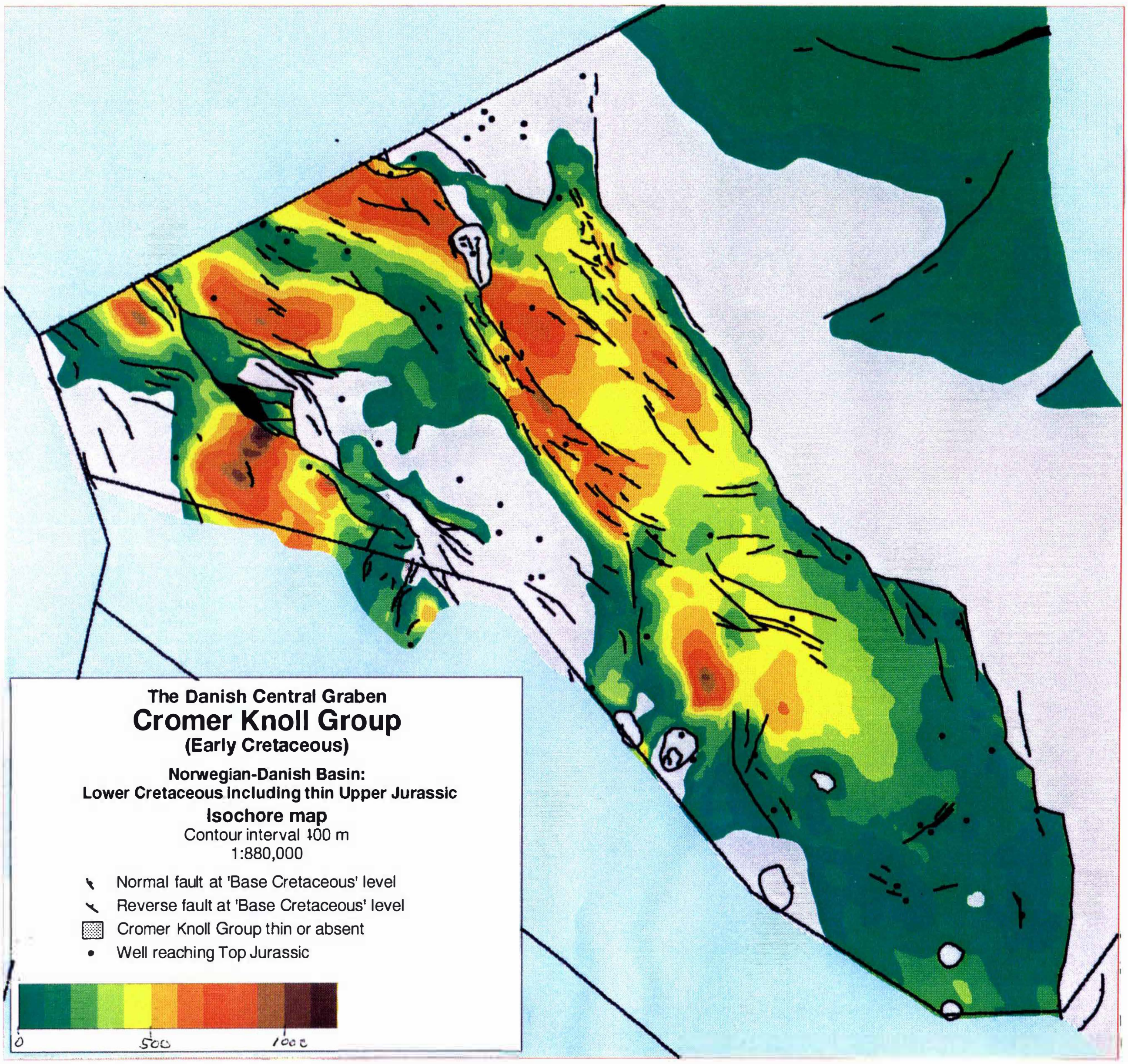
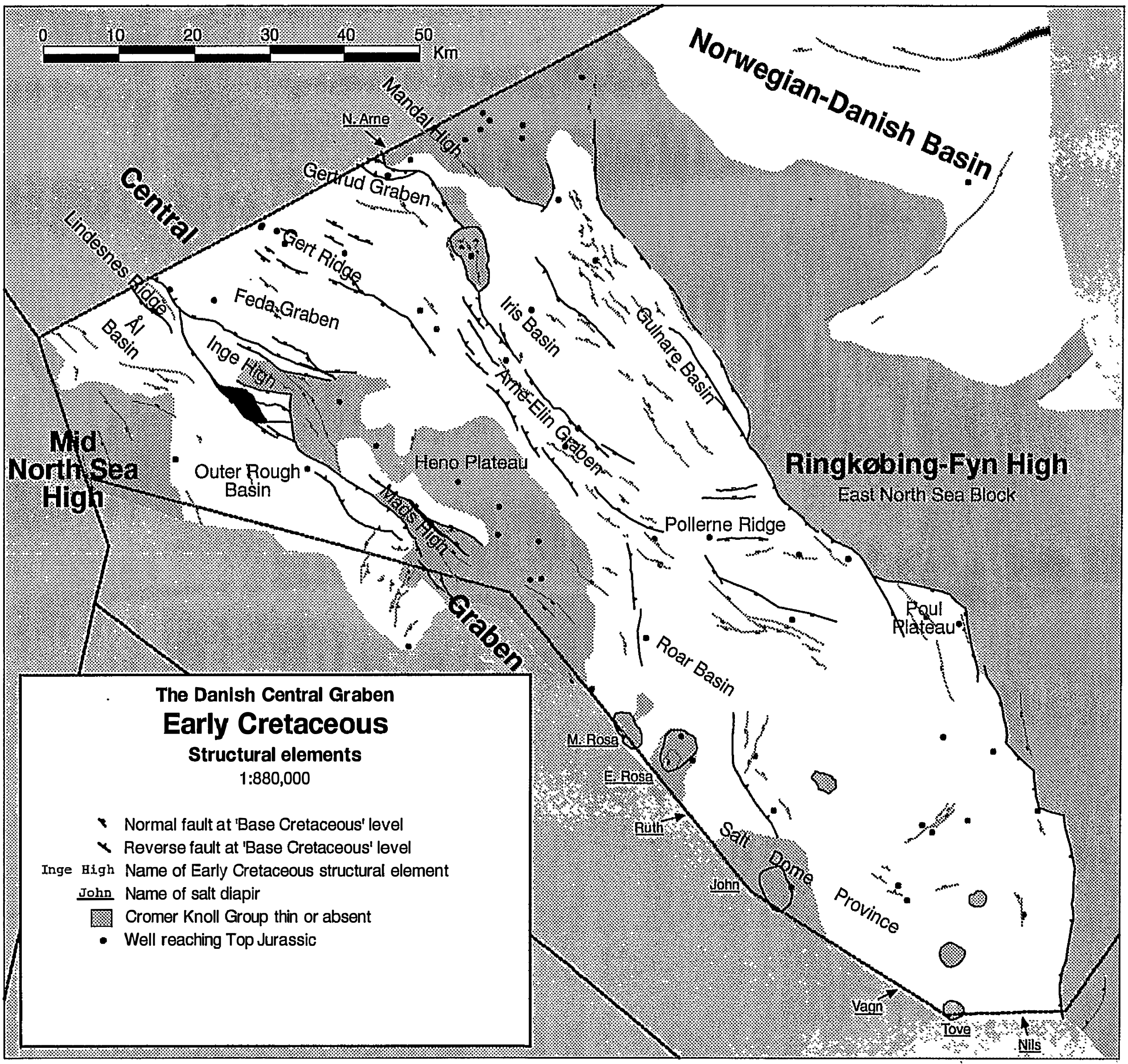

The Danish Central Graben
Cromer Knoll Group
(Early Cretaceous)
Norwegian-Danish Basin:
Lower Cretaceous including thin Upper Jurassic
Isochore map
Contour interval 100 m
1:880,000
Normal fault at 'Base Cretaceous' level
Reverse fault at 'Base Cretaceous' level
Cromer Knoll Group thin or absent
Well reaching Top Jurassic
0
500
1000

Fig.5



0 10 20 30 40 50 Km
Norwegian-Danish Basin
Central
Graben
Mandal High
N. Arne
Gertrud Graben
Gert Ridge
Lindesnes Ridge
Feda Graben
Ål Basin
Inge High
Iris Basin
Gulnare Basin
Arne-Elin Graben
Mid North Sea High
Outer Rough Basin
Heno Plateau
Mads High
Ringkøbing-Fyn High
East North Sea Block
Pollerne Ridge
Poul Plateau
Roar Basin
M. Rosa
E. Rosa
Ruth
Salt Dome Province
John
Vagn
Tove
Nils
The Danish Central Graben
Early Cretaceous
Structural elements
1:880,000
Normal fault at 'Base Cretaceous' level
Reverse fault at 'Base Cretaceous' level
Inge High Name of Early Cretaceous structural element
John Name of salt diapir
Cromer Knoll Group thin or absent
Well reaching Top Jurassic

Fig.6