DGU
DANMARKS GEOLOGISKE UNDERSØGELSE • KORTSERIE • NR. 49
GEOLOGICAL SURVEY OF DENMARK • MAP SERIES NO. 49

Geological map of Denmark
Geologisk kort over Danmark
1 : 200 000

The Danish Central Graben / Den danske Centralgrav

'Base Cretaceous' and the Cromer Knoll Group
(two-way traveltime and depth, interval velocity and isochore)

'Basis Kridt' og Cromer Knoll Gruppen
(to-vejs løbetid og dybde, intervalhastighed og vertikal tykkelse)

AF / BY
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Geologiske kort – et værktøj

Det geologiske kort er et værktøj, der bruges af brøndborere, ingeniørfirmaer, offentlige myndigheder, undervisere og mange andre.

DGU's vigtigste opgave er at kortlægge, dokumentere og informere om vort lands geologiske forhold: Hvad landet består af, hvorledes det er opbygget og dannet. DGU har over 100 års erfaring med udarbejdelse af sådanne geologiske kort.

Kortlægningen gælder undertiden mere specielle geologiske områder, f.eks. kortlægningen af fremstillingsråstoffer som grus, kalk og ler, og til andre tider er det energiråstoffer som brunkul, olie og geotermisk varme, men som regel indgår kortlægning af grundvand altid.

Det geologiske kort er den bedst egnede måde at beskrive landets opbygning og naturressourcernes fordeling på. Man kan imidlertid ikke fremstille et kort, der indeholder alt, og som kan anvendes til alle formål. Det enkelte kort indeholder derfor oftest et bestemt tema. Der findes således kort over bjergarternes udbredelse, såvel de overfladenære som de dybtliggende, hydrogeologiske kort, kort over prækvartæroverfladens højdeforhold, kort over grundvandsboringer, kort over strukturforholdene i den dybere undergrund og meget andet.

Ved udformningen og anvendelsen af kort er målforholdet af største betydning. Præcisionen i afgrænsningen mellem forskellige geologiske fænomener er afhængig af målforholdet. En ændring af målforholdet fra et lille til et stort (en forstørrelse af kortet) vil medføre en formindsket nøjagtighed. Det må endvidere tages i betragtning, at mængden af oplysninger på kortene ofte har måttet begrænses på grund af pladshensyn.

Et geologisk kort er, ligesom andre publikationer, udtryk for den viden, man har på det tidspunkt, kortet blev fremstillet. Men på grund af udviklingen i den geologiske videnskab og fremkomsten af nye oplysninger, kan der være behov for i tidens løb at revidere kortet.

Geological maps – a tool

The geological map is a tool used by well drillers, construction firms, public authorities, teachers, to mention a few.

The main tasks of the DGU are the mapping of the country, and providing documentation and information on the geological features of Denmark, the materials, their structures and genesis. The DGU has more than 100 years of experience in the preparation of geological maps of our country.

In addition the mapping aims at economic and public interest. It may be the mapping of manufacturing raw materials, i.e. clay, lime and gravel, or it may be energy raw materials such as lignite, oil and geothermal heat. The mapping of groundwater resources and the movement of the groundwater is an essential part of the work carried out by the DGU.

The geological map is the most suitable way to describe the geology of the country. Of course it is not possible to prepare a geological map which contains all available information and which can be used for all purposes. Therefore, specialized thematic maps are made, showing the geology of the subsurface, hydrology, position of water borings, preQuaternary surface, structural outline of the underground and much more.

In the presentation and the use of maps the scale is significant. The exactness of the boundaries between different geological phenomena depends on the scale of the map. A change of the scale from a small one to a larger one (an enlargement of the map) will diminish the accuracy. Furthermore, it must be considered that the geological documentation on the map frequently is limitated due to lack of space.

Like other publications a geological map expresses the knowledge of the area at a certain time. Because of the progress in geology and discoveries of new information it will be necessary to revise the map in the course of time.

DGU Danmarks Geologiske Undersøgelse
Miljø- og Energiministeriet

Danmarks Geologiske Undersøgelse (DGU) er en rådgivnings- og forskningsinstitution under Miljø- og Energiministeriet.

DGU har som hovedopgave at varetage dataindsamling og kortlægning samt forskning, rådgivning og formidling med sigte på at forbedre kendskabet til materialer, processer og sammenhænge, der har betydning for nyttiggørelsen og beskyttelsen af Danmarks geologiske naturværdier.

Blandt DGU's opgaver på miljøområdet kan nævnes rådgivning og forskning vedrørende miljøbeskyttelse, vandforsyning, råstofindvinding og naturbeskyttelse. På energiområdet bistår DGU med administration af lovgivningen om udnyttelsen af forekomster i Danmarks undergrund, herunder varetagelse af statens tilsyn med efterforskningen og indvindingen af olie, naturgas og jordvarme m.m. Desuden udfører DGU i vidt omfang opgaver for private firmaer på kontraktvilkår på miljøområdet såvel som på energiområdet.

Danmarks Geologiske Undersøgelse blev oprettet i 1888, og der er i de forløbne år publiceret en lang række afhandlinger om instituttets videnskabelige og praktiske virksomhed.

DGU *Geological Survey of Denmark*
Ministry of Environment and Energy

The Geological Survey of Denmark (DGU) is an advisory and research institution under the Danish Ministry of Environment and Energy.

DGU's primary function is to provide the essential geological service for the utilization and protection of Denmark's natural resources. This involves mapping, data collection and basic research, in addition to providing impartial advice and presenting geological results to both the general public and the scientific community.

Within the environmental sphere, DGU has both an advisory and a research role with respect to environmental protection, water supply, exploitation of raw materials and nature conservation. Within the energy sphere DGU assists in the administration of the utilization of deposits in the subsurface, including the supervision of exploration for and exploitation of oil, natural gas, geothermal energy etc. In addition, DGU undertakes numerous contract assignments for private firms, concerning both environmental and energy areas.

The Geological Survey of Denmark was established in 1888, and over the years a large number of papers have been published on the Survey's scientific and practical activities.

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Description

This publication comprises regional two-way traveltime and depth maps of the *'Base Cretaceous'* surface together with the Cromer Knoll Group interval-velocity and isochore maps. The maps are 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 sponsored by the Amoco 3rd Round Group, comprising Amoco Denmark, FLS-Energy, DENERCO, and DOPAS. The aim of the 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 three additional map sets (Britze, Japsen & Andersen, 1995a, b, c).

The mapped area covers the Danish Central Graben and part of the eastern foot-wall block, the East North Sea Block, a part of the Ringkøbing-Fyn High system of elevated basement blocks (Rasmussen, 1978). Where data are available, adjacent parts of Norwegian, British, and German waters are included to define structural trends.

This 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. Rifting in the area, largely during the Late Jurassic, resulted in a complex of grabens which form part of the North Sea Central Graben system. Cenozoic post-rift subsidence aligned over the former grabens created the North Sea Basin (Ziegler, 1990). In the context of this publication, however, the Central Graben refers to the area in the central part of the North Sea dominated by pre-Mid Cretaceous extensional faulting. The term 'Central Graben' as used in this wider geographical sense, has gained wide acceptance, in preference to 'Central Trough' as originally suggested by Rønnevik, van den Bosch & Bandlien (1975). It is, however, stressed that the area has experienced 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.

Database

All 1994 public domain petroleum industry seismic and well data were available for the study. The well database comprises 96 released exploration and appraisal wells drilled, as a minimum, into the Late Cretaceous – Danian Chalk Group, Lieberkind, Bang, Mikkelsen & Nygaard, 1982 (equivalent to the Shetland Group of the Norwegian shelf, Isaksen & Tonstad, 1989). The lithostratigraphic subdivision of most of the wells is presented in Nielsen & Japsen, 1991. Supplementary information is extracted from Danish Energy Agency, in press. Data from the recently drilled Alma-1 and Amalie-1 wells were made available for the publication of the maps by Mærsk Oil and Gas and Statoil, Denmark, respectively.

The seismic database 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. 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.

The structural traveltime map is an extension as well as a revision of the *'Near top Jurassic/Base Cretaceous'* time map, published by Møller (1986). The map is updated through merging of later unpublished regional interpretations and detailed field mappings undertaken by the DGU. Supplementary mapping is carried out on the East North Sea Block and to cover gaps. The drafts of the time structure maps are compiled manually in the scale of 1:100,000. The final maps are produced digitally with the ZMAP Plus mapping system using a 200 m gridding interval.

Seismic interpretation

The structural traveltime map of the base of the post-Jurassic deposits *('Base Cretaceous')* represents the base of the Early Cretaceous aged Cromer Knoll Group (Deegan & Scull, 1977) in the major part of the mapped area. Over the crests of the John and East Rosa salt diapirs the mapped surface locally represents the base of the Tertiary. Where the Cromer Knoll Group is ab-sent or below

seismic resolution, as indicated on the maps, the mapped surface represents the base of the Chalk Group.

In basinal areas, the *'Base Cretaceous'* is an easily identified seismic event marking the top of the low velocity Farsund Formation of mainly Late Jurassic age (Jensen, Holm, Frandsen & Michelsen, 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 marginal parts of the Norwegian-Danish Basin the mapped sequence also comprises sediments assigned a Late Jurassic age, as observed in the L-1 well.

Depth conversion

The depth to *'Base Cretaceous'* is calculated by adding the thickness of the Cromer Knoll Group to the *'Base Chalk'* depth (Britze et al., 1995b). The thickness of the Cromer Knoll Group is calculated by velocity-anomaly depth conversion combined with an empirical relationship between velocity anomaly and traveltime-thickness of the Cromer Knoll Group (Japsen, 1993, 1994). The choice of depth conversion method is based on an analysis of the relative success of a number of methods (Japsen, 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 the velocity of layer to increase 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 or depth is removed. The velocity-anomaly map, the seismic traveltime maps, and the linear velocity parametres for each layer constitute input for velocity-anomaly depth conversion. The output is depth and interval maps. The velocity-anomaly map for the Cromer Knoll Group is based on data from 46 wells; a simplified version is presented by Japsen, 1994. The high anomalies recorded in the Ugle-1 and V-1 wells are extra-polated towards NW along the East North Sea Block. The regional velocity function for the Cromer Knoll Group is taken to be $V = 1375\ m/s + 0.52\ s^{-1} \cdot Z$ (Z is depth in metres below mean sea level), Japsen, 1994. This function is based on an analysis of time-depth relationships recorded in wells in the area. The empirical relationship between velocity anomaly and time-thickness expresses the fact that negative velocity anomalies are found in areas of pronounced subsidence, whereas positive anomalies are found where carbonate-rich deposits dominate in relatively stable areas (Japsen, 1994). This relationship was not applied over the East North Sea Block.

The interval velocity of the Cromer Knoll Group generally increases with depth of burial of the *'Base Chalk'* surface, while it decreases with increasing time-thickness of the Cromer Knoll Group. Interval velocities less than 3000 m/s are thus encountered where the Cromer Knoll Group is thick and/or at a shallow depth of burial, i.e. in a NW-SE trending zone from the Iris-1 to the SE Igor-1 well. A minimum velocity of 2372 m/s is observed in the G-1 well. In the deep parts of the mapped area interval velocities are high. However, the Early Cretaceous depocenters are recognized as zones of relatively low velocity. In the Karl-1 well thin calcareous deposits have a maximum interval velocity of 5220 m/s. Along the East North Sea Block high velocities in two wells are related to the presence of coarse clastic deposits. On the East North Sea Block itself the velocity of the thin Lower Cretaceous is high relative to depth.

Depth to the mapped surface is found to vary between 618 m below mean sea level in the John-1 well, where Zechstein salt is piercing the Chalk Group, and 4800 m at the base of several Early Cretaceous depocenters in the northern parts of the Central Graben, e.g. east of the T-1 well, south of the Kim-1 well, south of the Olaf-1 well and north of the Jeppe-1 well. Minimum depth to the top of the Lower Cretaceous within the Central Graben is 2000 m near the Emma-1 well and 1900 m on the East North Sea Block.

Brief review of geological evolution

The Early Cretaceous was characterized by a general, relative sea-level rise, starting with a low in the Volgian (Rawson & Riley, 1982) and a general continued rise into the Late Cretaceous. This caused a change from deposition of black anoxic shales of the Kimmeridgian – Ryazanian Farsund Formation (Jensen, et al., 1986) in the basin centres to conformable deposition of greyish oxygenated claystones with marls dominating the Cromer Knoll Group (Michelsen et al., 1987). The introduction of pelagic limestones of the Tuxen Formation (Jensen et al., 1986) during the late Hauterivian generally reflects rising sea-level and decrease of clastic input.

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 more 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 from Hauterivian and onwards and gave way to regional subsidence and mild inversion movements (Vejbæk, 1986).

The major Early Cretaceous structural features are named on the Cromer Knoll isochore map. The terminology used generally follows that of Vejbæk (1986). In the western part of the mapped area the Ål Basin (Gowers, Holtar & Swensson, 1993) and the Outer Rough Basin separate the Mid North Sea High from the early development of the Lindesnes Inversion (Gowers et al., 1993), the Inge High, and the Mads High. The Heno Plateau with no or reduced thickness of Lower Cretaceous sediments grades north 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 Korstgaard, Lerche, Mogensen & Thomsen, 1993. The northern parts of the Late Jurassic Tail End Graben (cf. Britze et al., 1995c) 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 (Korstgaard et al., 1993). The E-W trending Pollerne Ridge separates these basins from the Roar Basin (new name) further 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 element and probably suffered erosion during Early Cretaceous time.

The maximum thickness of the Cromer Knoll Group is 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. Similarly, 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.

Hydrocarbon aspects

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. A distinction between oil and/or gas, and between shows and pay-zones, where hydrocarbons could be produced on tests, is attempted. The presence of hydrocarbons in the Cromer Knoll Group is indicated on the Cromer Knoll interval-velocity and isochore maps (49c, d), while hydrocarbons encountered in the underlying Late Jurassic sediments are shown on the *'Base Cretaceous'* structure maps (49a, b).

Hydrocarbons are frequently found in thin limestone beds of chalk-like character in the Tuxen Formation in the upper part of the Cromer Knoll Group (Ineson, 1993). The formation is relatively tight with low matrix permeabilities (Damtoft et al., 1992). The Valdemar oil field is the only discovery with a primary reservoir in the Cromer Knoll Group that has been declared commercial (cf. the *'Base Chalk'* depth map, Britze et al., 1995b). The field is located on a large, low-releif inversion structure with an area, above the oil-water contact, exceeding 200 km^2. The Valdemar field is currently in the initial stage of development using horizontal well technology (Danish Energy Agency, in press).

Jurassic sandstones are current exploration targets in the Danish Central Graben. Although exploration of deep pre-Chalk objectives has not achieved the same high success rate as Chalk exploration, two discoveries with Late Jurassic sandstone reservoirs have been declared commercial: The Gert field crossing the Norwegian-Danish borderline, and the Elly field. The locations are given on the *'Base Cretaceous'* depth map (49b). A development plan for the latter discovery has recently been approved (Danish Energy Agency, in press). Potential Late Jurassic clastic reservoirs occur in a number of separate stratigraphic levels (Damtoft et al., 1992). Thus the *'Base Cretaceous'* surface only poorly reflects the trap configurations, but basically represents the effects of post-Jurassic tectonic events. The hydrocarbon aspects of the Late Jurassic is briefly discussed by Britze et al., 1995c.

Dansk sammendrag

De foreliggende regionale kort viser de strukturelle forhold i reflektionstid og dybde for *'Basis Kridt'*-fladen samt intervalhastighed og vertikal tykkelse af Cromer Knoll Gruppen af Tidlig Kridt alder. Kortene er udarbejdet som led i en samlet kortlægning af Den danske Centralgrav baseret på seismiske data og boringer. Yderligere tre kortudgivelser er resultatet af denne kortlægning (Britze, Japsen & Andersen, 1995a, b, c). Kortene dækker den danske del af Centralgraven og dele af Den østlige Nordsøblok. Dele af den nærliggende norske, engelske og tyske sektor er inddraget i kortlægningen for at definere strukturelle retninger, hvor data var tilgængelige.

'Basis Kridt' betegner den flade, der udgør basis af lagene yngre end Jura. Fladen repræsenterer basis af Cromer Knoll Gruppen i størstedelen af det kortlagte område. Over Øst Rosa og John saltdiapirerne er fladen lokalt identisk med basis af Tertiæret. Hvor Cromer Knoll Gruppen iøvrigt er tynd eller mangler, sådan som det er markeret på kortene i denne publikation, repræsenterer den kortlagte flade basis af Kalk Gruppen. I de marginale dele af Det norsk-danske Bassin repræsenterer fladen dog toppen af aflejringer yngre end Mellem Jura, da en tynd øvre jurassisk lagserie ikke seismisk kan udskilles. Det seismiske tidskort er en udvidet og revideret udgave af kortet *'Base Cretaceous/Near top Jurassic'*, Møller, 1986.

Dybden til *'Basis Kridt'* er beregnet ved at addere tykkelsen af Cromer Knoll Gruppen med dybden til *'Basis Kalk'* (Britze et al., 1995b). De seismisk bestemte tider er digitalt omregnet til dybder efter en metode hvor et lag tilskrives en lineær hastighedsstigning med dybden (Japsen, 1993). Afvigelser fra hastighedsmodellen beregnes i boringerne og sammenstilles på et kort for hvert lag i modellen. Disse hastighedsanomalikort er på digital form anvendt til korrektion af den lineære hastighedsmodel. En empirisk relation mellem hastighedsanomali og tidstykkelse for Cromer Knoll Gruppen er anvendt som støtte i beregningen (Japsen, 1994). Den regionale hastighedsfunktion for Kalk Gruppen er bestemt til V = 1375 m/s + 0.52 s^{-1} · Z (Z er dybden i meter under havniveau), Japsen 1994.

Intervalhastigheden for Cromer Knoll Gruppen er beregnet til at variere mellem 2300 og 3000 m/s i et område, hvor dybden til *Basis Kalk* er lille og/eller tykkelsen af Nedre Kridt er stor. Intervalhastigheder på over 5000 m/s findes i de dybe dele af det kortlagte område. Dybden til den kortlagte flade varierer mellem 618 m under havniveau i John-1 boringen og 4800 m ved basis af flere tidlig kretassiske depocentre. Minimumsdybden til toppen af Cromer Knoll Gruppen er 1900 m i det østligste hjørne af det kortlagte område. Den maksimale vertikale tykkelse af Cromer Knoll Gruppen er 1000 m, både nord for N-1 boringen i syd, og syd for Olaf-1 boringen i den nordlige del.

Den tidlig kretassiske Cromer Knoll Gruppe er lithologisk domineret af lersten med mergel og med indslag af pelagisk kalksten i den øvre del. Det tektoniske regime med grabendannelse, som dominerede i Sen Jura, blev i Tidlig Kridt gradvist afløst af regional termal indsynkning. Afsætning af Cromer Knoll Gruppen fandt i hovedtræk sted over de samme bassiner, som var aktive i Sen Jura, dog med stærkt reduceret sedimentations-rate. Nedre Kridt aflejringerne er imidlertid afgrænset til en række mere isolerede depocentre delvis som følge af reduceret sediment tilførsel, men også forårsaget af hævning af mellemliggende rygge og blokke.

I sammenligning med den overlejrende Kalk Gruppe har efterforskningsresultaterne fra den nedre kretassiske lagserie været mere beskedne. Kulbrintefund er primært knyttet til tynde reservoirer i tætte kalksten med dårlige produktionsegenskaber. Kun Valdemar feltet, lokaliseret på en inversionsstruktur med lavt relief, men stor arealmæssig udstrækning, bliver for indeværende udnyttet ved anvendelse af horisontal brøndteknologi.

I den øvre jurassiske lagserie er efterforskningsmålene knyttet til sandstens-intervaller i forskellige stratigrafiske niveauer. To fund er erklæret kommercielle: Gert og Elly, hvor der for sidstnævnte er planlagt udbygning. I Gert feltet er oliereservoiret knyttet til basale øvre jurassiske sandsten. I Elly gasfeltet er sandsten tilhørende Heno Formationen af Kimmeridge alder reservoir.

Navne på tidlig-kretassiske strukturelementer er angivet på kortet over Cromer Knoll Gruppens vertikale tykkelse (49d). Navne på olie-gas felter med hovedreservoir i henholdsvis Nedre Kridt og Øvre Jura er angivet på *'Basis Kalk'* dybdekortet (48b, Britze et al., 1995b) og på *'Basis Kridt'* dybdekortet (49b). En karakteristik af kulbrinteforekomsterne er ligeledes angivet på kortene. Kulbrinteforekomster i Cromer Knoll Gruppen er markeret på intervalhastigheds- og isochorekort (49c, d), mens forekomster i Øvre Jura lagserien er markeret på de strukturelle kort over *'Basis Kridt'* (49a, b).

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DGU Map Series no 49. Map 49a.

The Danish Central Graben

'Base Cretaceous'

Base of the post-Jurassic deposits

Norwegian-Danish Basin:
Base of the post-Middle Jurassic

Time structure map

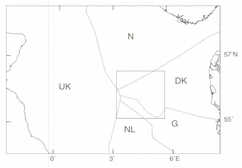
Contour interval 50 milliseconds

Mapped and compiled by
P. Britze, C. Andersen and O. V. Vejbæk

0 2 4 6 8 10 km

1:200.000, UTM zone 31
Spheroid: Hayford 1909

Printed 1995



Geological Survey of Denmark
Ministry of Environment and Energy

Legend

Structural geology

- Normal fault
- Reverse fault
- Cromer Knoll Group thin or absent on tick-mark side
- H Structural high
- L Structural low

Well information

- Mona–1 Well name
- Well symbol related to hydrocarbons in the Upper Jurassic
- 3525 Two-way time to 'Base Cretaceous', measured in the well (msec)
- Anne–3 Well name of a deviated well
- Trace of deviated well between surface and subsurface location
- 2121 Vertical two-way time to 'Base Cretaceous', measured in the well (msec)
- (Tobis–1) Well name, data not in public domain
- Surface location
- N–2 Well name - the well does not reach 'Base Cretaceous'

Well symbols related to hydrocarbons in the Upper Jurassic / Upper Jurassic not penetrated

- No shows
- Oil show
- Gas show
- Oil production (test)
- Gas/condensate production (test)
- Well drilled into older strata than the Upper Jurassic, Upper Jurassic absent
- MPESC–11 Seismic line

Two-way travel time
in milliseconds below mean sea level

DGU Map Series no 49. Map 49b.

The Danish Central Graben

'Base Cretaceous'

Base of the post-Jurassic deposits

Norwegian-Danish Basin:
Base of the post-Middle Jurassic

Depth structure map

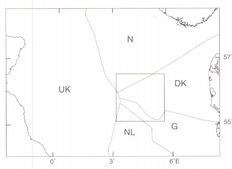
Contour interval 100 metres

Mapped and compiled by
P. Britze, P. Japsen, C. Andersen and O. V. Vejbæk

0 2 4 6 8 10 km

1:200.000, UTM zone 31
Spheroid: Hayford 1909

Printed 1995



Geological Survey of Denmark
Ministry of Environment and Energy

Legend

Structural geology

- Normal fault
- Reverse fault
- Cromer Knoll Group thin or absent on tick-mark side

Well information

- Mona–1 — Well name
- ◇ — Well symbol related to hydrocarbons in the Upper Jurassic
- 3958 — Depth to 'Base Cretaceous', measured in the well (m)
- Anne–3 — Well name of a deviated well
- ×–◇ — Trace of deviated well between surface and subsurface location
- 2402 — Vertical depth to 'Base Cretaceous', measured in the well (m)
- (Tabita–1) — Well name, data not in public domain
- × — Surface location
- N–2 — Well name - the well does not reach 'Base Cretaceous'

Well symbols related to hydrocarbons in the UpperJurassic / Upper Jurassic not penetrated

- ◇ / ◇ — No shows
- ◒ / ◒ — Oil show
- ◇ / ○ — Gas show
- ● / ● — Oil production (test)
- ◇ / ◘ — Gas/condensate production (test)
- ⊙ — Well drilled into older strata than the Upper Jurassic, Upper Jurassic absent
- *Gert* — Commercial discovery with reservoirs in the Upper Jurassic

Depth

in metres below mean sea level

- above 1600
- 1600-1800
- 1800-2000
- 2000-2200
- 2200-2400
- 2400-2600
- 2600-2800
- 2800-3000
- 3000-3200
- 3200-3400
- 3400-3600
- 3600-3800
- 3800-4000
- 4000-4200
- 4200-4400
- 4400-4600
- 4600-4800
- 4800-5000

Produced using Landmark's Z-MAP Plus application

Norway
Denmark
Germany
Netherlands
UK

DGU Map Series no 49. Map 49c.

The Danish Central Graben

Cromer Knoll Group

Early Cretaceous

Norwegian-Danish Basin:
Lower Cretaceous including thin Upper Jurassic

Interval velocity map

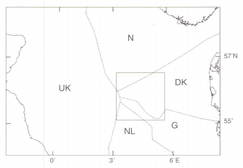
Contour interval 250 metres/second

Mapped and compiled by
P. Japsen

0 2 4 6 8 10 km

1:200.000, UTM zone 31
Spheroid: Hayford 1909

Printed 1995



DGU

Geological Survey of Denmark
Ministry of Environment and Energy

Legend

Structural geology

- Normal fault at 'Base Cretaceous' level
- Reverse fault at 'Base Cretaceous' level
- Cromer Knoll Group thin or absent on tick-mark side

Well information

- Mona-1 — Well name
- ◇ — Well symbol related to hydrocarbons in the Cromer Knoll Group
- 3075 — Interval velocity of the Cromer Knoll Group, measured in the well (m/sec)
- Anne-3 — Well name of a deviated well
- ×-◇ — Trace of deviated well between surface and subsurface location
- 2870 — Interval velocity of Cromer Knoll Group, from seismic and well data (m/sec)
- (Tabita-1) — Well name, data not in public domain
- × — Surface location
- N-2 — Well name - the well does not penetrate Cromer Knoll Group
- E-1 — Well name
- 2648 — Interval velocity of Cromer Knoll Group, from seismic and well data (m/sec)
- Adda-2 — Well name - end of log reached before 'Base Cretaceous'
- 2505 — Interval velocity of the Cromer Knoll Group, measured in the well, more than 75% of the Cromer Knoll Group thickness penetrated (m/sec)

Well symbols related to hydrocarbons in the Cromer Knoll Group / Cromer Knoll Group not penetrated

- ◇ / ◇ — No shows
- ◒ / ◒ — Oil show
- ☼ / ☼ — Gas show
- ● / ● — Oil production (test)
- ☼ / ○ — Gas / condensate production (test)
- ⊙ — Well drilled into older strata than the Cromer Knoll Group, Cromer Knoll Group absent

Interval velocity

in metres/second

- 2250-2500
- 2500-2750
- 2750-3000
- 3000-3250
- 3250-3500
- 3500-3750
- 3750-4000
- 4000-4250
- 4250-4500
- 4500-4750
- above 4750

Norway
Denmark
Germany
Netherlands

Landmark Produced using Landmark's Z-MAP Plus application

3°15′00″ 3°30′00″ 3°45′00″ 4°00′00″ 4°15′00″ 4°30′00″ 4°45′00″ 5°00′00″ 5°15′00″ 5°30′00″
56°45′30″ 56°38′00″ 56°30′30″ 56°23′00″ 56°15′30″ 56°08′00″ 56°00′30″ 55°53′00″ 55°45′30″
6.260.000 6.280.000 6.300.000 6.320.000 6.340.000 6.360.000 6.380.000
520.000 540.000 560.000 580.000 600.000 620.000 640.000 660.000

DGU Map Series no 49. Map 49d.

The Danish Central Graben

Cromer Knoll Group

Early Cretaceous

Norwegian-Danish Basin:
Lower cretaceous including thin Upper Jurassic

Isochore map

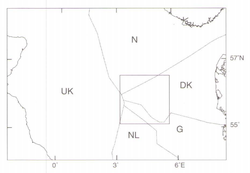
Contour interval 100 metres

Mapped and compiled by
P. Britze, P. Japsen, C. Andersen and O. V. Vejbæk

0 2 4 6 8 10 km

1:200.000, UTM zone 31
Spheroid: Hayford 1909

Printed 1995



Geological Survey of Denmark
Ministry of Environment and Energy

Legend

Structural geology

Normal fault at 'Base Cretaceous' level

Reverse fault at 'Base Cretaceous' level

Cromer Knoll Group thin or absent on tick-mark side

Feda Graben Early Cretaceous structural element

Well information

Mona–1 Well name

Well symbol related to hydrocarbons in the Cromer Knoll Group

550 Thickness of the Cromer Knoll Group, measured in the well (m)

Anne–3 Well name of a deviated well

Trace of deviated well between surface and subsurface location

78 Vertical thickness of the Cromer Knoll Group, from seismic and well data (m)

(Tabita–1) Well name, data not in public domain

Surface location

Adda–2 Well name - the well does not penetrate Cromer Knoll Group

393 Thickness of the Cromer Knoll Group, measured in the well (m)

Well symbols related to hydrocarbons in the Cromer Knoll Group / Cromer Knoll Group not penetrated

No shows

Oil show

Gas show

Oil production (test)

Gas/condensate production (test)

Well drilled into older strata than the Cromer Knoll Group, Cromer Knoll Group absent

Thickness

in metres

0-100
100-200
200-300
300-400
400-500
500-600
600-700
700-800
800-900
900-1000
1000-1100
1100-1200

Norwegian - Danish Basin

Ringkøbing-Fyn High

East North Sea Block

Central Graben

Mandal High

Gertrud Graben

Gert Ridge

Lindesnes Ridge

Al Basin

Feda Graben

Inge High

Mid North Sea High

Outer Rough Basin

Heno Plateau

Mads High

Iris Basin

Gulnare Basin

Arne - Elin Graben

Pollerne Ridge

Roar Basin

Salt Dome Province

Germany
Netherlands

This publication comprises regional two-way traveltime and depth maps of 'Base Cretaceous' together with the Cromer Knoll Group (Early Cretaceous) interval velocity and isochore maps covering an area of some 13,000 km^2 located in the western part of the Danish North Sea sector. The maps repre-sent an integrated geological and geophysical interpretation based on public domain petroleum industry seismic and well data.

De foreliggende regionale kort viser de strukturelle forhold i reflektionstid og dybde for 'Basis Kridt'-fladen samt intervalhastighed og vertikal tykkelse af Cromer Knoll Gruppen (Tidlig Kridt) i et ca. 13.000 km^2 stort område beliggende i den vestlige del af den danske sektor i Nordsøen. Kortene er resultatet af en samlet geologisk og geofysisk tolkning baseret på reflektions-seismiske data og boringsinformationer indsamlet som led i efterforskning
og indvinding af kulbrinter.

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