DANMARKS GEOLOGISKE UNDERSØGELSE • KORTSERIE • NR. 50
GEOLOGICAL SURVEY OF DENMARK • MAP SERIES NO. 50

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

The Danish Central Graben / Den danske Centralgrav

'Base Upper Jurassic' and the Upper Jurassic
(two-way traveltime and depth, interval velocity and isochore)

'Basis Øvre Jura' og Øvre Jura
(to-vejs løbetid og dybde, intervalhastighed og vertikal tykkelse)

AF / BY
PETER BRITZE, PETER JAPSEN & CLAUS ANDERSEN

With contributions by / Med bidrag af
Ioannis Abatzis, Morten Sparre Andersen, Carsten Langtofte, Carlos Møller, Jens Jørgen Møller, Kurt Damtoft Poulsen, Erik Skovbjerg Rasmussen & Ole Valdemar Vejbæk

Miljø- og Energiministeriet • København 1995
Ministry of Environment and Energy • Copenhagen 1995

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.

DANMARKS GEOLOGISKE UNDERSØGELSE • KORTSERIE • NR. 50
GEOLOGICAL SURVEY OF DENMARK • MAP SERIES NO. 50

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

The Danish Central Graben / Den danske Centralgrav

'Base Upper Jurassic' and the Upper Jurassic
(two-way traveltime and depth interval velocity and isochore)

'Basis Øvre Jura' og Øvre Jura
(to-vejs løbetid og dybde intervalhastighed og vertikal tykkelse)

AF / BY
PETER BRITZE, PETER JAPSEN & CLAUS ANDERSEN

With contributions by / Med bidrag af
Ioannis Abatzis, Morten Sparre Andersen, Carsten Langtofte, Carlos Møller, Jens Jørgen Møller, Kurt Damtoft Poulsen, Erik Skovbjerg Rasmussen & Ole Valdemar Vejbæk

Miljø- og Energiministeriet • København 1995
Ministry of Environment and Energy • Copenhagen 1995

Keywords:
Denmark, North Sea, contour maps, seismic methods, Jurassic, Middle Jurassic, Upper Jurassic, traveltime, depth, thickness, velocity, hydrocarbons.

Contents: 4 maps

Indhold: 4 kort

DGU Kortserie nr. 50
ISBN 87-89813-30-8
ISSN 0901-9405
Oplag 800
Repro af kort: Dystan, København
Tryk af kort: From & Co., København
Repro og tryk af omslag og tekst: AiO Tryk as, Odense
Dato 1995-05-19
Peter Britze, Peter Japsen & Claus Andersen
Danmarks Geologiske Undersøgelse
Thoravej 8, DK-2400 København NV
Redaktion: Ib Marcussen

I kommission hos Geografforlaget Aps, 5464 Brenderup
Telefon: +45 64 44 16 83
Telefax: +45 64 44 16 97

Description

This publication comprises regional two-way traveltime and depth maps of the *'Base Upper Jurassic'* surface together with Upper Jurassic 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 an adjustment to the proper level of the *'Near base Middle Jurassic/Top pre-Jurassic'* time map published by Møller, 1986. The map is updated through merging of the *'Top Middle Jurassic'* structure map of the Søgne Basin/northern Tail End Graben, by Korstgaard, Lerche, Mogensen & Thomsen (1993) and 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 griding interval.

Seismic interpretation

The structural traveltime map of the base of the post-Middle Jurassic deposits *('Base Upper Jurassic')* represents the base of the Upper Jurassic 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 Upper Jurassic is absent or below seismic resolution, as indicated on the maps, the mapped surface represents the base of the Cretaceous. On the northeastern part of the East North Sea Block the map represents the base of a thin sequence assigned a Late Jurassic age in the L-1 well. The thickness of this sequence is included in the Cromer Knoll isochore map (Britze et al., 1995c).

In the eastern part of the Central Graben the Upper Jurassic graben fill conformably overlies the Middle Jurassic. Here the 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 (cf. Britze et al., 1995a, b, c). This is due to the great depth of burial (up to 6 seconds two-way time), the structural complexity, and locally interference of multiples caused by thick, overlying chalk deposits.

Depth conversion

The depth to *'Base Upper Jurassic'* is calculated by adding the thickness of the Upper Jurassic to the *'Base Cretaceous'* depth (Britze et al., 1995c). The depth to *'Base Upper Jurassic'* is thus based on a five-layer depth conversion (cf. Britze et al., 1995a, b, c). 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 database for this interval. The thickness of the Upper Jurassic 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 drilled through more than 400 m Upper Jurassic without penetrating the entire sequence. The latter wells are included to define the velocity field of the thick Upper Jurassic sequence in the eastern part of the Danish Central Graben (the Tail End Graben, see below). Of the estimated maximum thickness of 3600 m only 1421 m has been drilled (the G-1 well). The low velocities (< 2600 m/s) 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). As the gas generation is related to the composition and depth of burial of the sediments the velocity contours are drawn to follow those of the Upper Jurassic isochore in the Tail End Graben. Only the major faults near the Kim-1, Gert and Karl-1 wells are included in the contouring of the interval-velocity map. Additional faults are plotted on the map in order to aid comparison with the isochore map of the Upper Jurassic.

The interval velocity of the Upper Jurassic is very low relative to depth in the Tail End Graben: 2556 m/s 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/s is 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 (Damtoft et al., 1992). Maximum interval velocity is recorded in the Ugle-1 well (4046 m/s).

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 7500 m in the deepest parts of the Tail End Graben. Minimum depth to the top of the Upper Jurassic in the graben area is 2000 m near the Emma-1 well.

Brief review of geological evolution

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 halfgrabens 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 (Johannesen & Andsbjerg, 1993). The syn-rift sedimentary fill is dominated by shale, which is very rich in organic matter at certain levels (Damtoft et al., 1992). Deposition of sandstone is genetically partly connected to the different rifting phases affecting the area, and partly to changes in relative sea-level (Rasmussen & Møller, in press). 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. Korstgaard et al., 1993). During the Kimmeridgian a change from the pre-Jurassic inherited N-S fault direction to a dominant NW-SE direction took place; 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 oppositely dipping fault blocks, have been recorded locally (Sundsbø & Megson, 1993 and Rasmussen, 1995).

The major Late Jurassic structural features are named on the Upper Jurassic isochore map. The terminology used generally follows that of Møller (1986). The dominant Upper Jurassic structural element is the Tail End Graben. It is a halfgraben where up to 3600 m of Upper Jurassic sediments have accumulated along the NW-SE trending segments of the Coffee Soil Fault; 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 (Gowers, Holtar & Swensson, 1993), 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, dominated by halokinetic movements of underlying rock salt. 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 extends further into Norwegian waters (Gowers et al., 1993), is the most prominent feature in the northwestern part of the mapped area. It is separated by the narrow Gert Ridge from the oppositely dipping Gertrud Graben. Towards the south, these depocentres grade into the Heno Plateau, characterized by intermediate thicknesses of Upper Jurassic sediments. This plateau is towards the east bounded by the Arne-Elin Graben, a structurally complicated hinge-zone to the Tail End Graben. Only a thin veneer of Upper Jurassic sediments are present on the flank of the Mid North Sea High in the area west of the Inge and Mads Highs. Upper Jurassic sediments are missing on the East North Sea Block, where Jurassic footwall uplift in excess of 2000 m have been predicted by modelling (Roberts & Yielding, 1991).

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 by produced on tests, is attempted. The presence of hydrocarbons in Upper Jurassic sediments is indicated on the Upper Jurassic interval-velocity and isochore maps (50c, d), while hydrocarbons encountered in pre-Upper Jurassic strata are shown on the *'Base Upper Jurassic'* structure maps.

Jurassic sandstones are current exploration targets in the Danish Central Graben. The potential reservoirs representing a variety of depositional environments occur in a number of different stratigraphic intervals. The Jurassic plays were discussed in detail by Damtoft et al., 1992. Two discoveries in Upper 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 (Britze et al., 1995c). A development plan for the latter discovery has recently been approved (Danish Energy Agency, in press). The deep-seated oil-bearing reservoir in the Gert field is basal Late Jurassic sandstones. It is situated on the structurally complicated Gert Ridge (Søderstrøm, Forsberg, Holtar & Rasmussen, 1991, Sundsbø & Megson, 1993, and Rasmussen, 1995) illustrated on the structure maps (50a, b). The main reservoir in the Elly-1 discovery well is Kimmeridgian regressive sandstones of the Heno Formation (Jensen, Holm, Frandsen & Michelsen, 1986). This formation is also the reservoir in the sub-commercial Ravn discovery, located some 10 km further to the north. Several wells have encountered oil shows in scattered, fine-grained sandstones, probably of low density turbiditic origin, interbedded in organic-rich marine shales of the Farsund Formation (Jensen et al., 1986). However, this distal turbidite play has not yet led to commercial discoveries. A unique example of oil recovery from a rich Late Jurassic source rock section without intercalated sandstones is given by the Jens-1 well. Sustained and surprisingly high flow rates were obtained from a probably fractured dolomitic claystone section.

The main exploration target in pre-Upper Jurassic comprises fluvio-deltaic to shallow marine Middle Jurassic sandstones belonging to the lowermost part of the syn-rift sediments. The most significant discovery is on the partly fault-controlled West Lulu structure, presently under development under the name of Harald West. The locations of discoveries with main reservoir in the Middle Jurassic is indicated on the *'Base Upper Jurassic'* depth map (50b). In the West Lulu-1 well gas and condensate were tested from a total pay-zone of 60 m in mainly shallow marine sandstones of the Bryne Formation (Jensen et al., 1986). The Lulita oil discovery, likewise in the Bryne Formation, located on the flank of the Lulu saltwall has recently been declared commercial. The reservoir development of the Middle Jurassic in the southern part of the Graben has until now proved less favourable. However, plans have been approved to produce the small accumulation of the Middle Jurassic Alma field (Danish Energy Agency, in press).

Only limited information is available on the hydrocarbon potential of the pre-Jurassic. Hydrocarbons have, however, been produced on tests from dolomitic intervals in the Zechstein Group, directly underlying chalk reservoirs on a number of salt piercement structures.

Dansk sammendrag

De foreliggende regionale kort viser de strukturelle forhold i reflektionstid og dybde for *'Basis Øvre Jura'*-fladen samt intervalhastighed og vertikal tykkelse af Øvre Jura. Kortene er udarbejdet som led i en samlet kortlægning af Den danske Centralgrav baseret på seismiske data og borin-ger. 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 Øvre Jura' betegner den flade, der udgør basis af lagene yngre end Mellem Jura. Fladen repræsenterer basis af Øvre Jura i størstedelen af det kortlagte område. På Øst Rosa og John saltdiapirerne er fladen lokalt identisk med basis af Tertiæret. Hvor Øvre Jura iøvrigt er tynd eller mangler, sådan som det er markeret på kortene i denne publikation, repræsenterer den kortlagte flade basis af aflejringerne af Kridt alder. Over den nordøstlige del af Den østlige Nordsøblok viser kortet basis af et tyndt interval, der i L-1 boringen er bestemt til Øvre Jura alder. Tykkelsen af denne sekvens er inkluderet på kortet over den vertikale tykkelse af Cromer Knoll Gruppen (Britze et al., 1995c). Det seismiske tidskort er en udvidet og revideret udgave af kortet *'Near base Middle Jurassic/Top pre-Jurassic'*, Møller, 1986.

Dybden til *'Basis Øvre Jura'* er beregnet ved at addere tykkelsen af Øvre Jura med dybden til *'Basis Kridt'* (Britze et al., 1995c). De seismisk bestemte tider er digitalt omregnet til dybder ved at gange tids-tykkelsen af Øvre Jura med lagets intervalhastighed. Ingen simpel relation mellem hastighed og dybde eller reflektionstid er blevet bestemt, der kunne gøre det muligt at prognosticere intervalhastigheden af Øvre Jura (Japsen, 1994).

Intervalhastighederne er lave for de tykke øvre jurassiske aflejringer i den østlige del Den danske Centralgrav, under 2600 m/s i flere boringer. De målte hastigheder er relativt høje, op til 4000 m/s, i den vestlige del af det kortlagte område og langs dele af forkastningen ind mod Den østlige Nordsøblok. Dybden til den kortlagte flade varierer mellem 618 m under havniveau i John-1 boringen og 7500 m i den dybeste del af Tail End Graven. Minimumsdybden til toppen af Øvre Jura i selve Centralgraven er 2000 m nær Emma-1 boringen.

I Sen Jura tid dominerede grabendannelse forårsaget af høje rater af skorpestrækning det kortlagte område. Et system af halvgrave og mellemliggende intra-graben horste og rygge med generel NNV-SSØ retning blev dannet. Det mest markante strukturelle element er Tail End Graven, hvor en øvre-jurassisk lagserie med en vertikal tykkelse på op til 3600 m er afsat langs hovedforkastningen til Den østlige Nordsøblok. Syn-rift afsætningen, som startede allerede i Mellem Jura, er domineret af lerede sedimenter, lokalt med et højt organisk indhold. Som følge af termisk modning på grund af efterfølgende indsynkning fungerer sidstnævnte som primær kildebjergart for områdets kulbrinteforekomster. Afsætning af sandsten kendes fra flere stratigrafiske niveauer. Udbredelsen synes kontrolleret delvis af de forskellige rifting faser, som har påvirket området, delvis af relative havspejlsændringer.

Jurassiske sandsten er stadig mål for efterforskningsaktivitet i den danske del af Centralgraven. En række fund er gjort både i Øvre og Mellem Jura, hvor der for flere er planlagt udbygning. To fund med reservoir i Øvre Jura, Gert og Elly, er erklæret kommercielle. I Gert feltet er oliereservoiret knyttet til basale øvre jurassiske sandsten på den strukturelt komplicerede Gert Ryg ved den norsk-danske grænse. I Elly gasfeltet er sandsten, tilhørende Heno Formationen af Kimmeridge alder, reservoir. Fluvio-deltaiske og grundmarine sandsten af Mellem Jura alder er reservoir i Harald Vest og Lulita mod nord og Alma mod syd.

Navne på sen jurassiske strukturelementer er angivet på kortet over Øvre Juras vertikale tykkelse (50d). Navne på olie-gas felter med hovedreservoir i henholdsvis Øvre Jura og i lagserien under *'Basis Øvre Jura'* er angivet på *'Basis Kridt'* dybdekortet (49b, Britze et al., 1995c) og på *'Basis Øvre Jura'* dybdekortet (50b). En karakteristik af kulbrinteforekomsterne er ligeledes angivet på kortene. Kulbrinter i Øvre Jura er markeret ved boringssymbolerne anvendt på intervalhastigheds- og isochorekort (50c, d), mens forekomster i lagserien under *'Basis Øvre Jura'* er angivet på de strukturelle kort over *'Basis Øvre Jura'* (50a, b).

References

Britze, P., Japsen, P. & Andersen, C., 1995a: Geological map of Denmark. 1:200,000. The Danish Central Graben. 'Top Chalk' and the Post Chalk Group (two-way traveltime, depth and interval velocity). Danm. geol. Unders., Map Series, 47, 7 pp. and 3 maps.

Britze, P., Japsen, P. & Andersen, C., 1995b: Geological map of Denmark. 1:200,000. The Danish Central Graben. 'Base Chalk' and the Chalk Group (two-way traveltime and depth, thickness and interval velocity). Danm. geol. Unders., Map Series, 48, 7 pp. and 4 maps.

Britze, P., Japsen, P. & Andersen, C., 1995c: Geological map of Denmark. 1:200,000. The Danish Central Graben. 'Base Cretaceous' and the Cromer Knoll Group (two-way traveltime and depth, thickness and interval velocity). Danm. geol. Unders., Map Series, 49, 7 pp. and 4 maps.

Buhrig, C., 1989: Geopressured Jurassic reservoirs in the Viking Graben: modelling and geological significance. Mar. Petrol. Geol., 6, 31–48.

Damtoft, K., Nielsen, L. H., Johannesen, P. N., Thomsen, E. & Andersen, P. R. 1992: Hydrocarbon Plays of the Danish Central Trough. In: Spencer, A. M. (ed.), Generation, accumulation and production of Europe's hydrocarbons II. Special Publication of the European Association Petroleum Geoscientists, 2, 35–58.

Danish Energy Agency, in press: Oil and gas production in Denmark 1994. Danish Energy Agency, København.

Gowers, M. B., Holtar, E. & Swensson, E., 1993: The structure of the Norwegian Central Trough (Central Graben area). In: Parker, J. R. (ed.), Petroleum Geology of Northwest Europe: Proceedings of the 4th Conference. The Geological Society, London, 1245–1254.

Isaksen, D. & Tonstad, K. (eds.), 1989: A revised Cretaceous and Tertiary lithostratigraphic nomenclature for the Norwegian North Sea. N.P.D.-Bulletin, 5, 59 pp.

Japsen, P., 1994: Retarded compaction due to overpressure deduced from a seismic velo-city/depth conversion study in the Danish Central Trough, North Sea. Mar. Petrol. Geol., 11, 715–733.

Jensen, T. F., Holm, L., Frandsen, N. & Michelsen, O., 1986: Jurassic-Lower Cretaceous lithostratigraphic nomenclature for the Danish Central Trough. Danm. geol. Unders. Ser. A, 12, 65 pp.

Johannesen, P., N. & Andsbjerg, J., 1993: Middle to Late Jurassic basin evolution and sandstone reservoir distribution in the Danish Central Trough. In: Parker, J. R. (ed.): Petroleum Geology of Northwest Europe. Proceedings of the 4th Conference. The Geological Society, London, 271–284.

Korstgård, J. A., Lerche, I., Mogensen, T. E. & Thomsen, R. O., 1993: Salt and fault interactions in the northeastern Danish Central Graben: observations and inferences. Bull. Geol. Soc. Danm., 40, 197–255.

Lieberkind, K., Bang, I., Mikkelsen, N. & Nygaard, E., 1982: Late Cretaceous and Danian limestone. In: Michelsen, O. (ed.): Geology of the Danish Central Graben. Danm. geol. Unders., Ser. B, 8, 49–62.

Møller, J. J., 1986: Seismic structural mapping of the Middle and Upper Jurassic in the Danish Central Trough. Danm. geol. Unders., Ser. A, 13, 37 pp.

Nielsen, L. H. & Japsen, P., 1991: Deep wells in Denmark 1935–1990. Lithostratigraphic subdivision. Danm. geol. Unders., DGU Ser. A, 31, 179 pp.

Rasmussen, E. S., 1995: Structural evolution of the Gert-Mjølner area. Mar. Petrol. Geol., 12, 377–385.

Rasmussen, E. S. & Møller J. J., in press: Structural Evolution of the Danish Central Trough During the Jurassic and Consequences for the Sedimentary Fill, European Association of Petroleum Geoscientists, 7th Conference, Glasgow, 1995.

Rasmussen, L. B., 1978: Some geological results from the first five Danish exploration wells in the North Sea. Danm. geol. Unders., III rk., 42, 46 pp.

Roberts, A. M. & Yielding, G., 1991: Deformation around basin-margin faults in the North Sea/mid Norway rift. In: Roberts, A. M., Yielding, G. Freeman, B. (eds.): The Geometry of Normal Faults. Geol. Soc. Special Publication, 56, 61–78.

Rønnevik, H. C., van den Bosch, W. & Bandlien, E. H., 1975: A proposed nomenclature for the main structural features in the Norwegian North Sea. In: Finstad, K. G. & Selley, R. C. (eds.), Jurassic Northern North Sea Symposium, Norwegian Petroleum Society, Stavanger, JNSS/18. 1–16.

Sundsbø, G. O. & Megson, J. B., 1993: Structural styles in the Danish Central Graben. In: Parker, J. R. (ed.), Petroleum Geology of Northwest Europe, Proceedings of the 4th Conference. Geological Society, London, 1255–1267.

Søderstrøm, B., Forsberg, A., Holtar, E. & Rasmussen, B. A., 1991: The Mjølner Field, a deep Upper Jurassic oil field in the Central North Sea. First Break, 29, 156–171.

Vejbæk, O.V., 1992: Geodynamic modelling of the Danish Central Trough. In: Larsen, R.M., Brekke, H., Larsen, B.T. & Talleraas, E. (eds.): Structural and tectonic modelling and its application to petroleum geology. NPF Special Publication, 1, 1–17.

Ziegler, P. A., 1990: Geological atlas of western and central Europe. Shell Internationale Petroleum Maatschappij B.V., 239 pp.

DGU Map Series no 50. Map 50a.

The Danish Central Graben

'Base Upper Jurassic'

Base of the post-Middle Jurassic deposits

Time structure map

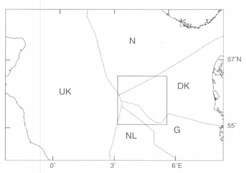
Contour interval 100 milliseconds

Mapped and compiled by
P. Britze, C. Andersen, J. J. Møller 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

Upper Jurassic thin or absent on tick-mark side

H Structural high

L Structural low

Well information

Karl–1 Well name

Well symbol related to hydrocarbons in the pre-Late Jurassic

3828 Two-way time to 'Base Upper Jurassic', measured in the well (msec)

Anne–3 Well name of a deviated well

Trace of deviated well between surface and subsurface location

2547 Vertical two-way time to 'Base Upper Jurassic', measured in the well (msec)

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

Surface location

N–2 Well name - the well does not reach 'Base Upper Jurassic'

Well symbols related to hydrocarbons in the pre-Late Jurassic

No shows

Oil show

Gas show

Oil production (test)

Gas/condensate production (test)

Seismic line

Two-way travel time
in milliseconds below mean sea level

Germany
Netherlands

DGU Map Series no 50. Map 50b.

The Danish Central Graben

'Base Upper Jurassic'

Base of the post-Middle Jurassic deposits

Depth structure map

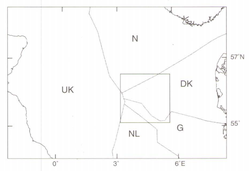
Contour interval 200 metres

Mapped and compiled by
P. Britze, P. Japsen, C. Andersen, J. J. Møller 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
- Upper Juassic thin or absent on tick-mark side

Well information

- Karl–1 — Well name
- ◇ 4456 — Well symbol related to hydrocarbons in the pre-Late Jurassic; Depth to 'Base Upper Juassic', measured in the well (m)
- Anne–3 / ×–◇ 3013 — Well name of a deviated well; Trace of deviated well between surface and subsurface location; Vertical depth to 'Base Upper Jurassic', 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 Upper Jurassic'

Well symbols related to hydrocarbons in the pre-Late Jurassic

- ◇ / ◇ — No shows
- ◒ / ◒ — Oil show
- ☼ / ◇ — Gas show
- ● / ● — Oil production (test)
- ☼ / ☼ — Gas/condensate production (test)

Harald — Commercial discovery with main reservoir in the Middle Jurassic

Depth

in metres below mean sea level

400-800
800-1200
1200-1600
1600-2000
2000-2400
2400-2800
2800-3200
3200-3600
3600-4000
4000-4400
4400-4800
4800-5200
5200-5600
5600-6000
6000-6400
6400-6800
6800-7200
7200-7600

DGU Map Series no 50. Map 50c.

The Danish Central Graben

Upper Jurassic

Norwegian-Danish Basin:
Thin Upper Jurassic sequence not mapped

Interval velocity map

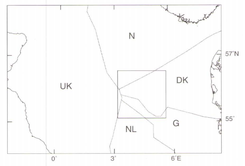
Contour interval 100 metres/second

Mapped and compiled by
P. Japsen

0 2 4 6 8 10 km

1:200.000, UTM zone 31
Spheroid: Hayford 1909

Printed 1995



Geological Survey of Denmark
Ministry of Environment and Energy

Legend

Structural geology

Normal fault at 'Base Upper Jurassic' level

Reverse fault at 'Base Upper Jurassic' level

Upper Jurassic thin or absent on tick-mark side

Well information

Karl–1 — Well name

◇ — Well symbol related to hydrocarbons in the Upper Jurassic

3245 — Interval Velocity of the Upper Jurassic, measured in the well (m/sec)

D. Gorm–1 — Well name of a deviated well

×–◇ — Trace of deviated well between surface and subsurface location

2752 — Interval velocity of the Upper Jurassic, from seismic and well data (m/sec)

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

× — Surface location

N–2 — Well name - the well does not penetrate Upper Jurassic

W–1 — Well name

2760 — Interval velocity of the Upper Jurassic, from seismic and well data (m/sec)

N. Jens–1 — Well name - end of log reached before 'Base Upper Jurassic'

2374 — Interval velocity of the Upper Jurassic, measured in the well, more than 400 m Upper Jurassic penetrated (m/sec)

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 Late Jurassic,

Interval velocity

in metres/second

- below 2500
- 2500-2600
- 2600-2700
- 2700-2800
- 2800-2900
- 2900-3000
- 3000-3100
- 3100-3200
- 3200-3300
- above 3300

DGU Map Series no 50. Map 50d.

The Danish Central Graben

Upper Jurassic

Norwegian-Danish Basin:
Thin Upper Jurassic sequence not mapped

Isochore map

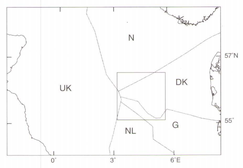
Contour interval 200 metres

Mapped and compiled by
P. Britze, P. Japsen, C. Andersen, J. J. Møller 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 Upper Jurassic' level

Reverse fault at 'Base Upper Jurassic' level

Upper Jurassic thin or absent on tick-mark side

Tail End Graben — Late Jurassic structural element

Well information

Karl–1 — Well name

Well symbol related to hydrocarbons in the Upper Jurassic

226 — Thickness of the Upper Jurassic, measured in the well (m)

Anne–3 — Well name of a deviated well

Trace of deviated well between surface and subsurface location

564 — Vertical thickness of the Upper Jurassic, from seismic and well data (m)

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

Surface location

G–1 — Well name - the well does not penetrate Upper Jurassic

1421 — Thickness of the Upper Jurassic, measured in the well (m)

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 Late Jurassic, Late Jurassic absent

Thickness

in metres

- 0 - 400
- 400-800
- 800-1200
- 1200-1600
- 1600-2000
- 2000-2400
- 2400-2800
- 2800-3200
- 3200-3600
- 3600-4000

Central Graben
Mid North Sea High
Ringkøbing-Fyn High
East North Sea Block
Mandal High
Piggvar Terrace
Gertrud Graben
Gert Ridge
Feda Graben
Inge High
Heno Plateau
Mads High
Søgne Basin
Tail End Graben
Arne Graben
Pouk Plateau
Rosa Basin
Salt Dome
John Plank Province
Norway
Denmark
Germany
Netherlands

This publication comprises regional two-way traveltime and depth maps of 'Base Upper Jurassic' together with Upper Jurassic 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 represent 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 Øvre Jura'-fladen samt intervalhastighed og vertikal tykkelse af Øvre Jura 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.

ISBN 87-89813-30-8
ISSN 0901-9405