

JURASSIC STRATIGRAPHY AND TECTONICS OF THE SOUTH-SOUTHEASTERN NORWEGIAN OFFSHORE¹

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ABSTRACT

Hamar, G. P., T. Fjæran & A. Hesjedal 1983 Jurassic stratigraphy and tectonics of the south-southeastern Norwegian offshore. In: J. P. H. Kaasschieter & T. J. A. Reijers (eds.): Petroleum geology of the southeastern North Sea and the adjacent onshore areas (The Hague, 1982) – Geol. Mijnbouw 62: 103-114.

Three major Early - Middle Jurassic unconformities in the Fiskebank Sub-Basin are represented by a hiatus in the Central Graben. The axial North Sea dome collapsed in Late Callovian, initiating the Central Graben, and causing coarse clastic sedimentation near topographic highs. The facies developments within the Norwegian-Danish Basin are controlled by the Lista Ridge. Anaerobic conditions are typical of the Late Jurassic, but highly radioactive shales are found only in the Central Graben and the Fiskebank Sub-Basin. A Mid-Volgian transgression established a seaway connection between these basins. Fifteen lithostratigraphic units are mapped. Evidence of strike-slip faulting in the Farsund Sub-Basin, and of halokinetic effects on the Jurassic sedimentation are presented.

INTRODUCTION

The geology of the Jurassic sediments in the North Sea has been discussed by many authors since the first hydrocarbon accumulation was encountered. Both, potential reservoir rocks and many promising hydrocarbon source rocks have been extensively analysed and organized into several lithostratigraphic units. The first Jurassic nomenclature for the south-eastern part of the North Sea was introduced by LARSEN (1966). This was later revised and redescribed by MICHELSEN (1975, 1977, 1978). An international committee published the subdivision of the Jurassic lithostratigraphy covering the North Sea north of the Central Highs (DEEGAN & SCULL, 1977). During the last five years large amounts of geologic data have been made available through the open government files in Norway, the United Kingdom and Denmark. Oil companies have also presented numerous data on the discovered oil and gas fields during the past years. All this information together with some of the most recent data from the southern Norwegian Shelf, comprises the background for our Jurassic litho-

stratigraphic subdivision of the studied area. The geologic evolution of Northwestern Europe has been presented by ZIEGLER (1982). An early Jurassic palaeogeographical summary was prepared by SKARPNES ET AL. (1980), which together with Ziegler's papers indicated that the available geological data contained information on environmental conditions which had not been discussed earlier.

The southern Norwegian offshore area can be subdivided into two major depressions and an intervening range of highs. In the west, the Central Graben is flanked by the Forth Approaches Basin and the Mid North Sea High, and on the east by the East North Sea Horst, the Mandal- and Jæren Highs and the intermediate Hidra fault zone (Fig. 1). The structural elements are described in the papers published by RØNNEVIK ET AL. (1975) and HAMAR ET AL. (1980). In the east the Norwegian-Danish Basin is subdivided into the Fiskebank Sub-Basin and the Danish Sub-Basins by the uplifted Lista Ridge.

The prominent Fjerritslev fault crosses the centre of the Danish Sub-Basin. This fault also forms the southern edge of the Farsund Sub-Basin, just off the southern tip of Norway.

A series of isopach maps and cross sections demonstrate that these tectonic elements mentioned above have been active since the Late Palaeozoic. Repeated crustal move-

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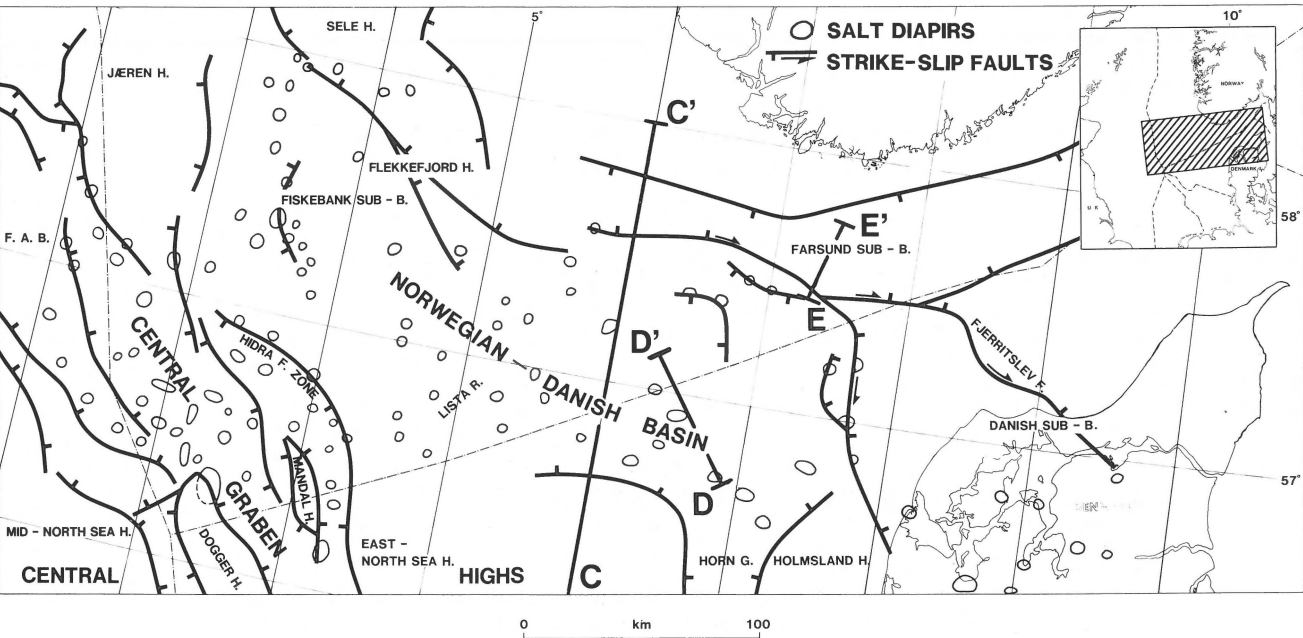


Fig. 1
Tectonic map of Central North Sea. Sections C-C', D-D' and E-E' are shown on figures 8c, 8d and 9. B-Basin, H-High/Horst, F-Fault, F.A.B.-Forth Approaches Basin.

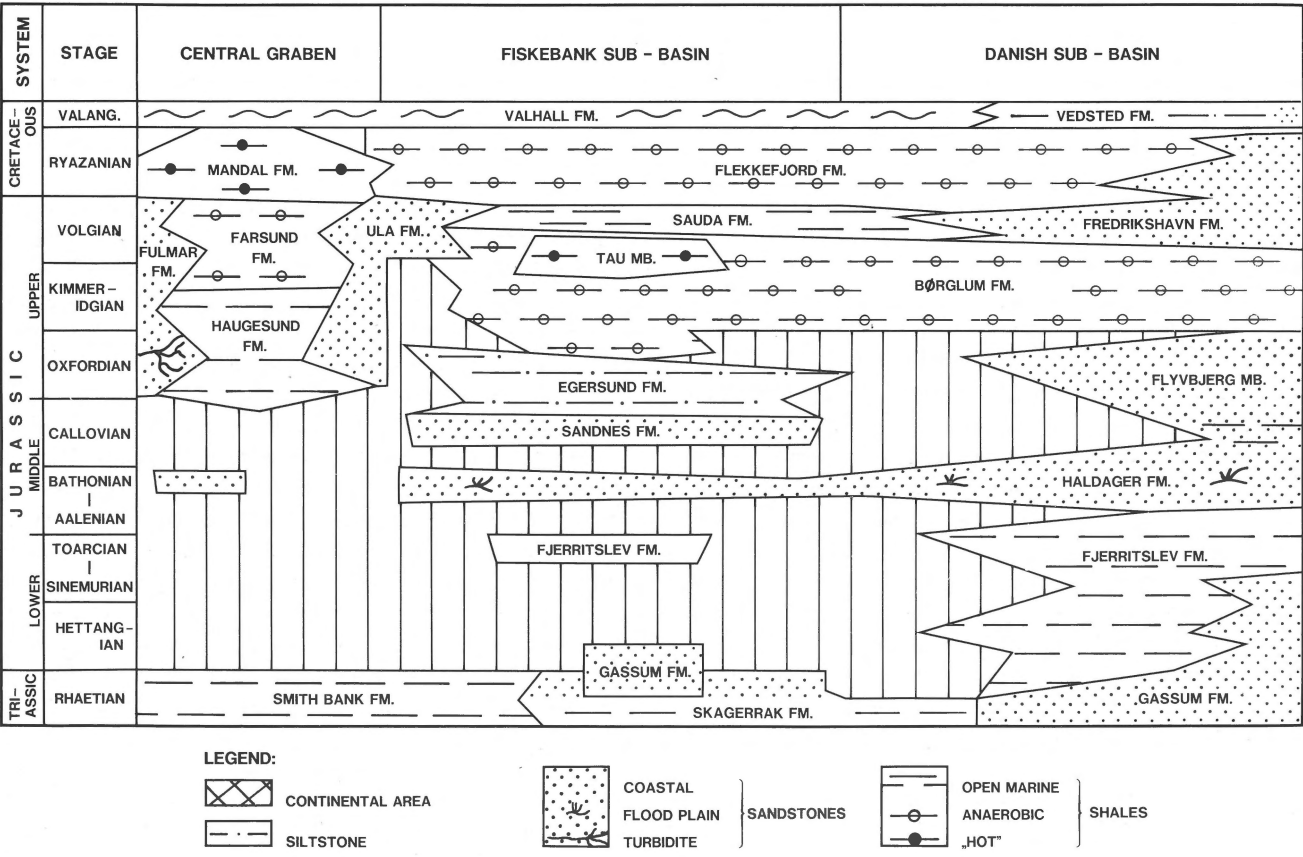


Fig. 2
Lithostratigraphic summary chart and legend. The same symbols are used on the palaeogeographic maps and stratigraphic cross sections, figures 3b, 4b, 5a, 6a, 6b, 7a. FM-Formation, MB-Member.

ments played a very important role during the whole Jurassic sedimentary cycle.

In this paper fifteen lithostratigraphic units have been identified, some of which have not been described earlier (Fig. 2). This paper presents the major lithological composition, thicknesses and the regional extent of these units. A systematic description and proposed changes of the lithostratigraphic nomenclature will be presented in future through the Norwegian lithostratigraphic committee.

Clastic sediments have progressively been filling the subsiding Central North Sea area. Shallow marine sandstones indicate the position of the ancient coastlines, while finer grained siltstones and shales dominate the central basinal areas. The Upper Jurassic marine shales show remarkable richness in organic carbon content, certainly associated with anaerobic depositional conditions. The Jurassic sequence is underlain by the Smith Bank and Skagerrak Formations, dated as Triassic, while the Gassum Formation is recognized to range from Rhaetian to middle Hettangian. The Gassum Formation marks the early Jurassic break-up of this area. A sporadic occurrence of the Gassum Formation is recognised in the Fiskebank Sub-Basin but an up-to-date description of this lithostratigraphic unit is still required.

The upper boundary for this Jurassic study was set between the Lower Cretaceous Valhall Formation and the Ryazanian shales, the Mandal Formation. The Mandal Formation underlies the Valhall Formation with an unconformity in marginal areas but seems to be conformable more centrally. A break in sedimentation has not been observed between the Flekkefjord - Valhall Formations in the western part of the Norwegian-Danish Basin.

LITHOSTRATIGRAPHY

A global sea level rise at the beginning of the Jurassic initiated the deposition of large amounts of fine-grained clastic sediments in the Norwegian-Danish Basin. This is most prominent in the southeastern part which subsided rapidly along the Fjerritslev Fault Zone (Fig. 3a). The faults which controlled the basin were less active in the west. Isolated erosional remains of the Fjerritslev Formation are found both in the Fiskebank Sub-Basin and in the Central Graben. These shale bodies are not definitely correlative to any of the four members of the Fjerritslev Formation formally defined in the Danish Sub-Basin (MICHELSEN, 1978). Palaeontological datings give a Pliensbachian to Toarcian age for these sediments which are time-equivalents of Member III of the Fjerritslev Formation's type section. The absence of Member I and II supports a Late Sinemurian subsidence of the Fiskebank Sub-Basin. This transgression was interrupted by major faulting and the whole area was elevated above the sea level in early Aalenian. Along the fault zones differential subsidence favoured the preservation of the Lower Jurassic shales.

An irregular topographic relief was created where the

Central Graben and the Norwegian-Danish Basin formed an unified plain during Middle Jurassic. The Central Highs and the Fennoscandian Shield constituted clastic source areas and numerous rivers brought these sediments into a marshland type environment during the Aalenian-Bathonian (Fig. 3b). The Haldager Formation consists primarily of sandstone, interbedded with siltstone, coaly shale and coal seams. The present distribution indicates deposition over most of the studied area (Fig. 3c). The thickness of the Formation is in excess of 100 m with a maximum of 200 m. It is visible in seismic interpretations and in well data (MICHELSEN ET AL., 1981), that the entire Middle Jurassic section is eroded in some areas just southwest of the Fjerritslev Fault (Fig. 3c).

Renewed fault activity at the Bathonian-Callovian boundary subdivided the depositional area. A ridge formed between the Central Graben and the Fiskebank-Sub-Basin. The Fiskebank Sub-Basin was flooded by the sea, probably from the north, and the Sandnes Formation was deposited. This consists of shallow marine sandstone which accumulated over the northern part of the Sub-Basin. Maximum thicknesses reach over 100 m (Fig. 4a), and the fossil assemblages indicate an open marine environment and a Callovian age (Fig. 4b). In the Central Graben mudstones were deposited at the same time, which are here assigned to the Haugesund Formation. Time equivalent sediments have not been identified in the Danish Sub-Basin. The hiatus here is either due to non-deposition or more probably to uplift and subsequent erosion. The Haldager Formation is in this area covered by the Flyvbjerg Member, which is shaly, silty and occasionally carbonaceous in the basal part. This indicates a depositional environment passing from non-marine in the lower part into a marine, shallow-water one upwards. The Flyvbjerg Member is dated by its ostracod faunas as Oxfordian (CHRISTENSEN, 1974), and reaches a moderate thickness within the Danish Sub-Basin (Fig. 4a).

The Main Kimmerian orogenic phase caused a new break-up of the area at the end of Callovian. The Central Graben started to subside rapidly, and sandstones of a turbiditic type, the Fulmar Formation, were deposited along the western side. On the eastern flank sandstones of shallow marine and offshore bar type, the Ula Formation, were developed (Figs. 4c and 5a). Both formations are restricted to a narrow belt close to the ancient shoreline of the Late Jurassic sea. Locally the thickness of the individual formations exceeds 200 m (Fig. 4c), and both are deposited over a period from Oxfordian to Volgian. Axially in this basin fine clastic material was deposited in an open marine, low energy environment. These shales and siltstones with thin sand interbeds of sporadic turbiditic origin are named the Haugesund Formation. A maximum thickness of about 400 m is found close to the northern tip of the Dogger High (Fig. 5b).

In the Fiskebank Sub-Basin siltstones and shales of the Egersund Formation are found to be of Late Callovian-Oxfordian age. The Formation thickness gradually decreases westward from 100 m to nil (Fig. 5b), where it is replaced by

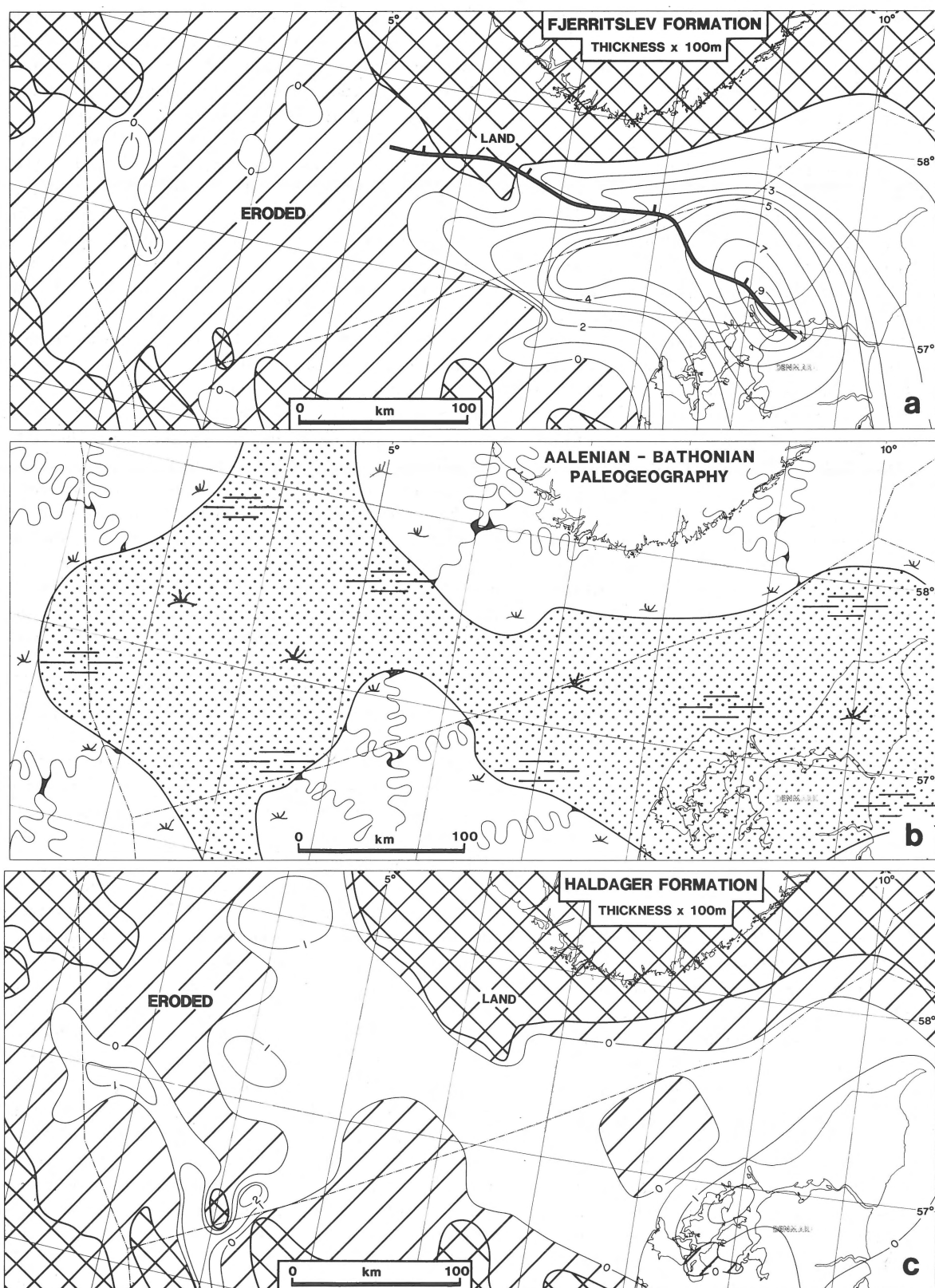


Fig. 3
Isopach and palaeogeographic maps, legend see figure 2.

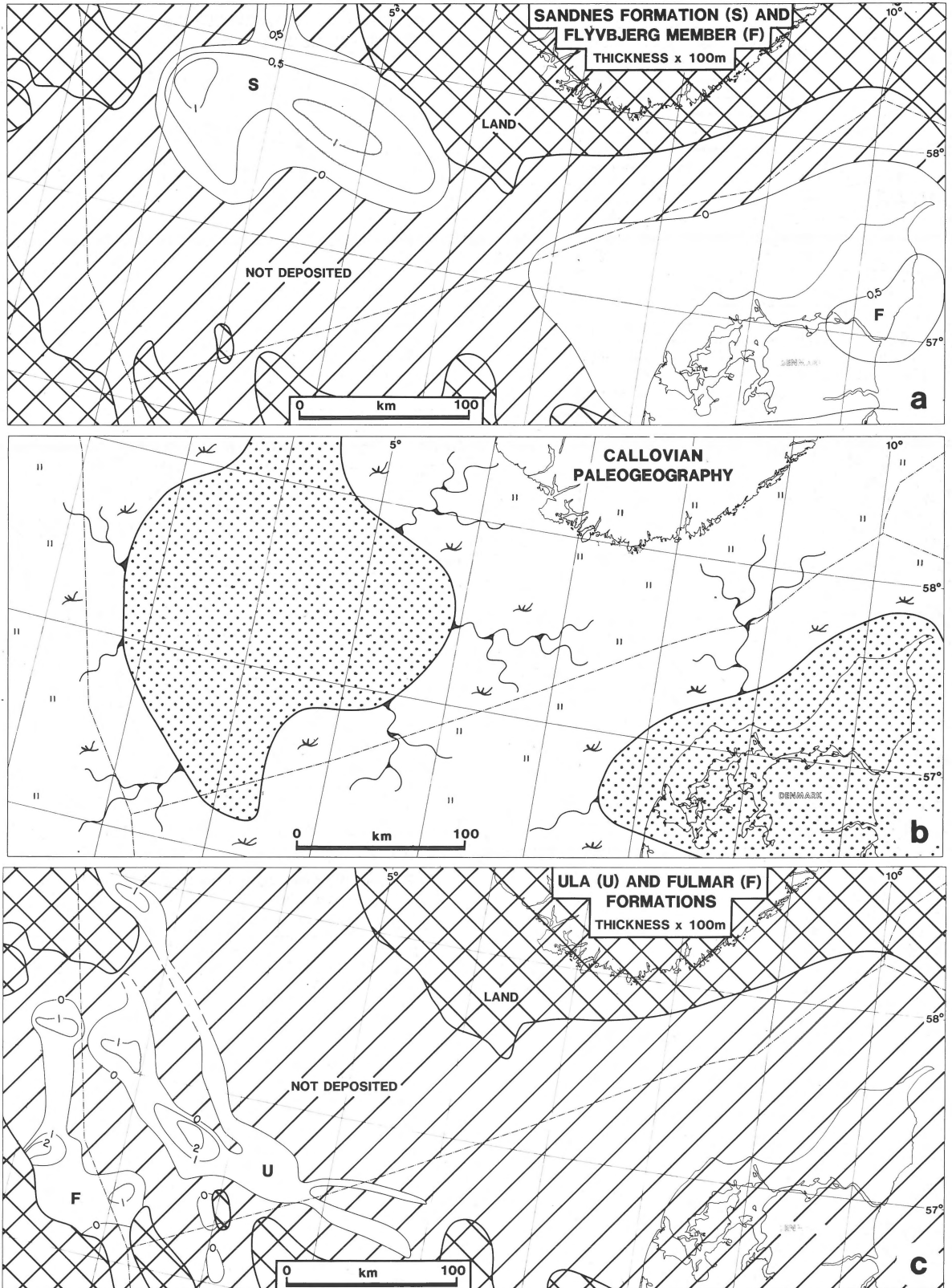


Fig. 4
Isopach and palaeogeographic maps, legend see figure 2.

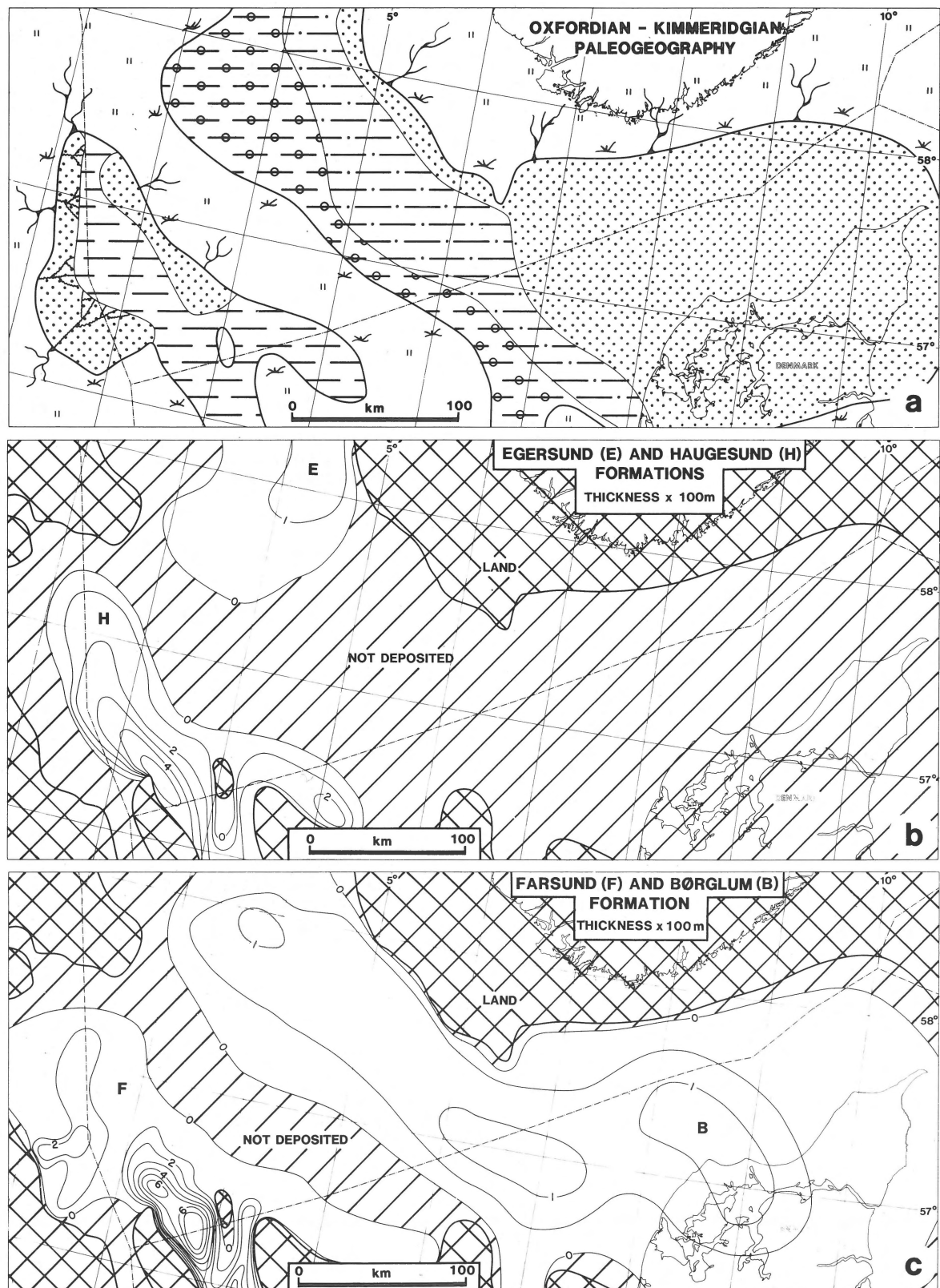


Fig. 5
Isopach and palaeogeographic maps, legend see figure 2.

fine-grained organic-rich shales. These cover most of the Norwegian-Danish Basin with moderate thicknesses, and are named the Børglum Formation (Fig. 5c). Within the upper part of this Formation a shale with considerably higher radioactivity is found in the centre of the Fiskebank Sub-Basin. Based on the areal distribution and the short time span (Figs. 6a, 6b) this shale is given member status, the Tau Member. Normally it is less than 50 m thick and on the map (Fig. 5c) it is included in the Børglum Formation. The Børglum Formation is palaeontologically dated as Oxfordian-Volgian, the Tau Member only represents the Early-Middle Volgian and disappears before the end of that stage. The high radioactivity together with abundant organic carbon is considered to be a reflection of anoxic bottom conditions and a low sedimentation rate. In the Late Volgian the sea became more oxygenated and a higher clastic influx due to a regression over the Norwegian-Danish Basin is noticed. This resulted in the accumulation of the open marine shales of the Sauda Formation (Fig. 6c), with thicknesses normally ranging between 50 and 200 m. In the Danish Sub-Basin the nearshore marine sands and siltstones of the Fredrikshavn Formation were developed through this regressive phase. In the Central Graben a dark grey shale petrographically similar to the Børglum Formation is found. The unit is named the Farsund Formation and it is dated as Late Kimmeridgian to Volgian (Fig. 5c). The Formation is mainly deposited in a low energy, unoxxygenated, marine environment (Figs. 6a and 6b). A marine connection over the ridge which separated the Central Graben and the Norwegian-Danish Basin was established during the Late Volgian (Fig. 6b).

The fault movement and resulting subsidence of the Central Graben continued into the Ryazanian, and a highly radioactive organic-rich shale accumulated west of the bordering fault zone. The thickness is normally less than 50 m, and the Mandal Formation is proposed as a name for this unit (Fig. 6c). The environmental conditions are interpreted to have been the same as for the previously mentioned Tau Member (Fig. 7a). Towards the end of the Ryazanian the flanks of the Central Graben are characterized by condensed sequences or non-deposition. The Mandal Formation continued to accumulate centrally in the basin. Shallow-water, nearshore conditions prevailed throughout the Ryazanian in the Danish Sub-Basin, but these conditions retreated eastwards towards the source area with time. The corresponding sediments constitute the upper part of the Fredrikshavn Formation. Westward the lithology changes to dark grey, occasionally carbonaceous shale, which in the Fiskebank Sub-Basin is named the Flekkefjord Formation (Figs. 6c and 7a). It was deposited under low-energy, restricted marine conditions.

Irregularly distributed sonic-log peaks associated with high gamma-ray readings are common in all anaerobic and 'hot' shales in the Central North Sea. The peaks mark limestone beds or calcareous rich zones. These beds originated from planktonic organisms with calcareous skeletons. Surface water currents distributed this material all over the basin. The

dead planktonic organisms sank to the anaerobic sea bottom and were preserved as microlaminates similar to those described from recent Black Sea sediments (DEGENS ET AL., 1978). Not only the similarity in the sediment composition, but also the palaeogeographical reconstructions (Figs. 6a and 6b) of the Central North Sea basins, show close resemblance to the Black Sea environment.

Unlike some of the recent anaerobic settings, for example offshore Namibia and Peru, phosphatic beds are not found in the Central North Sea. The presence of phosphatic nodules is considered to be typical of an 'upwelling' type of anoxic facies (DEMAISON & MOORE, 1980). A number of phosphatic nodule beds have been reported from the Oxford and Kimmeridge Clay Formations in the Southern North Sea (RHYS, 1974) and from onshore England (GALLOIS, 1978). A classification based on these facts suggest that the Upper Jurassic of the Southern North Sea and onshore England was deposited on the Tethyan Ocean Shelf in an 'upwelling' type of environment, and that the Central and Northern North Sea deposits accumulated in intra-cratonic depressions in a 'silled basin type' setting.

The main Jurassic depocentres in the studied area are the Central Graben, the Fiskebank Sub-Basin and the Danish Sub-Basin (1.2 km sediment thickness) (Fig. 7b). The basins are surrounded by emergent areas in the west and east and a series of islands in the south. The different types of clastic sediments that accumulated in the basins are related to this palaeotopographic configuration. Two stratigraphic cross sections show the relationship between the discussed formations (Figs. 8a and 8b). The bulk of the Lower Jurassic sediments belong to the Fjerritslev Formation. During the Middle Jurassic continental and shallow marine sandstones were deposited. These constitute a relatively thin sequence, but are widely distributed in the basins. The Upper Jurassic shales are rich in organic carbon and show a high level of radioactivity. They are found to be good indicators of the palaeo-environmental conditions and have also been used in the lithostratigraphic subdivision.

TECTONICS

Time-stratigraphic sequences are traced on a regional north-south cross section (C-C') between the two main depocentres in the Norwegian-Danish Basin (Fig. 8). The Lower and Middle Jurassic reach a maximum thickness north of the centre of the Permo-Triassic basin axis, while they are missing south on the East North Sea Horst. The Upper Jurassic is very thin, partly eroded in the middle, and evidently not deposited in the northern part of the studied area. Sediments of Cretaceous age, thickest in the extreme north, are at this position overlying Precambrian basement rocks. The Tertiary basin is dipping southwards. The Fjerritslev Fault is still existing at this level with an insignificant vertical throw, and is terminating the very northern part of the Permo-Triassic basin. The

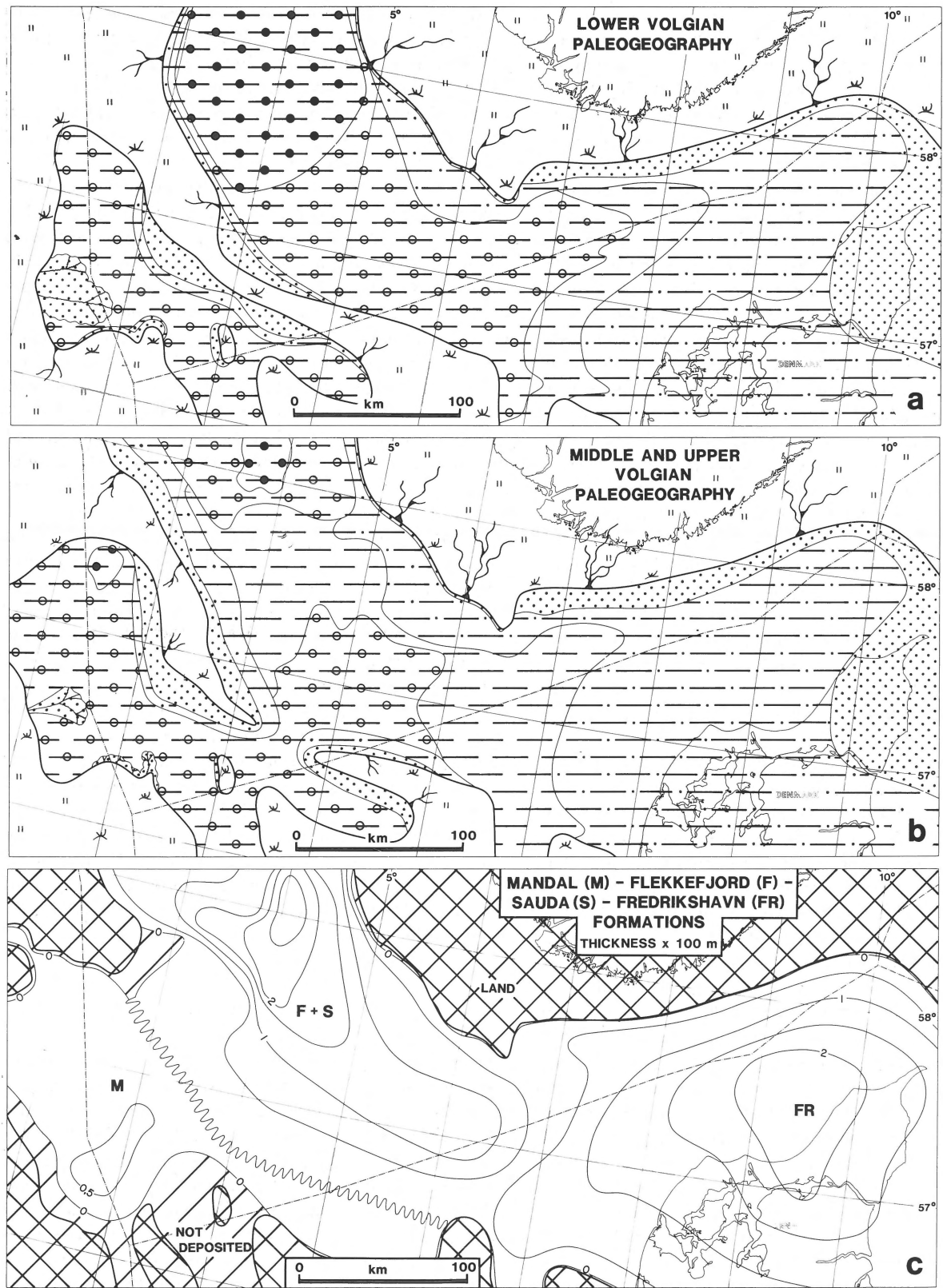


Fig. 6
Isopach and palaeogeographic maps, legend see figure 2.

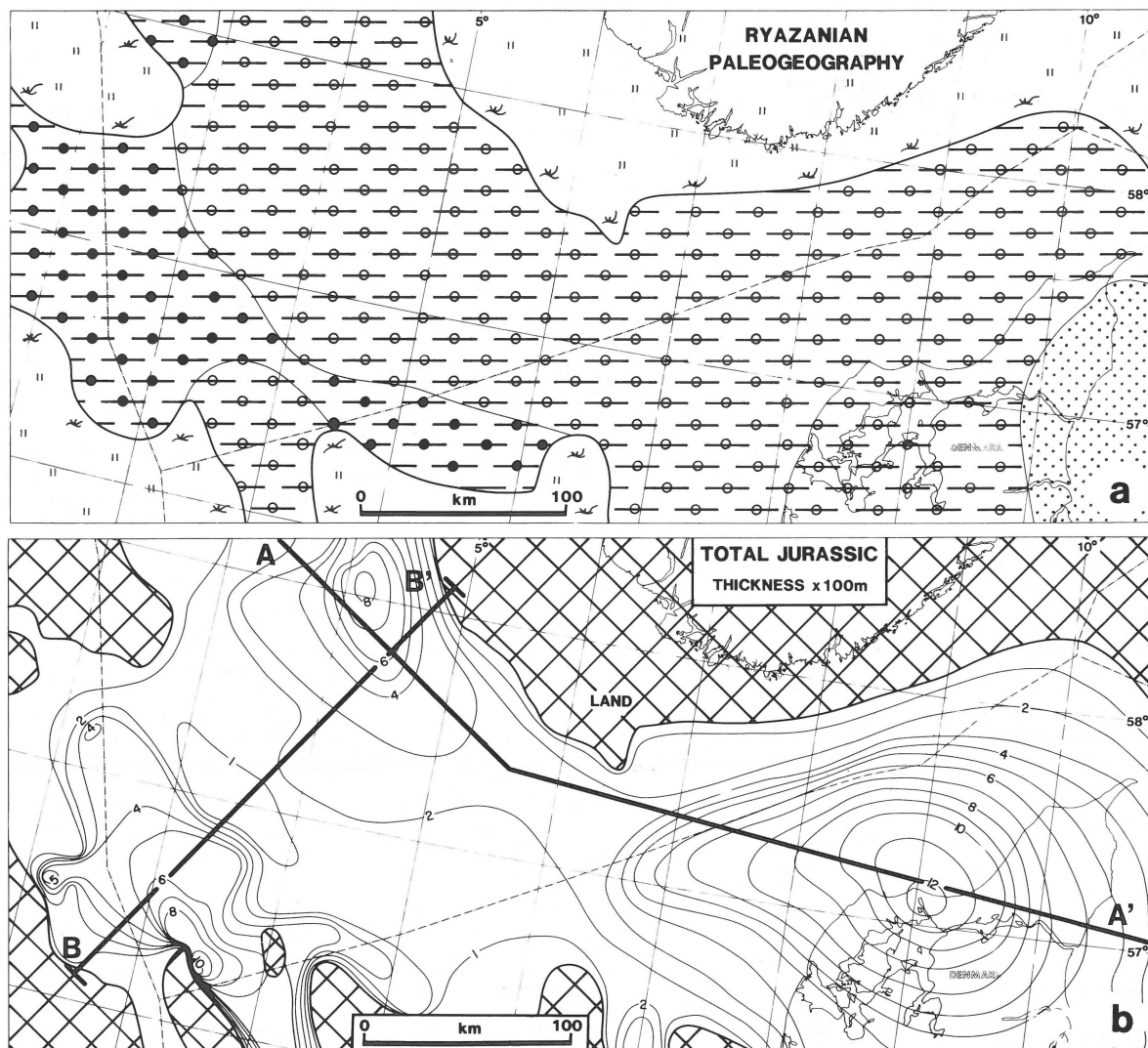


Fig. 7
Isopach and palaeogeographic maps, legend see figure 2.

Lista Ridge is expressed as a Triassic uplift in the central part and the lithofacies distributions discussed earlier are separated by this structural element.

Upper Permian salt deposits were mobilized in the deepest parts of the basins as early as Late Triassic. Faulting and earthquakes in connection with volcanism reactivated the salt structures and the movements continued throughout the entire Jurassic. Jurassic and post-Jurassic diapir structures are marked on the tectonic map (Fig. 1). Most of these have elliptical or circular shapes, and a large number are situated above or close to major faults. Salt walls, which are very common in the southern North Sea, have not been observed here. The Jurassic sediments thin over many of the salt domes and a few of the domes pierce these layers. A piercing diapir which moved in the Tertiary is illustrated on the southeastern end of the section D-D' (Fig. 8). The central part of this same section crosses a rim syncline belonging to another salt diapir.

The history of the movements started with a salt pillow swell beginning in the Triassic and ending in the Early Jurassic. Both the Upper Triassic and the Lower Jurassic are eroded above the pillow. The Middle Jurassic Haldager Formation is thin but extensive which suggests a period of stability. New diapirism induced offsets to the west of this section, and the rim syncline evolved at the beginning of Late Jurassic. The salt movements stopped in the Tertiary.

A migrated seismic section illustrates the tectonic history of the Farsund Sub-Basin (Fig. 9). The movements here observed are also recognized in other parts of the Central North Sea. The Farsund Sub-Basin is situated at the northern end of the Danish Sub-Basin and north of the Fjerritslev Fault Zone. This fault has been discussed in several publications. Both BERTELSEN (1980) and SMIDT (1982) show seismic sections crossing the fault which has a maximum vertical displacement in the Danish Sub-Basin. The authors emphasize synsedimen-

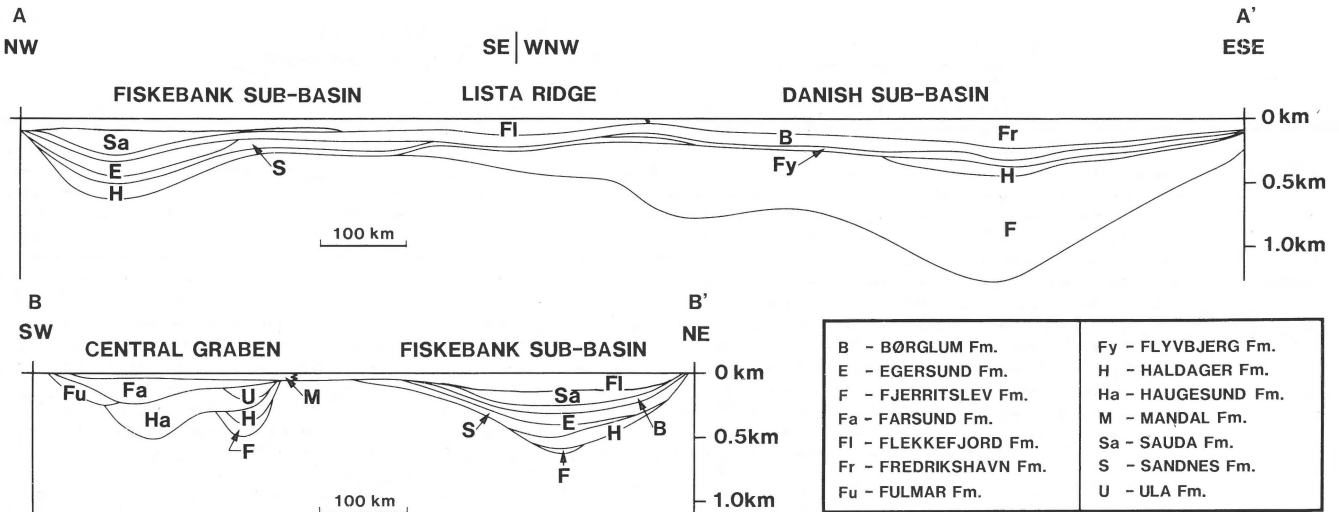


Fig. 8a and 8b
Stratigraphic cross sections, locations marked on figure 7b.

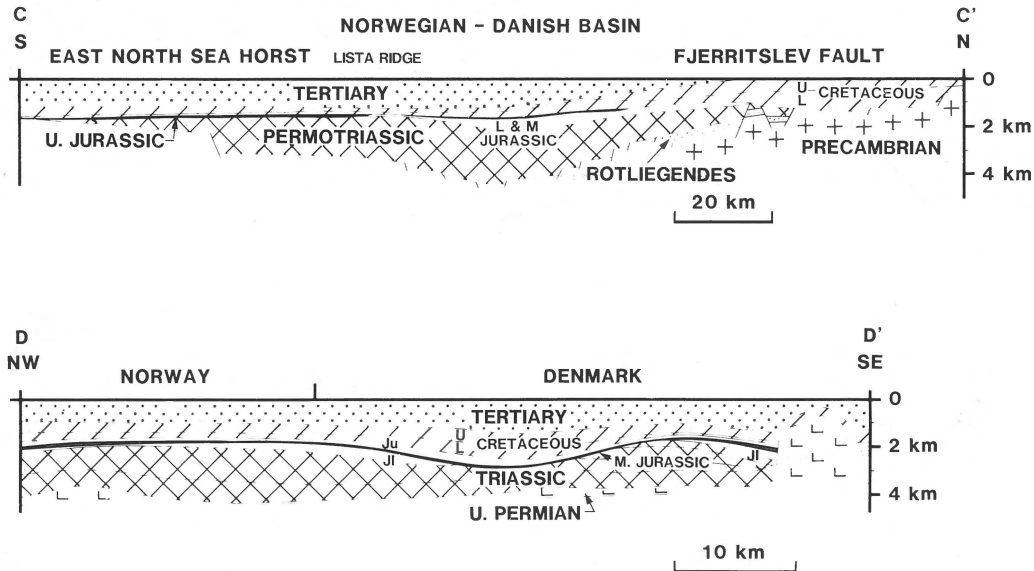


Fig. 8c and 8d
Structural cross sections, for locations see figure 1. Section D-D' is an interpretation of NOGEC a.s., RDT speck data.

tary movements during the Triassic and Jurassic along this fault and slight inversion of the basin – the downfaulted area – during the Laramide orogenic phase.

The deepest interpreted seismic reflector on the section in figure 10 is dated as Early Permian or older. Upper Permian sediments cover this surface and are thinning towards the northeast. The seismic reflection pattern within this sequence is irregular to the southwest and becomes more continuous to the northeast. The character change is interpreted as a possible lateral variation from a mobile to a more marginal type of evaporite facies. In the area of the predicted marginal facies two cone-shaped bodies protrude into the Triassic sequence above. They could be fossil reef bodies developed at the margin of the Zechstein Sea. The Triassic sequence thins from

SSW to NNE. The Triassic and Lower-Middle Jurassic beds can be allocated to three fault blocks, the central one dipping to the northeast and the others to the southwest. Several steps of 'basement' faults underlie the central fault block. The Triassic-Jurassic cover is prevented from breaking up in a similar pattern to the basement because of the decollement effect of the evaporite layer inbetween. The movement is dated as Callovian or Oxfordian. The sub-basin is filled with Upper Jurassic and Lower Cretaceous sediments. A reverse fault cutting the Lower Cretaceous sequence marks the first inversion of the sub-basin. Contemporary inversions are described from offshore Holland (OELE ET AL., 1981), from the northeastern Sole Pit Area (GLENNIE & BOEGNER, 1980) and from the Sele High Area (HESJEDAL & HAMAR, 1983, this vo-

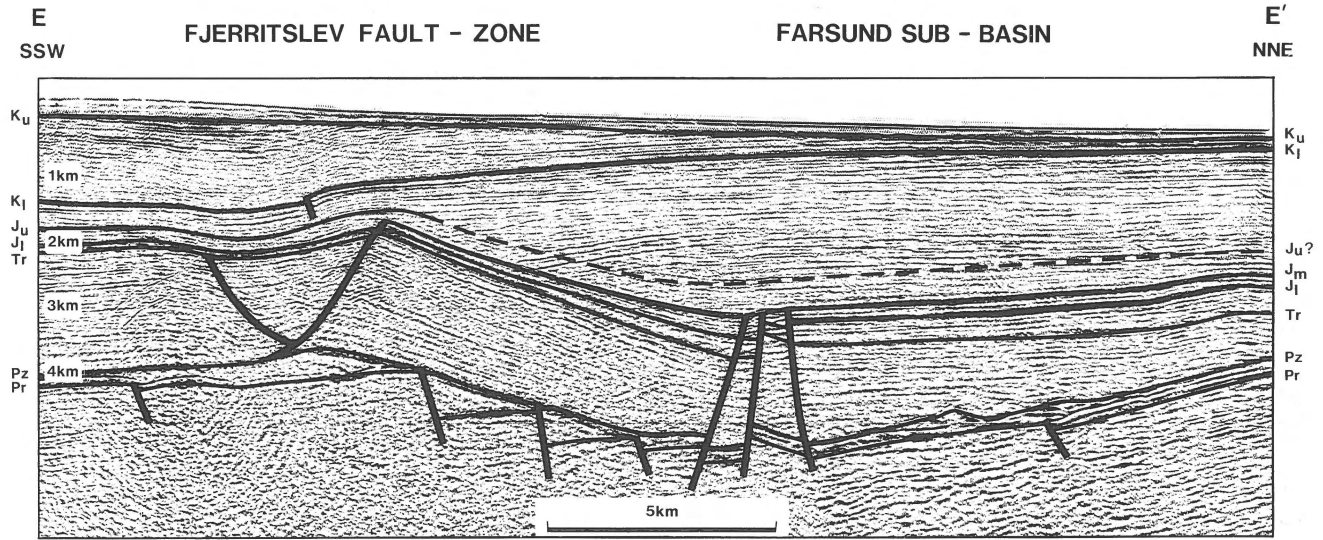


Fig. 9 Migrated seismic section in the Farsund Sub-Basin; location, see figure 1.

lume). All these movements were produced by the Austrian orogenic Phase. A repeated uplift in the Farsund Sub-Basin during the Laramide orogenic phase is also indicated by the deformed Upper Cretaceous chalk sequence above the reverse fault.

The Fjerritslev Fault has been active during a long period of time. In the Danish Sub-Basin the fault controlled the sedimentation of 5000 m of Triassic (BERTELSEN, 1980) and 1200

m of Jurassic (MICHELSEN, 1978). A late Middle Jurassic tectonic event formed the Farsund Sub-Basin in the north. The same movement elevated the Danish Sub-Basin and the Central Graben where major hiatuses are found. Recent studies of seismic data indicate inversion of the Farsund Sub-Basin associated with repeated strike-slip movements within the fault zone. Cenomanian dextral faults are marked by arrows on the tectonic map (Fig. 1) in the Danish Sub-Basin. They

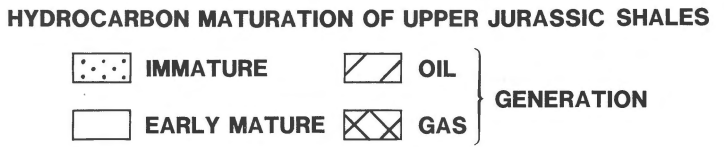
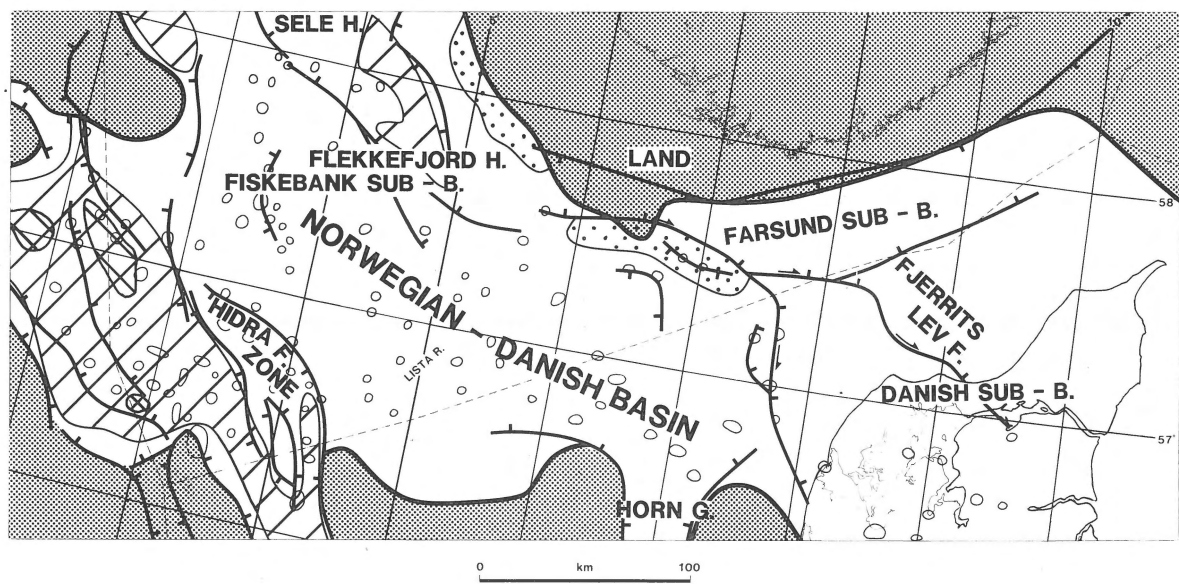


Fig. 10 Hydrocarbon maturation map of Upper Jurassic shales.

are interpreted as rejuvenated fault movements caused by rotation of the Fennoscandian Shield (HESJEDAL & HAMAR, 1983, this volume).

HYDROCARBON POTENTIAL

Good hydrocarbon potential for the Jurassic and early Cretaceous sediments in the southern Norwegian North Sea is indicated by the present study. The total organic carbon (TOC) is generally low in the open marine shales (Fjerritslev-, Sauda-, and Haugesund Formations), increasing up to 7% (TOC) for the anaerobic deposits (Børglum-, Farsund-, and Flekkefjord Formations). Maximum values from 7 to 17,5% (TOC) are measured in the 'hot' shales (Tau Member and Mandal Formation). The shales in the Central Graben are mature for oil generation, and in the very central part of the graben for gas expulsion (Fig. 10). Vitrinite reflectance measurements and calculations by the Lopatin method (WAPLES, 1980) indicate only moderate maturation levels over the whole Fiskebank Sub-Basin, except east of the Flekkefjord and Sele Highs, where the Upper Jurassic shales have reached the oil maturation window.

Sandstones (Haldager-, Sandnes-, Ula-, and Fulmar Formations) are present in different parts of the studied area, and one or several of these could form potential hydrocarbon reservoirs. Numerous traps of both fault- and diapiric-origin have been mapped and some of these have been drilled. Jurassic sandstones have been found to have reasonably high (up to 20%) porosities, even at depths of around 4000 m. Many structures have not yet been tested and specifically very few prospects have been drilled on the margin of salt diapirs, and even fewer stratigraphic traps have been tested. It can be concluded that the area continues to hold a number of promising prospects which need to be explored in the future.

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REFERENCES

- Bertelsen, F. 1980 Lithostratigraphy and depositional history of the Danish Triassic – Danm. geol. Unders., Ser. B, 4: 59 pp.
- Christensen, O. B. 1974 Marine communications through the Danish Embayment during uppermost Jurassic and lowermost Cretaceous – Geoscience and Man., VI, October 1, 1974: 99-115.
- Deegan, C. E. & B. J. Scull, 1977 A standard lithostratigraphic nomenclature for the Central and Northern North Sea – Rept. 77/25 Inst. Geol. Sci. and Bull. 1, Norwegian Petrol. Direct.: 35 pp.
- Degens, E. T., M. D. Dickman, S. Golubic & P. Stoffers 1978 Varve chronology estimated rates of sedimentation in the Black Sea deep basin – Int. Rept. Deep Sea Drill. Pro. V. 42 (2): 499-508.
- Demaison, G. J. & G. T. Moore 1980 Anoxic environments and oil source bed genesis – AAPG. Bull. 64: 1179-1209.
- Gallois, R. W. 1978 A pilot study of oil shale occurrences in the Kimmeridge Clay – Inst. Geol. Sci. Rep. 78/13.
- Glennie, K. W. & P. L. E. Boegner 1981 Sole Pit inversion tectonics. In: L. V. Illing & G. D. Hobson (eds.): Petroleum Geology of the Continental Shelf of North-West Europe – Heyden & Son Ltd., for Inst. of Petroleum, London: 110-120.
- Hamar, G. P., K. H. Jakobsson, D. E. Ormaasen & O. Skarpnes 1980 Tectonic development of the North Sea, north of the Central Highs – NPF Conference on The Sedimentation of the North Sea Reservoir Rocks. Geilo, 1980: 11 pp.
- Hesjedal, A. & G. P. Hamar 1983 Lower Cretaceous stratigraphy and tectonics of the south-southeastern Norwegian offshore. In: J. P. H. Kaasschieter & T. J. A. Reijers (eds.): Petroleum geology of the southeastern North Sea and the adjacent onshore areas (The Hague, 1982) – Geol. Mijnbouw 62: 135-144 (this issue).
- Larsen, G. 1966 Rhaetic - Jurassic - Lower Cretaceous sediments in the Danish Embayment (a heavy-mineral study) Danm. geol. Unders., II. række 91: 127 pp.
- Michelsen, O. 1975 Lower Jurassic biostratigraphy and ostracods of the Danish Embayment – Danm. geol. Unders., II. række 104: 287 pp.
- 1977 Jurassic deposits of the Norwegian-Danish Basin. In: K. G. Finstad & R. C. Selley (eds.): Mesozoic Northern North Sea Symposium, Oslo 1977 – Proc. Norwegian Petr. Soc., 6/1-6/26.
- 1978 Stratigraphy and distribution of Jurassic deposits of the Norwegian-Danish Basin – Danm. geol. Unders. Ser. B 2: 28 pp.
- Michelsen, O. (ed.) 1981 Kartlægning af potentielle geotermiske reservoirer i Danmark – Danm. geol. Unders. Ser. B 5: 96 pp.
- Oele, J. A., A. C. P. J. Hol & J. Tiemens 1981 Some Rotliegend gas fields of the K and L blocks, Netherlands offshore (1968-1978) – A case history. In: L. V. Illing & G. D. Hobson (eds.): Petroleum geology of the continental shelf of North-West Europe – Heyden & Son Ltd., for Inst. of Petroleum, London: 289-300.
- Rhys, G. H. 1974 A proposed standard lithostratigraphic nomenclature from the Southern North Sea – Inst. Geol. Sci. Rep. No. 74/8.
- Rønnevik, H. C., W. van den Bosch & E. H. Bandlien 1975 A proposed nomenclature for the main structural features in the Norwegian North Sea – NPF Jurassic Northern North Sea Symposium, Stavanger 1975, 18/1-18/16.
- Skarpnes, O., G. P. Hamar, K. H. Jakobsson & D. E. Ormaasen 1980 Regional Jurassic setting of the North Sea north of the Central Highs – NPF Conference on The Sedimentation of the North Sea Reservoir Rocks, Geilo, 1980: 8 pp.
- Smidt, J. M. 1982 Geofysiske undersøkelser i Skagerrak - med to eksempler – D.G.F. Årsskr.: 165-169 (with English summary).
- Waples, D. W. 1980 Time and temperature in petroleum formation: Application of Lopatin's method to petroleum exploration – AAPG. Bull. 64: 916-926.
- Ziegler, P. A. 1982 Geological Atlas of Western and Central Europe – Shell Int. Petr. Maatschappij, Elsevier (Amsterdam): 130 pp.