Corallian Group (mid-upper Oxfordian) succession in the cliffs north of Filey Brigg on the North Yorkshire coast. The Corallian Group comprises one of the most distinctive lithostratigraphic divisions of the Jurassic of the Southern Permian Basin area. They form a highly variable shallow-marine succession of bioclastic and ooidal limestones, with interbedded sandstones containing abundant siliceous spicules of the sponge *Rhaxella perforata*. Offshore they can be identified as a significant topographic feature at sea bed and also form a clearly defined seismic event in the subsurface.
1 Introduction

The Jurassic rocks of western and central Europe, which form the core of the SPB area, were deposited in a shallow epicontinental sea that extended from the present-day UK into the southern North Sea basin and, from south-east Germany, to Denmark in the north (Figures 10.1 to 10.7). Throughout much of the Jurassic, these were connections through the North Sea to a northern Boreal Ocean and, via the ‘Northern Seaway’ and ‘East Caucasian Gate’, to the Tethys Ocean to the south. The wasting and warming of these two oceanic areas had a profound influence not only upon sedimentation and facies in the Jurassic of the SPB area, but also for biostratigraphic correlation across the basin (Calefato, 2003; Page, 2003; Ziegler, 2003). The eastern limit of the basin was marked throughout the Jurassic by the Fennoscandian-Belorussian High where deposition was dominated by nonmarine clastic sedimentation along its margins. The subsidence patterns in this extensive basin were periodically disrupted, most notably during the Mid-Jurassic (Oxfordian and Pliensbachian) and by tectonic events beyond the area, directly linked to a continuation of extensional rolling in the Central Atlantic and Tethys areas (de Jager, 2003; Chapter 3). The palaeogeographic position of the European area in sub-tropical latitudes throughout the Jurassic also meant that sedimentation in the basin was characterized, particularly during deposition of the Lower Jurassic Lias Group, by both warm water Tethys influxes from the south, where carbonate sedimentation dominated, and Boreal (cold-water) influxes from the north, where deposition was characterized by detrital clastics, marine and nonmarine sedimentation.

A major phase of tectonic inversion and erosion took place during the Late Cretaceous to Early Cenozoic. As a result, Jurassic sediments have not only been uplifted and exposed at outcrop across much of the SPB area, but have also been eroded along the north-west European continental shelf as a series of disconnected basin margins submerging variable thicknesses of Cretaceous and Cenozoic sediments (Figures 10.1 to 10.6).

The regional context of Jurassic sedimentation in the area has been described by Ziegler (1984a), Ziegler & van der Weijden (1984), Ziegler & van der Weijden & Andsberg (1998) and Pietrasson & Schlücker (2008). There are also many detailed investigations of individual basins in the area (Cameron et al., 1992; Partington et al., 1993; Feldman-Olszewka, 1997; Fraser et al., 2002; Husmo et al., 2002; Herngreen et al., 2003; Michelsen, 2003; Page, 2003; Zeiss, 2003). The eastern limit of the basin was marked throughout the Jurassic by the Fennoscandian-Belorussian High where deposition was dominated by nonmarine clastic sedimentation along its margins. The subsidence patterns in this extensive basin were periodically disrupted, most notably during the Mid-Jurassic (Oxfordian and Pliensbachian) and by tectonic events beyond the area, directly linked to a continuation of extensional rolling in the Central Atlantic and Tethys areas (de Jager, 2003; Chapter 3). The palaeogeographic position of the European area in sub-tropical latitudes throughout the Jurassic also meant that sedimentation in the basin was characterized, particularly during deposition of the Lower Jurassic Lias Group, by both warm water Tethys influxes from the south, where carbonate sedimentation dominated, and Boreal (cold-water) influxes from the north, where deposition was characterized by detrital clastics, marine and nonmarine sedimentation.

The Jurassic succession in the SPB area includes lithological units that have proved to be of significant not only in terms of their proven oil-source rock potential (Lower and Upper Jurassic organic-rich mudstones), but also for biostratigraphic correlation across the basin (Calefato, 2003; Page, 2003; Ziegler, 2003). The local context of Jurassic sedimentation in the area has been described by Ziegler (1984a), Ziegler & van der Weijden (1984), Ziegler & van der Weijden & Andsberg (1998) and Pietrasson & Schlücker (2008). There are also many detailed investigations of individual basins in the area (Cameron et al., 1992; Partington et al., 1993; Feldman-Olszewka, 1997; Fraser et al., 2002; Husmo et al., 2002; Herngreen et al., 2003; Michelsen, 2003; Page, 2003; Zeiss, 2003). The most significant palaeogeographical changes during the Sinemurian to Pliensbachian stages was the gradual establishment of a northern seaway linking the SPB area with the Boreal Ocean to the north via the Muschelkalk Formation. The Hettangian to lowermost Toarcian succession is mainly dark grey to black, and other Mesozoic basins, including the offshore parts of the Dutch and Danish Central Graben and onshore West Belgium onshore West Belgium, Seawards of the Benelux margins. The relationship with the underlying Triassic is characterized by a distinct ammonite faunas available for stratigraphic correlation. Correlations with the interbedded shallow-marine, brackish, delta and continental facies of Poland become more sequential only on the sequence stratigraphy and tectonic evolution (Piecznicska, 2004).

The global transgressive event and sea-level rise that started in late Triassic to earliest Jurassic times is characterized by the development of shallow, open-marine, fine-grained marine sedimentation as seen in the US Lia Group (Krisis, 1989). The interbedded shallow-marine and brackish-water sandstones in western and central Poland (Skrzydlewicz, 2000). This resulted in calmer shallow-marine and sandstone facies in the central Polish area (Calefato, 2003; Partington et al., 1993; Feldman-Olszewka, 1997; Fraser et al., 2002; Husmo et al., 2002; Herngreen et al., 2003; Michelsen, 2003; Page, 2003; Zeiss, 2003). The eastern limit of the basin was marked throughout the Jurassic by the Fennoscandian-Belorussian High where deposition was dominated by nonmarine clastic sedimentation along its margins. The subsidence patterns in this extensive basin were periodically disrupted, most notably during the Mid-Jurassic (Oxfordian and Pliensbachian) and by tectonic events beyond the area, directly linked to a continuation of extensional rolling in the Central Atlantic and Tethys areas (de Jager, 2003; Chapter 3). The palaeogeographic position of the European area in sub-tropical latitudes throughout the Jurassic also meant that sedimentation in the basin was characterized, particularly during deposition of the Lower Jurassic Lias Group, by both warm water Tethys influxes from the south, where carbonate sedimentation dominated, and Boreal (cold-water) influxes from the north, where deposition was characterized by detrital clastics, marine and nonmarine sedimentation.

A major phase of tectonic inversion and erosion took place during the Late Cretaceous to Early Cenozoic. As a result, Jurassic sediments have not only been uplifted and exposed at outcrop across much of the SPB area, but have also been eroded along the north-west European continental shelf as a series of disconnected basin margins submerging variable thicknesses of Cretaceous and Cenozoic sediments (Figures 10.1 to 10.6).
The upper surface of the formation is erosively truncated and overlain by Upper Cretaceous rocks; younger shales (Posidonia Shale Formation) was deposited across much of this central European area. The upper more restricted during the Toarcian (Toarcian Anoxic Event) and a thin 30 m-thick unit of bituminous mudstone deposited. Petroleum Geological Atlas of the Southern Permian Basin Area.

In northern Belgium, the Lower Jurassic succession in the Ross Valley Graben forms a southerly extension of the Aalborg Formation of the Netherlands. The sediments comprise more than 450 m-thick sandstones to thin-bedded shales, the upper surface of the formation is variably truncated, overlain by Upper Cretaceous rocks; younger shales are absent.

The Lower Jurassic succession in Denmark is comprised mainly of the Gunsmidt and Fyrkat formations. The Rhuddanian to lower Kimmeridgian Gunsmidt Formation, which is only found in the Danish Basin, is a heterolithic succession of mainly palaeo-clinoidal and shallow marine sandstones that are up to 100 m thick, with thin claystones and mudstones. The formation is conformably overlain by a thin (up to 500 m), non-turbidite succession of more distal, dark grey to black, non-pelagic, calcarious carbonates, deposited in a marine-shelf setting and assigned to the upper Rhuddanian to lower Aalenian Fyrkat Formation. The Gunsmidt Formation is absent in the Danish Central Graben offshore, and consequently the Fyrkat Formation, although poorly known, is thought to lie conformably on uppermost Triassic (Rhuddanian) shallow marine rocks. Lower Thanetian dark-coloured organic-rich mudstone deposits correlate with similar arenaceous successions elsewhere in the IPT area (e.g. Posidonia Shale Formation).

The main sediment source for the Gunsmidt Formation was the Fenno-scandian High over which the unit backstepped as the shelf edge retreated and sea-level rose progressed. Further to the east in the Lower Jurassic outcrops of Bohemia and the contiguous Russo-Greater, the proximity and influence of this Fenno-scandian margin is even more distinct. Here, the Gunsmidt and Fyrkat formations are replaced by the sandstones, mudstones and coal-bearing successions of the 500 m-thickFormField Formation. The overlying shallow-marine sandstones and ammocoete-bearing mudstones of the 140 m-thick Hjulø Formation indicate a significant regional sea-level rise in the early Pliensbachian. This was followed by the late Pliensbachian to Toarcian by a return to alluvial sedimentation characterized by the coal-bearing successions of the 200 m-thick Sortel Formation. (Michelsen et al., 2005).

Lower Jurassic (mostly Lias Group) rocks in Germany crop out to the north in Lower Saxony and parts of Westphalia and Sauerland-Anhalt, but are exposed from the southern outcrops of the Dinelau-Frankonian Alb area by the Rhine-Bohemen Manifold. Elsewhere in Germany, Lower Jurassic rocks are buried beneath thick Cretaceous and Cenozoic strata that extend across the North German Basin into the North Sea Basin and southwards into France. A succession of more than 1000 m-thick Lias Group rocks are preserved at depth beneath the area north-west of Lower Saxony. The Lower Jurassic sequence is conformable with the underlying Triassic (Rhuddanian) strata in each of these areas. However, the upper boundary of the Lias Group is locally disconformable with the overlying Middle Jurassic Aalenian sedimentary rocks. The stratigraphy and distribution of these buried Jurassic successions is based on the description and interpretation of many thousands of boreholes drilled as part of the continuing exploration and exploitation of the area for hydrocarbons, salt and iron ores.
Figure 10.2  Depth to near base of the Lower Jurassic (base of the Lias Group). This lithostratigraphic horizon is shown as Horizon 6 on Figures 1.5 and 9.1.
Figure 10.3    Thickness of the Lower Jurassic.
Figure 10.4  Depth to near base of the Middle Jurassic (top of the Lias Group). This lithostratigraphic horizon is shown on Figures 5 on Figures 1.5 and 10.1.
Chapter 10 — Jurassic

Figure 10.5    Thickness of the Middle Jurassic.

Figure 10.6: Depth to near base of the Upper Jurassic (corresponding to a level varying from the Callovian to the base of the Oxfordian). This lithostratigraphic horizon is shown as Horizon 4 on Figures 1.5 and 10.1.
Figure 10.7: Thickness of the Upper Jurassic.
The Lower Jurassic rocks of northern Germany are represented by the Kamienna Group, which is subdivided into three subgroups: the Late Carnian (Kamienna Formation), the Early Carnian (Kamienna Formation), and the Middle Jurassic (Kamienna Formation). The Kamienna Formation is characterized by shallow-marine deposits, with the Late Carnian deposits consisting of fine-grained clastic sediments, while the Early Carnian deposits are dominated by bioturbated limestones. The Middle Jurassic deposits are characterized by shallow-marine and lagoonal sediments, with the Late Callovian deposits consisting of bioturbated limestones and the Early Oxfordian deposits consisting of sandstones and siltstones.

Detailed sedimentary examination and interpretation of numerous horizons and well logs, together with correlations with the successions known at outcrops, has led to the recognition of a series of depositional sequences that reflect complex changes in sea level within the shallow epicontinental Early Jurassic basins of the Polish area (Petrikowski, 2004). During this interval, the sea transgressed the Polish Basin several times from the west and occupied much of the western and central parts of the Mid-Polish Trough.

Sedimentation within the troughs seems to have been largely continuous into Mid-Jurassic times. The low-energy Jurassic coarse-grained clastic sediments appear to be conformably on Upper Triassic (Rhetic) strata. However, sedimentation was interrupted periodically in the adjacent platform areas and the successions are less complete or more condensed (Petrikowski & Schloeser, 2003). Zechstein salt diapiric activity has also resulted in local thickening variations within the trough.

2.2 Middle Jurassic (Aalenian to Callovian)

At the end of the Early Jurassic, the SPB area formed part of a shallow-water epicontinental basin in which fine-grained marine-clastic sediments dominated in the west and south, and coarse-grained clastic, clay, and marine-dominated sediments dominated in the north and east. Basinal sea-level rise continued into early Mid-Jurassic times across much of the SPB area, but still left exposed a series of local highs (Anglo-Brabant, Bohemian high, and the USB) that persisted largely into the Late Jurassic. The Anglo-Brabant structural high was further affected by tectonic uplift associated with mid-Callovian and late Callovian, and this complex was associated with concurrent re-activation and uplift of the adjacent Ringkøbing-Fyn and Limfjorden-Ribe triple-rift junctions. From late Toarcian times, this complex was associated with concurrent re-activation and uplift of the adjacent Ringkøbing-Fyn and Mid North Sea highs to the west and south-east (Ziegler, 1990a; Underhill & Partington, 1993; Calloman, 1993). By late Bajocian times, this simple depositional model was complicated by a series of long narrow grabens (Kaleje-Kamiensk and Laska-Posnan grabens) in which the trough is bounded by the more stable Paleozoic Platform (Szczecin-Piotrkow-Silesia-Krakow region). These grabens continued into early Mid-Jurassic times across much of the SPB area, but still left exposed a series of local highs (Anglo-Brabant, Bohemian high, and the USB) that persisted largely into the Late Jurassic. The Anglo-Brabant structural high was further affected by tectonic uplift associated with mid-Callovian and late Callovian, and this complex was associated with concurrent re-activation and uplift of the adjacent Ringkøbing-Fyn and Limfjorden-Ribe triple-rift junctions. From late Toarcian times, this complex was associated with concurrent re-activation and uplift of the adjacent Ringkøbing-Fyn and Limfjorden-Ribe triple-rift junctions.
begun until the mid-Callovian. Another important effect of the growth of this extensive area of uplift was in the formation of the North Sea, through the separation of the Baltic area from the North Sea. The Middle Jurassic succession in the East Midlands Basin is characterised by the continuous thinning of the Upper Jurassic succession, and the erosion of the Cleveland and Portland groups. The Middle Jurassic succession in the Cleveland-Sole Pit basins is a mostly Bajocian fluviodeltaic, marine limestone succession, and it is characterised by the Passa Bridge Formation (Bathonian) and the Hollyhead Formation (Callovian). The Middle Jurassic succession in the Cleveland-Sole Pit basins is a mostly Bajocian fluviodeltaic, marine limestone succession, and it is characterised by the Passa Bridge Formation (Bathonian) and the Hollyhead Formation (Callovian).

The Passa Bridge Formation is a thin-bedded, fossiliferous, marine limestone succession, and it is characterised by the Passa Bridge Formation (Bathonian) and the Hollyhead Formation (Callovian). The Passa Bridge Formation is a thin-bedded, fossiliferous, marine limestone succession, and it is characterised by the Passa Bridge Formation (Bathonian) and the Hollyhead Formation (Callovian).

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In general, the Middle Jurassic succession throughout the SPB area has a variably erosive and unconformable relationship with the underlying Lower Jurassic, which it may also overstep in places. In contrast, the Middle Jurassic succession in the Polish Basin, the Lower Saxony Basin, and the North Sea area has a more conformable relationship with the underlying Lower Jurassic.

The Middle Jurassic succession in the Cleveland-Sole Pit basins is a mostly Bajocian fluviodeltaic, marine limestone succession, and it is characterised by the Passa Bridge Formation (Bathonian) and the Hollyhead Formation (Callovian). The Middle Jurassic succession in the Cleveland-Sole Pit basins is a mostly Bajocian fluviodeltaic, marine limestone succession, and it is characterised by the Passa Bridge Formation (Bathonian) and the Hollyhead Formation (Callovian).
Deposition in the Polish Basin is characterized by eight transgressive-regressive sedimentary cycles (Fig. 10.10). From Aalenian to early Bathonian times, the deposits were mainly anoxic/dysoxic marine sandstone remnants followed by anoxic/anoxic/marine sandstone units. There were clear differences between the western/south-western parts and the central/eastern parts of the basin during mid- to late Bathonian and Callovian times. The former was characterized by repetitive mudstone-sandstone cycles; the latter by heterolithic shallow-marine lithologies that include calcareous sandstones, dolomites, and organic-rich limestones with ferruginous units (Soliman-Klimczewska, 1997; 1998a; Polakiewicz & Scholz, 2000).

Reliable correlation of the succession between the trough and adjacent south-western platform has been possible due to the presence of good ammonite assemblages. However, correlation is more difficult on the East European Platform where ammonites are rare in the more condensed deposits. Sedimentation on this platform was characterized by marginal-marine and shallow-marine shell clastics and carbonates (Soliman-Klimczewska, 1993b, Fig. 10.10). Middle to upper Callovian and lower Oxfordian deposits in the central, eastern and southern parts of the Polish Basin were strongly condensed to form a number of 'bedspace beds' with thicknesses from a few to several tens of centimetres, which can span several ammonite zones (Borzym-Caluckowska & Mory, 1998).

Unlike the basins to the west, deposition in the Polish area during Mid-Jurassic times was largely unaffected by the thermal uplift and rift events in the North Sea Basin. The clastic sediments supplied to the Polish Basin were derived mainly from the Fennoscandian High to the north-west and the Rhenohercynian High to the south-west. Connections with the North German Basin to the north-west were restricted during late Aalenian to Bathonian times. However, links with the Tethys Ocean to the south remained open, but were restricted to the axial part of the basin (the mid-Polish Trough). In southern Poland, there is close evidence of the centring influence of the Tethys Ocean on sedimentation from the development of marine, mud-dominated deposits with ammenite faunas inAalenian to Bathonian times, as local sea levels continued to rise and by more open-marine, sandy, glauconitic and bioclastic limestone developments in the late Bathonian and Callovian intervals.

2.3 Upper Jurassic (Oxfordian, Kimmeridgian and Volgian)

The onset of Early Jurassic sedimentation was marked by an extensional marine transgression, which gradually flooded almost the entire experimental basin that formed the SFB area throughout Early and Mid-Jurassic times. The gradual collapse of the Mid North Sea thermal uplift led to the re-opening of direct connections between the Tethys and Boreal seas, whereas the break-up of Pangea and subsequent rift formation associated with the on-going opening of the central Atlantic Ocean continued to have a significant effect on local tectonic and sedimentation patterns in the N. Netherlands and northern Germany. In the Polish area, Late Jurassic sedimentation patterns were controlled by tectonic events to the south, which caused regional subsidence of the central and southern Polish platform and the re-opening of the eastern links to the Boreal Sea (Dąbrowski, 1991a, 1991b: Fig. 10.8).

The Late Jurassic interval is subdivided into three stages, the Oxfordian, Kimmeridgian and Volgian (Tithonian): subduction and accretion of the Iberia principally relies on marine ammenite assemblages (see Zier, 2003). The biorstratigraphic resolution is similar to that of the Middle Jurassic in that correlation across Europe is still contentious in places due to the contrasting biorstratigraphic assemblages that developed in the warm-water Tithonian carbonate sediments that dominate the south, and the cool-water Boreal assemblages found in the clastic-dominated sediments to the north. However, the extension of marine sedimentation northwards and eastwards across the Polish area during the Late Jurassic generally improved correlations into and within, this eastern part of the operculostratigraphic basin.

2.3.1 Stratigraphy

The Upper Jurassic (Oxfordian to Volgian) succession of the UK is fully marine and is assigned principally to the Anchoras and Humber groups in the north, and Oxford Clay Formation, Kimmeridge Clay Group, Kimmeridge Clay Formation and Portland-Purbeck (part) groups to the south. Throughout the area, the succession rests conformably on the thin transgressive marine Callovian sandstones (Kelloway and Lackford formations) that terminated deposition of the underlying Middle Jurassic succession. The boundary is unconformable with the overlying Lower Cretaceous Spilsby Sandstone Formation in the north. However, to the south, it is conformable in the Wessel-Waal basin where sedimentation continued throughout the Volgian into the Berriasian.
the southern North Sea, where the ooidal limestones of the Corallian ‘Formation’ developed along the axis of the now inactive Isle of Wight and pass westwards across the East Midlands Shelf into the marine silty and calcareous mudstones of the Seeley Formation (Lott, 1992; Lott & Knox 1994). Although this depositional basin originally extended eastwards into the West Netherlands Basin, subsequent uplift and erosion during the latest Jurassic to earliest Cretaceous has removed much of the Jurassic succession, obliterating detailed relationships between the two basins.

Southwards, over the Market Weighton Anticline, the ‘Corallian’ limestones are replaced in the East Midlands Basin by marine silty and calcareous mudstones of the Seeley Formation; the limestones re-appear as an ooidal-bioclastic facies along the northern and southern margins of the Anglian-Brabant High and thickens southwards (~50 m thick) into the Weass–Noida basin. Thin sandstone developments are found locally within the Kimmeridge Clay Formation in the northern onshore area.

There are no Upper Jurassic rocks preserved in Belgium. The Upper Jurassic succession of the Netherlands is buried beneath variably thin and extensive Cretaceous and Tertiary sediments. Sedimentation was continuous across the Middle to Late Jurassic transition only in the Dutch Central Graben, where the very variable upper Callovian to Volgian (Tithonian) successions are assigned to the Schelved and Stuif groups. The Schelved Group is characterized by mainly continental and paralic deposits, but becomes interfingered with marine sediments of the overlying Stuif Group, which is restricted mainly to the Dutch Central Graben (Wong, 2007). Elsewhere, the base of the Schelved Group is strongly diachronous. Continental sedimentation appears to have been initiated at different times in areas such as the West Netherlands and Nord Friesian basins, where deposition resumed in the Kimmeridgian or Volgian (Tithonian) with lacustrine and laggonal fine-grained clastics.

In the north, sedimentation in the Dutch Central Graben and adjacent Ternshelling Basin led to the accumulation of up to 2000 m-thick sediments of the Central Graben Subgroup (uppermost Callovian to Volgian (Tithonian)). The basin-fill of this subgroup can be divided into three depositional sequences (Althaus et al., 2000). The oldest sediments (Sequence 1 – Gruenes, Middle and Upper Graben formations) are restricted to the Dutch Central Graben proper, where sedimentation during the Callovian to Volgian took place in nonmarine fluvial, lacustrine and deltaic environments, becoming fully marine during the...
The carbonate-dominated Upper Jurassic sediments of southern Germany are assigned to the Weilmünsterian. During transgression started during the early Volgian (Tithonian) and periodically re-established coarser-grained shallow-marine sandstone-limestone pairs (sequence 4, ‘Scruff Greensand Formation’). This type of sediment fill represents continental and paralic deposits during the Kimmeridgian and Volgian succession in the isolated Lower Saxony Basin. The Lias mudstones are moderately rich in organic material, particularly in the lower Lias Group of southern England, where gas shows have been recorded in a number of localities across the area. The first Jurassic offshore hydrocarbon discoveries in southern England took place in the late 19th century, when gas was detected in water wells drilled at Heathfield. Subsequent oil discoveries were made by the UK’s first producing gas well from the Kimmeridge Clay Formation. Despite further extensive exploration in the basin before and after World War II (1939 to 1945), with many gas shows recorded in the Bathurst field, the first commercial oil and gas discoveries were made in the Weald Basin in 1892 when oil was discovered at Rye (Box) (see Section 3.4.3) as well as the first Jurassic offshore field development in the German sector of the southern North Sea.

3 Hydrocarbon systems

Oil and gas play systems are developed in a number of Jurassic basins of the SPB area (Figure 10.11). These basins contain both source rocks and reservoir facies and their development as hydrocarbon systems are generally closely associated with their development as sedimentary basins, although variations in the timing of facies development may lead to different hydrocarbon developments in the same basins. Regional studies that suggest the fluvial systems in the Weald Basin are most probably sourced from the Lias Group (Wiseman & Milton, 1987). The Tertiary profile is at best marginally mature or substantively mature enough to have generated oil. Basin history diagrams suggest that oil generation and expulsion in the Jurassic successions of the East Midlands or contiguous southern North Sea.

The Oxford Clay Formation consists mainly of bituminous limestone, fossiliferous and calcareous mudstones, marls and siltstones, which are rich in organic material and have been studied extensively. Continental and paralic deposits dominate the Kimmeridgian and Volgian successions in the isolated Lower Saxony Basin. The Oxford Clay Formation consists mainly of bituminous fissile mudstones. The Oxford Clay Formation consists mainly of bituminous fissile mudstones, which are rich in organic material and have been studied extensively. Continental and paralic deposits dominate the Kimmeridgian and Volgian successions in the isolated Lower Saxony Basin. The Oxford Clay Formation consists mainly of bituminous fissile mudstones. The Oxford Clay Formation consists mainly of bituminous fissile mudstones, which are rich in organic material and have been studied extensively. Continental and paralic deposits dominate the Kimmeridgian and Volgian successions in the isolated Lower Saxony Basin.

3.2 Source-rock distribution and maturity in the Jurassic of the SPB area

The Lias succession of the East Midlands or contiguous southern North Sea.

3.2 Source-rock distribution and maturity in the Jurassic of the SPB area

The Lias succession of the East Midlands or contiguous southern North Sea.

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3.2 Source-rock distribution and maturity in the Jurassic of the SPB area

The Lias succession of the East Midlands or contiguous southern North Sea.

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The Lias succession of the East Midlands or contiguous southern North Sea.

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The Lias succession of the East Midlands or contiguous southern North Sea.
distribution of the formation due to severe erosion during later tectonic phases. There are additional oil occurrences in most of the Netherlands may be attributed to the patchy organic-rich mudstones are the principal source rocks for most of the oilfields in the eastern and central reservoirs, migrating preferentially to higher levels than oil during Tertiary uplift. They are best developed in the Netherlands, Germany and Poland where they are the significant source-rock reservoirs. Fields with Jurassic source rocks.

All the Jurassic oils studied from the Weald Basin are light crudes, with API gravities in the range of 35° to 42°, and are similar isotopically (Butler & Pullan, 1990). The closest match between oils and source rocks is also a known oil source rock in the German part of the basin, where it is part of the Buckeburg Formation. Moreover, the Lower Jurassic Aalburg Formation, with its type II source-rock characteristics, probably contributed to some degree to oil accumulations in the Dutch Central Graben (Wong et al., 1989) and West Netherlands Basin (de Jager et al., 1994). The intrustronic Clay Deep Member of the Eemseede Clay Formation in the northern part of the Dutch Central Graben also has oil-generating potential (Figure 10.13). However, the axial and stratigraphic extent of this member is much more limited than those of the equivalent and very productive "hot shale" in the Eemseede Clay Formations in the UK and Danish sectors of the North Sea. The coal-bearing strata of the Puzzle Hole, Middle Gravels, and Fosse Foul formation may have generated gas in place. However, the burial of these coals is considered insufficient to have yielded economic quantities (Wong et al., 1989).

The 2.7 to 70 m thick intrustronic black shales of the Olschoeder Formation are the main source rocks for oilfields in the Lower Saxony Basin, and the Gifhorn and Holstein troughs (Pienkowski & Schmalz, 2000).

3.2.1 Jurassic coals

Jurassic coals are rare in the UK area of the SPB; however, thin coal seams crop out in many places, for example, in the Efdale and Howslow hills within the paralic successions of the Ravenscraig Group in the Cleveland Basin (Saltwick and Goutham formations). These coals have been mined in the past for local fuel supplies. The coals are generally 0.15 to 0.3 m thick, but may be up to 0.6 m, and contain a rich, well-documented plant floral assemblage comprising horsetails, cycads, and conifers. Ginkgoales and Quercus are also common and often form large anthracitic fills or washouts of organic debris, but may also occur in upland or upland peat bogs. Vitrinite reflectance and other studies show that these Middle Jurassic coal-bearing sediments, which were reposed along the axis of the basin, reached the maturity zone for oil generation. This suggests that inversion of the basin during the Tertiary led to the removal of considerable thicknesses (>500 m) of Upper Jurassic and Cretaceous sediments (Montgomerie and Balder, 1982).

Within the intrustronic, fluvial-marine mudstones of the Jet River Member of the Upper Lias succession of the Cleveland Basin, there are concentrations of thin lenses, laminite and nodules of "jet", a hard, lustreous black lignite (compressed sewage sludge). Jet formed a basis of a once important local "jewellery" industry.

Figure 10.12 Distribution of Jurassic hydrocarbon reservoirs. Fields with Jurassic source rock.
from earliest times they were burnt as a coal substitute, and in Norfolk since the 17th century, but none yields in the range 312 litres/tonne. The term ‘oil shale’ is used where destructive distillation of a mudstone by the breakdown of broken rock. The term ‘oil shale’ is used where destructive distillation of a mudstone by the breakdown of organic matter in the form of kerogen, bitumen and mineral veins. The kerogens and bitumens extracted from the Kimmeridge Clay Formation oil shales show in resenes, asphaltenes and sulphur, and are similar to heavy oils and natural asphalts of tar sands and have a noticeable affect on the lithology of the rock, or where it imparts an organic smell to the freshly broken rock. The term ‘oil shale’ is used where destructive distillation of a mudstone by the breakdown of organic matter in the form of kerogen, bitumen and mineral veins. The kerogens and bitumens extracted from the Kimmeridge Clay Formation oil shales show in resenes, asphaltenes and sulphur, and are similar to heavy oils and natural asphalts of tar sands and sulphur content of the shales has proved a particular problem. The Kimmeridge Clay Formation crops not extensively in England from the Kimmeridge Bay type sections on the south coast of Dorset to the coastal seeps in Yorkshire, and continues at subcrop into the southern North Sea (Cox et al., 1981). The succession consists of almost entirely argillaceous shallow-marine mudstones, with local marine-influenced clastic depocenters. The succession is up to 560 m thick in the Weald Basin and is napped down in lower, middle and upper units in which a complex sequence of small-scale rhythmic cycles has developed. These are bound, thin, silty mudstones in the lower part of the succession, overlain by dark grey mudstones and pale grey calcareous mudstones; in the middle units, they are bituminous oil shales overlain by dark grey mudstones and pale grey calcareous mudstones. The upper part of the Kimmeridge Clay Formation consists of sandy and calcareous mudstones, but with no oil shales (Figure 10.14). Many of these individual cycles can be correlated over tens of kilometres (Cox & Gallois, 1981). There are oolitic-rich mudstones throughout the formation, but oil shales are confined to five specific intervals known as the Lower Kimmeridge, Upper Kimmeridge, Lower Portlandian and Portlandian. Most of these oil shale intervals can be traced at outcrop from Dorset into West Yorkshire and offshore into the Solway Firth Basin. The potential oil yields, as determined by two SP/Res-Eval methods, range from 10 to 85 USG/US ton but are mostly in the range 20 to 55 USG/US ton. The yields for a particular source are relatively constant over large areas. The ‘shale-oil’, as defined by pyrolysis at 500°C, are markedly different from naturally occurring crude oils in their physical and chemical properties. They are poor in hydrocarbons and rich in resenes, asphaltenes and sulphur, and are similar to heavy oils and natural asphalts of tar sands and mixed source rock in some basin areas when their depth of burial was greater, for example, in the Weald Basin, south Dorset and North Yorkshire. Fuels, oil, bituminous shales with sparse thin oil-shale horizons are also found within the lower Taconian Oil Shale Formation in the Cleveland Basin. The mudstones are part of the Jet Rock Member, which is in part coeval with the more extensive organic-rich mudstone developments of the Poznański Shale Formation of mainland Europe. Large reserves of organic material can be considered an oil shale.


3.1 Oil and gas generation and migration during the Jurassic

Hydrocarbon generation from the SPA Group in the UK probably began in the deepest parts of the Weald Basin in Early Cretaceous times (Penn et al., 1987), with peak generation in the mid- to Late Cretaceous. The Oxford Clay Formation was deposited in the deepest parts of the basin in latest Triassic times and the Kimmeridge Clay Formation probably reached maturity in the very centre of the basin at about the same time (Penn et al., 1987; Butler & Pullan, 1990). The lower part of the Kimmeridge Clay Formation is restricted to the southernmost part of the Weald Basin in Late Cretaceous times. Tertiary uplift progressively lifted the source rocks out of the temperatures and pressures required for hydrocarbon generation such that it had effectively ceased by Miocene times, although it may have continued in the less disturbed western areas. SPoil led to an important second phase of oil migration and re-formation of both oil and gas as a result of tectonic activity and destruction of many earlier traps. The phase of migration is supported by the fact that many reservoirs appear to have been invaded by the presence of hydrocarbons in some early-formed structures.

Migration pathways in the Weald Basin were influenced by both sedimentary and tectonic factors. The presence of three major widespread fauna mudstone/clay sections created three vertically separated fluid regimes with reservoir intervals of the Triassic, the Middle Jurassic and the Upper Jurassic. The Great Oolite is the best studied and documented of these pathways, and it permitted movement well away from the mature source area, although its effectiveness would have been reduced with time as progressive diagenetic processes took effect. For example, the Stockbridge and Gobions fields are situated some 30 km away from the postulated edge of maturity in the Weald Basin (which also demonstrates the effectiveness of the Oxford Clay Formation seal; Butler & Pullan, 1990). Tectonic controls on migration were provided by faults. There is a clear relationship between major faults and the occurrence of multiple reservoir horizons with hydrocarbons at both shallow and deeper levels, with hydrocarbons distributed throughout the stratigraphic column in areas strongly affected by Tertiary inversion. Movement along faults seems likely, because reservoir-reservoir juxtapositions are not seen and hydrocarbons are often found when drilling through fault planes (Butler & Pullan, 1990).

The main oil source in the Netherlands is the Poldervaart Shale Formation, which is preserved only in the rift basins. Although the Kimmeridge Clay Formation is a prolific source in the Central and Northern North Sea basins, it has not been a significant source of oil in these northern rift basins. Oil generation from the Lower Jurassic probably began in Late Jurassic to Early Cretaceous times and migration has been restricted largely to the rift-basin areas. It is thought that there has been limited gas generation from the real-earthing Jurassic successions of the Dutch Central Graben (De Jager & Solbak, 2007).

The oil generated in the Jurassic successions of Denmark was probably derived primarily from the organic-rich shales of the Upper Jurassic Farsund Formation; the upper part of the formation is generally considered to be the most oil-prone. However, the oil accumulations of the Laila and Fladmark fields in the Danish Central Graben are sourced from Middle Jurassic fluvial and paralic basins (type II kerogens) (Carr & Petersen, 2004).

Oil generation from the principal source rocks in Germany, the Pölling und Schleswig formations, probably took place following basin inversion during Late Cretaceous to Early Cretaceous times (see Chapter 9). No oil occurrences are known in the Jurassic successions of Belgium or Poland.

3.4 Reservoir rock units within the Jurassic

There are no proven hydrocarbon reservoirs within the SPA area in the Jurassic of Belgium or Poland. There are a number of both clastic and carbonate potential reservoir units in the Jurassic successions of the UK within the SPA area, although hydrocarbon fields are proven only in the Jurassic of the Weald Basin. The major reservoirs in the basin are the Middle Jurassic (Bathonian) Great Oolite Group limestones in which oil was first discovered in Storrington in 1986. These limestones form reservoirs in the Rye Gown, Hambleton, Geestmoor, Singleton and Kedderholt oilfields, and in the undeveloped Bunter’s Cape and Lidsey discoveries (Trenear, 2003). Oil production is from wells in the western half of the basin, as the quality of the reservoir decreases to the east due to factors varying and variable diagenetic history (McLellan & Védrich, 1987; Scott & Colley, 1987). For data availability on reservoir quality, which may be significantly affected by diagenesis. The best primary reservoir property in the Great Oolite Group limestones is developed in well-sorted, oolitic and bioclastic grainstones and relatively clean packstones (McLellan & Védrich, 1987). The basin has seen a history of petroleum generation ranging from less than 5% to in excess of 25% in Storrington 1 (McLellan & Védrich, 1987). The evolution of porosity and permeability is particularly dependent on the reservoir times in the freshwater diagenetic environment. Short residence times provided some early compaction, but the production framework support and protection during subsequent burial and compaction, whereas long residence times have significantly reduced the porosities. These variations are illustrated by the porosities...
of 11.5% in Bates’ Upper Cretaceous and Palaeocene Wood, whereas the Great Orme Limestone in Normandy 1 and Benoe shows that nearly all porosity is excluded by early fringe cements (McKearn & Mallick, 1987).

Three principal phases of cementation have been recognised (Selley et al., 1989). Early calcite-cementation is followed by late-stage, high-calcium, dolomite with associated opaline, and finally by low-calcium, dolomite with associated opaline cement. The late-stage cement is the Storrington oilfield, where gas break-out may have occurred during Tertiary uplift and tilting of pre-existing structures. Many reservoirs have oil columns with a gas cap, with the younger reservoirs generally containing more gas (De Jager et al., 1990).


depended on low energy, wave-dominated environments with no significant clastic input. It is thought that the present Sand Formation and the Corallian Group limestones and sandstones may have only minor hydrocarbon potential in the Mesozoic Basin. The Bridgford Sand Formation is poorly developed in the basin, and there does not appear to be an effective seal between this level and the Inferior Oolite and the Great钦 Oak Group. The Inferior Oolite Group limestones have had interesting shows. The lower beds of the Corallian Group may provide an effective seal, and the southern and eastern parts of the basin where carbonates from the reservoir in the Bletchingley gas discovery. The upper beds of the Corallian Group similarly have their greatest potential in the east-west trending belt just south of the London-Badhurst Platform, whereas the thickest sandstones are developed. The Palaeo Wood oilfield has established a large reservoir in the central structures. Structures occur along the Pewsey-London Platform and Wardour-Portsdown structures. Their prospectivity remains to be determined. Although it was inhibited from forming in the crests of pre-Tertiary structures, it does seem to occur in the crests of Tertiary structures.

To the depositional environments prevailed at the time, most of the Jurassic reservoirs are of better quality around the margins of the Weald Basin, with significant detritus in quality towards the basin center (Poncet et al., 1987; Butler & Pullan, 1985). Most of the Jurassic sediments in the Weald Basin depend on low energy, wave-dominated environments with no significant clastic input. It is thought that the present Sand Formation and the Corallian Group limestones and sandstones may have only minor hydrocarbon potential in the Mesozoic Basin. The Bridgford Sand Formation is poorly developed in the basin, and there does not appear to be an effective seal between this level and the Inferior Oolite and the Great钦 Oak Group. The Inferior Oolite Group limestones have had interesting shows. The lower beds of the Corallian Group may provide an effective seal, and the southern and eastern parts of the basin where carbonates from the reservoir in the Bletchingley gas discovery. The upper beds of the Corallian Group similarly have their greatest potential in the east-west trending belt just south of the London-Badhurst Platform, whereas the thickest sandstones are developed. The Palaeo Wood oilfield has established a large reservoir in the central structures. Structures occur along the Pewsey-London Platform and Wardour-Portsdown structures. Their prospectivity remains to be determined. Although it was inhibited from forming in the crests of pre-Tertiary structures, it does seem to occur in the crests of Tertiary structures.

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where several sandstones in the Upper Jurassic Central Graben Group contain light oil (about 55° API) with gas. The volume of oil initially in place in this field is about 100 million barrels (16 m³). Other Jurassic oil accumulations have been found at POS-FA, F15-FA, F17-FA, F17-8, F18-FA, L01-FA, L02-FA and L05-FA. Gas cap are present in POS-FA and F18-FA, whereas main gas is trapped in POS-FA. Most of these hydrocarbons have been generated from the Posidonia Shale Formation, with minor contributions from the Lower to Upper Graben formation sandstones of the Bryne and Lulita formations (Figure 10.9). Two main fault trends cross-cut the field (west-north-west and north-south trending) withthrows varying between 10 and 100 m. Many of the faults are open to flow as shown by production behaviour and acquired 4D seismic data. The combined-bore gas is sourced mainly from the Jurassic Posidonia shale (Transitional age), which is mature in large parts of the Central Graben area (Figure 10.2). The gas seal is formed by intraformational shales.

The Lower to Upper Graben formation sandstones are of Galliennes to Oxfordian age and belong to the Central Graben Subgroup, which in turn part of the Schelkland Group. The sediments were deposited in an active marine environment. The west–east-parallel tabular-faulted sequences resulted in a complex facies distribution comprising a highly heterogeneous combination of sands, cherts and coals that can not be generally correlated (Figure 10.20). The best reservoirs are tidal channel and channel sands.

The Lower Graben Formation comprises alternating sandstones and shales of up to 50 m thick, with individual sandstone bodies between 10 and 20 m thick (Figure 10.21). The Middle Graben Formation consists of three stacked sand bodies with thicknesses up to 15 m, 11 m and 4 m respectively. The sand bodies are separated by shales and they pinch-out to the south-east. The Upper Graben Formation is up to 110 m thick and is a sequence of alternating sandstones and shales; individual sandstone bodies are up to 30 m thick. The Lower Graben reservoir is by far the most important accumulation as it contains 72% of all hydrocarbons.

### Table 10.1. Properties of the Palmers Wood Field

<table>
<thead>
<tr>
<th>Property</th>
<th>Lower Graben Formation</th>
<th>Middle Graben Formation</th>
<th>Upper Graben Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithology</td>
<td>Sandstone</td>
<td>Sandstone</td>
<td>Sandstone</td>
</tr>
<tr>
<td>Depth to top (m)</td>
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<td>2805</td>
<td>2475</td>
</tr>
<tr>
<td>Initial pressure (bar)</td>
<td>81.4</td>
<td>100</td>
<td>100</td>
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<tr>
<td>Maximum column height (m)</td>
<td>12.9</td>
<td>12.8</td>
<td>12.8</td>
</tr>
<tr>
<td>Net to gross ratio</td>
<td>0.6-0.8</td>
<td>0.70-0.75</td>
<td>0.70-0.85</td>
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<tr>
<td>Porosity (%)</td>
<td>21</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Permeability (mD)</td>
<td>0.6-300</td>
<td>1000-2000</td>
<td>0.2-2000</td>
</tr>
<tr>
<td>Initial pressure (bar)</td>
<td>65</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>Temperature (°C)</td>
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<td>127</td>
<td>127</td>
</tr>
<tr>
<td>Source rock</td>
<td>Evaporite</td>
<td>Evaporite</td>
<td>Evaporite</td>
</tr>
<tr>
<td>Seal</td>
<td>Kimmeridge Clay Formation</td>
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</tr>
</tbody>
</table>

### 3.6.2 F03-FB gas field, offshore Netherlands

#### Table 10.2. Properties of the F03-FB field

<table>
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<tr>
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<td>0.2-2000</td>
</tr>
<tr>
<td>Initial pressure (bar)</td>
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<td>65</td>
<td>65</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>127</td>
<td>127</td>
<td>127</td>
</tr>
<tr>
<td>Source rock</td>
<td>Evaporite</td>
<td>Evaporite</td>
<td>Evaporite</td>
</tr>
<tr>
<td>Seal</td>
<td>Kimmeridge Clay Formation</td>
<td>Kimmeridge Clay Formation</td>
<td>Kimmeridge Clay Formation</td>
</tr>
</tbody>
</table>

### 3.6.3 F15-B gas field, offshore Netherlands

The F15-B field is located in the F15 block approximately 140 km north of Den Helder (Figure 10.22). In 1986, the Transect Volpriehausen sandstone was proven to be a gas-bearing by discovery well F15-1. One of the appraisal wells of this Dutch offshore basin was the F15-4. This was finally confirmed by the F15-9 exploration well, drilled in 1998. The F15-B field started production in the same year. The field is operated by Tullow (26.2%) with EEM (16%), Dyes (8.62%) and Lomond (2.8%) as partners. The F15 block lies between the eastern limit of the Dutch Central Graben and the north-western limit of the Tannachell basin on the south-eastern edge of the Schell Graben high (Figure 10.23). During Late Jurassic times, the area differentiated into rapidly subsiding basins, such as the Dutch Central Graben, and stable platforms such as the Schell Graben high. Thick packages of Upper Jurassic sediments were deposited in the deep basins whereas outside the basins they are thin, although where found they occur in sequences in rim-synclinal structures (Figure 10.23). The F15-B field is part of such a structure. It forms the eastern flank of a south-west–north-east trending rim-syncline, which is indicated by the fan-shaped geometry of the Upper Jurassic successions. The structure is controlled by a south-west–north-east trending salt diapir, and its top is cut by faults with relatively small displacements trending N 10° and N 160°. Salt-creep, and ultimately salt-spreading during Late Jurassic–earliest Cretaceous times led to thickness variations in the Upper Jurassic series with sequences pinching out to the east. The overlying Clay Deep Member forms an efficient seal for the F15-B reservoir. The source rocks are inferred to be the Carboniferous Coal Measures (Figure 10.3).
Figure 10.20  Well log and lithostratigraphy from representative well section F03-05-S1 in the F03-FB field.

Figure 10.21  Core photograph of sediments from the Lower Graben Formation. Figure 10.22  Structural elements of the F15-B gas-condensate field area.
The Scruff Group sandstones correspond to siliciclastic platform sediments deposited in a storm-controlled reef to shelf setting. The sandstones are fine-grained and strongly bioturbated with glauconite and sponge oplodes (Figure 10.24). Sponge colonies developed in the shallow water owing the salt diapirs and were later sealed to become a controlled product of the upper offshore transition zone. The base part of the Scruff reservoir is more sandy and displays reservoir characteristics that are slightly poorer than the oplode member that forms the main part of the reservoir. Porosity is linked mainly to the solution of the sponge oplodes and therefore is better in the upper reservoir. Despite the good permeabilities, the porosities are highly variable, ranging between 0.45 and 2.5 m².

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Scruff Depositional System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithology</td>
<td>Glauconitic sandstones and argillaceous sandstones</td>
</tr>
<tr>
<td>Grain size</td>
<td>1.45</td>
</tr>
<tr>
<td>Net reservoir thickness (m)</td>
<td>88</td>
</tr>
<tr>
<td>Net to gross ratio</td>
<td>74.7</td>
</tr>
<tr>
<td>Permeability (mD)</td>
<td>20.2</td>
</tr>
<tr>
<td>Porosity (%)</td>
<td>22-25</td>
</tr>
<tr>
<td>Fluid type</td>
<td>Gas</td>
</tr>
<tr>
<td>Source rock</td>
<td>Wettability, Cold Maturity</td>
</tr>
<tr>
<td>Seal</td>
<td>Clay Deep Member</td>
</tr>
</tbody>
</table>

**Table 10.3 Properties of the F15-A field.**

### 3.6.4 Mittelplate oilfield, offshore Germany

The Mittelplate field is located in the Jurassic West Helgoland Trough in the German Munden Sea (Figure 10.25). It is about 100 km south-west of Helgoland. It was discovered in 1980 by the Deutsche Termoil A.G. Mittelplate 1, which penetrated oil-saturated Middle Jurassic sandstones. Its original oil in place was estimated to be 1.7 bscf (9.4 x 10⁸ m³) in 1981 and confirmed a large oil accumulation approximately 7 km wide (x-axis) and 15 km long (y-axis). Two separate hydrocarbon columns were found, one in the Middle Jurassic (the “beta” sandstones and the other in the Middle Jurassic (the “gamma” sandstones), with a maximum of 17 m true stratigraphic thickness in the east and 20 m true stratigraphic thickness in the west. The reservoir is characterised by its low permeability and poor reservoir quality, which is due to the thick overburden and the high level of bioturbation. The reservoir section is divided into two main zones: the lower reservoir, which is composed of the “delta” sandstones, and the upper reservoir, which is composed of the “beta” sandstones.

**Figure 10.26 Schematic section across the Mittelplate oilfield.**

**Table 10.4 Properties of the Mittelplate field.**

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Middle Jurassic</th>
<th>Middle Jurassic</th>
<th>Middle Jurassic</th>
<th>Middle Jurassic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source rock</td>
<td>Dogger “beta” (grounded)</td>
<td>Dogger “gamma” (grounded)</td>
<td>Dogger “delta” (grounded)</td>
<td>Dogger “beta” (grounded)</td>
</tr>
<tr>
<td>Lithology</td>
<td>Sandstone</td>
<td>Sandstone</td>
<td>Sandstone</td>
<td>Sandstone</td>
</tr>
<tr>
<td>Depth to top (m)</td>
<td>2400</td>
<td>1900</td>
<td>1900</td>
<td>1900</td>
</tr>
<tr>
<td>Net reservoir thickness (m)</td>
<td>6-17</td>
<td>6-17</td>
<td>6-17</td>
<td>6-17</td>
</tr>
<tr>
<td>Permeability (mD)</td>
<td>15-24</td>
<td>15-24</td>
<td>15-24</td>
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</tr>
<tr>
<td>Fluid type</td>
<td>Oil</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 10.27 Sequence stratigraphy and tectonic events in the Mittelplate oilfield.**