Department of Energy & Climate Change

The prospectivity of the English Channel

Promote United Kingdom 2015

Abstract

This poster summarises the hydrocarbon geology of the English Channel from Prawle Point (Devon) in the west to the Straits of Dover (Kent) in the east and as far south as the UK-France median line. This area of 23,000 km² forms part of Strategic Environmental Assessment SEA8. Apart from a coastal strip between Portland Bill and the Isle of Wight (Fig. 3), the offshore area is unlicensed.

The study area is transected by a sparse grid of 2D seismic data, the most recent of which were shot in the 1990s. A total of 23 wells have been drilled since 1978.

Mesozoic strata, which form the only proven petroleum system in the area, occur in the offshore continuation of the Weald Basin and in the Central English Channel Basin, which lies south of the major Purbeck-Isle of Wight structure.

Source rocks occur in the Lias, Oxford Clay and Kimmeridge Clay (all Jurassic), while the principal reservoirs comprise the Sherwood Sandstone (Triassic) and Bridport Sands (Lias) in the Central English Channel Basin and the Great Oolite (Middle Jurassic) in the offshore Weald Basin.

At present hydrocarbon discoveries are restricted to the area north of the Purbeck-Isle of Wight structure, and include the offshore extension of the Wytch Farm Oil Field (Sherwood and Bridport Sandstone reservoirs) and the 98/11-2 Sherwood Sandstone discovery. Across the Central English Channel Basin the wells contain numerous minor indications of oil and gas, but a viable structure has yet to be found.

The major exploration risk is associated with Tertiary compression and resultant uplift and fault reactivation and reversal. Some areas have experienced 6,000 feet of uplift, most of which postdates the primary phase of hydrocarbon generation and migration. Valid trap generation has to rely on immunity from trap breaching (as at the Wytch Farm Oil Field) or re-migration or late migration (as at the Kimmeridge Oil Field).

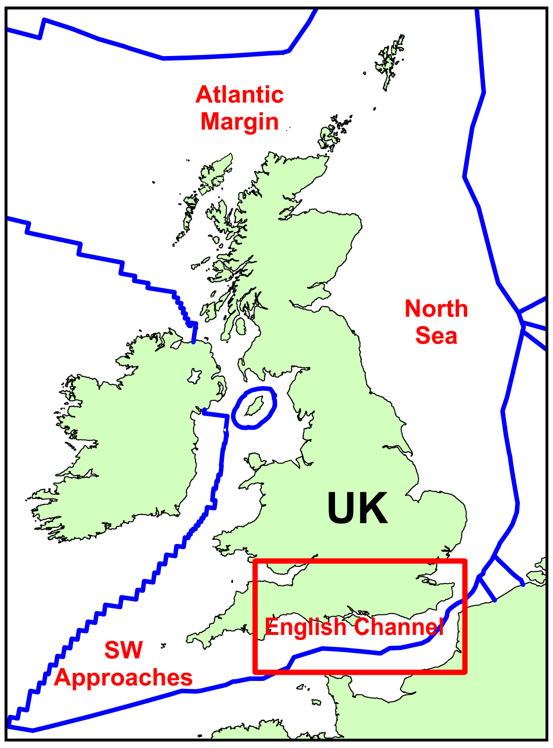


Fig. 1 Location map

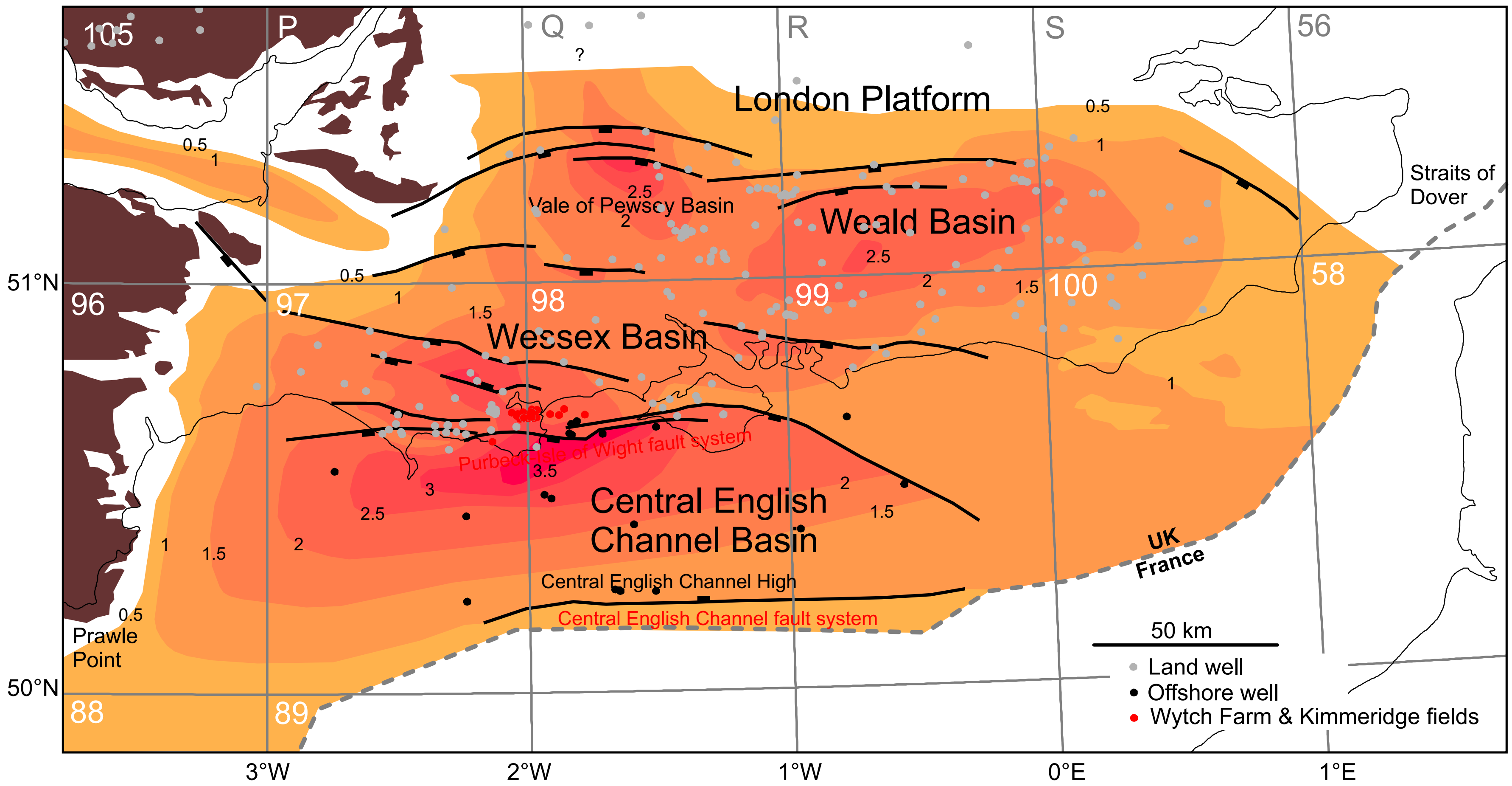


Fig. 2 The Permian to Jurassic structural framework of the Weald, Wessex and Central English Channel basins. The contours are depths to the top of the pre-Permian surface (in kilometres). The outcrop of Carboniferous and older strata is shown in brown.

1. Exploration history

Onshore in southern England, the first discovery of hydrocarbons dates from 1896 when gas was found at Heathfield (Kent). Later, oil was discovered at Kimmeridge (Dorset) in 1959 and, most importantly, at Wytch Farm (also Dorset) in 1974.

The first well to be drilled offshore was Lulworth Banks 1 (under an onshore licence). Completed in 1963 just 3.3 km off the Dorset coast, this well tested a large domed structure and found uncommercial gas in the Kellaways and Bridport sandstones.

The drilling of two wells on the Central English Channel High followed the 5th Offshore Licensing Round in 1978-79. The initial search was for a Kimmeridge look-alike, but it wasn't until a later phase of drilling in 1983-84 that gas was found in 98/11-2.

Further wells were drilled in the late 1980s and 1990s, with the only success being the proving that the Wytch Farm Oilfield extends offshore into Bournemouth Bay. Gas was also found in Southard Quarry 1 (on the Purbeck peninsula) in 1989, but the well was not tested.

In total, 23 exploration and appraisal wells have been drilled in the UK sector of the English Channel. The only wells drilled south of the Central English Channel High have been in French waters (no data from these are available).

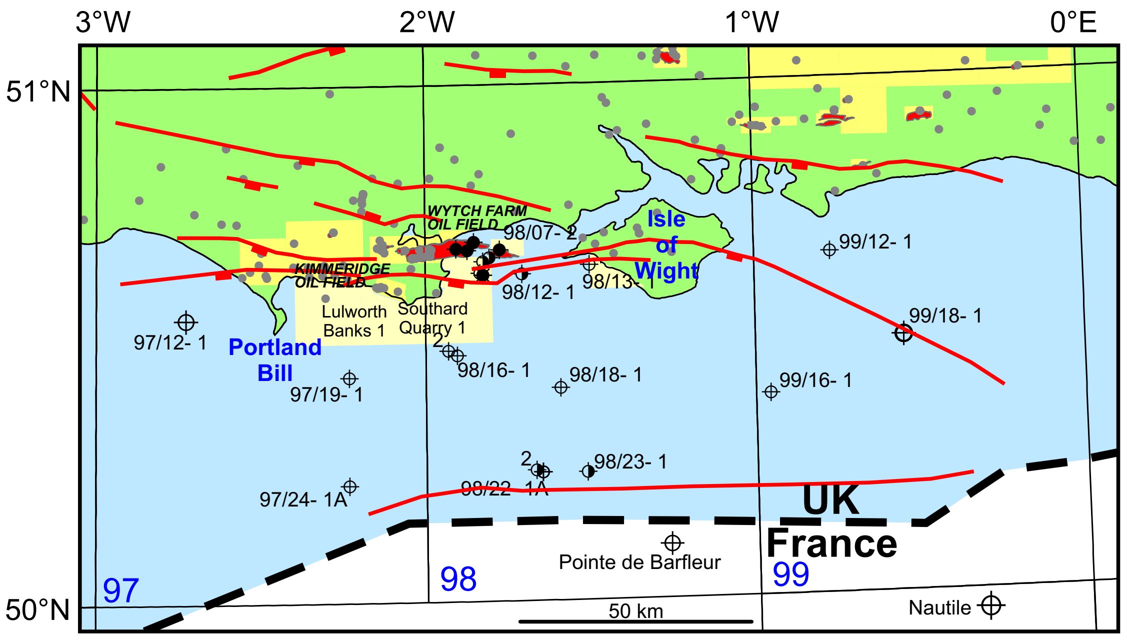
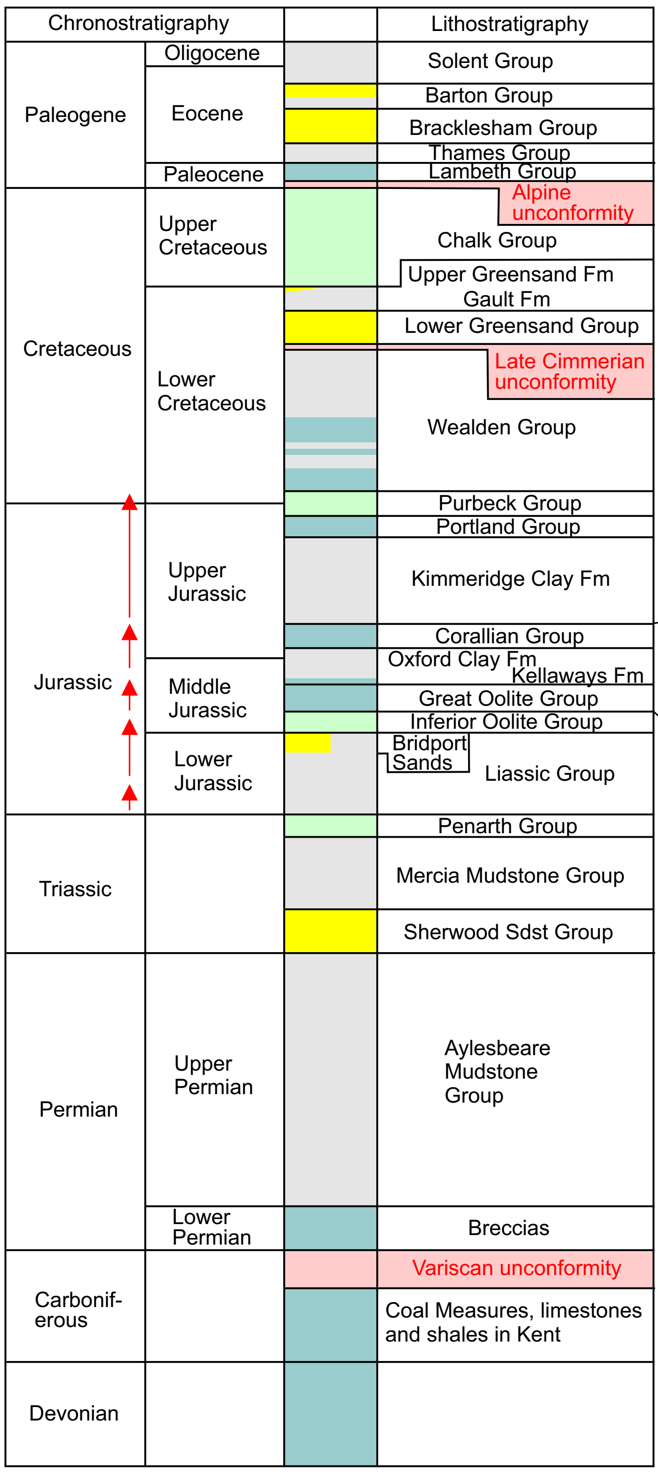


Fig. 3 Location map showing wells drilled in southern England and the English Channel. Oil fields and discoveries are shown in red and onshore wells by grey dots. Licensed acreage as of October 2014 (onshore and offshore) is shown in yellow.



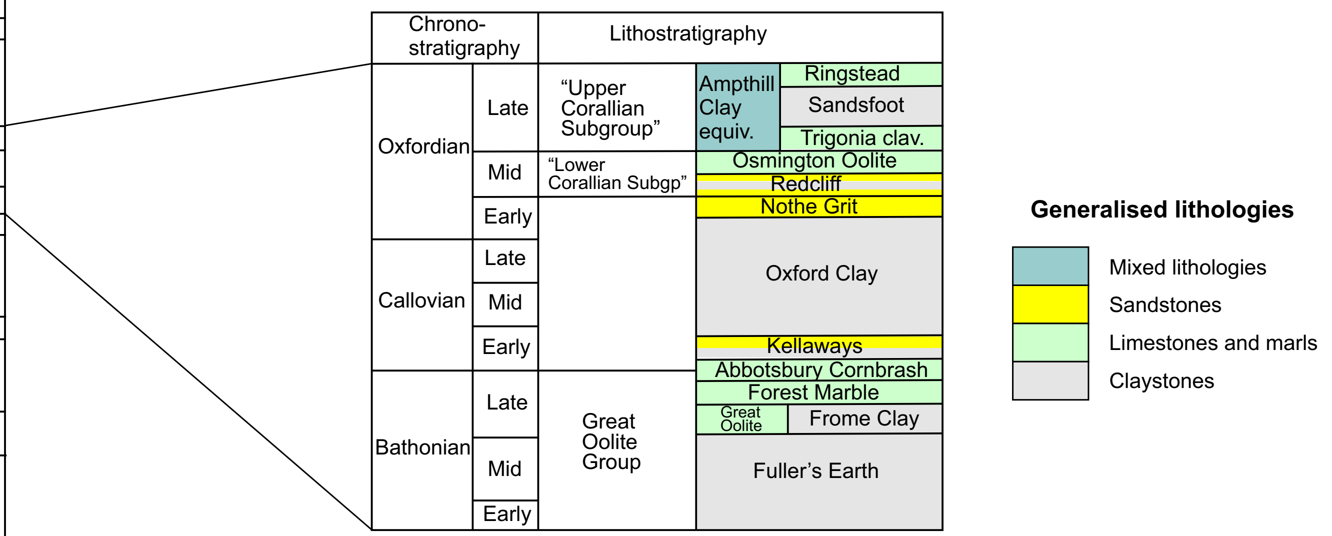


Fig. 4 Lithostratigraphy

2. Stratigraphy

The stratigraphic succession beneath the English Channel bears many similarities with that found onshore in the Weald and Wessex basins, particularly that found along the Dorset coast, although there are considerable facies changes across these basins which result in a complex and variable stratigraphy.

Three major unconformities subdivide the succession into four major sequences: (a) the Devono-Carboniferous sequence followed by the Variscan unconformity, (b) the Permian to Lower Cretaceous interval followed by the Late Cimmerian unconformity, (c) the Lower Greensand to Chalk interval followed by the Alpine unconformity and finally (d) the Paleogene.

The major controls on sedimentation are those of intermittent synsedimentary faulting and subsidence, and also successive phases of relative sea-level rise and fall. During the Jurassic, for instance, five depositional sequences are recognised, each of which displays a "shallowing upwards" profile. On a smaller scale, each sequence itself contains evidence of "shallowing upwards" cycles (e.g. within the Great Oolite Group).

3. Reservoirs and plays

Five reservoirs define five distinct hydrocarbon plays in the English Channel area. These are the same plays that are present onshore, where they all have proven reserves in fields and discoveries. Only two plays have so far proved successful offshore (marked * below).

3.1 Sherwood Sandstone Play*
3.2 Bridport Sandstone Play*
3.3 Great Oolite Play
3.4 Corallian Carbonate Play
3.5 Portland Carbonate Play

3.1 Sherwood Sandstone Play

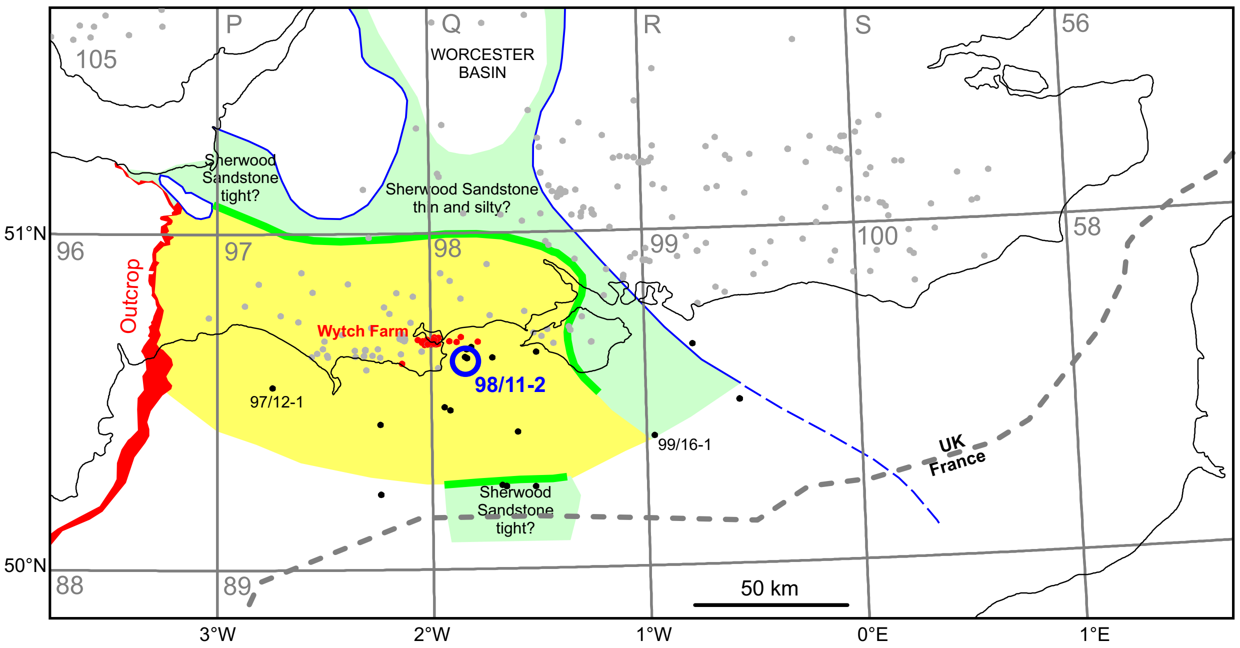


Fig. 5 Distribution of the Sherwood Sandstone Play in southern England and the English Channel (based on Penn *et al*. 1987)

Offshore, the Sherwood Sandstone Group thickens from 56 ft (of conglomerate) in well 99/16-1 to 993 ft of interbedded sandstone, siltstone and claystone in well 97/12-1, off the Dorset coast. This compares with c. 560 ft at the Wytch Farm Oil Field.

Deposition took place in a continental, braid-plain and playa-margin environment. The heterogeneous facies contain some highly porous zones.

Despite the presence of 754 million bbl STOIIP in the Wytch Farm onshore oil field (Underhill & Stoneley 1998), the offshore drilling has yet to yield any noteworthy hydrocarbon shows other than those in well 98/11-2. This is largely due to the special structural situation required to allow oil migration from Jurassic source rocks into the stratigraphically much lower Sherwood Sandstone.

Sherwood Sandstone Group in 98/11-2:

Gross thickness: 464 ft
Net:Gross: 0.72
Average porosity: 8%

DST 2 flowed 9.6 mmscf/d and 170 BCPD (48/64" choke)
DST 1 flowed 23.5 bbl oil in 1 hour

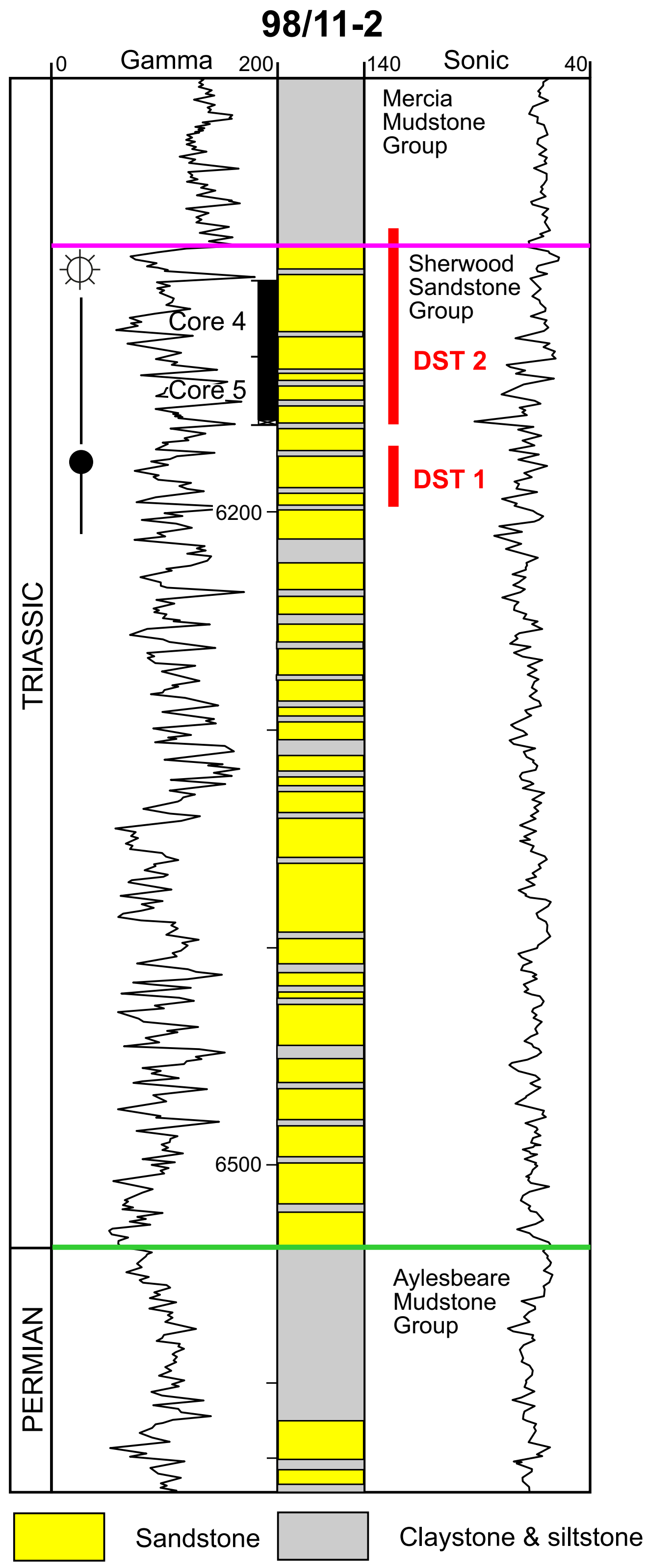


Fig. 6 Well log across the Sherwood Sandstone Group in well 98/11-2

3.2 Bridport Sands Play

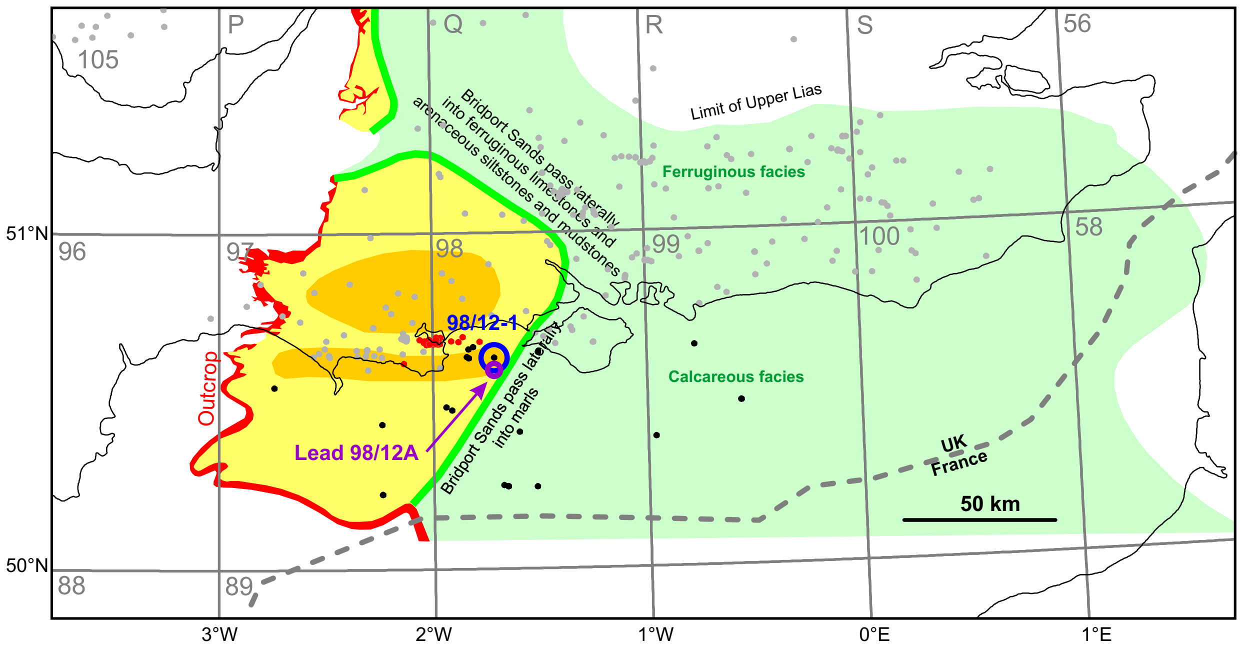


Fig. 7 Distribution of the Bridport Sands Play in southern England and the English Channel (based on Penn *et al*. 1987). See key below

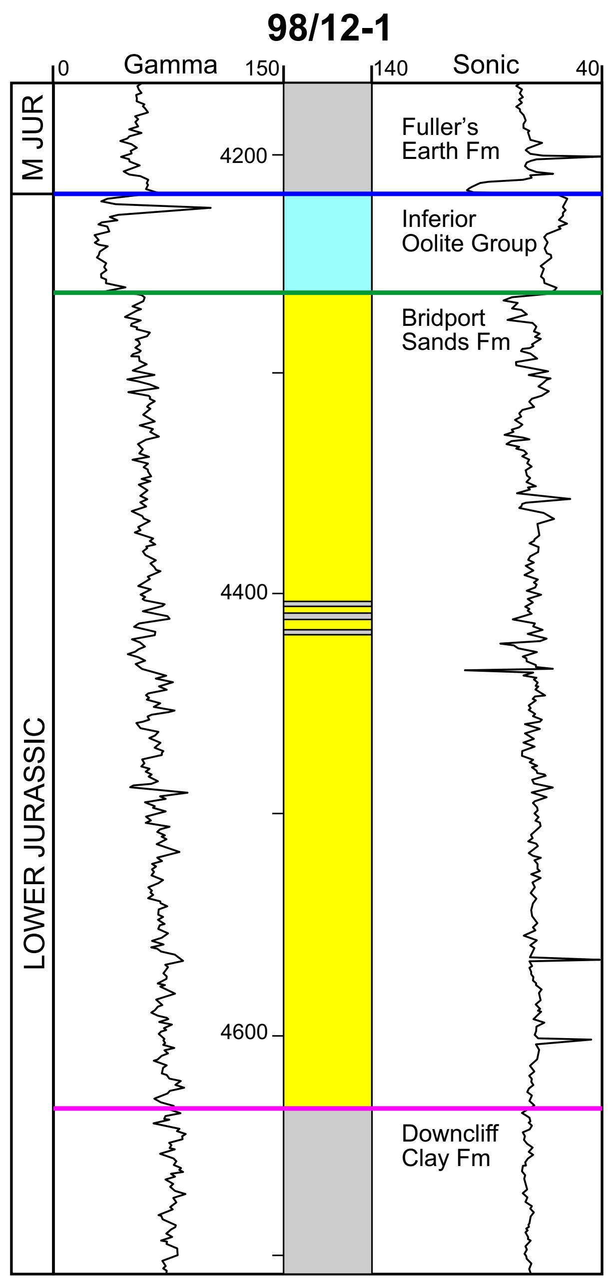
The Bridport Sands are well developed in the proximity of the Dorset coast. At the Wytch Farm Oil Field the unit is 150-240 ft thick (Colter & Havard 1981) and south of the Purbeck Disturbance, an active Liassic fault, 280 ft was drilled in well 98/16-2, 308 ft in well Southard Quarry 1 on the Isle of Purbeck (Dorset) and 370 ft in well 98/12-1. The unit thins rapidly to the south (114 ft in well 97/19-1 and 66 ft in well 97/24-1A) and is represented by a calcareous facies further to the east and south-east (e.g. well 98/18-1) and a ferruginous facies fringing the London Platform (both areas being starved of clastic input).

The Bridport sands were deposited in a shallow-marine, migrating barrier bar environment. Although heavily bioturbated, local small-scale cross-bedding indicates the presence of currents and some authors suggest that the abundant nodular beds (formed as a consequence of a high calcareous bioclastic component) indicate the influence of storms.

In addition to the 120 million bbl STOIIP reservoired in the Wytch Farm Oilfield (Underhill & Stoneley 1998), Lulworth Banks 1 and Southard Quarry 1 had gas shows in the Bridport Sands and these may be commercially viable. Well 97/19-1 had oil shows and core porosities up to 23% at the top of a coarsening-upwards sandstone unit.

Bridport Sands Formation in 98/12-1:

Gross thickness: 369 ft
Net:Gross: 0.9
Porosity: unknown



Sandstone | Claystone & siltstone | Limestone | All depths are in feet below KB

Fig. 8 Well log across the Bridport Sands Formation in 98/12-1

3.3 Great Oolite Play

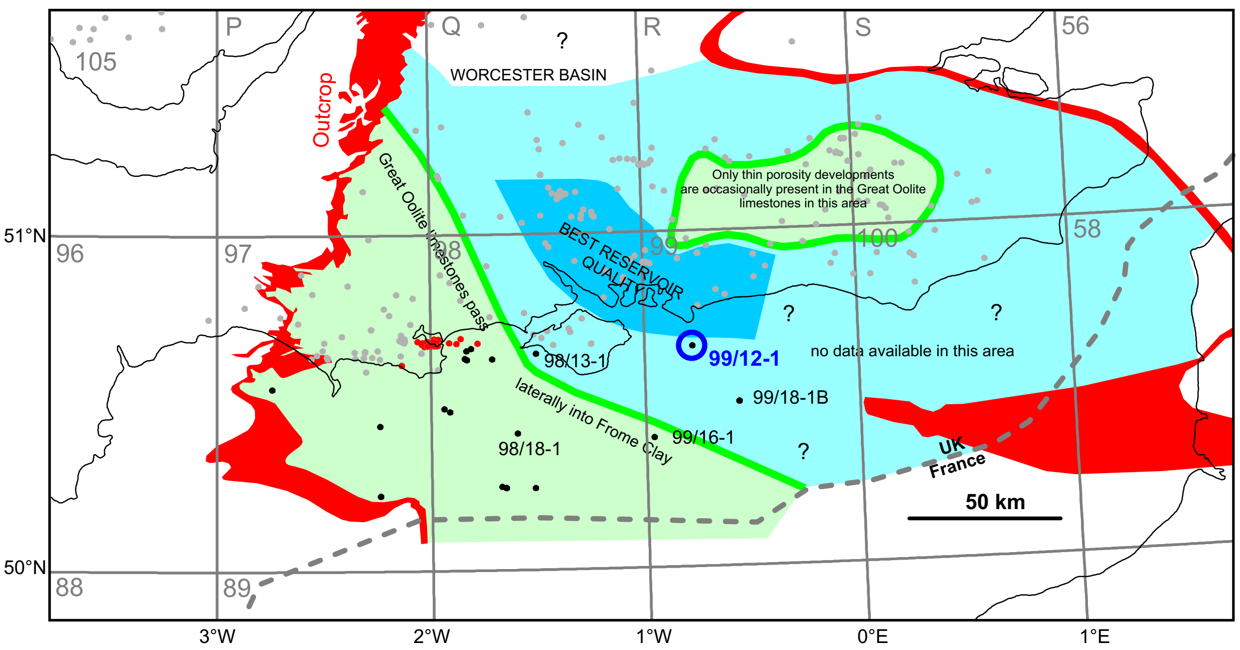
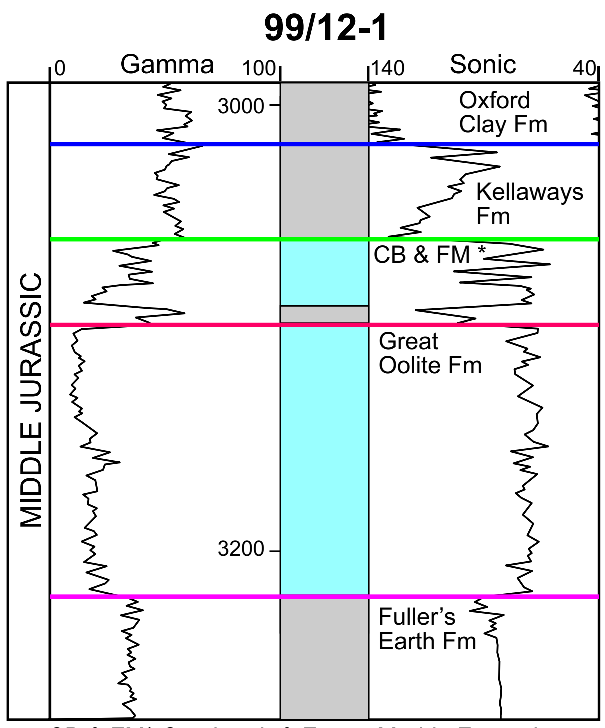


Fig. 9 Distribution of the Great Oolite Play in southern England and the English Channel (based on Penn *et al*. 1987). See key below

Limestones of the Great Oolite Formation, which in an oolitic shoal facies form a key reservoir in the western Weald Basin, are only present in the three north-easternmost English Channel wells: with 129 ft present in 99/12-1, 120 ft in 99/18-1B and 97 ft of cryptocrystalline limestone with minor oil shows in well 98/13-1 off the south-west coast of the Isle of Wight. Carbonates are also predicted in the eastern English Channel where there are currently no wells.

To the west the limestones grade into the argillaceous facies of the Frome Clay. Well 99/16-1 contains a transitional facies, with thin limestone units in an otherwise argillaceous succession. A poor show is recorded from some argillaceous limestone and marl in well 98/18-1.

Sandstone reservoir (high risk play)
Sandstone reservoir (low risk play)
Non-reservoir facies
Carbonate reservoir (high risk play)
Carbonate reservoir (low risk play)
Land well • Offshore well
Wytch Farm & Kimmeridge fields



CB & FM* Cornbrash & Forest Marble Formations

Claystone & siltstone
Limestone

All depths are in feet below KB

Great Oolite Formation in well 99/12-1:

Gross thickness: 119 ft
Net:Gross: 1.0
Porosity: unknown

Fig. 10 Well log across the Great Oolite Formation in well 99/12-1

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3.4 Corallian Carbonate Play

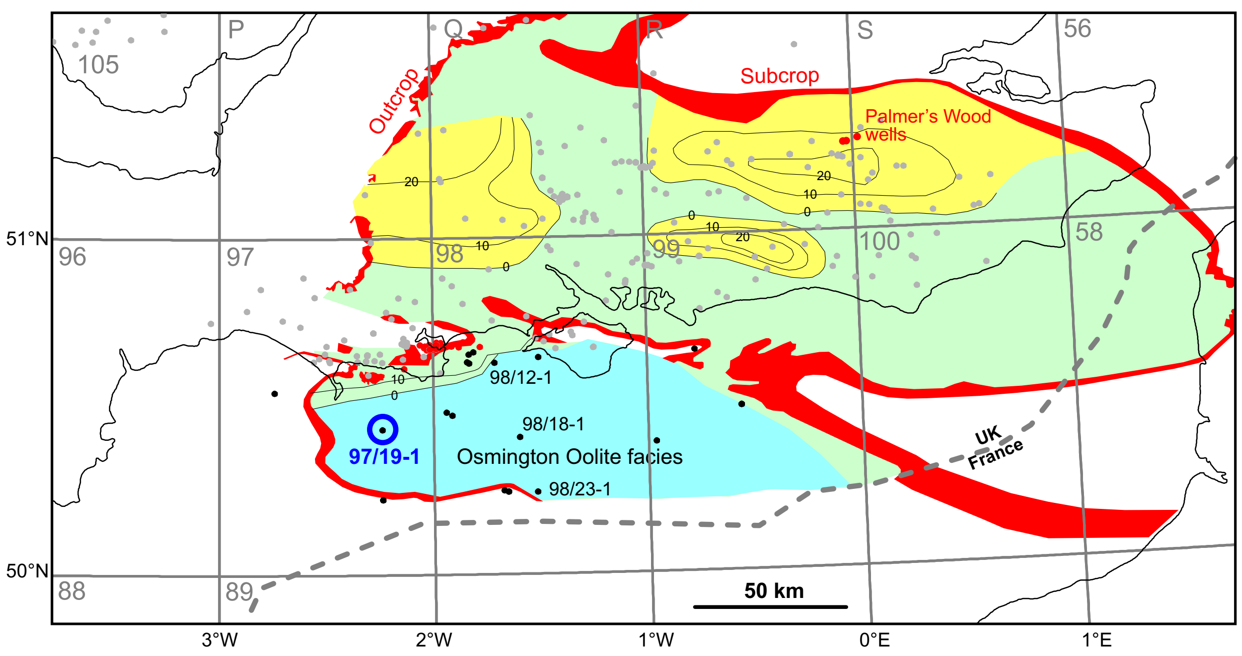
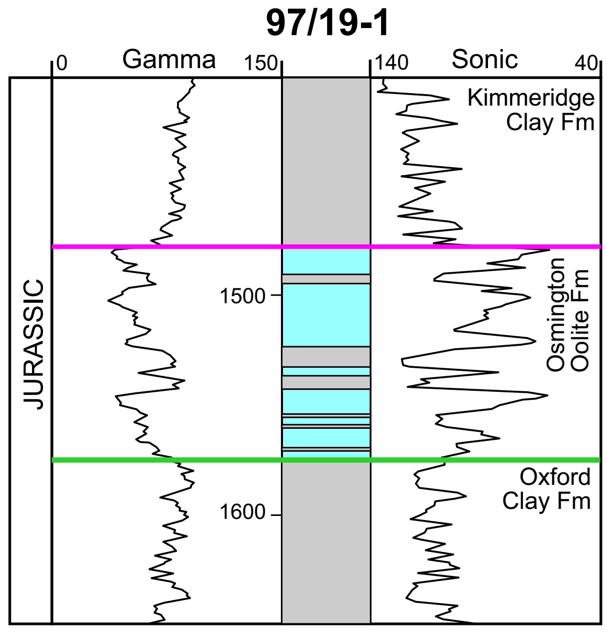


Fig. 11 Distribution of the Corallian Carbonate and Sandstone Play in southern England and the English Channel (based on Penn *et al*. 1987). Isopachs are gross thicknesses (in metres) of Corallian Sandstones (from Hawkes et al. 1998). See below for key



Claystone & siltstone

Limestone

All depths are in feet below KB

Osmington Oolite Formation in 97/19-1:

Gross thickness: 97 ft
Net:Gross: 0.65
Porosity: unknown

Fig. 12 Well log across the Osmington Oolite Formation (Corallian Group) in well 97/19-1

The Corallian Group contains potential reservoirs in shallow-marine sandstones (e.g. onshore oil in the Palmer's Wood wells) and inner shelf carbonates (e.g. the Osmington Oolite of the Dorset coast outcrops).

No significant sandstones are present offshore, but in this area the Osmington Oolite is best developed in a north-west to south-east zone sampled by wells 98/12-1, 98/18-1 and 98/23-1. Minor shows are present in all three of these wells. The thickness of the unit varies from 69 ft to 104 ft.

The Corallian Group has been eroded from the structural highs in the Dorset area, including the Wytch Farm Oil Field, and the Hampshire-Dieppe High.

3.5 Portland Carbonate Play

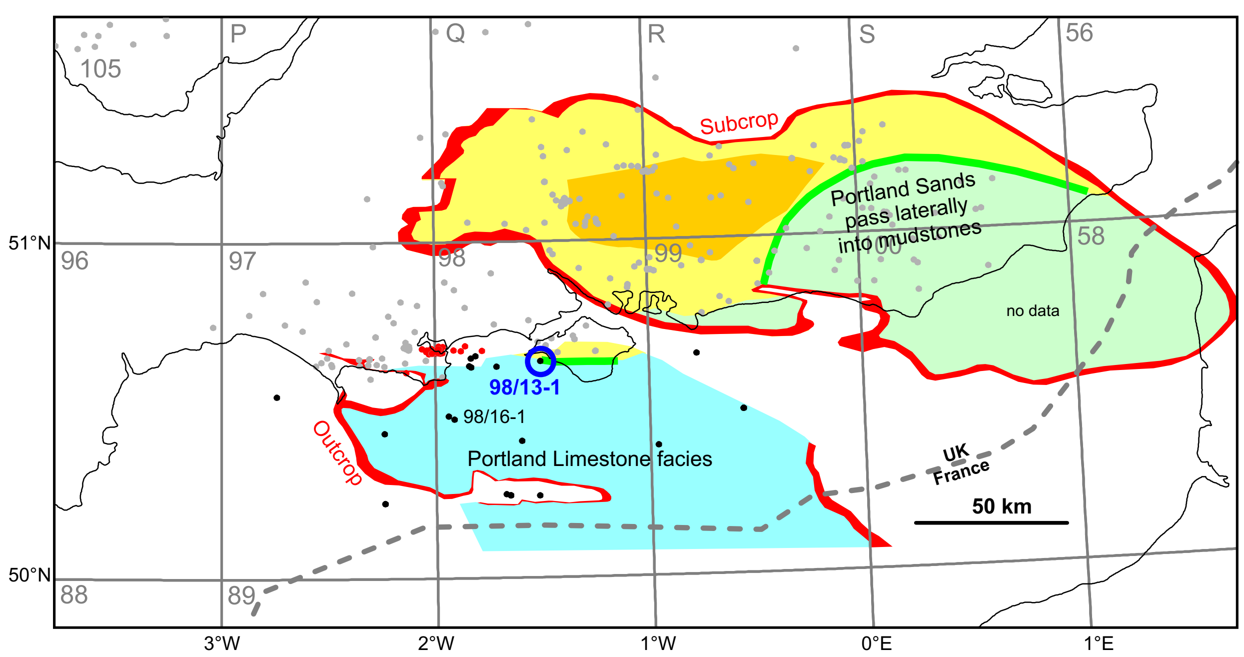
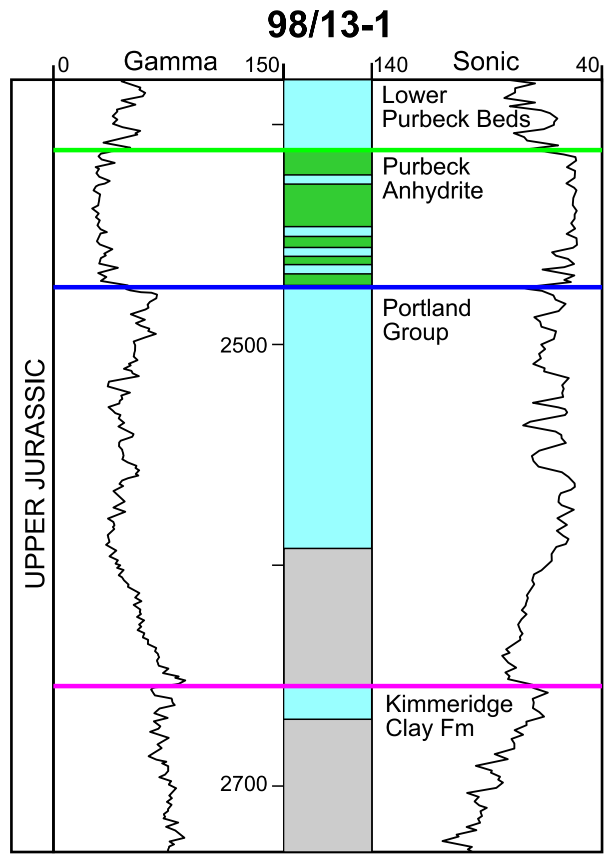


Fig. 13 Distribution of the Portland Carbonate and Sandstone Play in southern England and the English Channel (based on Penn *et al*. 1987). See below for key

Beneath the evaporites of the lower Purbeck Group, the Portland Group of the offshore area is composed of limestone and dolomite grading to claystone, and lacks the arenaceous lithologies that form the locally productive reservoirs in the Weald Basin. Limestone thicknesses vary from 48 ft to 188 ft. Minor oil-stained siltstones in well 98/16-1 may be related to the well crossing a major fault at this level.



Anhydrite

Claystone & siltstone

Limestone

All depths are in feet below KB

Portland Group in well 98/13-1:

Gross thickness: 179 ft
Net:Gross: 0.6
Porosity: unknown

Fig. 14 Well log across the Portland Group in well 98/13-1.

Sandstone reservoir (high risk play)

Sandstone reservoir (low risk play)

Non-reservoir facies

Carbonate reservoir (high risk play)

Carbonate reservoir (low risk play)

- Land well
- Offshore well
- Wytch Farm & Kimmeridge fields

4. Basin development, inversion and consequences

Surface outcrops, wells and seismic data reveal several key structural features in the onshore and offshore area: a series of monoclinal disturbances running east-west adjacent to major extensional growth faults. The faults controlled depositional thicknesses through the Triassic, Jurassic and Early Cretaceous; after which time stresses reversed into a compressional regime resulting in a pronounced reversal of movement on these faults and structural inversion of the basins.

The Central English Channel Basin is flanked to the north by the down-to-the-south Purbeck-Isle of Wight Fault, and to the south by the down-to-the-north Central English Channel Fault. Both have been reactivated to form a mirror image of each other on either side of the basin (Beeley & Norton 1998).

Estimates of the amount of uplift range from 1,500 feet (500 m) or less north of the Purbeck-Isle of Wight Fault (which is assumed to have remained relatively stable during inversion) to 3,000-6,000 feet (1-2 km) south of that fault (well 98/11-2) and north of the Central English Channel Fault (well 98/23-1) (Law 1998).

Tertiary (Alpine) inversion has had several effects on prospectivity:

(a) Late, reactivation of faults could have beached old hydrocarbon accumulations and also structural realignment could have caused previous accumulations to remigrate into new structures or to seep to the surface.

(b) Reservoirs in areas that have been uplifted retain reservoir properties, particularly porosity, associated with their pre-uplift location. In the centre of the Weald Basin, Great Oolite porosities are lower than would initially have be expected.

5. Trap types

Two trap types are recognised:

(a) Mesozoic tilted fault blocks and horsts which pre-date hydrocarbon generation. To succeed, these structures should be within migration distance of a source kitchen and importantly should not have been breached by Tertiary inversion. In the Wytch Farm area, the faults north of the disturbance remain in net extension and appear to have been little affected by the inversion process.

(b) Tertiary inversion anticlines which predominantly post-date hydrocarbon generation. These were the first structures to be targeted by exploration onshore, and with the exception of the Kimmeridge Oil Field, have all proved unsuccessful. Kimmeridge is possibly "the sole survivor of a much more significant play which was wiped out during inversion" (Evans *et al*. 1998).

(c) There is currently no evidence for stratigraphic traps in this area. Basin-scale facies changes are prevalent and no channelised or mounded sandstones have been identified in the generally tabular geometry of the seismo-stratigraphic units.

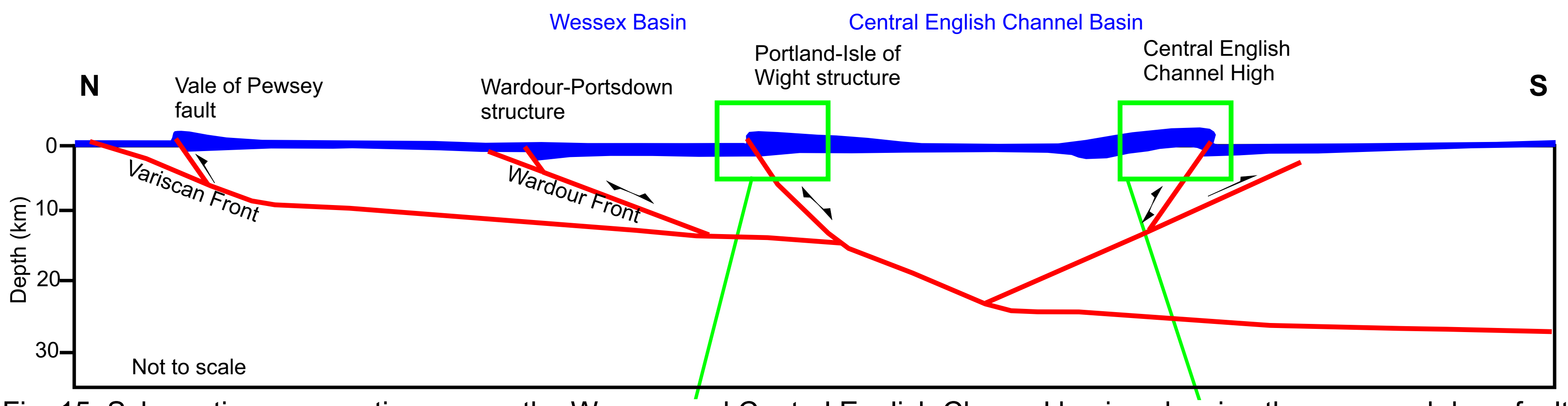


Fig. 15 Schematic cross-section across the Wessex and Central English Channel basins showing the proposed deep fault geometry of Beeley & Norton (1998)

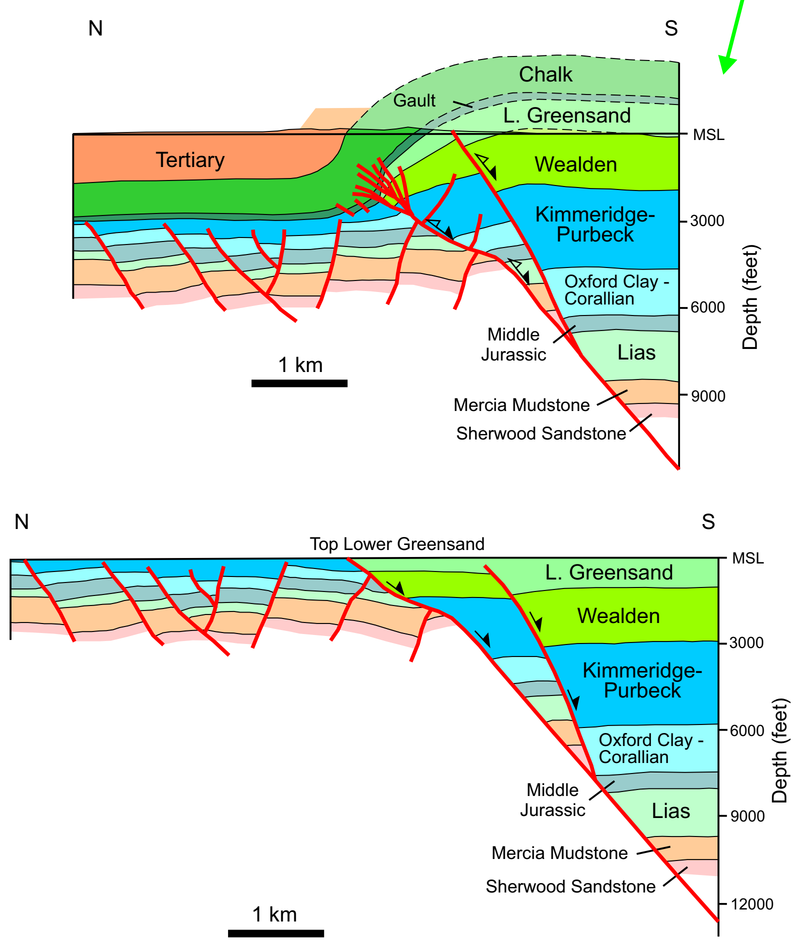


Fig. 16 Schematic cross-section across the Portland-Isle of Wight structure (Butler 1998) (a) restored to Albian time, (b) present day with eroded section added.

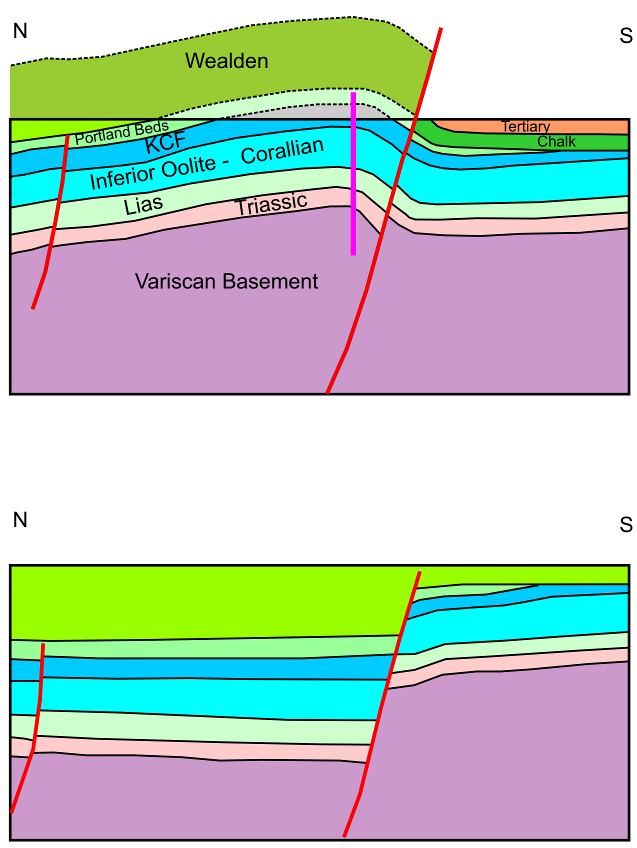


Fig. 17 Schematic cross-section across the Central English Channel High (Beeley & Norton 1998) (a) restored to Top Wealden, (b) present day with eroded section added.

6. Seismic examples

Two regional seismic profiles illustrate the regional structure and stratigraphic thickness variations across the English Channel.

Profile A traverses north-west to south-east across the main Central English Channel Basin and across the Central Channel High. Stratigraphic thickening towards the north-west is discernable, especially in the Permo-Triassic and Liassic intervals. The outcrop pattern provides evidence for uplift to the north-west and the south-east, with a syncline of Chalk preserved in the middle of the basin. Uplift caused by reversal of the Central Channel Fault is sufficient to expose the Kimmeridge Clay Formation at seabed. This structure was drilled by well 98/23-1. The succession found south of this major feature is speculative (the results of the French well Pointe de Barfleur are not available).

Profile B crosses the southern pat of the Central English Channel Basin and continues to the north-east across the continuation of the Purbeck-Isle of Wight Fault, also known as the Wight-Bray line or the Bembridge-St. Valery line. In the SW there is evidence for sedimentary thickening toward the Central English Channel Fault. To the north-east, on the Hampshire-Dieppe High, the effects of basin inversion in the mid-Cretaceous are evident with a major unconformity separating Middle Jurassic strata from the Lower Cretaceous. The uplifted area is overlain by a basin of Cretaceous and Tertiary age. The Permo-Triassic is thin in this eastern part of the study area.

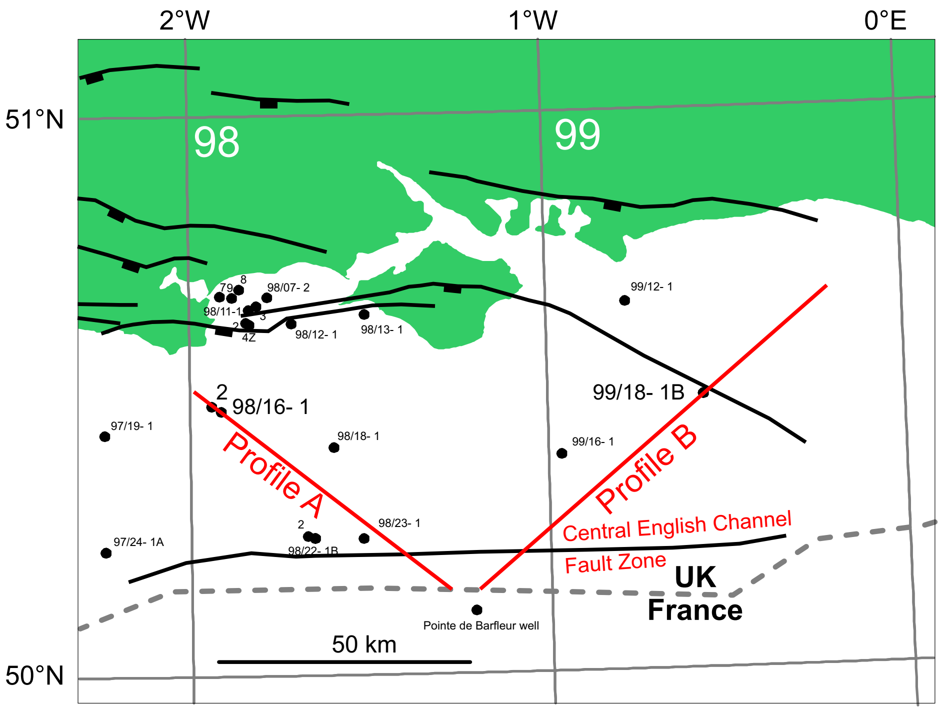


Fig. 18 Location map for seismic profiles A and B

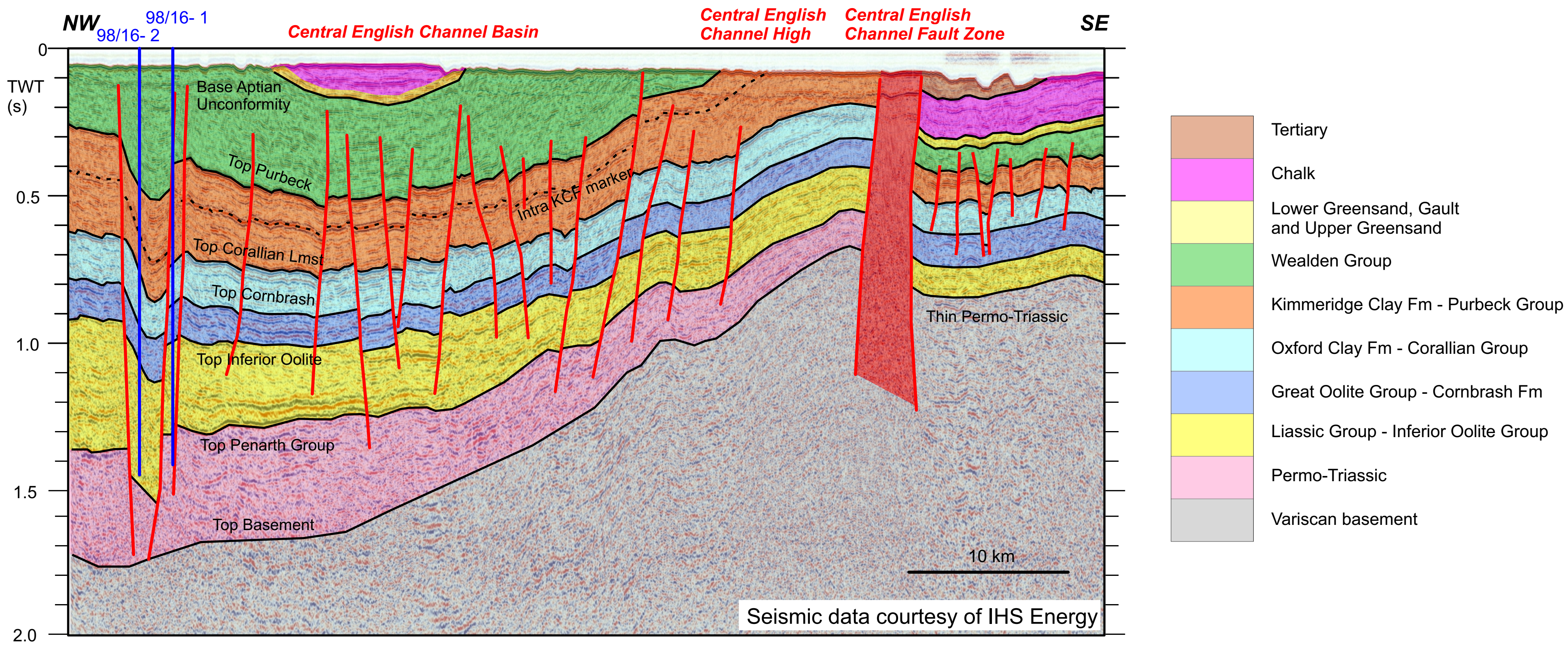


Fig. 19 Profile A: NW-SE-trending representative seismic line and geological interpretation, English Channel

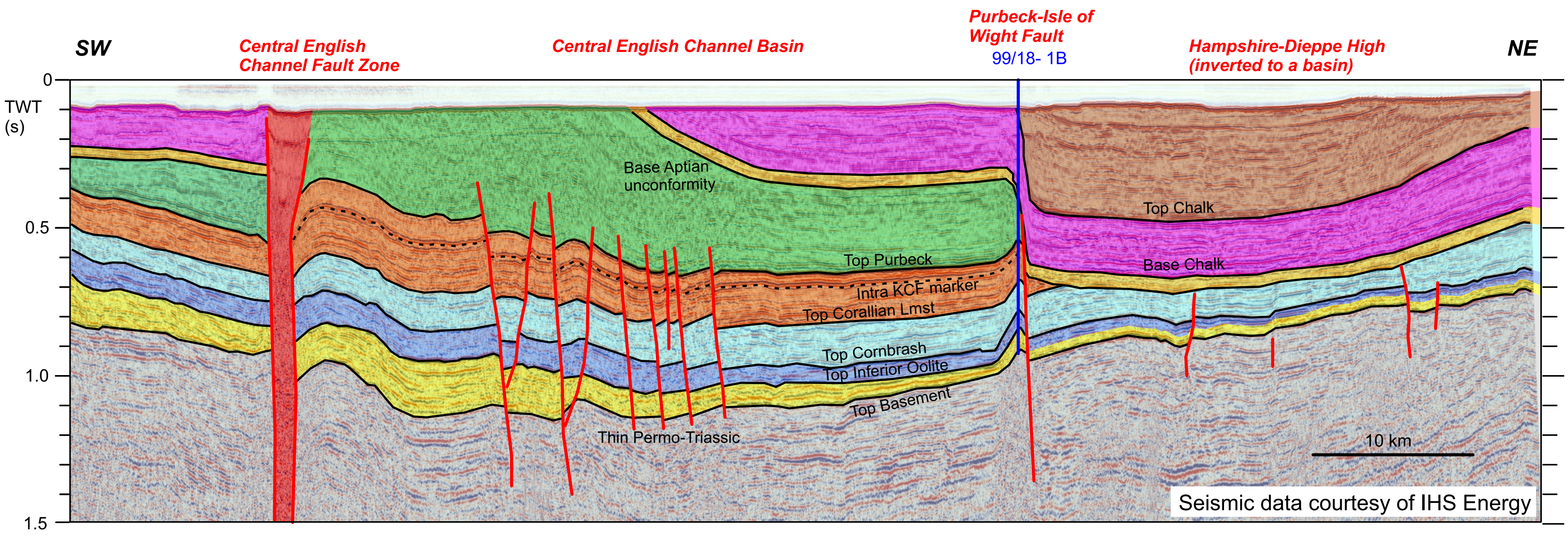


Fig. 20 Profile B: SW-NE-trending representative seismic line and geological interpretation, English Channel

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7. Source rocks

Viable source rocks are confined to the Jurassic, and occur at three levels. Black shales within the Lower Liassic Group, the lower part of the Oxford Clay Formation and the Kimmeridge Clay Formation all have higher than average levels of organic matter.

The Lower Lias contains alternations of laminated, dark grey, organic rich shales deposited in anoxic or dysaerobic bottom conditions and calcareous shales with limestones deposited in more aerobic bottom conditions. The Blue Lias, Black Ven Marls and Green Ammonite Beds contain the more organic-rich strata with TOC contents of up to 8%.

The Oxford Clay consists mainly of bituminous shales in its lower part, and calcareous mudstones and limestones in its middle and upper parts. The more organic-rich, lower part contains up to 12% TOC.

The Kimmeridge Clay also contains both organic-rich and more calcareous shales. The formation records TOC contents of up to 20% and represents the best potential source rocks in the English Channel area.

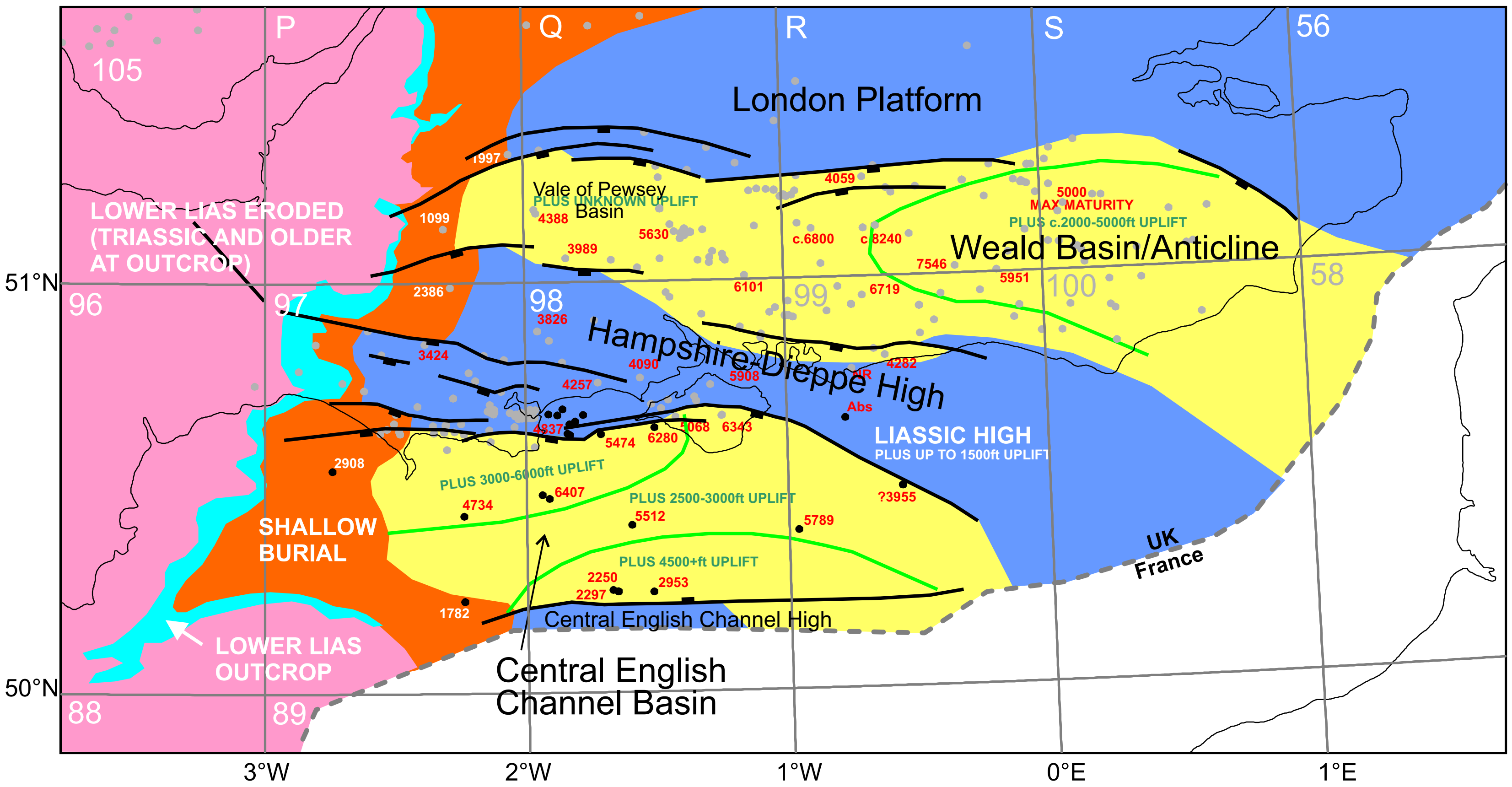

Fig. 21 Generalised distribution of potentially mature Lower Liassic source rocks (yellow) in southern England and the UK English Channel. Figures in red are depths to top Triassic (feet subsea) to which late uplift figures (green) should be added to give maximum Liassic burial. Uplift figures are derived from Law (1998) and McMahon & Turner (1998).

8. Maturation

The three Jurassic source rock intervals are locally mature for oil and gas generation, and in general only the relatively poor organic-rich, deeper horizons are mature for hydrocarbon generation. It is only in areas that received (Wealden Group) sediment during the phase of late Jurassic-early Cretaceous uplift and erosion that the Lias was buried to a sufficient depth for hydrocarbons to be generated (McMahon & Turner 1998).

The Lower Lias has reached the oil window over much of the Channel Basin and has been sufficiently deeply buried in the axial part to raise the possibility of significant gas generation. Reconstructions of burial history suggest that the onset of oil generation began during the early Cretaceous and peaked at about the mid-Cretaceous (Penn *et al*. 1987).

The Oxford Clay is considered to fall within the oil generation window in the northern part of the Channel Basin, but the Kimmeridge Clay does so only in the deepest, axial parts. Also, whereas the Oxford Clay may have locally reached peak oil generation, the Kimmeridge Clay is not thought to have reached this level of maturation (Penn *et al*. 1987).

In summary, the three principal source rocks have reached varying degrees of maturation in the Central English Channel Basin. Being the most deeply buried, the Lower Lias shales provide the largest volume of source rock which falls within and even beyond the oil generation window. Away from the basin depocentre and particularly in those areas severely affected by late Cimmerian uplift and erosion, levels are maturation are considerably lower.

9. Timing of migration relative to trap formation

The key issue in assessing the chance of success of specific structures within the Central English Channel Basin is the relative timing of hydrocarbon generation, migration and trap formation.

Without doubt much oil and gas have been generated, but unfortunately very little has been discovered in viable fields outside the Wytch Farm Oil Field.

Oil generation from the primary source, the Lower Lias, took place during the early to mid- Cretaceous, and the aim is to locate structures which existed at this time and which have not been subsequently disturbed by inversion.

It is feasible for later-formed structures to contain hydrocarbons, but these have to rely on remigration from earlier, transient reservoirs or very late stage hydrocarbon generation.

10. References

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