Read at the Annual Conference of the Ussher Society, January 1992

REVIEW OF THE HABITAT OF PETROLEUM IN THE WESSEX BASIN: IMPLICATIONS FOR EXPLORATION

R. STONELEY

Stoneley, R. 1992. Review of the Habitat of Petroleum in the Wessex Basin: Implications for Exploration. *Proceedings of the Ussher Society, 8, 1-6.*

Petroleum exploration involves the examination, integration and application of all available geological, geophysical and geochemical data, to assess the likelihood of finding oil or gas in a particular area. It requires the geologist to predict quantitatively the occurrence and distribution of oil and gas in order to guide expenditure on drilling costly wells. Given the predictive nature of the exercise, it is inherently impossible to arrive at definitive estimates of petroleum occurrence until all exploration has been completed. Parts of the Wessex Basin of Southern England provide a superb case-history of exploration principles, thinking and uncertainties.

R. Stoneley, Professor of Petroleum Geology, Department of Geology, Royal School of Mines, Imperial College, Prince Consort Road, London SW7 2BP

INTRODUCTION

Petroleum exploration consists, in essence, of making predictions. These may be tested subsequently by drilling, but we cannot know whether or not oil or gas underlies a particular locality until we have actually drilled and found it. Until that time, therefore, the job of the exploration geologist has to be to predict whether, and if so where and in what quantities, it may be found. He will use his knowledge of the area, from outcrop geology and from the results of earlier exploration, in trying to arrive at a fresh understanding and evaluation of the subsurface, to decide whether more money should be spent on drilling.

More specifically, the geologist will try to evaluate the following eight essential controls on the occurrence of hydrocarbon accumulations:

Source Rocks

Are potential source rocks present in the basin in sufficient volume to provide exploitable petroleum? Where do they occur? Are they oil or gas prone?

Maturity

What levels of maturity have the source rocks reached in different parts of the basin? Can they be expected to have generated oil or gas? Might they he over-mature?

Reservoirs -

Do adequate reservoir formations exist to contain exploitable quantities of petroleum? If so, where?

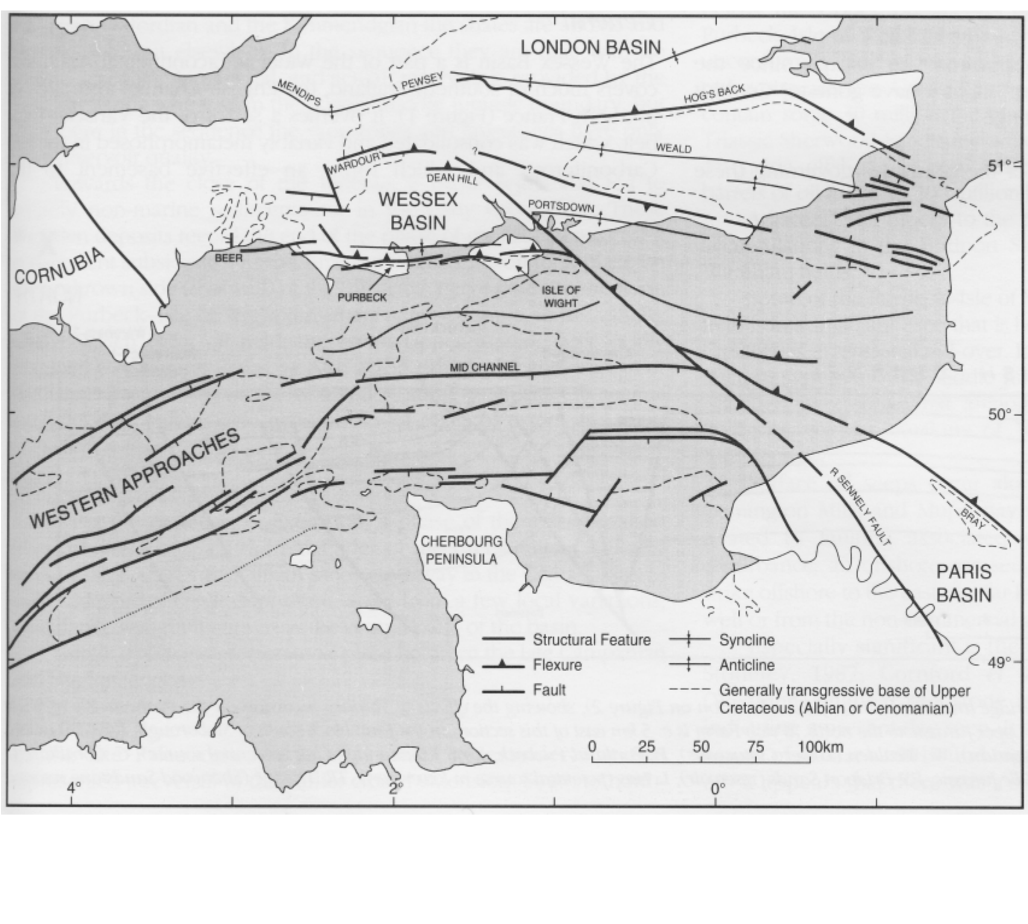

Figure 1: Location map for the Wessex Basin showing main lines of Mesozoic-Tertiary structural disturbance in southern England and the English Channel.

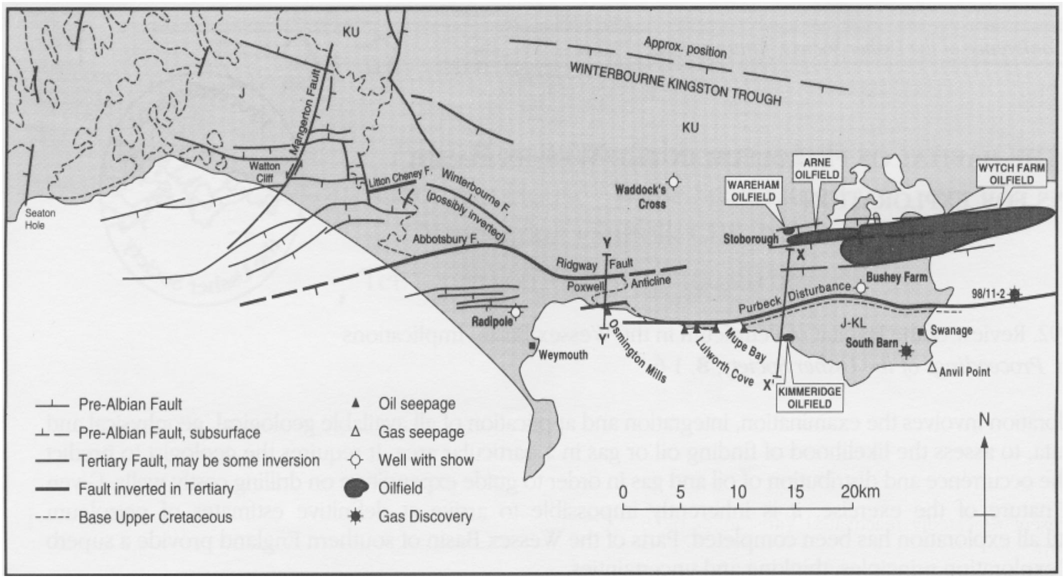

Figure 2: Locality map of the southern Wessex Basin, showing hydrocarbon occurrences and known faults with ages of movement.

Seals

Are the reservoirs adequately covered by impermeable rocks to retain the petroleum within them?

Traps

Are the reservoirs constrained in large enough traps to contain exploitable quantities of petroleum? If so, where? What is their geometry?

Migration Paths

Do channels of migration exist, or did they in the past, to enable hydrocarbons to move from the source rocks to the reservoirs in the traps? Are any hydrodynamic influences present?

Timing

Did the reservoirs, traps and migration paths exist at the time the hydrocarbons were generated and expelled from the source rocks? If not, they would have been lost.

Preservation

Has the petroleum had the opportunity to escape since the accumulation formed? If so, where might it have gone to? Could it have been destroyed by later heating?

It is our modern understanding of the principles governing these eight factors, and our ability to try to quantify them to arrive at figures for the amounts of oil that may be present, that gives exploration an acceptable chance of success in today's climate. Additionally, it is our relatively recently acquired computer assisted capacity to integrate and analyse often vast quantities of data that enables us to make the computations involved.

It is important to emphasise again, however, that the objective of exploration is to assess the unknown, that which cannot be known until it is too late-until we have actually spent our money on drilling. However much data we have, there will always be uncertainty in our predictions; our job is to try to minimise that uncertainty and risk. If we could know the answers for sure, we would never drill a dry hole.

With these thoughts in mind, let us look at the Wessex Basin which provides a superb case-history of exploration principles.

THE WESSEX BASIN

General

The Wessex Basin is a part of the wider intracontinental basin that covers much of southern England, the English Channel and parts of northern France (Figure 1). It overlies a sector of the Variscan foldbelt, which was consolidated and variably metamorphosed in the late Carboniferous and which forms an effective basement to the

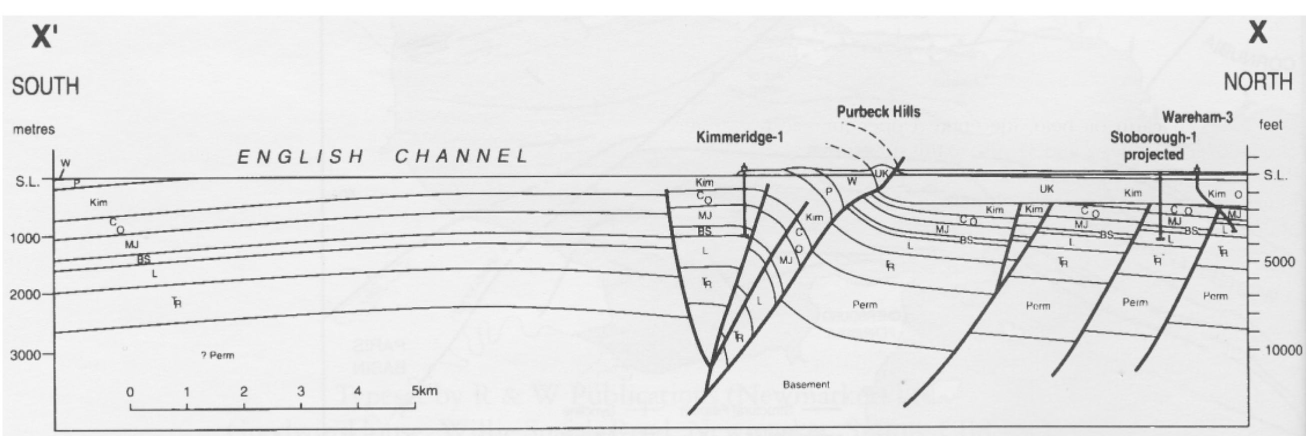

Figure 3: Cross-section through Kimmeridge and Wareham oilfields (Location on Figure 2), showing the effects of Tertiary inversion on the Purbeck-Isle of Wight disturbance: note the truncation of the Upper, Jurassic to the north. Wytch Farm is c. 5 km east of this section, in the fault block south of Stoborough. Key: T Tertiary, UK: Upper Cretaceous (Aptian to Campanian), W: Wealden (Lower Cretaceous), P: Portland/Purbeck, Kim: Kimmeridge Clay (potential source), C: Corallian, O: Oxford Clay (potential source), MJ: Middle Jurassic, BS: Bridport Sands (reservoir), L: Lias (potential source in lower part), TR: Triassic (Sherwood Sandstone reservoir in lower part). Perm: Permian.

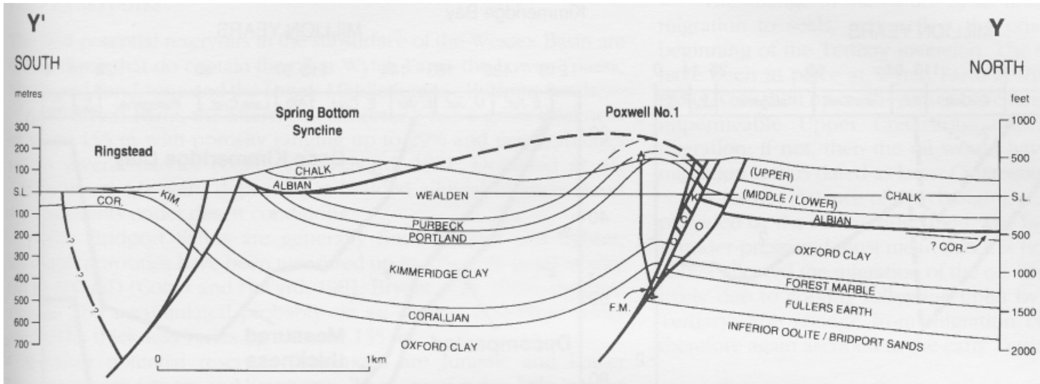

Figure 4: Cross-section through Poxwell Anticline (Location on Figure 2) showing the effects of pre-Albian erosion and Tertiary inversion. The anticline is known to be a Tertiary feature, probably due to high-level compression of an earlier extensional structure. The Osmington Mills seepage is in the Corallian, on the coast at the left of the section.

petroliferous basin. Sedimentary dips are generally gentle except along certain lines of dislocation where they become very steep: these are believed to represent repeatedly reactivated Variscan or older faults (Chadwick, 1986).

The Basin evolved from the Permian to the late Tertiary in three tectonic stages (e.g. Stoneley, 1982; Whittaker, 1985; Karner *et al.,* 1987; Lake and Karner, 1987; Stoneley and Selley, 1991):

(i) Permian to Early Cretaceous

Essentially north to south extension, expressed on major synsedimentary normal faults that were intermittently active, initiated basin subsidence in the form of half-grabens. Considerable thickness changes occur across these east-west faults, and there is evidence, at least in the case of the Purbeck-Isle of Wight disturbance, of the presence of contemporaneous roll-over anticlines in the hanging-wall on the southern downthrown side

Through the entire Permo-Triassic the sediments are of desert facies. Potential reservoirs are developed in fluvial and aeolian sands, and are sealed by thick red mudstones, sometimes with evaporites, of probable playa lake origin. The sequence is totally devoid of any petroleum source potential.

The Jurassic is almost entirely marine and epicontinental. After protracted shale deposition during the early Lias, a cyclicity was established which persisted almost to the end of the Jurassic: shales pass upwards into sand and then limestones. In the Lower Lias, the Callovian-Oxfordian and the Kimmeridgian the shales are anoxic and organic-rich, but elsewhere in the sequence they are oxic with no source potential. A potential, and actual, reservoir is provided by the Bridport Sands which span the Lower-Middle Jurassic boundary, but elsewhere in the sequence the sandstones and limestones have only poor reservoir quality.

Towards the close of the Jurassic, a major regression led to entirely non-marine sedimentation in the early Cretaceous. These Wealden deposits record the end of the phase of crustal extension and consequent subsidence. At this time, uplift and erosion took place on the upthrown side (footwall) of the still active major faults: to the north of the Purbeck-Isle of Wight disturbance, for example, in the vicinity of the Wytch Farm oil field, the entire Upper Jurassic was locally removed (see Figures 2 and 3). Also at this time, uplift and erosion of the western side of the basin, followed by subsequent late Cretaceous transgression, created an unconformity of regional extent and great importance.

(ii) Late Cretaceous

Following the cessation of extension, a phase of thermal relaxation (thermal sag) occupied the remainder of the Cretaceous. Gradually transgressive Aptian and Albian sands gave way in the Cenomanian to very widespread chalk deposition: apart from a few local variations, subsidence was uniform across the central parts of the basin.

Gentle uplift and erosion took place between the late Campanian and late Palaeocene.

(iii) Tertiary

By the late Palaeocene, earth movements were under way that represented a reversal of the earlier crustal extension. South to north directed compression caused inversion of the earlier structures and the formerly downthrown sides of the major faults now started to be uplifted. In southern England, therefore, the Tertiary sediments are confined to the north of the Purbeck-Isle of Wight disturbance: they are some 700m thick and almost entirely siliciclastic.

This compressive movement culminated in the late Oligocene-early Miocene with spectacular effects along the Purbeck-Isle of Wight disturbance: whereas at the level of the Lower Cretaceous and lower beds the previous down-to-the-south displacement was reversed, the overlying Upper Cretaceous and Lower Tertiary beds were flexed down to the north becoming vertical or even overturned along the line of the disturbance (Figures 2 and 3). The vertical amplitude of the flexure at Upper Cretaceous level varies up to some 1.5 km, but there is still a net downthrow to the south at deeper levels of at least a comparable amount. During this inversion, the earlier roll-over anticlines were preserved or enhanced. The shortening also locally created somewhat superficial anticlines at shallow levels: the Poxwell Anticline immediately south of the Ridgeway sector of the disturbance (Figure 4) is believed to be such a structure.

PETROLEUM OCCURRENCE

The southern Wessex Basin contains the Wytch Farm oil field in beds below the Upper Cretaceous unconformity; it lies north of the Purbeck-Isle of Wight disturbance but is separated from it by a subunconformity fault block, which is water bearing. The fault-sealed reservoirs are the Upper Liassic-Aalenian Bridport Sands, which contain some 30 million barrels of recoverable oil, and the Lower Triassic Sherwood Sandstone which, as a result of a recently proved extension offshore, is now believed to contain some 600 million barrels of oil in place (300 million barrels recoverable).

Adjacent fault blocks to the north of Wytch Farm contain small accumulations in the Bridport Sands in the Arne-Stoborough and Wareham fields.

South of the Purbeck-Isle of Wight disturbance, the Kimmeridge field is in a small anticline that is believed to have originated as a pre-Cretaceous extensional roll-over. It produces from an under-pressured fracture system in high Middle Jurassic beds. A significant show was obtained in a somewhat analogous position in a well drilled at Radipole, on the outskirts of Weymouth, some 25 km west of Kimmeridge.

Surface oil seeps occur along the east Dorset coast between Osmington Mills and Mupe Bay (Figures 2 and 4), and are clearly related to faulting associated with the Purbeck-Isle of Wight disturbance: an offshore gas seepage has been reported along the strike offshore to the east, not far from the small 98/11-2 gas discovery well or from the non-commercial gas at South Barn near Swanage.

Especially significant is the seepage at Mupe Bay (Selley and Stoneley, 1987; Cornford *et al.,* 1988). A Lower Cretaceous (Wealden) channel sandstone is impregnated with fresh live oil indicating a present day seep. It also contains boulders up to 1.2 m across of similar sand bound together by dead, black tarry residual oil. It appears that there was a seepage nearby in early Cretaceous

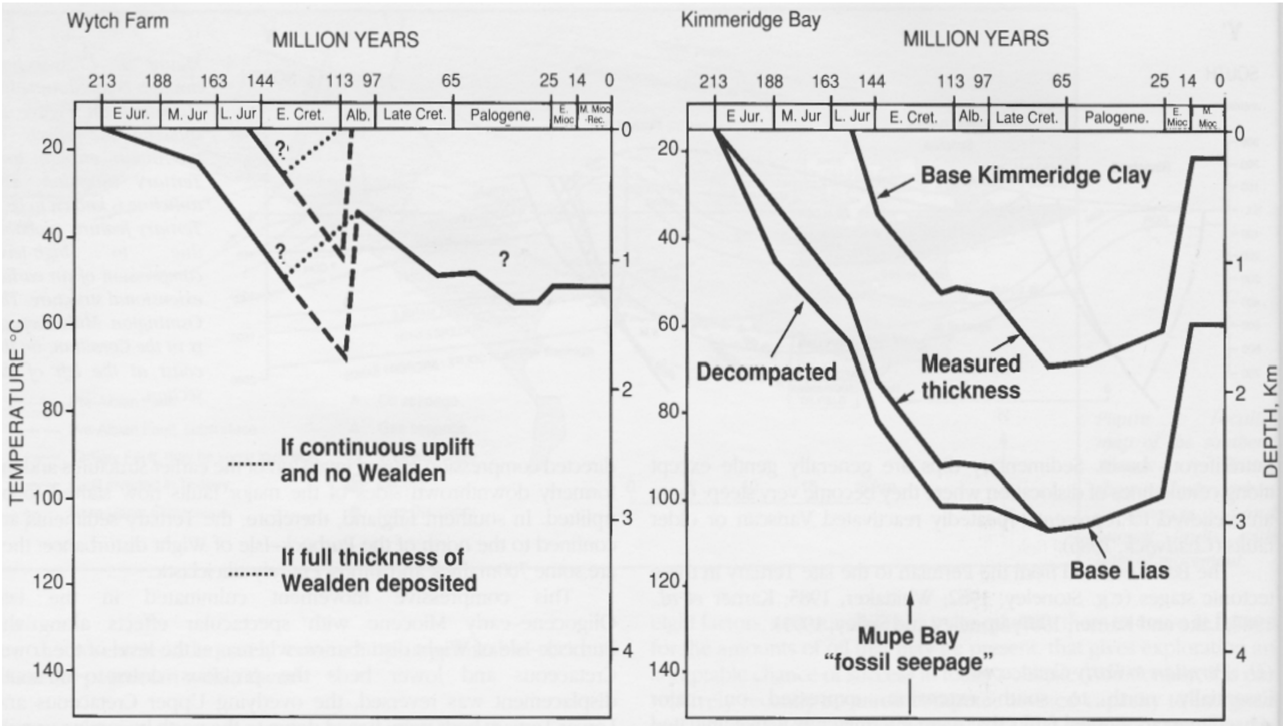

Figure 5. Burial history graphs for Wytch Farm, lying north of the Purbeck-Isle of Wight disturbance, and Kimmeridge oilfield to the south of it. Temperatures are based on regional present day, geothermal gradients. The age of the sands containing the Mupe Bay 'fossil seepage' is shown.

times saturating sands on the bank of the channel; pieces of this were broken off and incorporated into the sand of the channel itself. The importance of this occurrence is in suggesting that oil was already being generated and was migrating by the early Cretaceous, thereby providing a guide and constraint to maturation and generation modelling.

PETROLEUM EVALUATION

Let us now examine, in the Wessex Basin, the eight controls that were listed in the introduction to this paper as required for the occurrence of petroleum.

(i) Source rocks

Potential oil-source rocks are confined to three intervals in the Jurassic: the Lower Lias, where total organic carbon contents of up to 7.36% have been measured (Ebukanson and Kinghorn, 1985); the Oxford Clay (Callovian-Lower Oxfordian) with up to 12.36% TOC; and the Kimmeridge Clay (Kimmeridgian) with TOC up to 20.48%, but which also contains a 1m bed of oil shale with some 70% TOC. The organic matter is predominantly sapropelic oil-prone kerogen derived from marine plankton, although minor amounts of terrestrial material, much of it recycled, are also present.

None of these formations consists of anoxic shales of source quality throughout, and there is also variation laterally. Approximate thicknesses over which black shales occur may be: Lower Lias some 100 m north of the Purbeck-Isle of Wight disturbance, with possibly twice this thickness to the south of it; Oxford Clay, of which only the lower half is of potential source facies, 50 to possibly 10m; Kimmeridge Clay 550m south of the disturbance. An average oil-prone organic carbon content of 2% over these thicknesses was suggested by Cornford *et al.* (1988); this seems low but may not be unreasonable, although the figure could be higher for the Kimmeridge Clay.

Other argillaceous intervals in the Jurassic consist of grey bioturbated mudstones with benthonic fauna, and are devoid of any known petroleum potential. There are no pre-Jurassic rocks with any oil source possibilities whatsoever, and the few argillaceous rocks in the Cretaceous contain essentially terrestrial organic matter and are everywhere immature.

(ii) Maturity

Over the greater part of the southern Wessex Basin, the potential source rocks are either immature or just at the threshold of oil generation. Only in the deeper buried areas is the Lower Lias fully mature, and the Oxford Clay marginally at the top of the oil generation window: the Kimmeridge Clay is everywhere immature (Ebukanson and Kinghorn, 1986a).

At Wytch Farm, even the Lias is immature (Colter and Havard, 1981), although to the north it may have generated and contributed a little oil from a subsurface half-graben (the Winterbourne Kingston Trough). It is clearly established (e.g. Ebukanson and Kinghorn, 1986b) that the oils in both the Sherwood Sandstone (Triassic) and the Bridport Sands (Lower-Middle Jurassic) reservoirs have a common Lower Lias origin, having migrated from south of the Purbeck-Isle of Wight disturbance. The oils found on the south side of the disturbance, at the Kimmeridge field and in the natural seepages, are also Liassic. This belt of mature Lower Lias extends along the south side of the disturbance from the Isle of Wight westwards at least to the vicinity of Weymouth.

The differences of maturity between Wytch Farm to the north of the disturbance and the areas to the south may be highlighted by the burial history plots shown in Figure 5. These may also be used to examine the maturation history of the Lower Lias. It is clear that maximum maturity, corresponding to peak oil generation, was reached late in the Cretaceous immediately prior to the inversion uplift in the Tertiary; modelling, using the Lopatin-Waples (Waples, 1980) technique and a present-day regional average geothermal gradient of 30°C/km, would suggest that the oil-window was entered earlier in the late Cretaceous. However, we have indications from the Mupe Bay `fossil seepage' that the Lias was yielding early generated oil by the early Cretaceous (Cornford *et al.,* 1988). To model such early generation (assuming a required TTI of 16) seems to require a geothermal gradient of at least 38°C/km during the extensional phase of basin development: this may not be unreasonable, given the requirements that the crust was then thinned (Karner *et al.,* 1987) and that surface temperatures were higher during the Mesozoic than they are today.

(iii) Reservoirs

The best potential reservoirs in the subsurface of the Wessex Basin are in fact those that do contain the oil at Wytch Farm; the Lower Triassic Sherwood Sandstone and the Lower-Middle Jurassic Bridport Sands.

At Wytch Farm, the Sherwood Sandstone has a gross thickness of some 155 m with porosity ranging up to 29% and permeabilities up to several darcies (Colter and Havard, 1981; Dranfield *et al.,* 1987); the sands were deposited in braided alluvial to sheet-flood environments under desert conditions.

The Bridport Sands are generally finer grained and tighter, although porosities have been measured up to 32% with permeability up to 300 mD (Colter and Havard, 1981; Bryant *et* al., 1988): they are marine and accumulated probably on an extensive shallow water shelf. The thickness varies up to some 135 m.

Other potential reservoir formations are Jurassic and Lower Cretaceous sandstones and limestones. They are of rather little interest in the southern Wessex Basin, however, being either thin, very fine-grained, cemented or extensively exposed at outcrop. Minor flows have been tested from fractures in thin Middle Jurassic carbonates, the most notable being the sustained production of some 370 bbl/day from the one well Kimmeridge oil field where the fractures extend upwards from the Cornbrash limestone in to the Oxford Clay.

Elsewhere in southern England, limestones in the Middle Jurassic and limestones and sands in the Upper Jurassic provide the reservoirs for a number of rather small fields.

(iv) Seals

Shales occurring throughout the pre-Upper Cretaceous succession are sufficiently thick to act as effective seals to all of the known reservoirs.

(v) Traps

All presently known traps are structural. With the control currently available, the potential for encountering stratigraphic traps seems to be very limited. Both fault-sealed and anticlinal traps can be considered.

Both pools in the Wytch Farm field are in a gentle elongated half-dome structure, fault-sealed to the south (Hinde, 1980); and the other small accumulations in the vicinity are similarly fault-controlled. This faulting was caused by the pre-middle Cretaceous extension and is entirely covered by the Upper Cretaceous-Tertiary sediments.

On the south side of the Purbeck-Isle of Wight disturbance, small anticlines of limited length are believed to have originated as roll-over features during basin extension (Selley and Stoneley, 1987); they were clearly compressed somewhat during the Tertiary inversion uplift. The oil accumulation at Kimmeridge is in one of these anticlines and shows that at least this structure retains its integrity as a trap (Figure 3).

Farther west, however, the small sharp Poxwell Anticline immediately adjacent to a straight, faulted stretch of the disturbance can be shown not to have been fully developed in the mid-Cretaceous (Mottram and House, 1956) (Figure 4): it is believed to have been developed as a result of compression during inversion of an earlier extensional feature, and thus to be entirely a Tertiary structure. Anticlines south of the line of disturbance therefore seem to have been formed as a result of two separate mechanisms, one of them pre-middle Cretaceous and the other mid-Tertiary. Care is required to distinguish them.

(vi) Migration paths

Vertical migration of oil, both in the past and at the present day to feed the active seepages, must have occurred along fault planes, whereas the lateral component was clearly along the reservoir formations themselves. Thus the oil at Wytch Farm is believed to have migrated from south of the Purbeck-Isle of Wight disturbance, up the underlying fault and then laterally through the Triassic Sherwood Sandstone and the Bridport Sands reservoir formations (Colter and Havard, 1981): it must also have used the fault which now forms the southern margin of the field (Figure 3). The faults that trap the small accumulations nearby (near Wareham) are similarly sealing.

The change in the nature of all these faults, from channels of migration to seals, may reflect the onset of compression at the beginning of the Tertiary inversion. The oil is therefore believed to have been in place at Wytch Farm at that time. However, if these faults were then open, they must have been covered by the relatively impermeable Upper Cretaceous during peak generation and migration: if not, then the oil would have escaped to surface. The migration is thus dated as latest Cretaceous-earliest Tertiary.

A further instance of the changing sealing quality of the faults is provided by the Kimmeridge field. The fact that the reservoir system is under-pressured must mean that it is now isolated by faults which earlier allowed the migration of the oil. The under-pressuring is most likely due to cooling following uplift by some 1.5km in the mid-Tertiary. The change from migration channel to sealing fault is therefore again ascribed to the early Tertiary.

(vii) Timing of migration and entrapment

We have seen that oil generation south of the Purbeck-Isle of Wight disturbance started early in the Cretaceous and peaked in the late Cretaceous. It is unlikely that significant generation continued after the onset of uplift early in the Tertiary. We therefore have to find traps that were in existence during the Cretaceous, either to hold the oil or to store it temporarily until it remigrated. We have also seen that, at least in the case of the Wytch Farm oil, this migration was probably latest Cretaceous-earliest Tertiary. Structures that were formed entirely by the Tertiary compressive inversion movements, the Poxwell Anticline for example, can therefore be expected to have been formed too late and to be dry-unless, of course, they were fortuitously placed to receive any oil migrating for a third time as a result of these movements.

In the early Cretaceous, the only sealed structures that are believed to have been in existence were the roll-over anticlines adjacent to the major normal growth-faults. Any early generated oil that was preserved must therefore have been stored in them. The pre-late Cretaceous fault blocks north of the disturbance (Wytch Farm, Wareham, etc.) probably could not have acted as traps until covered by at least several tens of metres of the Upper Cretaceous (see section (v) above). This coincided with the onset of peak generation to the south, and it seems that their final sealing likewise coincided with the cessation of generation. This favourable coincidence of timing is a key factor in controlling the distribution of oil in the Wessex Basin.

(viii) Preservation

In the Wytch Farm-Wareham area, little has happened to disturb the accumulations since they were originally formed, and it is unlikely that any significant amount of oil has been lost. The gentle eastwards tilting during the Tertiary amounts to about 1° which, given the contours of Hinde (1980), would not have caused spillage to the west.

The fault block to the south, however, may have lost a considerable quantity from both the Sherwood Sandstone and Bridport Sands reservoirs. Oil is believed to have passed through this block on its way to Wytch Farm and some of it is likely to have been trapped. The Bushey Farm-1 test well, however, was dry. Oil could have been lost during the Miocene through the intense fractures along the disturbance that are well displayed in the Chalk at Lulworth Cove.

Of the original roll-over anticlines south of the disturbance, the Kimmeridge structure retained its oil throughout the period of inversion uplift. Two of the others, however, have been tested dry. It is uncertain whether oil has been lost or whether it never accumulated: the former is probable since residues were recorded in one of the wells (Arreton-2 on the Isle of Wight). It should he noted, however, that the region has not been completely explored and that there is still a possibility that oil is present in untested fault blocks.

CONCLUSION

Considerations that we have been following have produced guidelines for further exploration, both in the immediate vicinity of the existing discoveries in southern England and also elsewhere in the basin. However, even in the better explored areas, there is a shortage of publicly available data from which to make quantitative evaluations of the remaining potential: any estimates made without the benefit of detailed seismic data must he subject to a wide measure of uncertainty. But, if we had those data, uncertainties would still remain: we just cannot do more that arrive at our best evaluation, in the light of the information available to us.

On the basis of the source rock quality figures given above, and using average kerogen convertibility for different levels of maturity with average expulsion and migration loss figures, Selley and Stoneley (1987) estimated that possibly some 200 million barrels remained to he found in the Kimmeridge-Wytch Farm area in traps as yet incompletely defined. This figure was soon outdated, however, by the offshore extensions which virtually doubled the earlier estimates of the Wytch Farm reserves. Estimates by Cornford *et al.* (1988) have likewise been shown to be wide of the mark. Do these results imply that it is useless to try to produce quantitative evaluations? No: they *must* he made, as a basis for exploration decision making: it has to be recognised that, even with detailed data and precise analysis, there will always Be a degree of uncertainty. That is the very nature of the exploration process: we do our best, but it is impossible to guarantee success.

REFERENCES

BRYANT, I. D., KANTOROWICZ, J. D. and, LOVE. C. F. 1988. The Origin and Recognition of Laterally Continuous Carbonate-Cemented Horizons in the Upper Lias Sands of Southern England. *Marine and Petroleum Geology,* **5**, 108-133

CHADWICK, R. A. 1986. Extension Tectonics in the Wessex Basin, Southern England. *Journal of the Geological Society, London.* **140**, 893-911.

COLTER. V. S. and HAVARD, D. J. 1981. The Wytch Farm Oilfield. Dorset. In: *Petroleum Geology of the Continental Shell of North-West Europe.* Eds: L. V. Illing and G. D. Hobson. Heyden, London. pp 494-503.

CORNFORD. C., CHRISTIE, O, ENDRESEN, U., JENSON. P. and MYHR, M. B. 1988. Source Rock and Seep Oil Maturity in Dorset, Southern England. *Organic Geochemisty,* **13,** 399-409.

DRANFIELD, P., BEGG, S. H. and CARTER, R. R. 1987. Wytch Farm Oilfield: Reservoir Characterisation of the Triassic Sherwood Sandstone for Input to Reservoir Stimulation Studies. In: *Petroleum Geology of North West Europe.* Eds: J. Brooks and K. W. Glennie. Graham and Trotman, London, pp 149-160.

EBUKANSON, E. J. and KINGHORN, R. R. F. 1985. Kerogen Facies in the Major Jurassic Mudrock Formations of Southern England and the Implication on the Depositional Environments of the Precursors. *Journal of Petroleum Geology,* **8**. 435-462.

EBUKANSON, E. J. and KINGHORN, R. R. F. 1986a. Maturity of Organic Matter in The Jurassic of Southern England and its Relation to the Burial History of the Sediments. *Journal of Petroleum Geology,* **9**, 259-280.

EBUKANSON, E. J. and KINGHORN, R. R. F. 1986b. Oil and Gas Accumulations and their Possible Source Rocks in Southern England. *Journal of Petroleum Geology,* **9**, 413-428.

HINDE, P. 1980. The Development of the Wytch Farm Oilfield. *Communication* **1133**, Institute of Gas Engineers, London.

KARNER, G. D., LAKE, S. D. and DEWEY, J. F. 1987. The Thermal and Mechanical Development of the Wessex Basin, Southern England. In: *Continental Extensional Tectonics.* Eds: P. L. Hancock, J. F. Dewey and M. P. Coward. Geological Society, London. Special Publication **28,** 517-536.

LAKE, S. D. and KARNER, G. D. 1987. The Structure and Evolution of the Wessex Basin, Southern England: an Example of Inversion Tectonics. *Tectonophysics,* **137,** 347-378.

MOTTRAM, B. H. and HOUSE. M. R. 1956. The Structure of the Northern Margin of the Poxwell Pericline. *Proceedings of the Dorset Natural History and Archaeology Society,* **76**, 129-35.

SELLEY, R. C. and STONELEY, R. 1987. Petroleum Habitat in South Dorset. In: *Petroleum Geology of North West Europe.* Eds: J. Brooks and K. W. Glennie, Graham and Trotman, London. 139-148.

STONELEY, R 1982. The Structural Development of the Wessex Basin. *Journal of the Geological Society, London.* **139**. 543-554.

STONELEY, R. and SELLEY, R C. 1991. *A Field Guide to the Petroleum Geology of the Wessex Basin (3rd edition). R.* C. Selley & Co., Dorking.

WAPLES, D. W. 1980. Time and Temperature in Petroleum Formation: Application of Lopatin's Method to Petroleum Exploration. *Bulletin of the American Association of Petroleum Geologists,* **65.** 1387-1396.

WHITTAKER, A. (Ed.) 1985. *Atlas of Onshore Sedimentary Basins in England and Wales: Post Carboniferous Tectonics and Stratigraphy.* Blackie, Glasgow and London.