The Ecology of Poole Harbour
John Humphreys and Vincent May (editors)

1. The Geology of Poole Harbour

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The last 400 million years of the geological history of Poole Harbour and the region adjacent to it are reviewed. This is facilitated by the extensive exploration for oil which has been undertaken by BP in the development of the Wytch Farm oilfield, and the exploration wells made by English China Clay in search of economically viable deposits of kaolinite. The closure in the Carboniferous of the Rheic Ocean lead to the formation of east-west thrusts, now deep beneath southern England, which have determined the structural grain of the region. A series of en echelon thrusts run beneath east Dorset and the Isle of Wight. These thrusts have been reactivated extensionally during the opening of the Atlantic (Jurassic–Cretaceous), and compressionally during the early Alpine Orogeny in the Palaeogene, when collision between Africa and Europe commenced. Hydrocarbon accumulations were formed by burial of organic-rich Early Jurassic sediments on the southern, downthrown, side of a fault. This burial resulted in maturation of oil, which subsequently migrated up the fault plane to become trapped beneath Wytch Farm. Inversion in the Palaeogene, 40–50 million years ago, created the Hampshire Basin, and caused the uplift of the Chalk ridges of Purbeck and the Isle of Wight. A Proto-Solent drainage pattern, with a catchment to the north and west, thus developed in the Palaeogene. This brought kaolinite from the granites of Devon into the region, and valuable ‘ball clays’ were deposited during the Eocene Period. The Holocene transgression, 10,000 years ago, caused the sea to break through the Chalk ridge joining the Isle of Wight and Dorset, and created the western Solent Channel.

Introduction

From the viewpoint of a casual observer, the geology of Poole Harbour appears to be less than spectacular. The low topography of the region with few poor exposures of the underlying low-dipping, rather unfossiliferous Eocene sands and clays (Figures 1 and 2), river terrace gravels of Pleistocene age and extensive Holocene alluvium (see the BGS *Bournemouth Solid and Drift Geology Sheet* No. 339 and the *Bourmemouth Sheet Memoir*; Bristow *et al*., 1991) does not attract many geological visitors. Poole Harbour and its surrounding countryside and offshore region, however, have the most intensively studied geology in the entire south of England. This has been driven by two separate economic geological imperatives. Firstly, and more importantly, the discovery in 1973 of the Wytch Farm oilfield in the Jurassic Bridport Sands, 1500 m beneath Poole Harbour, encouraged extensive exploration of the region, with the use of deep boreholes and seismic profiles and lead subsequently to major discoveries in the Triassic Sherwood Sandstone (Underhill and Stoneley, 1998). Wytch Farm is the largest onshore oilfield in Europe, with estimated reserves of 300 million barrels (Buchanan, 1998). Much of the geological data obtained during exploration have now been published and enable a detailed reconstruction of the last 250 million years of geological history of the region, which is a microcosm of the history of southern England and the English Channel. Additionally, Permian, Triassic and Cretaceous rocks, essentially identical to those which underlie Wytch Farm, are extensively exposed in the sea cliffs of east Devon and Dorset (House, 1993), and thus allow detailed study at outcrop on what has become recently a UNESCO World Heritage Site.

The presence of layers of valuable clays in the Eocene Poole Formation in the area of Wareham and Poole Harbour (so-called ‘ball clays’) has resulted in extensive shallow exploration by English China Clays, and numerous open cast workings for these clays exist at the present time, as on the Arne peninsula. This exploration has resulted in a detailed stratigraphical understanding of the Eocene sediments beneath Poole Harbour (Bristow *et al*., 1991).

This chapter aims to provide the broad geological context and history, not just of Poole Harbour and its immediate environs, but also of the broader region of Wessex, including Dorset, south Hampshire and the Isle of Wight (Figure 1). I will try to show how the

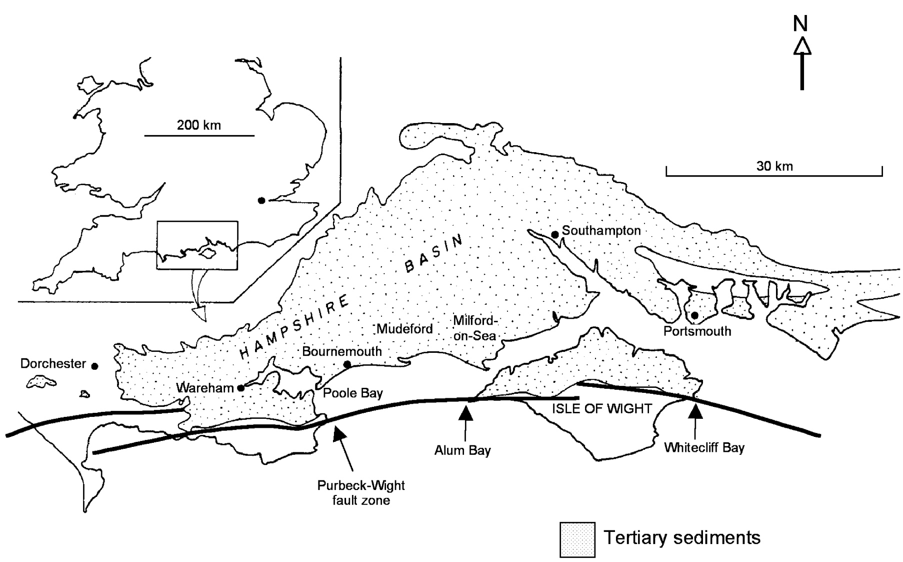

Figure 1 Geological and structural map of southern central England, to show the Hampshire Basin and the axes of anticlines which extend east-west through the Isle of Wight and Isle of Purbeck.

geological evolution of the region has lead to the sedimentary succession found in the region, the local landforms and geomorphology, and the formation and preservation of hydrocarbon. reserves.

Geological history of the Poole Harbour region

Closure of the Rheic Ocean

At 2700 m beneath Poole Harbour lie the oldest rocks known in Dorset – Devonian phyllites (silky-sheened recrystallized slates) found at the base of the deepest Wytch Farm wells (Figure 3). Closure of the Mid-European or Rheic Ocean in the Permian led to the Variscan Orogeny or period of mountain building when the phyllites formed through the processes of low-grade metamorphism (Warr, 2000). An important consequence of the Variscan Orogeny was the formation of east-west thrust faults, which now on the Variscan Front lie in the Palaeozoic Basement deep beneath southern England and northern France. These south dipping structures cut hard, brittle Devonian and Carboniferous limestones, and are well exposed in the quarries in the Palaeozoic inlier in the Boulonnais in the Pas de Calais, northern France. The ancient thrusts have acted as planes of weakness which have been reactivated again and again during the periods of extensional and compressional stress affecting the region. The prominent east-west ridges of the Purbeck Hill, Abbotsbury and the Isle of Wight seen on present day satellite images are a consequence of this deep structural grain.

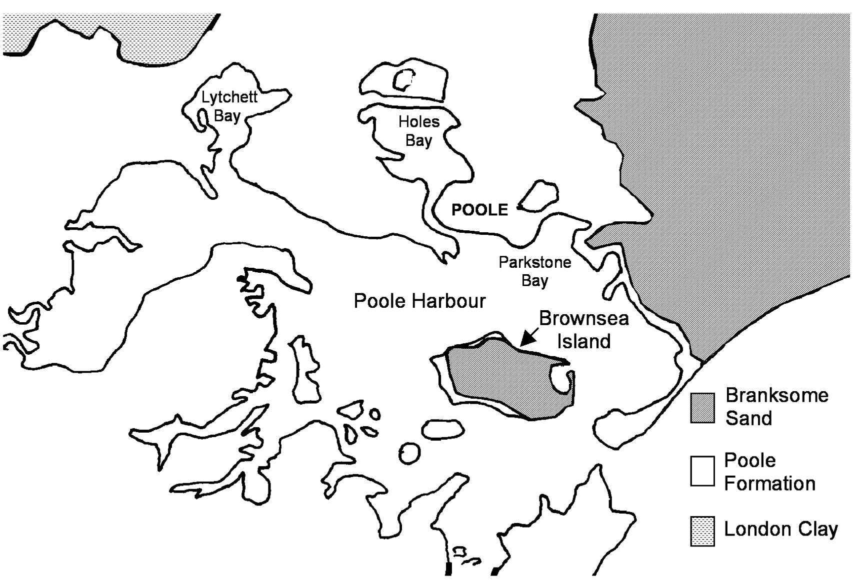

Figure 2 Geological map of Poole Harbour to show the distribution of solid deposits of Eocene age.

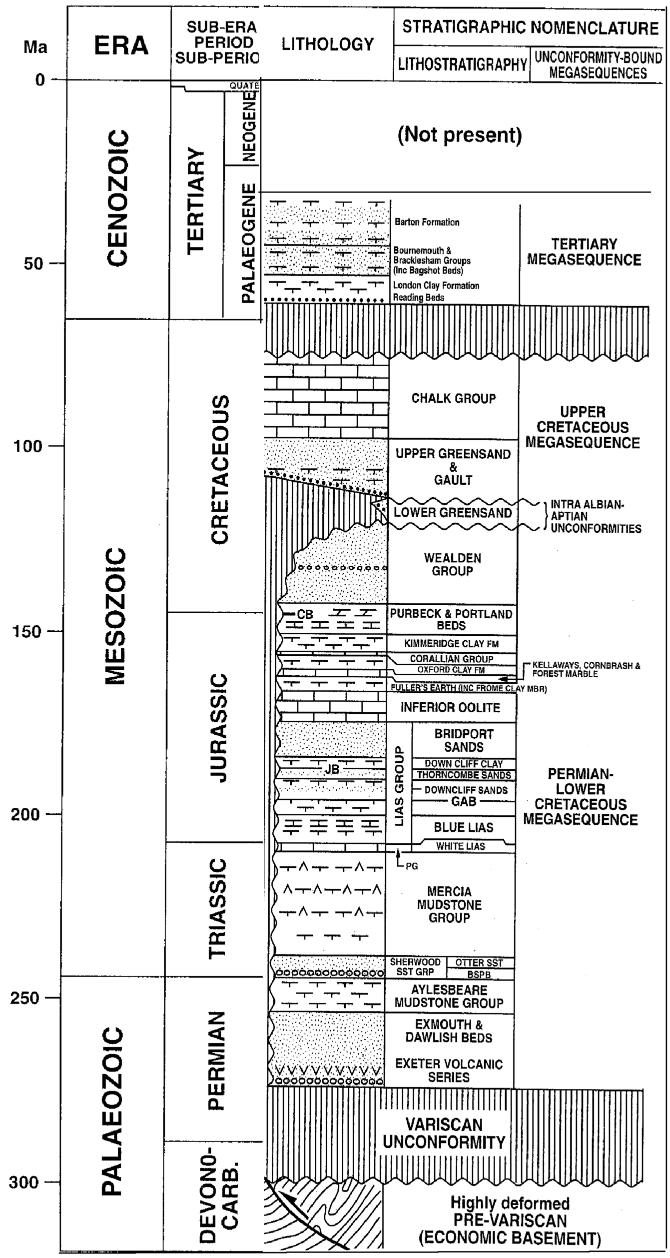

Figure 3 Geological history seen in the Wytch Farm wells. Note that after the substantial Variscan Unconformity, the succession of Triassic and Jurassic rocks is substantially complete. Note the unconformities of Early Cretaceous and Late Cretaceous-Palaeogene age. The Sherwood Sandstone and Bridport Sands form the reservoirs for oil at Wytch Farm. From Underhill and Stoneley (1999) with permission.

Triassic rifting and the initial opening of the Atlantic

Around 300 million years ago, in the Late Carboniferous, Europe and North America were part of the supercontinent Pangea. Shortly later, in the Early Permian, initial rifting of the North Atlantic commenced in the vicinity of the present Rockall Trough (Ruffell and Shelton, 2000). At the same time, the Tethys Ocean was opening in the south of Europe between Spain and Africa. The net consequence of this extensional pull apart was the formation of rift basins in which considerable quantities of Permian and Triassic sediment accumulated. In the Wessex Basin, beneath Dorset, Hampshire and the Isle of Wight, the deep Variscan structures became normal faults, and the Channel area was the focus of thick non-marine sedimentation through the latest Permian and Triassic. Approximately 1500 m of conglomerates, mudstones and sandstones deposited by flash floods, braided rivers and playa lakes are found in the Wytch Farm wells. The fluvial Sherwood Sandstone is the most intensively studied of these, for its higher porosity meant that it was to become the major reservoir for oil much later on. It lies between the Aylesbeare and Mercia Mudstones, and the latter would subsequently provide an impermeable cap, trapping the Wytch Farm oil. These deposits are magnificently exposed on the south Devon coast between Exmouth and Seaton, and the section to the east of Sidmouth in particular shows how successive braided river channels in the Sherwood Sandstone were cut, filled and abandoned.

Opening of the central part of the Atlantic, with generation of oceanic basaltic crust, was roughly coincident with the base of the Jurassic, 200 million years ago. The result of this event was increased stretching of the European continental margin with resultant thermal subsidence. A major marine transgression ensued, and the Early Jurassic deposits are the dark marine shales of the Lias which covered most of southern England, excepting the London Platform (Hesselbo, 2000). The Blue Lias (named after the quarrymen's dialect 'lias' meaning layers) comprises decimetre-scale alternations of dark, laminated organic-rich shale and limestone, essentially identical to the facies developed in the Wytch Farm wells. The Blue Lias is exposed in the crumbling cliffs to the west of Lyme Regis, and is famous as the source of superbly preserved fossil reptiles seen in the fossil shops of Lyme Regis and in various museums throughout the country. The Lias is the source rock for all the oil found in the Wessex Basin, including Wytch Farm, and coincidentally, the factors leading to the preservation of both the entire reptile skeletons and the oil were basically the same. The Liassic Sea periodically became stagnant, and the bottom waters almost entirely depleted in oxygen. As a result, the aerobic bacteria which destroy organic matter were unable to exist, and animal carcasses were not scavenged, nor was much organic matter broken down by anaerobic bacterial action.

The Jurassic succession in Wytch Farm is similar to that exposed on the Dorset coast, and it comprises clays, sands and thin limestones which can be examined at outcrop between Lyme Regis and Weymouth (House, 1993). The Bridport Sand in particular has received special attention in view of its importance as a reservoir in Wytch Farm. On the Dorset coast, to the east of West Bay, the Bridport Sand forms striking yellow-brown vertical sandstone cliffs, capped by the thin Inferior Oolite. The rather soft highly burrowed marine sands contain hard concretionary layers every metre or so, and these weather out to form ledges. The Bridport Sand is almost identical beneath Poole Harbour, where the hard concretions may pose a problem for reservoir engineers because they restrict the vertical flow of oil. The highest Jurassic formation in Wytch Farm is the Oxford Clay, which is truncated by an erosional unconformity (Figure 3).

Formation of the Channel Basin

Renewed extension during the Late Jurassic resulted in continued reactivation of the deep Purbeck–Isle of Wight lineaments as normal faults, and formation of the Channel Basin to the south of the faults. This basin received continuous sedimentation during the Early Cretaceous, and a thick non-marine (essentially fluvatile) Wealden and marine Lower Greensand succession was deposited in the south of the Isle of Wight and in south-east Dorset. On the hanging wall of the fault, Jurassic rocks were actively eroding and supplying sediment to the basin fill. Close to the fault in the eastern Isle of Wight, Jurassic fossils are found derived into Early Cretaceous sediments (Radley *et al*., 1998). Hanging wall uplift and erosion continued in the Poole Harbour area, such that the highest Jurassic was stripped off down to the Oxford Clay. Movement on the faults ceased in the Early Albian, and the areas north of the fault were transgressed by a shallow sea in which the Lower Greensand and Gault Clay Formations were deposited. Thus, the Lower Greensand rests unconformably upon Oxford Clay in the Poole Harbour region (Figure 3).

The Late Jurassic–Early Cretaceous normal movement on the Purbeck and Isle of Wight faults (and probably others, including the Abbotsbury fault), had a further consequence; on the southern footwalls of these faults, the organic-rich shales of the Lias source rock was taken down into the ‘oil kitchen’, the depth at which temperatures were sufficient to generate petroleum (Selley and Stoneley, 1987; Underhill and Stoneley, 1998). The newly formed oil migrated upwards during the Cretaceous, and spectacular ‘fossil’ oil seeps can be seen on the Dorset coast, east of Osmington Mills and at Mupe Bay, east of Lulworth Cove. Here, sands are cemented by sticky dark brown residual oil which escaped up faults, probably during the Cretaceous. It appears that oil actually cemented the banks of an Early Cretaceous river at Mupe Bay. Only at Wytch Farm did large quantities of oil migrate across two faults to become trapped in the tilted reservoirs of the Sherwood Sandstone and the Bridport Sands (Figure 4). Elsewhere, the bulk of the hydrocarbons was lost by leakage through the fault systems. The Kimmeridge Bay oilfield is the only example known in the region where migration occurred later on, in the Tertiary.

The base of the Late Cretaceous, 100 million years ago saw the commencement of a major marine transgression which was caused by a combination of factors (Gale, 2000a,b). Firstly, the rate of sea floor spreading increased globally and more water was displaced from the ocean basins by newly formed mid-ocean ridges. Secondly, tectonic subsidence of the Atlantic margin lead to increased marine transgression. Thirdly, the

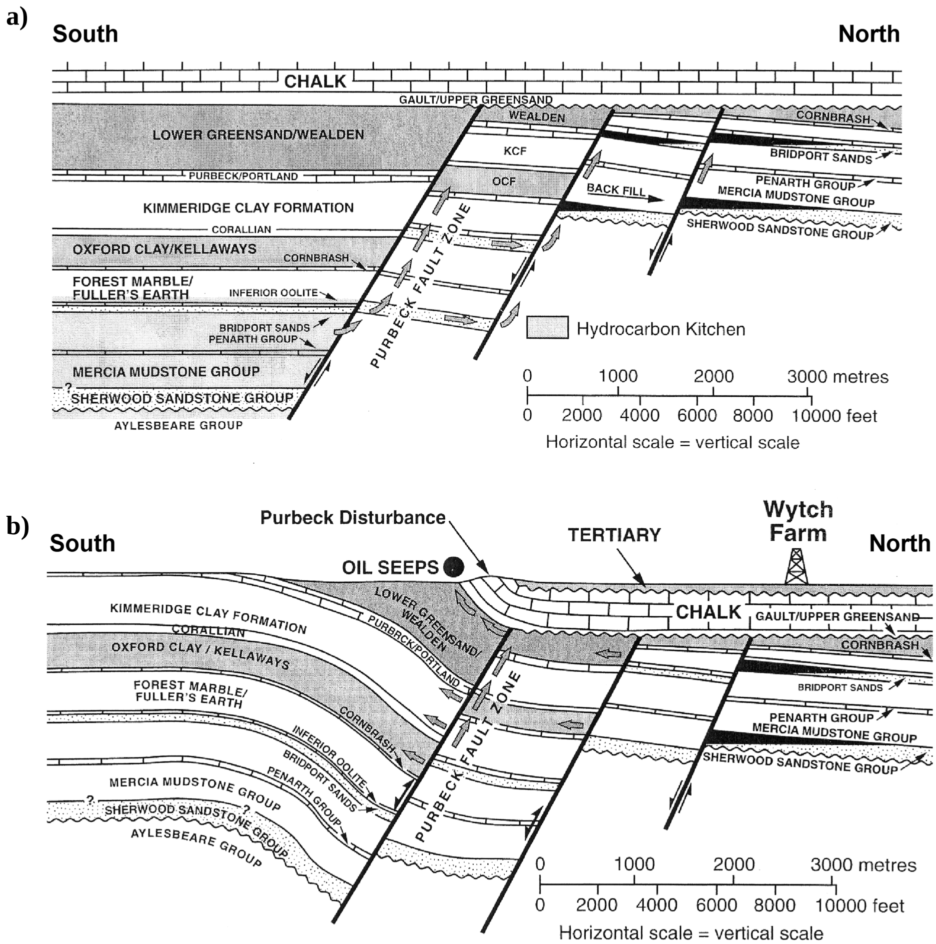

Figure 4 a) shows the reconstructed north-south cross-section of Wytch Farm at the time of oil migration in the Cretaceous. Extensional downfaulting to the south had taken the Lias source rock down into the hydrocarbon kitchen, the depth at which oil is generated. This migrated up fault planes into the Sherwood Sandstone and Bridport Sands beneath Wytch Farm. b) shows the present day cross-section with the position of Wytch Farm. Note that structural inversion has lead to the creation of the Purbeck Disturbance, and that oil which was probably present in a fault block to the south of Wytch Farm has been lost by leakage since the Cretaceous. From Underhill and Stoneley (1999) with permission.

warmest period in more recent earth history probably lead to melting of any polar ice which may have existed in the Antarctic. As a result, sea levels rose to the highest extent of Phanerozoic (post-Precambrian, the last 560 million years) time. The central part of continental Europe across to Central Asia was flooded, as was the Western Interior of the USA, and in these vast epicontinental seas Chalk was deposited. Chalk is a pelagic limestone formed from the calcite skeletons of myriad coccoliths, minute chrysophyte algae that live in the photic zone. Chalk was deposited more or less continually across the the UK for nearly 30 million years and it forms spectacular cliffs along the length of southern England from Devon to Kent. Chalk contains flint, derived by dissolution from the skeletons of siliceous organisms inhabiting the Chalk Sea.

Chalk has been important to the human species in various ways. The flint it contains proved ideal for the construction of tools and weapons by prehistoric peoples. The high porosity of many chalks has provided a fine aquifer, and although the Chalk has low matrix permeability, it has fractured extensively as a result of uplift, and the fracture zones form a conduit for water exploitation. The Chalk is the major aquifer across south Dorset and Hampshire.

The Alpine Orogeny: formation of the Hampshire Basin

The collision of Africa with southern Europe as the Tethys Ocean closed lead directly to the Alpine Orogeny and uplift of mountain chains which extend from Spain eastwards to Asia. The only existing remnant of the Tethys is the modern day Mediterranean. The compression from crustal shortening in the Alpine Orogeny was transmitted northwards and westwards across Europe, and resulted in reactivation of many deep structures. The Isle of Wight–Purbeck deep faults were no exception, and the infill of the Channel Basin was inverted, with development of steep dips on the strata immediately overlying the deep thrusts (Figure 4; Underhill and Paterson, 1998). Where the Chalk formed the nearly vertical northern limb of structures such as the Purbeck Anticline (and the Brixton and Sandown Periclines on the Isle of Wight), it partially recrystallized and created highly resistant ridges like the Purbeck Hills.

Although the Tethys Ocean started to close in the Late Cretaceous, as Africa collided with southern Europe, the first evidence of compression in the UK was the formation of a widespread unconformity at the summit of the Chalk, which probably dates to the earliest Palaeocene (Danian). Although this represents a considerable period of time (about 10 million years), the Chalk was only very gently folded. This unconformity was peneplaned by successive marine advances during the Palaeocene. Major inversion of structures in southern England commenced in the Mid Eocene, with initial uplift of the east-west periclinal structures in the Isle of Wight and Dorset, each of which overlie a deep basement thrust. The early history of this uplift is documented by reworking of progressively older sediments into the Hampshire Basin succession at Whitecliff Bay in the Isle of Wight during the Middle and Late Eocene (Gale *et al*., 1999).

The major geomorphological consequence of this inversion was uplift of the Chalk ridges which run east-west through Dorset and the Isle of Wight, and formation of the Hampshire Basin to the north. The drainage pattern which is seen at the present day, with catchment from the west and north draining into the Solent along the axis of the Hampshire Basin, can thus be shown to have developed initially in the Palaeogene.

Eocene sedimentation and the proto-Solent

Poole Harbour is underlain by sands and clays of the Poole Formation; the Branksome Sand is restricted to the summit of Brownsea Island and the coast east of Poole (Figures 1 and 5). Both formations are of Middle Eocene age and were deposited in the broad coastal plain of the proto-Solent river complex which flowed eastwards, to the north of the Chalk hills of Purbeck and the Isle of Wight (Figure 6). It drained a catchment lying to the west and north. The position of the shoreline fluctuated considerably, but open marine conditions existed in the eastern Isle of Wight and West Sussex throughout much of the Eocene (Plint, 1988).

The Poole Formation comprises an alternation of clay units 5 m to about 30 m in thickness, and cross-bedded quartz sands which locally contain pebbles. The clays commonly display a fine alternation of sand and clay, on a millmetric to centrimetric scale, evidence of tidally dominated deposition on mudflats, supported by the presence of marine dinoflagellates. Five clay members (Creekmoor, Oakdale, Haymoor Bottom, Broadstone and Parkstone) have been named and mapped around Poole Harbour. The sands, which are commonly erosionally based and fine upwards were mostly deposited in fluvial channels, but some may be marine barrier sands. Current directions taken from cross bedding indicate a dominant source to the west, with minor northern and southern influences. The Branksome Sand is erosionally incised into the summit of the Poole Formation and comprises coarse to fine grained sands in fining upwards packages, deposited by rivers.

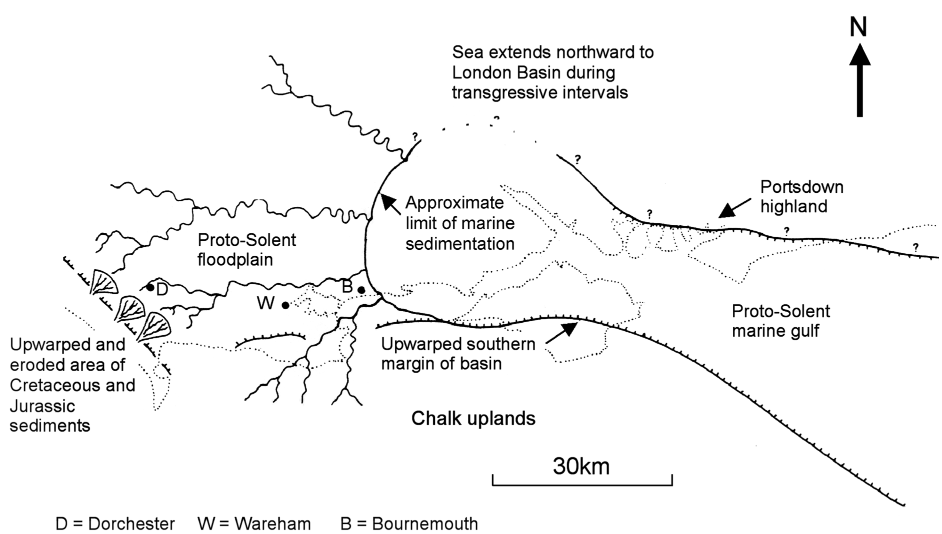

Figure 5 The succession in the London Clay, Poole and Branksome Formations in the Poole Harbour region. These sediments are of Mid Eocene age. The succession has been proved in many boreholes put down by English China Clay in the search for kaolinite deposits (ball clays). Modified after Bristow *et al.* (1991).

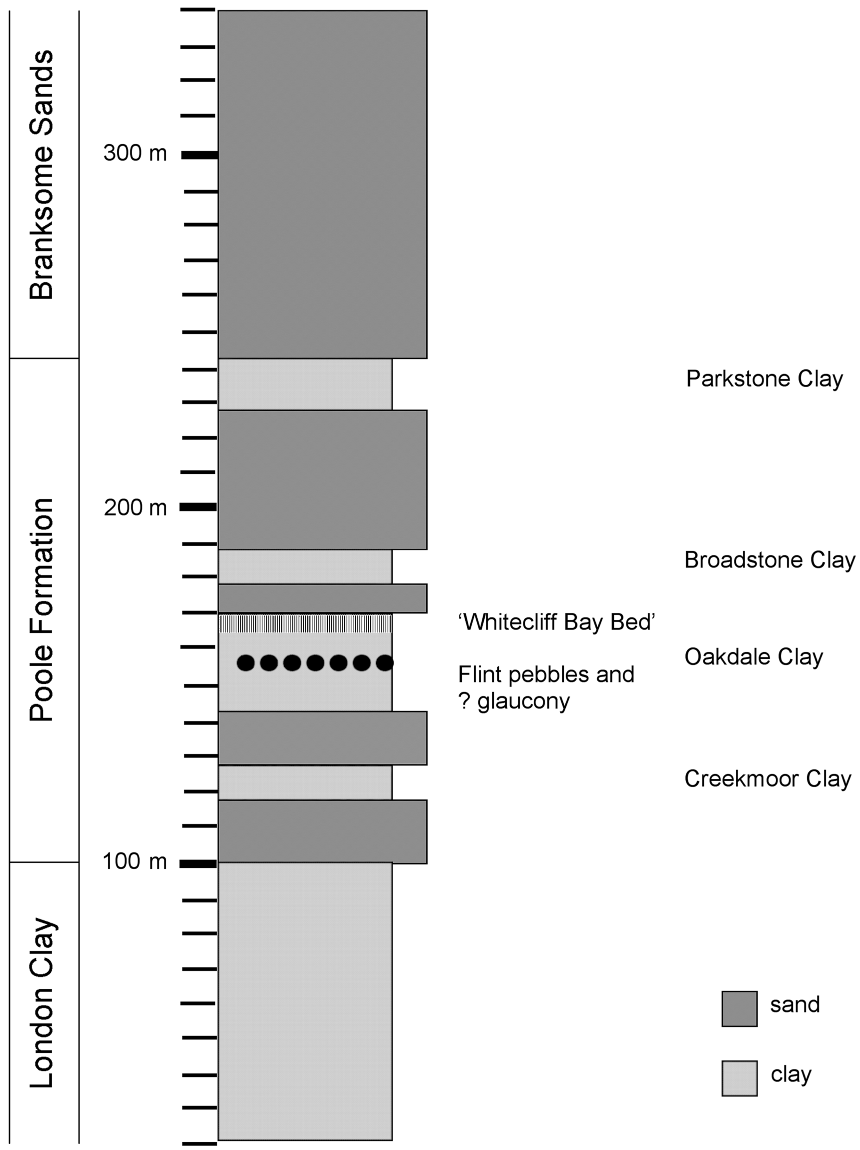

Figure 6 **Palaeogeographical map of east Dorset, south Hampshire and the Isle of Wight in the Mid Eocene. A gulf of the sea corresponding to the Proto-Solent extends from the east into the Hampshire Basin. Rivers from the west and north-west drain into this gulf, with more limited drainage from the Chalk uplands to the south and west. Poole Harbour was a region of fluviatile and brackish marine deposition.**

Additional evidence for the depositional conditions of the Poole and Branksome Formations comes from floras which are locally abundant in the laminated clays and are dominated by drifted leaves. Salt-tolerant ferns grew along the banks of rivers, adjacent to large expanses of sub-tropical forest. The clays themselves are of interest in terms of their ultimate sources, because the percentage of the clay mineral kaolinite increases westwards in the Poole Formation towards Wareham. Kaolinite is commonly derived from the weathering of granites in warm humid conditions, and the likelihood is that the catchment of the proto-Solent in the Eocene extended far westwards to the granite batholiths of Devon.

Evidence for correlation of the Poole and Branksome Sand Formations with the broadly coeval Bracklesham Group succession exposed in the Isle of Wight to the east is rather limited and inferential because neither formation yields fossils which provide high resolution ages. Although floras are locally diverse and abundant, only a limited number of rather long-ranging dinoflagellate taxa have been found, which indicates that most of the Poole Formation falls within the *coleothrypta* zone. The Parkstone Clay at the top of the formation and the overlying Branksome Sand fall within the *intricatum* zone above. Both zones represent long time intervals (probably several million years). Such correlations as have been made are essentially based on event stratigraphy, using in particular marine transgressions which have been identified in the Isle of Wight (Plint, 1988). A rooted palaeosol near the summit of the Oakdale Clay has been correlated with a rooted coal in the Wittering Formation of Whitecliff Bay in the east of the Isle of Wight, which may also be present in the Southampton district (Bristow *et al*., 1991).

Because the transgressive events identified in the Isle of Wight are well marked by sharp facies changes, and were caused by eustatic rises in sea level of perhaps 10 m to 20 m, it seems eminently plausible that they have direct correlatives in the low-lying coastal palaeoenvironments represented by the Poole and Branksome Formations of east Dorset. The most marine succession in the island is that in Whitecliff Bay, which is broadly similar to that seen on the West Sussex coast on the Selsey peninsula (Figure 7). At this locality, four major transgressions can be identified in the Bracklesham Group, represented by fully marine shelly glauconitic sands which locally contain well-rounded black flint pebbles (T1–4 of Plint, 1988). These transgressive surfaces rest abruptly and erosionally upon tidally laminated sands and clays containing occasional rooted soils.

In the west of the island at Alum Bay, the succession is less marine and dominated by alluvial sands (Figure 7) (Plint, 1988). Nevertheless, the four transgressive events seen in Whitecliff Bay can be identified from the distribution of marine facies. The correlation can then be extended to the Poole district, taking the clay horizons in the Poole Formation as representing the most marine events. Thus, the trangression seen in the eastern Hampshire Basin within the Wittering Formation appears to correlate with the glauconitic green clay containing sparse flint pebbles in the Oakdale Clay of Poole Harbour (Bristow *et al*., 1991).

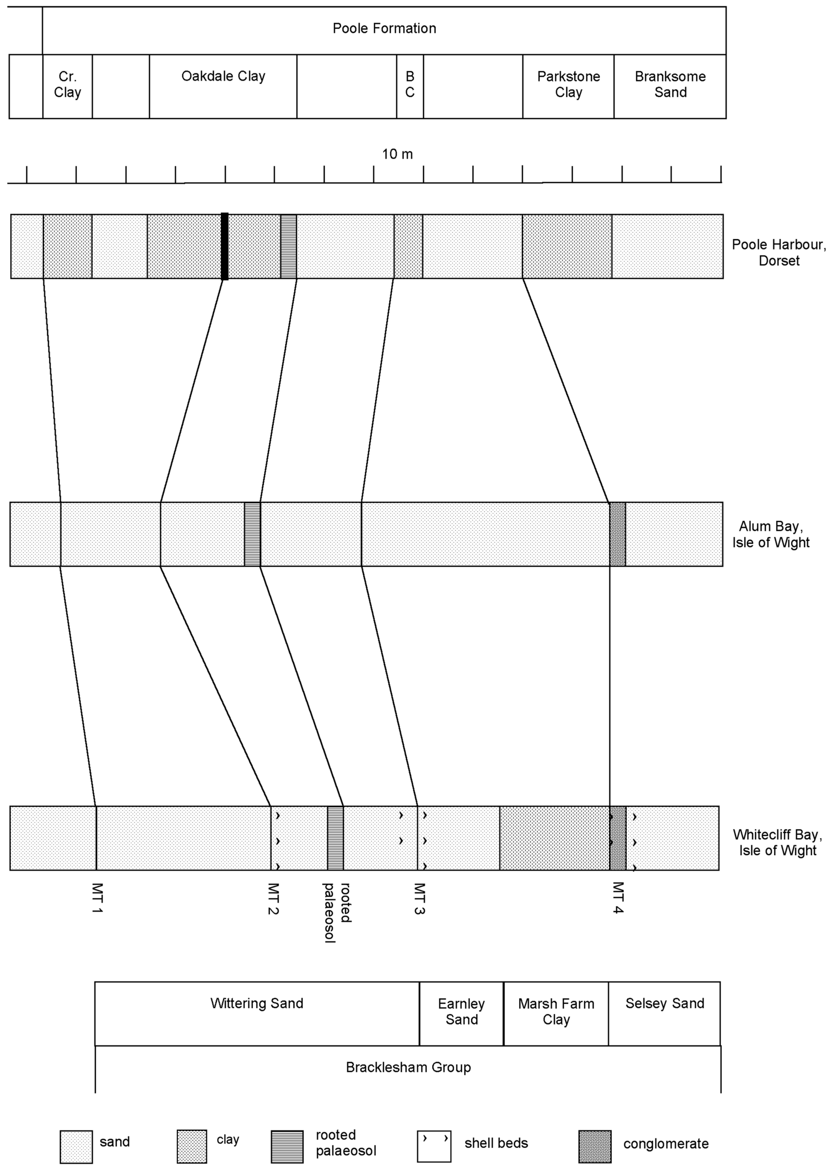

Figure 7 Correlation of the Mid Eocene sediments between the Isle of Wight and the Poole Harbour region. This is based upon four marine transgressions (MT1–3) of which MT2–4 are represented in the eastern Isle of Wight (Whitecliff Bay) by marine shelly sands. In the Poole Formation, the transgressions are represented by the Creekmoor (Cr), Oakdale, Broadstone (BC) and Parkstone Clays, which were of restricted marine facies. A rooted palaeosol, called the Whitecliff Bay Bed, appears to correlate with a group of rooted palaeosols present in the summit of the Oakdale Clay. The localities are shown in Figure 1.

The Palaeogene-Quaternary unconformity

In the Hampshire Basin, the Early Oligocene Solent Group is erosionally truncated (highest Bouldnor Formation, Isle of Wight) and there is no Late Oligocene or Miocene sedimentary record preserved here or elsewhere in southern England. Pliocene sediments are represented only by a few tiny outliers on the North Downs. The widespread unconformity between the Oligocene and Quaternary was interpreted by Wooldridge and Linton (1955) as evidence of a structural 'Alpine storm' of Miocene age, in which most of the anticlinal structures, such as those in the Weald and Purbeck–Isle of Wight, formed. However, this story is now replaced by one of more continuous uplift since the Mid Eocene when inversion seems to have commenced in the Isle of Wight at least (Gale *et al*., 1999). This latter model is supported by other lines of evidence. Firstly, the high level of Pliocene deposits on the North Downs suggests that considerable uplift has taken place in southern England over the past few million years. Secondly, Preece *et al*. (1990) recorded uplift rates from the Late Quaternary of the eastern Isle of Wight which are almost identical to those calculated by Gale *et al.* (1999) for the Eocene succession. The ultimate cause of uplift, the collision of Africa and southern Europe, is likely to have continued fairly constantly over the last 50 million years, and still does so today.

Quaternary history

The drift deposits of Poole Harbour have been mapped (Bristow *et al*., 1991) as river gravels, head and marine and estuarine alluvium. River gravels of Pleistocene age (the Frome Piddle Gravel Formation of Gibbard and Allen, 1995) directly overlie Middle Eocene sediments on the higher ground around Poole Harbour. These gravels were deposited by the easterly draining river complex of the Frome and Piddle, the major axial drainage system of the Hampshire Basin. These rivers originally drained into the substantial Solent River, which flowed eastwards along the line of the present Solent before eustatically driven marine erosion breached the Needles Channel during the early Holocene (Gibbard and Allen, 1995).

The river gravels comprise sandy gravels dominated by subangular flints and contain a small proportion of clasts including cherts and limestones of probable Jurassic age and sandstones derived from Tertiary sediments. The terraces have been numbered 1–14 in order of increasing age. The higher gravels are extensively cryoturbated from the effects of periglacial freeze-thaw. Gravels 1–10 have been identified in Poole Harbour (Bristow *et al*., 1991). The deposits mapped as head comprise mostly gravels that have solufluncted as result of freeze-thaw action. The estuarine alluvium found extensively around Poole Harbour comprises a lower gravelly unit and an upper silty clay with a high organic content, each a maximum of 1 m in thickness. Both were deposited in the Holocene during the Flandrian transgression.

Acknowledgements

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References

Bristow, C. R., Freshney, E. C. and Penn, I. E. (1991) Geology of the country around Bournemouth. *Memoir of the Geological Survey of Great Britain*. Sheet No. 329.

Buchanan, J. G. (1998) The exploration history and controls on hydrocarbon prospectivity in the Wessex Basins, Southern England, UK. pp. 19–39. In: *Development, Evolution and Petroleum Geology of the Wessex Basin*. Underhill, J. R. and Stoneley, R. (eds). *Geological Society Special Publication*, No. 133.

Gale, A. S. (2000a) Late Cretaceous to Early Tertiary deposition through the global highstand. pp. 356–373. In: *Geological History of Britain and Ireland*. Woodcock, N. H. and Anderton, R. A. S. (eds). Oxford: Blackwell.

Gale, A. S. (2000b) The Cretaceous world. pp. 4–19. In: *Global Change and the Biosphere; The Last 150 Million Years.* Culver, S. J. and Rawson, P. F. (eds). Cambridge: Cambridge University Press.

Gale, A. S., Jeffery, P.A., Huggett, J. M. and Connolly, P. (1999) Eocene inversion history of the Sandown Pericline, Isle of Wight, southern England. *Journal of the Geological Society*, **156**: 327–339.

Hesselbo, S. P. (2000) Late Triassic and Jurassic: disintegrating Pangaea. pp. 314–338. In: *Geological History of Britain and Ireland*. Woodcock, N. H. and Anderton, R. A. S. (eds). Oxford: Blackwell.

House, M. R. (1993) *The Geology of the Dorset Coast*. *Geologists' Association Guide*, No. 22.

Gibbard, P. L. and Allen, L. G. (1995) Drainage and evolution in south and south-east England during the Pleistocene. *Terra Nova*, **6**: 444–452.

Plint, A. G. (1988) Global esutacy and the Eocene sequence in the Hampshire Basin. *Basin Research*, **1**: 11–22.

Preece, R. C., Scourse, J. D., Houghton, S. D., Knudsen, K. L. and Penney, D. N. (1990) The Pleistocene sea-level and neotectonic history of the eastern Solent, southern England. *Philosophical Transactions of the Royal Society of London, Series B*, **328**: 425–477.

Radley, J., Gale, A. S. and Barker, M. J. (1998) Derived Jurassic fossils from the Vectis Formation (Lower Cretaceous) of the Isle of Wight, southern England. *Proceedings of the Geologists' Association*, **109**: 81–91.

Ruffell, A. H. and Shelton, R. G. (2000) Permian to Late Triassic post-orogenic collapse, early Atlantic rifting, deserts, evaporating seas and mass extinctions. pp. 297–313. In: *Geological History of Britain and Ireland*. Woodcock, N. H. and Anderton, R. A. S. (eds). Oxford: Blackwell.

Selley, R. C. and Stoneley, R. (1987) Petroleum habitat in south Dorset. pp. 139–148. In: *Petroleum Geology of North-west Europe*. Brooks, J. and Glennie, K. (eds). London: Graham and Trotman.

Underhill, J. R. and Paterson, S. (1998) The structural development of the Wessex Basin. *Journal of the Geological Society of London*.

Underhill, J. R. and Stoneley, R. (1998) Introduction to the development, evolution and petroleum geology of the Wessex Basin. pp. 1–19. In: *Development, Evolution and Petroleum Geology of the Wessex Basin*. Underhill, J. R. and Stoneley, R. (eds). *Geological Society Special Publication,* No. 133.

Warr, L. N. (2000) The Variscan Orogeny: the welding of Pangaea. pp. 271–294. In: *Geological History of Britain and Ireland*. Woodcock, N. H. and Anderton, R. A. S. (eds). Oxford: Blackwell.

Wooldridge, S. W. and Linton, D. L. (1955) *Structure, Surface and Drainage of South-east England.* London: George Philip.