The Geology of Poole Harbour and its environs

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At first sight the landscape and geology (Figures 1 and 2) of the harbour and surrounding area are unimpressive; no high spectacular sea cliffs, rocky platforms or broad sparkling beaches. These first impressions are deceptive. It is easy to disregard the fact that it is the second largest natural harbour in the world but 'how and why', is this natural wonder, here in Dorset.

Well, that story of 'how and why' is, in part, to do with the 'youngest' geological history of the area and those roots can be traced back to a time when the world was periodically dominated by glaciers and this part of England was often a frozen tundra in winter and crossed by a many-channelled fast flowing meltwater river in summer. At other times this river was a lazy meandering stream through lush warm temperate vegetation. Geologists talk of that river as the proto-Solent that had its origins 500,000 years or more before now. This 'young' geological story is not simple, and will be taken-up later but there is an equally compelling tale hidden in the rocks at depth beneath the calm waters of the harbour.

You only have to look southward toward the low-lying heathlands dominated by sandy and clayey soils supporting extensive forests and on further to the impressive ridge (Nine Barrow Down) founded on Chalk strata that forms the natural amphitheatre to the harbour. Hidden away in these modern coniferous woodlands are enclosures that protect the 'nodding donkeys' of Britain's largest onshore oilfield. Operated by British Petroleum, this Wytch Farm Oilfield, discovered first through a grid of seismic survey lines and then brought into production by the many deep oil-wells (the first in 1973), provide the substance and clues to a much more ancient and long geological history for the rocks that underlie the area.

Much of what is seen in the samples from those deep oil-wells takes the geological history of the area back some 260 million years (260 Ma in shorthand) or more and geologist's understanding of the even deeper rocks, called the Variscan Basement, take the story back even further.

At the end of this Variscan basement-forming time, landmasses were finally coalescing into a mighty super-continent called Pangea and the world looked a very different place to what we see today. Within that global collision an ancient sea, called the Rheic Ocean, was closing bringing together Avalonia (that forms much of what we now know as England and Wales) and Armorica/Iberia (including parts of Western Europe/France and Spain). We only have tantalising glimpses of these basement rocks from deep seismic interpretations and samples in the deepest boreholes across southern England and these show a number of deep southward dipping (northward compressing) thrusts and weakly metamorphosed rocks resulting from the collision. Renewed movement on these thrusts form an important part of the story in the rocks that overlie the basement and fill a geographical unit of Jurassic and Cretaceous age known as the Wessex Basin. This basin is a reflection of wider global events that saw the breaking up, over time, of the Pangea super-continent into

Laurasia (northern continent) and Gondwana (southern continent) and the later east to west opening of the Atlantic Ocean that separated Laurasia into the North American and Eurasian continents. A continental configuration that approximates to what we see today.

Throughout southern England many different rocks were deposited in the Wessex Basin as it was expanded over many millions of years. The thrusts in the underlying Variscan basement were reactivated during this expansion and a network of normal faults centred over these thrusts developed, such that the Wessex Basin became fragmented into a series of structural highs and lows (sub-basins); each fragment having its own subtlety changed sequence (Figure 3). These sequences have been intensively investigated in the search for hydrocarbons.

One of the oilfield boreholes (Figure 4), at Wytch Farm itself, penetrates 2700 metres into the basement and provides a window into the rocks beneath the harbour. These rocks tell the story of vastly changing climates and landmass movement through 250 million years of the Earth's history. In the borehole Wessex Basin rocks range in age from the Permian (may be as much as 260 million years old beneath this area), up into the Triassic, Jurassic, Cretaceous and at the top over 140 metres of Palaeogene strata. The relative ages of these rocks are shown on Figure 4.

The Permian and Triassic (Permo-Triassic) rocks, about 1450 metres thick in this borehole, represent a period of deposition in arid land-locked basins and shallow hypersaline (very salty) seas and because of their characteristic colour are often referred to as 'red-beds'. These desert dune and fluvial sandstones, mudstones, breccias (a rock made up of rock fragments) and salt deposits form the lower level of the hydrocarbon reservoir rocks for the Wytch Farm Oilfield.

The Jurassic and Cretaceous rocks above provide a record of the infilling of shallow tropical seas as the Wessex Basin further expanded. The Jurassic strata comprise shallow water limestones and deeper water clays. One of these clays, the Kimmeridge Clay Formation, is highly carbonaceous and when buried deeply enough and 'cooked' forms the source- rock for the hydrocarbons trapped in the strata of the Wessex Basin. The Bridport Sands Formation, also within the Jurassic, is the higher hydrocarbon reservoir in this oilfield.

The Cretaceous started with widespread fluvial deposition as sea levels fell and this can truly be said to be the dinosaur age. These rocks are absent beneath the harbour due to erosion, that also removed much of the Upper Jurassic (including the Kimmeridge Clay) in this borehole, but they can be seen along the southern coast of Purbeck and on the Isle of Wight. As seas expanded again marine sands and clays were laid down initially but were soon followed by a huge thickness of Chalk that was laid down in a vast warm ocean, at a time when the highest relative sea-levels were recorded in Earth's history. This widespread deposit is economically very important to the British Isles as it forms the largest aquifer from which most of southern and eastern England derives its water supply. The Chalk can be seen between Ballard Point and Handfast Point south of the harbour entrance and again at the Needles on the Isle of Wight. In both places the Chalk is practically vertical due renewed earth movements, the Alpine Orogeny, an event that forms an important part of the story later on.

The infilling of the expanding Wessex Basin effectively came to an end with the Chalk and a short break in deposition, as sea-level fell again and weak folding occurred, resulted in erosion of the uppermost Chalk strata.

The highest 140m of strata in the Wytch Farm Borehole record the events of the development of the most south-westerly part of the Palaeogene (or Tertiary) North Sea/Paris Basin. The inter-bedded clays and sands carry a record of fluctuating shallow marine, nearshore (inter-tidal), lagoonal and fluviatile deposition at a time when the climate was tropical to sub-tropical. Part of this succession forms the bedrock to the harbour and is known as the Bracklesham Group comprising the Poole and Branksome Sand formations. These form a shallow saucer shaped down-fold (syncline) that helps to delimit the natural harbour area (Figure 5). The Bracklesham Group is mainly fluviatile (river-deposited) with successions of fine- to very coarse-grained, cross-bedded fluvial sands interrupted by generally thinner grey to sandy-brown, carbonaceous, lignitic and commonly laminated lagoonal clays and coarse-grained estuarine/marine sand bars. These lagoonal clays and sand bars reflect periodic short-lived marine incursions into the otherwise fluviatile succession. The base of each fluvial sand unit is generally erosive and cuts down into the preceding lagoonal clay unit. Each of the cycles is named in the Poole area that represents the type area for the named succession. These clays, principally within the Oakdale and Parkstone Clay Members, were the major resource for the local pottery industry including the famous Poole Pottery itself. There are numerous exposures of these rocks on the foreshore around the harbour, notably on Brownsea Island where the National Trust have a geological trail and booklet available.

Younger Palaeogene deposits are present on the Isle of Wight but are absent in this area due to erosion following a major folding event about 20 million years. We have already mentioned this event, the Alpine Orogeny, as it created the spectacular vertical Chalk cliffs at Handfast Point and the Needles and ‘rucked-up’ the geological strata of southern England like a carpet. This folding created the broad downfold (syncline) that provided the youngest ‘basin’ over the area that was exploited by the proto-Solent River and its tributaries. This river was confined to the south by the chalk ridge that ran uninterrupted from Nine Barrows and Ballard downs, in Purbeck, to the Needles and beyond to Culver Down on the Isle of Wight; and in the north by the chalk ridge from Portsdown near Portsmouth to Brighton.

The youngest, Quaternary, deposits of the area were formed as a series of river terraces and related intertidal and marine deposits as the proto-Solent cut-down into the bedrock or built-up its deposits in response to major sea-level fluctuations. These sea-level fluctuations were large with sea-level being perhaps as much as 35-40 metres above or 60 metres (or more) below its present position at various times during the last 500, 000 years or so. These vast changes in sea-level were in response to the amount of water that was locked-up in glaciers as the world was gripped in a number of glacial and interglacial periods. There are many such glacial/interglacial cycles in the last 1.8 million years but two are particularly important within the UK. The most severe and oldest of the two is dated at around 450,000 years ago (the Anglian Glaciation) as vast ice sheets reached as far south as the River Thames area. The whole of southern England was within a tundra area suffering a winter freeze and a summer thaw where large quantities of meltwater used the multi-channelled ‘Solent

River' to deposit large spreads of gravel. Following each major glacial event climate returned to warm temperate or even sub-tropical in nature and sea-level rose, lower-river courses were drowned and streams reverted to sluggish meandering streams in wide floodplains.

That river had many tributaries but flowed, generally, eastward from what we now call Dorchester, through Southampton and north of the Isle of Wight, until it turned sharply southwards off Selsey Bill, and then flowed south-westward along the axis of the English Channel. As time passed the Solent River drainage system became more mature, abandoning higher terrace gravels and divided into the river systems we see today as it cut down through the bedrock. The Rivers Frome and Piddle that enter the harbour from the west became entities in their own right through time.

At various times during the history of this Solent River, when sea-levels were much lower than today, Britain was connected by a land-bridge to Europe and humankind took its first steps hereabouts following vast herds of animals in their annual migrations to lush summer pastures.

This glacial – interglacial cycle was repeated at least twice since the Anglian with the youngest glacial cycle, the Devensian, coming to an end only some 13,000 years ago. Britain is currently within a major interglacial climate event, termed the Holocene, where the majority of lower river valleys are being drowned as sea-levels rise and broad alluvial tracts develop. Poole Harbour is one of those drowned valleys where sedimentation has not yet completely filled the available tidal space. Part of the reason why this process is incomplete may be due to the breaching of the Ballard Down/Needles chalk ridge in this Holocene period. This event provided a short route for the sediment-laden river to deposit its load in deeper water and thus short-circuiting a longer route north of the Isle of Wight. This sedimentary process continues today with estuarine muds and sand-filled channels disgorging through a single entrance to the harbour between the geologically very young sand spits of Sandbanks and South Haven

All in all, a long and fascinating geological history that demonstrates the dynamic nature of Earth's past and the power of natural forces in shaping the present.

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Further Reading

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Captions for Figures

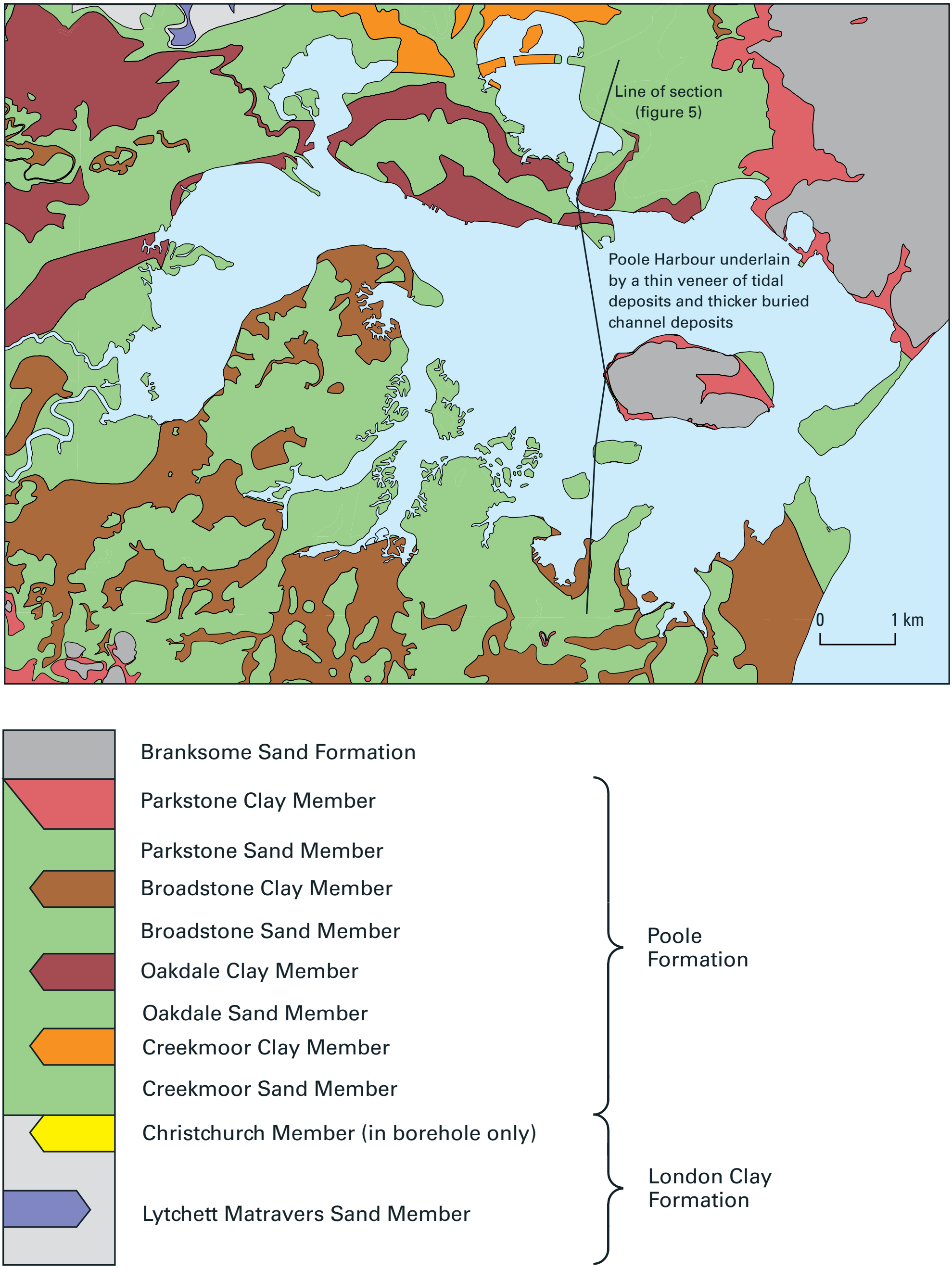
Figure 1. Simplified Bedrock Geology of the Poole Harbour area.

Figure 2. Simplified Superficial Geology of the Poole Harbour area.

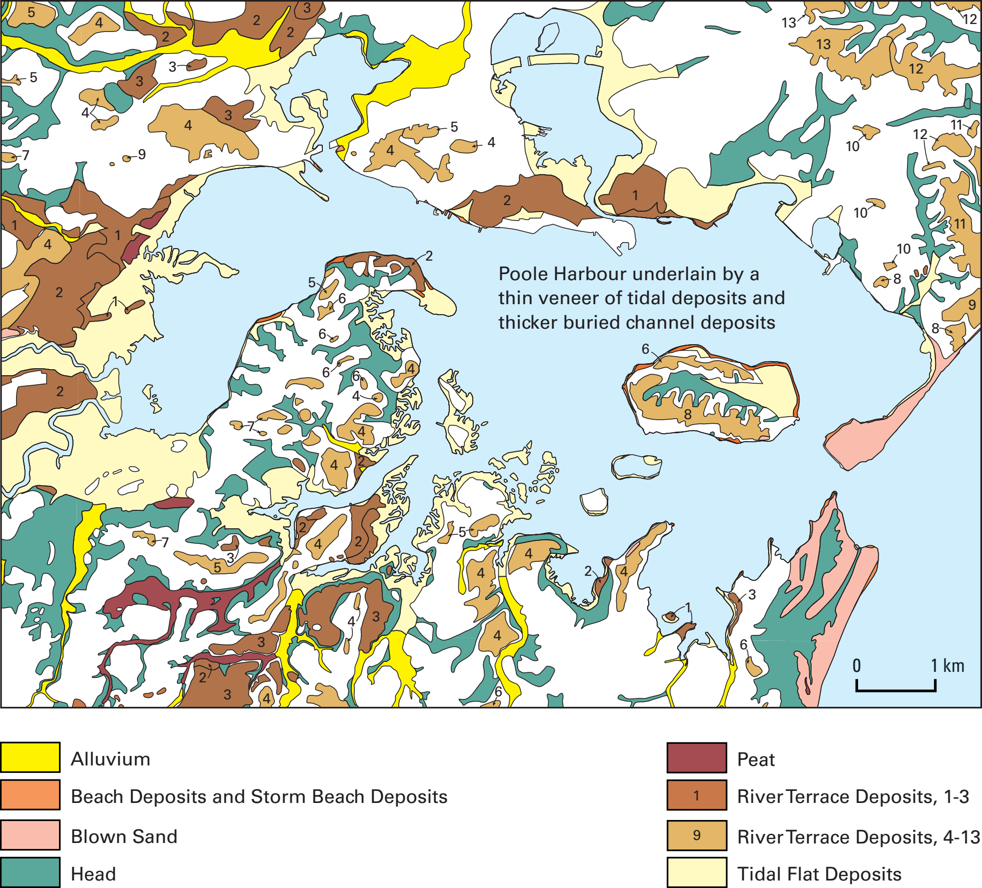
Figure 3. A sketch section showing the deep geology interpretation based mainly on seismic data and deep hydrocarbon wells.

Figure 4. The succession of rocks found in the Wytch Farm Borehole and an interpretation of the strata missing from that well.

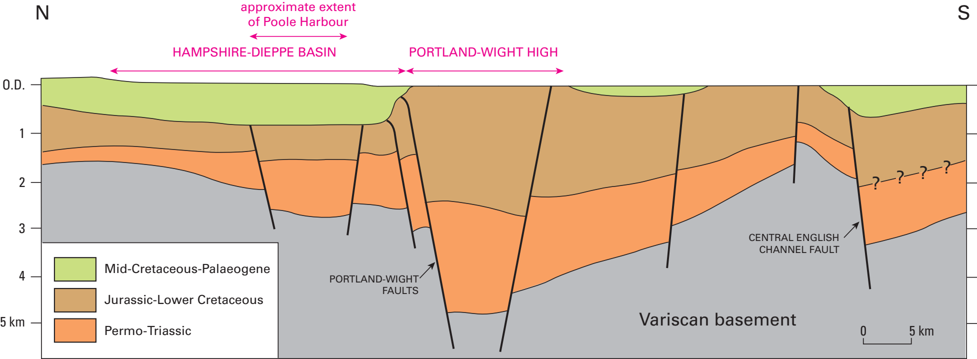
Figure 5. A north – south sketch section through Poole Harbour showing the shallow structure.

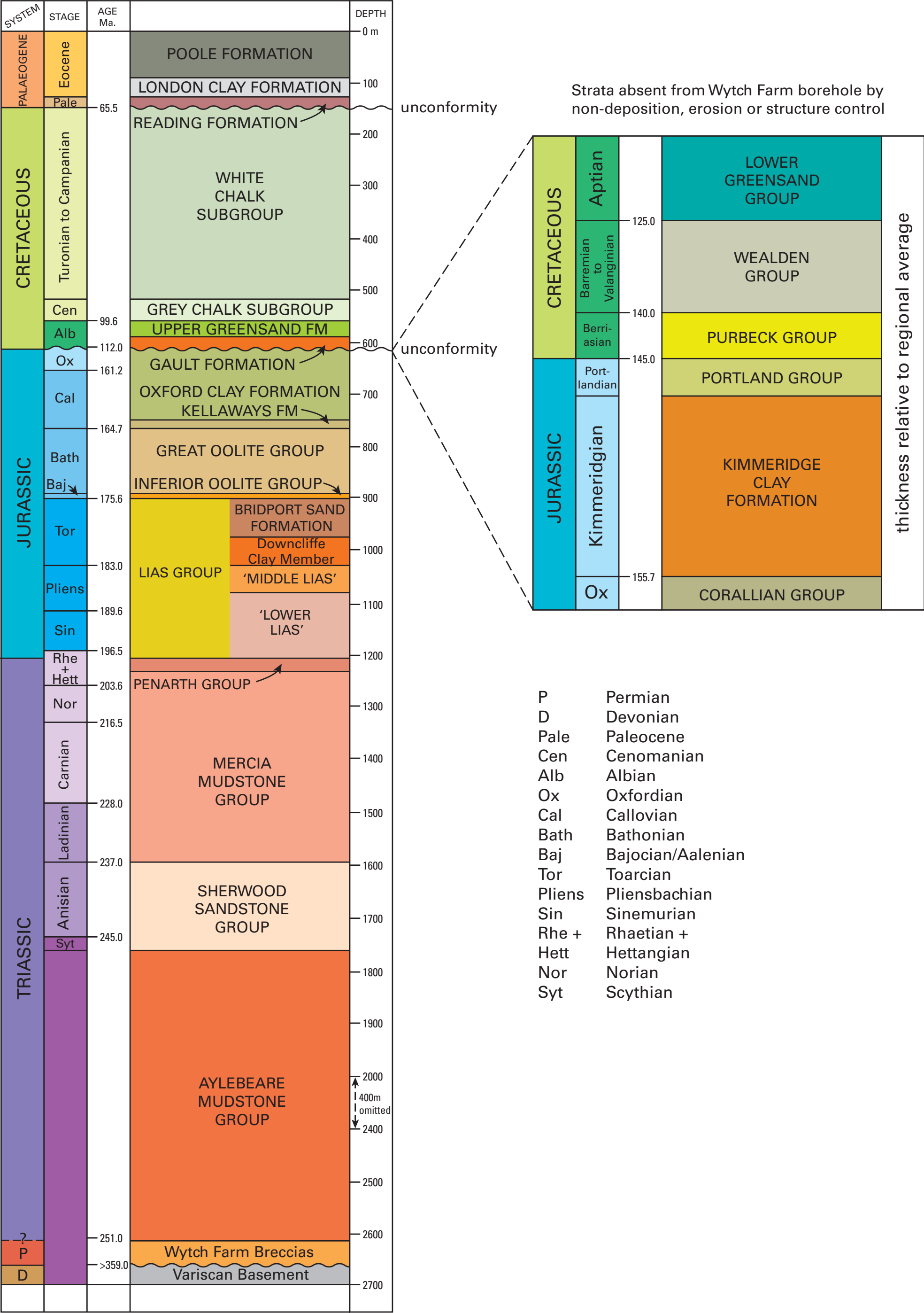


Line of section
(figure 5)
Poole Harbour underlain by a thin veneer of tidal deposits and thicker buried channel deposits
0
1 km
Branksome Sand Formation
Parkstone Clay Member
Parkstone Sand Member
Broadstone Clay Member
Broadstone Sand Member
Oakdale Clay Member
Oakdale Sand Member
Creekmoor Clay Member
Creekmoor Sand Member
Christchurch Member (in borehole only)
Lytchett Matravers Sand Member
Poole Formation
London Clay Formation

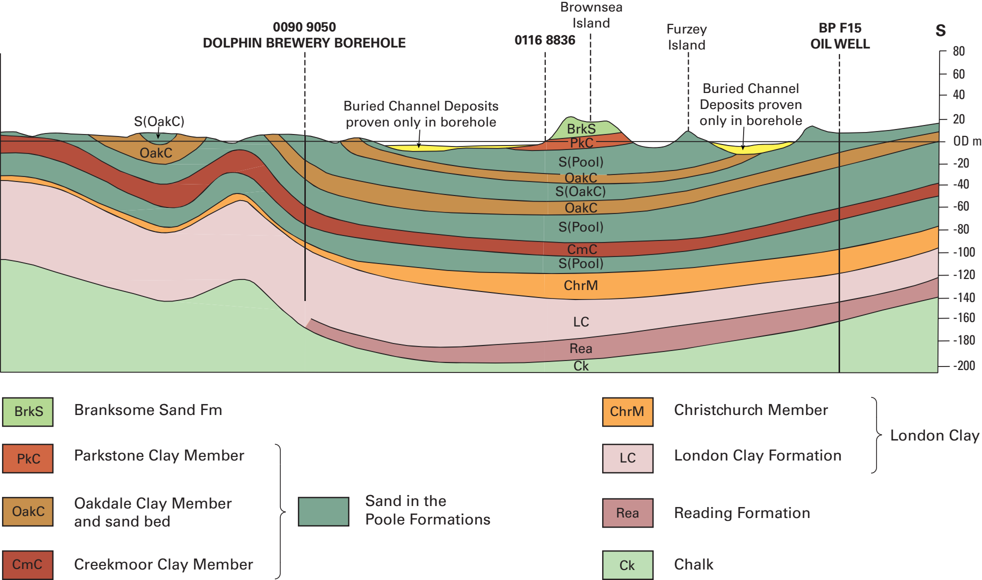


Poole Harbour underlain by a
thin veneer of tidal deposits and
thicker buried channel deposits
0
1 km
Alluvium
Beach Deposits and Storm Beach Deposits
Blown Sand
Head
Peat
1
River Terrace Deposits, 1-3
9
River Terrace Deposits, 4-13
Tidal Flat Deposits


N
S
approximate extent
of Poole Harbour
HAMPSHIRE-DIEPPE BASIN
PORTLAND-WIGHT HIGH
O.D.
1
2
3
4
5 km
Mid-Cretaceous-Palaeogene
Jurassic-Lower Cretaceous
Permo-Triassic
PORTLAND-WIGHT
FAULTS
CENTRAL ENGLISH
CHANNEL FAULT
Variscan basement
0
5 km



SYSTEM
STAGE
AGE Ma.
DEPTH
PALAEOGENE
Eocene
Pale
CRETACEOUS
Turonian to Campanian
Cen
Alb
JURASSIC
Ox
Cal
Bath
Baj
Tor
Pliens
Sin
TRIASSIC
Rhe + Hett
Nor
Carnian
Ladinian
Anisian
Syt
?
P
D
65.5
99.6
112.0
161.2
164.7
175.6
183.0
189.6
196.5
203.6
216.5
228.0
237.0
245.0
251.0
>359.0
POOLE FORMATION
LONDON CLAY FORMATION
READING FORMATION
WHITE CHALK SUBGROUP
GREY CHALK SUBGROUP
UPPER GREENSAND FM
GAULT FORMATION
OXFORD CLAY FORMATION
KELLAWAYS FM
GREAT OOLITE GROUP
INFERIOR OOLITE GROUP
LIAS GROUP
BRIDPORT SAND FORMATION
Downcliffe Clay Member
'MIDDLE LIAS'
'LOWER LIAS'
PENARTH GROUP
MERCIA MUDSTONE GROUP
SHERWOOD SANDSTONE GROUP
AYLEBEARE MUDSTONE GROUP
Wytch Farm Breccias
Variscan Basement
0 m
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
400m omitted
2400
2500
2600
2700
unconformity
unconformity
Strata absent from Wytch Farm borehole by non-deposition, erosion or structure control
CRETACEOUS
Aptian
Barremian to Valanginian
Berri-asian
JURASSIC
Port-landian
Kimmeridgian
Ox
125.0
140.0
145.0
155.7
LOWER GREENSAND GROUP
WEALDEN GROUP
PURBECK GROUP
PORTLAND GROUP
KIMMERIDGE CLAY FORMATION
CORALLIAN GROUP
thickness relative to regional average
P Permian
D Devonian
Pale Paleocene
Cen Cenomanian
Alb Albian
Ox Oxfordian
Cal Callovian
Bath Bathonian
Baj Bajocian/Aalenian
Tor Toarcian
Pliens Pliensbachian
Sin Sinemurian
Rhe + Hett Rhaetian + Hettangian
Nor Norian
Syt Scythian


0090 9050
DOLPHIN BREWERY BOREHOLE
0116 8836
Brownsea Island
Furzey Island
BP F15 OIL WELL
S
Buried Channel Deposits proven only in borehole
Buried Channel Deposits proven only in borehole
S(OakC)
OakC
BrkS
PkC
S(Pool)
OakC
S(OakC)
OakC
S(Pool)
CmC
S(Pool)
ChrM
LC
Rea
Ck
80
60
40
20
OD m
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
BrkS Branksome Sand Fm
PkC Parkstone Clay Member
OakC Oakdale Clay Member and sand bed
CmC Creekmoor Clay Member
Sand in the Poole Formations
ChrM Christchurch Member
LC London Clay Formation
London Clay
Rea Reading Formation
Ck Chalk