Weekend Field Excursion - Dorset

Friday 13th to Monday 16th September 2019

(Led by the Dorset Geologists' Association Group)

Organised by: Allan Holiday (DGAG) & Andrew Harrison (BCGS & WMRG)

Leader Saturday: Richard Edmonds

Leader Sunday: John Scott

Monday: Steve Etches

Field notes by : Ray Pratt

Led by local experts this was a field tip that had it all; Geomorphology; Slides and slumping; Current coastal processes and engineering solutions; Historical land use; Structural geology; Plate tectonics; Palaeontology and Stratigraphy. Oh and I forgot to mention that not only did we have glorious weather throughout, but the trip was absolutely free. In all 24 signed up for this excellent trip.

Saturday. Isle of Portland

We started the day looking over Chesil Beach from the Heights Hotel vantage point. **Richard Edmonds** gave us an overview of the geology and the geomorphology of the area. He explained issues related to quarrying waste disposal and development of the harbour and the remedial engineering work that had to be undertaken.

Heights Hotel Grounds

This contains large ammonites and a fossil tree. The hotel bought a collection of fossils found on Portland and used them in the hotel grounds. The fossil tree is preserved by silica, but unknown where the silica has originated from

The Portland Limestone has 3 layers;

- Top Roach Stone which is very Shelly.
- Middle Whitbed is slightly shelly
- Base bed very fine oolitic limestone no shells in it,

Above the Portland we have the fossil forest of the L Cretaceous Purbeck Group.
(The 3 layers of stone of the Portland Limestone were used to construct the Olympic logo by the Heights Hotel).

.After the deposition of the roach stones sea levels dropped sufficiently for islands to form where soils and later trees became established. Elsewhere whilst the fossil forest was growing the Portland stone was still being deposited, similar to the Bahamas today (island, oolitic sands, lagoon). This fossil forest only exhibits 1-2 generations of trees

The overlying Purbeck beds are probably the most complicated sequence of sandstones limestone's and silts with mud cracks, desiccation, salt crystals. All environments were close together, much like Arabia today where we have salt flats and sabkas going into shallow seas and lagoons with islands

	 Tree growth rings visible in this fossil tree. These are preserved down to a cellular level.	 Ammonite. Titanities gigantia. Shallow tropical sea like the Bahamas

Portland Stone riven by joints (called gullies by the quarrymen). All quarries worked along the joints which run NW-SW and NW-SE (Conjugate sets). The shape of the isle of Portland displays sections of sub-parallel sections of cliff. These are the NE-SW gullies, so it can be seen that these joints directly give the island its shape. The gullies also play a part in the driving mechanism of the landslides that are prevalent on the island.

West Wear Cliff

Walking down to West Wear Cliff see a big crack in the land and the pathway. 2012 this crack opened up and at some point will fail.

Views of West Wear Cliff

Portland Stone has been quarried off the top. The Quarry men only wanted the Face bed, the whit bed and the Roach stone The waste on the top (grassed) is mainly Lulworth Fm. This cliff face is a limestone with layers of black chert known as the Cherty Member at the base of the Portland Stone. This was of no value for building. It sits on a thin zone of Portland Clay. The waste from the quarry was often brought to the edge of the cliff and cascaded down the hill. There was too much to simply fill in the quarried area once operations moved ahead. Landslides are very sensitive to water within the landslide system. They are also sensitive to erosion at the toe of the landslide. They are also sensitive to additional weight being added to the top. Here the quarrymen have added hundreds of thousand tonnes to the landslide slope which is probably the reason the crack has appeared in the footpath leading to this point.

Failure of cliff imminent.

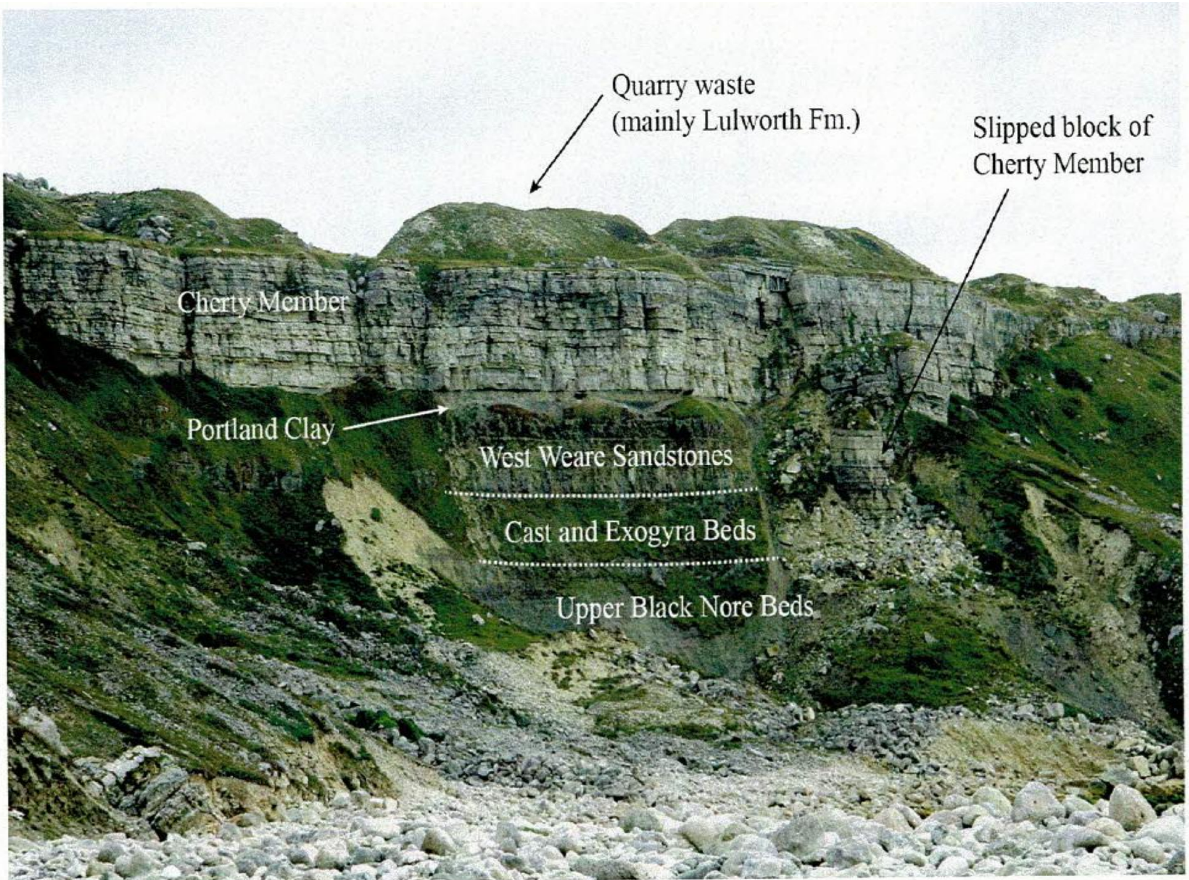


Figure 35. West Weare cliff showing the Portland Sand section overlain by the Portland Clay and Cherty Member. The cliff here would originally have been at least 12 m higher; the overlying Freestone Member and the Lulworth Fm. have been quarried away.

(Portland Clay, basal unit of Portland Stone Fm. above)
West Weare Sandstones (hard brown dolomites)… … … … … … … … … … 12·0 m
Cast Beds (soft dolomitic silts with harder nodules with bivalves) … … … … … … 1·5 m
Exogyra Beds (dolomitic clayey silts with *Nanogyra* throughout but abundant towards base in a harder band)… … … … … … … … … … … … … … … … … … 7·5 m
Upper Black Nore Bed (silty clays and dolomites) … … … … … … … … … 8·5 m
Black Nore Sandstone (dolomitic siltstone)… … … … … … … … … … … … 1·5 m
(Lower Black Nore Beds below)

The mechanisms for the formation and movement of **Chesil Beach** are also related to the historic sea levels. Most of beach made of chert and flint which originates from east Devon and west Dorset. Transported to the east by currents and waves. Dominant wave direction from the SW. During last cold period SLs lower. This instigates more movement in the landslides as they seek equilibrium. As sea levels rise they winnow away at this debris mobilising the sediment in the dominant current direction. Chesil Beach has probably formed several times at the end of each ice age. Dominant thinking is that the strong SW bring the cobbles to Portland and the lesser SE currents carry the finer grains westwards. The coarser the material the steeper it is. The east of Chesil Beach is much higher & steeper than the west end. However, when the beach is stripped out after a storm, little pebbles are seen her n the east end. The bigger pebbles move more easily. After a storm there is always a line of bigger pebbles due to their larger surface area, therefore move more quickly.

Walk into first quarry

Roach Stone

The succession in the Freestone Member recorded by Arkell (1947) is typical of that for the north of the island, but successions further south differ:

Roach. Oolitic limestone with mouldic preservation of *Laevitrigonia*, *Aptyxiella* and *Protocardia*… … … … … … … … … … … … … … … … … …	0·9 m
Whit Bed. Shelly freestone, sometimes with some chert 0.9 m from base … … … …	2·4 m
Flinty Bed. Limestone full of chert. *Titanites*… … … … … … … … … … … … …	0·6 m
Curf. Soft micritic limestone, occasionally oolitic. Abundant chert … … … … …	0–1·2 m
Base Bed Roach. Shelly oolite with moulds of *Laevitrigonia* etc. … … … … … …	0–0·6 m
Base Bed or **Best Bed**. Good workable white oolitic freestone with few shells … …	1·8–2·4 m

Portland stone showing minor channels and current bedding features


Ripple marks in Portland stone

Initial quarrying done by hand. Created a lot of waste. Built stone walls with waste, called Beaches. These were filled with overburden (Purbeck beds). Also left a lot of stone that was simply too big to move. In later life when technology and mechanisation became available much of the old quarries were reworked. Some used in masonry, lots used for sea defences.


Anthony Gormly sculpture

The Jurassic Cretaceous boundary used to be at the boundary of the Portland and Purbeck beds, but now located in the lower part of the Purbeck


Three holes remnants of trees (fossil forest). Holes surrounded by algal growth

Holes surrounded by algal growth. Brackish-water tufas (microbialites) formed around the bases of trees, or independently from trees, and these form the nuclei to microbial mounds, up to four metres thick and 20m across.

Portland Purbeck boundary

Kingbarrow Quarry. Stromatolites. Formed around base of trees in Purbeck beds.

Thrombolites. The tufas are complex vuggy lithologies but are principally constructed by thrombolites (microbial limestone's. with a clotted texture) with minor stromatolites, but also invertebrate burrow boundstones that form initially around the trees. This unusual facies is formed of peloidal mud's that are bound by burrow walls to form collars around the trees. Microbial filaments trap, bind and cement the locally produced peloidal, skeletal and intraclastic grains to form a framework that is itself cemented by early calcite cements.

The Fleet

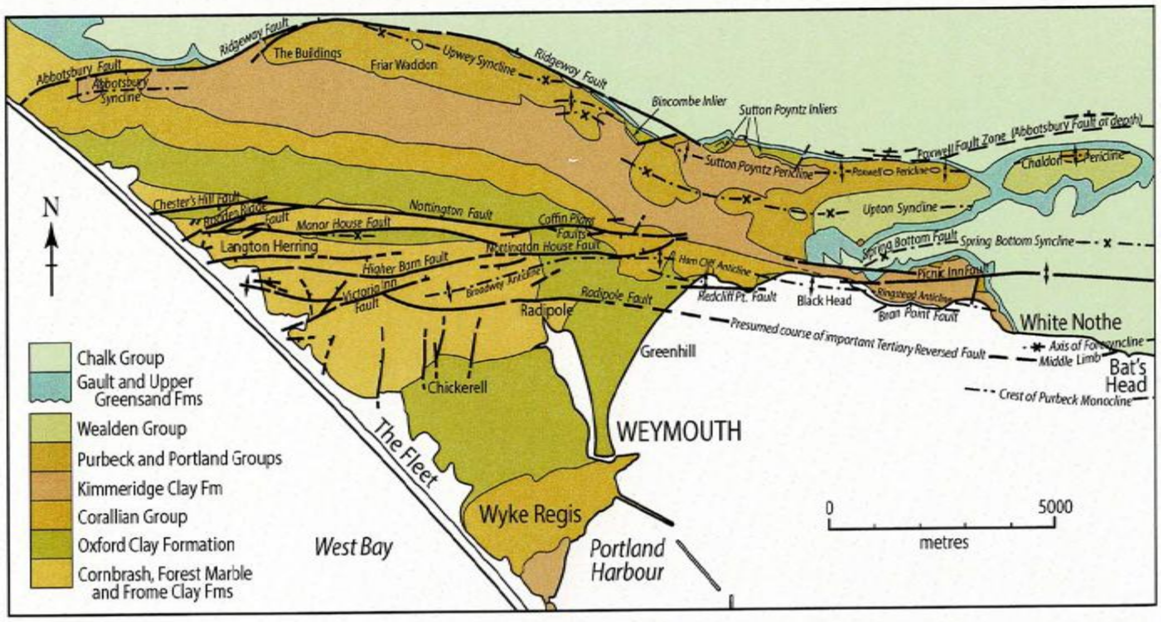


Figure 30. Geological structure of the Weymouth area. Modified after House (1989).

Chesil Beach

The back of Chesil Beach have periodic scours at the back, locally known as Cans. When there is a big sea and the water permeates through the shingle over the top of the clay core and creates these features as it pours into the Fleet. There location could be due to the variability of height of the core of the sandbar. The core of the beach was formed after the end of the last ice age when sea levels rose and the gunk was pushed up out of the bay to form this core of silt and mud. The shingle supply began with the increasing landslides from west Devon and Dorset as they became reactivated with the rising sea levels. Chesil beach changes with the environment and it is only a matter of time before the sea breaches it. Some suggest that if the beach were not there then the strand line would by now be close to Dorchester. After big storms, particularly down towards Abbotsbury West Bexington, (west of Weymouth), we get enormous lumps of peat washed up onto the seaward side.. This peat would have formed in a peat lagoon that was further offshore than it is today. As the beach moves landwards then the peat formed in a lagoon behind the beach becomes exposed to the open water and gets ripped up during storms. Good evidence that the beach is migrating inshore.

Walking east along the northern coast at the eastern end of East Fleet Lagoon looking at its formation and exposures of Middle to Upper Jurassic strata (Oxford Clay, Corallian Beds and Kimmeridge Clay).

We look at a section from the bottom to the top

Kimmeridge Clay
Sandsfoot Grit
Sandsfoot Clay
Clavellata FM
Osmington Oolite FM & Bencliff Grit

We start seeing plenty of thalassinoides burrows (made by shrimps) and the Osmington oolite, visible oolites. (

Moving east and up sequence we see a hard limestone which is likely to be the Clavellata Fm. It has a hard uneven surface, vuggy porosity. Thalassinoides burrows and lots of oyster shells

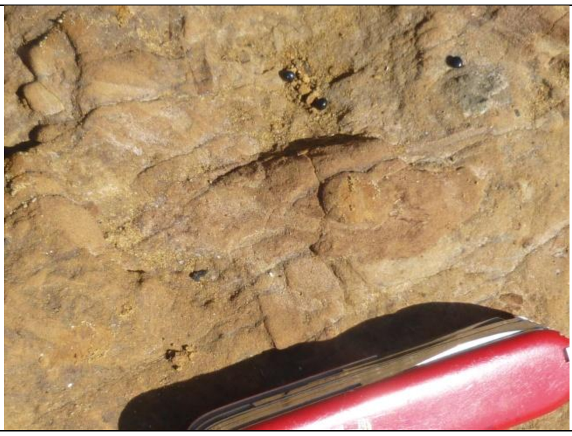
 

Looking back towards the Osmington oolite and Clavellata formations. The bay is carved into the weak clays of the Sandsfoot clay

Sandy Limestone

Grey colour but weathers yellow brown due to its iron content. Nodules of iron (Chamosite) can easily be seen. Low grade ironstone. Sandsfoot formation. Belemnite shells sticking out



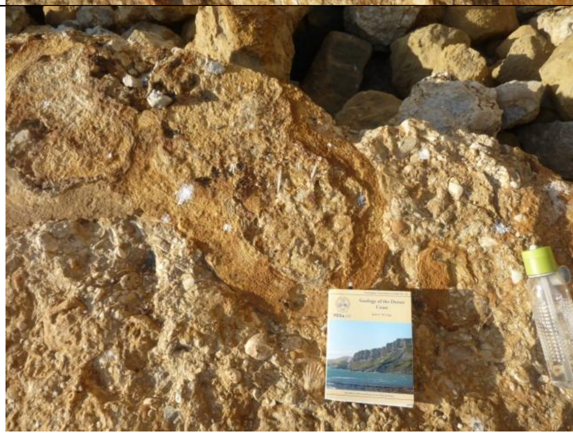
Ringstead Clay

The fleet lagoon gets wider where clay formations occur. The clays become very soft and plastic when wet, Knife easily pushed into the clay.

Burton Cliff - Burton Bradstock

Burton Cliffs, Bridport sands

Fallen blocks of Inferior oolite can be found at the base of the sea cliffs



Fullers earth at cliff top

Landslip of fullers earth and underlying inferior oolite

Blocks of inferior oolite on the beach. Snuff box concretions, as seen in these photos below, are large rounded limonitic concretions that are algal build-ups around shell fragments.



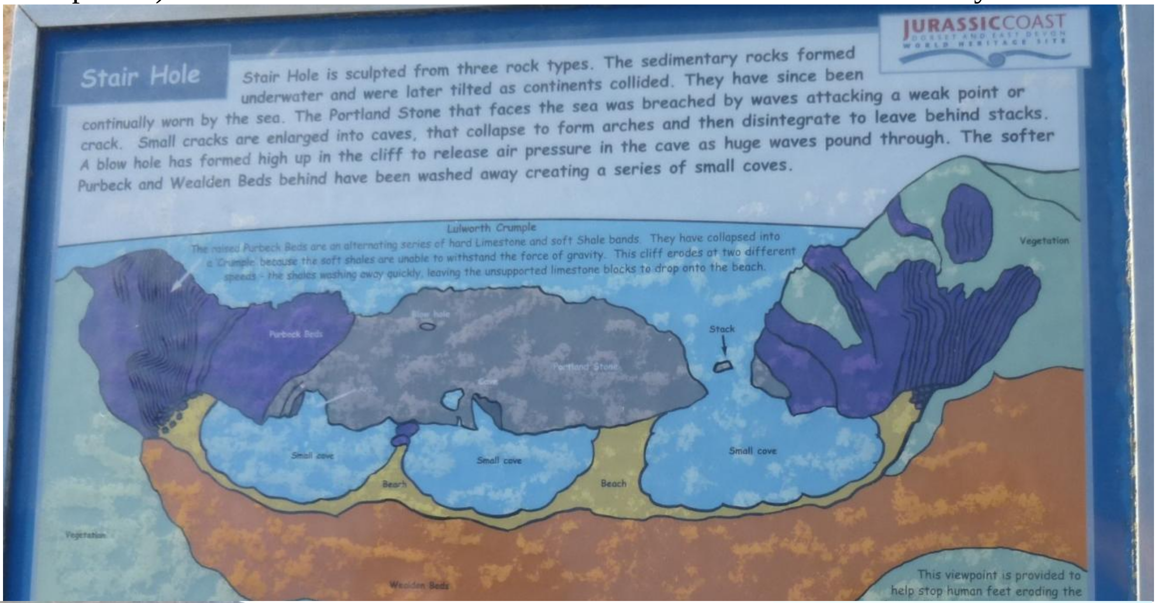





Sunday: Lulworth Cove & Durdle Door

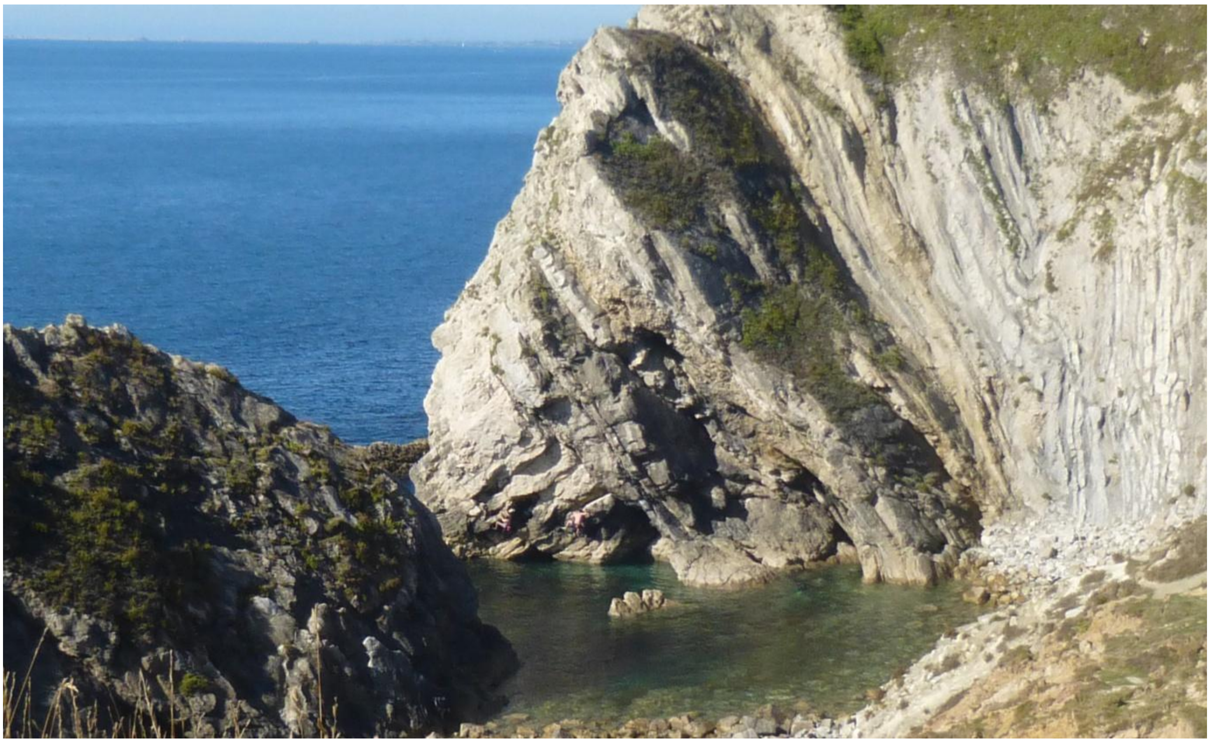
Stair Hole

Beds facing the sea are Portland beds (massive, sallow marine, oolitic in parts of Portland but here is just bioclastic), then towards land are the Purbeck beds of shales, marls, evaporites (now replaced). Where we stand is the Wealden - unconsolidated sand and clays.



Stair Hole (viewed from west side)

The traditional mechanism for the formation of these holes and bays , as outlined on the visitor panel, doesn't really take into account the resistance of the Purbeck beds. It has been suggested that this was once a quarry of the Purbeck Limestone (not shown in any textbooks). Stone could be easily moved out by boat. The village of Lulworth made from Purbeck limestone.


Stair Hole formations (viewed from east side)

Folding done during the Alpine orogeny, Pyrenean circa 44mmya (north south compression).

As rocks starting to fold the rocks may not have been fully cemented so there was the possibility that we could also be seeing sliding events. However, the folds require some form of plasticity which indicates deformation at depth where sliding would not occur. There could be some accommodation movement along shale bands. John suggests only buried 500m. .

The Purbeck environment was lagoonal, restricted circulation with the western side just the other side of Weymouth and the eastern edge in Germany (some lagoon). Initially was a closed lagoon without marine incursions. Basal beds contained evaporites (today find pseudomorph's). A bit higher we have a grey bed called the cinder bed which is full of oysters, which represents the first marine incursion into the lagoon. Following this we see cyclic marine incursions reverting back to a freshwater environment before another incursion.

The top bed is a limestone with (vivi paris ?) a freshwater gastropod. Then get the fluviatile Wealden strata. Folding commenced during the late Cimmerian period (200-150mmya) and Alpine phases creating the 3 major anticlines (Marshwood, Weymouth and Purbeck). Movement was still ongoing during the Wealden before deposition of the Gault Clay. There was lots of erosion going on with Jurassic fossils being redeposited in the Purbeck beds (Worbarrow Tout).

Variscan orogeny gave underlying EW structures with deep seated faults. Lots or erosion during the Permian and Triassic. Breaking up of Pangea caused space for further deposition in basins in the area. Cimmerian movement during early Cretaceous. More directed structures coming up . During Alpine orogeny existing normal faults became reverse faults. The Purbeck fault, was originally a normal fault and is now a reverse fault. Explains variability in thickness across the fault of the Wealden

Major work on faults in the area undertaken by Arkell in 1947, which is still used to this day

Lulworth Cove.

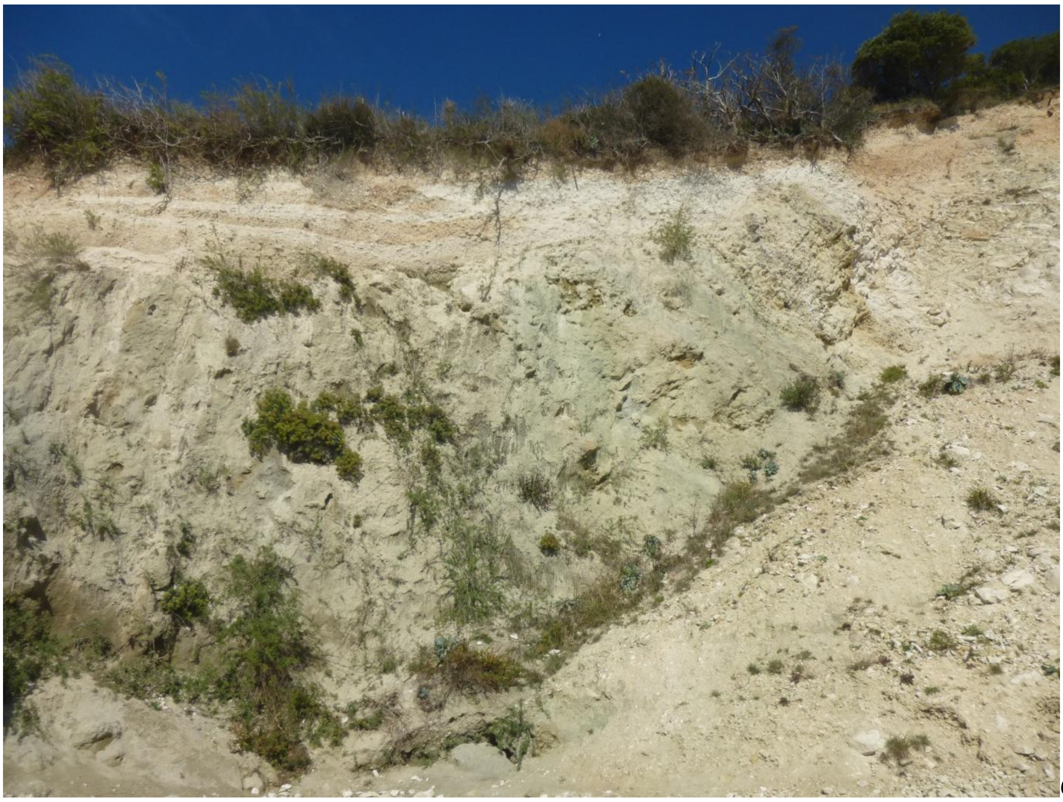
Formed at the mouth of a river valley. Also follow the line of a possible fault

Lulworth cove looking east from the west side

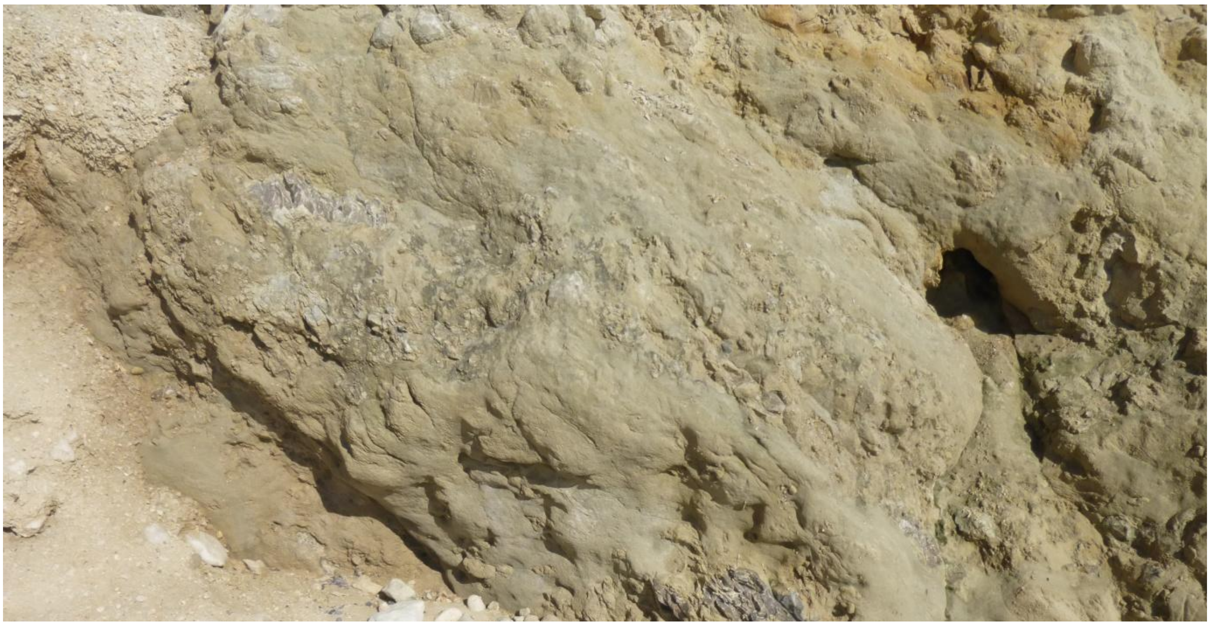
Walk down into Lulworth cove and walk to the western point of the bay, Look at the UNIL beds named after the bivalve contained within. Purbeck marble (with the Vivi Paris Gastropod) lies above it..

	The UNIL beds is more of an algal limestone. Structures within are "higgledy piggledy" as a result of seismic movement whilst still unconsolidated.. Known as a seismite
	Unil bed bivalves

Upper Greensand Lulworth Cove


Cliff face of Upper Greensand with buff white horizontal bedded Pleistocene head deposits on top

The Purbeck fault is seen in this face. The top of the Upper Greensand merges into the chalk,. The boundary is an unconformity with a basal conglomerate however the greensand conditions were still prevalent during early chalk deposition resulting in chlorite being deposited within the chalk.


Basal Beds - Conglomeratic chloritic chalk. It is highly burrowed giving it a nodular appearance. This chalk contains chert.

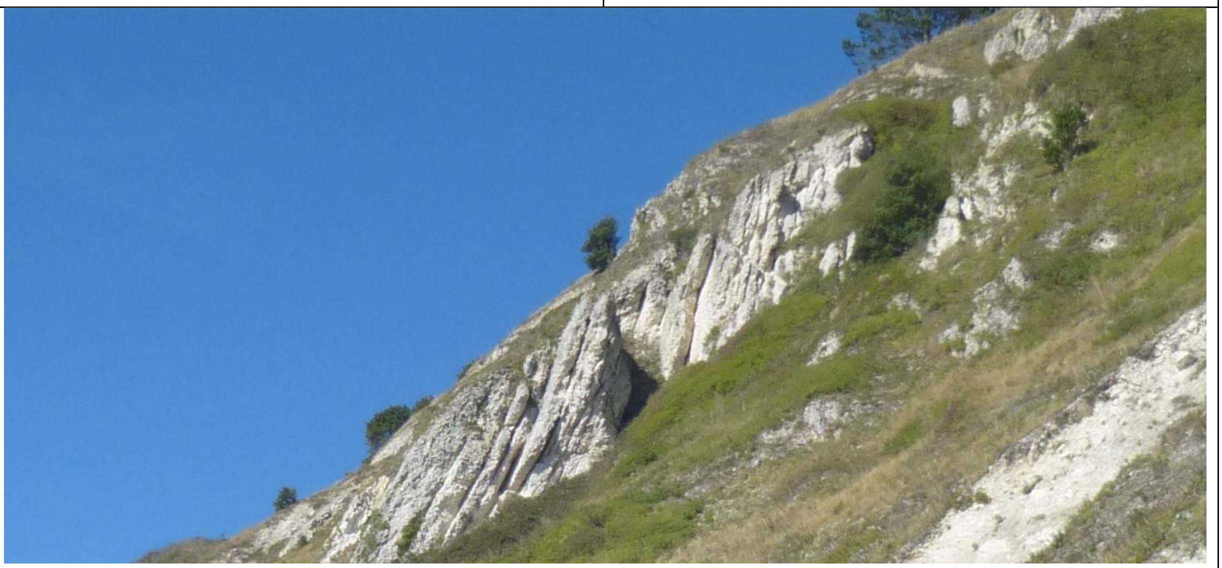
Above the chloritic chalk is the West Melbury chalk and zig zag chalk, not present in Lulorth. The diachronous equivalent is the phosphatic conglomerate, the chalk basement bed. and above this is

The Dorset swell occurred during the time of chalk deposition resulting in condensed deposits here, with some missing time (disconformities).

The white rock is chalk proper and the grey coloured material are burrows

This cliff face is a major fault. Slickensides are very visible

	*Low angle thrust fault in chalk cliff face*



The chalk is faulted in many directions. The cliff face above showing vertical bedding is actually showing overturned beds

Arkell 1947 identified 12 sets of faults.. Phillips, 1968, found another set. Bevan 1985 reduced it to 3 conjugate sets. One of the sets of faults belong to the Purbeck faulting period, but the thrusts are probably Alpine. Some faults have been reactivated from normal to reverse. The chalks have been tectonically hardened with a porosity of just 9%.

Upper Greensand (These beds crop out on the east side of the cove)

Upper Greensand. Deposited following the Gault clay which marks a major marine transgression

Junction between the Greensand and the Chalk with a large landslide sliding on the Gault clay and covers the lower greensand


Wealden beds with landslip caused by overlying Gault lubricity


Wealden beds. Liesegang rings can be seen in some parts of this deposit.

Iron rich waters permeating through the Wealden rocks precipitate out to form this conglomerate (recent). It captures pebbles laid down when the beach was higher.

Coarse sand with a liesegang ring

Moving around to the eastern cliffs of the cove we see an extensive vein of Beef Calcite

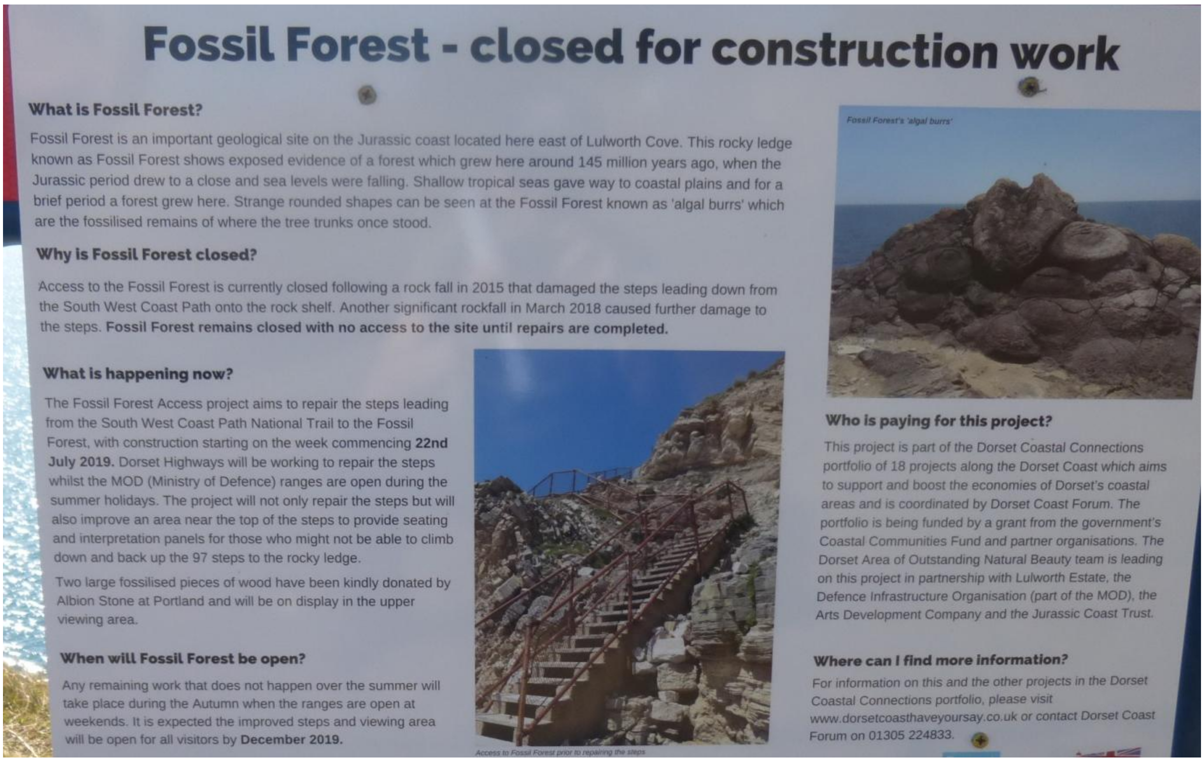
	*Blocks of cliff on foreshore: Microbial limestone (grey) and interbedded marl?*
	*Blocks on foreshore:* *Seismite beds ?*

Eastern cliffs East Point of Lulworth cove. Lower section contains rare examples of extensive bedding plane exposures providing valuable evidence for plan-view shapes of mounds; their sizes and spacing.

Here, the upper surface of the Hard Cap microbial mounds are partially exhumed on the bedding surface dipping to the foreground. The upper cliff comprises the Broken Beds, currently widely regarded as an evaporite collapse breccia.

Purbeck Pellitoidal or Unil beds ? on a faintly rippled bedding plane. Seen close to the top of the eastern side of Lulworth Cove

Fossil Forest



Stomatolites

During growth of trees the area was actively faulting. Relay ramps were in existence leading to variable thickness of accumulations. The faulting led to a drop in the land surface allowing lagoonal water to drown the trees. Algal growth around the base of the trees. Oval shaped rings are where trees had fallen and effected the growth of the algal mats. All material replaced by silica.

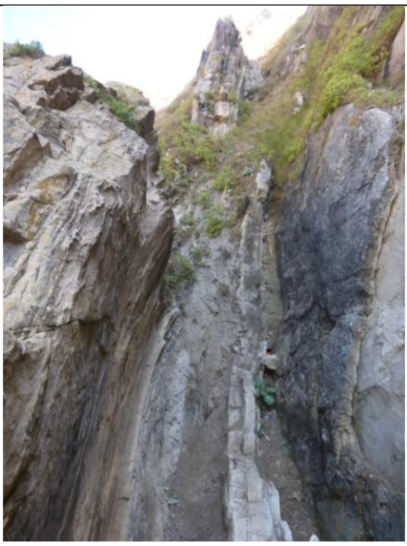
Durdle Door

Man o War cove on left and Durdle Door on right. Wealden here, (beds we are stood on), are much thinner than at Lulworth Cove

Man O War cove. Reefs are Portland limestone. Standing on the chalk. This is the closest the Portland and chalk come together along the entire coast (only a few metres). In front of us is the Purbeck bed, similar but thinner than at Lulworth Cove, Wealden, Greensand, Chalk. Tectonics has squeezed the Wealden beds out as it was not consolidated. The chalk is almost vertical


View westwards from Durdle Door


Durdle Door. Same structure as Stair Hole in Lulworth Cove

	*Photos of the broken beds of the Purbeck (Lulworth Formation). The Purbeck is split into two formations, the Lulworth and the Durleston Formations. Unable to find the Cinder beds which include oysters and represent the first incursion of marine water into the lagoon. Lower Greensand not present.* *Beds can be seen with ripple marks, but still lagoonal. Ripple marks with current flowing both ways are symmetrical e.g tidal. Asymmetrical indicate a unidirectional flow e.g a river.*

Nodularity a function of burrowing. Lot of chert from sponges

Plenus marl. Top of Plenus Marl is the base of the White Chalk Group

Bedding is vertical (and overturned). The Plenus Marl, to the left of the prominent whit chalk, is sheared out at the top

Row of caves line the thrust plane

Two thrust planes join. Everything here is totally crushed to clay grade particles

Fault face

Flints highlight vertical beds. Flints become crushed in fault zones.

Vertical beds & flint bands cut by a thrust fault. Head deposit in the upper 2 m

Spectacular folding highlighted by the cherts


Large accumulation of Pleistocene head on top of the chalk. Valleys would have been created with the permafrost sealing the chalk then the summer melt washes the sediment into the valleys below, enlarging them with the abrasive sediment load.


Spectacular fault face (conjugate faults as there are several)

Monday AM: The Etches Collection Museum - Kimmeridge

(see book)

Monday PM: Kimmeridge Bay

View of Kimmeridge Bay looking west (from the oil facility).

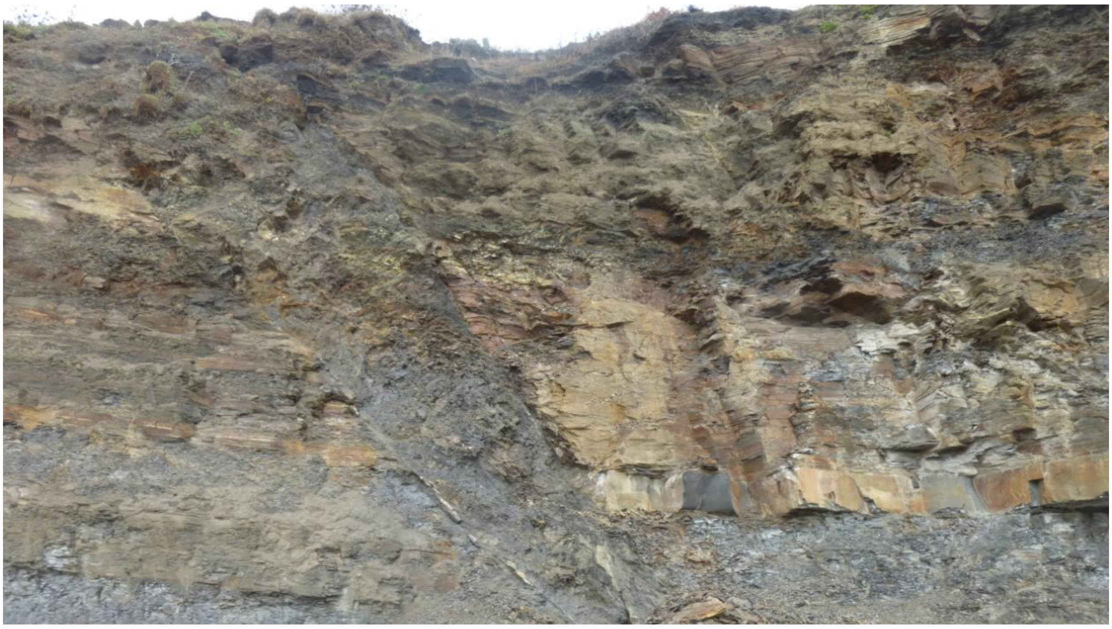
The part of the Kimmeridge Clay exposed in the bay shows cyclic sedimentation, first described by Downie (1955). The idealized cycle is:

D. coccolith limestone
   this may be laminated with alternating dark sapropelic and pale coccolith laminae or homogenised by bioturbation
C. oil shale
   up to 70% organic matter; the thickest is the Blackstone
B. bituminous clay
   clays with 10–30% organic matter
A. clay
   clays with up to 10% organic matter. Frequently shelly with abundant benthos

The cycles are often incomplete in this part of the succession and belong to the Autissiodorensis Zone and the top of the underlying Eudoxus Zone. Most frequently around Kimmeridge Bay the repetition is ABAB, with member C of the cycle appearing less frequently (Fig. 73). The stone bands around Kimmeridge Bay are not coccolith limestones, but were secondarily formed while buried in the methanogenic zone and are dolomitic (Irwin, 1979; Scotchman, 1989); they are thus laterally impersistent, whereas the coccolith limestones are remarkably persistent laterally.

The origin of the cycles has been explained by Milankovitch cyclicity. This was first suggested by Dunn (1974). The most recent analysis by Weedon *et al.* (2004) ascribed the larger cycles, of the range 1·87–4·05 m wavelengths, to orbital obliquity (*c.* 40,000-year cycle) and the smaller cycles, of about half this wavelength, to precession (21,000-year cycle). They recognised 95 longer wavelength cycles for the Kimmeridgian Stage (Lower Kimmeridge Clay) and 103 for the Bolonian Stage (Upper Kimmeridge Clay), from this they calculated that the Kimmeridgian lasted 3·6 Ma and the Bolonian 3·9 Ma.

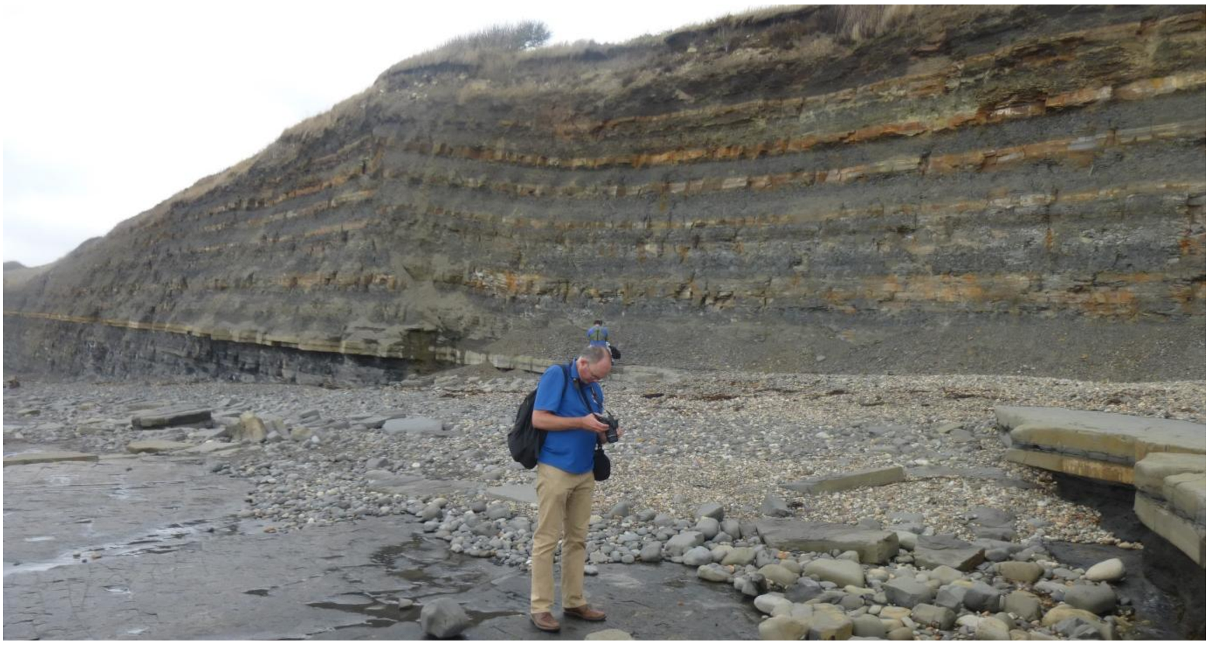
Cliffs on east side of Kimmeridge Bay



A fault zone is clearly visible in this cliff face

East side of the bay. The black shale overlying Maple Ledge stone band is the Kimmeridge oil shale (cycle C).

On the west side of the bay by Washing Ledge with its oil shale patrting, lies below the Autissiodorensis Zone, showing the ABAB type cyclicity developed there. Light brown Head deposit at top.



Brown bands of the hard, finely laminated bituminous shale and the grey material is blocky mudstones with less organic matter but with some carbonate content. The stone bands that break up the Lower Kimmeridge Clay succession ,(in descending order, The Maple Ledge, The Washing Ledge and The Flats Stone Band), are all secondary dolomitic stone bands.

Interesting compressional structures. Above photo showing the slickensided surface of a thrust plane. Flats Stone Band. Conjugate fracture patterns are seen in these dolomitic stone bands.

Flats Stone Band showing compressional features. This small thrust is part of a megapolygon. The "breaking wave" type front of the thrust is heavily jointed.

The cliff-top nodding donkey marks the site of the oil well that produces oil from a Cornbrash reservoir that has a Lias Group source (Fig. 7). The Cornbrash was encountered at a depth of 550 m on the summit of the Broad Bench anticline. The drill hole went lower, but the drill string was lost in the upper part of the Bridport Sand at 670 m. Initially the oil was sufficiently pressurized to flow to the surface, but for some decades now has required pumping; the present yield is about 65 barrels per day. There is a simplified geological section displayed on the perimeter fencing.

The oil is not coming from the Kimmeridge Clay which is at surface in the cliffs at Kimmeridge. However, such an origin is sometimes a misconception amongst the non-geological public, probably because the Kimmeridge Clay is the major source rock for the oil in the North Sea. There is no liquid oil in the exposed Kimmeridge cliffs, only oil-shale and bituminous shale containing kerogen, a brown waxy substance. The Kimmeridge Clay at Kimmeridge is not thermally mature (it has not been sufficiently heated by sufficiently deep burial at this particular locality). The real source of this oil is probably the deeper-buried, Lower Jurassic (Lias) bituminous shales in the offshore English Channel Basin