The Oxford Clay

A guide to the more common fossils from Must Farm pit and the King's Dyke Nature Reserve

The Oxford Clay is a formation of sedimentary rock which underlies much of southeastern England from Dorset to Yorkshire. It was laid down around 160 million years ago during the Oxfordian and Callovian ages. Bricks made from the clays have been made in huge numbers since the middle of the 19th Century, especially in the area around Peterborough. Because of the scale of this activity large collections of fossils, especially those of marine reptiles were made during the 19th and early 20th centuries, most notably those of the Leeds brothers. Although clay is now excavated by machine rather than by hand important new finds are still made on a regular basis.

Surface outcrop of the Oxford Clay
Red spot shows location of King's Dyke

Marine reptiles - ichthyosaurs, plesiosaurs and marine crocodiles - are relatively rare finds, and usually as isolated bones or bone fragments. The clay is rich in fossils of marine invertebrates, in particular ammonites, belemnites, oysters and other bivalves. Fish have rather delicate bones which don't fossilise well, and are usually found as isolated teeth and scales.

A comprehensive guide, "The Fossils of the Oxford Clay" (Martill and Hudson, 1991) was published by the Palaeontological Association but is hard to find these days as there was only a limited print run. This guide is far from comprehensive, and intended to show the fossils which you are likely to find on a field trip.

The clay was formed at the bottom of a shallow sub-tropical sea when Britain was only a few degrees north of the tropic of cancer. A fine sediment accumulating on the sea floor was oxygen-poor, good conditions for forming fossils. Although the clay appears superficially to be rather uniform in its nature throughout, there are considerable differences between stratigraphic layers within the section reflecting different rates of sedimentation and biological activity. At times the sediment was in the form of a "soupy substrate", too thick to swim in and too soft to walk on. The carcases of a large vertebrates could sink into this soft, oxygen-poor soup and be exceptionally well-preserved because of the relatively low rates of bacterial activity. Some beds are finely laminated and with a bit of care can be split along the bedding plane to show small fossils, tracks and burrows. There are several shell beds only a few centimeters thick packed with shell fragments and other fossils. These were formed by winnowing as severe storms or some other catastrophic event washed away the finer particles and may represent longer time-scales than a meter or more of clay in other parts.

Towards the bottom of the section there is a bed of large limestone nodules, well-known to collectors as Bed 10. In some pits these nodules are packed with reptile bones and many fine specimens have been excavated over the years.

Ammonites

Though superficially similar to the modern chambered nautilus, they are classifed in a different subclass within the cephalopoda, Like the nautilus they have a spiral shell consisting of chambers of increasing size, with the body of the animal in the last chamber.

They are valuable fossils for the study of geological time as the shape of their shells evolved rapidly. Most Oxford Clay ammonites are found crushed on the bedding plane which makes them hard to collect. Some nodules contain uncrushed examples.

Some species of ammonite are found with two morphologies representing male (microconch) and female (macroconch) forms.

Information on ammonites and bivalves courtesy of Keith Duff

Kosmoceras jason

Macroconch

Microconch

Kosmoceras obductum

Macroconch

Microconch

Kosmoceras grossouvrei

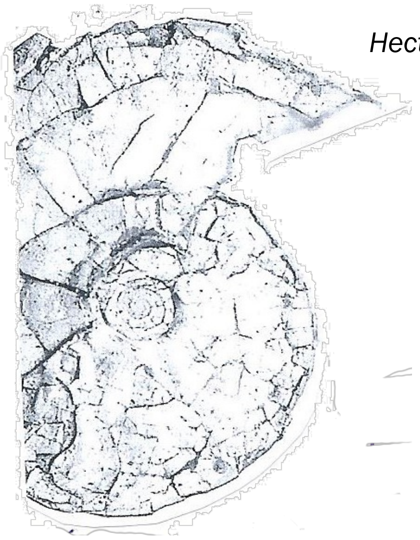
Macroconch

Microconch

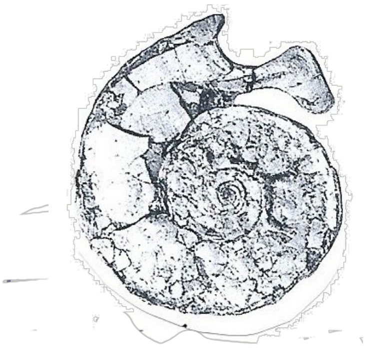
Sigaloceras enodatum

Ammonites

Hecticoceras lonsdali



Macroconch

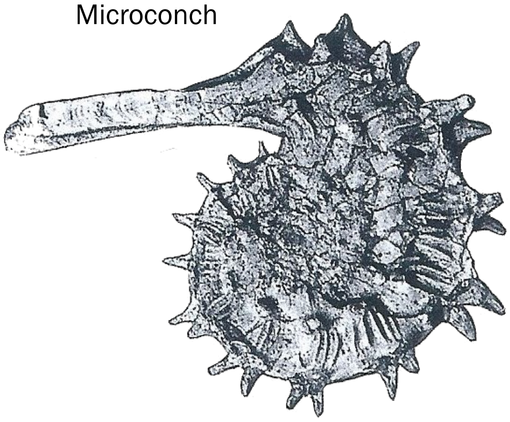


Microconch

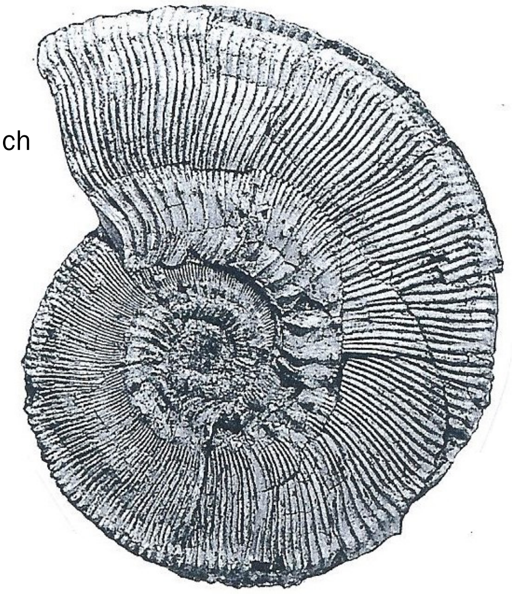
Erymnoceras coronatum

Kosmoceras phaeinum

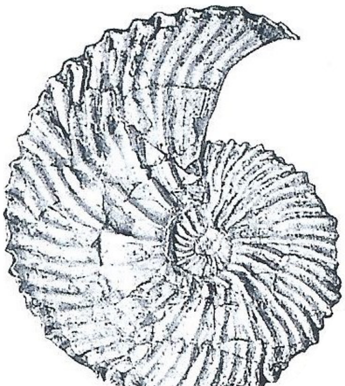
Microconch



Macroconch

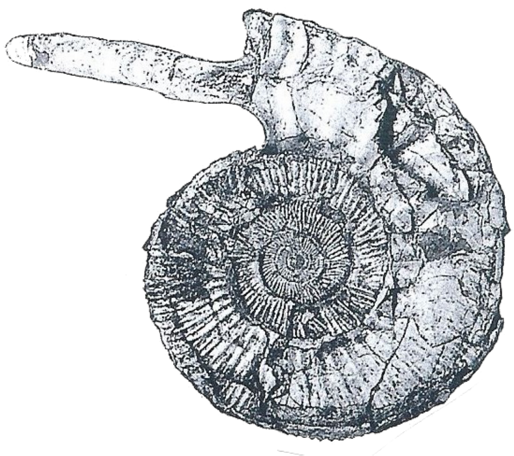


Longaeviceras laminatum

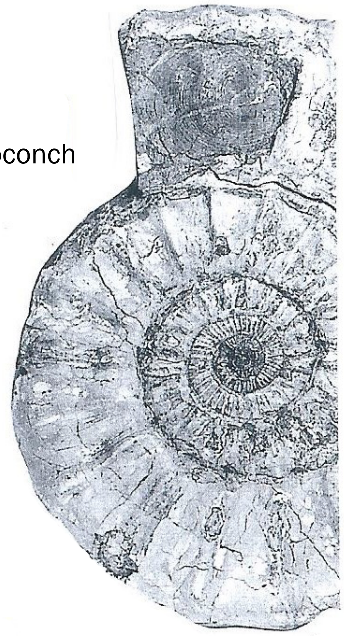


Binatisphinctes comptoni

Microconch



Macroconch

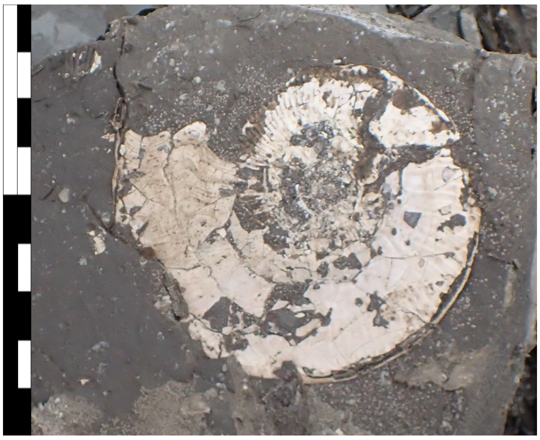


Ammonites

Three-dimensional preservation of the ammonite *Kosmoceras jason* within nodule containing plesiosaur bones in a nodule from Bed 10.

The nodule was collected from the King's Dyke fossil area and orginates from Must Farm.

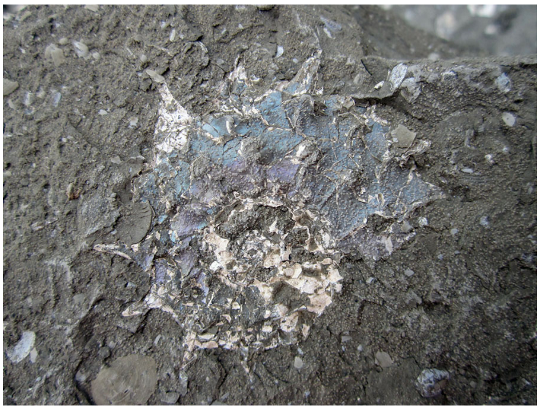
Photo : Richard Forrest



Kosmoceratid ammonite preserved flat on bedding plane. These specimen are hard to collect intact, though a coating of paraloid can help.

From Must Farm pit. Found in loose clay from a collapse of the quarry face it originates from one of the higher beds

Photo: Richard Forrest



Kosmoceras (Lobokosmoceras) phaeinium, microconch. This is a coarsely ornamented variant.

Photo: Darren Withers

Belemnites

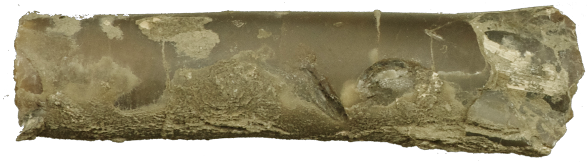
Belemnites were cephalopods, related to squid and cuttlefish. Their solid internal guards are very common in most beds. More rarely they are found with the phragmacone, the chambered section of the shell in place.

Cylindroteuthis. Lower Oxford Clay, Must Farm pit.

Photo: Richard Forrest

Hibolithes. Lower Oxford Clay, Must Farm pit.

Photo: Richard Forrest



Belemnite bearing impressions either of teeth, or crushing by shells during compaction of sediment. Lower Oxford Clay, Must Farm pit.

Photo: Richard Forrest

Belemnites are frequently found in large numbers on bedding planes. Here is a 'death assemblage' of belemnites and other invertebrates.

Photo: Darren Withers

Belemnites and other teuthids

Like modern squid and octopus, belemnites squirted clouds of ink to confuse predators. Here is the ink sac of a belemnite, a rare find.
Scale in mm.

Photo: Darren Withers

Most cephalopds are soft-bodied and therefore very unlikely to become fossilised. There are a few very rare cases soft tissue preservation in the Oxford Clay, but this seems to have occurred only in small areas under exceptional conditions. The only cephalopod which is neither an ammonite nor a belemnite which is relatively common is the coelid *Belemnoteuthis*,.

Crushed phragmacone of *Belemnoteuthis* in situ. The fragility of this shell makes them difficult to collect. Must farm pit.
Scale bar 1cm.

Photo: Richard Forrest

Unusually large phragmacone of *Belemnoteuthis* in situ. This specimen was found during the excavation of a plesiosaur at Must Farm in Bed 9. Scale bar in cm.

Photo: Naomi Stevenson

Bivalves, gastropods, brachiopods and annelids

The clay is packed with small bivalves and gastropods, usually in the form of shell fragments. Brachiopods are rarer but can still be found. Annelid worms are preserved as calcareous tubes, frequently grown on the oyster *Gryphaea*.

Overlooked by many collectors, they offer insight into changing environmental conditions in the Oxford Clay seas through statistical studies of their incidence in different beds.

Drawings courtesy of Keith Duff

Mesosacella (Bivalve)

Entolium (Bivalve)

Meleagrinella (Bivalve)

Procerithium (Gastropod)

Bositra (Bivalve)

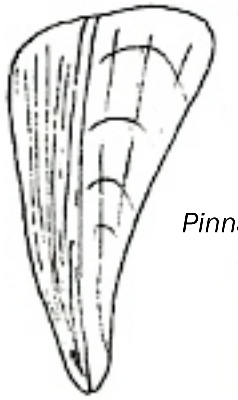
Palaeonucula (Bivalve)

Corbulomima (Bivalve)

Grammatodon (Bivalve)

Dicroloma (Gastropod)

Lingula (Brachiopod)

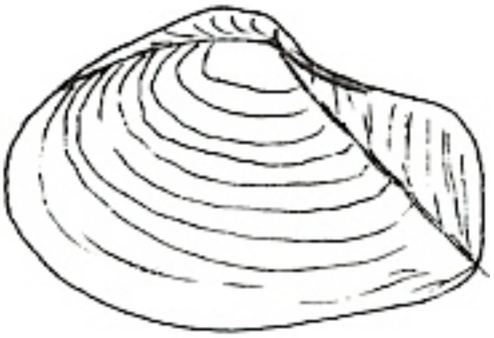


Pinna (Bivalve)

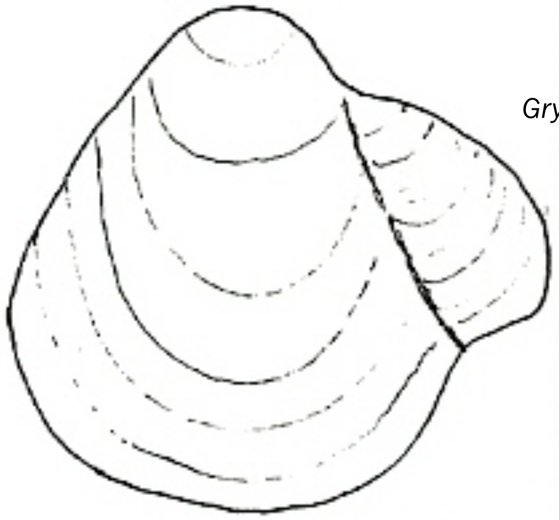
''flat oyster' (Bivalve)

Trautscholdia (Bivalve)

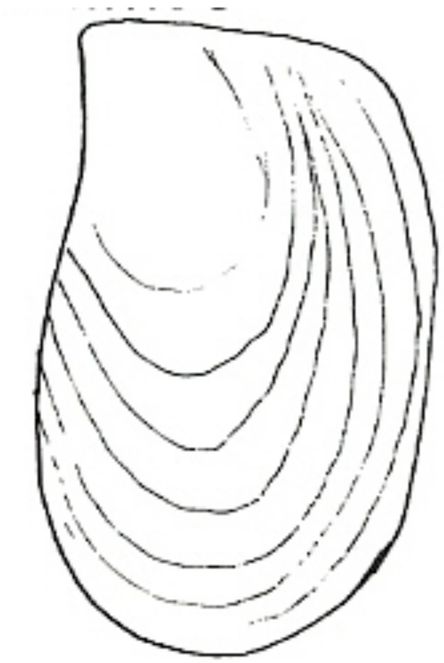
Discomiltha (Bivalve)



Thracia (Bivalve)



Gryphaea (Bivalve)



Parainoceramus (Bivalve)

The oyster *Gryphaea* is very common in some beds. Oysters grow on a hard substrate, and in some examples they have grown on a bivalve or an ammonite and are moulded to their shape. This phenomenon is correctly referred to as bioimmuration, though the terms pseudomorph or xenomorph are sometimes used.

Bioimmurations of *Pinna* (left) and a Kosmoceratid ammonite (right) on *Gryphaea.* Both specimens from Must Farm pit, found loose but probably from close to Bed 10. Scale is in millimeters.

Photos: Richard Forrest

Bivalves, gastropods, brachiopods and annelids

Gryphaea dilobotes. From Must Farm pit, found loose.

Photo: Richard Forrest

Parainoceramus subtilis in situ.

Photo: Darren Withers

Most worms - a term which covers a huge range of distantly related modern animals - are soft-bodied and therefore very unlikely to be preserved as fossils. Some form calcareous tubes which can be found as fossils. Burrows attributable to worms can be seen on some bedding surfaces.

Tube formed by the annelid worm *Genicularia* in situ. Must Farm pit, from loose material. Scale bar in mm.

Photo: Richard Forrest

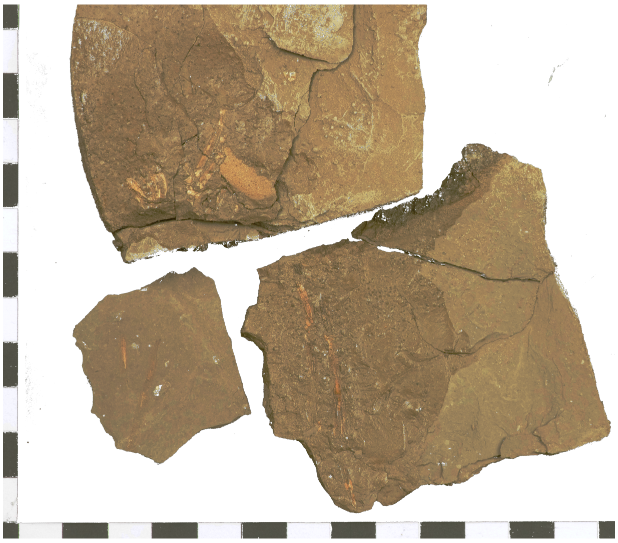
Genicularia (Annelid)

Specimens of *Genicularia*

Photo: Darren Withers

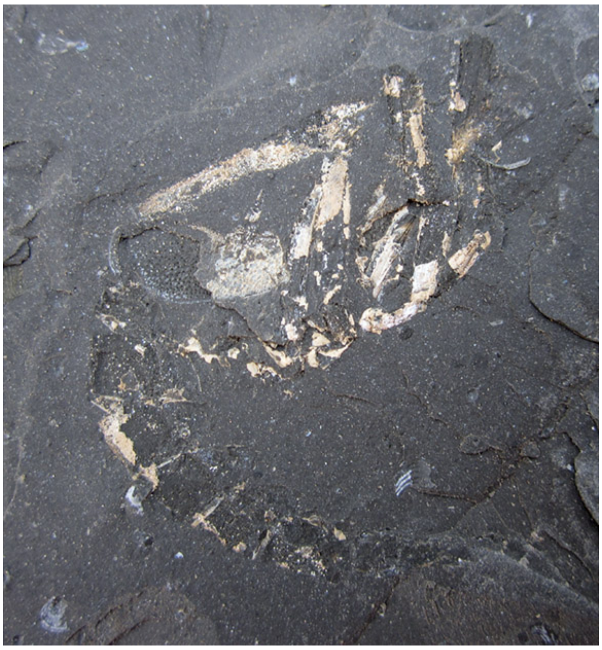
Crustaceans

The external skeleton of crustaceans have a poor potential for fossilisation because they are so fragile. Although generally rare, a layer of dark clay at the bottom of Bed 14 contains many shrimp specimens.



Fragments of shrimp bed with partial specimens of *Mecochirus*. From Must Farm pit, Bottom of bed 14.

Photo : Richard Forrest



Complete specimen of *Mecochirus*. From Must Farm pit, Bottom of bed 14.

Photo : Darren Withers

Fish

Fish fossils are relatively common, but almost always in the form of isolated scales, teeth and vertebral centra. More complete specimens are much rarer, and if in nodules can be preserved in three dimensions. Bones of *Leedsichthys,* the biggest fish from the Oxford Clay - and the biggest bony fish of all time - are a rare find, but in general specimens are small.

Unidentified fish bone

Photo: Darren Withers

Fish tooth, approximately 2mm long

Photo: Darren Withers

Scale of *Lepidotes* in situ

Photo: Darren Withers

Unidentified fish jaw in situ

Photo: Darren Withers

Hyobranchial bone of pachycormid fish. Must Farm pit, found loose. The specimen is about 3cm long.

Photo: Richard Forrest

Marine reptiles

The Oxford Clay is world-famous for its marine reptiles, many of which are described in detail in “A Descriptive Catalogue of the Marine Reptiles of the Oxford Clay”, by C W Andrews published in two parts in 1910 and 1913. This work (the Bible of plesiosaur palaeontologists!) was based on specimens from the Leeds Collection in the Natural History Museum, London. Well-preserved and substantially complete specimens, some of which are new taxa are still to be found in spite of limitations in access to pits and quarries. Most finds are in the form of isolated bones and teeth. In part this is because quarrying operations tend to break up specimens before they are found, but more commonly because elements were scattered by scavenging, and by currents as the carcase decayed on the sea floor.

Identifying isolated bones at species or genus level can be challenging even for experienced researchers and is outside the scope of this handout. Bone can generally be identified from its hardness and structure. The surface usually has a fibrous appearance under an hand lens, and if broken shows the cellular interior structure.

Rib fragment of the ichthyosaur *Ophthalmosaurus* showing healed wound. The specimen is from a disarticulated specimen scattered by quarrying operations, probably from the Middle Oxford Clay.

Photo : Richard Forrest

Detail from the right femur of the long-necked plesiosaur *Cryptoclidus*. This shows tooth marks made by a predator. The smoothly rounded cavity at the top was excavated by infection showing that the animal survived for a while after the attack. Specimen in Peterborough Museum, PET R.246. It was collected during the 19th century and has no information on where it was found.

Photo : Richard Forrest

Ichthyosaurs

Only one species of ichthyosaur, *Ophthalmosaurus icenicus*, has been recorded. This was a large animal, well over 4 meters long as an adult. Vertebrae are relatively short and usually have deeply indented faces. Teeth are rare, and it is likely older adults had none. Ichthyosaur teeth are circular in section, usually striated and with a long and rather bulbous root.

Tooth of *Ophthalmosaurus icenicus*.
Illustration from Moon and Kirton 2016

Vertebral centrum above, fragment of mandible right of large *Ophthalmosaurus*. Part of specimen scattered by quarry operations, probably Middle Oxford Clay.

Photos : Richard Forrest

Fragment of ichthyosaur jaw. Must Farm pit, found loose.

Photo: Richard Forrest

Ophthalmosaurus paddle digit.

Photo: Darren Withers

Plesiosaurs

Many species of plesiosaur have been recorded from the Oxford Clay ranging in size from the small long-necked plesiosaurs *Tricleidus* and *Picrocleidus* to the giant predatory pliosaur *Liopleurodon.* The most common plesiosaurs are the long-necked *Muraenosaurus* and *Cryptoclidus*, and the middle-sized pliosaur *Peloneustes*.

Most commonly isolated vertebrae and teeth are found. The vertebrae of plesiosaurs can be identified from the perforations on the underside or sides of the centrum referred to as nutritive foraminae.

Cervical centrum of the long-necked plesiosaur *Muraenosaurus* showing nutritive foraminae on underside. Found loose in Must Farm quarry, probably Bed 10.

The centrum is about 4cm in length

Photo: Richard Forrest

Tooth of the long-necked plesiosaur *Muraeonosaurus* in situ.

Photo: Darren Withers

The teeth of plesiosaurs are generally round in section. Those of the long-necked plesiosaur *Cryptoclidus* are rather slender and slightly recurved and with very light or absent striations, those of other long-necked plesiosaurs rather more robust and with moderate striation. Pliosaurs have robust teeth, and in the case of *Liopleurodon* can be very large - up t0 25cm long and 5cm in diameter.

Tooth of *Muraenosaurus*. From Must Farm pit, found loose. Scale bar 1cm.
Photo: Richard Forrest

An exceptional find. The substanitally complete skeleton of a juvenile of the long-necked plesiosaur *Cryptoclidus* excavated by Peterborough Museum Volunteers.

Photo: Richard Forrest

Marine reptiles

Marine Crocodiles

Crocodiles were much more diverse during the Jurassic than they are today and included forms fully adapted to life in water. They had paddle-shaped flippers and a tail-fin, and some species lost their body armour. Two genera of marine crocodile are known from the Oxford Clay, *Steneosaurus* and *Metriorhynchus*. Their vertebrae have a characteristic pinched-in shape.

Vertebra of marine crocodile as found, Must Farm pit. From lower beds of Oxford Clay. Note the pinched-in shape of the centrum.

Photo: David Savory

Dorsal scute of *Stenosaurus*. This genus has armour on its back, unlike *Metriorhynchus* which had smooth skin. From Pode Hole quarry, probably Middle Oxford Clay. Scale bar marked in cm.

Photo: Richard Forrest

The teeth of Oxford Clay marine crocodiles are generally slighly flattened in section, and are carinated - i.e with a serated edge - along two sides.

Other Vertebrates

Although the Oxford Clay is a marine sediment, finds have been made of dinosaurs and pterosaurs. These are very rare indeed. Only a couple of dozen such specimens are recorded, in contrast to tens of thousands of marine reptiles.

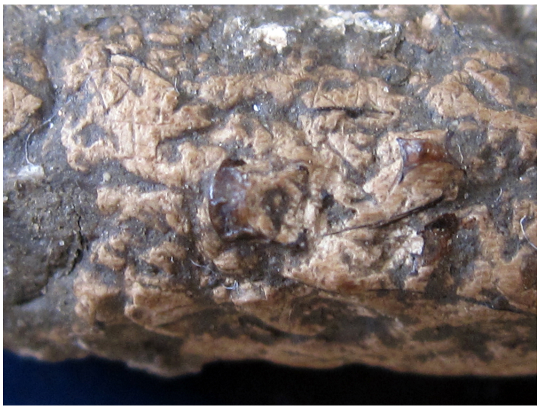
Cervical scute of Ankylosaurian dinosaur. Pode Hole Quarry, found loose but probably from Middle Oxford Clay. Specimen in Wollaton Hall Natural History Museum, Nottingham.

Photo: Richard Forrest

Coprolites are fossilised faeces. They can give some insight into the diet of the animal which delivered them. Most are small, and most likely from fish. Others can be much larger and in some cases contain bones or teeth, indicating that they were made by a larger predator.

Small coprolites, found loose at Must Farm pit

Photo: Richard Forrest.



Detail of coprolite with inclusion of fish vertebrae.

Photo: Darren Withers.

Trace fossils are phenomena such as tracks and burrows, only very rarely associated with any body fossils. They can be seen on bedding planes exposed by splitting laminated clays.

Worm burrows showing as greenish clay infil on bedding plane

Photo: Darren Withers

Fossil **wood** is very common, sometimes found in large blocks. It is black, and tends to fracture very easily. The surface sometimes bears the impression of ammonites or other shells. It dries our and disintegrates very quickly as soon as it is exposed to air.

Fossil wood with ammonite impression

Photo: Darren Withers

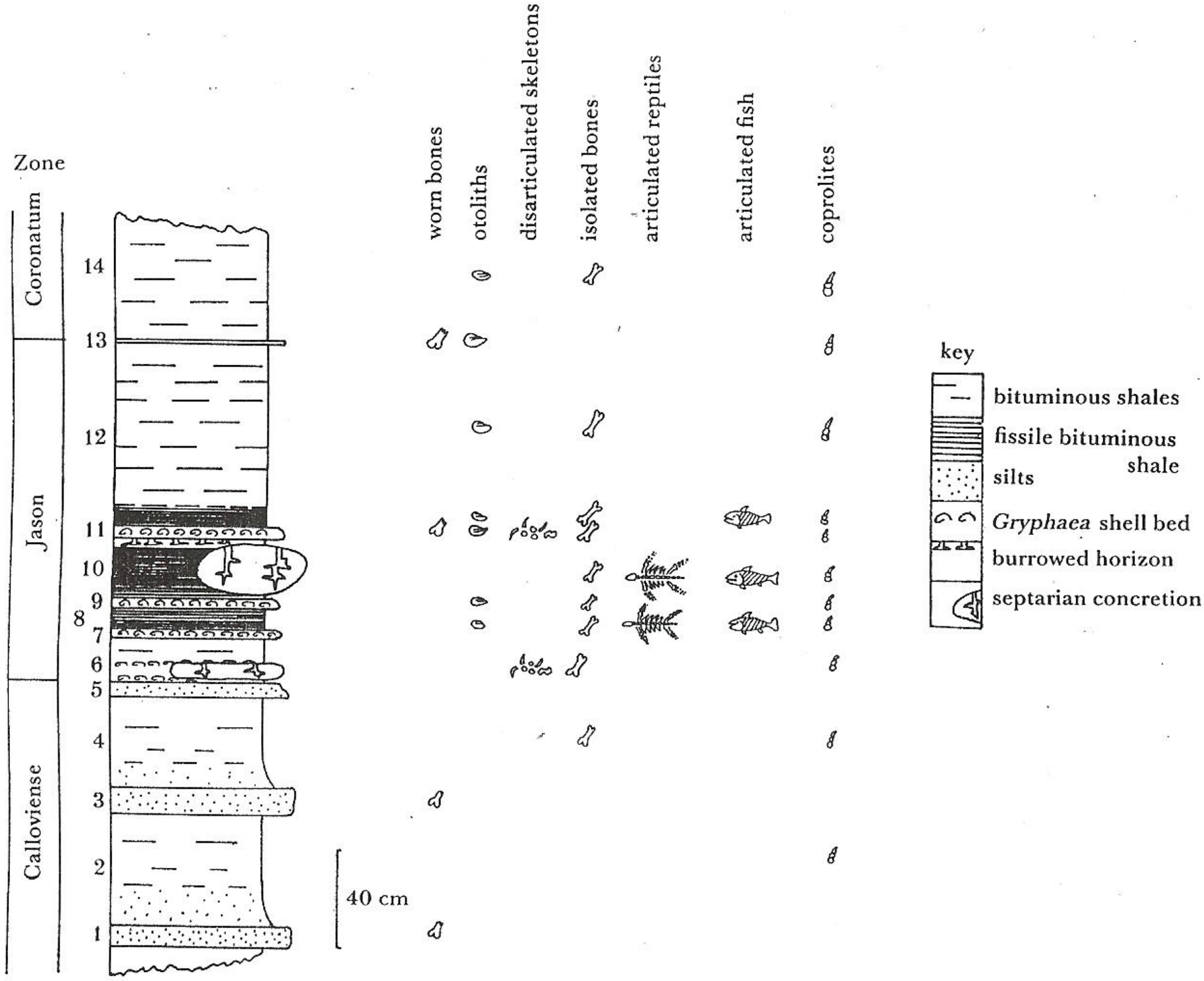


FIGURE 2. Generalized section through the basal beds of the Lower Oxford Clay of the Peterborough area showing the distribution of different preservational styles. Bed numbers correspond to those of Callomon (1968).

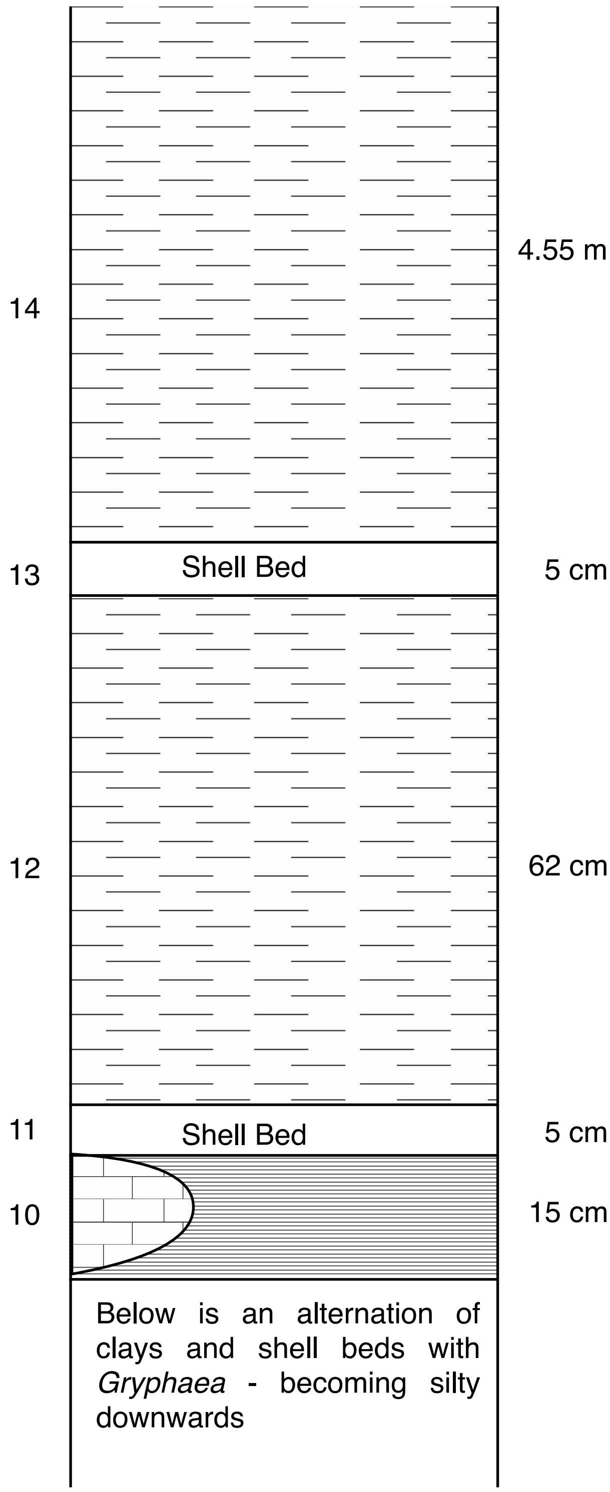
Beds 1–13, '*Gryphaea* and Reptile Beds'

13	Shell-bed, rounded clasts of wood	0.02
12	Shale, organic-rich, fissile in lower part, ammonites	0.46
11	Shell-bed. *Gryphaea, Grammatodon*	0.04
10	Shale, fissile, organic-rich, burrows in upper part; large calcareous septarian concretions. Ammonites abundant	0.17
9	Shell-bed, pyritous. *Gryphaea*	0.01
8	Shale, fissile, dark, organic-rich. Ammonites abundant, *Gryphaea*	0.09
7	Shell-bed, pyritous at top. *Gryphaea, Pinna, Kosmoceras*	0.05
6	Shale, fissile, grey, abundant *Kosmoceras, Meleagrinella, Pinna*, spat	0.14
5	*Gryphaea* shell-bed. *Gryphaea* shells in life orientation and inverted, belemnites, ammonites, wood	0.03
4	Shaly clay, brown. *Gryphaea* inverted	0.03
3	*Gryphaea* shell-bed, pyritous. *Gryphaea* inverted, belemnites	0.04
2	Shaly clay, olive-brown. Transitional base	0.06
1	Clay, silty. Sharp base	0.06

This shows the lower beds of the Oxford Clay from which most of the material at Nature Reserve is taken. Although rather jumbled it is possible to get a good idea of which bed a fossil is from by looking at the nature of the clay and the fossils it contains.

Figures from Martill and Hudson (eds.) 1991, "Fossil of the Oxford Clay", published by the Palaeontological Association.

Keith Duff has provided very useful notes on the sediments and fauna above bed 10.



14 Olive-green blocky shaly clay dominated by *Bositra*, *Meleagrinella*, some nuculacea. *Mechochirus* comes from this bed.

13 Shell fragments in dark sticky clay matrix. Some weak pyritisation of shells towards the top. *Kosmoceras*, *Meleagrinella*, *Palaeonucula*, *Grammatodon*, flat oysters.

12 Olive-green blocky shaly clay with patchy fossils. Some horizons seem unfossiliferous. *Protocardia* typical. Abundant *Bositra*, *Grammatodon*, *Oxytoma*.

11 *Grammatodon*-rich shell bed with ammonite plaster at base. *Grammatodon*, *Trautscholdia, Protocardia, Dicroloma,* flat oysters.

10 Dark, very well-laminated shaly clay with many crushed macroconch ammonites. Many horozontal trace fossil burrows up to 2cm wide infilled by greenish clay. *Grammatodon, Parainoceramus, Dicroloma, Pinna, Oxytoma, Trautscholdia, Melagrinella, Chlamys, Bositra*. Fish fragments - scales, teeth, centra - also characteristic. Septarian concretions at pit base occur within this bed.

Further Information

FIELD GUIDE TO FOSSILS: No. 4 - Fossils of the Oxford Clay; Authored by: David M. Martill (ed.) and J. D. Hudson (ed.); Series Number: 4; Publication Date: 1991; Pages: 283; Published by the Palaeontological Association.

C W Andrews, 1910 (Pt 1) & 1913 (Pt 2). A descriptive catalogue of the marine reptiles of the Oxford clay. Based on the Leeds Collection in the British Museum (Natural History), London. (Available as reproduction of the original from Elibron Classics).

Written by Richard Forrest (richard@plesiosaur.com), with valuable help from Keith Duff and Darren Withers. Most of the illustrations are of fossils in the personal collections of Richard and Darren, or drawings by Keith.

Please print and use, and if you find any mistakes or omissions, feel free to contact me.

Richard Forrest, 22nd February 2019.