
Peterborough Brickpits, Cambridgeshire

[TL 165 940], [TF 210 025], [TF 248 978]

K.N. Page

Introduction

Small brickpits working the Oxford Clay Formation have been in operation around Peterborough from at least the 18th century. The discovery that the clays of the lower part of the formation (now called the 'Peterborough Member'; Cox *et al.*, 1992) were sufficiently plastic to be 'dry' pressed into moulds and sufficiently organic-rich to part-fire themselves led to the establishment of the 'Fletton Process' in the 1880s. A massive industry producing cheap bricks subsequently developed; fuel costs for firing were much reduced and the bricks could be produced all year round, even in wet winter weather (Hillier, 1981). At various times, different pits have been operational south and east of the city, following the Oxford Clay Formation outcrop (Horton *et al.*, 1974; Horton, 1989) (Figure 4.24). Many areas are now worked out and recent production has focused on two areas, near Whittlesey east of Peterborough and Orton to the south, although working at the latter pit (Figure 4.25) ceased in January 1998.

The stratigraphy of the Oxford Clay Formation in the Peterborough Brickpits has been reported by Woodward (1895) and Arkell (1933), more fully described by Callomon (1955, 1964, 1968) and reviewed by Hudson and Martill (1994) (Figure 4.26). The Lower Callovian part of the sequence was re-described by Page (1988). More recently, much work has focused on the sedimentary geochemistry of the Peterborough Member (Williams, 1988; Hudson and Martill, 1991; Anderson *et al.*, 1994; Belin and Kenig, 1994; Hudson, 1994, Kenig *et al.*, 1994; Macquaker, 1994; Norry *et al.*, 1994); some of this work is summarized by Hudson (2001).

Description

The complete Callovian sequence is not now seen in the Peterborough Brickpits district as the basal beds, in the Cornbrash Formation (Abbotsbury Cornbrash Formation of Page, 1989) and Kellaways Formation (Cayton Clay and Kellaways formations of Page, 1989), are usually only exposed in temporary sections or boreholes (Callomon, 1968; Page, 1988). The sites here taken as representative of the Peterborough Member are (a) Orton Pit [TL 165 940], (b) Dogsthorpe Star Pit [TF 210 025] and (c) Kings Dyke, Whittlesey Nature Reserve site [TF 248 978]. The younger Stewartby Member can be seen, in part, at King's Dyke (Hudson and Martill, 1994) and was once exposed in the now-obiterated pits near Eye (Callomon, 1968). The following is therefore a composite sequence based on the exposures recorded in pits, past and present.

Kellaways Formation

The Kellaways Formation is occasionally seen in sumps at the base of working brickpits but more than about 2 m is rarely visible. It comprises olive-grey sand or silt with locally some soft silty sandstone ('sandrock'), and is assigned to the Kellaways Sand Member. Preservation of aragonitic-shelled fossils is usually poor and invariably specimens are crushed or distorted. Bivalves, including *Pleuromya*, *Pholadomya*, *Modiolus* and *Oxytoma*, are common, and *Gryphaea* and belemnites (*Cylindroteuthis*) occur in shell beds. Large blocks of calcareous sandstone, sometimes laminated, with bands of *Gryphaea* and *Cylindroteuthis* have been seen amongst material cleared from construction areas at the Orton site. Occasional ammonites, including *Kepplerites* (*Gowericeras*), large *Proplanulites* and *Sigalocerus* ex gr. *calloviense* (J. Sowerby), have been recorded in the district (Callomon, 1968; Page, 1988).

Oxford Clay Formation

Only the lower part (Peterborough Member) of the overlying Oxford Clay Formation is generally exposed. A composite sequence was described by Callomon (1968), and Hudson and Martill (1994) provided additional sedimentological and

palaeontological detail (the latter based, in part, on Duff, 1975, 1978) as well as a detailed measured section of the exposure at King's Dyke, Whittlesey. The Peterborough Member is dominated by brownish-grey fossiliferous organic-rich mudstone, alternating with paler, more calcareous levels with shell-rich beds at a number of levels. In the lower part of the sequence, a distinctive marker band of calcareous septarian concretions is present (Bed 10 of Callomon, 1968); these were regularly visible in the base of Orton Pit and in rock piles cleared from development areas at that site. Hudson (1978) and Hudson *et al.* (2001) described the petrography and geochemistry of these concretions. Hudson and Martill (1994) highlighted local differences in the details of the basal beds in the Peterborough area.

The benthic fauna is of relatively low diversity and dominated by bivalves including *Gryphaea* (mainly in the lowest part), *Meleagrinnella braamburiensis* (Phillips), *Mesosaccella*, *Bositra*, *Grammatodon* and *Oxytoma*. Gastropods (*Procerithium* and *Dicroloma*) are also common (Duff, 1975, 1978, 1991). The nektonic fauna is dominated by cephalopods with belemnites (common *Cylindroteuthis puzosiana* (d'Orbigny) (Page and Doyle, 1991, pl. 28) and *Belemnopsis bessina* (d'Orbigny), as well as *Belemnobea*) and abundant ammonites (Brinkmann, 1929a,b; Callomon, 1968; Page, 1991; Page and Doyle, 1991). The latter are typically crushed flat in the clays; uncrushed or partially crushed specimens generally only occur in the septarian concretions of Bed 10. Nautilids are, in contrast, very rare and few (including *Paracnoceras calloviense* (Oppel) (Page and Doyle, 1991, pl. 31, fig. 1)) have been recorded. Ostracods, foraminifera and other microfossil groups are also present.

The vertebrate fauna (Martill, 1991a) is exceptionally rich with diverse fish including sharks and rays (*Hybodus*, *Asteracanthus*, *Notidanus*, *Protospinax*, *Paracestracion*, *Heterodontus*, *Orectoloboides* and *Spatbobatis*), chimaerids (*Ischodus*, *Brachymylus*, *Pachymylus*, *Leptacanthus*) and bony fish (*Mesturus*, *Lepidotes*, *Heterostrophus*, *Caturus*, *Osteorachis*, *Asthenocormus*, *Leedsichthys*, *Hypsocormus*, *Aspidorhynchus* and *Pholidophorus*) (Martill, 1989a, 1991b; Woodward, 1888, 1890, 1896, 1928). Most exceptional amongst the bony fish are parts of the giant *Leedsichthys*, a genus possibly reaching more than 10 m in length (Woodward, 1890; Martill, 1985b, 1988b). Most fish remains are fragmentary but articulated specimens are occasionally recovered and the area has been the source of many type specimens.

The reptile fauna is also very diverse and internationally famous for marine species. Plesiosaurs (*Muraenosaurus*, *Tricleidus*, *Cryptoclidus*) (Seeley, 1874; Andrews, 1895, 1909a,b, 1910–1913; Charig and Horrell, 1971; Brown, 1981; Martill, 1991c), piosaurs (*Liopleurodon*, *Simolestes*, *Peloneustes*, *Pliosaurus*) (Andrews, 1910–1913; Brown, 1981; Martill, 1991c) and ichthyosaurs (*Ophthalmosaurus*) (Appleby, 1956, 1958; Martill, 1991c) are particularly prominent, accompanied by frequent sea-crocodiles (*Steneosaurus*, *Metricorhynchus*) (Lydekker, 1890; Andrews, 1909b, 1910–1913; Adams-Tresman, 1987a,b; Martill, 1991c). Remarkable but rare dinosaur and pterosaur (*Rhamphorhynchus*) remains are also present. The dinosaurs include sauropods (*Cetiosauriscus*, *Ornithopsis*), ornithomimids (*Callovosaurus*), stegosaurs (*Lexovisaurus*), ankylosaurs (*Sarcolestes*) and a possible theropod (Hulke, 1887; Lydekker, 1893; Martill, 1984, 1988a, 1991d). A remarkable number of articulate large marine reptiles has been recovered from Bed 10.

Interpretation

The Peterborough Brickpits are most important as the type locality of the Peterborough Member (formerly known as the Lower Oxford Clay) for which Cox *et al.* (1992) proposed the working clay-pit at Kings Dyke Pit, Whittlesey (TL 23 97) as the reference section (Hudson and Martill, 1994). In addition, the member here provides stratotypes for the Subboreal Middle Callovian Substage, its two ammonite-based zones (Jason and Coronatum) and their subzones (Medea, Jason, Obductum and Grossouvrei; Callomon, 1964, 1968; Cox, 1990; Page, 1991). The ammonites from this interval were investigated by Brinkmann (1929a,b) whose work remains one of the most detailed and famous layer-by-layer studies of morphological evolution (Callomon, 1995). Brinkmann measured the diameter of numerous ammonites collected centimetre-by-centimetre through the brickpit sequence and analysed the ribbing density and other features. His classification involving assignment of macroconchs ([M]) and microconchs ([m]) of a single species to different species, subspecies or subgenera confuses the evolutionary interpretation but nevertheless his work accurately demonstrates the progressive small changes within a single evolutionary lineage. One remarkable observation was that the size of mature (adult) specimens often 'jumps' across shell beds, thereby suggesting that such levels represent small non-sequences, interrupting otherwise continuous sedimentation (Callomon, 1955; Raup and Crick, 1982).

The sequence of these ammonite faunas in this interval is as follows (based on Callomon, 1968, and observations by the present author), using Brinkmann's (1929a,b) '0 cm' level as equating with the base of the Peterborough Member and Callomon's (1968) bed numbers:

Lower Callovian

Calloviense Zone, Enodatum Subzone

0–20 cm (Bed 4): *Sigaloceras* (*Catasigaloceras*) *anterior* (Brinkmann) ([M] and [m], including the holotype (Brinkmann, 1929b, pl. 3, fig. 1)) = *anterior* Biohorizon (stratotype, part).

The Enodatum Subzone is remarkably complete at Peterborough and the following three-fold succession of ammonite faunas (biohorizons) has been recognised: *S. pagei* (Mina) (= *S. enodatum* (Nikitin) a Callomon and Page in Callomon *et al.*, 1989) followed by *S. enodatum* p Callomon and Page (in Callomon *et al.*, 1989) (= *S. enodatum* Nikitin *sensu stricto*) followed by *S. anterior* (Brinkmann) including the specimens figured by Page (1991, pl. 14, fig. 1, pl. 15, fig. 2). At Peterborough, the first two biohorizons are entirely within the Kellaways Sand Member.

Middle Callovian (stratotype)

Jason Zone (stratotype), Medea Subzone (stratotype)

20–55 cm (beds 5–9): *Kosmoceras* (*Gulielmiceras*) *medea* Callomon ([M], including the specimen figured by Page (1991, pl. 15, fig. 3) and the holotype of *K. nodosum* Callomon (= Tintant, 1963, pl. 34, fig. 1) and [m]); ?*Homeoplanulites/indosphinctes*'sp.

Jason Zone, Jason Subzone (stratotype)

55–78 cm (Bed 10): *Kosmoceras* (*G.*) ex gr. *jason* auctt. early form ([M], including Tintant, 1963, pl. 25, fig. 1, and [m]); rare *Reineckeia* (*R.*) ex gr. *anceps* (Reinecke) (recorded by Callomon (1968) as *R. aff. stuebeli*, *R. cf. rehmanni*, *R. grossouvrei* and *R. tyranniformis*); *Cadoceras* cf. *compressum* (Nikitin) (Page, 1991, pl. 17, fig. 3) preserved in septarian concretion = *jason*' a Biohorizon (stratotype nov.).

78–135 cm (beds 11–13): *Kosmoceras* (*G.*) ex gr. *jason* auctt. ([M] and [m]); including late transient forms (*K. conlaxatum*) = '*Jason*'p) Biohorizon (stratotype nov.).

Coronatum Zone (stratotype), Obductum Subzone (stratotype)

135–559 cm (beds 14–16): *Kosmoceras* (*Zugokosmoceras*) *obductum* (S.S. Buckman) ([M], including the types of *K. pollucinum* (Tintant, 1963, pl. 43, fig. 1) and *K. castor anterior* Brinkmann (Tintant, 1963, pl. 40, fig. 2), and [m] including *K. aff. 'gulielmi'* (J. Sowerby) and *K. castor* (Reinecke)); *Erymnoceras coronatum* (Bruguère) (including large [M]).

Coronatum Zone, Grossouvrei Subzone (*sensu* Callomon, 1964, 1968) (stratotype)

559–854 cm (beds 17–18): *Kosmoceras* (*Z.*) [*obductum*] *posterior* Brinkmann ([M] and [m], the latter including *K. 'gulielmi'* and *K. castor* (Reinecke) (including the type of *K. castor* (Reinecke) *castor* Brinkmann (Tintant, 1963, pl. 40, fig. 3) at level 610 cm) = *posterior* a Biohorizon (stratotype nov.); upper 61 cm with *K. pollux* (Reinecke) only = *posterior* p Biohorizon (stratotype nov.).

854–895 cm (beds 19–20): *K.* ex gr. *grossouvrei* (Douvillé) ([M] and [m], including *K. cf. posterior* only in shell bed at base and the microconch forms *K. castor* and *K. pollux*); *Erymnoceras* sp. = *grossouvrei* a Biohorizon (stratotype nov.).

895–1054 cm (Bed 21): *K.* (*Z.*) ex gr. *grossouvrei* (Douvillé) ([M] and [m], the latter including the forms *K. castor* and *K. pollux*, and occasional specimens with 'bundled ribs', including the holotype of *K. fasciculatum* Tintant (1963, pl. 41, fig. 5 = *K. aculeatum anterior* Brinkmann) at level 988 cm = *grossouvrei* p Biohorizon (stratotype nov.).

1054–1093 cm (Bed 22): *K. ex gr. grossouvrei* (Douvillé) ([M] and [m], as Bed 21); *Binatisphinctes comptoni* (Pratt) ([M] and [m] common); *Hecticoceras (Sublunuloceras) cf. lonsdali* (Pratt) ([M] and [m] frequent) = *comptoni* Biohorizon.

Upper Callovian

Athleta Zone, Phaeinum Subzone

1093–1135 cm (Bed 23): *Kosmoceras (Lobokosmokeras) ex gr. phaeinum* (S.S. Buckman) ([M] and [m], the latter including the form *K. acutistriatum* (S.S. Buckman) = '*acutistriatum*' Biohorizon.

At least a further 5.8 m of Peterborough Member have been recorded in the district (Hudson and Martill, 1994). This is also referable to the Phaeinum Subzone with a similar ammonite fauna to that of Bed 23 given above. It has yielded the types of *Kosmoceras aculeatum* (Eichwald) *aculeatum* Brinkmann (Tintant, 1963, pl. 43, fig. 3) at level 1277 cm, and *K. proniae* (Teisseyre) *duplicosta* (Quenstedt) (Tintant, 1963, pl. 32, fig. 1) at level 1291 cm.

Older horizons of the Lower Callovian Substage are represented in the Kellaways Formation. The ammonites recovered from the Kellaways Sand Member (see 'Description' above) indicate the Calloviense Zone and Subzone and the underlying Koenigi Zone, but a macroconch specimen of *Macrocephalites polyptychus* Spath in Buntings Lane Borrow Pit, near Stanground ([TL 200 958]; Page, 1988) suggests that the lowest levels of this member may still belong to the Herveyi Zone (Kamptus Subzone, *polyptychus* Biohorizon).

The diversity and exceptional preservation of much of the fossil fauna in the Peterborough Brickpits has led to both taphonomic and ecological studies. Duff (1975) first investigated the succession using a quantitative analysis of the benthic macrofauna and trophic nucleus analysis. He recognized ten biofacies (some of which are shown in (Figure 4.26)), reflecting minor variations in bottom oxygenation, sediment consistency and other factors, such as winnowing leading to the development of shell beds. A number of clues as to trophic relationships between the diverse elements of the Peterborough Member fauna (Figure 4.27) include cephalopod hook-lets in the stomach contents of *Metriorhynchus* (Martill, 1986b) and *Peloneustes* (Martill *et al.*, 1994), supposed semionotid fish bite-marks on an ammonite shell (Martill, 1990a), ?pliosaur bite-marks on plesiosaur bones (Martill *et al.*, 1994), and a *Metriorhynchus* tooth embedded in a bone of *Leedsichthys* (Martill, 1985b). These, with other more circumstantial evidence, have facilitated the reconstruction of complex food webs (Martill *et al.*, 1994). Aspects of the taphonomy of the fauna, especially vertebrates, are discussed by Martill (1985c, 1986a) and Hudson and Martill (1991).

The establishment of an international Oxford Clay Formation Working Group in the late 1980s led to the application of a wide range of new geochemical analytical techniques to studies of the organic-rich mudrock of the Peterborough Member of the Peterborough Brickpits district (Hudson, 1994). Anderson *et al.* (1994) investigated the nature of the Peterborough Member sea by studying carbon and oxygen isotopic compositions of calcareous and phosphatic fossils. They concluded that the Peterborough Member was deposited in 'normal' continental-shelf seawater. The oxygen isotope palaeotemperatures are compatible with thermal stratification provided that the ammonite *Kosmoceras* inhabited warmer near-surface waters (mean temperature 21°C, with a range of 16–28°) and that belemnites (*Cylindroteuthis*), indicating cooler temperatures (15°C mean, 12–19°C range), were nekto-benthic or migrated (?seasonally) from cooler waters. As benthic bivalves (nuculaceans and *Gryphaea*) give a similar palaeotemperature range to the belemnites and as the latter include a range of growth stages from juvenile to adult, the nekto-benthic lifestyle is perhaps most likely.

Bulk geochemical analysis has revealed that the Peterborough Member is remarkably immature as regards its organic component (Kenig *et al.*, 1994). Some 75–95% of the amorphous organic matter is of marine origin and the contribution of terrestrial material is limited (Belin and Kenig, 1994). The variations in content partly coincide with ammonite subzonal boundaries, and also correspond to the biofacies (based on macrofaunal assemblages) of Duff (1975). The latter reflect environmental changes and are therefore significant. In particular, the deposit-feeder shales of Duff (1975), which were deposited under dysaerobic conditions are more organic-rich than the shell beds which formed under more aerobic conditions. Important constituents of the organic material include phytane and pristane, derived from the degradation of chlorophyll. The petrography and isotopic composition of the organic material indicates a marine source but no molecular biomarkers specific to any individual marine primary producers could be analysed (Kenig *et al.*, 1994).

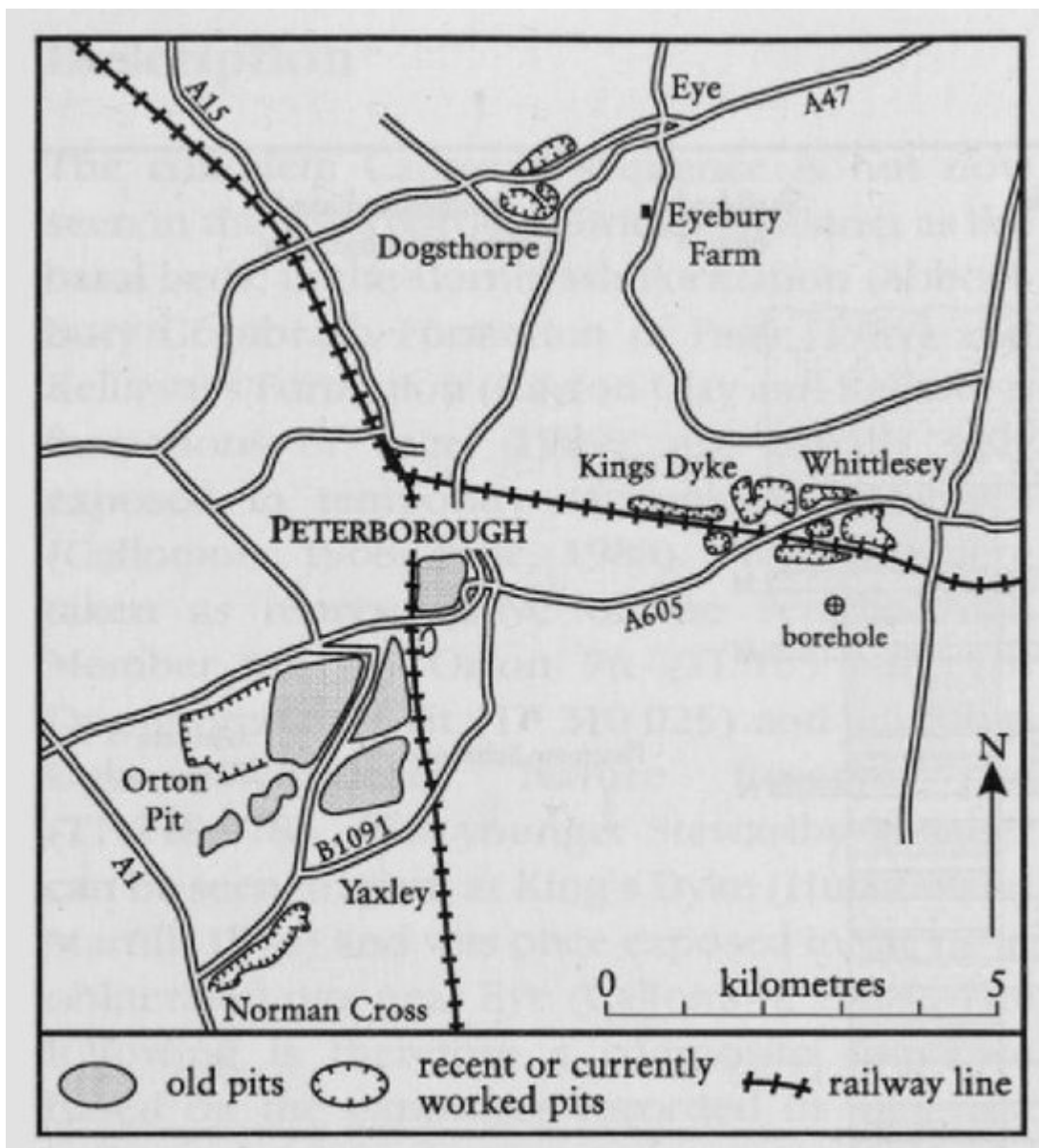
Belin and Kenig (1994) demonstrated that the sediments of the Peterborough Member have a microbioturbated texture indicating that the sea floor was never completely anoxic for long periods. The high organic content and its limited alteration, despite this reworking, indicate a very high productivity in the waters above and the most organic-rich levels, such as Bed 10, are rich in coccolith-containing faecal pellets confirming enhanced trophic activity. The presence of organic material, interpreted by Belin and Kenig (1994) as cyanobacterial coatings, indicates that the depositional environment was relatively shallow, certainly not greater than the photic zone.

Whole-rock elemental geochemistry and mineralogical analysis carried out by Norry *et al.* (1994) indicated that the mineral assemblage of the clays is mostly in-situ detrital material, with little diagenetic alteration. However, the presence of some heavy minerals may facilitate the identification of sources of the sediment. Macquaker (1994) indicated that the clay is dominated by illite, mixed layer illite–smectite and kaolinite mixed with the amorphous organic material. Minor components include authogenic pyrite, silt-sized quartz grains, calcareous nannoplankton (mainly disarticulated coccolith plates) and a variety of early carbonate cements. Some mudstones contain abundant foraminifera which is compatible with the observation of Kenig *et al.* (1994) that the seabed was at least intermittently oxygenated. However, recent work by Kenig and collaborators (summarized by Hudson, 2001) reveals the presence of the biomarker isorenieratane. This is derived from green sulphur bacteria that are photosynthetic but anaerobic, and shows that the water column was, at times, anoxic within the photic zone. Therefore, the Peterborough Member sea was characterized by an alternation between oxic and anoxic states, and the relative durations of these strongly influenced the benthic faunas.

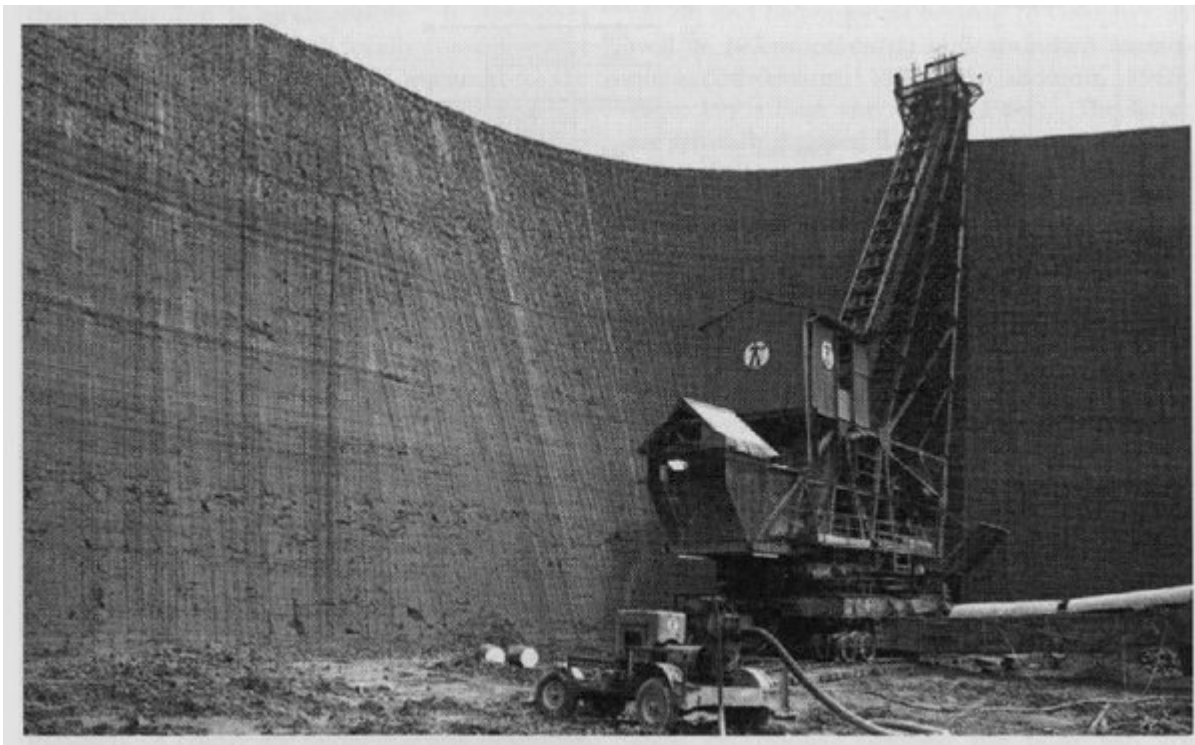
Conclusion

The famous exposures of the Peterborough Member of the Oxford Clay Formation near Peterborough (its type locality) yield rich fossil faunas of the upper Lower Callovian and Middle Callovian substages. They include reference sections for the entire Middle Callovian Substage, including its component Medea and Jason sub-zones (Jason Zone), and the Obductum and Grossouvrei subzones (Coronatum Zone). It is therefore of considerable international stratigraphical importance. In addition to stratigraphically and palaeontologically important ammonite faunas, diverse molluscan assemblages allow palaeoecological studies. The area is also world famous for its vertebrate faunas including fish, marine reptiles and rare dinosaurs. Recent sedimentary geochemical studies have revealed unusually well-preserved organic molecules, indicating a globally very rare preservational environment that contributed to the preservation of the rich invertebrate and vertebrate faunas.

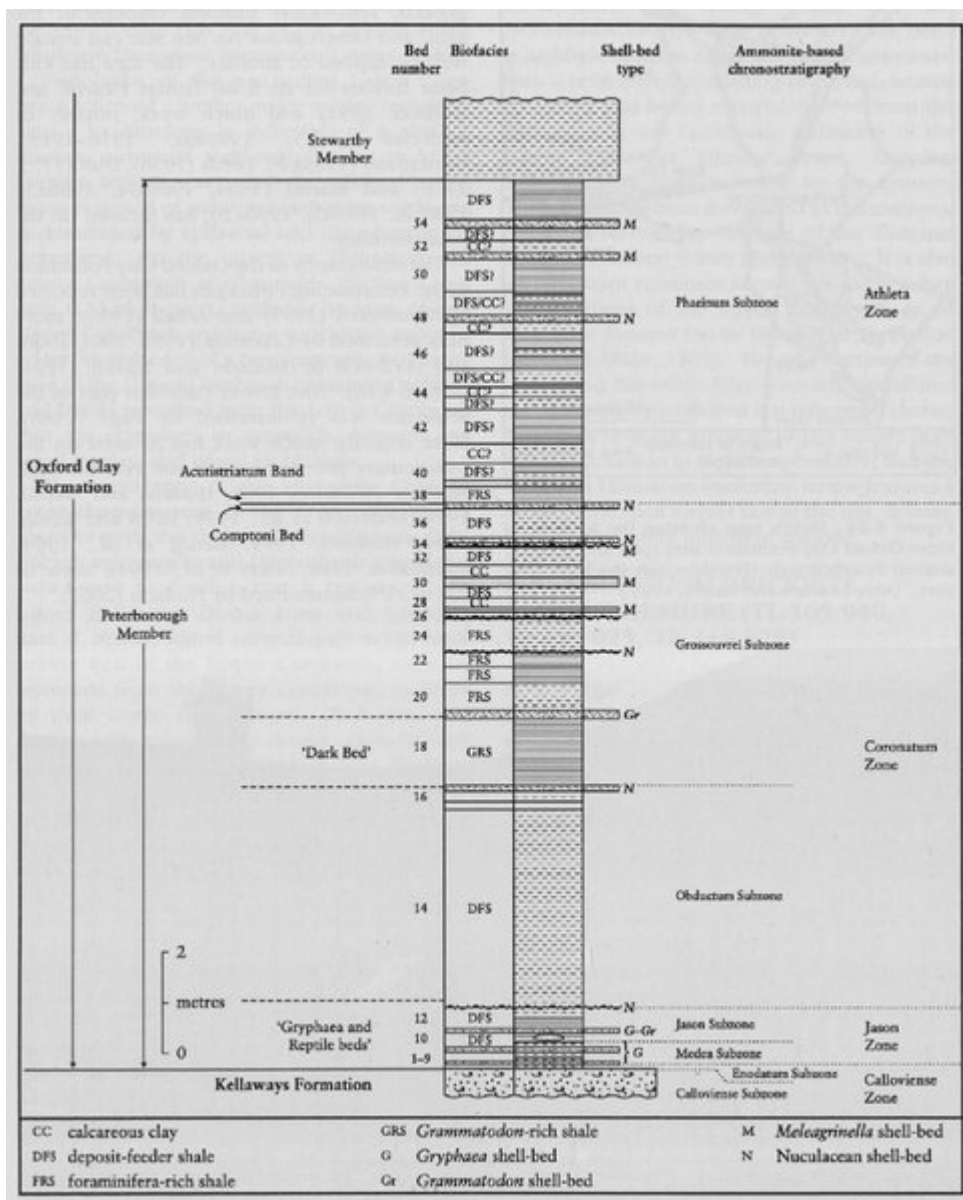
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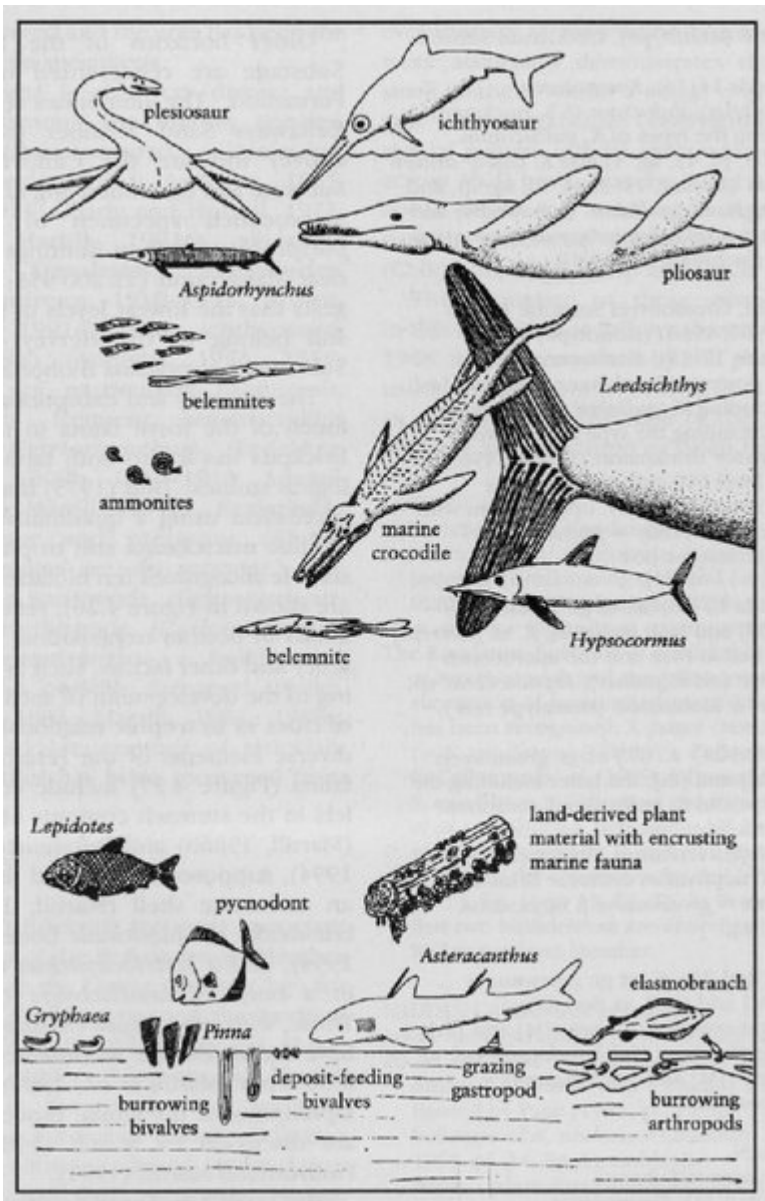
(Figure 4.24) Sketch map showing the location of some Oxford Clay Formation sites (past and present) around Peterborough (Peterborough Brickpits GCR site). (After Hudson and Martill, 1994.) Nevertheless, the Peterborough Member is, in general, remarkably uniform throughout the area, and observations on one site can equally well be applied to another. The area has long been famous for its fossil faunas (Martill and Hudson, 1991) and much work, notably by Andrews (1895, 1909a,b, 1910–1913), Brinkmann (1929a,b), Leeds (1956), Duff (1975, 1978) and Martill (1984, 1985a-c, 1986a,b, 1988a,b, 1989a,b, 1990a,b), has focused on the palaeontology.)



(Figure 4.25) King's Dyke Pit, Whittlesey. Shale-planar excavator digging the Oxford Clay Formation for brick-making. The section illustrates the marked alternations of darker, brownish-grey, organic-rich mudstone and paler, more calcareous, mudstone. The excavator works down to the lowest bed of concretions in the Oxford Clay Formation (Bed 10 of Callomon, 1968; and Hudson and Martill, 1994). (Photo: British Geological Survey, No. MN26846; reproduced with the permission of the Director, British Geological Survey, © NERC, 1987.)



(Figure 4.26) Graphic section of the Peterborough Member of the Oxford Clay Formation in the Peterborough district. (After Hudson and Martin, 1994; and Duff, 1975; bed numbers follow Hudson and Martill, 1994.)



(Figure 4.27) Diagrammatic representation of the Peterborough Member faunal community (After Hudson and Martill, 1991.)