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CHAPTER 14

THE KELLAWAYS BEDS AND THE OXFORD CLAY

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A. THE CORNBRASH

The Cornbrash marks a return everywhere from the regressive, in part deltaic, facies of the Bathonian to fully marine conditions. Its deposition reflects a major transgression of the seas in many parts of the world, covering for the first time some areas, such as parts of the U.S.S.R. and the Baltic shield, which probably had been above water since Palaeozoic times. The sediments which filled the newly formed basins of deposition were the products of renewed but slow erosion of nearby landmasses, comparable to the Lias, and the thick dark clays and shales with thin muddy limestones and cementstone concretions which form the Oxford Clay stand in great contrast to the calcareous rocks and cross-bedded sandstones of the Lower Oolites. The deepening of the seas also freed the processes of sedimentation from the immediate effects of currents and wave-action, so that the deposits succeeding the Kellaways Beds were laid down with remarkable uniformity. Whereas the Liassic seas transgressed across a highly undulating surface reflecting the remnants of Armorican folding, and their sediments vary rapidly in thickness and facies, these pre-Mesozoic irregularities had by Upper Jurassic times been almost finally smoothed out, and the Oxford Clay is one of the most uniform deposits in the European Jurassic. Beds a few feet or even inches thick persist over great distances, and the constancy of the faunal successions permits the setting up of a zonal and subzonal scheme of stratigraphic subdivision which has few rivals in the wideness of its applicability.

B. THE OXFORD CLAY AND KELLAWAYS BEDS

The Oxford Clay and Kellaways Beds attain their greatest thickness in England in the south, up to 600 ft. having been recorded in borings in Wiltshire. Following the outcrop northwards, the observed thicknesses decrease. At Shellingford [*SU 3393*], near Faringdon (Berks.), 450 ft. were recently measured (Falcon and Kent 1960, p. 14). In the region of Oxford, the estimated thickness is around 350 ft. (Arkell 1947), and at Bluntisham [*TL 3674*], 11 miles northwest of Cambridge, and March [*TL 4197*], 15 miles east of Peterborough, old borings showed 300 and 214 ft. At Warboys, 13 miles southeast of Peterborough, a recent Geological Survey boring combined with the section in the nearby brick-pit gave a total thickness of 250 ft.*. Thicknesses of this order seem to persist northwards through Lincolnshire; eastwards, a boring at North Creake [*TF 8538*], Norfolk (Kent 1947), indicated only 184 ft. This thinning is due in part to subsequent erosion, for younger beds of two widely differing ages cut down into, and come to rest on, intermediate zones of the Oxford Clay. Middle and

* The permission of the Director of H.M. Geological Survey to quote some data obtained from the Warboys borehole is gratefully acknowledged.

TABLE 15

Stages		*Zones*[1]	*Subzones*	*Divisions*	*Peterborough* (Brinkmann, cms.)
OXFORDIAN	Lower	*Cardioceras cordatum*	*C. cordatum*	Upper Oxford Clay (100 ft.+)	
			C. costicardia		
			C. bukowskii		
		Quenstedtoceras mariae	*C. praecordatum*		
			C. scarburgense		
CALLOVIAN	Upper	*Quenstedtoceras lamberti*		Middle Oxford Clay (c. 50 ft.)	2800–c. 3100
		Peltoceras athleta	Upper / Middle		1600–c. 2800
			Lower	Lower Oxford Clay (50–75 ft.)	1095–1600
	Middle	*Erymnoceras coronatum*	*K. (Zugokosmokeras) grossouvrei*		560–1094
			K. (Zugokosmokeras) obductum		136–559
		Kosmoceras jason	*K. (Gulielmites) jason*		56–135
			K. (Gulielmites) medea		21–55
	Lower	*Sigaloceras calloviense*	*S. (Catasigaloceras) enodatum*[2]		0–20
			Sigaloceras calloviense	Kellaways Rock (2–12 ft.)	
			Proplanulites koenigi		
		Macrocephalites macrocephalus	*M. (Kamptokephalites) kamptus*	Kellaways Clay (3–12 ft.) & Upper Cornbrash	
			M. (Macrocephalites) macrocephalus		

[1] The standard zones of the Callovian and Oxfordian, their authors, synonyms and type-localities were recently reviewed by Callomon (1964).

[2] Formerly *S. planicerclus* Subzone. Comparison of the type of *S. planicerclus* (Buckman 1923) with a plaster-cast of the holotype of *S. enodatum* (Nikitin 1881) kindly supplied by the Geological Institute of Leningrad shows them to be conspecific. The holotype is refigured by Tintant (1963).

Upper Oxfordian (Oakley Beds and Ampthill Clay) rest on the *Cardioceras praecordatum* or *C. scarburgense* Subzones of the *Q. mariae* Zone in Buckinghamshire, around Ampthill [*TL 0337*] and at least locally in Huntingdonshire; and Lower Greensand in turn cuts out all the Upper Jurassic sometimes down to the *C. scarburgense* Subzone in the region of Woburn [*SP 9433*] and Sandy [*TL 1649*]. Further to the southeast, the Oxford Clay wedges out completely against the old London-Ardennes Island under the Cretaceous overstep.

In part, however, the thinning of the Oxford Clay northeastwards is also the result of genuinely reduced sedimentation in a manner similar to but milder than that observed in earlier members of the Jurassic system. It coincides with an upswell in the underlying Palaeozoic platform on what may have been a ridge between London-Ardennes Island and the Palaeozoic rocks of the Midlands (the Moreton and Charnian axes of authors). Thus, at Shellingford [*SU 3393*], 14 miles southwest of Oxford, the base of the Kellaways Beds lies 960 ft. above the Keuper and 1585 ft. above the Palaeozoics, but at Noke [*SP 5413*], only 5 miles northeast of Oxford (Falcon and Kent 1960, p. 46), the height above Palaeozoics is reduced to 403 ft. At Calvert [*SP 6824*] it is 345 ft.; at Bletchley [*SP 8733*], 271 ft.; and Little Missenden [*SU 9298*], 22 miles south of Bletchley, only 172 ft. Except for those removed by erosion at the top, all the zones and subzones of the Oxford Clay appear nevertheless to be everywhere present, and the variations of total thickness are not reflections of non-sequences. Further to the east, the Palaeozoic platform drops again, to 1159 ft. below the Kellaways near Peterborough (Kent 1962) and 1303 ft. at North Creake.

Physically, the soft deposits weather to a flat, featureless and marshy landscape unfit for much besides pasture. In much of our region they are moreover concealed beneath glacial drift or Fen deposits. Natural exposures are rare, and little would be observable of the geology of the Oxford Clay, other than in the coastal sections in Yorkshire and Dorset, were it not for its particular suitability for brick-making. The Oxford Clay now supports a very large and flourishing brick industry which is concentrated mainly in four areas: around Peterborough; south of Bedford; near Bletchley; and at Calvert, 6 miles east of Bicester. In these areas it is mainly the shales of the Lower Oxford Clay that are exploited. The more plastic and calcareous Middle and Upper Oxford Clay are worked in a few isolated pits outside the immediate area considered here, at Warboys [*TL 3080*], 15 miles southeast of Peterborough; Woodham [*SP 7117*], 4 miles south of Calvert; and Purton [*SU 0887*], 5 miles northwest of Swindon. Between them, the pits expose an almost continuous section in central England from Cornbrash to Corallian, and it has become clear that the succession is better and more fully developed in this country than anywhere else. The beds are splendidly exposed to depths of 100 ft. in many enormous excavations, a compensation to the geologist for the closure which mechanization and modern techniques have forced on the ubiquitous small brickyards flourishing in the last century. Yet despite this, and with a few notable exceptions, the sections have so far hardly been studied, and many details remain to be worked out.

1. *The Oxford Clay Brick Industry*

It seems that any argillaceous rock that is sufficiently plastic to be workable can be fired to give a brick of sorts, but the economics of the process depend on five main factors. These are the water, free lime, clay-mineral, and organic (carbonaceous) contents of the basic material; and the absence of impurities such as calcareous macrofossils. The Lower Oxford Clay at present accounts for about a third of the bricks made in this country, and this reflects what is probably a uniquely favourable combination of these factors which are exploited in the 'Fletton' process, so named after the village near Peterborough where it was developed some seventy years ago. Only about the lowest 60 ft. of the strata are suitable, but this thickness varies somewhat from pit to pit.

(i) Water-content

Too much moisture in clay is undesirable for two reasons. Firstly, it makes the clay plastic, so that the freshly pressed green bricks have to be separately dried before firing, to acquire enough strength to be stacked in kilns without distorting under their own weight during firing, and to shrink uniformly. Secondly, expulsion of moisture is a major contributor to the fuel costs of firing. The Lower Oxford Clay contains around 20% moisture, which is low, and the green bricks have enough strength to be stacked straight into the kilns to their full height. The bricks are handled manually only once, and thereafter all movement is by fork-lift trucks.

(ii) Lime and Clay-minerals

The lime-content determines shrinkage during firing, and the colour, density and porosity of the fired brick (Freeman 1956). A minimum of at least 5% free calcium carbonate seems desirable to prevent serious shrinkage during the hottest period of the firing cycle; but amounts above 15% only increase the porosity of the product and add to the fuel costs through the expulsion of carbon dioxide. The lime-content of the Lower Oxford Clay varies between 2–3% in the *K. jason* Zone, 5–15% in the *E. coronatum* Zone, and exceeds 15% only in the higher zones, which are not worked in the Fletton process.

The clay-minerals determine the plastic characteristics of the clay, the details of the firing-cycle, and the strength of the product. The first of these is of dominant importance here, for the beds of the *K. jason* and *E. coronatum* Zones which are selected are shales rather than clays, containing up to 70% of micaceous non-clay minerals which give the green bricks their strength. The clays are mainly of illite types.

(iii) Organic Content

The Fletton process owes its economic advantage largely to the unusually high fuel-contents of the Lower Oxford Clay. This has a calorific value equivalent to about 5% free carbon (Freeman 1956; Brinkmann 1929a), which is sufficient to bring the bricks up to their full firing-temperature of 1050°C. Coal has in fact only to be added to control the firing and to maintain the bricks at their full temperature for a 'soaking' period of about twenty-four hours. The coal consumption is as low as 3% of the weight of the finished bricks, compared with 10–20% usual in other processes. Equally important is the low ignition-temperature of the bituminous material present in the clays. Were this too high, the fuel would either distill off, or its calorific value would not be available for the energy-consuming part of the cycle. Some of the more volatile fractions do in fact distill over, and with a northerly wind the characteristic smell of Peterborough is easily detectable in London, 70 miles to the south. The displacement of carbonaceous material leaves voids in the bricks without apparently diminishing their crushing-strength: the kiln chimneys, up to 300 ft. high, are built of them.

(iv) Impurities

They commonly contain calcitic macrofossils such as belemnites and *Gryphaea*. These are troublesome to remove, and if left even as small fragments after grinding can give rise to pockets of quick-lime in the fired brick which they split when slaked by the first rain-shower. The Lower Oxford Clay is highly fossiliferous, but except for a few thin pyritic shell beds the fossils are mostly preserved in soft friable lime. *Gryphaea* and belemnites abound in the lowest beds (up to *K. medea* Subzone), but are then rare throughout the worked beds, and only suddenly reappear in quantity in the upper *P. athleta* Zone. Cementstone concretions and stone bands are also only minor features, and the excavating, grinding and pressing operations can all be highly mechanized.

Their cheapness is one of the main reasons why the pressed, solid bricks used so much in this country have not given way to the much lighter, extruded hollow blocks favoured on the Continent.

2. *Summary of the Succession*

The Oxford Clay and Kellaways Beds have long been renowned for their fossils, yet because of the paucity of natural exposures and, formerly, the scatter of isolated small brick-pits, the faunal and stratigraphical successions in our region have been worked out only in fairly recent times. The earlier discoveries and descriptions are now of little but historical interest and are summarized by Woodward (1895), and Arkell (1933, pp. 347–358). The first modern attempts at classification are due to Buckman and Morley Davies, who attempted to combine information from the Yorkshire coast (Buckman 1913) and from pits and cuttings in Buckinghamshire (Davies 1916). In his later years Buckman published descriptions of numerous Callovian and Oxfordian ammonites in 'Type Ammonites' (Buckman 1909–30), many from old pits of Oxford, Buckinghamshire and Huntingdonshire, and some from the Oxford Clay shales of Calvert. The majority were not however from known levels in recorded sections, and Buckman's impressive chronological and faunal tables were based more on zoological arguments in which he claimed to be able to arrange ammonites according to the evolutionary stage they had supposedly attained, rather than established stratigraphical sequences. A summary of the generalized succession around Peterborough was published by Neaverson (1925), deduced from field observations but also without descriptions of actual sections.

The first detailed account of any of the large Oxford Clay brickpits was published in a classical memoir by Brinkmann (1929a). He had been attracted by the profusion and apparently continuous succession of forms of the ammonite genus *Kosmoceras* to be seen in the pits round Peterborough, to undertake a minute examination of the faunal succession to see what light it could shed on the processes of evolution. Ideally the subjects of such a study should be organisms which evolved rapidly, died and were preserved intact where they lived, and left an abundant and uninterrupted fossil record corresponding to a considerable period of time. A combination of these factors is rarely met, and it seemed that the succession at Peterborough might approach the ideal as closely as could be hoped for. Brinkmann therefore selected the lowest 43 ft. of the Oxford Clay above the Kellaways Rock in three pits south and east of Peterborough, and divided them into 1300 horizons at 1-cm. intervals as a basic stratigraphical scale to which to refer heights and thicknesses of beds and their contained

fossils. The level zero on this scale was arbitrarily fixed at the base of the pits. He collected some 3000 complete ammonites *in situ*, recording the height of each to the nearest centimetre, and measuring size, proportions, and details of ribbing. According to abundance, the data from suitable packets of strata ranging from 1 to 120 cm. thick were combined and treated statistically. Finally, he monographed the genus *Kosmoceras* systematically (Brinkmann 1929b).

The palaeontological results cannot here be gone into in detail, only some general conclusions summarized. The at first glance monotonous uniformity of the Oxford Clay is only apparent, and closer inspection reveals a rapid succession of distinct beds separated by sharp lithological boundaries. These boundaries often coincide with thin shell-beds or breccias, crowded with crushed ammonites ('ammonite-plasters') or bivalves, chiefly *Nucula*, and are sometimes pyritic. Two types of such shell-beds can be distinguished: basal shell-beds, marking the onset of a cycle of sedimentation; and terminal shell-beds marking its end. Oxford Clay sedimentation was thus no less discontinuous than in other formations. (For a summary in English, see Arkell 1933, pp. 57–58.) Similar discontinuities were found in the succession of *Kosmoceras* coinciding, where they occurred, with lithological breaks. There was therefore no way of deciding whether faunal breaks were to be attributed to evolutionary jumps or to gaps in deposition. Brinkmann preferred the latter interpretation and in a number of cases made an estimate of the lacuna by interpolation. This problem is one of several which might be solved by a study like Brinkmann's at another locality. In the meantime the breaks in development of *Kosmoceras* are very convenient stratigraphically in defining the precise limits of ammonite zones and subzones in at least one area, and the Peterborough succession must remain the principal starting point for any zonal classification of the Callovian stage. It provides a useful secondary standard for those zones and subzones which were originally defined elsewhere.

In the account that follows the palaeontological emphasis is inevitably on ammonites, because of their leading position in systematic stratigraphy. This is not to belittle the other faunas that occur, often in equal profusion. The Lower Oxford Clay has long been renowned for its vertebrate remains, both of fishes and reptiles (for bibliography and modern summary, see Arkell 1933, p. 357). The use of mechanical excavators means that these are no longer recovered intact, but loose vertebrae, jaws and teeth are still easy to find. Crustaceans include the crabs *Mecochirus* and *Goniocheirus*, common at certain levels. The belemnites are *Cylindroteuthis puzosiana* (d'Orbigny) (= *Bel. oweni* auctt.), *Belemnopsis sulcata* (Miller), and the Tethyan *Hibolites hastatus* (Blainville), the last named common only in the Middle-Upper Oxford Clay; and the Lower Oxford Clay yields *Belemnoteuthis antiqua* Mantell, a Boreal form in which the guard is reduced to a thin conical covering on a large phragmacone. At certain levels in the shales the phragmacones are fully preserved complete with pro-ostracum, but impressions of whole animals with ink-sac, hooked tentacles and eyes have not been found in this country in Oxford Clay outside Wiltshire.

Brachiopoda include *Rhynchonelloidella socialis* (Phillips), *Aulacothyris bernadina* (d'Orbigny) (= *Terebratula/Waldheimia impressa* auctt.) and *Acanthothiris lorioli* (Rollier), all from Middle-Upper Oxford Clay. Among the echinoderms, ossicles of *Pentacrinus* and tests of the echinoid *Collyrites* are found in the *P. athleta* Zone. A few gastropoda are common in the clays, including *Procerithium muricatum* (Sowerby) in colonies at certain levels, and *Dicroloma trifida* (Phillips) in the Lower Oxford Clay.

Many others occur in the less muddy beds of the Kellaways Rock and occasional limestone bands, for example in the Lamberti Limestone. Lamellibranch species are too many to list, but are strongly facies-dependent. In the shales bivalves often form fossil plasters, but usually of only one or two species at a time; *e.g.*, *Nucula* spp. with valves closed, or *Pinna lanceolata* Sowerby, *Thracia depressa* (Sowerby), *Oxytoma inaequivalvis* (Sowerby), *Meleagrinella* (= *Pseudomonotis* auctt.) sp., and ubiquitous oysters. As with the gastropoda, they occur together in the less argillaceous, more calcareous beds and are there joined by Pectens, *Plagiostoma* and *Trigonia*. The beds are also rich, if intermittently so, in microfaunas, and the relationships between sedimentary lithology and biofacies should provide interesting problems for future study. Floral remains are confined to fossilized wood, common in the Lower and Middle Oxford Clays at all levels, and seed-capsules, but more delicate structures such as leaves have not been preserved.

(i) Kellaways Beds

The transition from the limestones of the Cornbrash to the mass of the Oxford Clay is gradual and the intervening Kellaways Beds, although very variable, consist almost everywhere of a lower Kellaways Clay and an upper Kellaways Sand. The boundaries are however diachronous and beds of the same name can have quite different ages at different places. In south and central England, some or all of the following members may be represented.

V Oxford Clay, above.

IV *S. calloviense* Zone and Subzone: Kellaways Rock: fine sands or silts, locally soft sandstones with occasional doggers. *Sigaloceras calloviense*, *Proplanulites*, *Kepplerites*, *Cadoceras*; *Gryphaea bilobata* auctt.; belemnites.

III *P. koenigi* Subzone: upper Kellaways Clay: light blue plastic clay. *Proplanulites*, *Kepplerites*, *Cadoceras*, *Macrocephalites* (*Pleurocephalites*); *Ostrea* (*Catinula*) *alimena* auctt.

II *M. macrocephalus* Zone, *M. kamptus* Subzone: lower Kellaways Clay: black shaly clay with pyrites and buff phosphatic nodules. *Macrocephalites* (*Kamptokephalites*, *Dolikephalites*); *Ostrea* (*Exogyra*) *nana*; *Trigonia elongata*.

I *M. kamptus* and/or *M. macrocephalus* Subzone: Upper Cornbrash, below.

Member II has been separately traced (Callomon 1955) from Yeovil, where it attains its greatest thickness of 25 ft., via Frome (15 ft.), Kidlington (Oxford) (12 ft.), Bletchley, Bedford (Stewartby) (3½ ft.), to Peterborough (7 ft.); and it is probably present in the Casewick cutting (10 ft.) northwest of Peterborough, from which was recorded '*Am.* [= *Kamptokephalites*] *Herveyi* abundantly' (Morris 1853). Member III is known separately only from Wiltshire southwards; and from Oxford to the northeast it may have changed to sands and merged indistinguishably with the Kellaways Rock. Elsewhere undifferentiated Kellaways Clay attains 10 ft. at Akeley, near Buckingham (Douglas and Arkell 1932), 6 ft. at Calvert and 7½ ft. at Chetwode (old borings, Whitaker 1921), 10 ft. around Bedford (Woodward 1895), and 12½ ft. and 10 ft. at Dogsthorpe and Werrington, Peterborough, respectively (Woodward and Thompson 1909).

The Kellaways Rock (IV) in our region rarely yields the abundant and perfectly preserved ammonites for which it is renowned in Wiltshire and Yorkshire, but this is probably because of its softness. It is occasionally seen in drainage trenches dug in the floor of one of the large pits, and usually contains profuse bilobate *Gryphaea* and belemnites. At Peterborough Brinkmann recorded loose sands with doggers ranging up to level −120 cm. below zero, followed by sandy clays without fossils up to the base of the pits at level 'zero.' These lower beds were well exposed in large temporary excavations down to Cornbrash between Fletton and Yaxley in 1963. They consist in fact of fine silts with a hard bed at the top yielding profuse *Sigaloceras calloviense* amongst other species, and are thus all part of the Kellaways Rock. Brinkmann's level zero therefore coincides with the junction between Kellaways Rock and Oxford Clay, *S. calloviense* and *S. enodatum* Subzones. The junction with the Kellaways Clay (7 ft.) below was sharp, and the thickness of the Kellaways Rock 11½ ft. (350 cm.).

Elsewhere, thicknesses of 5–10 ft. seem typical. The contact with the overlying Oxford Clay is usually fairly sharp, but sandy intercalations may persist into the *K. jason* Zone.

(ii) Lower Oxford Clay

The most striking feature among the many fossils to be found in the Lower Oxford Clay is the profusion of ammonites which, although crushed, are otherwise usually complete up to the final aperture, with test often still preserved in iridescent white aragonite. By far the overwhelming proportion belong to the genus *Kosmoceras*, and the zonal classification is based on the evolutionary changes observed in this genus. Two groups of shells can be distinguished at all levels (Callomon 1955): large forms—macroconchs—in which the final body-chamber may become smooth, with simple, sinuous aperture; and smaller forms—microconchs—which are strongly ribbed to the end, and which bear long lappets on the final aperture.

(*a*) *S. calloviense* Zone, *S. enodatum* Subzone. The diagnostic ammonite is the macroconch *Sigaloceras* (*Catasigaloceras*) *enodatum* (Nikitin), with short primary ribs dividing low on the whorlside into sheaves of fasciculate secondary ribs which cross the tabulate venter uninterruptedly. There are no tubercles, the coiling is extremely involute, and the final body-chamber is smooth. Maximum diameter is *c.* 60 mm. Oysters, including *Gryphaea*, and belemnites are very common.

The *S. enodatum* Subzone was until recently known in this country only at its type-locality, South Cave [*SE 9331*], near Market Weighton, where it occurs as 10 ft. of typical Kellaways Rock. For this reason it was classed as part of the *S. calloviense* Zone. It is now clear that elsewhere it occurs widely as the lowest part of the Oxford Clay. At Peterborough it is represented by Brinkmann's levels 0–20 cm. (8 in.). At Stewartby, south of Bedford, it is about 1½ ft. (45 cm.) thick; at Bletchley, 2½ ft. (75 cm.); and at Kidlington ammonites collected too late to be included in the description of the section there (Callomon 1955) show that it has thickened to 6 ft. (180 cm., beds 7, 8). The subzone is also widely known abroad: in Normandy (Calvados), Deux-Sèvres, Haute Marne, Saône-et-Loire; northwest Germany (Wesergebirge), Franconia ('Goldschneckenfauna'), Argovian Jura; U.S.S.R.: Elatma, Saratov, Caucasus and Trans-Caspia (Mangyshlak).

(*b*) *K. jason* Zone

(1) *K. medea* Subzone. Diagnostic macroconchs *Kosmoceras* (*Gulielmites*) *medea* Callomon; like *S. enodatum*, but slightly larger (60–90 mm.), with lateral tubercles at points of furcation, and one to each secondary rib at the ventral margins. These tubercles distinguish *Kosmoceras* from *Sigaloceras*. The venter is smooth and the

primary ribs are accentuated at the umbilical margin into a second row of incipient tubercles. Oysters and belemnites are still profuse. At Peterborough, levels 21–55 cm. (1 ft. 1 in.), thickening to 2½ ft. at Stewartby, *c.* 6 ft. at Bletchley, 5 ft. at Kidlington.

(3) *K. jason* Subzone. Diagnostic macroconch *K.* (*Gulielmites*) *jason* (Reinecke); like *K. medea*, but larger (100–130 mm.) and ribbed to correspondingly later stages, although the body-chamber is still smooth. Primary ribbing consists of two rows of lateral tubercles separated by a spiral smooth band. The microconch is *K.* (*Gulielmiceras*) *gulielmi* (Sowerby), somewhat larger than 50 mm., but otherwise unchanged from predecessors in the lower subzones. Belemnites and oysters are now rare, and the *K. jason* Subzone is the lowest to be used everywhere for bricks. At Peterborough, levels 56–135 cm. (2 ft. 7 in.), thickening to *c.* 10 ft. at Stewartby, *c.* 15 ft. at Bletchley, 18 ft. at Calvert, and at least 43 ft. at Kidlington north of Oxford.

(c) *E. coronatum* Zone.

Although *Kosmoceras* continues to be the dominant genus, others begin to contribute appreciably to the total fauna, and are common at certain levels. One of these is the Stephanoceratid genus *Erymnoceras* which provides the zonal index. Little was known until recently about the occurrence of this genus in England, and there were doubts whether outside Dorset the index (common in France and the Jura) occurred at all. It is in fact very common in the *E. coronatum* Zone, and the index (including *E. reginaldi* (Morris), holotype figured by Arkell, 1933, plate XXXVI, figure 1, at most a variety of *E. coronatum*) is most appropriate.

(1) *K. obductum* Subzone. *K.* (*Zugokosmokeras*) *obductum* is the first of the macroconchs to retain some ornament to the end. It is somewhat smaller than *K. jason* (90–100 mm.), more involute and coarsely ribbed, and the ventral tubercles or ribs persist on the body-chamber. Microconchs like *K. gulielmi* continue little changed, but are joined by new, much more coarsely-ribbed and spinous forms of the subgenus *Spinikosmokeras*. *E. coronatum* is common at all levels. At Peterborough, levels 136–559 cm. (13 ft. 10 in.); Bletchley, *c.* 11 ft.; Calvert, *c.* 12 ft.

(2) *K. grossouvrei* Subzone. *K. obductum* is succeeded by forms which are similarly and wholly ribbed but larger (130 mm.) and more evolute, which Brinkmann called *K.* (*Z.*) *obductum posterior* (Peterborough, 560–854 cm.), and these are in turn replaced by the evolute, equally large and extremely densely finely ribbed *K.* (*Z.*) *grossouvrei* (Douvillé) (= *Zugokosmokeras zugium* Buckman) (855–1093 cm.). These two forms are not easy to distinguish in the field, and are best combined in the same subzone. Microconchs now include the coarsest form of *Spinikosmokeras*, *K.* (*S.*) *pollux* and *ornatum*, as well as *K.* (*G.*) cf. *gulielmi* much as previously. The subzone and zone terminate sharply with an ammonite plaster crowded with forms dominant amongst which are Perisphinctidae transitional to *Peltoceras*. Their inner whorls are extremely evolute and densely ribbed with fine, straight, single or simply bifurcating ribs that curve backwards on the venter, and have no constrictions. Pending generic separation they are usually referred to '*Perisphinctes*' or '*Binatisphinctes*': *comptoni*, *mosquensis*, *scopinensis* (microconchs) and *fluctuosus* (macroconch). *Ammonites mosquensis* Fischer has recently been made type of a new genus *Okaites* by Sasanov. Various species of *Hecticoceras* are also common, and *Erymnoceras* still occurs. This bed, a few centimetres thick, lies at level 1093 cm. at Peterborough, and is equally sharply defined at Bletchley, 45 miles to the southwest. It is recognizable at Bedford and Calvert, and was exposed in temporary excavations near Wytham, Oxford. The types

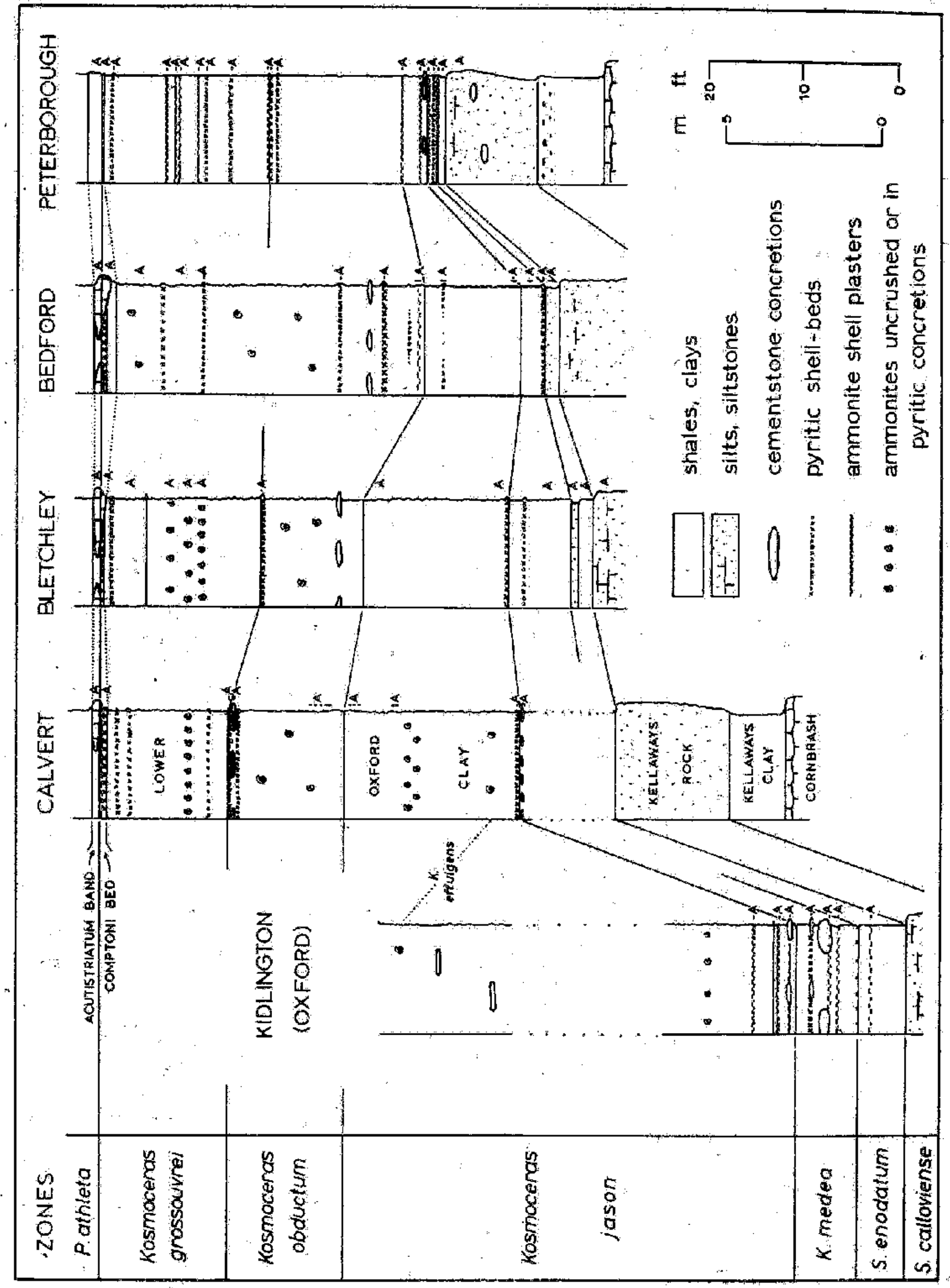

Figure 45. Diagrammatic representation of the Lower Oxford Clay in the various sections, up to the base of the *P. athleta* zone, to show the lateral variation of thickness of the individual zones and subzones.
A = levels at which ammonites are particularly common.

…omptoni and *P. fluctuosus* (Pratt) came from Christian Malford [*ST 9678*], …ire, and the *P. mosquensis*-group is common in the U.S.S.R.
…al range of the subzone at Peterborough is 560–1093 cm. (17 ft. 10 in.); at …ley, *c.* 17 ft.; and at Calvert, *c.* 14 ft.

(d) *P. athleta* Zone.

This zone is at present less well known than the preceding ones mainly because that at the base ammonites are much rarer. Lithologically there is a fundamental change somewhat below the middle of the zone in central England. The lower part consists of grey or brown more or less bituminous shales with crushed white fossils before, and is still suitable for Fletton bricks. There is then a fairly rapid transition blue or grey-green plastic and apparently nonstratified clays in the higher parts the zone, and this lithology continues thence to the top of the formation. The lithological break is prominent in sections, for the lower shales support almost vertical faces whereas the clays flow; and it serves conveniently to define the boundary between Lower and Middle Oxford Clay. Palaeontologically, three successive Kosmoceratid ammonite faunas can be distinguished in the zone and these may in time come to be the basis of separate subzones. Pending the necessary systematic work, however, the zone will here be divided only into lower, middle and upper parts.

(1) Lower *P. athleta* Zone. The level 1094 cm. at Peterborough sees a sharp change in the Kosmoceratidae from the forms of the *K. grossouvrei* Subzone to similar forms in which a new character is apparent; secondary ribs reunite in pairs at the ventral tubercles, which gain in prominence, so that the number of secondary ribs per whorl exceeds the number of ventral tubercles. The ratio on the last whorl, termed by Brinkmann the 'bundling-number,' jumps in the finely-ribbed macroconchs from 1·02–1·05 (*K. grossouvrei*) to 1·2–1·4 (*K. phaeinum, proniae*), and in the microconchs from 1·02–1·07 (*K.* aff. *gulielmi*) to 1·4–1·8 (*K. rimosum*); the difference in the microconchs is unmistakable in the field. Bundling is also observed in the coarse microconchs—*K.* (*Spinikosmokeras*) *acutistriatum* Buckman replaces *K. castor*; and in coarse macroconchs of the subgenus *Hoplikosmokeras*—*K.* (*H.*) *hoplistes* Buckman and *gemmatum* (Phillips) replace *K. pollucinum* (Teisseyre). At first glance this fauna seems more closely related to that of the *E. coronatum* Zone below than to the pyritized shells from higher up, but when due allowance has been made for the difference in preservation this is seen not to be so. In defining the boundaries of zones palaeontological grounds take precedence over lithological changes, and the sudden appearance of bundled ribs in the Kosmoceratids marks an easily and widely recognizable level at which to draw a zonal boundary. For this reason, and because of the disappearance of *Erymnoceras*, the beds above level 1094 cm. at Peterborough and their equivalents elsewhere are already included in the *P. athleta* Zone. Perisphinctidae of the *P. mosquensis* group and *Hecticoceras* continue to be common at certain levels, although not as common as in the top beds of the *E. coronatum* Zone.

The basal part of the Lower *P. athleta* Zone is highly calcareous and widely developed as a band of specially hard shale or limestone called by Buckman the Acutistriatum Band at Calvert (Buckman 1909–30, vol. v., plate 486c), a name that seems worth preserving for a useful marker-horizon. The special lithology seems to extend to Wiltshire, for it is now clear that most of the famous crushed but otherwise perfectly preserved ammonites on small tablets of mudstone from Christian Malford

to be found in almost every museum are of this age (Pratt 1842; Quenstedt 1887, plate 83, figure 27; Douvillé 1915, plate xii, figures 1, 2; plate xiii, figures 1, 2, 3, 5; Buckman 1924, vol. V, plates 486–90, 531, 532; Arkell 1933, plate 36, figure 2).

At Peterborough, levels 1094—*c.* 1600 cm. (16 ft.); thicknesses at Bedford, *c.* 31 ft., at Bletchley, *c.* 25 ft. and at Calvert, 25 ft.

(iii) Middle Oxford Clay

The non-bituminous, rather calcareous clays of the Middle and Upper Oxford Clay differ from the shales of the Lower Oxford Clay not only in their lithology but also biofacies. They are on the whole much more poorly fossiliferous. Gone are the fossil 'plasters' with their profusion of crushed white shells. Instead large *Gryphaea* reappears (*G. lituola, G. dilatata*), crowded in certain levels into complete fossil oyster-beds. Ammonites are also confined to a few levels and are preserved as uncrushed pyritic casts, usually of the inner whorls only. Other features are brachiopods, crinoid ossicles and hastate belemnites. Although the fauna and absence of bituminous matter gives the impression of much clearer and more aerated waters than those from which the Lower Oxford Clay was deposited, the ammonites at certain levels are unusual in that they are all juveniles, having died while less than half-grown. In contrast complete but immature shells in the Lower Oxford Clay are extremely rare. The reason for these micromorphic ammonite faunas is not known, although some sort of annual 'water-bloom' cycle has been postulated (Rutten 1956), such as is known in parts of the world today, leading to periodic complete deaeration of the sea and the death of all life in it.

(2) Middle *P. athleta* Zone. This produces the fauna which has usually been associated with the zone as a whole: pyritized *Kosmoceras* and large *Peltoceras*. Among the former, the leading macroconchs are *K.* (*Zugokosmokeras*) *rowlstonense* (Young and Bird), *K.* (*Lobokosmokeras*) *proniae* (Teisseyre) with many varieties, and *duncani* (Sowerby). *K. proniae* was the name used by Brinkmann for all the forms with bundled secondary ribs and double row of lateral tubercles separated by a spiral smooth band found from the top of the *E. coronatum* Zone upwards. The shells in the Lower *P. athleta* Zone are however strongly ribbed to the end, and it is useful to retain for them Buckman's name *K. phaeinum* to distinguish them from the true *proniae* of the Middle *P. athleta* Zone, which becomes smooth on the body-chamber. *K. duncani* (Sowerby) is characterized by flexuous ribbing and secondaries that reunite in sheaves of three or four at latero-ventral clavi rather than tubercles (neotype figured by Arkell 1939). Also common are *K. rimosum* (Quenstedt) (like *K. duncani* but with paired secondary ribs; Quenstedt 1886–87, plate 83, figure 15), *K.* (*Kosmoceras*) *tidmoorense* Arkell and *K.* (*Spinikosmokeras*) *transitionis* (Krenkel non Nikitin). The true *K. spinosum* does not seem to occur. The Peltoceratids include *P. athleta* (Phillips) and varieties, species of *P.* (*Rursiceras*), and *Pseudopeltoceras*. The material is usually fragmentary and close identification of the extremely variable forms is difficult (for illustrations see Quenstedt 1886–87; Prieser 1937; Jeannet 1951).

Only some of the large pits worked for Fletton bricks go as high as these beds, so that any pyritized ammonites from them are likely to be of this age. Two old pits in the Middle *P. athleta* Zone from which large collections now widely dispersed were formerly obtained were at Wolvercote [*SP 498104*] and Summertown [*SP 504086*], in north Oxford. Both the Wolvercote section and a typical collection from it have been described by Arkell (Arkell 1947, p. 71; 1939, p. 207), who showed that attempts to subdivide this part of the *P. athleta* Zone further according to the ranges of *K. proniae*, *duncani* and *P. athleta* have so far been unsuccessful.

(3) Upper *P. athleta* Zone. This is characterized by an abundance of the irregularly-ribbed *K.* (*Kosmoceras*) *spinosum* (Sowerby) and its allies, *K. tidmoorense* Arkell, *annulatum* (Quenstedt), *spoliatum* (Quenstedt), *distractum* (Quenstedt), and *arkelli* (Makowski 1952). Macroconchs also include *K. rowlstonense*, *K. compressum* (Quenstedt) and allied species, widely and incorrectly described under the name *K. duncani*, and *K. transitionis* (Nikitin). Perisphinctids (*Grossouvria*) are relatively common, as are *Hecticoceras* and the bicarinate Oppelids *Distichoceras* and *Horioceras*. Successors of *Erymnoceras* reappear in the form of species of *Pachyceras*.

The Upper *P. athleta* Zone is at present exposed in only one pit, at Woodham, where it is at least 35 ft. thick. There are no continuous sections through the whole *P. athleta* Zone anywhere, and the total thickness of Middle and Upper parts are hard to estimate, although unlikely to be less than 50 ft. There used to be a section in a faulted patch at Eye Green pit [*TF 230034*], near Peterborough (Neaverson 1925), in which, according to Brinkmann, the Middle-Upper *P. athleta* Zone extended from level 1600 to 2800 cm. (39 ft.).

The recent boring at Warboys showed a total of 103 ft. for the combined *P. athleta* and *Q. lamberti* Zones, which could not be separated in the cores.

(*e*) *Q. lamberti* Zone.

Just as this country was probably part of the area in which the Kosmoceratidae prospered most, another family, the Cardioceratidae, had its true home further north in Middle Callovian times, in what was probably then, as now, the Arctic Ocean. Thus although they do occur rarely in the *E. coronatum* and *P. athleta* Zones in this country, Cardioceratidae abound, for example, in Arctic Russia, Siberia and Alaska, where Kosmoceratidae in turn are rare. This complementary distribution was suddenly upset, and Cardioceratidae swarmed southwards in enormous numbers as far as the Alps, to dominate the ammonite faunas in this country almost to Upper Oxfordian times and occasionally later. They therefore replace the Kosmoceratidae for zoning. Roughly simultaneously with the southerly spread of the Cardioceratidae, other families normally dominant in yet another faunal realm, that of the ancient Tethys, south of the Alps, spread temporarily northwards. As a result, the *Q. lamberti* Zone yields in this country an ammonite fauna quite unusually rich both in species and individuals: some eighteen genera, representative of nine families, have been found side by side in the same bed.

The arrival in this country of the Cardioceratidaè defines the base of the *Q. lamberti* Zone. The first to appear in quantity were forms still with rounded venter—*Quenstedtoceras* (*Eboraciceras*) *henrici* Douvillé. These were quickly joined by forms with sharp venter—*Q.* (*Lamberticeras*) *lamberti* (Sowerby) and allies. *Kosmoceras* still persists in the *Q. lamberti* Zone, including *K. spinosum* (of which it yielded the type) and *K. compressum*, but then becomes extinct. The Tethyan elements include Perisphinctidae, Oppeliidae, Aspidoceratidae (*Aspidoceras* first appears in the zone), Pachyceratidae, and more rarely Reineckeidae (also becoming extinct thereafter), Phylloceratidae and Lytoceratidae. They make up some 35% of the individuals found.

The zone is now permanently exposed only at Woodham, where it consists of a bed of limestone a foot thick, together with about 3 ft. of clay beneath. At Peterborough,

Brinkmann recorded its fauna from levels 2800–3100 cm. (10 ft.). To judge from collections in the museums it was formerly worked elsewhere, particularly in Huntingdonshire. It crops out in the centre of Oxford, where it consists of at least 5 ft. of clay. At its type-locality, in Normandy, it is 30 ft. thick.

(iv) Upper Oxford Clay

(*f*) *Q. mariae* Zone.

(1) *C. scarburgense* Subzone. There is a sharp faunal break at the top of the *Q. lamberti* Zone, and Cardioceratidae become the dominant forms. They are often pyritized or limonitized. *Quenstedtoceras mariae* (d'Orbigny) is common in the basal part of the zone, to be gradually replaced in numbers by more sharply keeled, compressed forms: *Q. woodhamense* Arkell and *Cardioceras* (*Scarburgiceras*) *scarburgense* (Young and Bird). A characteristic accessory form is an Oppelid with a crenulate keel, *Creniceras renggeri* (Oppel), recently redescribed by Palframan (1966), after which beds of this age on the Continent are often called the Renggeri Marls. *Gryphaea dilatata* is common.

The subzone forms the 30 ft. of clay above the Lamberti Limestone at Woodham, and about 29 ft. used to be visible in the lower part of the pit at Warboys. The thickness in the borehole was 48 ft.

(2) *C. praecordatum* Subzone. *Cardioceras* continued to develop, the secondary ribs sweeping more and more forward on the venter to form a well differentiated keel in *C.* (*Scarburgiceras*) *praecordatum* Douvillé which becomes the commonest form after overlapping for a short range with *C. scarburgense*. The subzone is well-exposed at Warboys, where it is *c.* 22 ft. thick, and Purton, Wilts (Arkell 1941), where at least 30 ft. could be seen. Various parts of the *Q. mariae* Zone used to be worked in pits around St Neots and St Ives, Hunts.

(*g*) *C. cordatum* Zone.

The only part of the zone now visible in the area is the lowest *C. bukowskii* Subzone, which forms the top 29 ft. of clay at Warboys. The forward sweep of the secondary ribs on the venter becomes extreme in *C.* (*Scarburgiceras*) *bukowskii* Maire, and forms with prominent shoulders at the ventro-lateral margin and more inflated whorl-sections begin to appear. Various species of *Peltoceras* are common, especially *P.* (*Parawedekindia*) *arduennense* (d'Orbigny).

Higher subzones of the *C. cordatum* Zone appear to be largely missing along the outcrop between Yorkshire and Oxfordshire, having probably been removed by erosion, and the Oxford Clay is at many places immediately succeeded by Oakley Beds, Ampthill or Kimmeridge Clay, or Lower Greensand. Small islands of Corallian were preserved, *e.g.*, at Elsworth and Upware, and at these places clays or ferruginous marls of the *C. costicardia* subzone have been seen in temporary exposures.

LOCAL EXPOSURES

All the clay-pits listed here are in active work and are highly industrialized and it is necessary to obtain written permission to visit from the owners beforehand, usually from their main office.

14/1 *Peterborough* (Yaxley [*TL 1791*], Fletton [*TL 1895*], Kingsdyke [*TL 2597*], after Brinkmann 1929a, with amendments. These are the classical sections studied by Brinkmann.

		ft.	in.	*Brinkmann's scale, cm.*
	Superficial deposits			
	Boulder Clay, with Chalk (Yaxley)			
	Fen-deposits: black loam, containing large roots of bog-oak, and arctic willow (Kingsdyke)			
	River-gravel, sandy, well-bedded (Kingsdyke)			
	MIDDLE OXFORD CLAY			
	Q. lamberti Zone . . . . top,			*c.* 3100
28	Clay, with occasional concretions; pyritized *K. spinosum*, *Q. lamberti*, *sutherlandiae*, *grande*, *Perisphinctes* sp., *Hecticoceras* sp., *Aspidoceras* sp.			*c.* 2800
	Upper-Middle *P. athleta* Zone			
27b	Blue-grey clay, *Gryphaea lituola*, pyritized ammonites			
a	As above, occasional *G. lituola* only . together *c.*	23		*c.* 2100
	Lower *P. athleta* Zone			
26	Clay, greenish-grey, unstratified, barren . . .	14	6	1600
	LOWER OXFORD CLAY			
25	Shales, grey, alternating with greenish clays. Ammonites crushed, in white calcite, from here downwards; species as in bed 23, collected systematically only up to level 1310 cm.	14	6	1160
24	Clay, green, plastic, unstratified	2	10	1135
23	Acutistriatum Band; bituminous shales, many ammonites: *K. phaeinum*, *gemmatum*, *acutistriatum*, *aculeatum*, *ornatum*	1	4	1093
	E. coronatum Zone, *K. grossouvrei* Subzone			
22c	Comptoni Bed, 2 in.; many ammonites: *K. grossouvrei*, aff. *gulielmi*, *P. comptoni* (profuse), *Hecticoceras* spp.			
b	Shale, brown, bituminous, very fossiliferous, as above, 1 ft.			
a	*Nucula*-bed, 2 in. . . . . . together	1	4	1054
21	Clays, green or grey, alternating with brown bituminous shales; *K. grossouvrei*, *castor*, *pollux*, cf. *aculeatum*, aff. *gulielmi*, some already with occasional bundled ribs .	5	3	895
20	Clay, grey, with plasters of well-preserved ammonites at the base and the top: *K. grossouvrei*, *castor*, *pollux* .	1	0	864
19	Clay, grey, with plaster of well-preserved ammonites at the base: *K. obductum posterior*, *grossouvrei*, aff. *gulielmi*, *castor*, *pollux*, *E. coronatum* common		4	854

		ft.	in.	*Brinkmann's scale, cm.*
18f	Clay, shaly, grey, barren, 2 ft.			
e	Ammonite-plaster: *K. obductum posterior*, *gulielmi*, *castor*, *pollux* . . . . at			793
d	Clay, shaly, grey, barren, 11 in.			
c	Shell-bed with *Meleagrinella*, *Nucula*, ammonites, 2 in. at			765
b	Clay, shaly, dark grey, few fossils except near the top; *Belemnoteuthis antiqua*, 2 ft. 3 in.			
18a	*Nucula*-bed: clay, pyritic, crowded with shells, ammonites, *K. obductum posterior*, etc., 4 in. . . together	5	8	680
17b	Shaly clay, very dark, massive, few fossils			
a	Ammonite and *Nucula*-plaster at the base, with well-preserved shells: *K. obductum posterior*, *gulielmi*, *castor* .	3	10	559
	K. obductum Subzone			
16b	*Nucula*-bed, 1 in.			
a	Clay, shaly, with plaster of well preserved ammonites at the base		8	539
15	*Nucula*-bed: clay with *Meleagrinella* in the lower part and crowded with *Nucula* above; ammonites . . .		4	530
14	Clay or shales, grey, ammonites rare except at the top; crabs common 2 ft. above the base, and belemnites with phragmocones preserved in lowest 6 ft. *K. obductum*, *gulielmi*, *castor*, *E. coronatum*	12	10	135
	K. jason Zone, and Subzone			
13	Shell-bed with ammonite plaster, ½ in. . . . . at			135
12	Clay, shaly, green, and brown shales, many ammonites: *K. jason*, *gulielmi*	2	0	78
11	Shell-bed with ammonite plaster . . . . . . at			78
10	Clay, green-grey, or brown-black paper-shales, enclosing a layer of septarian concretionary cementstone nodules which mark the working-base of the pits and enclose uncrushed ammonites preserved in white calcite. *K. jason*, *gulielmi*, *Reineckeia* aff. *stuebeli*, *R.* cf. *rehmanni* (Arkell coll.); *R. grossouvrei*, *R. tyranniformis* (Callomon coll.) .		9	55
	K. medea Subzone			
9	Shell-bed: profuse belemnites and oysters . . . at			55
8	Clay, shaly, greenish, or brown bituminous paper-shales. Many ammonites: *K. medea*, *gulielmi*		6	39
7	Shell-bed, pyritic, many belemnites and oysters . at			38
6c	Clay, grey-green, many ammonites, 4 in.			
b	Ammonite plaster, with oysters . . . . . at			28
6a	Clay, shaly and sandy, 3 in., many ammonites . .		7	22

	ft.	in.	Brinkmann's scale, cm.
5 Shell-bed: many oysters, belemnites, ammonites. *K. medea, gulielmi*		1	20

S. calloviense Zone, *S. enodatum* Subzone

	ft.	in.	Brinkmann's scale, cm.
4 Clay, green, massive, many ammonites near the top. *S. (Catasigaloceras) enodatum, K. gulielmi anterior* Brink.		8	0

KELLAWAYS BEDS

S. calloviense Subzone

	ft.	in.
3 Kellaways Rock. Fine olive-grey sand or silt, locally soft sandstone, especially at the top, sometimes with doggers. Many white friable crushed fossils in the fresh rock, particularly in the top and bottom two feet. *Sigaloceras calloviense, Kepplerites gowerianus, Toricellites* sp., *Proplanulites koenigi* and very large species; common *Choffatia*, sp., and belemnites. Among the bivalves the commonest are *Gryphaea bilobata, Pleuromya alduini, Pholadomya deltoidea, Ph. lirata, Modiolus bipartitus, Oxytoma expansa*	11	6

M. macrocephalus Zone, *M. kamptus* Subzone

	ft.	in.
2 Lower Kellaways Clay. Sharp junction with the silts above, then blue-black tenaceous clay, non-calcareous and non-bituminous, a few white crushed fossils. Many small buff-white lenticular phosphatic concretions bearing cracks filled with zinc-blende, concentrated mainly into two courses about 1 ft. and 2 ft. from the top; lenticles of a sand of pyrites	7	0

UPPER CORNBRASH

	ft.	in.
1b Limestone, shelly, rubbly to massive, undulating upper surface. Large *Pholadomya* sp., *Trigonia elongata* (in borings)	5	0

LOWER CORNBRASH

	ft.	in.
1a Marl or clay, black, packed with coarse shelly detritus. *Meleagrinella echinata* (in borings)	5	0

The sections appear at first sight rather featureless, but three beds act as markers: the basal layer of concretions, bed 10; the massive dark shales of bed 17 sandwiched between *Nucula*-beds; and the green clay of bed 24. Most of the pits south of the town expose only Lower Oxford Clay, but those to the east, near Whittlesea, go up to bed 27a. The higher beds used to be exposed in a down-faulted patch near Eye Green. Some of the beds at the top of the *E. coronatum* Zone are highly calcareous and yield occasional uncrushed ammonite body chambers, among them a large *Reineckeia substeinmanni* (Lemoine). The higher beds at Eye Green have produced pyritized ammonites of the Middle-Upper *P. athleta* Zone in the past, just like those from Bletchley, Calvert or Oxford: *K. rowlstonense, proniae, compressum, spinosum, transitionis, duncani*, etc.; also *Longaeviceras placenta* (Leckenby) and *Reineckeia* sp.

14/2 *Bedford (Stewartby)* [*SP* 0142], *Marston Moretaine* [*SP* 9639]).

Topsoil and Drift.

MIDDLE OXFORD CLAY

Middle *P. athleta* Zone

	ft.	in.
22 Clay, weathered yellow . . . seen	5	0
21 Limestone, soft, impersistent; *Peltoceras* sp.	1	0
20 Clay, plastic, weathered yellow at the top, then blue; occasional *Gryphaea lituola*	40	0

LOWER OXFORD CLAY

Lower *P. athleta* Zone

	ft.	in.
19 Shell-bed, pyritic, variable		3
18 Shales and clays with white crushed fossils . . . *c.*	29	0
17 Acutistriatum Band: highly calcareous light grey fissile shales, locally hardened to cementstone welded to the beds below. Many ammonites: *K. acutistriatum, phaeinum, ornatum, rimosum* (all with bundled ribs), *P. comptoni, fluctuosus, Hecticoceras* spp. . . . *c.*	1	0

E. coronatum Zone

	ft.	in.
16 Shell-bed ('44 ft.'), pyritic, a mass of *Nucula*, variable, locally thin or absent . . . up to		6
15 Comptoni Bed: hard, light calcareous shale, full of *Nucula*, locally lenticles of limestone. Ammonites: *K. grossouvrei, castor*, aff. *gulielmi, pollux; P. comptoni, fluctuosus* very common; aptychi	1	0
14 Shales, light, very calcareous, occasional crushed pyritic ammonites, *K. grossouvrei, pollucinum*	5	0
13 Shell-bed ('38 ft.'), pyritic, not very prominent		1
12 Shales, brown, bituminous, papery	4	0
11 Shell-bed ('34 ft.'), pyritic, prominent, a mass of *Nucula*, ammonites: *K. grossouvrei, obductum posterior* . . . 2 in. to		6
10 Shaly clay, dark, with well-preserved belemnites, and *E. coronatum* crushed, pyritized and encrusted with pyrites into small concretions	14	0
9 Shell-bed ('20 ft.'), pyritic, variable . . . 0 to		2
8c Shales	3	0
b Layer of ellipsoidal septarian cementstone concretions, many formed attached to, and bearing the imprint of, a large *Erymnoceras*; also *K. obductum, castor, gulielmi* . . . 0 to		8
8a Clay	1	0
7 *Nucula*-Pyrites Bed ('16 ft.'), the main shell-bed in the lower part of the succession; a mass of *Nucula* as pyritic casts with valves closed. *K. obductum, gulielmi, castor; Hecticoceras lugeoni* Tsyt.; *E. coronatum*, some partly pyritized and well preserved		6
6c Shaly clay, dark grey, tough; good *K. obductum* 3½ ft. down; thin pyritic shell-bed 2½ ft. down in places	4	0

K. jason Zone and Subzone

	ft.	in.
6b Shaly clay as above: good *K. jason* and forms intermediate to *K. obductum* at the top; *K. jason* profuse 2 ft. below the top, with locally a thin pyritic shell-bed; and very common at the bottom. Also *K. gulielmi* . . . *c.*	10	0

			ft.	in.
	K. medea Subzone			
6a	Shaly clay as above, khaki; many *K. medea, gulielmi*		2	3
5	Shell-bed ('base'), down to which the pits are worked; a mass of pyritized fossils. *K. medea, gulielmi, Hecticoceras* sp., *Cadoceras*, perisphinctids, oysters, belemnites, fossil wood			3
	S. calloviense Zone, *S. enodatum* Subzone			
4	Clayey silts alternating with stiff clays; many fossils: *S. enodatum, K. gulielmi anterior, Gryphaea bilobata* auctt., belemnites, all very common, especially at the top		1	6
	KELLAWAYS BEDS			
	? *S. calloviense* Subzone			
3	Kellaways Rock. Light grey fine silts or soft sandstone, letting some water; barren. Seen in pits to 6 ft., in borings		15	0
	? *M. macrocephalus* Zone			
2	Kellaways Clay, black; in borings		3	6
	CORNBRASH			
1	Limestone, in borings (Upper Estuarine Series clays below)		7	3

The prominent features in the section are the calcareous beds near the middle, 14–17, the sudden change from dark bituminous shales below being marked by a line of vegetation on older faces where water seeps; and the various pyritic shell-beds which weather to rusty bands. The main ones have been labelled with their heights above the basal shell-bed, some being thus referred to when met in exploratory drilling in which they act as markers. To be noted is the fact that the impersistent limestone near the middle is here mainly at the top of the *K. grossouvrei* Subzone rather than in the Acutistriatum Band; i.e., stratigraphically slightly lower than the similar beds at Bletchley and Calvert. The cementstone concretions of bed 8 are also at a slightly different level.

Bletchley. There are at present two large pits in work, (a) that of the London Brick Company [*SP 8532*] to the southwest of the town, on the road to Newton Longville; and (b) one of Flettons Ltd. [*SP 8536*] on the northeast side of the Watling Street, miles northwest of Fenny Stratford. The following is a combined record of both sections.

		ft.	in.
Topsoil			
River gravel, sandy, well bedded	0 to	5	0
Chalky Boulder Clay	0 to	3	0
MIDDLE OXFORD CLAY			
Middle *P. athleta* Zone			
Clay, blue-grey, plastic; many *Gryphaea lituola, Hib. hastatus*, crinoid ossicles, occasional pyritic concretions formed round pieces of fossil wood. Pyritized well preserved ammonites: *K. rowlstonense, proniae, proniae-duncani* var. α Krenkel, *duncani; Pseudopeltoceras retrorsum* Spath; *P.* (*Peltoceras*) *athleta*, ibid. var. *spathi* Prieser, aff. *armiger* (Sowerby), *trifidum* (?Quenstedt) Prieser, *P.* (*Peltoceratoides*) cf. *athletoides* Lahusen, *P.* (*Rursiceras*) *baylei* (Prieser), *P.* (?*R.*) aff. *kontkiewiczi* (Siem.), (*Parawedekindia*) *oeschingenense* Prieser; *G.* (*Grossouvria*) *subtilis* (Neumayr); *Longaeviceras* sp. nov.	0 to	5	0

			ft.	in.
20	Limestone, argillaceous, impersistent	0 to	1	0
19	Clay, grey, occasional *G. lituola*	c.	15	0
	LOWER OXFORD CLAY			
	Lower *P. athleta* Zone			
18	Alternating clays and shales as follows			
18f	Clay, shaly, grey, with crushed white fossils			
e	Bed of bituminous dark brown pyritic paper shales, 6 in., 19 ft. above the base			
d	Shaly clay as above			
c	Brown bituminous paper shales, pyritic, 6 in., 15 ft. above the base			
b	Shaly clay, as above			
18a	Basal *Nucula*-breccia, 6 in. Crushed pyritized and encrusted ammonites from this bed but found loose include *K. phaeinum*, cf. *acutistriatum* and *ornatum*. Together,	c.	24	0
17	Acutistriatum Band. Hard calcareous shales, locally impersistent lenticular limestone which breaks along septarian jointing planes filled in the middle with black calcite, giving the impression when seen from the side of an inner dark band sandwiched between lighter layers. *K. phaeinum, gemmatum, acutistriatum, rimosum*, aff. *duncani*; occasional *P. comptoni, mosquensis, Hecticoceras* sp.; *Longaeviceras* sp. *Aptychus* (*Praestriaptychus*)		1	0
	E. coronatum Zone, *K. grossouvrei* Subzone			
16	Comptoni Bed. *Nucula*-breccia in hard shales, locally pyritic, the top part an ammonite plaster, and here and there consolidated into a fissile limestone welded to the underside of the bed above. A mass of fossils, including a profusion of ammonites, some very large: *K. grossouvrei*, typical, *gulielmi posterior, aculeatum, castor; P. comptoni* in profusion, with lappets, and its macroconch *P. fluctuosus; Hecticoceras lonsdali* (Pratt); *Erymnoceras argoviense* (Jeannet), *E.* (*Rollierites*) sp.; belemnites.	4 in. to		8
15	Clay			6
14	*Nucula*-bed, a mass of pyritized fossils in dark clay; belemnites			4
13e	Clay, brown			5
d	Clay, grey; a crocodilian jaw		1	0
c	Shales, dark brown, bituminous, many broken fossils			5
b	Clay, stiff, khaki: *K. grossouvrei, gulielmi posterior*		1	3
a	Locally a thin continuous band of pyrites, ½ in.			
12g	Alternating light and dark grey shales and clays		2	3
f	Layer of occasional pyritized and encrusted crushed ammonites: *E. coronatum*			
e	Shaly clay as above		2	3
d	Another layer of occasional pyritized ammonites: *K. grossouvrei*			
c	Shaly clay as above		1	3
b	Principal layer of crushed ammonites preserved and encrusted in pyrites to form pyritic concretions, commonly found loose in the pit. *E. coronatum* very common; *K. obductum posterior, castor, pollux; Cadoceras milaschevici* (Nikitin), *Longaeviceras* sp.; *Grossouvria leptoides* (Till). *Procerithium muricatum* in colonies			
a	Shaly clay as above		6	0

K. obductum Subzone

		ft.	in.
11	*Nucula*-Pyrites Bed, the most prominent shell-bed in the lower part of the succession, incorporating occasional cementstone concretions. A mass of pyritized *Nucula* with closed valves, *Procerithium*, *Astarte* and oysters. Ammonites mostly crushed and pyritized but yielding occasionally well-preserved specimens: *K. obductum*, *gulielmi; E. coronatum* and varieties common, *E. argoviense; C. (Pseudocadoceras) concinnum* and *laminatum* Buckmann; *Hecticoceras rosseinse* (Teiss.)		6
10	Clay, grey, with a few crushed pyritized ammonites. *K. obductum*, *E. coronatum*	8	0
9	Layer of ellipsoidal septarian cementstone concretions, best seen in tips. Few fossils, badly distorted; *K. obductum*		
8b	Clay, grey, as above. *K. obductum* c.	2	6

K. jason Zone and Subzone

		ft.	in.
8a	Clay, grey, as above. *K. jason*, *gulielmi*, at top and bottom c.	15	0
7	Shell-bed, pyritic, many oysters and belemnites		4

K. medea Subzone

		ft.	in.
6	Clay, dark: *K. medea*	1	6
5	Shell-bed, pyritic, with oysters and *Nucula*		1
4	Clay, shaly: *K. medea*, *gulielmi* common, *Pseudocadoceras* sp.; to working base of pits	5	0

S. calloviense Zone, *S. enodatum* Subzone

		ft.	in.
3b	Fine silt, with *Gryphaea* aff. *bilobata*, *Oxytoma* spp., *Rhynchonella*, and crushed ammonites: *S. enodatum* very common		8
3a	Stiff clay with partings of silt 1–2 in. thick and worm-tracks. *S. enodatum*, *K. gulielmi anterior*; *Choffatia (Homeoplanulites)* sp. common at top; oysters	1	6

KELLAWAYS BEDS

S. calloviense Subzone

		ft.	in.
2	Kellaways Rock. Silt or soft sandstone with calcareous nodules. *Sigaloceras calloviense*, *Chamoussetia lenticularis* (Phillips), *Proplanulites koenigi*, *P.* sp. (large); *Gryphaea bilobata*, *Ostrea alimena*, *Trigonia scarburgensis*, and belemnites seen c.	2	0

M. macrocephalus Zone, *M. kamptus* Subzone

		ft.	in.
1	Kellaways Clay. Black silty clay with buff phosphatic nodules: *Macrocephalites (Kamptokephalites)* cf. *herveyi*, *M. (Dolikephalites) typicus* Blake		

Beds 13 to 18 are best studied at the Fletton's pit, where the profusion and preservation of fossils in the Comptoni-Acutistriatum Beds approaches that of the famed Christian Malford beds. All the other beds are better seen in the London Brick Company's pit. The long exposed faces in this pit show that all the higher beds have been tectonically disturbed, the crumpling of the Acutistriatum Band being particularly prominent. These disturbances do not extend down to the base of the pit, however, and must therefore be of glacial origin, a legacy perhaps of permafrost conditions. As a consequence some of the estimated thicknesses given above are in some doubt. The junction between *K. jason* and *E. coronatum* Zones is not marked lithologically and remains to be fixed precisely.

This is one of the most rewarding pits palaeontologically, for both Kellaways Beds and *P. athleta* Zone have yielded unusually rich faunas. Its special feature is the abundance of *Erymnoceras* in the *E. coronatum* Zone, only partly crushed specimens being not uncommon. However, a note of warning is necessary: of the pyritic specimens obtained from this pit only those from beds 11 and 18 are stable, the others rapidly decomposing when exposed to air.

14/4 Calvert [SP 6723].

		ft.	in.
	Topsoil		
	Boulder-clay with Bunter pebbles, traces in places		

MIDDLE OXFORD CLAY

? Upper *P. athleta* Zone

		ft.	in.
13c	Clay, weathered yellow, plastic, much selenite, profuse *Gryphaea lituola*. Limonitic ammonites common at a level about 10 ft. up: *K. spinosum* and sp. aff., *tidmoorense*, *Hecticoceras (Brightia) glyptum* and sp., *Perisphinctes* nuclei. Also common is the small simple coral *Trochocyathus magnevillianus* (Michelin) seen to c.	20	0

Middle *P. athleta* Zone

		ft.	in.
13b	Clay, plastic, blue, with *Gryphaea*, mainly concentrated in a few beds. *Rh. socialis*, crinoid ossicles, gastropods, Pectens; *Hib. hastatus*. Uncrushed pyritized ammonites: *K. rowlstonense*, *proniae*, *proniae-duncani* var. α Krenkel, *duncani*, *bigoti* (Douvillé), *rimosum*, *transitionis* Krenkel non Nikitin, *tidmoorense*, cf. *spinosum*; *P. (Peltoceras) athleta* var. *bifidum* (Quen.), *trifidum* (?Quen.) Prieser, *P. (Peltoceratoides)* cf. *trapezoides* (Prieser), cf. *broilii* (Prieser), *P. (Rursiceras) pratti* Spath and spp., nuclei common, *P. (Parawedekindia) oeschingenense* (Prieser), and spp. indet.; *Grossouvria convoluta* (Quenstedt) s.l.; *Hecticoceras pseudopunctatum* (Lahusen), *auritulum* (Oppel); *Reineckeia* sp. nucleus c.	8	0
13a	Row of occasional septarian cementstone concretions.		

Lower *P. athleta* Zone

		ft.	in.
12	Clay, blue, plastic, very few fossils; occasional *Pachyteuthis*, very rare *Gryphaea*	9	0

LOWER OXFORD CLAY

		ft.	in.
11	Alternating shales and clays as follows:		
n	Shale, light grey, calcareous, hard, serving as working platform for the mechanical excavators at the top of the pit. Crushed white fossils: *K. rowlstonense*, cf. *proniae*	1	0
m	Shaly clay	2	6
l	Shale, hard, calcareous	1	0
k	Thin bed of black pyrites, continuous, ½ in.		
j	Clays, shaly, grey	9	6
i	Paper-shales, hard, calcareous	1	0
h	Shaly clay	3	9
g	Paper-shales, hard, calcareous	1	0
f	Clay	1	6
e	Paper-shales, hard, calcareous	1	0
d	Clay, shaly, as above	5	6
c	Thin shell-bed with layer of pyritic nodules: *K. hoplistes* (Buckman)		
b	Shaly clay, as above	2	9
11a	Basal *Nucula*-breccia, a mass of non-pyritic shells in shale		3

		ft.	*in.*
10	Acutistriatum Band. Hard compact highly calcareous shales, locally lenticles of limestone with dark calcite veins in the middle of jointing-planes as at Bletchley. *K. phaeinum, rimosum, ornatum; P. comptoni; Aptychus (Praestriaptychus)*	1	0
	E. coronatum Zone, *K. grossouvrei* Subzone		
9	Comptoni Bed. *Nucula*-breccia, a mass of shells, more or less pyritic, the top inch an ammonite plaster: *K. grossouvrei, castor*, etc.; *P. comptoni* (very common), *fluctuosus; Erymnoceras* sp. 5 in. to		9
8	Alternating brown, friable, bituminous and grey shales and clays as follows:		
i	Green-grey shaly clay	1	2
h	Shell-bed, pyritic		2
g	Shales	1	2
f	Shell-bed, pyritic		1
e	Alternating shales, etc.	6	0
d	Layer of pyritic concretions formed round crushed ammonites: *K. obductum posterior*		
c	Shales, etc.	2	0
b	Shell-bed, thin, with pyritic *Nucula*, and pyritized and encrusted crushed ammonites: *K. obductum posterior, E. coronatum*		1
8a	Shales, tough: *K. obductum posterior, pollux*	2	0
	K. obductum Subzone		
7	*Nucula*-Pyrites Bed, the main shell-bed in the lower part of the succession; a mass of pyritized fossils. Crushed ammonites, very large *E. coronatum, argoviense*, thick belemnites		6
6	Clay, shaly, tough, dark brown, bituminous, enclosing at the top a layer of ellipsoidal septarian cementstone concretions. Profuse crushed but well-preserved ammonites in the clay: *K. obductum*, rare *obductum posterior, castor, gulielmi*		6
5	*Nucula*-bed; a mass of more or less pyritized shells		3
4	Clay, shaly, tough, khaki, with crushed but well-preserved fossils. *K. obductum* common in at least the basal 4 ft. of the bed (from which came the type), with occasional pyritized and pyrites-encrusted specimens; *K. gulielmi*	11	0
	[illegible]*son* Zone and Subzone		
[illegible]	Shale, grey, with profuse *Nucula; K. jason* var. transitional to *obductum, Choffatia* sp.; *Meleagrinella, Procerithium*, oysters and belemnites *c.*	1	0
	[illegible]ing into		
	[illegible]y clays, grey *c.*	4	0
	[illegible], brownish, many *K. jason*, typical but a little smaller than usual *c.*	1	0
[illegible]	[illegible], tough, grey, shaly, with two rows of crushed pyritic ammonites [illegible] the top. *K. jason* typical, large, common throughout, but especially [illegible] basal foot of the bed, *K. gulielmi, Cadoceras compressum* (Nikitin), [illegible]*cadoceras concinnum; Dicroloma trifida* *c.*	12	0
[illegible]	[illegible]bed, pyritic ('base'), down to which the pits are worked. A plaster [illegible]itized, crushed but beautifully-preserved ammonites: *K. jason*, [illegible]; *Choffatia* cf. *patina* (Neumayr), *Ch. (Elatmites) submutata* [illegible] common, *Grossouvria* sp., *Cadoceras* sp.; *Nucula* spp., *Astarte* [illegible] *Trigonia scarburgensis*, belemnites and oysters		3
	[illegible] gritty shale		1
	[illegible] band of pyrites		½
		45	0

		ft.	*in.*
	K. medea Subzone		
1e	Clay, green. *K. medea, gulielmi*		2
d	Ammonite-plaster, incorporating a layer of occasional small ellipsoidal buff concretions, perhaps 3 in. thick and 12 in. across. *K. medea, gulielmi*		1
c	Clay, green, tough: many crushed but well-preserved *K. medea, gulielmi*		5
b	Shale, soft, flaky, dark brown, ammonites as above		3
1a	Clay, khaki, many oysters, belemnites, *K. medea, gulielmi*, seen in trench to at least 6 in.		
	(*S. calloviense* Zone, *S. enodatum* Subzone not seen)		
	Total thickness of *K. medea* and *S. enodatum* Subzones in borings	10	0
	S. calloviense Subzone		
	Kellaways Rock. Sand with *G. bilobata*, formerly exposed in drainage ditches.		

At the top, most of the pits reach up only into the lower part of bed 13 which is then wholly weathered, and all that remains of the fossils is *Gryphaea* and suggestive patches of limonite. Higher parts of the bed and the fauna recorded here are to be seen at only one place, a down-faulted area at the western extreme of a large pit now disused, one mile due west of Calvert station. The faulting is very localized and the exact succession through the higher beds not easy to pick out. The impression during collecting was that there were two distinct faunas of pyritized ammonites in bed 13b: a lower one with large *P. athleta, K. proniae* and allies, and many small nuclei of *Peltoceras* and *K.* cf. *spinosum* slightly higher up. Comparison of the latter with collections from Woodham show them to be similar but not quite the same. Higher still, the limonitic forms from bed 13c resemble very closely those from the lowest beds of Woodham, including now in both cases an appreciable proportion of Oppeliidae and Perisphinctidae, and there seems thus to be a small stratigraphical overlap between the Calvert and Woodham successions.

Of the marker-beds in the main faces, the Acutistriatum Band (10) and *Nucula*-Pyrites Bed (7) correlate readily with the similar beds at Bletchley, but the main layer of septarian concretions at Calvert (6), Bletchley (9) and Stewartby (8b) are, despite their similarity, all at different levels. Palaeontologically, the speciality at Calvert is the basal shell-bed of the *K. jason* Zone from which, with a little care, exquisite specimens may be obtained. The pyrites from this bed and beds 7 and 11 is stable, but that from others again liable to decompose. Another feature at Calvert is the occurrence of uncrushed body-chambers of a variety of *K. jason* named *Gulielmites effulgens* by Buckman. It differs from the typical forms of the species mainly in being almost wholly smooth and has been found *in situ* (J. Horrell coll.) only 3 ft. above the base of the *K. jason* Subzone. The holotype came from Kidlington, only 14 miles west-southwest, where it was found 43 ft. above the base of the *K. jason* Subzone (Callomon 1955). There seems therefore little doubt that the thickening of the *K. jason* Subzone, from 2 ft. 7 in. at Peterborough to 18 ft. at Calvert, continues westwards with increasing rapidity.

14/5 Woodham [*SP 7117*]. The pit is on the main road halfway between Bicester and Aylesbury. The section has been described in detail by Arkell (Arkell 1939; see also Arkell 1947; Rutten 1956; Callomon 1957; Palframan 1966). Subsequent collecting has expanded the faunal lists still further; some 100 ammonite species have now been recorded.

J.D. Hudson & D.E.B. Palframan, 1969. (Q) Jl geol. Soc.
— section renumbered;
— [illegible]

		ft.	in.
	Upper Oxford Clay		
	Q. mariae Zone, *C. scarburgense* Subzone		
A	Selenitic Mariae Clays. Brown weathered clays with selenite; uncrushed limonitic ammonites, mainly *Cardioceras scarburgense* (90% of the fauna). Additions to Arkell's list include another *Phylloceras demidoffi*, *Quenstedtoceras* (*Pavloviceras*) *pavlowi* Douvillé, *Goliathiceras* sp., large *Card.* cf. *harmonicum* Maire	19	
B	Blue Mariae Clays with many small pyritized ammonites, especially in the lower part. *Q. mariae*, *woodhamense* and *C. scarburgense* equally common; *Taramelliceras richei*, *Creniceras renggeri*, and many others. Also *Lytoceras polyanchomenum* Gemmellaro	10	
	Middle Oxford Clay		
	Q. lamberti Zone		
C	Lamberti Limestone. Mudstone or marly limestone, packed with fossils, mainly crushed ammonites. Commonest are Boreal *Quenstedtoceras*, ranging from small *Q.* s.s. *leachi* to the huge *Q.* (*Eboraciceras*) *grande* Arkell, round as a cannon-ball; but Tethyan Oppeliidae, Perisphinctidae and Aspidoceratidae make up 35% of the fauna. The commonest *Aspidoceras* is *A. ferrugineum* Jeannet, whose outer whorls are indistinguishable from those of *P. athleta*, and it is doubtful whether the fragments quoted as such by Arkell are correctly identified. Other additions include several more Reineckeiidae, Pachyceratidae, *Horioceras baugieri* and *Lytoceras adeloides* (Kud.)	1	
D(2)	Upper Spinosum Clays. Khaki clays, poorly fossiliferous besides *Quenstedtoceras henrici* (Douvillé), pyritized and quite common, the source of many found on tip-heaps. At the bottom a bed of *Gryphaea lituola*	3	
	Upper *P. athleta* Zone		
D(1)	Khaki clay as above, 2–3 layers of *Gryphaea*, a 6 in. mudstone band at the base. *K. spinosum*, *rowlstonense*, *Hibolites hastatus*	6½	
E	Lower Spinosum Clays. Khaki clay as above, occasional *Gryphaea*, uncrushed pyritic small *K. spinosum*, *tidmoorense*, *proniae*, *compressum*, *Peltoceras*; *Rh. socialis*. Formerly seen to 29 ft., now c.	15	

Additional species from beds D–E include *Pachyceras* cf. *crassum* Douvillé, *Longaeviceras* sp., and *Pseudocadoceras boreale* Buckman.

The specimens of *Lytoceras* from beds B and C are the first to be recorded in this country between the Inferior Oolite and the Cretaceous.

Warboys [*TL 3182*]. The section and fauna were described by Spath (1939) and the zonal terminology revised by Arkell (1941). Spath's numbering is retained here, with some modifications at the top where the beds are now more extensively exposed than formerly.

		ft.	in.
	Ampthill Clay		
	? *G transversarium* Zone		
12	Clay, black, pyritic or selenitic, weathered, profuse huge *Gryphaea dilatata* encrusted with serpulae . . . seen to	5	0
11	Limestone, argillaceous, well bedded, barren . . . 2 ft. to	3	0
10	Mudstone, silty, or soft limestone, variable, a mass of *Gryphaea* and other lamellibranchs in lowest 6–12 in. Large *Perisphinctes* (? *Arisphinctes*) seen in bits . . . c.	1	0

		ft.	in.
9	Clay, bluish-black, highly pyritic, becoming selenitic on weathering. Small crushed white ammonites: *Amoeboceras* (*Amoeboceras*) cf. *alternans* and spp., closely resembling forms from the Birmenstorfer Beds of Switzerland, *Cardioceras* spp., *Gryphaea dilatata*, Pectens, *Astarte* sp., *Pleuromya* sp., *Homomya* sp., *Pinna* sp., and belemnites		6

Non-sequence

[The whole of the *P. plicatilis* Zone, and the upper two subzones of the *C. cordatum* Zone missing.]

		ft.	in.
	Upper Oxford Clay		
	C. cordatum Zone, *C. bukowskii* Subzone		
8b	Clay, light greenish-grey. Angular pieces of this clay project into the overlying Ampthill Clay and vice-versa, and wholly detached pieces form a kind of clay breccia, although the boundary between the two kinds of clay is everywhere line-sharp. *Peltoceras* sp., a pyritic nucleus, *in situ* in a detached piece of Oxford Clay entirely surrounded by Ampthill Clay		
H	Row of infrequent flat calcareous concretions		—
8a	Clay, blue-grey, calcareous, with pyritized ammonites: *Cardioceras bukowskii* Maire (= *martini* var. *anglica* Spath), *C. svelta* Maire (= *suessiforme* Spath), *Goliathiceras* sp., *Creniceras crenatum* (upper part), *C. renggeri* (lower part), *Ochetoceras henrici* (d'Orb.), *Peltoceras* cf. *arduennense* common in the upper part	22	6
G	Limestone, argillaceous		6
7	Clay, as above	6	0
F	Calcareous band or impersistent marly limestone		6
	Quenstedtoceras mariae Zone, *C. praecordatum* Subzone		
6	Clay, as above: *C. praecordatum* and varieties transitional to *C. bukowskii*, *C. alphacordatum* Spath, rare *Q.* cf. *mariae*	4	3
E	Calcareous band or impersistent marly limestone		6
5	Clay, as above, ammonites as in bed 6; also *Peltoceras* aff. *eugenii* (d'Orbigny), *Scaphitodites scaphitoides* (Coquand); belemnites	4	3
D	Marly limestone		6
4	Clay, as above: *C. praecordatum* very common, *C. alphacordatum*, *Q. mariae*, *Q.* (*Pavloviceras*) *stibarum* Buckman . . . c.	12	0
C	Marly limestone		6
	C. scarburgense Subzone		
3	Clay, as above: *C. scarburgense* and varieties transitional to *C. praecordatum*, *Q. mariae*	11	6
B	Marly limestone		4
2	Clay	1	0
A	Marly limestone		6
1	Clay, as above: *C. scarburgense*, *Q. mariae*, belemnites; formerly seen to	15	0
	Other ammonites found loose include *Perisphinctes* (*Properisphinctes*) *bernensis* de Loriol, *Aspidoceras* sp., *Q.* (*Pavloviceras*) *pavlowi* Douvillé, *Hecticoceras* spp., and *Grossouvria miranda* de Loriol		

There has been much discussion as to the age of the limestone beds at the top. Arkell always maintained them to be Corallian of the *P. plicatilis* Zone, but rather more Perisphinctids now available show them to be distinct from those of the *P. plicatilis*

Zone (Callomon 1960, p. 192). The Cardioceratids in the bed immediately underneath (bed 9) still resemble, as far as can be seen, the highly keeled, compressed forms like *C. bukowskii*, and on the strength of this the present author previously inclined to the opinion that this and overlying beds were still in the *C. cordatum* Zone. However, the forms of bed 9 could equally well be small *Amoeboceras*, and the Perisphinctids of bed 10 accord closest with Upper Oxfordian types of the subgenus *Pseudarisphinctes*. A specimen of *Amoeboceras* (*Prionodoceras*) has also been found in the pit (Spath 1939, p. 83). The interpretation here adopted agrees also with the Geological Survey, which has mapped the top of Warboys Hill as Ampthill Clay.

Thanks are due to the London Brick Company for providing data from some of their exploratory boreholes.