Notes on the Callovian and Oxfordian Stages

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A. INTRODUCTION

In view of the considerable divergences in viewpoint which exist among different authorities as to what the basis of stratigraphical classification should be, it is perhaps as well to start with a few notes on the principles which have, wherever possible, been adopted in constructing the stratigraphical tables that follow.

(a) Stratigraphical units

(1) Within the Mesozoic, the Systems (Trias, Jurassic, Cretaceous), Stages, Substages, Zones and Subzones are regarded as successive subdivisions of similar types but different ranks, such that a unit of higher rank encompasses several of next lower rank, etc.

(2) The basis of the units is palaeontological, i.e. divorced from details of lithology.

(3) Units of different rank may differ in the geographical extent of their applicability.

(b) Definition of units

The number of stratigraphical subdivisions that can now be recognized is so large that the problem of their terminology has become acute, and a need has long been felt to regulate the terminology through some set of rules analogous to those of zoological nomenclature. Such

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a set (a minimum) has been proposed by Arkell (1946), and will be followed here where possible, amplified where necessary by the following considerations.

From point (a)-(1) above, it follows that there can be two definitions of any one unit: (i) typological, i.e. as defined by a particular section at a type locality; and (ii) hierarchical, i.e. any particular unit is defined in terms of those of next lower rank which it encompasses. Both definitions can lead to difficulties in themselves; for on the one hand no particular section (and hence unit based upon it) is likely to be complete lithologically or ideal palaeontologically; and on the other hand to define e.g. a stage in terms of the zones contained in it merely shifts the problem elsewhere. However, if definitions of both kinds are found for any particular unit and modified to be mutually consistent, most difficulties can be overcome.

(c) Stages

The division of the Jurassic into stages by d'Orbigny has been exhaustively discussed and is now so generally accepted that little need be added here. One point remains, however. If the stages are to be the most general units for world-wide correlations, they are the units least likely to be sufficiently defined by any particular section at any one place. Perhaps d'Orbigny realized this, for in his first systematic table of stages (1850), which, following Arkell, should be taken as the starting-point of any modern classification, he specified his units not in terms of single localities and beds, but gave lists of several in each case: he was making use in part of the hierarchical principle and defining the whole in terms of the sum of the parts (which were themselves chosen on palaeontological grounds). This generality should be largely retained, for attempts now to select one of his localities as single type-locality would often create more problems than it would solve. A stage should therefore be defined in terms of its constituent zones in a type area, not single locality: and this area should be left quite large.

(d) Sub-stages

As Arkell pointed out (1946), these may be useful locally, provided they are clearly defined. Another requirement is however that they do not traverse the boundaries of the stage of which they are part: i.e. a substage should not be part of more than one stage. This immediately excludes many of the vast number of stage-names proposed in the past (listed, up to 1933, by Arkell (1933)), even if amended within plausible limits.

(e) Zones

For the present purpose, the zonal concept followed here is that of Oppel and Arkell. The minimum requirements are (1) a faunal ammonite assemblage (not single species), (2) one member of which is selected as index — preferably, but not necessarily, a species most typical of and largely restricted to its nominal zone — whose (3) title as index does not (although its actual name does) change if its zoological name falls in synonymy or otherwise changes for systematic reasons.

Faunal assemblages at zonal level are very sensitive to ecological factors (facies, faunal realms and provinces), and a faunal assemblage defining a zone has therefore itself to be defined, at least in outline, by a type locality, which should now be quite closely specified. This having been done a zone and its name are then to a considerable extent immune to uncertainties in the systematic standing of the index species. Thus, for example, Salfield defined the Cymodoce Zone of the Lower Kimmeridgian by a definite faunal assemblage at a particular locality. He chose as index *Am. cymodoce* d'Orbigny, a species based on an illustration which is unrecognizable and whose type material seems to be lost. Controversy has raged over interpretation of the species: the definition of the zone is however in no doubt. To emphasize this difference in use of a name,
it is strongly urged that a specific name used as zonal index should be differently written, e. g. with capital initial in normal type — thus, "Cymodoce Zone, index Am. cymodoce d'Orbigny". It also reflects the point that the type-locality of the zone and of the index species are independently defined, and need not coincide.

(f) Subzones

Local sections usually reveal alternations of faunal assemblages which allow subdivision into much finer units than the standard zones. Comparison with other sections further afield is required to establish which of such finer subdivisions have purely local significance, or which reflect more widespread distributions which could usefully be generalized and incorporated into a standard zonal scheme. The temptation is to be resisted to extend the number of full ammonite zones unduly, and a most useful function is fulfilled by subzones. Sub-zonal differentiation is based usually on the occurrence of one or two species, and the dividing-line between full and subzonal rank can be guided by the following rough rules: (1) A stratigraphic unit should have full zonal rank only if the geographic distribution of the main elements of the defining faunal assemblage approaches that of the faunal realm or province (if any) of that fauna as a whole; and (2) a lesser unit defined by only one or two species should not exceed subzonal rank if its defining elements can be recognized over only a small part of a faunal realm.

(g) Infra-subzonal units: horizons

At the lower end of divisibility, a stratigraphical unit should meet certain minimum requirements to qualify even as a subzone. It should be recognizable over the whole of some other natural geographical unit, e. g. a whole basin of deposition, or lithofacies province. As a rough guide this seems to indicate distances of the order of 300 km.

Sometimes even lesser units than subzones are worth recording in a standard table, for if limitation of known extent is due to lack of knowledge or exposures, such units are candidates on probation for subzonal status. A suitable term for such units is horizon. Some examples are given below.

The ultimate resolvable and observable stratigraphic unit on the ammonite scale is the thinnest bed or packet of strata in a single section which can be identified by a single species. To this Trueman applied the term epibole.

B. THE CALLOVIAN STAGE

(a) Original definition

There has been some confusion in the past as to how the stage should be interpreted, for d'Orbigny did not specify a particular type locality; and the examples he quoted of lithological units said to belong to the stage are, perhaps not surprisingly in the light of modern knowledge, not wholly mutually consistent.

d'Orbigny's original definition (1850, p. 608) provides three guides to a modern interpretation:

(1) The name of the stage. This follows Sowerby's latinisation of the Kellaways estate in Wiltshire, 3 km N.E. of Chippenham, whence William Smith's "Kelloway's Stone" (1815), a notable source of fossils, yielded Ammonites calloviensis Sowerby, 1815. d'Orbigny wrote: "Je fais dériver ce nom de Kelloway (Calloviensis) qui, en Angleterre, a été le premier point ou l'Étage ait été bien défini."
(2) The list of lithological representatives. This includes only one English example: «C'est le Kelloway-rock, Phillips; ...». The rest are various other examples from France, Switzerland and Germany which add little to the picture; but notable is the inclusion of d'argile de Dieu des géologues Normands».

(3) The list of ammonite species typical of the stage. This calls for few comments, except that it does include Amm. Herveyi, macrocephalus, Lamberti, and Sutherlandiae. The only name in it now thought to be seriously out of place is Amm. Mariæ, but the exact level of this species was almost certainly not known at the time.

(b) Modern definition

Type area. Past interpretations have differed because of varying emphasis placed on one rather than another of d'Orbigny's criteria given above. Thus, Arkell in 1933 was guided more by the name of the stage and concluded that the type-section should be the Kellaways Beds of Wiltshire. In 1946, when considering the problem of interpreting d'Orbigny's stages more generally, he came to place more emphasis on the lists of typical members; and as the only English one given by d'Orbigny was the «Kelloway-rock, Phillips», he took as type-section the Yorkshire coast, to which Phillips' description referred. Arkell's later interpretation is, I think, preferable, but I do not think either interpretation need be narrowly stressed for in the light of modern knowledge it is clear that d'Orbigny's most comprehensive picture of the stage in fact coincides quite closely with a part of the succession which forms, in terms of ammonite faunas, a natural unit at least in the classical areas of Europe, bounded at top and bottom by quite sharp and widely recognizable faunal breaks. The Callovian succession in England seems to be the best-developed and most complete anywhere, and is at present certainly the best exposed and best known in the world; and I think it suffices therefore, for all practical purposes to take as type-area of the Callovian stage the whole of England, and to define the stage in this area in terms of its zones (see below).

The Bathonian-Callovian boundary in England

The Bathonian rocks of England are typically oolites, or clays of somewhat peculiar facies (Fullers Earth, or deltaic deposits). The Callovian stands in contrast mainly as a great mass of Oxford Clay, with subsidiary sandstones, all of fully and typically marine facies. Attempts to fix the Bathonian-Callovian boundary have usually been focused on the transition-bed, the Cornbrash.

The Cornbrash has at first glance the appearance of a variable but remarkably persistent deposit, from Dorset to Yorkshire, with thicknesses of between 0 and 10 metres. The Cornbrash of Yorkshire, described by Phillips, was included in the Bathonian by d'Orbigny, and hence the record of Amm. Herveyi in his list of Bathonian ammonite species. Oppel, however, took Macr perplexus (including Amm. Herveyi) as diagnostic of the Callovian, and hence placed the Cornbrash of Wiltshire in the Bathonian on the grounds that, where he saw it, it did not yield Macrocephalitids, only Clydoniceras. Later, Macrocephalites came to be found in Cornbrash outside Yorkshire, and it was assumed that Clydoniceras and Macrocephalites coexisted. This was presumably the basis of Spath's view in which the whole of the Cornbrash was always placed in the Bathonian.

As a result of careful and systematic study, however, Douglas and Arkell (1928, —32, —33) showed that the Cornbrash consisted of two parts (already distinguished by William Smith), a Lower and an Upper, which differed but slightly in lithologies, but contained considerably different faunas. The ammonites fall in three groups: (i) Clydoniceras, confined to Lower Cornbrash; (ii) Macrocephalites, found only in Upper Cornbrash, and (iii) various Perispheinctidæ

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(Choffatia) common throughout. Clydoniceras and Macrocephalites are mutually exclusive and occur in succession. Although this has been rigorously established so far only in England, it has, as far as I know, not been contradicted by finds anywhere else, and the appearance of Macrocephalites therefore serves ideally to define the Bathonian-Callovian boundary. Even if Macrocephalites comes to be found in beds which are older than Callovian as defined in England, pre-Callovian age could only be invoked if the same beds definitely contained Clydoniceras. Thus, the age of a particular bed is in doubt only if it contains both Clydoniceras and Macrocephalites. This criterion disposes of certain references in the literature to pre-Callovian records of Macrocephalites (leaving out of account misidentifications due to confusion with Morrisiceras). Spath (1952, p. 141, 145) refers to Macrocephalites from the Lower Bathonian of southern Poland, and grasps this record to allow him to evolve certain Arctic genera (Cranocephalites) from this exclusively Tethyan group and to date a whole boreal faunal succession as Callovian or at earliest post-late Bathonian. He seems to have based his view on a description of the Polish Middle Jurassic by Rehbinder, for he states (1932, p. 16) «...the true Macrocephalites, the first members of which Rehbinder has found to occur... well below the Cornbrash». His reference is to Rehbinder's first memoir (1912), in Russian with French summary. The same work was republished in German (1914): I have carefully read this version, and find in it nothing to support Spath's views, or to refute the criteria set out above.

Most of the English Cornbrash is therefore Bathonian, all of it so at the localities visited by Oppel (the Upper Cornbrash is often wholly absent). The Yorkshire development is, however, wholly Upper Cornbrash, and if we exclude this item from d'Orbigny's list of Bathonian beds, we see that the modern junction drawn at the Clydoniceras-Macrocephalites break coincides quite closely with d'Orbigny's and Oppel's views.

The junction between the Bathonian and Callovian stages marks therefore not only a change from the widespread regressive facies of the Bathonian to a fully marine regime in the transgressive Callovian, but also an abrupt redistribution in habitat of two major Tethyan families of ammonites. These considerable changes are now known to have been accompanied by another major faunal migration: the Bathonian-Callovian boundary marks the onset of the so-called Boreal Spread (Arkell 1956, p. 610). Two Boreal families, the Cardioceratidae and Kosmoceratidae, which had been evolving in circum-arctic oceans during the Bathonian and which later in the Callovian become the predominant forms of north-central Europe, first make their appearance there in the Cornbrash. Only a single Cadoceras is so far known (C. breve Blake), and that from unspecified Cornbrash of Dorset; but some dozen or so Kepplerites have now turned up in Cornbrash between Oxford and the Dorset coast. All the specimens (about 6) whose exact horizons could be established were from the Upper Cornbrash, and none of the others came from localities at which Upper Cornbrash is absent. The forms represented are at least conspecific with Amm. keppleri Oppel and Amm. macrocephalus evolutus Quenstedt, which are fairly common in the «Macrocephalenooolit» of Württemberg; and with forms which occur in the Tyhonis Zone of East Greenland. These discoveries have served to establish the base of the Callovian from the Arctic to the Alps as one of the most important geological timeplanes (see Callomon, 1959).

The Callovian-Oxfordian boundary

This question has been discussed in detail by Arkell (1939). The boundary is to-day drawn between the Lamberti and Mariev Zones. Briefly, the reasons for this are:

(1) Of the two English successions attributed to the Callovian by d'Orbigny, only the one in Yorkshire, described by Philips (1829), is any guide to the limits of the Stage. The Yorkshire «Kelloway Rock» terminates sharply at the top of the Lamberti Zone, and is immediately succeeded by shales — «Oxford Clay» — of the Mariev Zone.
(2) d’Orbigny’s examples from outside England specifically include the «argiles de Divès», which commence and are most fossiliferous in the Lambertii Zone.

(3) His fossil lists include Am. Lambertii and Sutherlandiæ as typical of the stage.

(4) Palaeontologically, the Lamberti-Mariae junction sees a break in the ammonite succession as great as that at the base of the Callovian, for it marks the extinction of two major families: the Kosmoceratidæ (Boreal), and Morphoceratidæ (Reineckeia, Tethyan). The only alternative boundary that has been seriously proposed — between the Athleta and Lambertii Zones — marks only a minor break, reflecting mainly the migration of the Cardioceratidæ from Russia westwards, and is quite unrecognizable either in the true Boreal areas (in which the succession of Cardioceratidæ is continuous) or those entirely extra-Boreal, e.g. Tethyan, in which the Lambertii Zone cannot be recognized (although the Athleta Zone can).

(5) The only serious argument that has been raised against this boundary is that it falls in most of England in the middle of the Oxford Clay and this, because of its name, ought to be regarded as Oxfordian. However, this subordinates palaeontological arguments to lithological ones, which it is the whole purpose of d’Orbigny’s classification to avoid.

Résumé

The type-area of the Callovian stage for practical purposes is England, the type-locality in theory probably being the «Kelloways Rock» of Yorkshire. The Stage is defined in terms of its zones, ranging from the Macrocephalus to Lambertii Zone inclusive.

C. THE ZONES OF THE CALLOVIAN STAGE IN ENGLAND

These were reviewed on a previous occasion (Callomon, 1955) and what follows serves only to bring the subject up to date.

LOWER CALLOVIAN

(a) Macrocephalus Zone

Author: Oppel, 1857.

Index: Macrocephalites (Macrocephalites) macrocephalus Schlothümel. Supporting fauna: Macrocephalites spp., Choffatia spp., Kepplerites (Kepplerites) spp., (rare), and (in Europe) various «bullati» —oduleceras and Bomberites.

Type locality: Chippenham-Trowbridge, Wiltshire, England.

Remarks: Oppel, in founding this zone, had the Macrocephalites-bearing beds of Germany and France mainly in mind. However, in his account the only description of and reference to detailed sections relate to Wiltshire, the equivalence of all beds between the Lower Cornbrash and Oxford Clay (some of which did yield profuse Macrocephalites) to the German «Macrocephalocnoolites» being inferred correctly. As mentioned above, he did not see the fossiliferous Upper Cornbrash at the localities he visited, and this was later included in the Macrocephalus Zone by Wright (1870) and Woodward (1894-95).

The original Macrocephalus Zone was already subdivided by Oppel himself, who separated out the Calloviense Zone (see below). This is now a full zone, so Oppel’s zone in a restricted sense is what remains. Two subzones are recognized.

(i) Macrocephalus Subzone

Author: Callomon, 1955.

Index: as for the whole zone.
Characteristic fauna: Large, compressed, smooth or finely-ribbed involute macroconch Macrocephalitids, including macrocephalus; smaller fine-ribbed microconch forms of subgenus Dolikephalites, Kepplerites s.s. (macroconch) and subgenus Toricelliceras (microconch). Choffalia spp.

Type locality: Sutton Bingham, near Yeovil, Somerset, here designated. Section described by Arkell, 1954, beds 4-10.

Remarks: Douglas and Arkell recognized two brachiopod subzones in the Upper Cornbrash: the Siddingtonensis and Lagenalis Subzones. The Macrocephalus Subzone includes all of the former, and perhaps part of the latter, which is only locally represented as Cornbrash, and which, even if present elsewhere as clay, would then be unrecognizable owing to the absence of brachiopods.

(ii) Kamptus Subzone
Author: Callomon, 1953.
Index: Macrocephalites (Kamptokephalites) kamptus Buckman.
Characteristic fauna: Forms of Macrocephalites like those of the Macrocephalus Subzone persist, but are joined by inflated coarsely-ribbed forms of the subgenus Kamptokephalites such as M. (K.) kamptus Buckman, granatus (Oppel), pila (Nikitin).
Type locality: Kidlington, Oxford; the Kellaways Clay there, Callomon 1955, p. 219, beds 3, 4.

Remarks: The subzone is variable in facies. It occurs as the Cornbrash of Yorkshire and Kent, and in part as Cornbrash around Peterborough and probably at various localities in Wiltshire and Dorset. Elsewhere, e.g. at Yeovil, Frome, Kidlington and Bletchley it is a characteristic black clay. The Cornbrash of Yorkshire was the only example quoted in a table by Spath (1932, p. 145) in which he defined a Herveyi Zone as including everything between the Discus and Koenigi Zones; the Herveyi Zone is therefore synonymous with the Macrocephalus Zone.

(b) Calloviense Zone

Author: Oppel, 1857.
Index: Sigaloceras calloviense (Sowerby).

Characteristic fauna: The zone marks the sudden appearance in great strength of the Boreal families Kosmoceratidae: Kepplerites (Gowericeras, Toricelliceras), Sigaloceras (s.s., Gulfimina) and Cardioceratidae: Cadoceras (s.s., Pseudocadoceras), and the last colinear descendent of Arctioceras, Chamousetia. The Tethyan forms persist: evolute, strongly-ribbed globose Macrocephalitidis appear (subgenera Indocephalites, Pleurocephalites), as does a new Perispindoceratid: Proplanulites. Reineckeia becomes common (although isolated examples are known from the Macrocephalus Zone).

Type locality: Chippenham, Wiltshire: the Kellaways Beds.

Remarks: Oppel first used the zone to include only the Kellaways Rock of Wiltshire. Its fauna is, however, so similar to that of the there immediately underlying Kellaways Clay, that Woodward (1895) expanded the zone to include it. The lithologies of the beds are very variable, and three successive faunas can be distinguished, which are bases for three subzones.

(i) Koenigi Subzone
Author: Buckman, 1913 (as full zone); Spath, 1933, pp. 857, 872 (as subzone).
Index: Proplanulites koenigi (Sowerby).
Characteristic fauna: as for the Callovian Zone as a whole; but in England including *Macrocephalites*, and no *Sigaloceras*. The oysters are also useful: *Ostrea (Catinula) alimena* auctt. occurs with *Gryphæa*.

Type locality of original zone: Yorkshire, the Kellaways Rock of the coast section, i.e. PHILIPPS' «Kelloway Rock» minus SMITH’s Hackness Rock.

Type locality of restricted subzone: Chippenham, Wiltshire: the Kellaways Clay there.

Remarks: The fauna of the Yorkshire Kellaways Rock differs from that of Wiltshire principally in the absence from the former of *Macrocephalites* and *Sigaloceras*. BUCKMAN supposed this to indicate differences in age, but it is now thought to be due merely to ecological factors. But for these two differences, or pending others revealed by systematic monographing of the whole faunas, they seem identical, and BUCKMAN’s *Koenigi* Zone is thus synonymous with the *Callovian* Zone as enlarged by WOODWARD. However, the use of *koenigi* as a zonal index has become so familiar in the literature, especially in describing the Kellaways Beds of Wiltshire rather than those of Yorkshire, that it seems useful to retain it to indicate one of the two successive faunas that can be distinguished there, namely that of the Kellaways Clay.

Most of the fossils from the Kellaways Clay of Chippenham, which are now to be found in almost every museum in the world, came from a long, deep railway-cutting through Cocklebury Hill, just north of the town. No section was ever recorded at the time it was excavated, but during recent work of resloping the sides, the following section could be recorded:

Section in Kellaways Beds, Chippenham, Wiltshire.

3. Topsoil, etc.

2. Kellaways Rock: yellow or grey fine sand, locally consolidated into lenticles of grey sandstone with pockets of fossils: *Cacoceras* cf. *sublæve* (Sow.), *Kepp.* (*Gowericeras*) sp.; *Gryphæa bilobata* auctt., *Ostrea (Catinula) alimena* auctt.; many lamellibranchs, brachiopods etc. ...seen ca. 3,00 m. passing through ca. 1 m of transition beds into:

1. Kellaways Clay: light blue soapy clay, with occasional small mudstone concretions, down to rail-level. Fossils crushed flat, or preserved as characteristic mudstone casts: *O. (C.) alimena*, *Trigonia scarburgensis* Lycett, etc. ...seen ca. 10,00 m. There is no sign of the black clays of the *Kamplus* Subzone, and the Cornbrash is not reached.

(ii) Callovien Subzone

Author: OPPEL, 1857.

Index: *Sigaloceras callovien* (Sow.).

Characteristic fauna: as of the *Koenigi* Subzone, but now including *S. callovien* (macroconch) and *S. (Guillemina) quinqueplicata* BUCKMAN (microconch).

Type locality: Kellaways, Chippenham, Wiltshire. Good sections in the banks of the River Avon are still visible.

Remarks: In the absence of *Sigaloceras* s.s. the subzone is not recognizable. *S. callovien* is very common in Wiltshire, but otherwise its distribution seems to be very limited. Northwards, it has been found as far as Peterborough (author’s collection); southwards, it is known from Dorset, Normandy, and the Boulonnais (DOVILLÉ, 1915).

(iii) Enodatum Subzone

= *Planicerclus* Subzone, CALLOMON, 1955.

Author: BRINKMANN, 1929; CALLOMON, 1955, emend. here.
Index: Sigaloceras (Castasigaloceras) enodatum (NIKITIN).

Characteristic fauna: Catasigaloceras (macroconch) and Gulielmiceras (microconch); Cadoceras s.s. and Pseudocadoceras; Choffatia, Proplanulites and K. (Gowericeras) very rare. Gryphaea bilobata autct.

Type locality: South Cave, Yorkshire.

Remarks: The first to refer to an Enodatum Zone seems to have been BRINKMANN, 1929, in a table correlating previous classifications of the Oxford Clay with ranges of various species of Kosmoceras as he had determined them at Peterborough. It is clear, however, that he was using the words «zone» and «subzone» in the sense of «ranges of individual species», i.e. biozones, for some beds he ascribes to as many as five zones simultaneously. Besides this, he makes no further attempt to define the zone specifically in terms of any of the extremely carefully measured sections which he described.

In founding the Planicercus Subzone in 1955, I was trying to generalize the result of some stratigraphical correlations between Yorkshire and Europe which included neither Peterborough nor Kidlington, nor Russia, the type area of enodatum. There seemed sufficient points of difference between planicercus and NIKITIN's figure of enodatum to make it advisable to retain the English name; and I could form no estimate from his account whether the forms which BRINKMANN recorded from Peterborough as enodatum were conspecific with either planicercus or NIKITIN's enodatum, for his subsequent monograph (1929b) of the whole genus Kosmoceras shows that he used specific names in a widely comprehensive sense.

Two developments have occurred since. Firstly, through the courtesy of the Geological Institute of Leningrad, and M. Jean ROGER (Paris), I have received a plaster-cast and photographs of the holotype of Cosmoceras enodatum NIKITIN 1881. These show that NIKITIN's figure was not unsuccessful, but enlarged to 1.27 times the original (true diameter 48 mm), and that it carries the complete body-chamber of just over half a whorl as NIKITIN stated, but contrary to the impression given by his front-view figure which suggested that it was wholly septate. These uncertainties removed, there is no question but that planicercus (including curvicercus and crispatum BUCKMAN) and enodatum NIKITIN are conspecific.

Secondly, re-examination of the section at Peterborough shows that the true enodatum does occur there, at levels 0-20 cm in BRINKMANN's section. It is immediately followed after a sharp break by K. medea (see below), levels 21-50 cm. It has now also been found at similar horizons in brick-pits near Bedford and Bletchley (Buckinghamshire), and examination of material collected at Kidlington too late to be included in the account of the sections there (CALLOMON, 1955) shows that it is present there also (bed 7). At its type-locality the Planicercus Subzone, now recte Enodatum Subzone, occurs as typical Kellaways Rock, but elsewhere it turns into typical Oxford Clay.

Further south, e.g. in Aargau, the Boreal Kosmoceratidae are replaced by Tethyan forms. The section at Herznach has shown that the Enodatum Subzone (bed A3, JEANNET 1951) contains profuse Reineckeia so that it might be tempting to include the beds already in the Anceps Zone of the Tethyan realm. However, the same bed also still contains abundant Macrocephalites; and if the Anceps Zone is defined to begin not with the appearance of Reineckeia, but rather the disappearance of Macrocephalites, it would have the merit of making the Tethyan Callovienne-Anceps and Boreal Callovienne-Jason boundaries coincide.

The Enodatum Subzone has an unusually wide distribution. Besides England (Yorkshire to Oxford, and a boring south of London), it has been recognized in France (Deux-Sèvres, Haute Marne), Germany (Wesergebirge, «Goldschneckenfauna» of Franconia), Switzerland (Herznach, Solothurn), Russia (Elatma, Donetz) and Trans-Caspia (Mangyshlak). This area comprises distances up to 3700 km, in contrast to the Callovienne Subzone below, which is recognizable over at most 500 km.
All three subzones are thick and easily recognizable, in clay facies, in the tile-works and potteries at Bréville and Argence, E. of Caen in Normandy (April, 1962). S. calloviense and enodatum are common but crushed.

**MIDDLE CALLOVIAN**

The Middle Callovian in most of England falls wholly in the Oxford Clay, and was until recently the least understood part of the stage and formation. The only detailed section of all of it so far recorded was by Brinkmann at Peterborough (1929), but a single section at only one locality is insufficient to serve as basis for a standard zonal table. I have since had the opportunity of examining similar sections elsewhere, and in particular those at Bletchley, 75 km to the S.W.; and while details remain to be filled in, it is clear that the Peterborough succession is remarkably reproducible over considerable distances. Conversely, we may take the Peterborough succession as a reliable secondary standard, and the appropriate levels as recorded by Brinkmann will be quoted below. The history of the zones and their names was reviewed by Arkell (1939).

(c) _Jason Zone_

- Anceps Zone, Oppel, pars 1857
- Conlaxatum Zone, Neaverson, 1925.

**Author:** d’Orbigny, 1852.

**Index:** Kosmoceras (Gutielmites) jason (Reinecke).

**Characteristic fauna:** Kosmoceras with smooth body-chambers (Gutielmites) as well as lappeted forms (Gutielmiceras); occasional Cadoceras, Pseudocadoceras; Hecticoceras, Pseudoperiprionellophorites; Reineckeia s.s.


**Remarks:** d’Orbigny (1852, p. 509) prefaced his description of the «12e étage: CALLOVIEN, d’Orb.» by the sentence: «Zone des ammonites: Lunula, Athleta, Coronatum, Jason; ...». There are no further details of what he had in mind as constituting a «zone» but these indices were listed in the correct stratigraphical order (except the first, probably due to misidentification) and subsequently adopted as separate zonal indices. It seems appropriate therefore to follow Arkell in attributing priority to d’Orbigny in the use of these names.

Oppel (1857) preferred to found a more comprehensive Anceps Zone for beds together equivalent to what is now called _Jason_ and _Coronatum_ Zones, for the descriptions in the literature dealt mostly with the condensed, incomplete successions which predominate on the Continent, and did not allow him to subdivide the zone further. He stresses (p. 557-8) the importance of both _jason_ and _coronatum_ as indices of the Anceps Zone. Wright (1870? or 1872), in an important paper, defined a _Jason_ Zone on the Wiltshire Oxford Clay, but it is now clear that his and Oppel’s zones are, by a coincidence, exactly synonymous. A more restricted _Jason_ Zone was quoted by Neumayr (1871) for S.W. Germany, and has been used there ever since (e.g. Reuter, 1908).

(i) _Medea Subzone_

**Author:** Callomon, 1955.

**Index:** Kosmoceras (Gutielmites) medea Callomon.

**Characteristic fauna:** small, smooth Kosmoceras not exceeding 80 mm in diameter, and a small subspecies of _K. gutielmi_ (Sow.). _K. medea_ resembles _S. enodatum_, but differs in having ventrolateral tubercles and a ventral smooth band on inner whorls.

**Type-locality:** Kidlington, Oxford: beds 9-14. Also Peterborough levels 21-55 cm.
Remarks: S. enodatum, K. medea and K. jason barely overlap in their ranges. The subzone has now been recognized at Peterborough, Bedford, Bletchley, Calvert, Kidlington, Wiltshire, Dorset and Kent; and the index is known from Orne, Sarthe, Hte-Marne and Vosges.

(ii) Jason Subzone

Author: Callomon, 1955 (as subzone).

Index: K. (G.) jason (Reinecke).

Characteristic fauna: large, smooth Kosmoceras, 90-120 mm in diameter; the true K. (G.) guilelmi (Sow.).

Type-locality: Peterborough (levels 56-135 cm) and Kidlington (beds 15-26).

Remarks: The subzone has been recognized in Scotland, England, the Paris basin and Rhône valley (Ardèche), Germany, Poland and Russia.

(d) Coronatum Zone

= Castor and Pollux Zone auctt.

= Anceps Zone, Oppel, pars. 1857.

Author: d'Orbigny, 1852; Buckman, 1913 and Morley Davies, 1916.

Index: Erymnoceras coronatum (Brugièrè-d'Orbigny).

Characteristic fauna: Kosmoceras macroconchs wholly ribbed but without bundling at the ventro-lateral margins (obductum, grossourei); and similar coarse microconchs (castor, pollux). Profuse Erymnoceras spp.; Cadoceras (milaschevici Nütting) and Pseudoceras; Pseudoperisphinctidae (Grossouwria) and, at the top, forms intermediate to Peltoceras, with rursiradiate secondary ribbing, of the mosquensis-scopinensis group; Reineckeia.

Type-locality: none yet apparently chosen. Buckman (1913) refers to the «continental coronatum zone». Peterborough: levels 136-1094 cm.

Remarks: This is the upper part of Oppel's Anceps Zone. The first properly-defined subdivision appears to be the Castor-and-Pollux Zone (Reuter, 1908; type-area Franconia), although beds of this age had previously been united with those of the Athleta Zone into an Ornatum Zone. However, it seems once again appropriate to accord priority in the name to d'Orbigny. Reuter himself states that coronatum, although rare in Franconia is characteristic of, and confined to, the Castor-Pollux Zone. Arkell (1946) has at times supported the retention of the Castor-Pollux Zone for parts of Europe where Erymnoceras happens to be rare. However, this seems no longer necessary, for the name is precisely synonymous with «Coronatum», and the supporting fauna is the same. Erymnoceras in fact has an unusually wide distribution, including both «Boreal» Russia and «Tethyan» Arabia and India.

It was previously thought that E. coronatum is rare or absent in England (Arkell 1933, p. 341) and represented there only by E. reginaldi (Morris). Closer investigation of many sections has shown that the English forms are in fact the same as those from France and the Jura; that reginaldi is probably no more than a variety of coronatum; and that the genus abounds in the zone and makes a most appropriate index.

(i) Obductum Subzone

Author: (Buckman, 1925, as «hemera»), Callomon, 1955.

Index: Kosmoceras (Zugokosmokeras) obductum (Buckman).

Characteristic fauna: K. obductum s.s. is a relatively small species (ca. 100 mm) compared with both fore-runners and successors (130 mm +). It is wholly but coarsely ribbed, and involute. Microconchs include K. (Spinikosmokeras) castor, but not pollux. Erymnoceras abounds, especially E. coronatum.
Type-locality: Peterborough, here designated: levels 136-560 cm.

Remarks: The index has been recorded from England, Germany, Lithuania and Russia. In Aargau it occurs in the principal coronatum bed (Jeannet 1951, pl. 25, fig. 11).

(ii) Groussouvrei Subzone

-=? Elizabethæ Zone, Neaverson, 1925; index species composite and indeterminate.

Author: Callomon, 1955.

Index: Kosmoceras (Zugokosmokeras) grossouvrei (Douvillé).

Characteristic fauna: Macroconch Kosmoceras now large, densely-ribbed and evolute; microconchs include both K. castor and pollux. Erymnocecras becomes rarer in the upper part of the subzone; instead there is a profusion of Pseudoparisisphinctidae transitional to Peltoceras of the group of «Perisphinctes» mosquensis, comploni (Prat), scopinensis (Neumayr) etc.

Type-locality: Peterborough, here designated: levels 561-1093 cm.

Remarks: Two successive faunas can be distinguished and the subzone divided into two horizons: a lower one with forms intermediate between K. obductum (Buckman) and grossouvrei Douvillé called obductum posterior Brinkmann (Peterborough, levels 561-864 cm); and an upper one with the very fine-ribbed grossouvrei proper (865-1093 cm). K. obductum posterior has the coarse ribbing of obductum, but the size and evoluteness of grossouvrei from which it is less easy to distinguish in the field than obductum, so that this horizon is put in the Grossouvrei rather than Obductum Subzone.

UPPER CALLOVIAN

(e) Athleta Zone

-= Ornatum Zone auctt. pars

-= Duncani Zone auctt.

-= Proniaæ Zone auctt.

-= ?Castor Zone, Neaverson, 1925.

Author: d'Orbigny, 1852; Oppel, 1857.

Index: Peltoceras (Peltoceras) athleta (Phillips).

Characteristic fauna: Kosmoceratidæ with secondary ribbing bundled at the ventro-lateral margin into tuberces (proniaæ) or clavi (duncani Sowerby, non auctt.); Peltoceras spp.; Réinèckeia (Collothia) spp.; bicarnatæ Oppelids (Dislichoceras Horioceras); Longaviceræ and Pseudocadoceræ; many Pseudoparisisphinctidae.

Type-locality: none apparently so far designated. English successions known to Oppel were confined to Wiltshire and Yorkshire, neither of which are even to-day useful for defining the Athleta Zone. Of the French successions known to Oppel the best-characterized are those in Maine-et-Loire and Deux-Sèvres (faunas monographed by Gérard and Contaut, 1936), but they are highly condensed. The Swabian succession quoted by Oppel suffers from a clay-facies in which the ammonites occur only as nuclei. The best and probably most complete sections (20 m +) are again in England: Peterborough, levels 1094- ca. 2700 cm; Bletchley; Woodham (Arkell, 1939); Dorset (ibid., and Spath 1933, p. 857).

Remarks: Various attempts have been made in England to subdivide the zone (Buckman, Pringle, Neaverson) using athleta, proniaæ, spinosum or duncani as separate indices. These have so far however only reflected local variations. K. proniaæ appears quite sharply at the base of the zone and ranges throughout. Peltoceras becomes common only in the upper part of the zone, but this may only be apparent owing to the scarcity of fossils in the lower part. It and K. duncani appear simultaneously.
Gérard and Contaut separate two subzones (1936) whose faunas seem however barely distinguishable.

(f) Lamberti Zone

= Gregarium Zone, Buckman, 1913.
= Vertunnum Zone, Buckman, 1913.

Author: Hébert, 1857, 1860.

Index: Quenstedtoceras (Lamberticeras) lamberti (Sowerby).

Characteristic fauna: profuse Quenstedtoceras s.s. and subgenera Lamberticeras, Eboraciceras; Kosmoceras sensu stricto including spinosum but excluding duncani and proniae. The remaining fauna is the same as in the Athleta Zone.

Type-locality: the Calvados coast, Normandy (Hébert, 1857, p. 44) (beds H1-4).

Remarks: although Hébert did not call his units «zones» but «couches» or «assises», he stressed (1857, p. 86) that it is their fossil-contents that characterize them, and thus defined zones in fact if not in name. His «couches à Amm. athleta et lamberti» and Oppel's Athleta Zone were published independently and simultaneously, but whereas the former was based primarily on the Calvados succession, where only the Lamberti Zone is exposed, Oppel's zone was confined to pre-lamberti beds (1857, p. 522), the Normandy section being mentioned only in passing. Oppel himself later recognized a separate Lamberti Zone in the Argovian Jura (1863, p. 163, 167) succeeding the Athleta Zone.

I have had an opportunity to examine the type-sections in Normandy. The true lamberti occurs already at the base of bed H 1. The junction between Lamberti and Mariæ Zones is sharp and falls in the middle of bed H5. From below:

Bed H5(a): Lamberti Zone. Marly limestone, grey, a mass of fossils, i. a. Q. (E.) grande Ark. (C), cadiforme Buck. (C), Q. (Q.) aff. henrici Douy., A. (Euaspiloceras) ferrugineum Jeannet (C); Ostrea (Exogyra) cf. or aff. alimena d'Orb. (VC) ...ca. 0.50 m

Bed H5(b): Mariæ Zone. Hard marl, brown, with mudstone nodules and limonitic ooliths near base. Q. (Pavloviceras?) aff. williamsoni Buck.; Ostrea (Gryphaea) dilatata, typical (C) ...ca. 0.40 m

Bed H6: (i) Shale or clay, black; G. dilatata ...0.05 m

(ii) Clay, brown in lowest 40 cm, then grey.

Q. (Q.) mariæ d'Orb., C. (S.) scarburgense (Y. and B.), both typical and common in the lowest 1 m.

Hence the old records of Q. lamberti and mariæ as overlapping in ranges.

The Lamberti Zone may be divisible. Sayn (1930) distinguishes at la Voult a lower «Zone à Peltoceras athletoides et Quenstedtoceras henrici (p. 206)» from an upper «Zone à Quenstedtoceras lamberti» (p. 212), although in the absence of figures it is impossible to judge whether his specific identifications are correct. There is also some evidence of divisibility in Normandy (summary in Arkell, 1939, p. 203) and Dorset (Spath, 1933, p. 858). Two levels can definitely be recognized at Woodham (Arkell, 1939): Q. henrici occurs commonly alone, in at least the top 1 m of the clays immediately underlying the Lamberti Limestone (and hence all the loose pyritized specimens recorded by Arkell). A Henrici Subzone may therefore one day be established; at present only provisional separation of a horizon of Q. henrici seems justified.
D. THE OXFORDIAN STAGE

(a) Original definition and type-area

The problems of interpreting d’ Orbigny’s «étage Oxfordien» resemble those in the case of the Callovian. In selecting a type-area Arkell followed the same principles: the derivation of the name led him to consider only English localities in d’ Orbigny’s list of formations, and among these the only explicit reference is to Phillips’ description of Yorkshire, which is therefore to be regarded as the type-area. This choice also serves to define the lower boundary of the stage as at the base of the Marie Zone, as discussed previously, for the «Oxford Clay, Phillips» is not the same as the Oxford Clay of Oxford.

The upper limit of the stage cannot be usefully deduced from d’ Orbigny’s original definition, for (1) the upper part of the Yorkshire Oxfordian is poor in ammonites, and (2) its completeness cannot be verified, for the Kimmeridgian is there nowhere properly exposed. Elsewhere, as is well known, the upper parts of the Oxfordian formations assume widely differing facies which for the first time in the European Jurassic raise serious problems of correlation. To accommodate some of these formations d’ Orbigny created his «étage Corallien», but as was already pointed out by Oppel, the formations listed as belonging to this stage have widely differing ages, in many cases including Kimmeridgian, and use of «Corallien» as a stage-name never caught on.

(b) Modern definition

The problem of defining the upper limit of the Oxfordian has, ever since Oppel’s time, been transmuted into that of defining the lower limit of the next overlying stage, and, by abolishing the «étage Corallien», referring to the Oxfordian everything immediately below it. Detailed stratigraphical information is available in two principal provinces: the N.W. European (England, N. France, N.W. Germany, Baltic), and Franco-Swabian (central France — Jura — Swabia — Franconia). Two major points must be borne in mind.

(i) In order to avoid ambiguities the post-Oxfordian stage used to define the upper limit of the Oxfordian must be in the same province as the Oxfordian itself. The Oxfordian stage therefore comprises all deposits between Callovian and Kimmeridgian as defined in England. This interpretation was essentially followed by Oppel, all English geologists ever since and Salfield (author of the first modern revision of the Upper Jurassic). The last Oxfordian bed in the Kimmeridgian type area is the Ringstead Coral Bed, Pseudocordata Zone.

(ii) A major geological event occurred in about the middle of the stage. This had two effects. Firstly, the continent of Europe seemed to undergo some sort of pivoted tilting so that there was an exchange of basins of deposition. As a result there is a complementarity of deposits. Those of the earlier part of the stage are thick and probably complete in N.W. Europe, but condensed, or in part or wholly absent, in Jura — Swabia — Franconia; and the opposite is the case in the later part. This event marks one of the most prominent geological features, the transition from Brown to White Jura. It seems useful to give it a name, and I propose to call it the «Oxfordian Tills».

Secondly, the event was accompanied by a separation of the ammonites into faunal provinces, which has created all the subsequent problems of correlation.

(c) Subdivision of the Oxfordian

From what has been said above, it is clear that (1) subdivision of the whole of the Oxfordian cannot be based on either of the two main provinces alone; (2) the stage as a whole is rather extensive and unwieldy; and (3) a division into two sub-stages would be convenient and desirable.
Past attempts to subdivide the Oxfordian have been many and confusing, and have attained no commonly accepted finality. They have been of two types:

(i) Division into Lower and Upper Oxfordian. This line has in N.W. Europe been generally drawn between Cordatum and Plicatilis Zones (see Salfeld, 1914, and Arrell in all his works). It presents a fair balance.

(ii) Division into sub-stages. Of the many which have been proposed, I shall discuss briefly only those that have the remotest claim to continued use:

Argovien, Marcou 1848 (Argovia = Kt. Aargau, Switzerland). Founded pre-1850 (Arrell 1946, rule 3). Widely used and interpreted since, both as stage-name and facies-term.

Sequanien, Marcou 1848 (Sequania = Franche-Comté, France). Used predominantly as facies-term; but where used as stage-name applied to beds of both Upper Oxfordian and Lower Kimmeridgian ages. Hence useless.

Rauracien, Gressly 1867 (Rauracia = area round Basel). Same remarks.

Dipéïen, Renuvier 1874 (Dives, Normandy). Lamberti — Cordatum Zones, clearly defined; thus Upper Callovian ÷ Lower Oxfordian, and unsuitable as sub-stage of the Oxfordian alone.

Lusitanien, Choffat 1885 (Lusitania = Portugal). Defined clearly as a stage-name, and hence an alternative to Argovien if this is thought to denote facies only. However, the type-area lies outside the two provinces under consideration, and correlation with Argovien raises separate problems (see Salfeld 1914, p. 135). It moreover includes Lower Kimmeridgian.

Neo-oxfordian, Spath 1933, p. 872. The first stage to be defined in terms of its contained zones; exactly synonymous with Upper Oxfordian.

The present dilemma is, then, that none of the familiar names is really suitable as it stands to be used as a sub-stage; for a sub-stage should be wholly contained within a stage and, in the present case, should coincide at one of its boundaries with the Oxfordian Tilt.

(d) The age of the Oxfordian Tilt

In much of England the Oxfordian terminates with the Coral Rag of the Plicatilis Zone. In the Franco-Swabian province typical thick White Jura usually starts with the Birmensdorf Beds (Transversarium Zone by definition) or their equivalents, resting often unconformably on older beds down to Middle Callovian. The crux of the discussion therefore depends on the correlation of the Plicatilis and Transversarium Zones. Arrell always considered them to be largely equivalent, attributing the difference in their faunas to ecological factors. His views were based largely on a study of the ammonites from Trept, Isère, which he visited in 1936 (Arrell 1946b, revision of de Riaz, 1898). However, the Trept faunas contain only a small proportion of forms of the English Plicatilis Zone; and they were not collected in situ from a measured section. That they may be of mixed age was indicated by the Cardioceratids, which were unlike those of the Plicatilis Zone and already contain true Amoeboceras (Arrell 1948, p. 391). I have myself studied the Perispinhectids of the Aargauer Birmensdorf Beds and English Plicatilis Zone, and could never find anything in common between them.

The matter seems to be settled by the following observations.

(i) Plicatilis and Transversarium faunas are now both known at each of two localities. At Blumberg (Baden, S. Germany; Zeiss 1955a, b, 1957) typical Cordatum Zone is separated from typical grey Birmensdorfer Beds by a thin bed of green, highly glauconitic marl (Mumien-schichtle) which yields the fauna of the Plicatilis Zone. I have myself seen Perispinhectidae from this bed in Tübingen (through the courtesy of Dr. H. Hölder), and confirm Zeiss's conclusion based on Cardioceratidae. This bed and its fauna is absent in Aargau, although it persists in Bavaria (Gümbel's Perispinhectidae chloroolithicus — sic).
Secondly, recent mapping by Dr. D.V. Ager and B. Evamy in the area of Bugey, near Virieu-le-Grand (Ain), only 15 km east of Trept (but in the folded-Jura) has yielded Plicatilis Zone Perisphinctids from the lowest part of the White Jura which are in a different preservation — creamy non-argillaceous limestone — from that of the overlying, typical Birmensdorf Beds.

Plicatilis Perisphinctidae have also been recorded (although not in situ) from Liesberg (de Loriot 1896, section in Koby, 1899), 20 km S.W. of Basel; La Fauville (Ronchadez 1917; type of P. rotoides); St. Sorlin (Jura; type of P. parandieri de Loriot).

(ii) Through the courtesy of Prof. P. Trümpy, I have been able to examine a considerable collection of Cardioceratids from the Birmensdorf Beds of Kt. Aargau. None are exactly like Plicatilis Zone forms; and among them are, as at Trept, several typical Amoeboceras.

Thus, the Plicatilis and transgressive Transversarium Zones are not equivalent but succeed each other; and the Oxfordian Tilt coincides precisely with the junction between them.

(e) Sub-stages of the Oxfordian

(i) Division into Lower, Middle and Upper Oxfordian. Most authors have agreed on the use of Lower Oxfordian for the Marix-Cordatum Zones; and Upper for the Transversarium-Bimammatum Zones. In England the Plicatilis Zone has also usually been included in the Upper Oxfordian, for in much of the country it is the highest present. It seems that English and Continental usage can be made consonant quite simply by introducing Middle Oxfordian (following Zeiss, 1957) for the beds between Cordatum and Transversarium Zones, i.e. for the Plicatilis Zone.

(ii) Substages. I hesitate to introduce yet more new names or redefinitions of older ones; but should a need for such names be felt, I suggest tentatively the following:

- **Lower - Middle Oxfordian: Marix-Plicatilis Zones of both provinces:**

  — EUOXFORDIAN. Type area: Oxford.

  **Upper Oxfordian sensu emendato:**

  Cautisnigrae-Pseudocordata Zones of the N.W. European province:

  — NEOXFORDIAN SPATH, sensu emend. Type-area: Osmington, Ringstead, Dorset.

  Transversarium-Bimammatum Zones of the Franco-Swabian province:

  — ARGOVIAN sensu emend., comprising the Birmensdorf - Wangen Beds of Moesch (1867). Type-area: Aargau.

E. THE ZONES OF THE ENGLISH OXFORDIAN

**LOWER OXFORDIAN**

The zones were reviewed by Arkell, 1941.

(a) Marix Zone

- Renggeri Zone, BECKMAN 1913, et auctt.

  **Author:** H. DOUVILLE, 1881, p. 442.

  **Index:** Quenstedtoceras (Quenstedtoceras) marix (D’ORBIGNY).

  **Characteristic fauna:** Cardioceras of subgenus Scarburgiceras; crenulate Oppelids — Creniceras renggeri; Taramelliceras (Proscaphites).

  **Type-locality:** Villers-sur-Mer, Normandy.
Remarks: *Quenstedtoceras* is dimorphic, and *Q. mariae* (d’Orb.) (lectotype figured by Arkell, 1939) is a microconch. *Pavloviceras* (type *Q. pavlowi* Douville) is a macroconch and becomes large and smooth.

(i) *Scarburgense* Subzone  
= *Mariae* Subzone, Spath, 1939.  
**Author:** Buckman, 1913 and Morley Davies, 1916 (as zone).  
**Index:** C. (Scarburgiceras) scarburgense (Young & Bird).  
**Characteristic fauna:** the index (abundant).  
**Type-locality:** Yorkshire, lowest Oxford Clay there.  
**Remarks:** discussed and properly defined by Arkell, 1941. Well exposed at Woodham. *Q. mariae* is only common in the lowest part of the subzone.

(ii) *Præcordatum* Subzone  
= ?*Tenticostatum* Zone, Brinkman, 1929.  
**Author:** Morley Davies, 1916 (as *pre-cordatum* zone, later as *præcordatum* Zone).  
**Index:** C. (Scarburgiceras) *præcordatum* Douville.  
**Characteristic fauna:** the index, and profuse Peltoceras.  
**Type-locality:** Buckinghamshire, England.  
**Remarks:** Interpretation of the index discussed by Arkell, 1941.

(iii) *Cordatum* Zone  
= *Perarmatum* Zone of Oppel, Hudleston and auclt. partim.  
**Author:** d’Orbigny, 1852.  
**Index:** C. (Cardioceras) *cordatum* (Sowerby).  
**Characteristic fauna:** many Cardioceratidae, Aspidoceratidae.  
**Type-locality:** Normandy, oolithe ferrugineuse, according to Arkell, 1941.  
**Remarks:** lectotype of index validated by ICZN Opinion 235. History of zone reviewed by Arkell, 1936. *Aspidoceras perarmatum* (Sowerby) is a species of the *Plicatilis* Zone.

(i) *Bukowskii* Subzone  
**Author:** Arkell, 1941.  
**Index:** C. (Scarburgiceras) *bukowskii* Maire.  
**Type-locality:** Purton, Wiltshire, and Yorkshire: Ball Beds.  
**Remarks:** type of the index from Poland. The subzone is also well-developed in Scotland: Staffin, Skye; and has been recognized at Blumberg (Baden) (Zeiss, 1957).

(ii) *Costicardia* Subzone  
= *Vertebrale* Zone, Buckman et auclt.  
= *Cardia* Zone or Subzone, Spath.  
**Author:** Arkell, 1941.  
**Index:** C. (Cardioceras) *costicardia* Buckman.  
**Type-locality:** Purton, Wiltshire: Red Nodule Bed.  
**Remarks:** *C. vertebrale* is a species of the *Plicatilis* Zone; *C. cardia* is a synonym of *C. subcordatum* Pavlow, which probably occurs in the next higher *Cordatum* Subzone. The Red Nodule Beds also occur in Dorset and Normandy; and most of the Continental beds attributed to the *Cordatum* Zone (e. g. Herznach) belong to this subzone.
(iii) Cordatum Subzone.

**Author:** Arkell, 1941 (as subzone).

**Index:** C. (Cardioceras) cordatum (Sowerby) sensu stricto.

**Type-locality:** Seend – Calne, Wiltshire; Lower Calcareous Grit.

**Remarks:** the true *cordatum* is relatively rare, known in England only from isolated areas of Lower Calcareous Grit in Wiltshire and (in unlocalized beds) in Yorkshire. Zeiss claims to have recognized it at Blumberg (1957). The stratigraphic position of the subzone, once in some doubt, has been confirmed in Dorset (Arkell, 1948).

**MIDDLE OXFORDIAN**

(c) Plicatilis Zone

= *Perarmatum* Zone auctt. pars

= Martelli Zone, Morley Davies, 1916.

The Corallian Beds of the N.W. European province are so variable and the ammonite faunas so intermittent, that a proper succession based on sound stratigraphical work has only emerged in the last 25 years. The zonal nomenclature previously in use was correspondingly so confused that there is little point in trying to unravel it all again. The picture is now clear, largely due to work by Arkell (summary of zones: 1936); revision of the Corallian around Oxford by Callomon, 1960.

**Author:** Hudleston, 1878.

**Index:** Perisphinctes (Arisphinctes) plicatilis (Sowerby).

**Characteristic fauna:** many large Perisphinctes spp., Cardioceratidae and Aspidoceras; Oppeliiids very rare, no Peltoceras.

**Type-area:** Yorkshire.

**Remarks:** Amm. *plicatilis* was already cited as a diagnostic index-fossil by Hébert, 1857. *P. martelli* (Oppel) is of Transversarium age.

(i) Vertebrale Subzone

**Author:** Arkell, 1947, p. 98 (as subzone).

**Index:** C. (Vertebriceras) vertebrale (Sowerby).

**Characteristic fauna:** Cardioceratidae predominate; only small species of Dichotomosphinctes.

**Type locality:** around Oxford (Callomon, 1960).

**Remarks:** includes Arkell’s Calena Subzone. There is also some doubt about the German Tenuicosalatum Zone. According to Brinkmann, this zone would be equivalent to the Praecordatum or Bukowski Subzone; according to Zeiss the species is typical of the whole of the Cordatum Zone; and Salfeld (1914) and Siegfried (1952) use it for the Lower Hecrsumer Beds, which belong largely to the present subzone.

(ii) Antecedens Subzone

**Author:** Arkell, 1947, p. 98 (as subzone).

**Index:** P. (Dichotomosphinctes) antecedens Salfeld.

**Characteristic fauna:** Cardioceratids recede; Perisphinctids now include large Dichotomosphinctes and the first Perisphinctes s.s. (non martelli (Oppel), nêu parandieri de Loriol).

**Type-locality:** around Oxford (Callomon, 1960).

(iii) Parandieri Subzone

**Author:** Callomon, 1960; ?Tintant, 1958.
Index: P. (Perisphinctes) parandieri de LORIOL.

Type-area: Oxford, Wheatley Limestone, equivalent to the Coral Rag.

Remarks: relatively few ammonites are so far known from this zone. They tend to be more finely-ribbed than those of the lower subzones, and the possibility that this subzone is already equivalent in part to the Transversarium Zone cannot altogether be ruled out.

Since writing on the Plicatilis Zone I have come across the paper by H. TINTANT, 1958: Sur la stratigraphie de l'Oxfordien supérieur aux environs de Dijon (Côte-d’Or), C.R. Acad. Sci. (Paris), 246, 2504. He divides the Transversarium Zone into three sub-zones: 1. Sous-zone à Vertebriceras vertebrale; 2. . . . à Perisphinctes parandieri; 3. . . . à Perisphinctes wartæ. From 1 are recorded species typical of the Vertebrale and Anpectodens Subzones; and 3 yields the usual Birmensdorfer fauna. If the Perisphinctids from 2 have been correctly identified, Parandieri Subzone TINTANT 1958 has priority, and the implicit type-locality is Dijon. The position seems in accord with experience elsewhere, between Plicatilis and Transversarium Zones as hitherto usually understood. TINTANT places all three subzones in the Transversarium Zone on the strength of G. transversarium which he records from already the lowest of them. His vertebrale beds are however thin (iron oolite) and also yield forms from the Lamberti-Cordatum Zones, suggesting a condensed deposit. A record of the true transversarium from pre-Birmensdorf beds would be of such great interest that it seems desirable to exclude beyond doubt the possibility of mis-identification through confusion with one of the forms of Pelloceras (e.g. Rursiceras) common in the Lower Oxfordian, some of which resemble Gregoryceras quite closely.

UPPER OXFORDIAN

The record in England is patchy, and the zonal scheme by no means final.

(a) Cautisnigræ Zone

= ?Wartæ Zone, SALFELD.

Author: ARKELL, 1945.

Index: Perisphinctes (Perisphinctes) cautisnigræ ARKELL.

Type-locality: Dorset: Red Beds (Trigonia clavellata beds).

Remarks: This is the earliest English post-Plicatilis zone so far recognized. Correlation with the Franco-Swabian province is still not certain; but if anything, favours equivalence with Bimannatum rather than Transversarium Zone, implying a faunal lacuna. P. wartæ Bukowski itself has not been found in England.

(b) Decipiens Zone

Author: SALFELD, 1914.

Index: Decipia decipiens (Sowerby).

Type-locality: none so far selected.

Remarks: the zone is very imperfectly known, mainly from isolated shallow and unconnected exposures in Ampthill Clay of central England; and Upper Calcareous Grit of Yorkshire. Also East Greenland.

(c) Pseudocordata Zone

Author: SALFELD, 1914.

Index: Ringsteadia pseudocordata (Blake & Hudleston).
Type-locality: Dorset (Ringstead) and Wiltshire (Westbury).

Characteristic fauna: Ringsteadia spp., Microbiplices; Amoeboceras, group of marstonense Spath.

Remarks: This zone is well-established: it correlates with part of the Bimammatum Zone s.s. of Franconia (lowest White Jura 3). It is also well-developed in Scotland (Skye: Staffin Bay), and East Greenland (Callomon, 1961).

F. SUMMARY

A brief introduction discusses certain aspects of the nomenclature and definition of stages and zones.

The Callovian and Oxfordian stages are then discussed: their original definitions, delimitations, and modern interpretations. New discoveries in recent years now allow the Oxfordian to be subdivided into Lower, Middle and Upper parts in a way which is satisfactory for both major faunal provinces in Europe. Suitably defined substages are suggested should they be felt to be necessary.

The subdivision of the stages into standard ammonite zones and subzones as applied in England is outlined, listing authors, indices and type-localities. With the exception of the Upper Oxfordian, this zonal scheme is now rather satisfactory and its durability may be viewed with some confidence.

Table I

ZONES OF THE CALLOVIAN

<table>
<thead>
<tr>
<th>Stages</th>
<th>Zones</th>
<th>Subzones</th>
<th>Horizons</th>
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<tbody>
<tr>
<td></td>
<td><strong>Lamberli</strong></td>
<td></td>
<td>lamberti</td>
</tr>
<tr>
<td>UPPER</td>
<td><strong>Athleta</strong></td>
<td></td>
<td>henrici</td>
</tr>
<tr>
<td></td>
<td><strong>Coronatum</strong></td>
<td><strong>Grossouvrei</strong></td>
<td>grossouvrei</td>
</tr>
<tr>
<td>CALLOVIAN</td>
<td><strong>Obductum</strong></td>
<td></td>
<td>obductum posterior</td>
</tr>
<tr>
<td>MIDDLE</td>
<td><strong>Jason</strong></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td><strong>Medea</strong></td>
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<td></td>
</tr>
<tr>
<td>LOWER</td>
<td><strong>Calloviense</strong></td>
<td><strong>Enodatum</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Calloviense</strong></td>
<td><strong>Koenigi</strong></td>
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<tr>
<td></td>
<td><strong>Macrocephalus</strong></td>
<td><strong>Kamplus</strong></td>
<td><strong>Macrocephalus</strong></td>
</tr>
</tbody>
</table>
Table II

ZONES OF THE OXFORDIAN

<table>
<thead>
<tr>
<th>Franco-Swabian Province Zones</th>
<th>Substages</th>
<th>Stages</th>
<th>Substages</th>
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<tr>
<td>Bimammalum</td>
<td>ARGOVIAN</td>
<td>UPPER</td>
<td>NEOXFORDIAN</td>
<td>Pseudocordata</td>
</tr>
<tr>
<td>Transversarium</td>
<td></td>
<td></td>
<td></td>
<td>Decipiens</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Caustisnigræ</td>
</tr>
</tbody>
</table>

OXFORDIAN

| LOWER | EUOXFORDIAN |                 |             | Parandieri |
|       |             | Plicatilis      |             | Antecedens |
|       |             | Vertebræ        |             |            |
|       |             | Cordatum        |             | Costicardia |
|       |             |                  |             | Bukowskii   |
|       |             |                  |             | Precordatum |
|       |             |                  |             | Scarburgense |

No Upper Oxfordian zonal correlation is implied by this table.
Separate names for sub-stages were not thought necessary at the Colloquium, and those included above not adopted.

G. REFERENCES

Brinkmann, R., 1929b: Monographie der Gattung Kosmoceras. ibid., iv.
Buckman, S.S., 1925: Type Ammonites. V. London.
Callomon, J.H., 1959: The Ammonite Zones of the Middle Jurassic Beds of East Greenland. Geol. Mag., 96, 505.


