

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, SALFELD 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 Kelloways 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 «l'argile de Dive 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 *Sutherlandia*. 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 *Macrocephalites* (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, —35) 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 *Perisphinctidæ*

(*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 (1932, 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 «Macrocephalenoolit» of Württemberg; and with forms which occur in the Tychonis 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 time-planes (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 *Mariæ* 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 PHILIPPS (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 *Mariæ* Zone.

(2) D'ORBIGNY's examples from outside England specifically include the «argiles de Dives», which commence and are most fossiliferous in the *Lamberti* Zone.

(3) His fossil lists include *Am. Lamberti* 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 *Lamberti* 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 *Lamberti* 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 *Lamberti* 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* SCHLOTHEIM. Supporting fauna: *Macrocephalites* spp., *Choffatia* spp., *Kepplerites* (*Kepplerites*) spp., (rare), and (in Europe) various «bullati» — *Kheraicerias* and *Bomburites*.

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 «*Macrocephalenoolit*» 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). *Choffatia* 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, 1955.

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, *grantanus* (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 *Kosmoceratidæ*: *Kepplerites* (*Gowericeras*, *Toricelliceras*), *Sigaloceras* (s.s., *Gulielmina*) and *Cardioceratidæ*: *Cadoceras* (s.s., *Pseudocadoceras*), and the last colineal descendent of *Arcticoceras*, *Chamoussetia*. The Tethyan forms persist: evolute, strongly-ribbed globose Macrocephalitids appear (subgenera *Indocephalites*, *Pleurocephalites*), as does a new Perisphinctid: *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 *Calloviense* 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 *Calloviense* 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: *Cadoceras* 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 *Kamptus* Subzone, and the Cornbrash is not reached.

(ii) *Calloviense* Subzone

Author: OPPEL, 1857.

Index: *Sigaloceras calloviense* (Sow.).

Characteristic fauna: as of the *Koenigi* Subzone, but now including *S. calloviense* (macroconch) and *S. (Gulielmina) 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. calloviense* 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 (DÉVILLÉ, 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. *Gryphæa bilobata* auctt.

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 *Planicerclus* 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 *planicerclus* 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 *planicerclus* 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 *planicerclus* (including *curvicerclus* 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 *Planicerclus* 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 *Kosmoceralidæ* are replaced by Tethyan forms. The section at Herznach has shown that the *Enodatum* Subzone (bed A5, 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 Calloviense-Anceps and Boreal Calloviense-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 Calloviense 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

= *Conlazatum* Zone, NEAVERTON, 1925.

Author: D'ORBIGNY, 1852.

Index: *Kosmoceras* (*Gulielmites*) *jason* (REINECKE).

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

Type-locality: none apparently so far established. Here suggested: central England. Peterborough: levels 20-135 cm (BRINKMANN). Kidlington, Oxford: beds 9-26 (CALLOMON).

Remarks: D'ORBIGNY (1852, p. 509) prefaced his description of the «12^e 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* (*Gulielmites*) *medea* CALLOMON.

Characteristic fauna: small, smooth *Kosmoceras* not exceeding 80 mm in diameter, and a small subspecies of *K. gulielmi* (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.) guilielmi* (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* (BRUGIÈRE-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 (milashevici)* NIKITIN and *Pseudocaceras*; *Pseudo-perisphinctidæ (Grossouwia)* 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* zones». 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) *Grossouvrei* 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*. *Erymnoceras* becomes rarer in the upper part of the subzone; instead there is a profusion of *Pseudoperisphinctidæ* transitional to *Peltoceras* of the group of «*Perisphinctes*» *mosquensis*, *comptoni* (PRATT), *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.

= *Proniæ* Zone auctt.

= ?*Castor* Zone, NEAVERSON, 1925.

Author: D'ORBIGNY, 1852; OPPEL, 1857.

Index: *Peltoceras* (*Pelloceras*) *athleta* (PHILLIPS).

Characteristic fauna: *Kosmoceratidæ* with secondary ribbing bundled at the ventro-lateral margin into tubercles (*proniæ*) or clavi (*duncani* SOWERBY, non auctt.); *Peltoceras* spp.; *Reineckeia* (*Collotia*) spp.; *bicarnate* *Oppelids* (*Distichoceras* *Horioceras*); *Longævicerias* and *Pseudocadoceras*; many *Pseudoperisphinctidæ*.

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*, *proniæ*, *spinosum* or *duncani* as separate indices. These have so far however only reflected local variations. *K. proniæ* 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.

= *Vertumnum* 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 *spinorum* 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 HI-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 characterizes 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* DOUV., *A. (Euaspidoceras) 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 oolites 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 Voulte a lower «Zone à *Peltoceras athleoides* et *Quenstedticeras henrici* (p. 206)» from an upper «Zone à *Quenstedticeras 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 *Maria* 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 SALFELD (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 Tilt*».

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 ARKELL 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 (ARKELL 1946, rule 3). Widely used and interpreted since, both as stage-name and facies-term.

Sequaniens, 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.

Divésien, RENEVIER 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.

Neoxfordian, 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. ARKELL 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 (ARKELL 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* (ARKELL 1948, p. 391). I have myself studied the *Perisphinctids* 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-schicht») which yields the fauna of the *Plicatilis* Zone. I have myself seen *Perisphinctidæ* from this bed in Tübingen (through the courtesy of Dr. H. HÖLDER), and confirm ZEISS's conclusion based on *Cardioceratidæ*. This bed and its fauna is absent in Aargau, although it persists in Bavaria (GÜMBEL's *Perisphinctes 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 foded-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 Perisphinctidæ have also been recorded (although not in situ) from Liesberg (DE LORIOU 1896, section in Koby, 1899), 20 km S.W. of Basel; La Faucille (RONCHADZÉ 1917; type of *P. rotoides*); St. Sorlin (Jura; type of *P. parandieri* DE LORIOU).

(ii) Through the courtesy of Prof. R. 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 *Mariæ-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: Mariæ-Plicatilis Zones of both provinces:

— EUOXFORDIAN. Type area: Oxford.

Upper Oxfordian sensu emendato:

Cautisnigræ-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) *Mariæ* Zone

= Renggeri Zone, BUCKMAN 1913, et auctt.

Author: H. DOUVILLÉ, 1881, p. 442.

Index: *Quenstedtoceras* (*Quenstedtoceras*) *mariæ* (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. mariæ* (D'ORB.) (lectotype figured by ARKELL, 1939) is a microconch. *Pavlovceras* (type *Q. pavlowi* DOUVILLÉ) is a macroconch and becomes large and smooth.

(i) *Scarburgense* Subzone

= *Mariæ* 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. mariæ* is only common in the lowest part of the subzone.

(ii) *Præcordatum* Subzone

= ?*Tenuicostatum* Zone, BRINKMAN, 1929.

Author: Morley DAVIES, 1916 (as pre-*cordatum* zone, later as *præcordatum* Zone).

Index: *C. (Scarburgiceras) præcordatum* DOUVILLÉ.

Characteristic fauna: the index, and profuse *Peltoceras*.

Type-locality: Buckinghamshire, England.

Remarks: Interpretation of the index discussed by ARKELL, 1941.

(b) *Cordatum* Zone

= *Perarmatum* Zone of OPPEL, HUDLESTON and auctt. partim.

Author: D'ORBIGNY, 1852.

Index: *C. (Cardioceras) cordatum* (SOWERBY).

Characteristic fauna: many *Cardioceratidæ*, *Aspidoceratidæ*.

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 auctt.

= *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., *Cardioceratidæ* and *Aspidoceras*; *Oppeliids* 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: *Cardioceratidæ* predominate; only small species of *Dichotomosphinctes*.

Type locality: around Oxford (CALLOMON, 1960).

Remarks: includes ARKELL's *Catena* Subzone. There is also some doubt about the German *Tenuicostatum* Zone. According to BRINKMANN, this zone would be equivalent to the *Præcordatum* or *Bukowskii* 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 Heersumer 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), nec *parandieri* DE LORIOLE).

Type-locality: around Oxford (CALLOMON, 1960).

(iii) *Parandieri* Subzone

Author: CALLOMON, 1960; ?TINTANT, 1958.

Index: P. (Perisphinctes) parandieri DE LORIO.

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 *Antecedens* 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-Cordatium* 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 *Peltocheras* (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 *Bimammatum* 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 ♀). 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

Stages		Zones	Subzones	Horizons	
CALLOVIAN	UPPER	<i>Lamberti</i>		<i>lamberti</i>	
				<i>henrici</i>	
	MIDDLE	<i>Athleta</i>			
			<i>Coronatum</i>	<i>Grossouvrei</i>	<i>grossouvrei</i>
				<i>Obductum</i>	<i>obductum posterior</i>
			<i>Jason</i>	<i>Jason</i>	
				<i>Medea</i>	
			LOWER	<i>Calloviense</i>	<i>Enodatium</i>
	<i>Calloviense</i>				
	<i>Koenigi</i>				
	<i>Macrocephalus</i>	<i>Kamplus</i>			
		<i>Macrocephalus</i>			

Table II

ZONES OF THE OXFORDIAN

Franco-Swabian Province Zones	Substages	Stages	Sub-stages	N.W. European Province		
				Zones	Subzones	
<i>Bimammalum</i>	ARGOVIAN	OXFORDIAN	UPPER	NEOX-FORDIAN	<i>Pseudocordata</i>	
<i>Transversarium</i>					<i>Decipiens</i>	
	<i>Caustisnigræ</i>					
	MIDDLE		EUOXFORDIAN	<i>Plicatilis</i>	<i>Parandieri</i>	
					<i>Antecedens</i>	
					<i>Vertebrale</i>	
	LOWER			<i>Cordatum</i>	<i>Cordatum</i>	
					<i>Costicardia</i>	
					<i>Bukowskii</i>	
			<i>Marixæ</i>	<i>Præcordatum</i>		
		<i>Scarburgense</i>				

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

- ARKELL, W.J., 1933: *The Jurassic System in Great Britain*. Oxford University Press.
- ARKELL, W.J., 1936: *The Ammonite zones of the Upper Oxfordian and the horizons of the Sowerbys' and Buckman's types*. Quart. J. Geol. Soc., 92, 146.
- ARKELL, W.J., 1939: *The ammonite succession at the Woodham Brick Company's pit, Akeman Street Station, Buckinghamshire and its bearing on the classification of the Oxford Clay*. Quart. J. Geol. Soc., 95, 135.
- ARKELL, W.J., 1941: *The Upper Oxford Clay at Purlton, Wilts, and the Zones of the Lower Oxfordian*. Geol. Mag., 78, 161.
- ARKELL, W.J., 1945: *The zones of the Upper Jurassic of Yorkshire*. Proc. Yorks. Geol. Soc., 25, 339.
- ARKELL, W.J., 1946: *Standard of the European Jurassic*. Bull. Geol. Soc. Amer., 57, 1.
- ARKELL, W.J., 1946b: *A revision of the Upper Oxfordian Ammonites of Trepl (Isère), Figured by de Riaz*. Geol. Mag., 83, 129.

- ARKELL, W.J., 1947: *The Geology of Oxford*. Oxford University Press.
- ARKELL, W.J., 1948: *Monograph of the Ammonites of the English Corallian Beds*. Palaeontogr. Soc. (London), pt. xiv.
- ARKELL, W.J., 1954: *Three complete sections of the Cornbrash*. Proc. Geol. Ass., 65, 115.
- ARKELL, W.J., 1956: *Jurassic Geology of the World*. Edinburgh and London: Oliver & Boyd.
- BRINKMANN, R., 1929: *Statistisch-Biostratigraphische Untersuchungen an mitteljurassischen Ammoniten über Artbegriff und Stammesentwicklung*. Abh. Ges. Wiss. Göttingen, Math.-phys. Kl., N.F. 13, iii.
- BRINKMANN, R., 1929b: *Monographie der Gattung Kosmoceras*. *ibid.*, iv.
- BUCKMAN, S.S., 1913: *The 'Kelloway Rock' of Scarborough*. Quart. J. Geol. Soc., 69, 152.
- BUCKMAN, S.S., 1925: *Type Ammonites*, V. London.
- CALLOMON, J.H., 1955: *The ammonite succession in the Lower Oxford Clay and Kelloways Beds at Kidlington, Oxfordshire, and the zones of the Callovian stage*. Phil. Trans. Roy. Soc., B 239, 215.
- CALLOMON, J.H., 1959: *The Ammonite Zones of the Middle Jurassic Beds of East Greenland*. Geol. Mag., 96, 505.
- CALLOMON, J.H., 1960: *New Sections in the Corallian Beds around Oxford, and the Subzones of the Plicatilis Zone*. Proc. Geol. Ass., 71, 177.
- CALLOMON, J.H., 1961: *The Jurassic System in East Greenland*. In: *Geology of the Arctic*, ed. G.O. Raasch, University of Toronto Press.
- DAVIES, A. Morley, 1916: *The Zones of the Oxford and Amptill Clays in Buckinghamshire*. Geol. Mag., 53, 395.
- DOUGLAS, J.A. & ARKELL, W.J., 1928: *The stratigraphical distribution of the Cornbrash. I: The South-Western area*. Quart. J. Geol. Soc., 84, 117.
- DOUGLAS, J.A. & ARKELL, W.J., 1932: *II: The North-Eastern area*. *Ibid.*, 88, 112.
- DOUGLAS, J.A. & ARKELL, W.J., 1935: *Sections of Upper Cornbrash at Enslow Bridge near Oxford*. *Ibid.*, 91, 318.
- DOUVILLÉ, H., 1881: *Note sur la partie moyenne du terrain jurassique dans le bassin de Paris*. Bull. Soc. géol. France, sér. iii, 9, 439.
- DOUVILLÉ, R., 1915: *Etude sur les Cosmoceratidés des collections de l'école nationale supérieure des mines*. Mém. Carte Géol. France.
- GÉRARD, C. & CONTACT, H., 1936: *Les ammonites de la zone à Peltoceras athleta du centre-ouest de la France*. Mém. Soc. géol. France, 29.
- HÉBERT, E., 1857: *Les mers anciennes et leurs rivages dans le bassin de Paris*. Première Partie: *Terrain Jurassique*. Paris.
- HÉBERT, E., 1860: *Du terrain jurassique supérieur sur les cotes de la Manche*. Bull. Soc. géol. France, sér. ii, 17, 300.
- HUDLESTON, W.H., 1878: *The Yorkshire Oolites. Pt. II: The Middle Oolites*. Proc. Geol. Ass., 5, 407.
- JEANNET, A., 1951: *Die Eisen- und Manganerze der Schweiz. Stratigraphie und Paläontologie des oolithischen Eisenerzlagers von Herznach und seiner Umgebung*. Beitr. Geol. Schweiz, Geotech. Ser., Lief. xiii, 5.
- KOBY, E., 1899: (Note stratigraphique). In DE LORIOU: *Etude des mollusques et brachiopodes de l'Oxfordien inférieur ou Zone à Ammonites renggeri du Jura bernois*. Mém. Soc. Pal. Suisse, 26.
- LORIOU, P. DE, 1896: *Etude sur les mollusques de l'Oxfordien supérieur et moyen du Jura bernois*. Mém. Soc. Pal. Suisse, 23.
- MOESCH, C., 1867: *Geologische Beschreibung des Aargauer Jura und der nördlichen Gebiete des Kantons Zürich*. Beitr. Geol. Karte d. Schweiz, Lief. iv.

- NEUMAYR, M., 1871: *Jurastudien, V: Der penninische Klippenzug*. Jahrb. Geol. Reichsanst. Wien, 22, 451.
- NEAVEYERSON, E., 1925: *The Zones of the Oxford Clay near Peterborough*. Proc. Geol. Ass., 36, 27.
- NIKITIN, S., 1881: *Der Jura der Umgebung von Elatma*. Mém. Soc. Imp. Nat. Moscou, n.s. 14, ii.
- OPPEL, A., 1856-58: *Die Juraformationen Englands, Frankreichs und des südwestlichen Deutschlands*. Stuttgart.
- OPPEL, A., 1863: *Paläontologische Mittheilungen aus dem Museum des K. Bayer. Staates*, iii. *Über jurassische Cephalopoden*. 163-266.
- D'ORBIGNY, A., 1850: *Paléontologie Française, Terrain Jurassique. Céphalopodes*. (Stratigraphic summary: p. 600 et seq., 1850). Paris.
- D'ORBIGNY, A., 1852: *Cours élémentaire de paléontologie et de géologie stratigraphiques*. Vol. ii, Paris.
- PHILLIPS, J., 1829: *Illustrations of the Geology of Yorkshire*. Pt. I: The Yorkshire Coast. London.
- REHBINDER, B., 1912: *Argiles médio-jurassiques à minerai de fer le long du côté S.O. des hauteurs entre Cracovie et Wielun*. Mém. Com. Géol. St. Petersbourg, N.S. 74, 198.
- REHBINDER, B., 1914: *Die mitteljurassischen eisenführenden Tone längs des südwestlichen Randes des Krakauer-Wieluner Zuges in Polen*. Z. Deutsch. Geol. Ges. 65, 181.
- REUTER, L., 1908: *Die Ausbildung des oberen Braunen Jura im östlichen Teile der Fränkischen Alb*. Geogn. Jahresh. 20, 1.
- RIAZ, A. DE, 1898: *Description des Ammonites des couches à Peltoceras transversarium de Trept (Isère)*. Paris & Lyon.
- RONCHADZÉ, J., 1917: *Périsphinctes de l'Argovien de Chézery et de la Faucille*. Thèse, Fac. Sci. Univ. Genève, no. 590.
- SALFELD, H., 1914: *Die Gliederung des oberen Jura in Nordwesteuropa*. N. Jahrb. Min., Geol. u. Pal., Beil.-Bd. 37, 125.
- SAYN, G., 1930: *Oxfordien*. In: *Monographie stratigraphique et paléontologique du Jurassique moyen de la Voulte-sur-Rhône*. Trav. Lab. Géol. Lyon, fasc. xiv, mém. 11, 199-238.
- SIEGFRIED, P., 1952: *Die Heersumer Schichten im Hildesheimer Jura-Zug*. Geol. Jahrb., 67, 273.
- SPATH, L.F., 1932: *The Invertebrate Faunas of the Bathonian-Callovian deposits of Jameson Land (East Greenland)*. Medd. Gronland, 87, no. 7.
- SPATH, L.F., 1933: *Revision of the Jurassic Cephalopod Fauna of Kachh (Cutch)*. Pal. Indica, n.s. 9, mem. ii, pt. vi, 659.
- SPATH, L.F., 1939: *The ammonite zones of the Upper Oxford Clay of Warboys, Huntingdonshire*. Bull. Geol. Surv. Gt. Brit. 1, 82.
- WOODWARD, H.B., 1895: *The Jurassic Rocks of Britain: The Middle and Upper Oolitic Rocks of England (Yorkshire excepted)*. Vol. V. Mem. Geol. Surv. U.K.
- WRIGHT, T., 1870: *On the correlation of the Jurassic Rocks, in the Dept. of the Côte-d'Or, France, with the Oolitic formations in the counties of Gloucester and Wilts, England*. Proc. Cotteswold Nat. F.C., 5, 143.
- ZEISS, A., 1955a: *Zur Stratigraphie des Callovien und Unter-Oxfordien bei Blumberg (Südbaden)*. Jahresh. geol. Landesamt Baden-Württ., 1, 239.
- ZEISS, A., 1955b: *Pholadomya (Procardia) ziergiebeli n. sp., eine neue Lamellibranchiaten-Art aus dem Callovien Europas*. Monatsh., N. Jahrb. Geol. Pal., 11, 498.
- ZEISS, A., 1957: *Die ersten Cardioceraten-Faunen aus dem oberen Unter-Oxfordien Süddeutschlands und einige Bemerkungen zur Dogger/Malm Grenze*. Geol. Jahrb., 73, 183.