THE AMMONITE SUCCESSION IN THE LOWER OXFORD CLAY AND KELLAWAYS BEDS AT KIDLINGTON, OXFORDSHIRE, AND THE ZONES OF THE CALLOVIAN STAGE

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(*Communicated by W. J. Arkell, F.R.S.—Received* 2 *March* 1955)

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CONTENTS

The paper describes temporary sections through the Lower Oxford Clay, Kellaways Rock and Kellaways Clay down to the Cornbrash in a part of England in which these beds were previously little known. All the beds were fossiliferous, and more than 200 ammonites ascribed to twenty-five species were collected *in situ*, bed by bed throughout the succession.

The ammonites of the genus *Kosmoceras* in the Lower Oxford Clay were sufficiently numerous to allow them to be studied statistically by the methods employed by Brinkmann in 1929 on similar ammonites of the same age from the Lower Oxford Clay at Peterborough. His results for the lower part of the sequence comprising the *jason* Zone were fully reproduced. In addition, ammonites of other genera were found, including several specimens of *Reineckeia*, among the first to be recorded from beds of this age in this country.

The Kellaways Rock, consisting mainly of sands, was extremely fossiliferous and yielded, besides many lamellibranchs and gastropods, numerous, although poorly preserved, ammonites. These were the same as those of the Kellaways Rock of Wiltshire, with the addition of a specimen of *Macrocephalites sensu stricto*.

The Kellaways Clay was poorly fossiliferous, but it produced six specimens of *Macrocephalites* (subgenera *Kamptokephalites* and *Dolikephalites*), an assemblage similar to that of the Upper Cornbrash of Yorkshire and quite different from that of the Kellaways Clay of Wiltshire. The position of this clay above typical Upper Cornbrash as developed in south-west England, and belonging to the *siddingtonensis* and in part *lagenalis* brachiopod Subzones, confirms previous suspicions that the Cornbrash of Yorkshire is later than that of the south-west.

In the light of these results, the older evidence relating to the beds of this age in this country and abroad, including some of the old collections, is re-examined. Additional information from new or undescribed exposures at Calvert, Frome, Sutton Bingham near Yeovil, Weymouth, and Herznach in Switzerland, is included. In consequence, a much closer correlation of the beds of the Middle and Lower Callovian than was previously possible is now made between outcrops in Scotland, Yorkshire, north-west Germany, central and south-west England and the Argovian Jura.

A revised zonal table of the Callovian has been constructed, designed to be generally applicable to the area outlined above and including as subzones finer divisions which are in practice recognizable more locally. The relation between these west European zones and some of those used in the Mediterranean province is briefly indicated.

1. Introduction

Between 1948 and 1951, trenches and pits dug in connexion with a sewerage project at the village of Kidlington, 5 miles north of Oxford, temporarily revealed sections of the lowest beds of the Oxford Clay and the whole of the local Kellaways Beds. The village lies 3 miles north of Wolvercote, Oxford, where a section in the *athleta* Zone of the Oxford Clay was at one time exposed and worked for bricks (Arkell 1947*a*). It is also immediately west of the Islip area where Arkell (1943) recognized the boundary between the Kellaways Sands and Oxford Clay during surface mapping. A mile to the north, at Kidlington Station, are disused quarries which formerly showed reduced Upper Cornbrash resting on Lower Cornbrash and lower members of the Great Oolite Series.

The nearest section of the lowest beds of the Oxford Clay, the *Kosmoceras* shales, is at the London Brick Company's pit at Calvert, Buckinghamshire, about 14 miles to the north-east, where, judging from material in Oxford University Museum, Kellaways Beds could formerly also be seen at the base of the pit. There does not, however, appear to be any detailed published record of this exposure. The nearest locality at which a detailed succession in the Lower Oxford Clay has been recorded is in the large brick-pits around Peterborough, 70 miles to the north-east, published by Neaverson (1925) and Brinkmann (1929*a*).

The clays and sands which immediately overlie the Cornbrash and which comprise the Kellaways Beds crop out along a narrow belt across England from Dorset to the Humber, but they do not normally provide exposures, and detailed information regarding the series is therefore mainly derived from a few scattered excavations and from records of boreholes. Between Kellaways Bridge, near Chippenham, Wiltshire, and Bedford, information is available of only parts of the Kellaways Beds. Kidlington is almost exactly half-way between these two well-known localities.

Better knowledge of the palaeontology of the English Kellaways Beds is desirable for two reasons. First, it was in Callovian times that ammonites first became abundant and of world-wide distribution after the separation of the Jurassic seas into faunal realms which had occurred in the Bathonian; and secondly, England occupies a special position in the region of overlap between two of these realms, the Boreal and the Tethyan or Mediterranean. The faunas are correspondingly mixed, containing elements of both realms, and are therefore of special value for world correlations.

In order to avoid lengthy repetition in the text, the following abbreviations are used:

O.U.M. Oxford University Museum.

S.M. Sedgwick Museum, Cambridge.

B.M. British Museum (Natural History).

G.S.M. Geological Survey Museum, Kensington.

Min. Conch. refers to J. and J. de C. Sowerbys' *Mineral Conchology* (1812–46).

T.A. refers to S. S. Buckman's *Yorkshire Type Ammonites* (I and II) and *Type Ammonites* (III–VII) (1909–30).

Kosm. refers to R. Brinkmann's Monographie der Gattung *Kosmoceras* (1929*b*).

2. The sites

The information set out in the tabulated section is derived mainly from excavations for two pumping stations (Sites 1 and 2), which reached depths of 27 and 23 ft. respectively, and two lines of trenching of average depth about 12 ft. (Sites 3 and 4). In addition, an excavation for the boiler-house of a new school $\frac{3}{8}$ mile east of Site 1 and $\frac{1}{2}$ mile south-south-west of Site 2 showed about 10 ft. of blue shaly clay. The disposition of these sites is shown on the map (figure 1).

FIGURE 1. Sketch map of the Kidlington area.

The holes at the pumping stations, of about 15 ft. diameter, were dug by hand and they could be kept under almost continuous observation. In this way, it was possible to undertake detailed stratigraphical examination and precise collection of fauna, while sufficient measurements of the kosmoceratids were made to carry out direct comparison with the results of the work of Brinkmann (1929*a*) at Peterborough.

Continuity in the stratigraphical succession between Holes 1 and 2 was established by the use of a 6 in. auger at the bottom of Hole 1, and the position of the Cornbrash was determined similarly to be 2 ft. below the base of Hole 2. An overall thickness of 47 ft. of strata above the Cornbrash was thus observed. Examination of the trenches as they were dug served to confirm the observations made at the holes, especially regarding the strata intervening between Holes 1 and 2, but the use of mechanical excavators resulted at times in obscuring the details of the succession, and the large amounts of water generally encountered at the junction of the clays and the overlying gravel often made any sort of examination extremely difficult. The succession of strata, together with the stratigraphical position and range of strata at the individual sites is shown diagrammatically in figure 2.

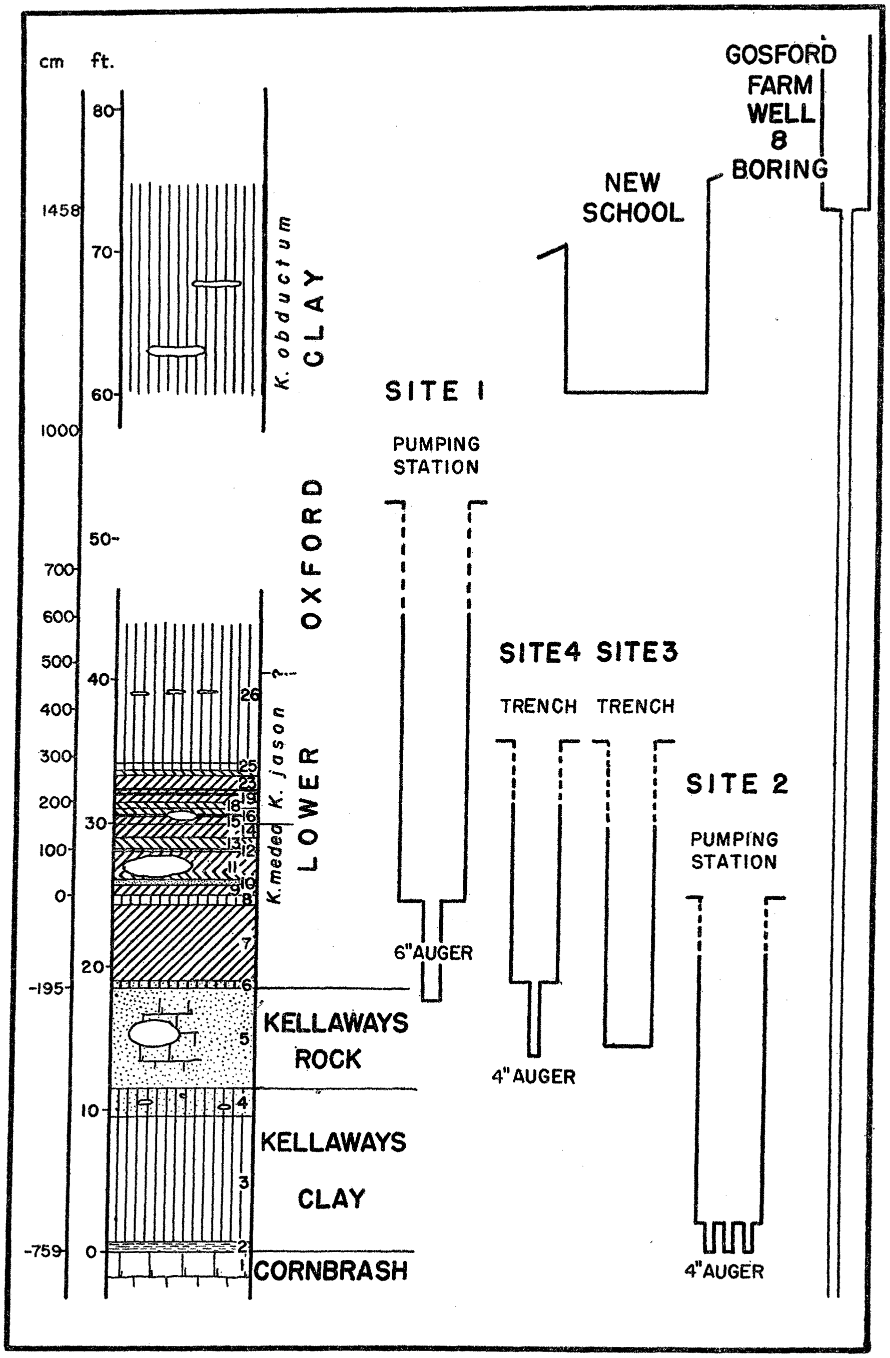


FIGURE 2. Diagram of the composite section and disposition of the sites at Kidlington.

3. THE SECTION

In the tabulated details of the section given below, the first column gives thicknesses in feet and inches; the second column the heights of the bottoms of beds above the Cornbrash in feet and inches; and the third column the heights of beds in centimetres above an arbitrary zero which is used to facilitate direct comparison with Brinkmann's work.

	ft.	in.	ft.	in.	cm.
Surface			52	3	833
Soil and alluvium	1	0	51	3	806
Gravel and reworked clay	4	0	47	3	681
OXFORD CLAY					
27. Clay, yellow, with selenite	3	6	43	9	574
26. Clay, blue, stiff, non-stratified					
First ammonites at			43	3	559
Ammonites becoming frequent at			42	1	523
(*b*) Pyritized concretions formed around large ammonite shells (*Gulielmites*) at			39	3	443
(*a*) Ammonite plaster at			34	5	290
	9	7	34	2	282
25. Clay, grey, very stiff, non-stratified, with ammonites and other shells		6	33	8	267
24. Clay, brown, stiff, shaly		3	33	5	260
23. Clay, green, very stiff, shaly, well-stratified; many shells	1	1	32	4	226
22. Pyrites, black, hard, a continuous band		½	32	3½	225
21. Clay, green, stiff, solid		3	32	1	217
20. Plaster of ammonites, most of the larger shells broken		1	32	0	215
19. Clay, green, well-stratified with layers of shells		6	31	6	200
18. Clay, dark brown, solid, platy; many shells		6	31	0	185
17. Clay, dark brown, solid; ammonite plaster at the top		4	30	8	175
16. Plaster of ammonites, shells mainly broken		1	30	7	173
Row of cementstone crackers incorporating the above plaster; the ammonites in part uncrushed and of calcite; the stone brownish and highly bituminous above the plaster, greenish and less bituminous below; the nodules up to 6 in. thick					
15. Clay, green, with ammonites		8	29	11	152
14. Clay, green-grey, solid, platy; many ammonites, mainly broken		10	29	1	127
13. Shale, brown, hard, flaky, gritty and shelly; many ammonites, mainly broken		10	28	3	102
12. Oyster-pyrites bed: layer of oyster shells, ammonites and belemnites, mainly broken and preserved in or heavily encrusted with pyrites; thickening locally into cementstone crackers		2	28	1	96
11*c*. Clay, khaki, many ammonites; fossils becoming rare downwards, colour changing to brown					
11*b*. Row of cementstone crackers up to 18 in. thick					
11*a*. Shell plaster with many belemnites at			26	6	49
	2	0	26	1	36
10. Shell plaster, shells broken; many belemnites; going into clayey sand		5	25	8	23
9. Clay, greenish; ammonites		9	24	11	0
8. Sandy clay and sand, light grey; occasional fossils, pyritized *Gryphaea* and lignite		7	24	4	
7. Clay, green, greasy, non-stratified, going into khaki clay, unfossiliferous; fossils at			22	3	
	5	4	19	0	
6. Sandy clay		6	18	6	−195
KELLAWAYS ROCK AND SAND					
5*c*. Sand, grey, compact, variable to sandstone up to 1 ft. thick; cemented locally by pyrites, letting in water; very fossiliferous with much lignite; passing into					
5*b*. Sand, dark, locally sandstone; fossils becoming fewer					
Row of cementstone crackers, very fossiliferous, embedded in sand or sandstone at			15	3	
5*a*. Sand or rock with shells, belemnites and lignite	6	6	12	0	
KELLAWAYS CLAY					
4. Clay, blue, platy, sandy, variable to stiff, shaly, slightly sandy, dark grey clay with lenticles of sand and pyrites-grit; occasional kidney-shaped lime nodules	2	3	9	9	
3. Clay, dark grey, tough, shaly, with much pyrites-grit; fossils rare	9	5		4	
2. Marl, light grey, with shell fragments		4		0	−759
CORNBRASH					
1. Limestone, tough, light grey					

The excavation at the site of the new school showed about 5 ft. of yellow, weathered clay overlying 10 ft. of blue, shaly clay. This clay is estimated to lie between 60 and 75 ft. above the Cornbrash.

As shown above, the Oxford Clay that was exposed consisted of a succession of beds of clays which varied in colour between dark brown, light slate-blue and green, and they were frequently sandy. They contained varying amounts of bituminous matter, the green clays in general being less bituminous than the brown. Lignite was common throughout. There was a noticeably large content of iron pyrites, both as concretions around fossil nuclei and as a fine 'grit' in the more sandy beds.

Layers of cementstone crackers occurred at two levels, 30 and 27 ft. above the Cornbrash respectively. Those in the upper layer rarely exceeded 6 in. in thickness and 2 ft. in diameter and contained many ammonites, some of which were preserved uncrushed in calcite and could be extracted in perfection. The concretions of the lower horizon were up to $1\frac{1}{2}$ ft. in thickness and only rarely contained a few crushed fossils. Both sets of concretions were traversed by many cracks filled with calcite (septaria), the whole having the appearance of having been crushed. Cone-in-cone structure occurred in the clay on the upper sides of some of the nodules. Both series of concretions appeared to persist uniformly through the sections, and they served as useful datum lines in following the succession in the trenches. These concretions also occur as derived boulders in the gravels of the neighbourhood, and it is now possible to fix the horizon from which these boulders come.

The ammonites in the clay are mostly preserved with body chambers crushed flat and formed of friable, somewhat iridescent, white calcium carbonate, a state of preservation typical of the Lower Oxford Clay of many localities. When there is a profusion of individuals, they form layers which merit the term 'plaster', used above. Occasionally, they are enclosed in pyritic concretions.

The equivalent of the Kellaways Rock consists of a grey, fine, silty sand. It resembles a sandy clay to the touch; however, on shaking in water it settles almost completely, leaving the water clear. When thus washed, the material yields a nearly white sand on drying. Locally, the sand is cemented to a soft sandstone. Lignite occurs commonly and fossils are at times encrusted with pyrites. Of the fossils, the oysters and belemnites are of the usual translucent calcite, while the shells formerly composed of aragonite are all more or less distorted or crushed, and preserved as casts coated with a thin layer of friable calcium carbonate. The casts of the lamellibranchs and body chambers of the ammonites are of sandstone, while the camerae of the ammonites are of a fine brown chalky marl.

The lithological change at the junction between the Kellaways Rock equivalent and the Kellaways Clay was gradual. The bulk of the Kellaways Clay consisted of a uniform, tough, slabby clay. This contained 'gritty' lenticles, sometimes up to $\frac{1}{2}$ in. thick, composed largely of crumbled pyrites. Occasional kidney-shaped nodules of chalky material occurred in the upper part of the clay. Chemical analysis of one of these showed 4 % P_2O_5, equivalent to 8 % of normal calcium phosphate. Throughout the Kellaways Clay, fossils were very rare. Ammonites occurred only in the top 5 ft. and only the body chambers with sometimes a few of the last camerae were preserved, also in a chalky material. The occasional lamellibranchs were casts with the shell partly replaced by pyrites.

The basal 4 in. of marl (bed 2) are probably the lateral equivalent of the 10 in. of Upper Cornbrash marl immediately underlying the Kellaways Clay at Upper Greenhill Quarry, Bletchingdon, 2 miles to the north-north-west (Douglas & Arkell 1935).

4. The fauna other than ammonites

4·1. *Oxford Clay*

This produced an abundant fauna of the usual clay facies type, as described, for instance, by Brinkmann (1929*a*):

Nucula spp. abundant throughout.
Pinna cf. *lanceolata* J. Sowerby, especially at 29 ft. (bed 13).
Camptonectes lens (J. Sowerby).
Oxytoma expansa (Phillips) throughout.
Meleagrinella sp. at 29 ft. (bed 13).
Protocardia sp. at 30 ft. (bed 16).
Procerithium sp. abundant in the oyster-pyrites bed (12).
Belemnites spp. throughout, with phragmocones preserved at 34 ft. (bed 25).

4·2. *Kellaways Rock*

The following list has been prepared by Mr R. V. Melville of the Geological Survey on the basis of material collected by him (G.S.M. R. M. 2494–2561), with additions:

4·21. Lamellibranchiata

Anisocardia aff. *cucullata* (Tate).
Astarte (*Trautscholdia*) sp.
Camptonectes lens (J. Sowerby).
Chlamys (*Aequipecten*) *fibrosa* (J. Sowerby).
Corbula macneilli Morris, abundant.
Cucullaea sp.
Grammatodon aff. *pictum* (Milaschewitch).
Grammatodon cf. *gnoma* (d'Orbigny).
Gryphaea bilobata (J. Sowerby), abundant.
Isocyprina depressiuscula (Morris & Lycett).
Isocyprina aff. *depressiuscula* (Morris & Lycett).
Meleagrinella '*braamburiensis*' (Phillips) (doubtfully distinct from *M. echinata* W. Smith).
Modiolus bipartitus J. Sowerby, abundant.
Myopholas acuticostata (J. de C. Sowerby).
Nucula sp.
Ostrea (*Catinula*) *alimena* d'Orbigny, abundant.
Ostrea (*Lopha*) sp.
Oxytoma expansa (Phillips) (= *O. inaequivalvis* (J. Sowerby) pars).
Oxytoma sp. (= *Oxytoma* sp. Cox 1940, pl. 6, fig. 13; and see Arkell 1933, p. 194).
Pholadomya deltoidea (J. Sowerby).
Pholadomya lirata (J. Sowerby).
Pleuromya alduini (Brongniart), abundant.
Pleuromya uniformis (J. Sowerby).
Protocardia citrinoidea (Phillips).
Trigonia scarburgensis Lycett.
Trigonia elongata J. de C. Sowerby.

4·22. Brachiopoda

Rhynchonelloidella sp. indet.
Ornithella sp. cf. *ornithocephala* (J. Sowerby) pars.

4·23. Gastropoda

Cryptaulax (?) sp.
Dicroloma obtusata (Hébert & Deslongchamps).
Procerithium (*Rhabdocolpus*) *lorieri* (Hébert & Deslongchamps).

4·24. Belemnoidea

Belemnites were abundant throughout.

The preservation of the fossils is not sufficiently good to allow critical comparison with the lists published for Wiltshire by Buckman & Pringle (in H. J. O. White 1925). *Gryphaea bilobata* Sowerby was absent in the hole at Site 2 but abundant in the trench to the south, 50 yards away.

4·3. *Kellaways Clay*

This proved poorly fossiliferous. With the exception of six ammonites found near the top, it yielded only one specimen each of:

Trigonia cf. *scarburgensis* Lycett.
Pleuromya cf. *alduini* (Brongniart).
Modiolus bipartitus J. Sowerby.

5. The ammonites of the Lower Oxford Clay

Synopsis. The following species were found:

Kosmoceras (*Gulielmites*) *medea* n.sp.
Kosmoceras (*Gulielmites*) *jason* (Reinecke)
Kosmoceras (*Gulielmites*) *nodosum* n.sp.
Kosmoceras (*Gulielmiceras*) *gulielmi* (J. Sowerby) and subsp. *anterior* (Brinkmann).
Cadoceras (*Pseudocadoceras*) *concinnum* S. Buckman.
Cadoceras (*Pseudocadoceras*) *laminatum* S. Buckman.
Erymnoceras? sp.
Grossouvria cf. *comptoni* (Pratt).
Binatisphinctes cf. *fluctuosus* (Pratt).
Reineckeia (*Reineckeites*) *duplex* (S. Buckman).
Reineckeia (*Reineckeites*) sp.
Reineckeia (*Kellawaysites*) *greppini* (Oppel).

Genus **KOSMOCERAS** Waagen, 1869

Type species *Ammonites spinosus* J. de C. Sowerby, 1826 (I.C.Z.N. Opinion 303).

Nearly all the Kidlington shells ascribed to this genus fall into two groups:

(*a*) Medium-sized to large involute shells, 60 to 140 mm in diameter, with fine ribbing which is lost on the outer whorl, contracting body chamber which gives the impression of uncoiling, and smooth sinuous adult aperture;

(*b*) small to medium-sized evolute shells 30 to 60 mm in diameter with strong coarse ribbing retained on the body chamber and long narrow lappets on the adult aperture.

The smallest forms were found in the oldest, the larger in the newer beds. Following Brinkmann, the two groups are identified with two subgenera, *Gulielmites* S. Buckman and *Gulielmiceras* S. Buckman respectively.

Subgenus **GULIELMITES** S. Buckman, 1923

Type species *Gulielmites conlaxatum* S. Buckman 1923, *T.A.* IV, pl. cdxviii.

Synonym *Zugokosmokeras* Buckman in Brinkmann pars.

Ammonites, especially shells of *Kosmoceras*, were very abundant over the range of the Lower Oxford Clay exposed at Kidlington. It was therefore possible to carry out some statistical investigation of the way in which the forms of this genus change over the succession of strata, on the lines of Brinkmann's work (1929*a*) on the Lower and Middle Oxford Clay at Peterborough.

For the purposes of collection, the profile at Kidlington was divided into levels 1 cm apart, the zero point on the scale being arbitrarily chosen as the base of the hand-dug hole. This level corresponded with the first appearance of ammonites in abundance, the clays below being poorly fossiliferous; it also corresponded roughly to the level zero chosen by Brinkmann in the succession at Peterborough. The clays were found to be divisible into a series of beds each spanning a small range of levels, bounded by sharp changes in lithology. Ammonites were collected from one bed at a time; it was not possible to subdivide beds into 5 cm intervals as done by Brinkmann at Peterborough.

Only complete shells were considered, although these frequently represented only a small fraction of those present. The shells were always crushed flat, with the exception of some of those found in nodules. In consequence it may be argued that all measurements made are unreliable; however, the error introduced is estimated to be not in excess of 5 %, which may safely be ignored for the purpose of this investigation. This is supported by the fact that measurements made on the uncrushed shells found in the levels 96 to 102 cm (bed 12) are continuous with those of the crushed shells below and above. Further, although it is impossible to detect subtle differences in whorl thickness, which are rarely the basis of specific differentiation, all the fine detail of ribbing and tuberculation was exactly and fully preserved, the more so as the tests of all the shells were still present. It was therefore possible to pronounce with confidence upon the homogeneity of species within the different subgenera.

Systematically, it is proposed to use Buckman's name *Gulielmites* subgenerically for this, the *jason* group and, unlike Brinkmann, to separate it from *Zugokosmokeras*. This is done for the following reason. Although among the successors of *Kosmoceras jason* are undoubtedly to be found *K. obductum* (Buckman) and subsequently *K. grossouvrei* (Douvillé) (= *Zugokosmokeras zugium* Buckman), the direct connexion which would fit into the gap at level 135 cm at Peterborough is not found in this country. There is a sharp and complete faunal break at level 135 cm at Peterborough with *K. jason* below and *K. obductum* above. Examination of the type of *K. obductum* (O.U.M. J1851), together with other material from Calvert, shows it to be appreciably different from *K. jason* in that it is at first smaller, more involute, and differently and wholly ribbed. The differences are well shown in plate 3, figures 1 and 2, and also in Brinkmann's plate 2 (1929*a*).

Statistically, the changes in form of the subgenus have been measured in respect of two characters: the end-diameter of fully grown shells, and the diameter at which external tubercles cease. These are recorded in table 1: column 2 gives the number of individuals collected; column 3 the mean value of the end-diameter in mm with the mean probable error d; and column 4 the standard deviation of the end-diameter as a percentage of the end-diameter. The change in end-diameter is shown graphically in figure 3; the mean values are shown as thick full lines, with plus and minus three times the mean probable error indicated above and below by thin full lines.

TABLE 1. STATISTICAL VARIATION OF *KOSMOCERAS* THROUGH THE LOWER OXFORD CLAY AT KIDLINGTON

	Gulielmites				*Gulielmiceras*						
level	no. collected	end-diameter with mean probable error (mm)	standard deviation as % of end-diameter	diameter at which ext. tubercles cease (mm)	no. collected	end-diameter with mean probable error	standard deviation as % of end-diameter	no. of primary ribs on outer whorl	no. of secondary ribs on outer whorl	ratio prim./sec. ribs	length of lappet (mm)
0–23	6	58 ± 2	9·5	—	2	40 ± 3	8·8	—	—	—	5
23–36	—	—	—	—	—	—	—	—	—	—	—
36–49	—	—	—	—	—	—	—	—	—	—	—
49–96	33	77 ± 1	6·5	45	19	38 ± 1	8·5	—	—	—	7·5
96–102	2	72	—	41	1	33	—	—	—	—	—
102–127	8	75 ± 2	6·6	46	3	40 ± 3	—	—	—	—	—
127–152	14	65 ± 2	11	45	6	34 ± 2	12	24	—	—	7·5
152–173	—	—	—	—	—	—	—	—	—	—	—
173–175	3	115 ± 7	—	75	—	—	—	—	—	—	—
175–200	9	99 ± 2	6·7	66	16	56 ± 1	7·1	—	—	—	11
200–215	—	—	—	—	—	—	—	—	—	—	—
215–217	5	108 ± 3	6	—	8	54 ± 1	9	20	70	3·5	—
217–225	—	—	—	—	—	—	—	—	—	—	—
225–226	—	—	—	—	—	—	—	—	—	—	—
226–260	—	—	—	—	1	50	—	24	75	3·12	11
260–267	—	—	—	—	—	—	—	—	—	—	—
267–282	—	—	—	—	—	—	—	—	—	—	—
282–290	6	117 ± 1	4	75	12	63 ± 0·3	5	22	75	3·5	11
376	4	119 ± 4	7	70	1	63	—	—	—	—	—
443	2	140	—	88	—	—	—	—	—	—	—
488	2	115	—	—	2	54	—	—	64	—	—

In addition, occasional measurements on whorl height and umbilical width were made; these, expressed as percentages of the diameter in the usual way did not vary sufficiently, however, to be significant.

The relative abundance ratio of *Gulielmites*: *Gulielmiceras* was usually of the order of 3:1; however, in the levels 175 to 200 cm *Gulielmiceras* preponderated, whereas around 375 cm *Gulielmites* was the commoner in the ratio 10:1.

Usually the proportion of shells which were complete was of the order of 20 %; however, at 127 to 152 cm, although shells were extremely common, only about 5 % were intact.

The results at Kidlington shown in figure 3 may be compared with those obtained by Brinkmann and shown in figure 4, drawn to the same scale (see Brinkmann 1929 *a*, Tab. 39,

p. 103; and fig. 28, p. 104). It will be seen that, except for a difference in the time-scale, closely parallel evolution occurred at these two localities. At Peterborough, an increase in the size of *Gulielmites* from about 60 to 120 mm occurs in 135 cm of sediment. At Kidlington an increase from 58 to about 140 mm covers 450 cm. The increases are not wholly continuous, and the discontinuities seem to occur at about the same diameters.

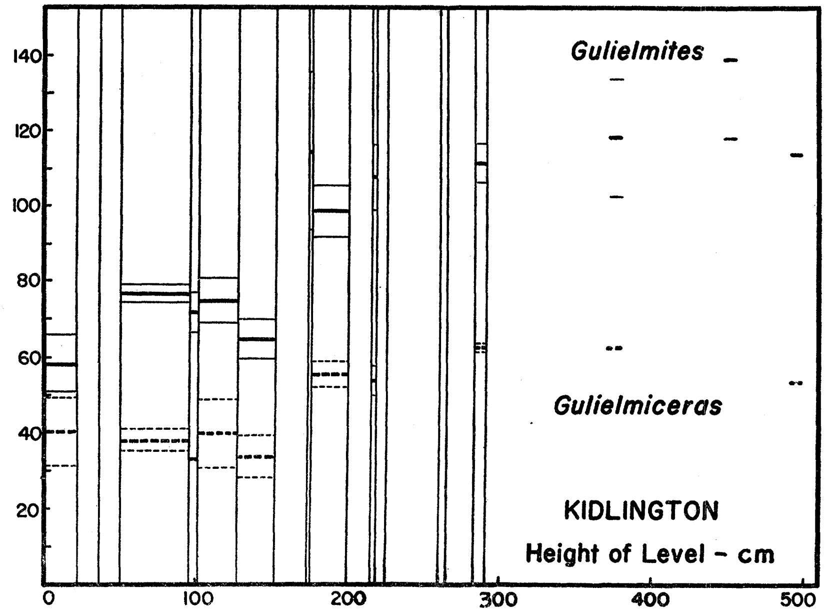


FIGURE 3. The stratigraphical changes in the end-diameter of *Gulielmites* and *Gulielmiceras* at Kidlington. (Vertical scale, mean end-diameter of shell in mm.)

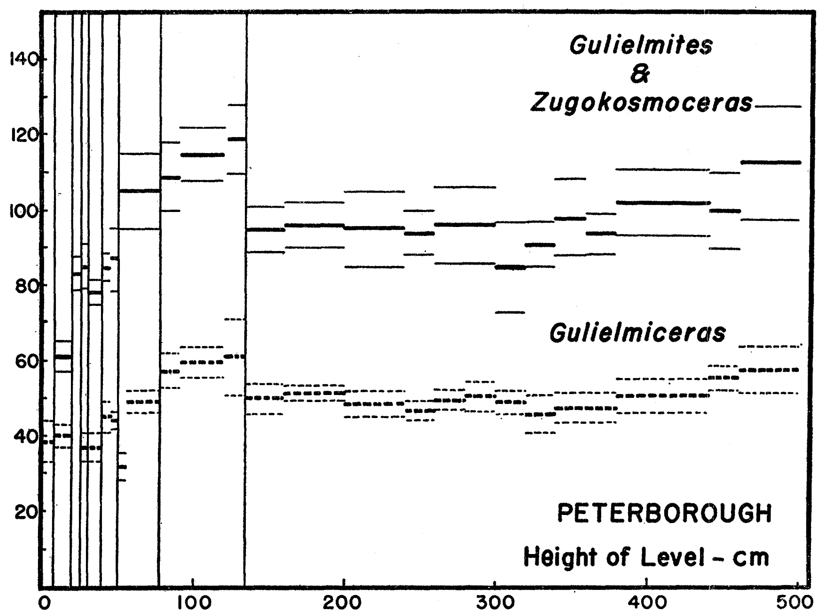


FIGURE 4. The stratigraphical changes in the end-diameter of *Gulielmites*, *Zugokosmokeras* and *Gulielmiceras* at Peterborough (after Brinkmann 1929*a*, Tab. 39, p. 103, and Tab. 63, p. 133). (Vertical scale, mean end-diameter of shell in mm.)

There is an anomalously low value at one point, at levels 127 to 152 cm at Kidlington, which is associated with an abnormally low proportion of intact shells, and Brinkmann's explanation (p. 42) that any excessive destruction, due, for example, to wave action in a slowly accumulating sediment, would tend to destroy large shells more than small ones, thus leaving an intact assemblage biased in favour of the smaller shells, may well be correct. It would predict an abnormally high standard deviation due to the effect of selective destruction in addition to natural variability, and this is observed—11 % compared with the normal 7 %. In addition, there is no corresponding dip in the value of the diameter at which external tubercles disappear.

The sharp break at level 135 cm at Peterborough was not observed at Kidlington although the last figures given in table 1 may refer to shells of a later type. They were, however, very badly preserved owing to proximity to the surface, and details of ornament were indistinct. The 135 cm gap at Peterborough would appear, according to Brinkmann, to correspond to a considerable time interval of non-sedimentation, and it may therefore be that the shells from level 443 cm at Kidlington, which are appreciably larger than the largest at Peterborough, are of a later age than level 135 cm at Peterborough and of a type absent there.

It is proposed to follow Brinkmann in dividing the above range of forms into two species.

Kosmoceras (Gulielmites) medea n.sp.,* plate 2, figures 1 to 4; plate 3, figures 3, 4

Cosmoceras Jason Douvillé 1915, p. 36; pl. 9, fig. 7; pl. 10, figs. 4, 5.
Kosmoceras (Zugokosmoceras) enodatum posterior Brinkmann 1929*a*, p. 102; pl. 2, fig. 1.
Kosmoceras (Zugokosmoceras) enodatum Brinkmann 1929*b*, *Kosm.* p. 39 (pars).
Cosmoceras jason Corroy 1932, p. 160; pl. 25, figs. 1–3 (fine-ribbed variety).
Cosmoceras enodatum Corroy 1932, p. 161, pl. 25, figs. 8, 9 only.

Number of specimens collected. 63, levels 0 to 152 cm.

Description of the types. The holotype (O.U.M. J 6057), together with the small paratype (O.U.M. J 6131) and the paratype (O.U.M. J 1379), came from a cementstone nodule, levels 96 to 102 cm (the oyster-pyrites bed, 12) out of a trench opposite the King's Arms Inn, Gosford, Kidlington (G.R. (4)503(2)135). The dimensions are:

Holotype: at 71 mm: 35, 26, 32.
50 mm: 48, 26, 21.
Small paratype: 15 mm: 43, 34, 31.

The nucleus up to 15 mm is that of a typical *Kosmoceras*, evolute with comparatively broad smooth venter and rounded trapezian cross-section with about 60 % inclusion of inner whorls. At larger diameters, the shell becomes more compressed and involute, of subtriangular section, the sides becoming flat and the venter narrow in comparison with the diameter. Inner whorls are four-fifths included, giving a narrow and deep umbilicus. The body chamber commences at a diameter of 52 mm and occupies three-fifths of a whorl; at the same time the umbilical seam begins to uncoil so that at the aperture the inner whorl is less than half overlapped. Near the aperture the section becomes suddenly more inflated with corresponding flattening of the venter, so that at the aperture it is elliptical. The peristome is smooth and slightly sinuous. The maximum size is 71 mm.

* Medea was the wife of Jason.

On the nucleus the primary ribs start strongly in the umbilicus and with gentle sweep forward connect each with one lateral tubercle placed two-fifths of the way up the whorl side. From the lateral tubercles the secondary ribs, 2–3 commencing at each tubercle, pass with pronounced forward sweep each to a ventral tubercle, a row of these on each side bordering the flat, smooth venter. As the shell grows, the primary ribs swell at their point of commencement into short sharp ridges which serve to define sharply the umbilical edge and give the appearance of a row of tubercles. Between these and the lateral tubercles the primary ribs become weaker, forming a partly smooth spiral band reminiscent of the much later *K. proniae* Teisseyre. The secondary ribs become finer, weaker and more numerous. At about 25 mm, the lateral tubercles degenerate into ridges, and finally fade at 35 mm, the whorl side becoming nearly smooth. The external tubercles fade and finally disappear at 40 to 45 mm, the venter becoming rounded, and the last traces of the secondary ribs have disappeared near the venter at 50 mm. Remnants of the umbilical ridges persist as gently rounded nodes, and on the body chamber these strengthen temporarily into a series of strong, distant, straight, prorsiradiate ridges passing well up the whorl side. Near the aperture the shell is again wholly smooth.

The suture-line is simple with small short lobes on a straight base-line, indistinguishable from that of *K. jason*. As so often, sutures of *Kosmoceras* are very variable between individuals of the same species, and are useless as a basis for specific differentiation.

Similarly, the ornamentation is subject to a good deal of variability, especially on the body chamber: there is complete gradation between individuals having the strong ridges of the holotype, reminiscent of *Sigaloceras calloviense*, and ones having only a row of round umbilical nodes so characteristic of *Kosmoceras jason*.

Comparison with allied species. This species was grouped by Brinkmann with *K. enodatum* Nikitin (1881 *b*, p. 112, pl. 10, figs. 12, 13 *a*, *b*) from Elatma in Russia. The latter is, however, quite different and is probably a *Sigaloceras*. It differs from *Kosmoceras medea* in being more inflated and having no lateral tubercles after a diameter of about 25 mm; little distinction between primary and secondary ribs; and no ventral tubercles at the point where the venter of the outer whorl first becomes visible (*ca*. 30 mm), at which point the secondary ribs are still strong and pass over the venter in full strength.

Also included in *K. enodatum* by Brinkmann are the three ammonites from South Cave in Yorkshire figured by Buckman as *Catasigaloceras planicerclus* (*T.A.* IV, pl. cdxvii), *C. crispatum* (*T.A.* V, pl. cdxxxiv) and *C. curvicerclus* (*T.A.* V, pl. cdxxxv) (which are doubtfully distinct specifically). These, too, belong to *Sigaloceras*, as listed by Spath (1933, p. 856; 1934, p. 111) and Arkell (1944, p. 340), although they are distinct from *Sigaloceras enodatum* (Nikitin). In the absence of ventral views, Buckman's photographs show much resemblance to *Kosmoceras medea*, but handling of the large number of specimens from South Cave in the S.M. shows the same essential differences to exist between *K. medea* and *Catasigaloceras* Buckman as between *Kosmoceras medea* and *Sigaloceras enodatum* (Nikitin). These differences may be seen by comparing the specimen of *S. planicerclus* figured here (plate 2, figure 5) with the type of *Kosmoceras medea* (plate 2, figure 1). Although South Cave lies south of the Market Weighton axis, *Sigaloceras planicerclus* has not so far been found in the south of England and *S. calloviense*, together with the much more common *Kepplerites*, seems to be absent at South Cave (see below, p. 244). The distinction between

Sigaloceras planicerclus and *S. calloviense* may be seen by comparing the specimen of the former shown in plate 2, figure 5, with the septate nucleus of the latter from the Kellaways Rock of Wiltshire shown here in plate 3, figure 5, and adult, plate 3, figure 6.

S. planicerclus also occurs in north-west Germany in the Weser-Wiehengebirge, from which v. See (1910, p. 714; pl. 22, figs. 4, 5) figured two shells under the name *Kepplerites franconicus* Greif. However, Greif first applied his MS. name to forms from the Franconian Jura, one of which is figured by Reuter (1908, p. 115) and is quoted by v. See in his synonymy. This, together with the two shells figured by v. See, is therefore a syntype of *K. franconicus* v. See, 1910 (Greif did not publish his name). As there appear to be material differences between Reuter's figure and v. See's two figures, it is proposed to designate Reuter's syntype as lectotype of *Sigaloceras franconicum* (v. See), and to use for v. See's other syntypes the name *S. planicerclus* (S. Buckman).

S. planicerclus occurs also in Switzerland at Herznach, Aargau, from which locality Jeannet (1951) figured five specimens under the name *Kepplerites enodatum* Nikitin (p. 156; pl. xxv, figs. 8, 9, not 10; pl. xxvi, figs. 12–14). R. Douvillé's (1915) pl. 9, fig. 2, from the south-west margin of the Paris Basin (Deux-Sèvres), may also be of this species.

On the other side, *Kosmoceras medea* passes into *K. jason*, from which it differs mainly in size and degree. An arbitrary junction would appear to fall most suitably at a diameter of 90 mm, limiting *K. medea* to shells of diameters between 60 and 90 mm, and *K. jason* to shells greater than 90 mm in diameter.

Range and distribution. *K. medea* appears to be limited to the lower part of the *jason* Zone at levels corresponding at Kidlington to 0 to 173 cm, and at Peterborough to 0 to 50 cm. It is common at similar levels at Calvert brick pit, Buckinghamshire, and at Weymouth (Putton Lane brick pit, collected by the author 1951); also Kent (Guilford and Dover Collieries), and throughout the Paris Basin (Douvillé 1915; Corroy 1932).

Kosmoceras (Gulielmites) jason (Reinecke), plate 2, figure 6; plate 3, figure 2

Type (neotype) *Gulielmites jason* S. Buckman 1924, *T.A.* v, pl. diii. From Gammelshausen, Württemberg.

Nautilus Jason Reinecke 1818, p. 62; pl. iii, figs. 15–17.
Ammonites Jason Zieten 1830, p. 5; pl. iv, figs. 6*a–c*.
Ammonites Sedgwickii Pratt 1842, p. 163; pl. v, fig. 1.
Ammonites Jason d'Orbigny 1845, p. 442; pl. xxxvi, figs. 13–15 (not 9–12).
Ammonites Jason d'Orbigny 1847, p. 446; pl. cdx, figs. 1, 2 (not 3, 4).
Ammonites Jason Quenstedt 1849, p. 140; pl. x, figs. 4*a*, *b*, 5*a*, *b*.
Cosmoceras Jason Bayle 1878, pl. lxii, figs. 1, 2.
Cosmoceras subnodatum Teisseyre 1884, p. 553; pl. ii, figs. 9–11.
Ammonites Jason Quenstedt 1887, p. 713; pl. lxxxiii, figs. 1, 3, 11, 14, 16, 18, 19 (not 9, 12, 13, 15, 17).
Ammonites Jason compressus Quenstedt 1887, p. 714; pl. lxxxiii, fig. 2.
Cosmoceras Jason Reuter 1908, p. 112; Textbeilage F, fig. 1.
Cosmoceras Jason Douvillé 1915, p. 36; pl. ix, fig. 6; pl. x, figs. 3, 3*a*, 9 (not 4–8); text-figs. 18–20, p. 65.
Gulielmites conlaxatum Buckman 1923, *T.A.* iv, pl. cdxviii.
Gulielmites jason Buckman 1924, *T.A.* v, pl. diii (neotype).
Gulielmites delicatus Buckman 1924, *T.A.* v, pl. dxxi.
Gulielmites sedgwickii Buckman 1925, *T.A.* vi, pl. dxcviii.
Kosmoceras (*Zugokosmoceras*) *Jason Jason* Brinkmann 1929*a*, pl. ii, fig. 2.
Kosmoceras (*Zugokosmoceras*) *Jason* Brinkmann 1929*b*, p. 43 pars.

Number of specimens collected. 31, above level 173 cm.

Remarks. This common species represents another case of a highly ornamented species in which no two individuals are quite alike. Ribbing, dimensions and suture are all subject to considerable variation. The main characteristics are the size (100 to 150 mm), smooth body chamber, and the strong rounded nodes, sometimes growing into simple rounded ridges passing well up the whorl side of the outer whorl. The body chamber aperture is smooth, somewhat sinuous, and has no lappet.

The original figure by Reinecke (1818) is of a nucleus of unknown size, for he did not state the degree of magnification, and the type appears to be lost. Zieten's figure similarly shows an incomplete specimen. The first to connect these small nuclei with the large smooth shells appears to have been d'Orbigny (1845), although he also included in the synonymy *Ammonites Gulielmi*, *A. Castor* and *A. Pollux*, and others. In this he was followed by later authors, notably Quenstedt, and although *Kosmoceras pollux* was subsequently separated again by Neumayr (1876, p. 343) and *K. castor* by Nikitin (1881*a*, p. 71), confusion between *gulielmi* and *jason* persisted (e.g. Douvillé 1915). The true distinctions were first clearly established and the synonymies unravelled by Brinkmann (1929*a*, *b*). A neotype, also a nucleus, was figured by Buckman (1924). It agrees well with Reinecke's figure. Unfortunately, both Reinecke's figure and the neotype are too small to be attributable definitely to *K. jason*, for both could equally well be nuclei of *K. medea* or *K. obductum*. The first large shells were figured by d'Orbigny (1845, 1847), and his figures are probably idealized and not necessarily accurate. It is therefore uncertain whether d'Orbigny's 1845 figure is based on Russian material. It is also doubtful whether much of the material from eastern Europe described under *K. jason* (e.g. Krenkel 1915 from Popilany) truly belongs to this species; although it has the smooth body chambers the inner whorls appear to be of later style suggestive of *K. obductum* of the *coronatum* Zone. A specimen of *K. obductum*, probably from Wiltshire, is shown here in plate 3, figure 1, for comparison with *K. jason*.

K. (*Gulielmites*) *effulgens* Buckman (1925, *T.A.* VI, pl. dxcvii A, B) was also included by Brinkmann in his synonymy of *K. jason* as a 'phylogenetic late-form', presumably on the assumption that it came from the *jason* Zone. The type, however, came from a well-sinking and boring at Gosford Hill Farm, $\frac{3}{8}$ mile east-south-east of the present Site 1, at a height of 73 ft. above the Cornbrash. This is 47 ft. 10 in. above the level 'zero' at Site 1, corresponding to level +1458 cm, and cannot possibly be in the *jason* Zone. Unfortunately other *Kosmoceras* found at the same locality as *effulgens* (in the G.S.M.) are too small to be specifically identifiable, but appear to be of post-*jason* type. There is, in addition, a specimen of *K. effulgens* in the O.U.M. (J1289) from Calvert, but from an unknown level. The species is distinguished from *K. jason* mainly by its almost complete absence of ribbing on the outer whorls.

Kosmoceras (Gulielmites) nodosum n.sp.

Holotype *Kosmoceras* (*Kosmoceras*) n.sp. Brinkmann 1929*a*, p. 174, pl. iii, fig. 13.
Kosmoceras (*Kosmoceras*) n.sp. Brinkmann 1929*b*, *Kosm.*, p. 86.

Number of specimens collected. 3, incomplete but uncrushed, all from levels 96 to 102 cm (oyster-pyrites bed, 12).

Remarks. A few specimens occurred in an uncrushed state in the nodules at 96 to 102 cm. They agree well with Brinkmann's figure and his description cannot be bettered. The species resembles *K. jason* in size (about 80 to 90 mm), the loss of fine ribbing on the body chamber and the simplicity of its adult aperture. It differs from *K. jason* in being more evolute and inflated, and in the coarseness of its lateral tubercules, of which it has a double row, large and widely spaced. External tubercles are lost at an earlier stage with a resulting rounder venter. The style of ribbing varies much.

Brinkmann placed this species in *Kosmoceras sensu stricto* as the alleged antecedent of a number of rare forms, becoming more frequent in later strata, which he claimed lead to the familiar *spinosum* type of shell. While the connexion with some of these later forms, e.g. *K.* (*Kosmoceras*) *pollucinum anterior* Brinkmann (*non* Teisseyre 1884) (1929*a*, pl. iii, fig. 14), may be real, a direct connexion with *K. spinosum* is improbable, as this, together with *K. compressum* (Quenstedt 1849), seems to be directly traceable back to *Gulielmiceras* or *Spinikosmokeras* of the *coronatum* Zone. The species is therefore placed here provisionally in *Gulielmites* on morphological grounds. It occurs at similar levels at Calvert.

Subgenus **GULIELMICERAS** S. Buckman, 1920

Type species *Ammonites Gulielmi* J. Sowerby 1821, *Min. Conch.* IV, p. 5, plate cccxi.

Synonym *Anakosmokeras* S. Buckman 1924: *Anakosmoceras* Brinkmann, 1929*a*, *b*.

Apart from the fact that Brinkmann apparently overlooked the prior use of *Gulielmiceras* by Buckman in 1920 instead of 1924, it is proposed to retain here Brinkmann's subgeneric attribution. Although the inner whorls strongly resemble those of *Gulielmites*, it is easy to distinguish the two subgenera by the size of fully grown individuals, the coarseness of ribbing, the strength of tubercles, and the form of the adult aperture.

At Kidlington, *Gulielmiceras* was not as common as *Gulielmites*, and hence rather less data were obtained (see table 1). The changes in end-diameter are followed graphically in figure 3 (lower part, dotted lines).

Gulielmiceras follows roughly the same course at Kidlington as at Peterborough. Again the shells from levels 127 to 152 cm are rather smaller than those above and below, for presumably the same reason as in *Gulielmites*.

Kosmoceras (**Gulielmiceras**) **gulielmi** (J. Sowerby)

Ammonites Gulielmi J. Sowerby 1821, *Min. Conch.* IV, p. 5; pl. cccxi.
Ammonites Gulielmi Zieten 1830, p. 19; pl. xiv, fig. 4.
Ammonites Elizabethae Pratt 1842, p. 162; pl. iii, fig. 2.
Ammonites Stutchburii Pratt 1842, p. 163; pl. iv, figs. 2, 3.
Ammonites Jason d'Orbigny 1847, p. 446; pl. clix, figs. 1–5 (not pl. clx).
Ammonites Jason Damon 1860, p. 28, fig. 16.
Cosmoceras Jenzeni Teisseyre 1884, p. 569; pl. iii, fig. 23*a*, *b*, *c*.
Ammonites Jason (*Gulielmi*) Quenstedt 1887, p. 714; pl. dxxxiii, figs. 4, 5, 17.
Cosmoceras Jason Douvillé 1915, p. 36; pl. x, figs. 6, 7, 8.
Gulielmiceras gulielmi S. Buckman 1920, *T.A.* III, pl. cxciv (topotype).
Anakosmokeras stutchburii Buckman 1924, *T.A.* v, pl. dxxxi (not dxxxi A) (holotype refigured).
?*Gulielmiceras intronodulatum* Buckman 1924, *T.A.* v, pl. dxxxii.
Kosmoceras (*Anakosmoceras*) *Gulielmii anterior* Brinkmann 1929*a*, pl. iii, fig. 1.
Kosmoceras (*Anakosmoceras*) *Gulielmii Gulielmii* Brinkmann 1929*a*, pl. iii, fig. 2.
Kosmoceras (*Anakosmoceras*) *Gulielmii* Brinkmann 1929*b*, *Kosm.* p. 58 (pars).

Number of specimens collected. 71, levels 0 to 488 cm.

Remarks. There is some doubt as to the type locality. Sowerby did not state an exact locality or bed but suspected that 'it was found in the clay above the Kelloways Rock'. Brinkmann stated that the type came from the 'Kelloway Clay, probably Wiltshire', presumably as a consequence of J. W. Tutcher's statement appended to the photograph of a paratype of Pratt's *Ammonites Stutchburii* (*?Gulielmiceras intronodulatum* Buckman, see above) that its matrix was 'light blue, matching Kell. Clay Macrocephaloids'. In addition, Buckman states that the topotype of *A. Gulielmi* figured by him (see synonymy above) came from the upper Kellaways Rock of Kellaways, again by deduction from matrix.

The true source of both the holotype and Buckman's topotype seems most probably to be a series of septarian nodules in the Oxford Clay of the Chippenham district at or near the same level as the nodules at Kidlington at levels 173 to 175 cm (bed 16). Parts of such nodules, labelled 'Chippenham' and crowded with ammonites, some closely resembling the holotype of *gulielmi*, are in the O.U.M., and the Kidlington nodules have yielded similar ammonites. The matrix of such nodules, when weathered, strongly resembles the more calcareous Kellaways Rock, and this probably explains Buckman's statement concerning the origin of his topotype.

The failure of English geologists to record whether their specimens came from the clays above or below the Kellaways Rock was deplored by Oppel (1857, p. 515), and has caused much confusion since.

Following Brinkmann, one specific name is used for the forms encountered over this range of strata. The earlier shells are perhaps rather more strongly ribbed than the later, but it seems impossible to detect any difference useful as a basis of specific differentiation. As the figures of the types of *A. Gulielmi* Sowerby and *A. Stutchburii* Pratt are both of the later forms, it may be expedient to designate the earlier smaller forms as subspecies *anterior* Brinkmann 1929.

Occasionally a shell was found which was sufficiently strongly ribbed to be classed with the subgenus *Spinikosmokeras* Buckman. Of note are the two shells found in the highest layers at 488 cm, which show a marked decrease in both end-diameter and density of secondary ribbing on the outer whorl compared with earlier shells. If this decrease is real, it would appear to indicate that the sharp discontinuity observed by Brinkmann at Peterborough at 135 cm, if also present at Kidlington, lies between 443 and 488 cm, and that the two shells from 488 cm are already from the beds containing *Kosmoceras obductum* of the *coronatum* Zone. The nodules at 173 to 175 cm also produced incomplete specimens of a type of shell more inflated than the true *gulielmi*, but this seemed to be linked by intermediates to the normal form.

Genus **CADOCERAS** Fischer, 1882

Type species *Ammonites sublaevis* J. Sowerby 1814, *Min. Conch.* I, p. 117; pl. liv.

Subgenus **PSEUDOCADOCERAS** Buckman, 1919

Type species *Pseudocadoceras boreale* Buckman 1919, *T.A.* II, pl. cxxi B.

The subgenus is characterized mainly by its relatively small size, compressed shell strongly and wholly ribbed when fully grown, and a sharp venter across which the ribbing passes with increased strength. It is the small 'complement' to *Cadoceras sensu stricto* (see below under *Macrocephalites*, p. 237).

Of the four syntypes of *Amm. longaevus* Leckenby, 1859, three are of true Kellaways Rock age and the fourth is from the Hackness Rock. One of the former was made holotype of *Pseudocadoceras boreale* Buckman (*T.A.* II, pl. cxxi B), while the latter was designated by Buckman (*T.A.* II, pl. cxxi A) lectotype of *Longaeviceras longaevum* (Leckenby), the genotype of *Longaeviceras*. Arkell has compared the type of *longaevum* with the figures of *Cadoceras nikitini* Sokolov (1912, pl. i, fig. 3*a–d*) from N. Russia, which are of one specimen which can be taken to pieces showing the various stages of growth of the shell, and he points out that probably they are specifically identical. *Longaeviceras* therefore grows up into a large smooth cadicone, wholly unlike *Pseudocadoceras*.

Pseudocadoceras occurs in the Kellaways Rock of the Yorkshire coast, South Cave and Wiltshire. *Longaeviceras* appears to occur in the *athleta* Zone (Oxford, old brick pits; Woodham, Buckinghamshire, author's collection) and *lamberti* Zone (Hackness Rock, the lectotype of the type species, and a topotype in the O.U.M. in the same piece as a *Quenstedtoceras lamberti* (O.U.M. J 1290)).

Cadoceras (**Pseudocadoceras**) **concinnum** Buckman

Pseudocadoceras? concinnum Buckman 1927, *T.A.* VII, pl. dccxxxv.

Number of specimens collected. 3; 1 at level 376 cm (bed 26), 2 at 282 to 290 cm (bed 26).

Remarks. All the specimens, as well as the holotype from Christian Malford, are crushed flat. The agreement in style and density of ribbing between the holotype and the Kidlington specimens is good.

Cadoceras (**Pseudocadoceras**) **laminatum** Buckman

Pseudocadoceras? laminatum Buckman 1927, *T.A.* VII, pl. dccxxvii.

Number of specimens collected. 1, at level 185 cm (bed 18).

Remarks. The species is distinguished from the foregoing by its considerably coarser ribbing. Both the Kidlington specimen and the type from Christian Malford have thirty-two ribs on the outer whorl, as opposed to thirty-nine in *C.* (*P.*) *concinnum*.

Both this and the foregoing species were originally defined by Buckman (1929*a*) on the basis of Canadian material; but his paper, written in 1922, was not published until 1929, and the specimens from Christian Malford figured under these two names in *Type Ammonites* in 1927 therefore became holotypes.

Genus **ERYMNOCERAS** Hyatt, 1900

?Erymnoceras sp.

Number of specimens collected. 2, parts; from the oyster-pyrites bed (12). Poorly preserved.

Genus **GROSSOUVRIA** Siemiradzki, 1898

Type species *Perisphinctes subtilis* Neumayr, 1870, designated by Buckman 1920, *T.A.* III, p. 28 (see also Arkell 1939, p. 157, footnote).

Grossouvria cf. **comptoni** (Pratt)

Ammonites Comptoni Pratt 1842, p. 163; pl. iv, fig. 1.
Binatisphinctes comptoni Buckman 1924, *T.A.* v, p. 25; pl. cdlxxxv (holotype refigured).
Perisphinctes comptoni Brinkmann 1929*a*, p. 38.

Number of specimens collected. 2; 1 at 420 cm and 1 at 520 cm (bed 26).

Remarks. Both specimens were crushed and are tentatively assigned to this species on general appearance. The type is relatively small and has a lappet. The systematic position of this and allied species is doubtful but they are probably assignable to *Grossouvria* rather than to *Binatisphinctes*, as already remarked by Spath (1931, p. 327).

Genus **BINATISPHINCTES** Buckman, 1921

Type species *Ammonites binatus* Leckenby (lectotype designated and figured by Buckman 1921, *T.A.* III, pl. cclxi A).

?Binatisphinctes cf. **fluctuosus** (Pratt)

Ammonites fluctuosus Pratt 1842, p. 163; pl. vi, fig. 1.
Binatisphinctes fluctuosus Buckman 1925, *T.A.* VI, pl. dcxv.

Number of specimens collected. 3; at 440 cm (bed 26), 280 cm (bed 25) and 120 cm (bed 13).

Remarks. Again assignment is by general appearance. The species differs from the foregoing in attaining a much greater size, the ribbing on the outer whorls becoming modified and very coarse and finally fading almost entirely. The specimens from levels 120 and 440 cm were over 300 mm in diameter. Owing to the poor state of preservation it was impossible to make a definite distinction from the closely allied forms called *Orionoides* by Spath (1931, p. 327) (the type of which is *Perisphinctes pseudorion* Waagen and not *Orionoides sita* as stated by Gérard & Contaut (1936, p. 57)). However, there is no doubt about the distinction from *Grossouvria*.

Genus **REINECKEIA** Bayle, 1878

Type species *Ammonites anceps* (Reinecke)

Subgenus **REINECKEITES** Buckman, 1924

Type species *Reineckeites duplex* Buckman 1924, *T.A.* v, pl. dxxii.

Reineckeia (**Reineckeites**) **duplex** (Buckman)

Reineckeites duplex Buckman 1924, *T.A.* v, p. 33, pl. dxxii.

Number of specimens collected. 1, at levels 127 to 152 cm (bed 14); and 1 fragment at levels 0 to 40 cm (bed 9 or 10).

Remarks. Agreement with the holotype is excellent. The complete specimen is only partly crushed and shows a complete lappet, constrictions, a ventral smooth band, and a coronate nucleus.

It may be that as more examples of this group are obtained, *R. duplex* will prove to be synonymous with *R. stuebeli* (Steinmann), 1881, as was pointed out by Spath (1928, p. 256). There is certainly a great resemblance to the examples from the east of France figured by d'Orbigny (1847, pl. clxvi, figs. 3, 4, lectotype of *R. stuebeli*, designated by Petitclerc 1915, p. 101) and by Corroy (1932, pl. xiv, figs. 3–7, not 1, 2). The type of *R. duplex* came from

'Greenhill' near Weymouth. Damon (1860, pp. 30, 31) includes in lists of ammonites from Greenhill and Radipole Backwater *Ammonites macrocephalus*, *koenigi*, *modiolaris* and *jason*, as well as later ones, but his determinations cannot be relied upon. It may thus well be that the type of *Reineckeia duplex* came from nodules in the Lower Oxford Clay, perhaps the *jason* Zone.

Brinkmann (1929*a*, p. 38) records one specimen of this group, identified by Spath as *Reineckeia* cf. *stuebeli*, from the *jason* Zone (level 70 cm) at Peterborough; another, in the B.M., is from the Lower Oxford Clay of Tytherton, Wiltshire, and was figured by Spath (1928, p. 270; pl. xxxiv, fig. 6). A third, G.S.M. 72894, is from 'near Weymouth, Dorset.' Dr Arkell has also found a fragment of *Reineckeia* cf. *rehmanni* (Oppel) in the *jason* Zone of Peterborough. In addition, there is a *Reineckeia* (*Reineckeia*) cf. *anceps*, agreeing closely with specimens figured under this name by Corroy (1932, pl. xiii, figs. 1–5), from the *coronatum* Zone of Calvert in the Gaddum collection in the O.U.M. (J 1291). It is seen, therefore, from the above and following sections that *Reineckeia* is commoner than supposed in the Lower Oxford Clay of this country (Arkell 1947*b*, p. 30).

Reineckeia (**Reineckeites**) sp. indet.

Number of specimens collected. 1, from level 282 cm (bed 26), now in the G.S.M.; and 1 seen loose. Too badly preserved for closer identification.

Subgenus **KELLAWAYSITES** Buckman, 1925

Type species *Reineckeia multicostata* Petitclerc, 1915

Reineckeia (**Kellawaysites**) **greppini** (Oppel)

Ammonites Greppini Oppel 1862, p. 154.
Reineckeia Greppini Roman & Sayn 1930, p. 194 (type).
Reineckeia Greppini Corroy 1932, p. 122; pl. 15, figs. 2–4.

Number of specimens collected. 1, at levels 260 to 282 cm (bed 25).

Remarks. Confusion in the interpretation of this species was due to a misunderstanding of Oppel's synonymy and the fact that Oppel did not publish a figure, as has been pointed out by Roman (1930), who first figured Oppel's type specimen; see also Corroy (1932, p. 123).

6. The ammonites of the Kellaways Rock and Sand

Synopsis. The following species were found:

Kepplerites gowerianus (J. de C. Sowerby) and spp. aff. *gowerianus*.
Sigaloceras (*Sigaloceras*) cf. *calloviense* (J. Sowerby).
Cadoceras (*Cadoceras*) *sublaeve* (J. Sowerby).
Cadoceras (*Cadoceras*) sp.
Macrocephalites (*Macrocephalites*) sp.
Proplanulites koenigi (J. Sowerby).

Ammonites were common in the Kellaways Rock of Kidlington, but poorly preserved. As a rule only body chambers were found as casts, and some phragmocones filled with sediment. The casts were invariably of compacted sand coated with the remains of a friable white shell, crushed and distorted. In the circumstances no close identifications could be made.

Genus **KEPPLERITES** Neumayr, 1892

Type species *Ammonites Keppleri* Oppel.

Kepplerites gowerianus (J. de C. Sowerby) and spp. aff. **gowerianus**

Ammonites Gowerianus J. de C. Sowerby 1826, *Min. Conch.* VI, p. 94; pl. dxlix, fig. 2.

Number of specimens collected. 7, and others seen.

Remarks. The preservation of the specimens was poor, but they appeared to cover the range of forms illustrated by Buckman (*T.A.*).

While the classification of this group has been rendered unnecessarily complex by the large number of new names introduced by Buckman, Brinkmann appears to have gone to the other extreme of including a large range of forms under one name. The forms described under *Torricelliceras* by Buckman (type species *Ammonites torricellii* Oppel, 1862) differ from *Kepplerites* in being much smaller and having lappets. They appear to be the small 'complement' of *Kepplerites* (cf. below under *Macrocephalites*, p. 237).

Ammonites uralensis d'Orbigny (1845, p. 429; pl. xxxii, figs. 6–10) included by Brinkmann in his synonymy of *Kepplerites gowerianus* is not a *Kepplerites* but a Kimeridgian *Rasenia* (see Arkell 1951, p. 179).

Genus **SIGALOCERAS** Hyatt, 1900

Including *Catasigaloceras* Buckman, 1923 (as subgenus).
Type species *Ammonites calloviensis* J. Sowerby

Sigaloceras (**Sigaloceras**) cf. **calloviense** (J. Sowerby)? (plate 3, figures 5, 6).

Ammonites calloviensis J. Sowerby 1815, *Min. Conch.* II, p. 3; pl. civ.
Ammonites calloviensis d'Orbigny 1847, p. 455; pl. clxii, figs. 10, 11.
Kepplerites calloviensis R. Douvillé 1915, p. 31; pl. vii, fig. 2 only; pl. viii, figs. 6, 7 only; pl. ix, fig. 4.
Sigaloceras micans Buckman 1921, *T.A.* III, pl. cclv.
Kosmoceras (*Kepplerites*) *calloviense* Brinkmann 1929*b*, *Kosm.* p. 29.

Number of specimens collected. 1, part of a body chamber.

Remarks. The species appears to be somewhat local. It is common in the Kellaways Rock of Wiltshire and South Gloucestershire, but I have failed to find any originating from farther north than Kidlington. A record from South Cave by Spath (1933, p. 856; 1934, p. 111) was based on three nuclei in the Alexander collection (SM 3339–3341) which are too small to identify specifically but which are definitely not *Sigaloceras calloviense*. Comparison with the large amount of material in the C. W. Wright collection from South Cave in the Sedgwick Museum shows that they are nuclei of *Catasigaloceras*. The distinction between *S.* (*C.*) *planicerclus* and *S.* (*S.*) *calloviense* may be seen by comparing the specimen of the former shown in plate 2, figure 5, with the septate nucleus of the latter from the Kellaways Rock of Wiltshire shown here in plate 3, figure 5. The species also occurs in Normandy and the Boulonnais (Douvillé 1915).

Genus **CADOCERAS** Fischer, 1882

Subgenus **CADOCERAS** *sensu stricto*

Type species *Ammonites sublaevis* J. Sowerby, 1814, designated by Spath 1932*a*.

Cadoceras (Cadoceras) sublaeve (J. Sowerby)

Ammonites sublaevis J. Sowerby 1814, *Min. Conch.* I, p. 117; pl. liv.

Number of specimens collected. 6.

Remarks. The larger figure on Sowerby's plate was designated lectotype of *Cadoceras sublaeve* by Pompeckj (1900, p. 77).

Cadoceras (Cadoceras) sp.

Number of specimens collected. 2.

Remarks. These were more strongly ribbed, retaining the ribbing longer than *C. sublaeve.*

Genus **MACROCEPHALITES** Zittel, 1884

(See below, p. 237)

Subgenus **MACROCEPHALITES** *sensu stricto*

Macrocephalites (Macrocephalites) sp.

Number of specimens collected. 1, from the basal foot of the bed, 5*a*.

Remarks. The specimen is badly preserved but is assigned to *Macrocephalites sensu stricto* because it is large, over 200 mm in diameter, has a narrow and deep umbilicus, and is wholly and finely ribbed, with the ribbing fading on the umbilical part of the last whorl near the aperture.

Genus **PROPLANULITES** Teisseyre, 1884

Type species *Ammonites Koenigi* J. Sowerby

Proplanulites koenigi (J. Sowerby)

Ammonites koenigi J. Sowerby 1820, *Min. Conch.* III, pl. clxiii, fig. 3.

Number of specimens collected. 2, and others seen.

7. The ammonites of the Kellaways Clay

Ammonites were confined to the top two feet of the Clay (bed 4), although rare fragments occurred throughout. They were first identified by Dr Arkell who made most of the identifications which follow. The preservation was as uncrushed casts, mainly of body chambers, in a brownish grey chalky matrix, and coated with a characteristic reddish brown layer, which clearly distinguishes them from the light blue or grey preservation and matrix of other familiar Kellaways Clay ammonites. Small well-formed ruby crystals of zinc-blende adhere to the interiors of some of the body chambers. They were identified by X-ray diffraction methods by Mr A. W. G. Kingsbury of the Department of Geology and Mineralogy, Oxford.

Synopsis. The following species were found:

Macrocephalites (*Kamptokephalites*) *kamptus* Buckman.
Macrocephalites (*Kamptokephalites*) aff. *herveyi* (J. Sowerby).
Macrocephalites (*Kamptokephalites*) cf. *bedfordensis* or *subpila* Spath.
Macrocephalites (*Dolikephalites*) *typicus* Blake.
Macrocephalites (*Dolikephalites*) cf. *dolius* Buckman.
Choffatia sp.

Genus **MACROCEPHALITES** Zittel, 1884

Type species *Macrocephalites macrocephalus* (Schlotheim, 1813) designated by Buckman (1922, *T.A.* IV, pl. cccxxxiv A, B) and here interpreted as *M. macrocephalus* Zittel, 1884, p. 470, *pars*, as proposed by Arkell 1951, p. 170.

Synonyms *Macrocephaliceras* Buckman, 1922, ?*Tmetokephalites* Buckman, 1923.

Much has been written in the last fifty years about foreign representatives of this genus but the only monograph of the British forms is that of Blake (1905). The material available to him was by modern standards very limited and seldom of accurately known origin, and a new treatment of the genus is desirable. While such a treatment would be a major undertaking and is impossible here, a few points will be suggested which may prove useful as a basis for a systematic classification.

First, it is essential, when defining species of this genus and indeed of any of the Stephanocerataceae and Perisphinctaceae, to consider only shells which are fully grown and complete. Maturity is nearly always obvious, indicated by a contraction of the body chamber towards the aperture with uncoiling of the umbilical seam; some small modification of the ribbing, usually approximation, near the end; and approximation and degeneration of the last septal sutures. It is found that in mature shells the size is one of the most closely defined characters of a species, and often of a subgenus. The variability of this character may in favourable cases not exceed 10 %, as the foregoing section on the kosmoceratids appears to show. This constancy has been verified in other genera; for instance with the author's large collection of *Quenstedtoceras*, subgenus *Eboraciceras*, from Woodham, Buckinghamshire (see Arkell 1939); and the Oxfordian perisphinctids described in a monograph by Arkell (1935–48).

The prerequisite of maturity and completeness often creates difficulties; at least it inevitably reduces greatly the proportion of the available material useful in the first instance, and it may render almost impossible a systematic study of a whole fauna. An example is the pyritic fauna of the Middle Oxford Clay of central England: although the shells are perfectly preserved they are all nuclei. Facies seems to have some profound effect upon this, as was already stressed by Reuter (1908) and the difficulty may often be overcome by moving to a more favourable area, e.g. in the example quoted, Yorkshire.

Secondly, *Macrocephalites* shows, in common with many other genera of the Stephanocerataceae and Perisphinctaceae, a sort of dimorphism. In one group the shells are large, 200 to 300 mm and over in diameter when fully grown, and lose their ribbing with maturity and have almost smooth body chambers. The other group comprises shells half this size when fully grown, usually more strongly ribbed than those of the previous group, and wholly ribbed to the end with no loss of rib-strength. Typical of the first group is *Macrocephalites sensu stricto*, and of the second group the subgenus *Kamptokephalites* Buckman.

Four previous cases of this phenomenon have already been mentioned above: *Kosmoceras* (p. 222), *Cadoceras* (p. 231), *Grossouvria* (p. 232) and *Kepplerites* (p. 235). Amongst other authors, Brinkmann (1929 *a*, *b*) recognized the division in *Kosmoceras* (with the exception perhaps of some of the youngest and oldest forms), and Arkell (1935–48) in his monograph on the Corallian ammonites. Dr Arkell also states that the same division occurs in the Stephanocerataceae, Perisphinctaceae, Sonniniidae and other families. On the other hand, neither Buckman (*Type Ammonites*) nor Spath (e.g. 1927–33, Cutch, and 1932, Greenland) seems to have recognized the division.

The generalization may be summarized as follows. The two groups may be conveniently called macroconchs and microconchs.

Superfamilies STEPHANOCERATACEAE and PERISPHINCTACEAE

Group A. *Macroconchs*

Shells large, becoming smooth when full-grown. Adult aperture simple, somewhat sinuous.

Group B. *Microconchs*

Shells small (often about half the size of the corresponding macroconchs), strongly ornamented, with no loss of ornament in the adult. Adult aperture frequently with lappet (e.g. *Kosmoceras*) or long rostrum (e.g. *Pseudocadoceras* and some *Cardioceras*).

The following are some relevant examples known personally to the author:

Macroconchs	**Microconchs**
Genus *Macrocephalites* Zittel	
Macrocephalites sensu stricto	*Kamptokephalites* Buckman
Indocephalites Spath	*Pleurocephalites* Buckman
Family KOSMOCERATIDAE Haug	
Kepplerites Neumayr	*Torricelliceras* Buckman
Sigaloceras Hyatt	*Gulielmina* Buckman
Gulielmites Buckman	*Gulielmiceras* Buckman
Zugokosmokeras Buckman	*Spinikosmokeras* Buckman
Lobokosmokeras Buckman	*Kosmoceras sensu stricto*
Subfamily CADOCERATINAE Hyatt	
Cadoceras Fischer	*Pseudocadoceras* Buckman
Longaeviceras Buckman	
Arctocephalites Spath	*Arcticoceras* Spath
Genus *Reineckeia* Bayle	
Reineckeia sensu stricto	*Reineckeites* Buckman
Collotia de Grossouvre	*Kellawaysites* Buckman

This list contains genera as well as subgenera, and no attempt is here made to attribute the one rank or the other to any one name. The ranks of family and subfamily are as used by Arkell (1950). The order in the two columns is such that names appearing opposite each other are frequently, although not always, those of forms which are thought to be contemporaneous.

Within the divisions mentioned above, classification may proceed in the usual way according to the characters of the shell: ribbing, whorl-section and suture-line. It is of course important to compare only forms that are contemporaneous, for in a genus like *Macrocephalites* changes are small and the danger of homeomorphy great. Whorl-thickness by itself is of little value as a generic character; for instance, among a large heap of *Macrocephalites sensu stricto* seen by the author in the mine at Herznach in Switzerland was a complete range of forms from compressed to extremely inflated. It is doubtful whether the suture-line is of great value as a generic character, and of any value as a specific one. It varies so much in one individual at various stages of growth that it is difficult to decide at which stage of development it should be used for comparison. For the same reason it cannot be used for comparison of individuals which at the same stage of development are of radically different size, i.e. between macroconchs and microconchs. Immature and fragmentary material becomes of use in establishing the development of the shell from the nucleus onwards; however, great care is necessary, for the inner whorls of contemporary macroconchs and microconchs are often indistinguishable. Much confusion has arisen on this score in the past, as for instance in distinguishing *Gulielmites* from *Gulielmiceras* as described above. The best solution usually lies in the dissection or cross-sectioning of an adult.

The main distinguishing features of the sub-genera of *Macrocephalites* here recognized are listed in the following brief diagnoses.

A. Macroconchs

Macrocephalites Zittel, *sensu stricto*

Type species *M. macrocephalus* (Schlotheim) = *M. verus* Buckman, 1922

Maximum size 200 to 300 mm or over; shell very involute, finely and densely ribbed, becoming smooth, first around the umbilicus. Umbilicus very narrow with smooth vertical walls and sharp lateral margin, the primary ribs commencing on this margin with a slight forward twist.

Examples of other species:

M. jacquoti H. Douvillé (type Quenstedt 1849, pl. xv, fig. 1*a–c*), (recorded by Arkell 1954, from Sutton Bingham).
M. formosus (J. de C. Sowerby), 1840*a*, pl. xxiii, fig. 7.
M. madagascariensis Lemoine, 1911, p. 51; 1910, pl. iii, fig. 3 (holotype).

Indocephalites Spath

Type species *I. kheraensis* Spath 1928, p. 184 = *Ammonites Herveyi* J. de C. Sowerby, 1840*a*, pl. xxiii, fig. 5 (size 115 mm wholly septate).

Paratype of type species *Stephanoceras tumidum* Waagen 1875, p. 115; pl. xxvi, fig. 1*a*, *b*; pl. xxvii, figs. 1*c*, 2*a*, *b* (complete adult).

Maximum size *ca*. 200 mm or greater; shell involute, densely ribbed, becoming smooth. Nucleus inflated. Umbilicus fairly wide, umbilical margin rounded, crossed by the primary ribs which commence on the rounded umbilical wall with an initial forward twist. Main distinction from adult *Macrocephalites sensu stricto* lies in the umbilicus, which is wider and has less steep walls.

Examples of other species:

Indocephalites chrysoolithicus (Waagen) 1875, p. 127.
Indocephalites diadematus (Waagen) 1875, p. 130.
?*Macrocephalites tumidus* Reuter 1908, p. 88, fig. 3*c* only.

B. Microconchs

Kamptokephalites Buckman, 1922

Type species *K. kamptus* Buckman 1922, *T.A.* iv, p. 54; pl. cccxlvii.

Maximum size 100 to 150 mm; shell involute, wholly and coarsely ribbed to the end. Umbilicus as in *Macrocephalites sensu stricto*. Ribs quite straight or somewhat flexuous, with or without an initial forward twist on the umbilical margin.

Examples of other species:

Kamptokephalites herveyi (J. Sowerby) 1818, *Min. Conch.*, p. cxcv.
Kamptokephalites grantanus (Oppel) 1857, p. 548.
Kamptokephalites dimerus (Waagen) 1875, p. 132.
Kamptokephalites magnumbilicatus (Waagen) 1875, p. 133.
Kamptokephalites lamellosus (J. de C. Sowerby) 1840; (type figured by Spath 1928, pl. xix, fig. 8).
Kamptokephalites pila (Nikitin) 1885, p. 50, pl. (viii) x, figs. 45, 46.

Dolikephalites Buckman, 1923

Type species *D. dolius* Buckman 1923, *T.A.* iv, p. 54; pl. ccclxxii.

Maximum size *ca.* 100 mm; shell involute, compressed, wholly and densely ribbed to the end. Umbilicus shallow. Ribs more or less flexuous, with or without an initial forward twist. Of the subgenera of *Macrocephalites* this bears the greatest resemblance to *Kepplerites* Neumayr. It is probably linked by transitions to *Kamptokephalites*.

Examples of other species:

Dolikephalites typicus (Blake) 1905, p. 42.
Dolikephalites subcompressus (Waagen) 1875, p. 139.

Pleurocephalites Buckman, 1922

Type species *P. lophopleurus* Buckman 1922, *T.A.* iv, p. 54; pl. cclxxxiv.

Maximum size *ca.* 100 mm; shell relatively evolute, usually inflated, wholly and densely ribbed to the end. Umbilicus wide, umbilical margin and walls rounded and traversed by the primary ribs with an initial forward twist. There is a tendency for the venter to flatten, so that the region of maximum curvature in the cross-section of the shell is on the flanks and not the venter. Nucleus finely ribbed and inflated. The main distinction from other subgenera is the wide umbilicus. Extreme forms strongly resemble *Kepplerites gowerianus*.

It is uncertain whether such evolute but coarsely ribbed microconchs as *Ammonites elephantinus* J. de C. Sowerby, 1840 (holotype refigured by Spath, 1928, pl. xxiv, fig. 1), and *Macrocephalites elephantinus* Corroy 1932 (pl. xi, figs. 1, 2) should be included in *Pleurocephalites*; they would perhaps be better in *Kamptokephalites*. There is one such shell in the B.M. (23863) from Weymouth, in clay.

Examples of other species:

Pleurocephalites folliformis Buckman 1922, pl. cccxlviii.
Nautilus tumidus Reinecke 1818, p. 74; fig. 47.
Nautilus platystomus Reinecke 1818, p. 81; fig. 60.
Ammonites macrocephalus rotundus Quenstedt 1849, p. 184; pl. xv, fig. 2*a*, *b*.
Pleurocephalites cuenoti (Corroy) 1932, p. 104.
Macrocephalites subtumidus Corroy 1932, pl. x, fig. 1.

It is too early yet to attempt an explanation of the phenomenon of dimorphism. An objection to the assumption that it is sexual is the rapid and wide variation in the relative abundance of complementary macro- and microconchs which are found together in beds of successive ages. On the other hand, that the two groups appear to be genetically linked is shown strikingly in at least one case, that of the genus *Kosmoceras*. New characteristics appear in both groups simultaneously.

The forms found at Kidlington follow.

Subgenus **KAMPTOKEPHALITES** Buckman

Type species *K. kamptus* Buckman, 1922.

Macrocephalites (**Kamptokephalites**) **kamptus** (Buckman)

Kamptokephalites kamptus Buckman 1922, *T.A.* IV, pl. cccxlvii.

Number of specimens collected. 1 body chamber (O.U.M. J 1285).

Remarks. The specimen agrees closely with the holotype, which came from Peterborough. Spath may be correct in considering the species to be doubtfully distinct from *M.* (*K.*) *herveyi*, but the latter is somewhat more finely ribbed, and much larger.

Macrocephalites (**Kamptokephalites**) sp. aff. **herveyi** (J. Sowerby)

Ammonites Herveyi J. Sowerby 1818, *Min. Conch.* II, p. 215; pl. 195.

Number of specimens collected. 1 body chamber (O.U.M. J 6068).

Remarks. There is good agreement with Sowerby's type (the larger of two syntypes, designated lectotype by Spath 1928, p. 173: B.M. no. 46485, from Lincolnshire) in all characters except that *herveyi* is slightly more inflated, more finely ribbed, and larger.

The Kidlington specimen agrees in detail with S.M. J 16478 from the Cornbrash of Scarborough; with O.U.M. J 1284 (in the Beesley collection) of unknown origin but probably from the Oxford area, in Kellaways Clay; with Bristol University Department of Geology collection no. 868 from the Kellaways Clay of Chippenham; with G.S.M. BW 244, 246 from the Kellaways Clay of Frome; and with at least two shells found in the Kellaways Clay in the excavation for a reservoir at Sutton Bingham near Yeovil (seen by the author in the contractor's office, 1952). A similar specimen is G.S.M. 25624 from Peterborough.

Macrocephalites (**Kamptokephalites**) cf. **bedfordensis** Spath or **subpila** Spath

Ammonites Herveyi J. Sowerby 1818, *Min. Conch.* II, p. 205; pl. 195 (smaller figure = holotype of *M. subpila* Spath).
Macrocephalites macrocephalus Blake 1905, p. 43; pl. IV, fig. 1 (holotype of *M. bedfordensis* Spath).
Kamptokephalites bedfordensis Spath 1928, p. 172.
Kamptokephalites subpila Spath 1928, p. 173.

Number of specimens collected. 1 body chamber (O.U.M. J 6066).

Remarks. This belongs to the *herveyi* group, and in the absence of more known material at differing stages of growth, *subpila*, from the Bath district, and *bedfordensis*, from Bedford, appear doubtfully distinct from *herveyi* itself.

The Kidlington specimen compares closely with S.M. J 16451 and S.M. J 16448 from the Cornbrash of Scarborough, and B.M. 33078, labelled 'Oxford Clay, Weymouth'.

Subgenus **DOLIKEPHALITES** Buckman, 1923

Type species *Dolikephalites dolius* Buckman.

Macrocephalites (Dolikephalites) typicus Blake

Macrocephalites typicus Blake 1905, p. 42; pl. iii, fig. 1.

Number of specimens collected. 1, O.U.M. J 6067.

Remarks. The specimen seems identical with the type, S.M. J 5730, from the Cornbrash of Scarborough. It resembles G.S.M. JHT 256, from Titmarsh, Northants.

Macrocephalites (Dolikephalites) cf. dolius (Buckman)

Dolikephalites dolius Buckman 1923, *T.A.* IV, pl. ccclxxii.

Number of specimens collected. 1 complete nucleus (O.U.M. J 1196), and 1 fragment of a larger body chamber (O.U.M. J 1286).

Remarks. The nucleus compares closely with S.M. J 16477 from the Cornbrash, Dover Colliery, and S.M. J 16438 from Thrapston. The fragment agrees with S.M. J 16459 and S.M. J 18288, presumed to be from Scarborough, and S.M. J 16468 from Thrapston. The nucleus is presumed to belong to *dolius*, which name is used for fine-ribbed forms close to *typicus*, but the type of *dolius* is rather small and questionably distinct from inner whorls of *typicus*.

Genus **CHOFFATIA** Siemiradzki, 1898

Type species *Perisphinctes cobra* Waagen 1869, p. 174, pl. xlv, fig. 1 *a–c*.

Choffatia sp.

Number of specimens collected. 1 fragment (O.U.M. J 1292).

Remarks. The fragment agrees, as far as it goes, with typical Cornbrash *Choffatia* in the Sedgwick Museum and with the species from South Cave figured by Buckman as '*Anaplanulites*' *difficilis*, *T.A.* IV, pl. cccxxix.

8. Summary of conclusions

New information has been obtained directly from the excavations at Kidlington by collection of the fauna bed by bed, and indirectly by consequent re-examination of the collections in museums and of the literature. Before proceeding to consider the zones of the Lower Callovian in other areas, the results so far may be briefly summarized.

8·1. *At Kidlington*

8·11. The succession of forms of the genus *Kosmoceras* has been shown by means of statistics to be the same as at Peterborough, as determined by Brinkmann (1929*a*), and to comprise those of the *jason* Zone. By means of such a study it has been found possible to make accurate stratigraphical correlations between widely separated localities. 500 cm of sediment at Kidlington were found to be equivalent to only 135 cm at Peterborough.

8·12. The Kellaways Rock contains the fauna of the *calloviense* or *koenigi* Zones, but it was not possible to distinguish separate zones.

8·13. The Kellaways Clay does not contain the fauna of the Kellaways Clay of Wiltshire, but instead the ammonite fauna of the Yorkshire Cornbrash, which is not the same as that of the southern Cornbrash.

8·2. *Elsewhere*

8·21. It appears that *Sigaloceras calloviense*, the zonal index of the *calloviense* Zone, is of limited geographical distribution.

8·22. *S. planicerclus* (Buckman) from South Cave has been recognized as occurring in north-west Germany and the Argovian Jura at accurately known horizons.

8·23. After a re-examination of old collections and with the aid of some new temporary exposures, the ammonite fauna of the Yorkshire Cornbrash has been followed through to the Dorset coast. Beyond the Bedford region, southwards along the outcrop, it is found in clays immediately above the Cornbrash, thereby confirming previous statements by Buckman and Lycett that the Yorkshire Cornbrash is younger than that of Southern England.

8·24. Reineckeids of the *anceps* Zone are commoner than supposed in the English Oxford Clay.

8·25. Some new points are suggested as a basis for classification of the genus *Macrocephalites*.

9. Correlation with other British areas

9·1. *Oxfordshire and Buckinghamshire*

9·11. *Lower Oxford Clay and Kellaways Beds.* The author has briefly re-examined the section at Calvert brick-pit. The pit is now worked by mechanical grab and covers a vast area. The base is just above a 6 in. bed of pyrites, containing a mass of fossils, oysters and lignite. The contained kosmoceratids, as well as those from just above and below, show this to be on a horizon identical in age with the oyster-pyrites bed at Kidlington (bed 12). About a foot below it is a layer of small impersistent cementstone nodules, containing on their lower surfaces uncrushed moulds of *Kosmoceras medea, K. gulielmi* subspec. *anterior* Brinkmann and *K. nodosum*. In addition, the oyster-pyrites bed has yielded a perisphinctid and a small crushed *Cadoceras sensu stricto*. It is most probably the source of a typical cadicone, smooth, pyritized *Cadoceras sensu stricto* in O.U.M. labelled 'Calvert, base', and of similar specimens in the collection of Dr Arkell. According to the foreman, 'greensand' occurs 10 ft. below the base of the pit and is used as the datum in exploratory borings when extending the area of working. This places the oyster-pyrites bed at the same height above the sand at Calvert as at Kidlington. The sand is occasionally exposed when drainage trenches are dug, and hence probably came the examples of *Gryphaea bilobata* in sandy matrix collected in the past and now in O.U.M.

Ten feet of clay followed by 6 ft. of sand were recorded by Woodward above the Cornbrash in Woodstock railway-cutting 3 miles north-west of Kidlington, but no fossils were found; and 10 ft. of clay followed by 4 ft. of sand were recorded at Akeley, north of Buckingham (Douglas & Arkell 1932, p. 127). These thicknesses are the same as at Kidlington. The Kellaways Beds can now also be identified in the records of old borings, e.g. at Wytham Lodge, 4 miles to the south (Blake 1902, p. 103). The total of 18 ft. is rather less than previous estimates (Arkell, 1947*a*, p. 68).

9·12. *Cornbrash.* The Upper Cornbrash is thin in the area: 3 ft. 8 in. in Woodstock railway-cutting, 1 ft. 3 in. at Bletchingdon (see Douglas & Arkell 1935, p. 318), and

1 ft. 0 in. at Hanborough. It appears to have been present in the old quarries at Kidlington station, for there is a *Macrocephalites* labelled 'Kidlington' in the Buckland collection (O.U.M. J3484). Upper Cornbrash ammonites are also known from Shipton-on-Cherwell (G.S.M.), Woodstock (G.S.M.) and Witney. Beds of this age seem to be absent at Islip and Bicester.

The transition from Douglas & Arkell's South-western Area to their North-eastern Area, which they emphasize in their account of the Cornbrash of the Bletchingdon section (1935), is therefore reflected in the ammonites, for at Kidlington the distinction between the Upper Cornbrash and Kellaways Clay ammonites is clearly shown.

9·2. *Bedfordshire to the Humber*

9·21. *Oxford Clay and Kellaways Beds.* Enough has already been said of the Oxford Clay at Peterborough. The Kellaways Beds appear to traverse the country more or less unchanged, and although they have frequently been exposed, they seem to have yielded almost no ammonites. An exception is Casewick railway-cutting in south Lincolnshire, described by Morris (1853, p. 332). Here the Cornbrash is overlain by 10 ft. of dark clay which contained '*A. Herveyi* abundantly', followed by sands with *Gryphaea bilobata*. Search has so far failed to trace the ammonites, but it is clear that they indicate an age similar to the Kellaways Clay at Kidlington as opposed to the Kellaways Clay of Chippenham.

9·22. *Cornbrash.* Upper Cornbrash occurs near Bedford and thence continues in greater or lesser strength to the Humber. It has produced many macrocephaloid ammonites, some of which, especially from the Peterborough area, are the same species as those from the Kellaways Clay of Kidlington and those from the Cornbrash of Scarborough. The Cornbrash of Peterborough is therefore at least partly of the same age as that of Yorkshire.

9·3. *South Yorkshire*

The quarries at South Cave, just north of the Humber and a few miles south of the Market Weighton anticline, have long been known for the section which they show of the Kellaways Beds, and for the peculiar fauna which these beds yield there. The section is described by Keeping & Middlemiss (1883), and the fauna discussed by Arkell (1944, p. 340). A brief re-examination of the fauna, including material since collected, shows it to consist of *Cadoceras*, *Pseudocadoceras*, *Catasigaloceras*, *Gulielmiceras*, *Proplanulites* (rare) and *Choffatia*, but no *Kepplerites*, *Macrocephalites* or *Sigaloceras calloviense*. The *Gulielmiceras* identified as *gulielmi* (Sowerby) by Spath and Arkell is in fact distinct and does not occur in the Wiltshire Kellaways Rock. While the cadoceratids and rare *Proplanulites* show general correspondence with the Kellaways Rock of Wiltshire, the exact correlation has hitherto been uncertain. The paper by von See (1910) describing the Jurassic of Porta Westfalica, near Hanover, appears to settle the question, however, while at the same time indicating a direct sea-link between South Yorkshire and Germany in Callovian times and providing a close correlation with the Kellaways Beds of the Continent. He figures *Sigaloceras planicerclus* (see above, p. 228) and states that it is of localized occurrence, but always occurs only in levels above those which contain *Kepplerites* but which themselves do not contain it, and immediately below beds containing *K. jason*. The South Cave Kellaways

Rock appears therefore to be of slightly later age than that of Wiltshire. This is also in accordance with the evidence of the oysters, although too much emphasis perhaps should not be placed on this; *Gryphaea bilobata* is abundant, but *Ostrea* (*Catinula*) *alimena* is absent. Both were abundant at Kidlington throughout, and according to Arkell (1934, p. 54) *bilobata* is a later development of *alimena*. It is therefore proposed to make a late subzone of the *calloviense* Zone, with *S. planicerclus* as index, and South Cave as type locality (see below, p. 258).

The existence of a direct sea-link between Yorkshire and Germany was also inferred by Arkell (1935–48) to exist in Oxfordian times.

The Kellaways Rock is underlain at South Cave by unfossiliferous sands and there is no Cornbrash.

9·4. *The Yorkshire Coast*

The succession is well known, and the history of the stratigraphy has been outlined by Arkell (1933, p. 362). Briefly, it is:

Hackness Rock }
Kellaways Rock } so-called Yorkshire 'Kelloway' Rock
Shales of the Cornbrash
Upper Cornbrash
Estuarine Series

9·41. *Kellaways Rock.* The fauna is as nearly the same as that of Kidlington as can be expected of two localities 180 miles apart, with one or two differences, the chief of which is the absence in Yorkshire of *Sigaloceras calloviense*. It was presumably because of this that Buckman (1913*a*) created the *koenigi* Zone, of which the Yorkshire coast is the type locality. Exact delimitation of the beds according to zones is not possible, for a considerable thickness of unfossiliferous sandstone underlies the fossiliferous beds.

9·42. *Upper Cornbrash.* This consists usually of about 10 ft. of shales, the 'Shales of the Cornbrash', resting on about the same thickness of fossiliferous sandstone or limestone. The fauna, other than ammonites, has been discussed by Douglas & Arkell (see Arkell 1933, p. 338), and presents points of difference which had already led Lycett (1863, p. 117) to suspect it of being of later age than the Upper Cornbrash south of the Humber. The ammonites are also different, consisting mainly of the more coarse-ribbed *Kamptokephalites* and *Dolikephalites*, although *Macrocephalites sensu stricto* (mostly inflated forms) also occurs; while the large gerontic *Macrocephalites sensu stricto* with fine-ribbed inner whorls so typical of the southern Upper Cornbrash appear to be absent. That this ammonite fauna indicated a later age for the Yorkshire Upper Cornbrash than that of the southern Upper Cornbrash was suspected by Buckman (1927*a*, p. 17; 1929*a*, p. 27), Spath (in Douglas & Arkell 1932, p. 139) and Arkell. That the fauna would be found in Kellaways Clay above the Cornbrash in the southern area was predicted by Buckman (1927*a*, p. 17), and this has now been shown to be the case at Kidlington. The later age of the Yorkshire Upper Cornbrash is therefore confirmed.

The 'Shales of the Cornbrash' are grouped with the Cornbrash itself, and not with the Kellaways Beds as suggested by Douglas & Arkell (1932, p. 139), for from them are recorded *Ammonites macrocephalus* by T. Wright (1870, p. 208) and *Macrocephalites* by Blake (1905, p. 17).

The lower part of the Upper Cornbrash, with which *Ornithella siddingtonensis* is usually associated, appears to be absent, as does the entire Lower Cornbrash.

9·5. *East Scotland: Brora*

The first bed resting on the Estuarine Series is the Brora Roof Bed (see Arkell 1933, p. 369) which, except for one doubtful record of *S. calloviense*, appears to have the same fauna as the Yorkshire Kellaways Rock; it is immediately followed by shales of apparently *jason* age.

9·6. *Wiltshire: Chippenham to the Mendips*

Despite the numerous perfectly preserved fossils which were obtained from cuttings in this area when the railways were built early in the last century, and which have found their way into almost every collection in the world, there has not been a single section through the beds under discussion from which fossils were collected in detail by modern standards; and there is only one record of a complete section down to the Cornbrash, namely the cuttings at Trowbridge described by Mantell (1850). The following faunas can, however, be made out and, with the aid of the knowledge now available, placed in their correct sequence. The main elements are:

Oxford Clay: faunas of the *coronatum* and *jason* Zones.

Kellaways Rock: *Sigaloceras calloviense*, *Gulielmina* sp.; *Kepplerites* spp., *Torricelliceras*; *Proplanulites* spp., *Choffatia*, *Grossouvria*; *Cadoceras*, *Pseudocadoceras*, *Chamoussetia*; occasional *Reineckeia* and *Macrocephalites*; *Gryphaea bilobata*.

Kellaways Clay: upper (pyritic facies): *Kepplerites* spp., *Torricelliceras*; *Proplanulites* spp., *Choffatia*, *Grossouvria*; *Cadoceras*, *Pseudocadoceras*, *Chamoussetia*; *Macrocephalites* s.s., *Pleurocephalites* spp.; *Ostrea* (*Catinula*) *alimena*.

Kellaways Clay: lower (phosphatic facies): *Macrocephalites* s.s., *Kamptokephalites* spp.; *Ostrea* (*Exogyra*) *nana*.

Upper Cornbrash (thin or absent locally): *Macrocephalites* s.s., *Dolikephalites*, *Kamptokephalites* (rare).

This succession may be pieced together as follows.

9·61. *Oxford Clay*. The ammonites in the famous slaty shales from Christian Malford, distributed largely by William Buy at the time of the construction of the railway, are mainly from the *coronatum* Zone, consisting largely of *Kosmoceras castor*, *pollux*, *grossouvrei* and *obductum*; but the collections do occasionally contain *K. jason* and *gulielmi*. The author has seen no *K. medea* from the area, although the beds are probably there. In the levels of *K. jason* is a row of cementstone crackers crowded with typical uncrushed *K. jason* and *gulielmi* in perfect preservation, and probably the source of the type of *K. gulielmi* (Sowerby).

9·62. *Kellaways Rock*. The fauna is familiar and little needs to be added; it is in every way similar to that at Kidlington. A typical collection from Kellaways itself is in the G.S.M. and is described by Buckman in the 1925 Marlborough Memoir (White 1925). The rock was a source of fossils near Christian Malford, at Kellaways Bridge, Trowbridge, Bancombe Wood near Corston, and at South Cerney and Siddington near Cirencester.

9·63. *Kellaways Clay*. (*a*) Upper—pyritic facies. The lower junction between Rock and Clay is not always clear and is often gradual. At most of the localities at which the Rock was exposed the underlying clays also yielded abundant ammonites, although with the exception of Trowbridge cutting the whole clay down to Cornbrash was never exposed at one time. As the foregoing list shows, the fauna is essentially the same as in the Rock above, but the ammonites are preserved in pyrites with a white covering, with inner whorls complete, and characteristic white chalky body chambers. There is one important addition: the Kellaways Clay of Chippenham has yielded many *Macrocephalites* (*Pleurocephalites*) with an occasional inflated *Macrocephalites sensu stricto* or *Indocephalites*, which may now be seen in the Walton collection (S.M.), Cunnington collection (G.S.M. and B.M.) and Chaning Pearce collection (Bristol City Museum) and in Bristol and Reading Universities, and elsewhere. They seem all to have come from two railway-cuttings through Cocklebury Hill, immediately north of Chippenham Station. In these cuttings neither Cornbrash below nor Kellaways Rock above seems to have been exposed, and the exact position of the exposed clay in the sequence is therefore not certain. However, the cuttings have also yielded the remaining fauna in abundance, and the preservation is identical. The only other occurrence of these particular macrocephalitids in this country seems to have been Trowle Common near Trowbridge (Chaning Pearce collection). On the Continent the group is abundant in the upper part of the (there) '*Macrocephalus* Zone' and is usually called *M. tumidus*; in Franconia it occurs frequently in a special pyritic facies (Goldschneckenfauna, Reuter 1908). There was no sign of it at Kidlington, unless the isolated *Macrocephalites sensu stricto* from the basal Kellaways Sand was a representative.

(*b*) Lower—phosphatic facies. An unknown thickness of the Kellaways Clay contains an entirely different fauna from that mentioned above, namely, that of the Kellaways Clay of Kidlington. The preservation is quite distinct: inner whorls of ammonites are usually missing and the body chambers are of buff rather than white marl and covered by a chocolate-coloured layer. Analysis for phosphorus of one of the Kidlington specimens indicated the equivalent of 8 % of normal calcium phosphate; it is because of this and to point out the analogy with similar clays in Franconia as described by Reuter that the term 'phosphatic facies' is here used.

That these clays occur at Chippenham, probably at the base of the Cocklebury Hill cuttings, is shown by a specimen of *Kamptokephalites* aff. *herveyi* identical with one of the specimens from Kidlington (as described above) and labelled 'Chippenham', in Bristol University collection (no. 868). Their position immediately above the Cornbrash has been shown at Kidlington, and in the railway-cuttings made at Frome in 1930–31. These were referred to by Arkell in 1933 (p. 330), and the section inclusive of Cornbrash downwards has now been described by him (1954). The part from the Cornbrash upwards was described by him in 1934 (p. 55) and is briefly:

Kellaways Rock: sand, etc.	13 ft.
Kellaways Clay: clay, with a bed of *Ostrea* (*Catulina*) *alimena* at the base	5 ft.
Grey clay, with *Exogyra nana* at the base	15 ft.
Upper Cornbrash	

Two *Kamptokephalites* aff. *herveyi* (G.S.M. BW 244, 246) specifically identical with the one from Kidlington and the similar one from Chippenham (see above) came from the lower 15 ft. of clay.

9·64. *Upper Cornbrash*. This is thin or locally absent in the area.

9·7. *The Mendips to Weymouth*

A fine section from Kellaways Clay to Forest Marble was exposed in excavations for a reservoir at Sutton Bingham, south of Yeovil, during 1952–53. The section through the Cornbrash is described by Arkell (1954). The topmost rock band of the Cornbrash was overlain by dark shaly clay of which up to 25 ft. were exposed in the curtain-wall trench for the dam, with no sign of the Kellaways Rock. The lowest 6 ft. contained *Exogyra nana* in profusion, and *Modiola*, *Pleuromya*, *Nucula* and *Trigonia* also occurred. Ammonites were confined to body chambers of *Macrocephalites*, among which were seen *Kamptokephalites* and *Dolikephalites* (10), *Macrocephalites sensu stricto* (6). They occurred up to at least 15 ft. above the top rock of the Cornbrash, and their preservation was identical with that of specimens from Frome and Kidlington. Of the *Kamptokephalites* at least two were specifically identical with the *M.* (*K.*) aff. *herveyi* mentioned above from Kidlington.

That true Kellaways Rock occurs in the area appears to be indicated by the presence of a typical *Cadoceras* in rock matrix in Bristol University collection, labelled 'Yeovil'.

That clays of this Yorkshire Upper Cornbrash age also occur at Weymouth is deduced from specimens in old collections, and their matrix or state of preservation, e.g.:

Kamptokephalites aff. *bedfordensis* Spath (BM 33078) 'Oxford Clay, Weymouth'.

?*Kamptokephalites* aff. *magnumbilicatus* (Waagen) or *elephantinus* Corroy non Sowerby (BM 23863) 'Lower Oxford Clay, Weymouth'.

Macrocephalites cf. *macrocephalus* (Schlotheim) (G.S.M. 69892) 'Backwater, Weymouth'. Ditto, figured by Buckman, *T.A.* IV, pl. cccxiii. (G.S.M. 47128) 'Weymouth Backwater, clays above the Cornbrash'.

9·8. *Kent*

The Callovian has been traversed many times by borings and mine-shafts in the concealed coalfield of Kent. The strata vary rapidly from place to place, but in general a good thickness of typical Oxford Clay passes downwards gradually into about 20 to 30 ft. of marls, sands and sandstones, rich in iron and often oolitic, generally grouped as Kellaways Beds and underlain by white limestones of the Cornbrash. Of the many sections described by Lamplugh, Kitchin & Pringle (1911, 1923), only three need be considered here, namely the mine-shafts of Dover, Guilford and Tilmanstone. The faunas have been briefly re-examined and the following sequence emerges.

9·81. *Oxford Clay.* Lamplugh records *Kosmoceras jason* from the lower clays at Guilford and Tilmanstone (above −1198 and −1044 ft. respectively). Re-examination of the two ammonites from Guilford quoted by Lamplugh (1923, pp. 68, 72) as *K.* cf. *rowlstonense* or *sedgwicki* (Pratt) after Buckman and now in the G.S.M. (WM 180 and WM 289) shows them to be *K. medea*. They are recorded as having come from between −1204 and −1234 ft., which includes the whole of the Kellaways Rock according to Lamplugh's classification. To judge by their preservation, which is in greenish marl full of brown ferruginous 'millet-seed' ooliths, they came from the top of Lamplugh's Kellaways Rock, i.e. −1204 to −1207 ft. Thus, lithologically, Kellaways Rock ranges upwards higher here than in other parts of the country. There are two further examples of *K. medea* in the Bomford collection from Dover, in similar preservation but from an unknown horizon; and the *S. calloviense* recorded by Lamplugh from Tilmanstone at −1052 ft. (1923, p. 142), which is again at the very top of the Kellaways Rock, is probably of this species also.

9·82. *Kellaways Rock.* With the exception of possibly one fragment of a *Proplanulites*, all the usual ammonites appear to be missing. On the other hand, there are abundant oysters, mainly *G. bilobata* and *O. alimena.* Their sudden appearance fixes the lower limit of the Kellaways Rock. Below are usually a few feet of dark clay with few fossils, and then Cornbrash.

9·83. *Cornbrash.* The best section was at Tilmanstone and is briefly:

Kellaways Rock above			down to
Cornbrash: dark grey marl	1 ft.	6 in.	−1076 ft.
Hard grey limestone	17	0	−1093
Nodular limestone and marls	2	0	−1095
Grey limestone	5	0	−1100
Forest Marble below			

From it are recorded *Microthyridina lagenalis*, *Ornithella obovata* and *Cererithyris intermedia* between −1093 and −1099 ft., and *O. ornithocephala* at −1094 ft. Both Lower and Upper Cornbrash appear to be present therefore, with the junction possibly at −1095 ft. Of interest is Lamplugh's record of *Macrocephalites herveyi* from −1076 ft. which, however little can be said of the positions here of the various brachiopod subzones of the Cornbrash, is well above the highest of them, that of *M. lagenalis*. This indicates an age for the top part of the Kent Cornbrash similar to that of the Yorkshire Cornbrash and the Kidlington Kellaways Clay.

Further evidence of this are several other macrocephalitids from the Cornbrash of Guilford in the G.S.M. (WM 433, 438), and from Dover in the S.M. (referred to under *M. dolius* above) and Bomford collections. All these are small, and specific identifications are therefore difficult; nevertheless, as a group they resemble the Yorkshire Cornbrash fauna unmistakably.

The lower extent of the Upper Cornbrash is not well known, although Lamplugh's record of *Ornithella* cf. *siddingtonensis* would suggest that it is complete.

10. Correlation with some foreign areas

10·1. *East France*

Good figures of ammonites are given by Corroy (1932), but they are mainly from old collections inadequately documented stratigraphically. Most of the English forms occur, and the leading groups which may be recognized include, in descending order:

jason Zone: *Kosmoceras* cf. *jason*, *K. medea*, many perisphinctids and reineckeids.
calloviense Zone: *Kepplerites* (rare), *Cadoceras* (rare), *Chamoussetia* (rare), *Proplanulites*, *Choffatia*, *Pleurocephalites* spp.
Macrocephalus Zone: *Macrocephalites* s.s., *Kamptokephalites* and *Dolikephalites* spp.

One can detect on passing south the gradual displacement of Boreal elements (e.g. *Kosmoceras*, *Cadoceras*) by an increasing proportion of Tethyan forms (e.g. *Macrocephalites* and *Reineckeia*).

10·2. *The Argovian Jura*

The iron-ore deposits of Callovian age around Herznach, some 16 km north of Aarau, have long been known for the profusion and perfection of their ammonites. Intensified working of the ore during the last 15 years has made the mine at Herznach one of the finest sections of the Callovian and Oxfordian in Europe. The section has been recorded in detail by Jeannet (1951) in the first part of a memoir describing the ammonites, which has the great merit of identifying the precise levels from which they came. The main collection made in the mine is now at the Federal Institute of Technology, Zürich, and there is another at the Heimatsmuseum in Aarau. In addition, there is much material collected in the vicinity of Herznach and farther afield by earlier workers, e.g. Rollier and Moesch, although the exact levels from which much of this material came are not known. Through the kindness of Professors Jeannet and Hartmann, the author was able to examine these collections in the summer of 1953.

The importance of the area lies in the fact that during Callovian times it was near a shoreline of Tethys against the Black Forest and included rich Mediterranean as well as north-west European faunas. It thus provides a key to zonal correlation between the two provinces. The deposits are very variable. At Herznach mine the Callovian, beds A–D, is some 10·5 ft. thick, consisting of limestones and oolitic iron ore. Below are 30 ft. of unfossiliferous sandstone (Kornberg Sandstein) and above are a few feet of shales and nodular limestones of highly condensed Lower Oxfordian (*mariae* and *cordatum* Zones). The iron ore is reduced to only 1 or 2 ft. at the Staffelegg, 3 km north of Aarau, while it is expanded to at least 20 ft. of false-bedded, non-fossiliferous sandstone at Mandach, 10 km north-east of Herznach.

At the mine, the *lamberti* Zone may be recognized at the top of the Callovian (bed D). It has yielded many *Quenstedtoceras*, of subgenera *Q. sensu stricto*, *Eboraciceras* and *Lamberticeras* Buckman, including *Q. lamberti* itself, the whole bearing an astonishing resemblance to the fauna of bed C at Woodham (Arkell 1939). The lower part of bed E appears also to belong to this zone (and not to the *mariae* Zone), which probably accounts for the record from it of *Kosmoceras spinosum*. In this connexion it may be added that the '*Cosmoceras duncani*' (=*K. compressum* (Quenstedt)) figured on Jeannet's pl. xxvi, fig. 2 did not come from Herznach, and that its alleged origin in the *cordatum* Zone (F 2) is extremely doubtful. The author knows of no instance of a *Kosmoceras* having been found in beds younger than of *lamberti* age.

Below is the *athleta* Zone with large bispinous reineckeids, and below that again is a layer which yields *Erymnoceras coronatum* in profusion and perfection, together with many *Reineckeia* and *Zugokosmokeras* cf. *obductum* (Buckman). Below this, the kosmoceratids of the *jason* Zone are absent and the next fauna that can be correlated with Britain is that of bed A5, which contains *Sigaloceras planicerclus* (Buckman), *Kosmoceras* aff. *gulielmi* (Jeannet, pl. xxv, fig. 12) which is the same as that of South Cave, and many reineckeids and perisphinctids. Bed A4 contains *Sigaloceras* spp. non *planicerclus* (Jeannet, pl. xxv, fig. 10; pl. xxvi, fig. 9) and may be equivalent to the Wiltshire Kellaways Rock. The lower beds are not worked in the mine and are rarely exposed; their faunas do not appear to have been systematically studied. Lower beds older than Wiltshire Kellaways Rock appear to be present in the area, however. There are in the Rollier collection three plaster casts of *Kepplerites*, of which the originals are in Basel, labelled 'Herznach'. In addition, Professor Jeannet showed me a small collection of ammonites which had been obtained in a temporary excavation for a sewer at Anwil (BL), 8·5 km west-south-west of Herznach, 10 km north-west of Aarau. Included in this were specimens of *Cadoceras*, *Pseudocadoceras* and typical *Macrocephalites* (*D.*) *typicus* Blake with its characteristic flexuous ribbing. Finally, there are in the collections many large gerontic *Macrocephalites* s.s. from limestones, rather than ironstone, collected in the past and very similar to ones found in the English Upper Cornbrash, and probably from the Kornberg Sandstone.

A description of the Callovian of the Weissenstein chain near Solothurn, 50 km to the south-west, is given by Erni (1934). The Middle and Upper Callovian ironstone has been further reduced to between ½ and 2 ft., and is immediately underlain by a bed of sandy limestone between 1 and 3 ft. thick and containing the fauna of beds A4–5 at Herznach. Erni quotes *Sigaloceras planicerclus*, *curvicerclus* (Buckman) and *Kosmoceras* (*G.*) aff. *gulielmi* (Sowerby) (fairly common); *Reineckeia* spp. and *Macrocephalites* spp.; as well as many perisphinctids. He states that *Sigaloceras calloviense* is absent in the Swiss Jura and that *Kepplerites* is present but confined to lower levels. This is in accordance with the evidence at Herznach, north-west Germany and South Cave, Yorkshire.

These sections are of special interest in showing the vertical range of *Macrocephalites*. *Macrocephalites sensu stricto* at Herznach ranges up through bed A and is very common in bed B1, i.e. in levels at least as young as or younger than the South Cave Kellaways Rock, and the mounds of specimens of this genus described by Quenstedt as having been found in southern Germany and distributed throughout collections the world over probably came from beds also of this age. The bed also yields *Pleurocephalites* and *Kamptokephalites*, including a form of the latter as inflated as *Macrocephalites tumidus* (author's collection), as well as *Dolikephalites subcompressus* Waagen and forms resembling some figured by Spath from India under the name *Eucycloceras*.*

Similarly, light is thrown on the ranges of the various forms of *Reineckeia*. At Herznach these commence in bed A5, where they are most common, and this may be compared with the occurrence of a specimen in the Kellaways Rock of Wiltshire, figured by Buckman. The species appear to have relatively long ranges; a major transition appears to occur between the *coronatum* and *athleta* Zones, the large forms of the *anceps* group being replaced by the even larger bispinous forms of the subgenus *Collotia*, which in England persists into the *lamberti* Zone (Arkell 1939, with subsequent finds).

10·3. *Northern Germany*

The Callovian of north-west Germany was described by von See (1910). The generalized succession is:

	ft.
Sandy micaceous shales (Ornatenton)	*ca.* 100
Ironstone, siliceous, oolitic	4
Porta Sandstone	40
Sandstone and marls, 'Zone of *O. aspidoides*'	

* *Note added in proof*: A description of the macrocephalitids from Herznach has been recently published by Jeannet (1954).

The ironstone is variable and diminishes in thickness to only 8 in. locally; it is rich in pyrites and overlain by pyritic bituminous shales. The faunas are briefly:

Shales: *Kosmoceras jason* and higher zones.
Ironstone: pyritic (higher) development: *Sigaloceras planicerclus*;
oolitic (lower) development: *Proplanulites*, *Choffatia*, *Kepplerites*, *Chamoussetia*; *Macrocephalites* s.s. and *Pleurocephalites* ('*M. tumidus*'), also *Kamptokephalites* (cf. *magnumbilicatus* Waagen and *grantanus* Oppel *fide* See).
Porta Sandstone: *Macrocephalites macrocephalus* and *Choffatia*.

The upper pyritic part of the ironstone is therefore equivalent to the Kellaways Rock of South Cave and bed A5 at Herznach; the main oolitic ironstone is equivalent to the Kellaways Rock and Kellaways Clay of Wiltshire and Kidlington, and the Porta Sandstone below at least in part the equivalent of the Upper Cornbrash as developed in the English south-western area.

The succession serves therefore to place the Kellaways Rock of South Cave relative to that elsewhere, and at the same time provides a connecting link to the Callovian of Switzerland.

10·4. *Cutch*

Although the Callovian deposits of Cutch may appear far removed from the area so far considered, it is interesting to re-examine briefly the succession there and to compare it with the Callovian of the Jura chain at, for example, Herznach, in view of what is now known of the latter.

The extensive faunas are described in the two memoirs by Spath (1924, 1927–33). The stratigraphical evidence is based upon the records of several collectors, made at different times; in addition, the zonal classification of the Callovian was in a state of flux in the 9 years covering publication. It is therefore understandable that tables of the zonal and stratigraphical successions should differ somewhat in different parts of the work. A summary of the Callovian in Cutch is therefore given here in table 2, based upon five places in Spath's memoirs: a table of zones is given in Memoir (1) (1924, pp. 20, 21); an amended table is given in Memoir (2) (1928, p. 81); the most detailed and best-described section at any one locality is that at Jumara (1933, p. 739); a synopsis of the various formations is given in (1933, p. 758); and the stratigraphical occurrence and ranges of the ammonite species are given in (1933, pp. 864 and 872).

The junction between Callovian and Oxfordian appears to fall at the base of the Dhosa Oolite, which contains faunas similar in age and appearance to those of the *mariae*, *cordatum* and *plicatilis* Zones of Europe. The *athleta* Beds are also readily correlated; it is with the Middle and Lower Callovian that Spath appears to have had difficulty in determining the European equivalents. Buckman showed that in England forms of *Macrocephalites* range upwards from the Cornbrash to the Wiltshire Kellaways Clay, with possibly one example from the lower Kellaways Rock (see *T.A.* IV, 1922, pl. CCXC; 1929*a*, p. 17). Spath presumably took this to determine the upper limit of *Macrocephalites* in India also. In addition, he states on p. 768 that the reineckeids indicate that the *rehmanni* Beds must already be earlier than the Kellaways Rock of Wiltshire.

It is here that the section at Herznach comes to aid. The parallel lies between the *diadematus* and *rehmanni* Zones in Cutch (e.g. the Golden Oolite of Khera) and beds A5 and B1 at Herznach. In both areas the first appearance of reineckeids coincides with or immediately succeeds the greatest abundance in numbers and species of macrocephalitids; and as has been shown above, bed A5 is of about the age of the South Cave Kellaways Rock, which is later than that of Wiltshire. The *rehmanni* Zone is therefore equivalent to the basal part of the European *anceps* Zone, and on the basis of the reineckeids is hardly distinguishable from the *anceps* Zone of Cutch.

The other zones then also fall into place; downwards, the *dimerus* Zone is presumably equivalent to the Kellaways Clay of Wiltshire and the Yorkshire Cornbrash, and the *triangularis* Zone to the Upper Cornbrash of Southern England. Upwards, the *anceps* Beds are the equivalent of beds B2–B7 at Herznach, which are equivalent to the *jason* and *coronatum* Zones, followed by the Lower *athleta* Beds which, both in India and at Herznach, still contain *Erymnoceras* and also the first *Collotia*.

TABLE 2. THE CALLOVIAN OF CUTCH

lithological divisions (Waagen & Spath) Dhosa Oolite					zones (Spath)				European equivalents here suggested: England	Herznach	zones
Chari Group	Upper	*athleta* Beds	Upper		*lamberti*		UPPER	CALLOVIAN	Oxford	D	*lamberti*
			Middle		*athleta* (4)	*duncani*					*athleta*
			Lower			*fraasi*				C1	
	Middle	*anceps* Beds	Upper		*anceps*		MIDDLE			B7	*coronatum* and *jason*
			Lower						Clay		
		rehmanni Beds	Up.	Khera Golden Oolite	*rehmanni*						
			Lo.							B1	
	Lower	*macrocephalus* Beds	Up.		*diadematus*		LOWER		South Cave Kell. Rock	A5	*calloviense*
			Up. Middle		*dimerus*	(3)			Wilts. Kell. Rock Wilts. Kell. Clay		
			Lo. Middle						Kidlington Kell. Clay		*macrocephalus*
Patcham Group (5)			Lower (2)		*triangularis* (1)				Upper Cornbrash		
		Patcham Coral Bed									
		Patcham Shelly Limestone									

(1) *triangularis* Zone = *trigonalis* Zone of Mem. (1).
(2) Lower *macrocephalus* Beds: put with *triangularis* Zone in the Jumara section (p. 740) but not zonally classified on p. 81; put in the Chari Group on p. 758, Patcham Group on p. 760.
(3) Division between *dimerus* and *diadematus* Zones not defined.
(4) Subdivision of the *athleta* Zone not present in Mem. (1), p. 21.
(5) Put in Bathonian in Mem. (1), p. 21, and Mem. (2), p. 758.

The Callovian of Cutch therefore resembles that of South Germany more than that of England, and Waagen (1873–75), familiar with both South Germany and Cutch, was justified in regarding the two as closely similar.

We have seen how greatly the lower part of the Callovian varies lithologically from place to place and level to level, but that study of the included faunas allows correlations to be made within quite narrow limits between widely separated areas. A revised table of the zones of the Callovian has been constructed on the basis of these faunas (table 4) and is discussed in the section which follows. The correlation of the lithological divisions of the Lower Callovian as they occur in the various areas considered above is shown diagrammatically in figure 5. Table 3 shows the zonal ranges of the more important elements of the ammonite faunas; in it, however, *Kepplerites* does not include *Cerericeras* Buckman (see Arkell 1953, p. 117); and *Cadoceras* does not include *Paracadoceras* Crickmay, which occurs very rarely in the Upper Cornbrash of Dorset (see Blake 1905, p. 48; and Cox & Arkell 1950, p. 95).

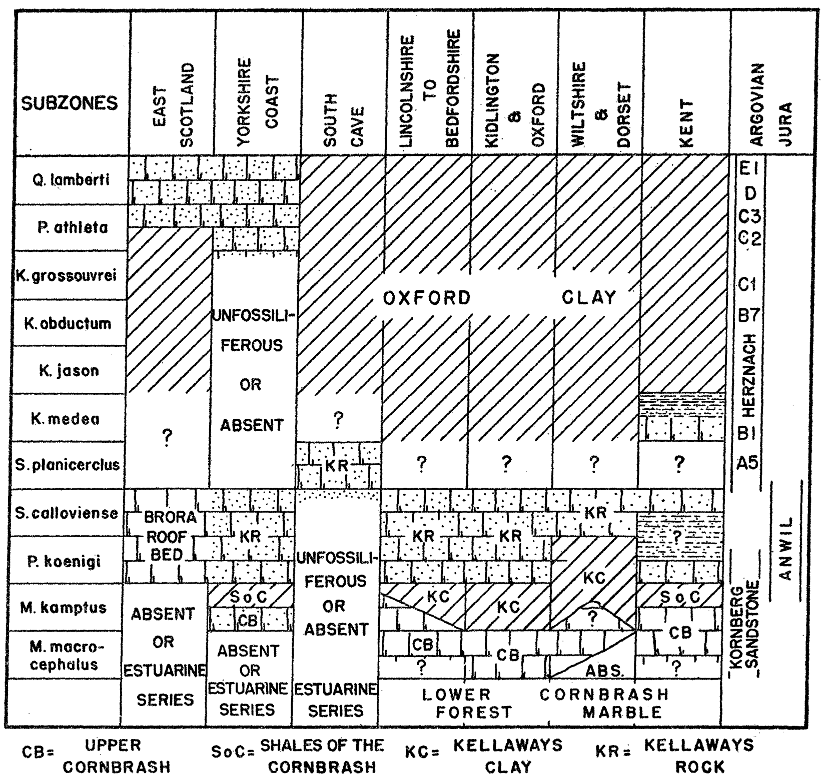


Figure 5. The zonal correlation of the lithological divisions of the Lower Callovian in Great Britain.

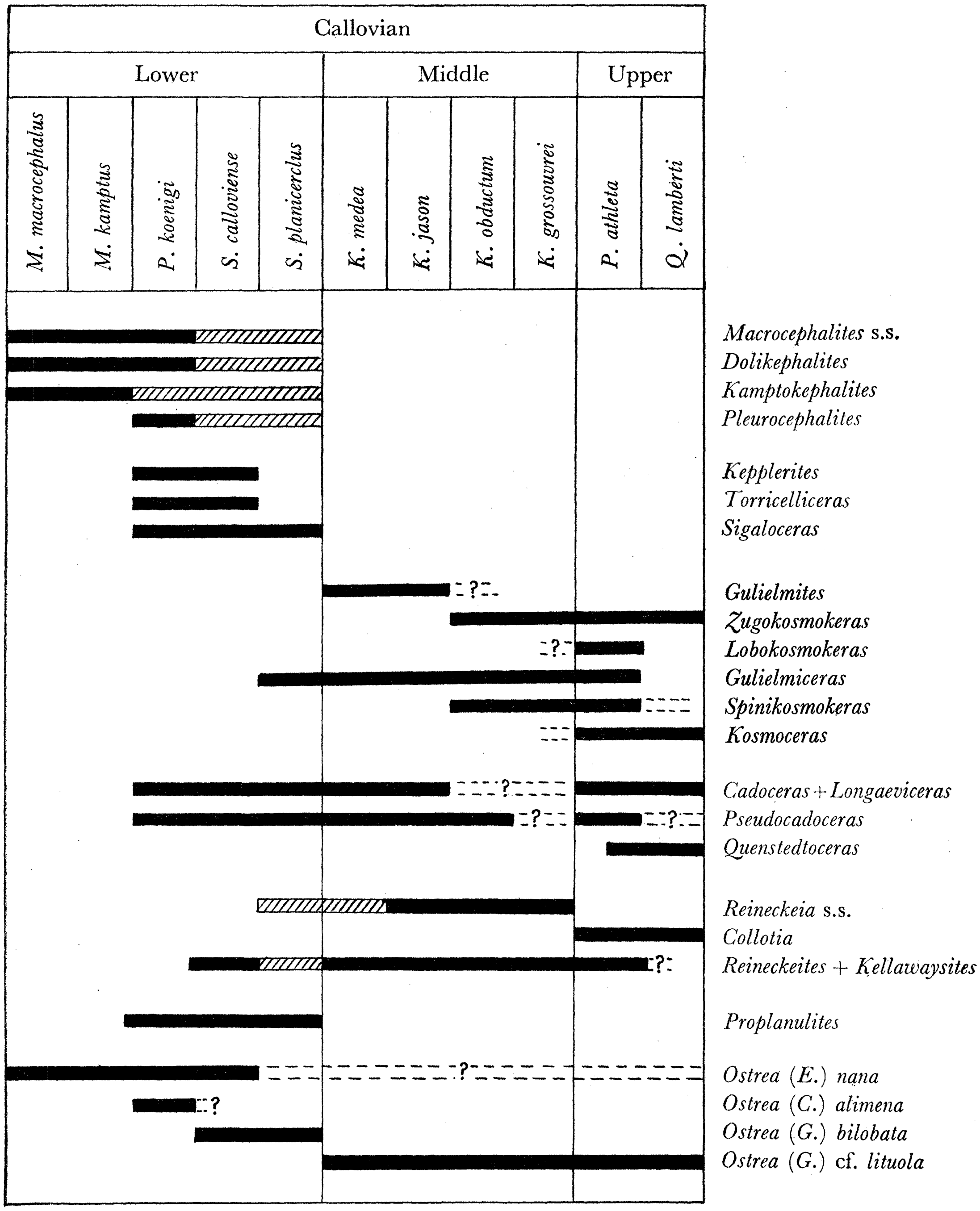
11. The zonal sequence of the Callovian

The revised table of zones is shown in table 4. The Callovian Stage is taken as first used by d'Orbigny in 1850, and explained by Arkell (1946, p. 8). The upper limit is between the *lamberti* and *mariae* Zones (Arkell 1939, p. 213), and the lower limit between Lower and Upper Cornbrash *discus* and *macrocephalus* Zones (Douglas & Arkell 1932, summarized in Arkell 1933, p. 326). The division of the Callovian into Lower, Middle and Upper is here taken to coincide with two major changes of fauna, and it is seen that they almost coincide with Oppel's original three zones.

11·1. *Upper Callovian*

Zones of *Quenstedtoceras lamberti* and *P. athleta*. No change is made in Arkell's table of the higher zones (1939, p. 213).

TABLE 3. ZONAL RANGES OF SOME CALLOVIAN AMMONITES



Solid lines: ranges as found in Great Britain.
Shaded lines: ranges in other parts of the North-west European Province.

TABLE 4. THE ZONES OF THE CALLOVIAN IN GREAT BRITAIN

stage	substage	zones	subzones	Oppel's zones (1857)	Jura Chain (Arkell, 1946, p. 19)	author first using index now used for subzones
OXFORDIAN		*Quenstedtoceras mariae* (d'Orbigny)		*A. biarmatus*	*Aspidoceras biarmatum*	
CALLOVIAN	UPPER	*Quenstedtoceras lamberti* (Sowerby)				Hébert 1857, 1860
		Peltoceras athleta (Phillips)		*A. athleta*	*Kosmoceras spinosum*	d'Orbigny 1852
	MIDDLE	*Erymnoceras coronatum* (Bruguière)	*K. (Zugokosmokeras) grossouvrei* (Douvillé)	*A. anceps*	*Kosmoceras castor* and *pollux*	nov.
			K. (Zugokosmokeras) obductum (Buckman)			Buckman 1925
		K. (Gulielmites) jason (Reinecke)	*K. (Gulielmites) jason* (Reinecke)		*Kosmoceras jason*	d'Orbigny 1852
			K. (Gulielmites) medea n.sp.			nov.
	LOWER	*Sigaloceras calloviense* (Sowerby)	*Sigaloceras planicerclus* (Buckman)	*A. macrocephalus*; *A. callo-viensis*	*Macrocephalites macrocephalus*	nov.
			Sigaloceras calloviense (Sowerby)			Oppel 1857
			Proplanulites koenigi (Sowerby)			Buckman 1913
		M. (Macrocephalites) macrocephalus (Schlotheim)	*M. (Kamptokephalites) kamptus* (Buckman)			Buckman 1922
			M. (Macrocephalites) macrocephalus (Schlotheim)			Oppel 1857
BATHONIAN		*Clydoniceras discus* (Sowerby)				

11·2. *Middle Callovian*

11·21. Zone of *Erymnoceras coronatum*. The true *E. coronatum* is rare or absent in Britain, although *E. reginaldi* and other species occur. In practice, therefore, other subsidiary fossils are generally used, usually species of *Kosmoceras*. Previously *K. castor* and *pollux* were chosen (Reuter 1908; Brinkmann 1929*a*); they have however long ranges and the 'Zone of *castor* and *pollux*' is synonymous with that of *Erymnoceras coronatum* (Arkell 1939, p. 212). A finer subdivision may be recognized on the basis of the equally common *Zugokosmokeras*, and two subzones of the *coronatum* Zone, that of *Kosmoceras* (*Z.*) *obductum* (sparsely ribbed) below and *K.* (*Z.*) *grossouvrei* (densely ribbed) above, are therefore proposed. According to Brinkmann (1929*a*) these two forms succeed each other and do not occur together. A brief examination of the section at Calvert appears to confirm this.

11·22. Zone of *K. jason*. The sections at Peterborough, Kidlington and Weymouth show the stratigraphical relationship of *K. jason* to the earlier *K. medea* n.sp., and this may also be used to distinguish two subzones, that of *K. jason* above and *K. medea* below. The upper limit of the *jason* Zone is shown by an abrupt faunal break in at least one area, that of Peterborough, at Brinkmann's level 135 cm. The lower limit is less well known.

11·3. *Lower Callovian: Kellaways Beds and Upper Cornbrash*

The terms Kellaways Rock, Sand, Clay etc., are based on lithological divisions and indicate no particular zone; their history is summarized by Fox-Strangways (1892) and White (1925, p. 9). The same applies to the terms Cornbrash and 'Shales of the Cornbrash'. The diachronic nature of these beds is shown clearly in sections 9 and 10 of the paper. It has created difficulty in the past in attempting a zonal classification.

Their equivalence as a whole to the familiar '*macrocephalus*-beds' of the Continent was stated already by Oppel (1857) who saw them in this country as they occur in Wiltshire. At the top of his 'Zone des *Am. macrocephalus*' he included the Kellaways Rock which, although not itself containing macrocephalitids, bore the same general fauna as the underlying clays with macrocephalitids. The lower limit of his zone was somewhat less certain, for he was unaware that *Macrocephalites* occurs in part of the Cornbrash in this country; moreover, the Upper Cornbrash is thin or absent at the localities which he visited, namely Stanton and Chippenham. It appears, however, that Oppel's *macrocephalus* Zone extended from the top of the Kellaways Rock to the base of the Upper Cornbrash.

First attempts at subdivision were made by Oppel himself, and he is the author of the *calloviense* Zone (Arkell 1946, p. 3, Rule 3); his table 34 on p. 506 (1857) is the first use of the name of the index-fossil in connexion with the word 'Zone'. He introduced it as a subzone for the Kellaways Rock only. For the remaining (lower) part of his original *macrocephalus* Zone he named no new zonal index (although he spoke of the 'Horizont des *Amm. bullatus*' which is in any case inappropriate in this country), and this lower part must therefore be considered as the 'Zone of *A. macrocephalus* of Oppel in a restricted sense'.

Oppel was followed closely by T. Wright (1870, p. 207) who clearly defined the *macrocephalus* and *calloviense* Zones, the latter consisting as before of the Kellaways Rock only; and he based them on the section exposed in the railway-cuttings at Trowbridge described by Mantell.

Woodward (1895, p. 8) expanded the *calloviense* Zone to include the Kellaways Clay of Wiltshire, because of the great similarity of the faunas of the Kellaways Rock and Clay.

Subsequently, further names were introduced by Buckman (1913*a*) and Spath (1932*a*). However, as shown in table 4, it is proposed here to retain only the two main zones: that of *Sigaloceras calloviense* above, and that of *Macrocephalites macrocephalus* below. Each is divided into subzones.

11·31. *Zone of* Sigaloceras calloviense.

Subzone of *Sigaloceras planicerclus*. Type locality South Cave, Yorkshire. The stratigraphical position relative to the *jason* Zone above and the *calloviense* Subzone below is shown by the succession in north-west Germany. In Britain it has been recognized so far only at South Cave.

Subzone of *Sigaloceras calloviense*. Type locality Wiltshire; first defined by Oppel (1857). As has been shown previously, the index-species appears to be of very localized geographical distribution and, pending the possible outcome of detailed monographing of the faunas, the subzone is hence only locally distinguishable from the subzone of *Proplanulites koenigi* below. It appears to be differentiated from the subzone of *Sigaloceras planicerclus* above by the absence from the latter of *Kepplerites*.

Subzone of *Proplanulites koenigi*. Buckman (1913*a*, p. 154), describing the fauna of the Kellaways Rock of Scarborough, made a new zone of *P. koenigi*, which he based on the fossiliferous part of the Kellaways Rock (as distinct from the higher Hackness Rock) as there exposed. Presumably he thought that this bed was of earlier age than the Kellaways Rock of Wiltshire, for he stated: 'above ... on the evidence of South of England strata, should be a zone of *calloviense*; ... but it is noticeable that *Sigaloceras calloviense* appears to be absent from the Yorkshire strata. There is evidently a lacuna here ....' He implied therefore a direct equivalence to the upper Kellaways Clay of Wiltshire and Dorset, which yielded the lectotype of *Proplanulites koenigi*. The absence of *Sigaloceras calloviense* has been shown above to be due to causes other than non-deposition or erosion, and in the absence of detailed monographing of the faunas, there seems at present no reason to suppose that there is in fact any difference between the ages of the Kellaways Rock of Yorkshire and both Kellaways Rock and Clay of Wiltshire, i.e. between Buckman's *koenigi* Zone and Woodward's *calloviense* Zone. That Buckman later possibly suspected this is suggested by the table on p. 24 of his 1929 paper (Buckman 1929*a*, written 1922).

Use of the term *koenigi* Zone has in fact nearly always implied an age similar to that of the Kellaways Clay of Wiltshire rather than the Yorkshire beds. It is proposed, therefore, formally to restrict Buckman's Zone of *Proplanulites koenigi* to beds of the age of the upper (pyritic) Kellaways Clay of Wiltshire. In this way the familiar index-fossil would be retained and the common usage of the past preserved. It should, however, be emphasized again that distinction between this subzone and that above is only locally possible. Thus in Wiltshire, for instance, the criteria for the *koenigi* and *calloviense* Subzones are the presence of *Pleurocephalites* in the former and *Sigaloceras calloviense* in the latter; however, on the Continent *Pleurocephalites* ranges upwards, while in other parts of Britain both *Pleurocephalites* and *Sigaloceras calloviense* are absent. For this reason it is proposed to retain the zone as a subzone rather than a full zone. It is differentiated from the *macrocephalus* Zone s.s.

by an apparently sharp faunal break: it marks the first appearance in north-west Europe of *Cadoceras*, *Proplanulites* and *Kepplerites*.

11·32. *Zone of* Macrocephalites macrocephalus. The type-locality of Oppel's original zone is Wiltshire, for in his chapter describing the zone (1857) the only detailed description of any specific locality refers to the Chippenham-Trowbridge area. He excluded the Cornbrash of the localities which he visited on the grounds that no *Macrocephalites* was known from it, and as the Upper Cornbrash there is thin or absent, his zone definitely excluded what is now recognized as the *discus* Zone of the Bathonian. When *Macrocephalites* was found in the Cornbrash, the latter was included at least in part in the *macrocephalus* Zone by T. Wright, Woodward and Buckman. It was not then known whether *Macrocephalites* and *Clydoniceras* occur together or in succession. Blake (1905) asserted that they occurred together, but Douglas & Arkell (1928, 1932) showed that he was mistaken, and that the Cornbrash south of the Humber could be divided into a lower subdivision with *Clydoniceras* and an upper with *Macrocephalites*. Spath (1932*a*, p. 145) subdivided his *macrocephalus* Zone into a lower (*herveyi*) and an upper (*koenigi*) Zone; but although he mentioned only the Yorkshire Cornbrash in the *herveyi* Zone, as equivalent to everything between the *discus* and *koenigi* Zones in his table, it is synonymous with the *macrocephalus* Zone. It has now become clear that in this country there are two successive macrocephalitid faunas between the *discus* and *koenigi* Zones and it is proposed to make these the basis of two subzones. The lower is here named the subzone of *Macrocephalites* (*M.*) *macrocephalus sensu stricto*; for the higher is adopted *M.* (*Kamptokephalites*) *kamptus* Buck., already made a hemeral index by Buckman in 1922 (*T.A.* IV, pl. ccclxvii); the type specimen came from the Cornbrash of Peterborough.

Subzone of *M.* (*Kamptokephalites*) *kamptus*. Type locality Kidlington. To this subzone belongs the whole of the Kellaways Clay of Kidlington; also the Cornbrash and 'Shales of the Cornbrash' of Yorkshire, part at least of the Upper Cornbrash of Peterborough and Kent, and the lower (phosphatic) part of the Kellaways Clay of Wiltshire and Dorset. The main feature of the fauna of the subzone is the predominant coarse-ribbed, depressed *Kamptokephalites*; however, it should be added that both *Kamptokephalites* and *Dolikephalites* are found in the subzone of *Macrocephalites macrocephalus* below, and typical *Macrocephalites sensu stricto* occurs in England at least up to the *koenigi* Subzone, and on the Continent much higher. The junction with the subzone below is therefore probably gradual, and it will be only rarely possible to make the distinction at any one locality with only one or two examples of *Macrocephalites* available.

Subzone of *M.* (*M.*) *macrocephalus*. This includes the remaining Upper Cornbrash, i.e. that of most of Douglas & Arkell's South-western Area. The macrocephalitids have not been monographed, but appear to be mainly large fine-ribbed *Macrocephalites sensu stricto* with smooth body chambers frequently preserved. It is noteworthy that the most frequent records of *Kamptokephalites* from Upper Cornbrash in the South-western Area (see, for example, Cox & Arkell 1948–50, p. 93) are from localities in which the *lagenalis* Subzone, the higher of the two brachiopod subzones based upon the Upper Cornbrash and defined by Douglas & Arkell, is well-developed, i.e. Malmesbury to Fairford and South Dorset. Most of these ammonites are small and difficult to identify; it may well be, however, that at these localities part of the Upper Cornbrash belongs to the *kamptus* Subzone.

Comparison of the two ammonite subzones with the two brachiopod subzones of Douglas & Arkell does not reveal any immediate correlation, and must be incomplete because of the sensitivity of brachiopods to changes in facies; they are generally absent in clay. However, at the places at which the fauna of the *kamptus* Subzone has been recognized, it occurs above *Microthyridina lagenalis*; thus at Yeovil, Frome and Hanborough (near Kidlington) the *kamptus* clays are underlain by a few inches of rusty marls containing abundant crushed *M. lagenalis*. It can therefore be said that the *macrocephalus* Subzone embraces all of the *siddingtonensis* Subzone, and possibly some of the *lagenalis* Subzone. The upper limit of the latter has not been determined, for a long sack-like ornithellid (*Ornithella ornithocephala* auctt.) persists into the Kellaways Rock.

The zones of table 4 are seen to be relatively few in number, with numerous subzones. This scheme has been adopted for the reason already indicated, namely that in the Callovian of north-west Europe, Britain occupies a special position. It is the meeting place of the faunas of several faunal provinces, and this has created a rapidly changing record of fossils which locally admits of fine stratigraphical subdivision. While it has been thought to be useful to embody these recognizable subdivisions in the zonal table, the creation of a large number of full zones would have attached undue weight to the Lower Callovian and given an exaggerated impression of its relative duration.

For permission to carry out this examination, I am indebted to Mr Jackson of the Tilbury Construction Company, to Mr E. M. Stubbs of the Oxfordshire County Council Surveyor's department and to the Surveyor's department of the Ploughley Rural District Council. I am grateful to Mr R. V. Melville, who visited the site with me and identified the lamellibranch and gastropod faunas, for much help so readily given; also for the assistance of Mr W. S. McKerrow and for the wholehearted co-operation of the workmen at the site. Brig. G. Bomford has allowed me to examine his collection of Callovian and Oxfordian ammonites from Kent, and I thank also Mr A. G. Brighton of the Sedgwick Museum, Dr D. T. Donovan and Mr M. L. K. Curtiss of Bristol for sending me ammonites on loan from the collections in their custody. Dr L. F. Spath, F.R.S., helped with the relevant ammonites in the British Museum. I am also much indebted to the Resident Engineer and Mr S. Worraker of Messrs Herbert Lapworth Partners for showing me over the site of the new reservoir at Sutton Bingham and allowing me to examine the ammonites obtained; and to Herrn K. Knecht, manager of the iron-mine at Herznach, Aargau, for showing me the mine and presenting me with some choice ammonites from the collection kept there. Professor A. Jeannet of the Eidgenössische Technische Hochschule, Zürich, and Professor A. Hartmann, of Aarau, showed me much kindness in allowing me to examine the magnificent collections from Herznach and surroundings and by describing the local geology to me. Finally, I acknowledge my debt and express my gratitude to Dr W. J. Arkell, F.R.S., for his assistance with many troublesome points, many discussions, and constant encouragement; and my friend James Edmonds of the Oxford University Museum for his help and kindness at all times while collecting at the site and in the preparation and writing of this account.

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Description of plates 2 and 3

Plate 2

Figures 1–4. *Kosmoceras* (*Gulielmites*) *medea* n.sp. Figure 1. Holotype; 1*a*, adult with complete body chamber; 1*b–d*, with body chamber removed. O.U.M. J 6057. Kidlington, bed 12. Figure 2. Paratype; nucleus, wholly septate, with test preserved. O.U.M. J 6131. Kidlington, bed 12. Figure 3. Paratype; adult with half a whorl of body chamber. O.U.M. J 1379. Kidlington, bed 12. Figure 4. Complete adult. G.S.M. WM 180. Guilford Colliery, Kent, 1204 to 1234 ft.

Figure 5. *Sigaloceras* (*Catasigaloceras*) *planicerclus* (S. Buckman). Complete adult, with some test preserved. G.S.M. Zk 1449, C. W. Wright coll., South Cave, Yorkshire.

Figure 6. *Kosmoceras* (*Gulielmites*) *jason* (Reinecke). Wholly septate specimen with test preserved. O.U.M. J 6070. Kidlington, nodules in bed 16.

All figures natural size, by the author.

Plate 3

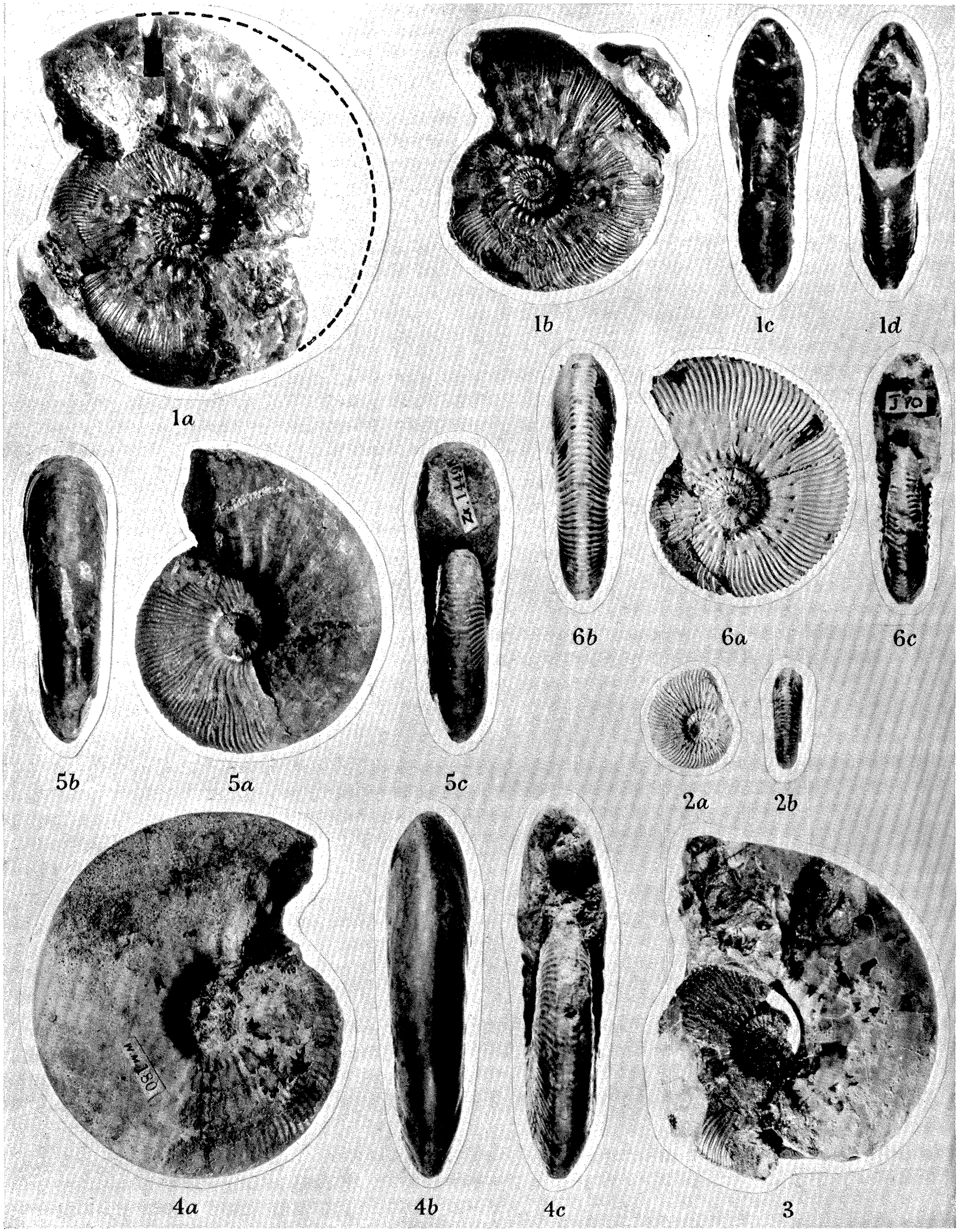
Figure 1. *Kosmoceras* (*Zugokosmokeras*) *obductum* (S. Buckman). Wholly septate, with test preserved. O.U.M. J 3413. Origin unknown, probably Wiltshire.

Figure 2. *Kosmoceras* (*Gulielmites*) *jason* (Reinecke). Adult, with some body chamber. G.S.M. 26072, Cunnington coll. Locality unknown, probably Wiltshire.

Figures 3 and 4. *Kosmoceras* (*Gulielmites*) *medea* n.sp. Figure 3. Evolute variety. Complete adult, G.S.M. WM 289. Guilford Colliery, Kent. 1204 to 1234 ft. Figure 4. Compressed variety. Adult with some body chamber, Bomford coll. no. 562. Dover Colliery, Kent.

Figures 5 and 6. *Sigaloceras calloviense* (J. Sowerby). Figure 5. Nucleus, wholly septate with test preserved. O.U.M. J 3412. Wiltshire. Figure 6. Complete adult, with some test preserved. O.U.M. J 3411. Wiltshire.

All figures natural size, by the author.



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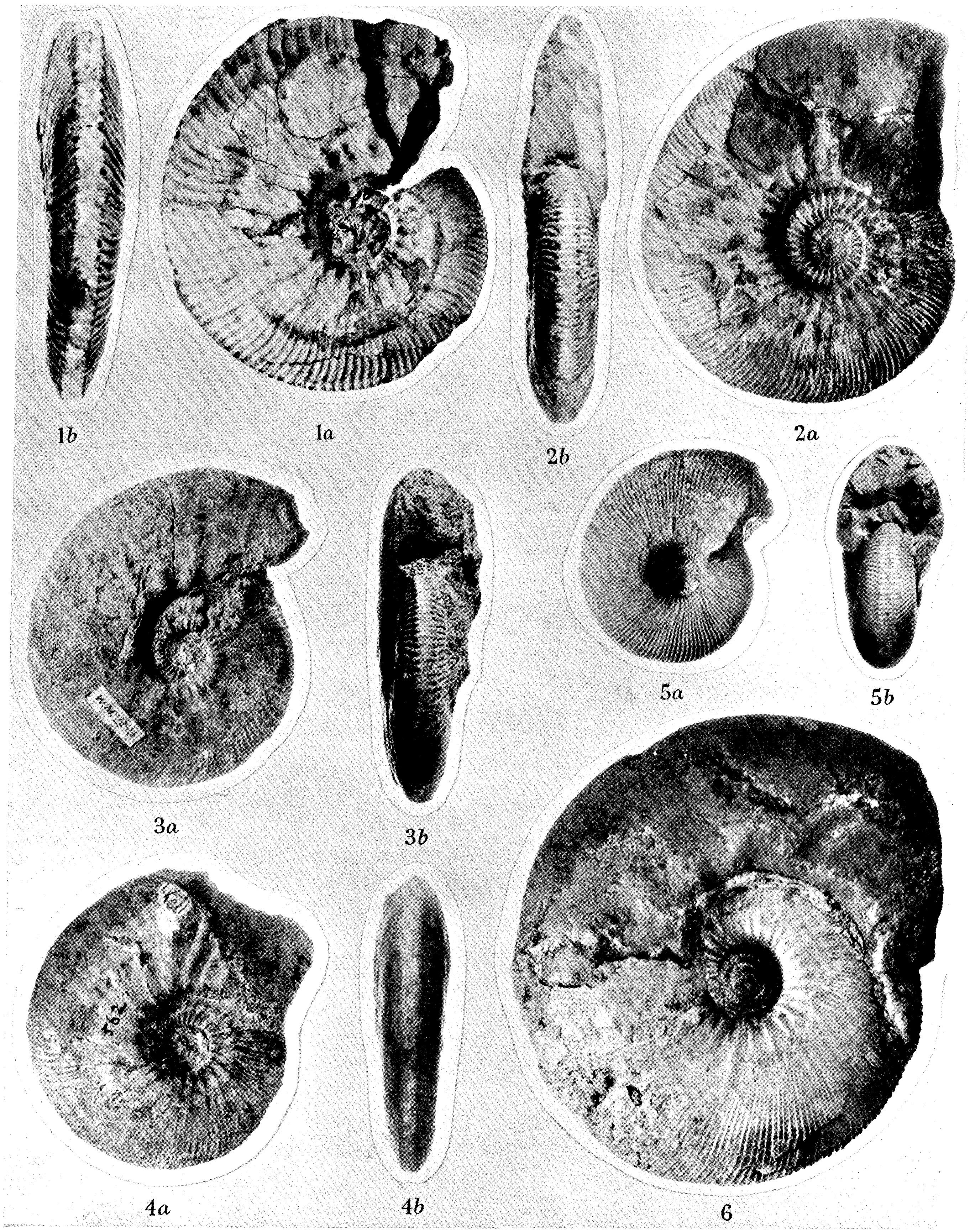
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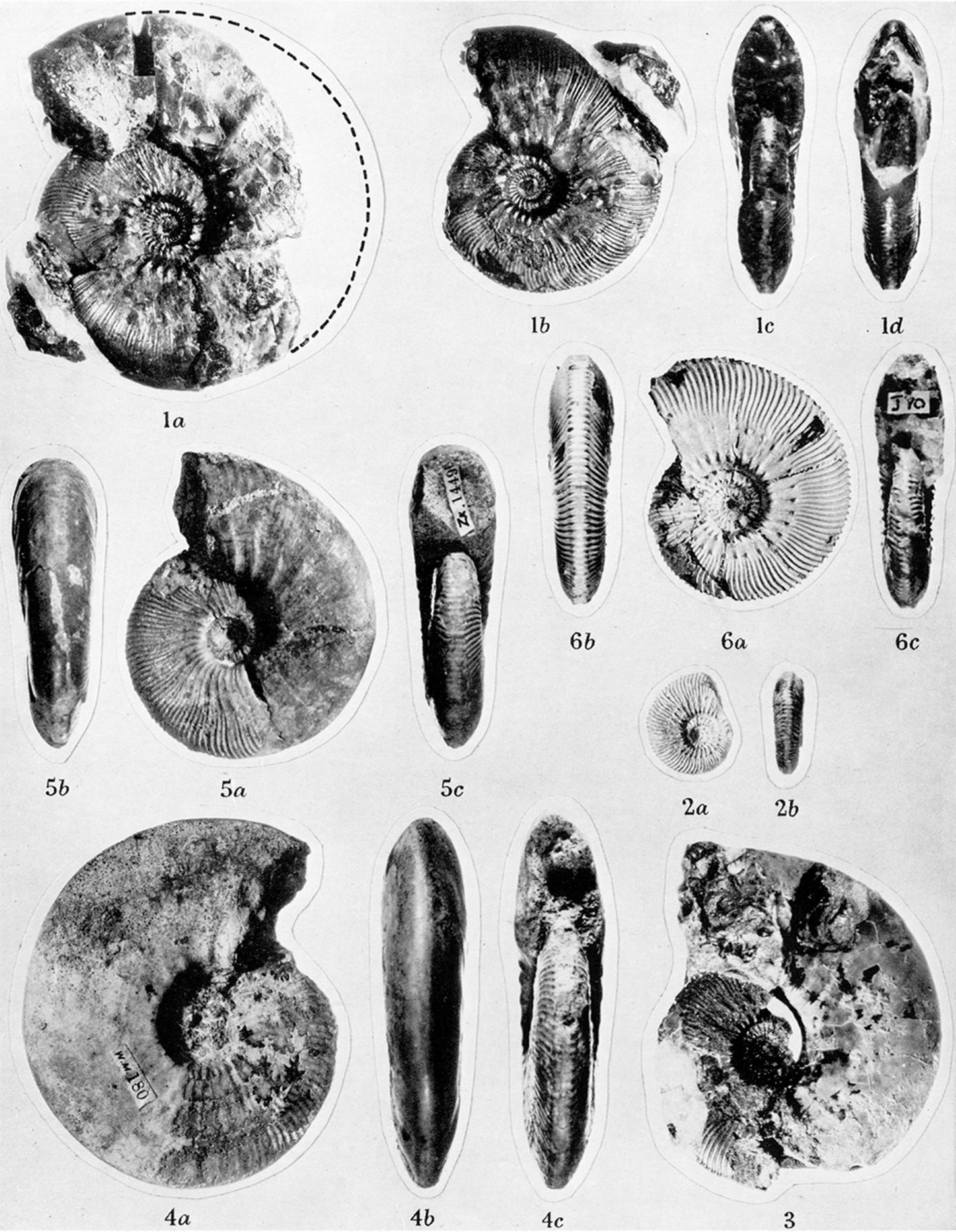

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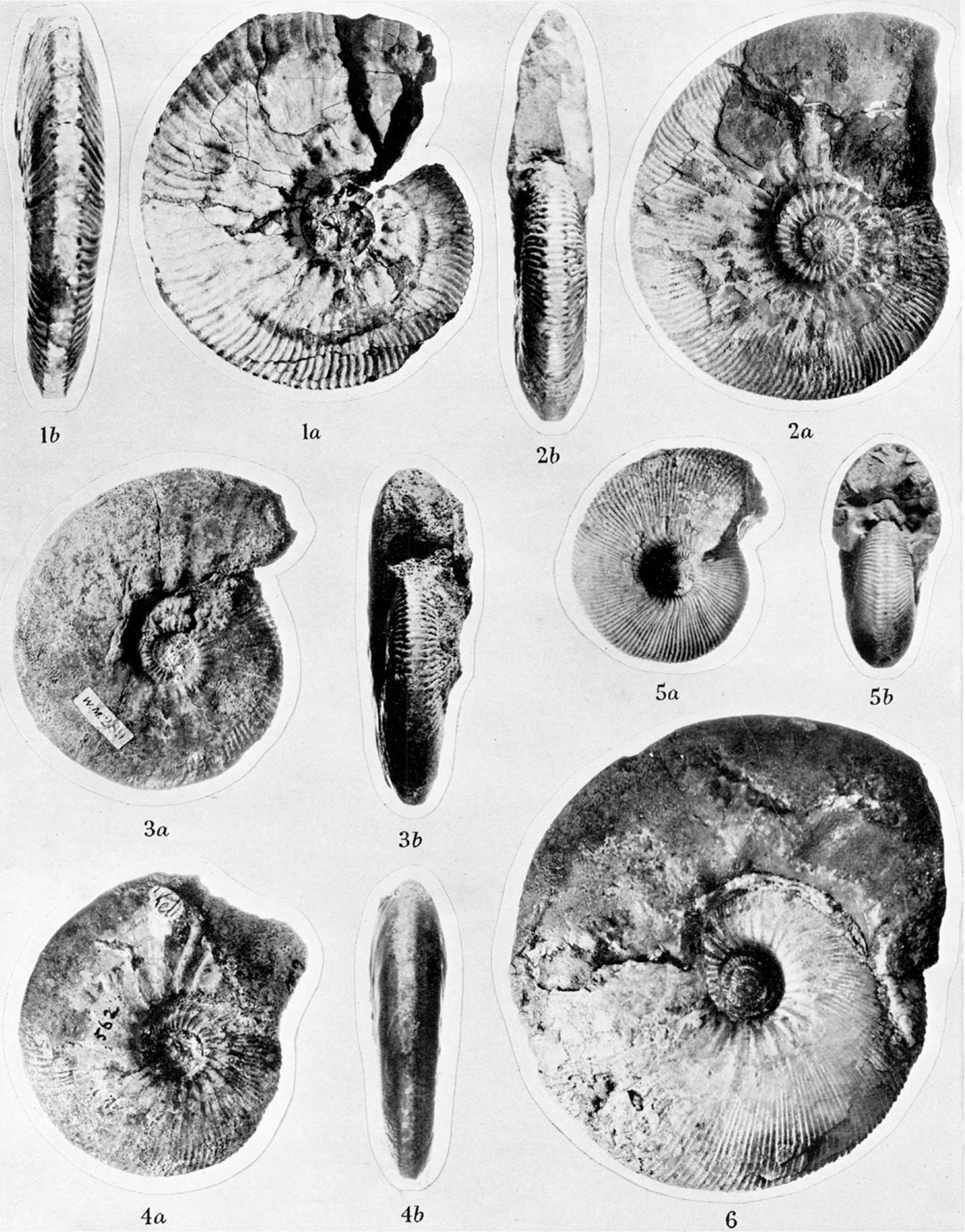

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