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TO BE HELD AT BURLINGTON HOUSE.
SESSION 1912–1913.

1913.

Wednesday, May ..... 7 —28*
„ June 11 25*

[*Business will commence at Eight o'Clock precisely.*]

The asterisks denote the dates on which the Council will meet.

THE

QUARTERLY JOURNAL

OF THE

GEOLOGICAL SOCIETY OF LONDON.

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THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

...quod si cui mortalium cordi et curæ sit non tantum inventis hærere, atque iis uti, sed ad ulteriora ...scere; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter ...sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant.

Novum Organum, Præfatio.

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MCMXIII.

9. *The* 'Kelloway Rock' *of* Scarborough.[1]

By S. S. Buckman, F.G.S. (Read March 5th, 1913.)

Contents.

I. The Rock and its Ammonite Fauna.

Over fifty years ago an important paper on 'The Kelloway Rock of the Yorkshire Coast' was published by John Leckenby in this Society's Journal.[2] It dealt chiefly, if not entirely, with the development of the stratum in the neighbourhood of Scarborough. From this rock he recorded over thirty species of ammonites, many of which were new. Several of these were not figured, and they may be said to have remained almost unknown to science, except perhaps locally. Even of those figured it has been difficult to determine from the descriptions and illustrations what were their generic affinities—a task not altogether easy, even when the specimens themselves are handled.

It is obvious from the ammonite fauna which Leckenby described that the Kelloway Rock of Yorkshire comprises more than the Kellaways Rock of Wiltshire, that it is in part a calcareous equivalent of the Oxford Clay of the southern counties. But, at the same time, this does not state the whole of the facts: for the ammonite fauna of the Yorkshire stratum is not found, so far as many species are concerned, in the Oxford Clay of the southern counties; while certain species of the Kellaways Rock are absent from the Yorkshire deposit. It therefore becomes of interest to see what the ammonites are, and what zonal series they represent.

By the kindness of Prof. McKenny Hughes and Mr. Woods of the Sedgwick Museum, Cambridge, all the types of the ammonites described by Leckenby which are in their possession have been sent to me for study.[3] The authorities of the Museum of Practical Geology, Jermyn Street, London, have also sent to me a considerable series of Callovian-Oxfordian ammonites for determination, among them being many species from the Kelloway Rock of Yorkshire. To all these gentlemen I beg to tender my best thanks.

[1] The appellation 'Kelloway' is here used for quotations from Leckenby or in reference to Yorkshire beds, and 'Kellaways' in relation to deposits in Wiltshire and elsewhere.

[2] Q. J. G. S. vol. xv (1859) p. 4.

[3] The intention is to figure these types in some future issues of 'Yorkshire Type Ammonites.'

From the examination of these specimens it is possible (1) to say what the ammonite fauna is; (2) to arrange the ammonites in groups, according to the different matrices which they exhibit; and (3) to make a supposition as to the relative order of the different matrices. The results arrived at may be stated as follows, beginning with the bed which underlies the so-called 'Oxford Clay' of Yorkshire, according to the statements in the literature.

Table I.—Matrices and Ammonite Fauna of the 'Kelloway Rock' of Scarborough.

Gregarium zone.

Bluish, calcareous, with many close-packed oolitic grains which are fairly large.

Quenstedtoceras gregarium Bean-Leckenby sp.
Q. turgidum Bean sp.
Aspidoceras hirsutum Bayle.
Lunuloceras conterminum Bean-Leckenby sp.
L. cf. *pompeckji* Parona & Bonarelli.
Oppelia sp.

Vertumnus zone.

Grey, with a few fairly-large oolitic grains.

Quenstedtoceras vertumnus Bean-Leckenby sp.
Q. aff. *vertumnus*.
Pachyceras rugosum Bean-Leckenby sp.
Oppelia glabella Bean-Leckenby sp.
Siemiradzkia poculum Bean-Leckenby sp.
S. plana (?) Siemiradzki sp.
Hectioceras ombilicatum Tsytovitch.
H. puteale Bean-Leckenby sp.

Perisphinctes alligatus Bean-Leckenby sp.

This has a bluish matrix, with occasional fairly-large oolitic grains; but there is not much matrix attached.

Bluish, marly, calcareous, with a few oolitic grains.

Aspidoceras faustum Bayle sp.
Quenstedtoceras vertumnus Bean-Leckenby sp.
Q. aff. *gregarium* Bean-Leckenby sp.

Lamberti zone.

Bluish, somewhat argillaceous, a few large grains.

Quenstedtoceras lamberti J. Sowerby sp.
Q. flexicostatum Phillips sp.

Athleta zone.

Greyish, calcareous, oolitic.

Peltoceras subtense Bean sp.
P. bifidum (?) Quenstedt sp.

Bonarellia sp.=*bipartita* Quenstedt, 'Amm. Schwäb. Jura' 1886–87, pl. lxxxv, fig. 3.

Brown, calcareous, oolitic; mixed with irony sand. Matrix and fossils much iron-stained.

Peltoceras athleta Phillips sp.
P. subtense Bean sp.
P. reversum Simpson-Leckenby sp.
P. propinquum (?) Waagen.
P. cf. *chauvinianum* d'Orbigny sp.
P. murrayanum(?) Simpson-Leckenby sp.
Quenstedtoceras aff. *gregarium* Bean-Leckenby sp.
Q. longævum Bean sp.
Cosmoceras gemmatum Phillips sp.

Cosmoceras jason (?) Reinecke sp.=*elizabethæ* Pratt sp., Ann. Mag. Nat. Hist. vol. viii (1842) pl. iii, fig. 3 (cf. *C. pollucinum* Teisseyre, 'Cephalop. d. Ornatenthone in Rjäsan' Sitzb. k. Akad. Wissensch. Wien, vol. lxxxviii, 1883, pl. v, fig. 30).
C. jason spinosum Quenstedt sp., 'Amm. Schwäb. Jura' 1886–87, pl. lxxxiii, fig. 28.
C. elizabethæ (?) Pratt sp. *op. cit.* 1842, pl. iii, fig. 4 (cf. *C. pollux* Teisseyre, *op. cit.* 1883, pl. iv, fig. 27).

Peltoceras cf. *propinquum* Waagen.
Lunuloceras aplanatum Tsytovitch sp.
L. lahuseni Tsytovitch sp.

Cosmoceras duncani J. Sowerby sp.
Siemiradzkia aff. *comptoni* Pratt sp.

The species below the line show a grey sandstone matrix, which is presumably only a less decomposed condition of the bed. *C. duncani* shows the grey sandstone matrix in the chambers, but the irony sand with oolitic grains outside.

Ornatum zone.

Grey or yellowish grey, with many coarse grains which fall out readily.

Cosmoceras compressum Quenstedt sp.
C. rotundum Quenstedt sp.
C. ornatum (?) Nikitin.

Cosmoceras cf. *transitionis* Nikitin.
Quenstedtoceras placenta Simpson-Leckenby sp.

Kœnigi zone.

Light brown, calcareous, with many small oolitic grains.

Proplanulites kœnigi J. Sowerby sp.
Pr. arciruga Teisseyre.
Cadoceras (?) sp. cf. *chrysolithicum* Waagen sp.
C. grewingki Pompeckj.
C. sp. nov.=*longævum* Bean sp. *pars.*

Phlycticeras hyperbolicum Simpson-Leckenby sp.
Kepplerites toricellii Oppel sp.
K. sp.=*gowerianum* Phillips sp. *non* Sowerby.

Cadoceras sublæve J. Sowerby sp., in a loose sandy matrix.

The following Yorkshire species, which for various reasons have not yet been thoroughly studied, are tentatively assigned as under:—

Table II.—Species and Suggested Zones.

Zones.	Species.
Gregarium	*Quenstedtoceras dissimile* Brown sp.
	Ammonites faniferus Phillips.
	Ammonites lenticularis Phillips.
Vertumnus	*Perisphinctes rotifer* Brown sp.
Athleta	*Hecticoceras nodosum* J. Sowerby sp.
do. (grey sandstone)	*Ammonites binatus* Bean-Leckenby=several Perisphinctean forms.
Kœnigi	*Ammonites rowlstonensis* Young & Bird.

These lists of ammonites total nearly sixty species, that is, about double the number which Leckenby mentioned; yet there are certainly several more.

Appended are the original section as described by Leckenby and a more modern section published by Fox-Strangways. It will then be possible to see how these compare with the matrices of the ammonites, and how they can be zoned.

Section I. The Kelloway Rock at Red Cliff (Leckenby).[1]

	Thickness in feet.
'A. Moderately compact irony sandstone, 1½ foot thick, traversed by darkened veins of the same metallic character, across which *Ammonites* are often placed, and which divide the fossil into separate portions when an attempt is made to extract it. This bed is characterised by the presence of *Am. Kœnigi*, *Am. flexicostatus*, and *Belemnites tornatilis*. *Am. flexicostatus* is here special to the bed	[1½]
'B. Loose friable sand and sandstones, without fossils	4
'C. Bed similar to A, but much richer in organic remains, containing, besides *Am. Kœnigi* and *Belemnites tornatilis*, *Am. sublævis*, *A. Gowerianus*, *A. Chamussetti*, *Pholadomya acuticosta*, *Modiola pulchra*, *Terebratulæ*, *Gryphæa dilatata*, and other shells. It is more nodular and cherty than the upper zone, and its fossils are better preserved	1½
'D. Compact sandstone, entirely unfossiliferous, with the rare exception of a stray Belemnite or Ammonite in the centre of one of its huge blocks	20'

Section II. The Kellaways Rock at Red Cliff (Fox-Strangways).[2]

		Thickness in feet.
	'Shales of the Oxford Clay. Few oolitic nodules.	
All these seem to become one irony rock further west.	Hard band, very oolitic	1·
	Soft shaly rock, like Oxford Clay, but much more calcareous. *Belemnites*	9
	Soft sandstone	3
	Red irony rock full of *Gryphæa dilatata*. Oolitic in upper part	6
	Sandstone soft in places, sometimes very hard and siliceous; weathering into large doggers. *Avicula* in lower part	4
	Soft sandstone and hard doggers, few fossils	10
	Soft yellow sandstone with *Gryphæa*, etc.	6
	Yellow sandy shales	8
	Grey shales of the Cornbrash.'	

[1] Q. J. G. S. vol. xv (1859) p. 5.
[2] 'The Jurassic Rocks of Britain: vol. i—Yorkshire' Mem. Geol. Surv. 1892, p. 280.

Leckenby (*op. cit.* pp. 4, 5) mentions a thin band of calcareous pisolite a short distance to the south of Gristhorpe Bay, which immediately underlies the Oxford Clay and is 5 inches thick. He does not seem to have considered this bed of importance, as he does not mention it in his section. But the description seems to fit the matrix of the *vertumnus* zone: its fairly-large oolitic grains might well be described as small pisolites. Such a bed, therefore, should be placed on the top of his section. In that position Fox-Strangways mentions a hard band very oolitic, and 'very oolitic' is a term which exactly describes the matrix of the *gregarium* zone. Further, Fox-Strangways says, of the north side of Osgodby Nab:

'At the top of the rock is a thin band of dark-coloured calcareous shale, with oolitic grains, which also contains many ammonites including a large tuberculated species. This is probably the calcareous pisolite ...' (*op. cit.* p. 281).

This description seems to fit the matrix of the *gregarium* zone. 'A large tuberculated species' of ammonite is very vague: it might be a *Cosmoceras*, a *Peltoceras*, or an *Aspidoceras*; certainly *Aspidoceras hirsutum* Bayle answers well to the description, and that is a species of the *gregarium* zone.

Assuming a general identity of the calcareous pisolite with Fox-Strangways's 'dark-coloured calcareous shale,' then the following suggestion may be made as to the zoning of the sections given by the two authors:—

TABLE III.—ZONES AND SECTIONS OF THE 'KELLOWAY ROCK' CORRELATED.

Zones.	Leckenby.	Fox-Strangways.
Gregarium.....	Calcareous pisolite.	Hard band, very oolitic.
Vertumnus.....		
Lamberti.....		Soft shaly rock, calcareous.
Athleta	A. Irony sandstone.	Soft sandstone.
Ornatum.....		
(?)	B. Sand and sandstone.	Red irony rock.
Kœnigi	C. Irony sandstone.	
(?)	D. Unfossiliferous sandstone.	Three beds of sandstone.

II. REMARKS ON THE FAUNA AND THE ZONES.

Beginning at the base:—Leckenby's bed D, which is above the Cornbrash with *Macrocephalites* (*Macrocephalus* zone), cannot be assigned to any one zone on the evidence now available. His bed C may be regarded as forming the *kœnigi* zone. Above that, on the evidence of South of England strata, should be a zone of *calloviense*: this may be represented by Leckenby's unfossiliferous bed B; but it is noticeable that *Sigaloceras calloviense* appears to be absent from the Yorkshire strata. There is evidently a lacuna here, for the zone of *Reineckeia anceps* is also missing. This zone, which is well shown by Continental deposits, would seem to be entirely absent from Yorkshire, and to have been practically removed from

the Callovian strata of the rest of England: the only evidence for it known to me being a solitary *Reineckeia* from Wiltshire, and another reported by Dr. A. Morley Davies from Dorset. Such isolated finds appear to indicate that the zone was denuded except, perhaps, for a fragment or two left in pockets. But in Scotland at Duart House, in the Isle of Mull, the *Reineckeia-anceps* zone is represented by several species and many specimens; the material was submitted to me for professional work by the Geological Survey of Scotland.

Another Continental zone, that of *Ammonites coronatus* (*Erymnoceras coronatum* Bruguière sp.), occurs about this horizon, above *anceps*. It also must have suffered by denudation. There appears to be no trace of *Erymnoceras* in Yorkshire. In Wiltshire there is a representative, *E. reginaldi* Morris sp.: this appears to have been not uncommon, and is quoted from a rock-band about 10 feet above '*Ammonites jason*.'[1] From the brickyard, Calvert Station (Buckinghamshire), I have the same species; this exposure shows about 90 feet in the so-called '*ornatum* zone.' In the *ornatum* zone of Oxford the species or its allies appear to be wanting; perhaps these strata represent only the upper part of the Calvert series.

The *ornatum* zone in the Kelloway Rock of Yorkshire is represented by a stratum with coarse oolitic grains, yielding several species of *Cosmoceras*. Other species of the genus show a more iron-stained matrix, which is similar to that yielding many species of *Peltoceras* (*athleta* zone); but perhaps the iron-staining of the *Cosmocerata* is deceptive, being due to filtration from a superior stratum. These *Cosmocerata* are remarkable for their large size, and in some cases for their robust proportions; they are unlike the usual *ornatum*-zone series found in the Midlands. And the series of *Peltoceras* is more varied than in the Midlands: *P. reversum* is a very noticeable form, quite suggestive of *P. transversarium* Quenstedt sp. and *P. toucasianum* d'Orbigny sp., which are from the Argovian.

On the evidence of Fox-Strangways's section, where calcareous shaly rock follows above soft sandstone resting on the irony bed, the zone of *lamberti* is next in order above that of *athleta*, for the matrix of the species examined and placed in this zone is the only one which seems to correspond with his description. Apparently, however, there is much difference in the *lamberti* zone of Yorkshire, as compared with that of counties south of the Humber; the former is much less fossiliferous than the latter.

Above the *lamberti* zone comes the *renggeri* zone, well developed in Buckinghamshire and on the Continent, and very fossiliferous. I have seen no evidence for this zone among the Yorkshire specimens

[1] R. N. Mantell, 'Strata ... exposed ... near Chippenham, &c.' Q. J. G. S. vol. vi (1850) p. 313; *Ammonites reginaldi* is figured in pl. xxx, fig. 6.

examined; but, as Fox-Strangways quotes *Ammonites crenatus* from the Kellaways Rock of Yorkshire (p. 277), and as *A. crenatus*, or rather a *Creniceras*, is fairly unmistakable, it is reasonable to conclude that there is some trace of the *renggeri* zone. At the same time, the lack of the associated fauna would seem to indicate a poor development. Its position is presumably in the calcareous shaly rock.

There remain yet two matrices, two zones, to be accounted for —*vertumnus* and *gregarium*: the former answers to Leckenby's calcareous pisolite and the latter to Strangways's 'hard band, very oolitic' or to his 'dark-coloured shale with oolitic grains,' which he thinks is the equivalent of Leckenby's rock. At any rate, both authors find this stratum, or these strata, at the top, close under so-called 'Oxford Clay.'

The *vertumnus* zone shows a fauna which differs considerably from any fauna found, so far as my experience goes, in the rest of England.

Aspidoceras faustum, *Quenstedtoceras vertumnus*, *Q.* aff. *gregarium*, *Pachyceras rugosum*, *Oppelia glabella*, *Siemiradzkia poculum* are all species which seem to be special to Yorkshire as distinct from the rest of England, leading to the inference that the Oxford Clay deposits of the Midlands and the South are incomplete. *A. faustum* and *S. poculum* are found in Normandy, where also are found species of *Pachyceras* allied to *P. rugosum*. *A. faustum* is remarkable for its likeness to certain forms of *Aspidoceras* found in the Lower Calcareous Grit (basal Argovian) of Oxford and the neighbourhood, but that corresponds to a much higher stratum in Yorkshire.

The *gregarium* zone also shows a fauna peculiar to Yorkshire, as compared with the rest of England. *Quenstedtoceras gregarium* is most like some Russian species. *Q. turgidum* and *Aspidoceras hirsutum* are found in France.

It is obvious that, at present, it is not possible to say which is the higher of the two matrices and the two faunas. The sequence now indicated is a supposition; but the calling of attention to it may be the means of obtaining the required solution. It is presumed that these strata represent in a general way the *mariæ* zone of the Normandy coast, and the likeness of *Quenstedtoceras vertumnus* to *Q. mariæ* favours this view. But I have seen no evidence as yet for any *mariæ* fauna in the Oxford Clay of the rest of England.[1]

A few words may now be said about the Oxford Clay of Yorkshire. Fox-Strangways (*op. cit.* p. 295) quotes fifteen ammonites

[1] Identifications of *Ammonites mariæ* cannot be accepted without investigation: A. d'Orbigny mixed several forms. (See below, p. 164.)

from it, but eight of these he also gives as from the Kellaways Rock. Of the remainder, three more are of the age of the 'Kelloway Rock,' as developed in Yorkshire: that is to say, *Ammonites comptoni* and *A. elizabethæ* are species of the *ornatum* zone, while *A. eugenii* belongs to the *athleta* zone.

This leaves only four species. Of these, two, *A. cordatus* and *A. vertebralis*, are, when correctly identified, species of the Lower Calcareous Grit as developed in the Oxford district. But in the top layer of Oxford Clay, subjacent to the Lower Calcareous Grit, is a fauna with several *Cardioceras*-like species, which are often incorrectly assigned to *A. cordatus* and *A. vertebralis*. Such a fauna, which must be worked out another time, may be indicated by the citation of these species from the Oxford Clay of Yorkshire.[1]

There remain now only two species, *A. vernoni*[2] and *A. oculatus*.[3] By the kindness of the authorities of the York Museum, which I gratefully acknowledge, the types of these two species have been placed in my hands for study. So far as I know, they are quite peculiar to Yorkshire. They may have lived contemporaneously with the *Cardioceras*-like species, or they may indicate another date.[4] It will not commit us, then, irretrievably to mark the Oxford Clay of Yorkshire, which is not contemporaneous with the 'Kelloway Rock,' as being of *vernoni* hemera, until the facts can be more accurately ascertained.

There is yet another species from the Oxford Clay of Yorkshire, *Peltoceras intertextum* Simpson sp.[5] incorrectly assigned to the Lias by its author. But it is a derived fossil, and is pyritized, and is, moreover, an Oxford Clay form. It is probably from the *athleta* zone, where that zone is argillaceous and not calcareous. My thanks are due to the late Mr. T. Newbitt, F.G.S., and the authorities of the Whitby Museum for kindly allowing me to have the type for study.

The results of the foregoing remarks may be stated graphically as follows (Table IV, p. 160):—

[1] A flat (? thin) form of the so-called '*Am. cordatus*' is presumably *Am. scarburgensis* Young & Bird, which is thus described ('Geol. Surv. Yorkshire Coast' 2nd ed. 1828, p. 265):—'We have a small ammonite resembling this [*A. speetonensis* Bean] on the side, but very flat, and with a crenated keel, found by Mr. Williamson in the second shale [Oxford Clay] at Scarborough. This species may be named *A. scarburgensis*.'

[2] 'Geol. Surv. Yorkshire Coast' 2nd ed. (1828) pl. xiv, fig. 5.

[3] J. Phillips, 'Geol. Yorkshire' vol. i (1829) p. 138 & pl. v, fig. 16.

[4] In certain MS. lists of Jurassic zones which I drew up for the Geological Survey, I used the term 'pre-*cordatus*' for these *Cardioceras* strata of the Oxford Clay which underlie the Calcareous Grit where *C. cordatum* occurs. This provisional term was necessary, because there are no correctly identified ammonites to give a name.

[5] 'Fossils of the Yorkshire Lias' 1855, p. 50.

TABLE IV.

TIME-TABLE AND COMPARISON OF CALLOVIAN-DIVESIAN (OXFORDIAN) DEPOSITS.

	Hemeræ.	Strata. Yorkshire.	Strata. Midlands, etc.		Remarks.
Divesian.	*vernoni*	Oxford Clay.			
	gregarium ...	Oolites at top of Kelloway Rock locally developed.	No evidence of fauna or deposit.		*Mariæ* Zone of Normandy Coast.
	vertumnus ...	Oxford Clay according to quoted fossils at other places.			
	renggeri	A trace of the fauna.	Well developed in Buckinghamshire Upper Oxford Clay.		
Callovian.	*lamberti*	Kelloway Rock locally.	Lower Oxford Clay.		
	athleta	Passes laterally into Oxford Clay according to quoted fossils.	*Athleta* Zone, Oxford. Perhaps incomplete.	Late	development of *Cosmoceras*.
	ornatum		Clay with *Cosmoceras*, Oxford.	Middle	
	coronatum ...	Neither fauna nor deposit found.	*Reginaldi* Bed, Trowbridge.	Early	
	anceps		Trace of fauna in Kell. R. Wilts. Deposit nearly removed.		Deposit with good *Reineckeia* fauna, Isle of Mull, Hebrides.
	calloviense ...	Fauna and deposit may be present.	Kellaways Rock.		Kellaways Rock. H. B. Woodward.
	kœnigi.....	Kelloway Rock (Leckenby).			Kellaways Clay. H. B. Woodward.

The foregoing Table shows that the 'Kelloway Rock' of Yorkshire is, in the main, contemporaneous with the Oxford Clay of the Midlands and the South of England, and is therefore later than the Kellaways Rock of these parts. It also shows that, according to the evidence of the Oxford-Clay fossils of Yorkshire cited by Fox-Strangways,[1] the 'Kelloway Rock' of Yorkshire is

[1] The following table shows the zones which the ammonite species cited by Fox-Strangways from the Oxford Clay of Yorkshire may be presumed to indicate; some records have been interpreted:—

TABLE V.—'OXFORD CLAY' AMMONITE ZONES.

vernoni	*A. vernoni*, *A. oculatus* (*A. cordatus*, *A. vertebralis*= *Cardioceras* spp. may be higher).
gregarium	*A. perarmatus*=*Aspidoceras hirsutum* Bayle.
vertumnus	*A. mariæ*=*A. vertumnus*.
renggeri	*A. crenatus*=*Creniceras* sp.
lamberti	*A. lamberti*.
athleta	*A. binatus*, *A. eugenii*.
ornatum	*A. elizabethæ*, *A. comptoni*.

There is also *A. crenularis* Phillips, 'Geol. Yorks.' vol. i (1829) pl. xii, fig. 22, probably a *Quenstedtoceras*, and presumably from the *lamberti* zone.

only developed locally so far as certain of its beds are concerned, and that even within the county itself it passes laterally into, and is contemporaneous with, the Oxford Clay.

The idea that the Kellaways Rock and the Oxford Clay were always and wholly sequential deposits, carried out in our literature and in the museum arrangement of specimens,[1] where the same species are found in a lower case headed 'Kellaways Rock' and in a higher case labelled 'Oxford Clay,' is one which must be abandoned. These stratigraphical terms are misleading: they do not indicate sequential deposits, but beds which were in the main contemporaneous. All that they indicate is the lateral change from arenaceous or calcareous to argillaceous conditions.

It is suggested that for the earlier deposits the term 'Callovian' be retained; the Callovian will then roughly coincide with the development of the genus *Cosmoceras* and its allies *Kepplerites* and *Sigaloceras*. For the later deposits the term 'Divesian' (Dives, Calvados) has been suggested to me by Prof. Welsch; it marks the development of *Quenstedtoceras*. When *Quenstedtoceras* is replaced by *Cardioceras* (Lower Calcareous Grit, Coral Rag, and, perhaps in some cases, highest layer of Oxford Clay) the term should be 'Argovian' for *Cardioceras*-yielding strata following Divesian.

These terms would be uniform; but the terms 'Oxford Clay,' 'Kellaways Rock,' etc., are useful, if it be remembered that they vary in value in different localities.

It is inadvisable to use 'Oxfordian' for Divesian, because in Continental usage 'Oxfordian' stands mainly for Argovian (Oxford Oolites).

The suggestion illustrated in Table IV is that the Callovian-Divesian deposits are locally incomplete; that the deposits of certain hemeræ have been locally removed by penecontemporaneous erosion, as is usual with deposits of the Bajocian, Aalenian, etc.; that a full sequence of deposits can only be obtained by placing together the developments of many localities; and that, to express the entire sequence, a full table of zonal or hemeral names, such as is now given, is necessary. The object of a full table of hemeral names is to obtain a true record of the sequence of ammonite faunas as a necessary prelude to a study of their development.

A theory of unrepresented zones may explain in part why the ammonite fauna of certain beds is so peculiar to Yorkshire; but in other cases, where zones are represented, and yet there is distinctive peculiarity, that explanation fails. It may then be necessary to

[1] Such statements have given much trouble: see J. F. Pompeckj, 'Jur. Fauna of Cape Flora' Norwegian North Polar Exped. vol. i (1900) No. 2, p. 130. The Professor rightly judges that 'the Kellaways Rock and the Oxford Clay [of English geologists] may be petrographically different facies of faunistically corresponding strata'; but then he adds, 'and in both the Kellaways Rock (especially that of Yorkshire) and the Oxford Clay, the different zones of the Callovian, as they may be observed on the Continent, cannot be separated.' That statement is disputable: the Yorkshire specimens, from their different matrices, are easily separable into zones in the study, and it must be possible in the field.

suppose that at times there was not free communication between the districts north and those south of the Humber.

It is now for the Yorkshire geologists, or those who have the opportunity to work the Yorkshire cliffs, to ascertain how far the facts in the field agree with this armchair stratigraphy. Here, at any rate, are the suggested points for consideration; and, if only building operations or slips of Boulder Clay have not concealed the important beds, observation of the zonal sequence should not be difficult. Further facts will be welcome, whether they confirm or contradict the present suggestions. The object is to call attention to the knowledge required, and to put forward something which may be a working hypothesis—something which may stimulate the attainment of further knowledge.

Examinations of old collections may be useful, but it must be remembered that the labels of localities in collections are not to be trusted. Yorkshire and Wiltshire specimens have been mixed, and specimens from the Scarborough Limestone (Bajocian) and Scarborough 'Kelloway Rock' have been interchanged. But they can all be separated by examination of matrices: the matrix is really the most trustworthy label that a fossil possesses.

III. Palæontological Remarks.

Ammonites ordinarius Bean-Leckenby (Leckenby, p. 8). I have reason to think that this is not a 'Kelloway Rock' species, but is from the Calcareous Grit, and has been wrongly placed and perhaps wrongly localized. If so, it is a *Cardioceras* more or less nearly identical with *Am. goliathus* d'Orbigny (pl. cxcvi, figs. 1 & 2 only), and it may be a synonym of *Nautilus ammonoides* Young & Bird.[1]

Cadoceras grewingki Pompeckj.[2] This species is hardly a true *Cadoceras*, but it belongs to a series which in form and appearance is intermediate between *Cadoceras* and *Quenstedtoceras*. This species and its allies occur in the Kellaways Rock of Kellaways, and have been placed sometimes as *Ammonites mariæ* d'Orbigny. The 'Russian variety' which he figures by that name[3] belongs to the *grewingki* series, but the other examples are quite distinct (see *Q. mariæ*, p. 164).

Cadoceras, sp. nov. Some of Bean's examples of *Am. longævus* belong here as a much compressed ally of *C. grewingki*. The form is also near to *Quenstedtoceras primigenium* Parona & Bonarelli.[4]

Cadoceras sublæve J. Sowerby sp. By this name is intended the small form figured in the lower right-hand corner of Sowerby's

[1] 'Geol. Surv. Yorks. Coast' 2nd ed. (1828) p. 271.
[2] 'Jura-Fossilien aus Alaska' Verhandl. K. Russ. Mineral. Gesellsch. ser. 2, vol. xxxviii (1900) pl. vi, figs. 1–3.
[3] 'Terr. jurassiques: Céphalopodes' 1842–49, pl. clxxix, figs. 7 & 8 only.
[4] 'Call. inf. Savoie' Mém. Acad. Savoie, ser. 4, vol. vi (1895) pl. ii, fig. 4.

plate ('Min. Conch.' vol. i, 1812, pl. liv), leaving the more globular form as a matter of convenience under the name *C. modiolare* Lhywd-d'Orbigny sp., of which A. d'Orbigny's figure[1] would be the type.

From Gristhorpe Bay I have a fragment of *C. sublæve* as above defined. It is from a matrix of loose sand, suggesting Leckenby's bed B, but he says that this is unfossiliferous.

C. sublæve (+*modiolare*) would appear to be easily identifiable; but in one case it has been very much misunderstood (see below, *Pachyceras robustum*).

Pachyceras rugosum. Bean's *Ammonites rugosus* is a species of the rare genus *Pachyceras*, differing sufficiently from *A. lalandeanus* d'Orbigny. I cannot recall any other record of an English species of the genus.

Pachyceras robustum, nom. nov. This is founded on *Stephanoceras sublæve*, E. E.-Deslongchamps, 'Foss. Oxford. Coll. Jarry; Notes Paléontologiques,' vol. ii (1889) pl. i, figs. 2–4, taking fig. 4 as the type. Prof. Pompeckj[2] has noticed that the species is not identical with Sowerby's *Am. sublævis*, but he has failed to see that it is not a *Cadoceras*, for he has definitely assigned it to that genus. However, the straight massive ribs and the nodose ornament strong on the umbilical border show that it is not a *Cadoceras*: it belongs to the genus *Pachyceras*, and like this genus but unlike *Cadoceras* it becomes less inflated with age.

P. robustum is near to *P. rugosum*, but has more pronounced ornament and strong umbilical nodosities, of which *P. rugosum* shows only traces. *P. rugosum* is also thinner. The position of *P. robustum*, *lamberti* beds of Villers-sur-Mer (= *lamberti-gregarium* zones, perhaps, of this paper), is correct for a *Pachyceras*, but is incorrect for a *Cadoceras*—a genus which belongs to the Lower Callovian.

P. robustum shows that the genus *Pachyceras* is an offshoot of the genus *Erymnoceras*: the study of *P. rugosum* had already led me to form the same conclusion. *P. robustum*, *P. rugosum*, *P. lalandeanum* form in this order a good catagenetic series, in which ornament and thickness are decreasing.

The identification of *P. robustum* with *Ammonites sublævis* and as a *Cadoceras* is good testimony to the deceptiveness of homœomorphy in certain cases, and the likeness thus testified to is an example of a rather unusual form of homœomorphy (see § IV, 'On Development & Homœomorphy' p. 165).

Peltoceras murrayanum. There must be some error in Simpson's description given by Leckenby (*op. cit.* p. 10). To describe a species of this genus as 12 inches in diameter but only three-quarters of an inch thick, must be incorrect; yet the description

[1] 'Terrains jurassiques: Céphalopodes' 1842–49, pl. clxx.
[2] 'Jurassic Fauna of Cape Flora' Norw. North Polar Exped. vol. i (1900) No. 2, p. 79.

obviously refers to a *Peltoceras*. I have received from the Whitby Museum a specimen supposed to be the type. It is rather more than 2 inches in diameter, and is then three-quarters of an inch thick; but it does not altogether agree with the description. Further search for any specimen so named by Simpson may be requested of those who have charge of old collections of Scarborough fossils.

PELTOCERAS SUBTENSE. Leckenby identified this doubtfully with *Ammonites arduennensis* d'Orbigny, but it is not that species. The regular radial (versiradiate) costæ, which bifurcate about the middle of the lateral area, distinguish it from d'Orbigny's species. The position of furcation distinguishes it from many other species. It is a much compressed form, carrying the costate stage a long time, and hardly attaining to the bituberculate stage. The largest example is 176 mm. in diameter.

PHLYCTICERAS HYPERBOLICUM. Simpson's *Ammonites hyperbolicus* is a most remarkable and interesting species. It is the senile development of the genus *Phlycticeras*,[1] which, so far as I recollect, has not yet had any of its species recorded from England. It has lost nearly all ornament, though there remain just sufficient traces of rib-contour to indicate the generic association. The keel has been reduced to a mere ridge. Such a senile species of the genus has not, so far as I know, been recorded.

QUENSTEDTOCERAS GREGARIUM. This species has as a distinctive feature ribs much forwardly inclined across the whorl (prorsiradiation). A Russian species, *Amaltheus leachi* Nikitin[2] (*non* Sowerby), has the same style of tangential ribbing—as if the periphery had been turned forwards around the centre; and it has much the same proportions. Another Russian species, *Amaltheus rybinskianus* Nikitin,[3] is what one would expect as the involute stouter-whorled development. I have not seen such tangentially ribbed forms from any other English localities where other *Quenstedtocerata* abound.

QUENSTEDTOCERAS LONGÆVUM. Leckenby's placing of this as a synonym of *Ammonites lamberti* Sowerby was not correct. The Bean types show two species belonging to two different stocks, one is near to *Q. placenta* (see below) and the other belongs to the *Cadoceras-grewingki* series (see *Cadoceras*, sp. nov., p. 162).

QUENSTEDTOCERAS MARIÆ. D'Orbigny ('Terr. jurassiques: Céphalopodes' pl. clxxix) has several forms under this name. It is

[1] *Phlycticeras* Hyatt = *Lophoceras* Parona & Bonarelli. For a treatise on the species see their work, 'Call. inf. Savoie' Mém. Acad. Savoie, ser. 4, vol. vi (1895) p. 90.

[2] 'Die Jura-Ablagerungen zwischen Rybinsk, &c.' Mém. Acad. Imp. St. Pétersb. ser. 7, vol. xxviii (1881) No. 5, pl. i, fig. 5.

[3] *Id.* pl. i, fig. 8.

advisable to fix one as the type, and for this the example depicted in his figs. 5 & 6 is selected. I understand that this occurs high in the Divesian; but it is doubtful whether we have it in England. The Russian variety (figs. 7 & 8) has nothing to do with it, and probably occurs low in the Callovian. See *Cadoceras grewingki* (p. 162).

QUENSTEDTOCERAS PLACENTA. This very involute species is not a true *Quenstedtoceras*, but still less is it a *Cadoceras* of the *grewingki* series. It would seem to be peculiar to Yorkshire.

QUENSTEDTOCERAS TURGIDUM. This is a senile form, like the example which A. d'Orbigny has ascribed to *Ammonites lamberti* ('Terrains jurassiques: Céphalopodes' pl. clxxviii only), but with a more trigonal whorl, and the venter is more acute in the costate stage.

QUENSTEDTOCERAS VERTUMNUS. This is a species with stout ribs, which look like pieces of cord wound round the whorl. I have not seen it from any other locality. Dr. Pompeckj rightly associates it with *Q. mariæ* d'Orbigny sp., but it is not 'a modification of a *Quenstedtoceras mariæ* d'Orb. sp. with a wider umbilicus':[1] rather is *Q. mariæ* the involute inflated development of *Q. vertumnus*.[2]

IV. On Development and Homœomorphy.

There is an interesting repetition in development, leading to homœomorphy, in many of the Middle Jurassic ammonites. They pass repeatedly and independently from evolute compressed to involute inflated, in some cases to sphærocones, a phenomenon which may be observed in the Callovian genera *Cadoceras*, *Phlycticeras*, in the Divesian *Quenstedtoceras*, and in the Argovian *Cardioceras*. (A similar line is followed by the Kimmeridgian *Amœboceras*, but is not carried so far.) The same phenomenon is also repeated again and again in the different stocks of these various genera quite independently. This phenomenon has caused much confusion in the identification of the various species, and has led to much 'lumping,' because it was not understood. And the 'lumping,' or the failure to recognize what were the critical points of distinction, underlying the likeness, has caused stratigraphical lists to be invalid, and has also given a wholly false range to some much-quoted species, thereby impairing stratigraphical correlation. And that the likeness, the homœomorphy, should have caused the 'lumping' is the best testimony to its completeness. The likeness is often the greater when, as is so frequently the case, the loss, or nearly so, of the principal distinctive characters (ornament, keel, etc.) has accompanied the inflation.

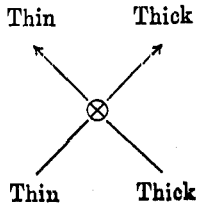
Other genera not dissimilar in time and in appearance, *Macrocephalites*, *Erymnoceras*, *Pachyceras*, develop in a different direction—

[1] J. F. Pompeckj, 'Jurassic Fauna of Cape Flora': Norw. North Polar Exped. vol. i (1900) No. 2, p. 97.

[2] See § IV, 'On Development & Homœomorphy.'

as they become involute and more aged [1] they lose inflation, and by this criterion they may be distinguished from the preceding series of genera.

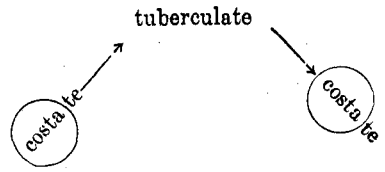
Now, when one series is travelling from thin to thick and another from thick to thin, there is every possibility of their reaching a median collision-point, thus :—



At the median point, given certain factors, there would be homœomorphy : not the homœomorphy of subparallel lines of development as in the first-quoted genera, but the more interesting—and, by the nature of the case rarer—phenomenon of homœomorphy of crossing lines of development. The very interesting case of *Pachyceras robustum* and *Cadoceras sublave* mentioned above (p. 163) is an example, and a very good example, of such homœomorphy. It caused incorrect identification and, in consequence, an unwarranted extension of the zonal range of *Cadoceras*.

Homœomorphy of the first kind may be called parallel homœomorphy, that of the second transversal homœomorphy : these terms refer to the manner in which the phenomenon was produced. Isochronous and heterochronous homœomorphy state whether the homœomorphous species lived in the same or at different times.

There is yet another mode of producing homœomorphy, and this may be called cyclical homœomorphy. It arises when a species in the course of its development retraces its tracks : that is to say, when a species showing a catagenetic stage apes one in an anagenetic stage. For example, an anagenetic species is in the pre-tuberculate costate stage, the catagenetic species is in the post-tuberculate costate stage. The position may be illustrated diagrammatically thus :—



The circles represent the main stages of the two species which

[1] There would be renewed evolution (outcoiling) in extreme old age (incipient scaphiticone stage).

look like enough to be confused (are homœomorphous) until they are analysed ontogenetically, which is not always done.

Such a heterochronous case, partly concerned with species dealt with in the present paper, is not of the most striking kind, but it deserves mention ; it is the case of the young costate *Peltoceras*, like enough to *Dactylioceras* of the *communis* type to cause the former to be sometimes labelled as the latter and relegated to the Lias. Now the former is anagenetic (renewed anagenetic, perhaps), it is in the pre-tuberculate costate stage ; the latter is catagenetic, it is in the post-tuberculate costate stage.

By attention to the various phases of homœomorphy the apparent tangle of ammonite species and the apparent anomalies of stratigraphical records are found to come into definite order. Then it is seen that the many names for genera and species are insufficient to express the facts, and that more names will give a clearer picture of the lines of evolution—that they are a real help to the memory, and not a hindrance.

Discussion.

Mr. J. W. Stather remarked that the beds from which the old collections were obtained are now inaccessible, being covered by buildings at Scarborough and by landslips at Gristhorpe. These fossiliferous beds occur in the uppermost part of the Kellaways Rock, the remainder of the formation being practically unfossiliferous. He mentioned that the best opportunity for obtaining Kellaways fossils in Yorkshire, during recent years, was in the cutting on the Hull & Barnsley Railway at South Cave, and he hoped that the Author would examine the collections made by the local geologists from that locality.

Mr. L. F. Spath congratulated the Author on his most interesting paper and the Society on receiving that valuable palæontological contribution. When he thought of the state of hopeless confusion in which Hyatt had left the classification of these Callovian (as, indeed, of all other) ammonites, putting such closely allied genera as, for example, *Sigaloceras* and *Kepplerites* or *Grymnoceras* and *Reineckeia*, not only into different families, but different super-families, and when he remembered the misdoings of the French school, who at the present day included in the Oxfordian genus *Pachyceras*, so ably traced by the Author that evening, even certain Portlandian holcostephanoids, he felt that all palæontologists must look forward to a study of the details of this paper with the greatest interest.

A point to which he desired to draw attention was the use of the terms Callovian and Oxfordian. There was hardly a stratigraphical term which was employed less definitely and less satisfactorily at the present day than those terms Callovian and Oxfordian, not only on the Continent, but also in this country. In one great London museum, for example, even Kimmeridge-Clay ammonites were labelled 'Oxfordian.' In the speaker's opinion

the Society was greatly indebted to the Author for his table of zones, which indicated how the terms Callovian and Oxfordian, or preferably Divesian, might profitably be employed. His classification was not the orthodox one, but it rested on a sound palæontological basis.

Dr. A. M. Davies said that those geologists who were interested in the Upper Jurassic strata should rejoice in the knowledge that the Author was turning his attention to the zoning of those rocks. It was certain that the number of Upper Jurassic zones would have to be increased.

The President (Dr. A. Strahan) reminded the meeting that the relations of the Kellaways Rock of Yorkshire to the Oxford Clay, and the fact that it was not strictly correlative with the Kellaways Rock of Wiltshire, had been pointed out by the late Mr. Hudleston many years ago. He enquired whether it was contemplated that the misspelling 'Kelloway' could or ought to be perpetuated. The phenomena described under the names of cyclical and transversal homœomorphy appeared to be of great interest and to deserve close scrutiny.

The Author, in reply, remarked that the spelling 'Kelloway Rock' was not his, and he had merely adopted a suggestion made, he believed in the first place, by the late Mr. Hudleston, to keep 'Kelloway Rock' for the Yorkshire bed and 'Kellaways Rock' for the more limited Wiltshire stratum, as a temporary measure. In conclusion, he heartily thanked the Fellows for their kind reception of his paper.