Quarterly Journal of the Geological Society

On the Cotteswold, Midford, and Yeovil Sands, and the Division between Lias and Oolite

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Quarterly Journal of the Geological Society 1889, v.45; p440-474.
doi: 10.1144/GSL.JGS.1889.045.01-04.31

Notes

29. *On the* Cotteswold, Midford, *and* Yeovil Sands, *and the* Division *between* Lias *and* Oolite. By S. S. Buckman, Esq., F.G.S. (Read February 20, 1889.)

It has been observed that attention to lithology is likely to insure success in the matter of correlation. I am bound to confess, however, that my experience of Jurassic rocks tells me that in many cases this observation is quite incorrect. Within the limits of one basin it may happen that the same horizon can often be identified by the similarity in lithology; but even within such limits it certainly will not be safe to place much reliance on such a guide; while in correlating the strata of one basin with those of another, such an idea will probably lead to very decided errors. The strata now to be discussed have suffered singularly in the matter of correlation from this similarity of lithology.

In the counties of Dorset, Somerset, and Gloucester there occur in most places, between clay of Upper Liassic age and limestone of the Inferior-Oolite period, certain yellow micaceous sands, which contain, at intervals, in some places regular bands, in others lines of more or less lenticular masses, of a hard, greyish, sometimes blue-hearted, sandstone. Among other local names, these sandy strata have been known in the county of Gloucester as Cotteswold Sands, in North Somerset as Midford Sands, in the county of Dorset and in South Somerset as Yeovil Sands. On account, however, of the similar position which they occupy with regard to Lias clay and Inferior-Oolite limestone, and also, no doubt, on account of their exactly similar lithological appearance, the name "Midford Sands"* (a name first applied by William Smith to the sands at Midford) has been used to designate these sands in the three counties; under this name they have been mapped by the Geological Survey.

Around the sands which lie between Liassic clay and Oolitic limestone a constant discussion has been waged for the last thirty years or more, as to whether they should be classed with the Liassic or Oolitic periods. According to the opinion of those whom I may call the first generation of geologists, whose pioneer was William Smith, the sands were "Sands of the Inferior Oolite." The celebrated Dr. Oppel, who visited this country about 1855, comprehended the positions of these sands with his usual acute perception; and had our English geologists given to his work the attention which it deserves, it ought to have been impossible for the discussion to have been maintained. In 1856 Dr. Oppel, in the 'Juraformation,' p. 296, places the Cotteswold Sands of Frocester Hill in "the zone of *Posidonomya Bronni*," that is, with the Upper Lias; while on the

* In the following paper the term "Midford Sands," written thus, means that it is used in the same sense as by the Officers of the Geological Survey; while Midford Sands refers only to the yellow micaceous sands round Bath, Midford, &c.

other hand, at p. 253, he states that at Ilminster the sands of the Inferior Oolite (that is the Yeovil Sands) begin above a bed filled with *Amm. jurensis*, *discoides*, *radians*, &c. Here we have the keynote of the whole affair, published more than thirty years ago. Dr. Oppel saw that the Cotteswold Sands and the Yeovil Sands are on two entirely different horizons; and actually placing the one series in the Lias and the other in the Inferior Oolite, he located between them the zone of *Amm. jurensis*. Yet, in spite of what Oppel had written, the position of the "Sands" remained a bone of contention for very many years, and but little notice was taken of his statements.

It was also in the year 1856 that Dr. Wright proposed* to assign to the Upper Lias those Yellow Sands of Gloucestershire, Somerset, and Dorset which had, from the time of William Smith, been classed as "Sands of the Inferior Oolite." With them he also united the marly-limestone cap which overlies them in the former county, and which is now known as the Cephalopoda-bed of Gloucestershire. Finding that the Sands of Dorset reposed beneath a similar lithological cap, he considered this also to be on the same horizon; and thus it came to pass that he included in the Upper Lias the *Murchisonæ*-zone, the *Concavum*-beds, and even part of the *Parkinsoni*-zone of the Bradford-Abbas and Halfway-house strata. It is instructive to notice the species of Ammonites which he quotes, from the so-called Upper-Lias Cephalopoda-bed of Bradford Abbas, in support of this view, p. 310:—

1. Ammonites jurensis, *Zieten.*
2. ,, concavus, *Sowerby.*
3. ,, dorsetensis, *Wright.*
4. ,, variabilis, *d'Orbigny.*
5. ,, striatulus, *Sowerby.*
6. ,, insignis, *Schübler.*

Because we know, at the present day, that of these six species the identification of five must have been incorrect, while the one whose identification is correct—*A. concavus*—happens not to be an Upper-Lias Ammonite at all. The correct names of the others are the following:—

1. Lytoceras confusum, *S. Buckm.*
3. Parkinsonia Parkinsoni (*Sowerby*).
4. Sonninia, sp.
5. Dumortieria grammoceroides, *Haug.*
6. Hammatoceras amaltheiforme (*Vacek*), or a near ally.

In 1860 Dr. Wright† removed the Bradford-Abbas beds from this position to place them, also incorrectly, in the *Humphriesianum*-zone, and then noticed the existence of another bed on the horizon, as he supposed, of the Gloucestershire Cephalopoda-bed. This bed, together with the sands, he classes as "Upper Lias Sand-zone of *A. jurensis*." This opinion remained practically unchanged.

* "The Palæontological and Stratigraphical Relations of the so-called Sands of the Inferior Oolite," Quart. Journ. Geol. Soc. vol. xii. p. 292 (1856).

† "Inferior Oolite," Quart. Journ. Geol. Soc. vol. xvi.

The only difference was that the upper part of the Frocester-Hill Cephalopoda-bed was placed in the zone of *A. opalinus*; while the Sands were sometimes spoken of as part of the zone of *A. bifrons*, at other times as the zone of *A. jurensis* *: all were included in the Upper Lias.

The chief opposition to the above views came from my father †, who first of all considered the Cotteswold Sands as equivalent to the Freestones of the Cheltenham district, but at a later date placed the Yeovil Sands in this position, the Cotteswold Sands being allowed to go to the Upper Lias because their position was altogether below that of the Yeovil Sands. This view of the different positions of the Cotteswold and Yeovil Sands is noticeable, for it coincides closely with Oppel's; and it is clearly set forth in a diagram of the Midford Sands compared with Haresfield ‡.

To the sands which throughout the greater part of England lie between Liassic clay and Oolitic limestone, Prof. Phillips § extended Smith's name and applied the term "Midford Sands;" although he placed them in the Liassic period, he considered them as Transition Strata. H. B. Woodward, in the first edition of his standard work ‖, restricted the term "Midford Sands" to the counties of Dorset, Somerset, and Gloucester, and attached them to the "Oolitic." Lately (1887), in the second edition (p. 285), he places them in the "Inferior Oolite Series," considers them transitional, and defines them as follows:—

	"Zones."
Midford Sand.	Ammonites (Harpoceras) opalinus.
	„ (Lytoceras) Jurensis."

Such is the position of affairs at present, and thus the name "Midford Sands" is in common use for the Yellow Sands of Gloucestershire with the overlying Cephalopoda-bed, for the Yellow Sands of North Somerset, and for the Yellow Sands and shelly Sandstones of South Somerset and Dorset ¶. Now the questions arise, Do these series of Sands begin on the same horizon, and, including the Cephalopoda-bed, do they end on the same horizon? How much of this horizon is found at Midford? Do the limits of the *Opalinum-* and *Jurense*-zones correspond with the limits of the Sands; or do they not go above and below them in some cases, and not reach the bottom in others? Are the sands all on one horizon, as stated by Wright; or are they on two different horizons, as Oppel and my father thought?

We must appeal to the Ammonite-fauna; and having by means of that fauna selected a definite horizon as a fixed point, it will be

* "Lias Ammonites," Palæont. Soc. p. 137 *et. seq.* (1879).

† "The Oolites," Quart. Journ. Geol. Soc. vol. xiv. p. 106; also "The Cephalopoda-bed," Quart. Journ. Geol. Soc. vol. xxxiii. p. 3.

‡ "On the so-called 'Midford-Sands,'" Quart. Journ. Geol. Soc. vol. xxxv. p. 738 (1879).

§ Geology of Oxford and Valley of Thames. p. 118 (1871).

‖ The Geology of England and Wales, p. 166 (1876).

¶ H. B. Woodward, *op. cit.* 2nd ed. p. 287.

possible to compare the strata of the different localities therewith, to see if they fall contemporaneously, or above or below the fixed horizon.

The series selected is that of the *Striatulum*-beds, which are traceable in the Cotteswold, Midford, and Dorset-Somerset* districts. In the following sections the top of the *Striatulum*-beds is the point from which one section should be compared with another.

Frocester Hill is almost the northernmost point at which the *Striatulum*-beds appear; at Haresfield Beacon they are practically absent, and at Leckhampton only the very top of the Cephalopoda-bed is seen resting on sands. The following section, taken at Buckholt Wood, which is a short distance north of the well-known Frocester-Hill section, gives the Cephalopoda-bed (the Limestone capping of the Cotteswold Sands) in fairly full development.

I. *Section at Buckholt Wood.*

			ft.	in.
Cephalopoda-bed.	*Moorei*-beds.	1. Brownish limestone with darker brown grains. *Dumortieria Moorei* (Lycett); *Dum. subundulata* (Branco); *Dum. sparsicosta*, Haug; *Grammoceras mactra* (Dumortier); *Rhynch. cynocephala*; *Terebratula haresfieldensis*; *Belemnites*	1	9
	Dumortieria-beds.	2. Yellowish; but more often dark grey, almost black mudstone with dark brown grains. Ammonites scarce and badly preserved. *Dum. rhodanica*, Haug; *Rh. cynocephala*; *Terebr. haresfieldensis*	2	0
		3. Reddish-yellow, somewhat sticky, gritty marl; in places numerous *Belemnites*		6
	Dispansum-beds.	4. Dark grey, ironshot, soft stone breaking up into shales. *Gramm. dispansum*, *Hamm. insigne*, *Astarte*, sp.	1	0
		5. Marl		2
	Striatulum-beds.	6. Light yellow, soft stone. *Dumortieria rhodanica*? *Gramm. dærntense* (Denckmann), *Gramm. striatulum* (Sowerby)		9
		7. Brownish marl, numerous dark brown grains. *Grammoceras*, sp., involute		7
		8. Yellowish stone with brown grains. *Gramm. striatulum* abundant, *Haugia Eseri*		6
		This bed lies above and fills the interstices of the very uneven-topped		
Cotteswold Sands.	*Variabilis*-beds.	9. Hard, blue-hearted sandstone	1	3
		10. Yellow micaceous sands		

This section does not exhibit the Cotteswold Sands, and in order to obtain an exposure of them we must go to Coaley Wood; but it displays certain features connected with the Cephalopoda-bed in a better manner than Coaley. The following Section has already appeared in my monograph on Inferior Oolite Ammonites (Pal. Soc. 1887, p. 45); but it is here reproduced with some additions and alterations.

* The district south of the Mendips is thus designated.

II. *Section at Coaley Wood.*
(1½ mile from Section I.)

			ft.	in.
Ragstone.	*Parkinsoni*-zone.	1. Ragstone with *Terebratula globata*.		
Freestone.	*Murchisonæ*-zone.	2. Deep Freestone quarry.		
Sandy ferruginous Limestone.	*Opalinum*-beds?	3. Pale-yellow stone, with light-coloured oolitic grains. About	5	6
	Opalinum-beds.	4. Very hard, pale-coloured compact rock, with very small brown grains; gives a metallic ring when struck. *Lioc. opalinum* fairly abundant; hardly any other fossils.....	1	4
Cephalopoda-bed.	*Moorei*-beds.	5. Hardish, somewhat irregular, yellowish rock (with more brown grains, but not so compact as 4). *Lioc. opalinum*; *Lytoc. Wrighti*, S. Buckman; small *Chemnitzia*; *Belemnites*, &c.		6
		6*. Rubbly, oolitic, irregular stone, like 5; hardly separated from it, but softer, and mixed with marl. *Lytoc. torulosum*; quantity of *Belemnites* and *Astarte*; also *Opis*, *Cypricardia*, and many *Lamellibranchiata*, *Lytoceras Wrighti* ...		8
	Dispansum-beds.	7. Hard, compact, pale yellow stone, with darker grains. *Gramm. fallaciosum*, *Gramm. dispansum*, *Gramm. dærntense*, *Pseudolioceras compactile*, *Oxynoticeras*? *discoides*, *Hammatoceras insigne*.....		6
	Striatulum-beds.	8. Brown rubbly marl, with numerous dark-brown grains; looks like crushed linseed. *Gramm. striatulum*, *Gramm.* sp., *Haugia Eseri*		7
Cotteswold Sands.	*Variabilis*-beds.	9. Very hard, bluish-grey, sandy, nodular-shaped lumps imbedded in the marly paste of the bed above	0	2–3
		10. Hard, blue-centred stone		6
		11. Fine, yellow, micaceous sands, about	50	0
		12. Brownish, concretionary rock, very slightly micaceous, containing dark oolitic grains and pieces of broken shells; has a similar appearance to Bed 7, but is harder. Some Ammonites; but they are scarce	2	9
		13. Two bands of hard, yellowish-blue, somewhat sandy stone. Large *Limæ*; *Haugia* sp., &c.	2	0
		14. Yellow sands, becoming blue in the lower part.	10	0
		15. Dark yellowish-brown, concretionary marl with Ammonites.		3
		16. Band of yellowish-blue, hard, sandy stone. Ammonites fairly abundant, especially on the top. *Haugia variabilis*, *Lytoceras sublineatum*, *Dactylioceras crassum*		9
		16 *a*. Fine yellow sands, about	25	0
	Commune-zone.	17. Band of yellowish-blue, hard sandstone. *Hildoceras bifrons*, abundant; *Pseudolioceras compactile*.....	1	0
		18. Yellow sands, visible for some feet, and conjectured to extend down to the spring of water	40	0
Upper Lias.		19. Blue Clay?		

* This was, by oversight, in my Monograph, Pal. Soc. vol. xli. p. 45, relegated to the *Striatulum*-subzone. The lettering shows this is an error. No. 7 should have been so designated, and marked C¹.

The next section shows how the *Dumortieria*-beds have expanded; it also gives a very clear account of the Sands, especially with the addition of the roadside cutting at Stinchcombe. These sections, III. and III. A, appeared in my Monograph (pp. 46, 47).

III. *Section at Nibley Knoll.*
($3\frac{1}{2}$ miles from Section II.)

			ft.	in.
Ragstone.	*Parkinsoni*-zone.	1. *Trigonia*-grit and rubble	5	0
Freestone.	*Murchisonæ*-zone ?	2. Pale-coloured freestone with white oolitic grains. Occasional dark brown bands	25	0
		3. Freestone imperfectly shown, about	10	0
Sandy ferruginous Limestone.	*Opalinum*-beds ?	4. Pale, somewhat sandy rock, very slightly oolitic; imperfectly shown. *Pholadomya fidicula, Trigonia striata, Astarte.* About	8	0
	Opalinum-beds.	5. Band of pale, slightly oolitic rock, with irony grains	1	2
Cephalopoda-beds.	*Moorei*-beds.	6. Light-yellow, rubbly marl with irony grains. *Lioc. opalinum, Gramm. Steinmanni, Hammatoceras* sp.		9
		7. Band of rock. *Rhynch. cynocephala*		8
	Dumortieria-beds.	8. Yellowish-grey, clayey marl	1	0
		9. Yellow marl, oolitic, somewhat concretionary	1	2
		10. Yellow and yellowish-grey marly shales, many dark oolitic grains. *Dumortieria rhodanica*	3	6
		11. More concretionary marl. *Catulloceras Dumortieri*	2	6
	Dispansum-beds.	12. Much the same as 10. *Gramm. dispansum*	1	2
	Striatulum-beds.	13. Hardish, yellow, oolitic rock. *Gramm. striatulum, Hamm. insigne*	1	0
		14. Dark-brown, oolitic paste; looks like crushed linseed. *Gramm.* sp.		7
		15. Hard, irregular rock in two layers. *Gramm. striatulum*, abundant; *Lytoceras jurense, Haugia Eseri*	1	2
Cotteswold Sands.	*Variabilis*-beds.	16. Fine, yellow sands, harder at the top; perhaps divided by concretionary layers, but none such visible; about	60	0
		17. Yellowish-brown, concretionary, sandy layer; no fossils		9
		18. Hard, bluish-yellow, slightly sandy rock. *Belemnites, Turbo, Amberleya, Lima,* &c.		7
		19. Fine yellow sands		10
		20. Yellow, sandy stone; only one small species of *Haugia*, poorly preserved		6
		21. Yellow sands	5	0
		22. Band of yellow, sandy stone		4
		23. Yellow sands	3	0
		24. Band of yellow, sandy stone		7
		25. Yellow sand	7	0
		26. Band of yellow, sandy stone		4
		27. Yellow sand	3	6
		28. Band of blue-centred sandy stone. *Haugia variabilis, H. Ogerieni, Pseudol. compactile, Dactyl. crassum, Belemnites,* &c.		6
		29. Yellow sands	6	0
		30. Band of blue-centred sandy stone. *Lytoc. sublineatum, Pseudol. compactile, Haugia Ogerieni, Dactyl. crassum, Nautilus Jourdani*		6
		31. Blue and yellow sands (for continuation see next section); about	30–35	0

III. A. *Section in the road at Stinchcombe.*
(May be considered as a continuation of the preceding Section.)

			ft.	in.
Cotteswold Sands. Upper Lias.	*Commune*-zone.	31. Yellow sands		
		32. Very dark-brown, argillaceous marl. *Hildoceras bifrons, Pseudolioceras lythense, Belemnites*, &c.		1
		33. Brownish, and sometimes bluish, shelly, somewhat sandy stone, with plenty of small ferruginous specks; top part very uneven, and filled with the bed above. *Hild. bifrons, Dactylioceras, Rhynchonella, Terebratula*, &c....		8
		34. Dark-blue clay, without fossils, containing large blue-hearted nodules of stone which break with a conchoidal fracture and are non-oolitic.		

The next section is remarkable for the fact that a great change of lithology takes place. Instead of being oolitic marl or limestone as in the previous sections, the *Dispansum*- and the *Striatulum*-beds are now yellow and grey sands with bands of sandstone. The thickness of the sands also has much diminished; but the thickness of the *Dispansum*- and *Striatulum*-beds is much increased, simply owing to the prevalence of sandy conditions.

IV. *Section at Little Sodbury.*
(8 miles from Section III.)

			ft.	in.
Freestone.		1. Whitish limestone, with numerous white grains.		
Sandy ferruginous limestone.	*Opalinum*-beds?	2. Straw-coloured, shelly, sandy limestone, about	2	0
		3. Reddish-brown, very hard, ironshot limestone, about	1	0
Cephalopoda-bed.	*Moorei*-beds.	4. Greyish, much ironshot marl; in some places softer, in others harder. *Rhynch. cynocephala, Dumortieria Moorei*	4	6
	Dumortieria-beds.	5. Darker, soft mudstone, much ironstone. *Dumortieria rhodanica, Rhynch. cynocephala, Chemnitzia procera*	2	6
		6. Grey ironshot marl	3	0
Cotteswold Sands.	*Dispansum*-beds.	7. Grey sandstone. *Lytoc. Germaini*, fragment ...		4
		8. Yellow and grey micaceous sands	8	0
	Striatulum-beds.	9. Hard, yellowish, somewhat ironshot stone. *Gramm. striatulum*		10
		10. Grey marl	1	2
		11. Much ironshot marl and mudstone with "*Gramm.* sp., involute"		8
		12. Grey, shelly sandstone, some few brown oolitic specks. *Gramm. striatulum, Haugia occidentalis*	1	6
		13. Yellow sands. *Gramm. striatulum* towards the top	2	0
		14. Grey sandstone. *Gramm. striatuium*		4
		15. Greyish sands	2	6
		16. Grey sandstone. *Gramm. striatulum*		9
		17. Yellowish sands	4	0
		18. Yellow sandy stone. *Gramm. striatulum*, with very coarse ribs...	1	8
		19. Yellow sands, a few inches only visible.		

There are about 15–20 feet more before the Clay is reached, but being unexposed it cannot be said if any hard bands are contained therein, or what Ammonites.

Pseudol. compactile was found in a block of fallen sandstone.

Lyncombe. The following section was brought to my notice by the kindness of the Rev. H. H. Winwood, F.G.S., with whom I visited the spot. He also made some notes of this section when the line was first opened and I refer the reader to them *.

The most remarkable feature in the Section is probably a point now noticed for the first time, namely, that one single block of stone, only 1 foot 7 inches thick, contains portions of three different zones, and exhibits three different bands of matrix firmly cemented together †.

Brown, coarse, oolitic stone, 5 inches.	*Striatulum*-beds; *Jurense*-zone.
Brown, oolitic stone, not so coarse in texture, 4 inches.	*Commune*-zone.
Bluish-grey stone with a soapy feel, non-oolitic, 10 inches.	*Falciferum*-zone.

The attenuation of the *Commune*-zone is very great, and not improbably careful research would show some admixture of its species with those of the *Striatulum*-beds above. The other two zones extend, one above—*Jurense*-zone, *Dispansum*-beds—the other below—*Falciferum*-zone, Blue Clay.

Another point to be noticed in this Section is that the Yellow Sands have ascended one stage higher. They do not, as at Sodbury, envelop the strata known as the *Striatulum*-beds, but they begin above them. Consequently the next series (that of the *Dispansum*-

* "Notes on some Railway Sections near Bath," Proceedings of the Bath Natural History and Antiquarian Field Club, vol. iii. no. 2, p. 129 (1875).

† I had, not long previously, discovered a similar, but perhaps more extraordinary, instance of the same feature. At a small quarry on Lodge Hill, just south of Castle Cary, Somerset, the lower part of the *Parkinsoni*-zone is cemented firmly to Sandstone of the Yeovil Sands (*Opalinum*-zone); and the mass comes from the quarry as one piece of stone exhibiting two bands of very different matrix, thus:—

Brownish oolitic limestone, 3 inches.	*Parkinsoni*-zone.
Bluish-grey, hard, gritty sandstone, 8 inches.	*Opalinum*-zone.

This is the more remarkable when we consider that the time of formation of the *Murchisonæ*- to the *Humphriesianum*-zones inclusive had elapsed between the deposition of the upper and lower of these two bands.

beds) is very much thicker than before. It is not known at present if any higher horizon is included in the upper part of the Sands; but it is possible.

V. *Section exposed in Greenway Lane and Lyncombe cutting, near Bath; Somerset and Dorset Railway.* (14 miles from Section IV.)

			ft.	in.
Inferior Oolite.	*Parkinsoni*-zone.	1. Yellowish oolitic limestone. *Tereb. globata, Rhynch. spinosa*, &c.		
Midford Sands.	Uncertain.	2. Yellow micaceous sands not well exposed, about ...	65	0
	Dispansum-beds.	3. Yellow sands with about a dozen lines of "Sand-burrs." From fallen "Sand-burrs" *Gramm. fallaciosum* was obtained	35	0
Junction beds.	*Striatulum*-beds.	4. Yellowish-brown stone, with very numerous lighter-coloured oolitic grains which fall out and leave the stone pitted. *Gramm striatulum.*		5
Upper Lias.	*Commune*-zone.	5. Yellowish stone with the oolitic grains less numerous, and therefore appearing of a closer texture. *Hild. bifrons, Dactyl. Holandrei, Dactyl. crassum, Waldheimia Lycetti, Rhynchonella*, sp.		4
	Falciferum-zone.	6. Close-grained, smooth-feeling, greyish-blue stone, without any trace of grains as in the bed above. *Harpoceras falciferum*.....		10
		7. Greyish-blue clay		6
		8. Close-grained, greyish, mottled stone		4
		9. Greyish-blue clay		

The above section is superior, for our purpose, to the one exhibited at Midford. Considering that it is only about a mile and a half from Midford it may be taken as a thoroughly representative Section of Midford Sands joining Lias Clay.

The next Section, that of the classic locality of Ham Hill, in Somerset, is very interesting from a geological point of view, but wholly disappointing palæontologically. The large mass of freestone and sandstone (both composed of comminuted and crushed shells, among which *Rhynch. cynocephala* or (?) *Beneckei* * occurs), preceded and followed by yellow micaceous sands, is, without much doubt, on the same horizon as the similarly-composed band at Stoford, and probably only an altered condition of the upper part of the Yeovil Sands as seen at Babylon Hill. My father was the first to point this out †; and the opinion has been confirmed by H. B. Woodward ‡. Therefore the Geological Survey has erred in mapping Ham Hill as different from the "*Mid-*

* See Davidson, "Brach.," Pal. Soc., Appendix to Supp. pl. xx. figs. 8, 9, 10 (1884).

† "Cephalopoda-bed and Oolite-Sands," Extract Proc. Somerset Arch. Soc. vol. xx. p. 13 (1874). "The Ceph. beds of Gloucester, Dorset, and Somerset," Quart. Journ. Geol. Soc. vol. xxxiii. p 5 (1876).

‡ "Note on the Ham Hill Stone," Proc. Bath Ant. Field Club, p. 184 (1887).

ford Sands." The true position of the Stone-beds is probably that horizon of the *Opalinum*-zone which I have designated *Moorei*-beds. In this connexion it is interesting to notice that a *Dumortieria*, probably referable to *Dum. rhodanica*, was met with in the Yellow Sands below, and also that the shell-bed at Stoford contains exactly the same Ammonites as the *Moorei*-beds of Buckholt Wood and other Cotteswold localities.

VI. *Section at Ham Hill.* (37 miles from Section V.)

			ft.	in.
Marked as Inferior Oolite on the Ordnance Survey Map.	*Moorei*-beds.	1. Fine yellow Sand	10	0
		2. "Waste" or "riddings." Occasional layers of stone mixed with layers of yellow sands. The stone is full of comminuted shells. It is generally buried in the quarry, unless wanted for rough work	30	0
		3. Best freestone in immense blocks, a mass of comminuted shells imbedded in a sandy matrix; it is sawn and worked for elaborate designs	50	0
		4. "Bottom Bed." Hard sandstone	1	6
Yeovil Sands.	*Dumortieria*-beds.	5. Yellow micaceous sands with irregular bands of hardened sand-rock at irregular intervals of every few feet. Some isolated lenticular masses of sandstone occur. Thickness about...	55	0
		6. Sand-rock containing a fragment of *Dumortieria rhodanica*		10
		7. Yellow, micaceous sands as in 5. Thickness about	35	0

These Yellow Sands were observed in the lane leading from Montacute to the top of the Hill. They seem to begin just above Montacute Church and to continue the whole distance. A few yards then brings one to the freestone-quarry measured, which, it will be seen, extends 90 feet in depth. It would therefore seem as if the freestone had been let in by a fault, something like 85 feet. The "Bottom Bed" crops out in the lane near some fir trees; while on the opposite side of the road there is a quarry of rough stone evidently faulted down.

I beg to express my thanks to the Director-General of the Ordnance Survey, who very kindly gave me the height of Ham Hill. It is about 90 feet above Montacute church.

The next section is important, because it exhibits the junction of the Yeovil Sands with Upper-Lias Clay. It is noticeable that now the yellow micaceous sands do not begin until we have finished with the *Dispansum*-beds: while the Upper-Lias Clay is here exactly contemporaneous with the Cotteswold Sands, together with the two lower divisions of the Cotteswold Cephalopoda-bed.

VII. *Section at White Lackington Park near Ilminster, Somerset.* (6½ miles from Section VI., West.)

			ft.	in.
Yeovil Sands.		1. Yellow micaceous sands, becoming browner towards the bottom		
Junction bed.	*Dispansum*-beds.	2. Arenaceous marl-bed, somewhat decomposed, brown and light yellow; occasional pockets of bluish-grey argillaceous marl. (This bed is apparently a mixture of No. 1 with the decomposition of No. 2.) *Lytoc. jurense, Lytoc. Germaini, Lytoc. rubescens, Pelecoceras serrodens, Hammatoceras insigne, Oxynot. discoides*; fragment of *Gramm. dispansum*; fragment like *Gramm. striatulum*		2
Upper Lias.		3. Yellowish-grey, soft stone, somewhat sticky, soapy feel. *Oxynot. discoides, Hamm. insigne*		9
	Probable position of *Striatulum*-beds.	4. Bluish-grey tenacious clay with occasional nodules. No fossils found.		

The next Section shows the Lithology and Fauna of the Upper part of the Yeovil Sands in the Yeovil district.

VIII. *Section at Stoford* *, *Somerset.*
(6 miles from Section VI., East.)

About thirty feet below the Inferior Oolite Limestone, and separated therefrom by that amount of more or less unfossiliferous yellow sands, occurs a rich shell-bed, in appearance not unlike the Ham-Hill stone, but less sandy, and with the shells not so much comminuted. This bed is about two feet thick; it is used for building-purposes.

Several years ago my father † and myself obtained as the result of our different visits the following fossils:—

Moorei-beds ‡.

Dumortieria Moorei (Lyc.).
Grammoceras mactra (Dum.).
Dumortieria subundulata (Branco).
Trigonia literata, Young and Bird.
Pecten demissus, Phillips.
Astarte elegans, Sowerby, var.
Ceromya bajociana, d'Orbigny, and many other species.

* See Mr. Hudleston's "Report on Excursion to Sherborne," Proc. Geol. Assoc. vol. ix. No. 4, p. 4 (1885).

† It was from this shell-bed that many of the species quoted in "So-called Midford Sands" (Quart. Journ. Geol. Soc. 1879, p. 743) were obtained.

‡ The sandy strata in the neighbourhood of Bradford Abbas more usually belong to the upper part of the mass of Yeovil Sands. They show various beds of hardened sand-rock isolated from one another by yellow sands. These beds contain *Dumortieria Moorei, Gramm. mactra, Dumortieria subundulata, Dumortieria pseudoradiosa, Dumort. radiosa* var. *gundershofensis, Dumort. Levesquei*?, *Rhynch. Beneckei*. The absence of the sandy grits with *Lioc. opalinum*, which are found at Burton Bradstock, Stoke Knap, &c., brings the beds into immediate contact with the Inferior Oolite Limestone (*Murchisonæ*-zone), and the so-called "Dew Bed" is probably their uppermost member.

Section IX. (of the interesting exposure at Burton Bradstock) exhibits the junction of Inferior-Oolite Limestone and the Yeovil Sands. With our knowledge of the Cotteswold Cephalopoda-bed we see that we have here a higher horizon than at Bradford Abbas, Stoford, &c.—and a horizon absent from those places. Read in conjunction with the other sections of yellow sands south of the Mendips, we obtain the knowledge that the yellow micaceous sands of this area (the Yeovil Sands) are on exactly the same horizon as the two upper divisions of the Cotteswold Cephalopoda-bed (the *Dumortieria-* and *Moorei*-beds) and also as part of the "Sandy ferruginous Limestone."

IX. *Section at Burton Bradstock.*

(16½ miles from Section VIII., South.)

Made July 5th, 1888, in company with Mr. J. F. Walker, F.G.S., and Mr. J. E. Clark, F.G.S.

			ft.	in.
Inferior Oolite.	*Parkinsoni*-zone.	1. Yellowish oolitic limestone; few fossils. *Parkinsonia Parkinsoni*	4	0
		2. Whitish, shelly, oolitic limestone, glistening with crystal. *Park. Parkinsoni, Waldheimia carinata, Astarte obliqua*	1	7
	Humphriesianum-zone?	*3. Greyish ragstone with many iron grains, somewhat broken up. *Astarte obliqua, Terebratula sphæroidalis,* Gasteropoda. Some iron nodules occasionally: well-marked break		3
	Humphriesianum-zone.	*4. Hard, light brown stone. *Pœcil. cycloides, Terebratula sphæroidalis*		3
		5. Greyish limestone, occasionally stained with iron. *Rhynch. spinosa* at the top, rare. No other determinable fossils	2	0
	Murchisonæ-zone?	6. Irony band, with numerous dark-brown concretionary nodules, and with lumps of limestone with large iron grains		3
	Opalinum-zone.	7. Steel-grey limestone with few iron grains. *Trigonia striata, Lioc. opalinum* and the variety *comptum, Parkinsonia scissa, Rhynch. cynocephala*	1	0
Yeovil or Bridport Sands.		8. Sandy parting. *Lioc. opalinum,* in fragments, *Lytoceras Wrighti?*		3
		9. Irregularly-mixed masses of stone and sand. *Lioc. opalinum,* poor	1	3
		10. Yellow micaceous sands much pierced by worms	2	2
		11. Hard grey sand-rock		7
		12. Yellow sands. *Lioc. opalinum*	1	9
		13. Sand-rock. *Lioc. opalinum*		4
		14. Yellow sands		4
		15. Sand-rock		3
		16. Yellow sands occasionally containing *Lioc. opalinum*	2	8
		17. Sand-rock		
	Moorei- and *Dumortieria*-beds.	18. The yellow sands, with lines of sand-rock, exposed in the cliff. Ammonites are occasionally found in the masses fallen from the upper part, namely, *Gramm. mactra, Catulloceras Dumortieri, Gramm. aalense,* &c. The total thickness of these sands is perhaps	200	0

* It must be from bed 3 or 4 that the following species have been obtained at Burton Bradstock:—*Cosm. Garantianum, Oppelia subradiata, Oppelia Truellii,* var.

At Down Cliffs, about three miles from this locality, we are able to find the continuation of this section, although the exposure is not very good, and I was not able to work it thoroughly.

IX. A. *Section at Down Cliffs, near Seatown, Dorset.*

		ft.	in.
Upper Lias.	18 Yellow sands, a continuation of those seen in the last Section, passing gradually into a		
	19. Blue, somewhat micaceous clay. No fossils were observed. Thickness about 70–80		0
	20. Pink-coloured rock with *Hildoceras bifrons*; attached to a rock like marlstone.		

The first thing which must strike us on examining these sections is the totally different faunas which Nos. III. and VIII. exhibit—sections which show the junction of the so-called "Midford Sands" with Upper Lias Clay. Not one species do they possess in common. The Yeovil Sands (Section VII.) overlie a fossiliferous bed; and if we seek in the section at Nibley for the same fauna which that bed contains, we find it, not below, but above, the Cotteswold Sands. Here we have, to start with, the great and fundamental difference between the position and palæontology of the Yeovil and the Cotteswold Sands. These two little sections (Nos. III. and VII.), both, as it happens, taken from exposures by the roadside, are, after all, the two most important sections in the series. They supply the keynotes to the situation; the others give us general details.

In the first column of the various sections I have placed the usual lithological signification under which the strata have passed. In the second column I have appended certain names to the beds, for the purpose of distinction, taken from some characteristic Ammonite *.

Going through the sections in order, we shall find that the sandy strata continue to begin later, and to end later, in regard to the palæontological evidence as expressed in the second column. Sections II. and III. show us the position of the Cotteswold Sands in the Haresfield-Wotton district, this position being below the *Striatulum*-beds. In the Sodbury district (Section IV.) the sands did not end until the *Dispansum*-beds had been deposited. In the Bath district (Section V.) we do not know the time of the ending of the Midford Sands; but they differ totally from the Cotteswold Sands proper, in that they did not begin until the *Striatulum*-beds had been deposited. In the Ilminster district (Section VII.) the Yeovil Sands did not begin until the *Dispansum*-beds had been laid down, while their ending, as we can find out from Burton Bradstock (Section IX.), from Broad Windsor, and Stoke Knap, occurs towards the top of the *Opalinum*-zone.

* It is not intended to state that the Ammonite of which the name is used is confined to that horizon; but merely that it is most characteristic thereof, that, in fact, it is the dominant species. The word "beds" is used in a different sense to "zone," and is in no way necessarily equivalent thereto. For instance, the *Opalinum*-beds and the *Moorei*-beds are parts of the *Opalinum*-zone.

It may be advantageous to make a thorough comparison of the yellow sands as exhibited in the Cotteswolds, around Bath, and in the Dorset-Somerset area.

Without taking account of the development north of Haresfield Beacon, which seems to be generally unimportant, we may divide this district into two portions :—

I. The Cotteswolds.

A. *The Haresfield-Wotton district.*—Here the sands average about 150 feet in thickness, of light yellow, micaceous, sandy strata, with occasional lines of hardened, bluish-grey sand-rock (sometimes in huge lenticular masses). At the very base is a dark-brown bed, chiefly filled with dwarf specimens of *Hildoceras bifrons* (Stinchcombe). Forty feet from the base occurs a bluish-grey sandstone filled with numerous fine specimens of *Hildoceras bifrons* (compressed variety), and with *Pseudol. compactile* occasionally (Coaley Wood). About 25 feet above this come sundry bands of sandstone &c., with *Haugia variabilis*, *Dactylioceras crassum*, *Lytoceras sublineatum**. Above this come sandy rock-bands (Nibley) with a few Ammonites, among them *Haugia*, sp. The last 50 or 60 feet apparently contain no fossils.

B. *The Sodbury district.*—The sands here are only about 40 feet thick. The lower 15-20 feet are concealed, and their contents could not be ascertained. The upper part contained frequent bands of sandstone, with *Gramm. striatulum*, *Pseudol. compactile*, *Haugia occidentalis*, &c.

II. The Bath District.

The Midford Sands.—These are about 100 feet thick. They are fine, yellow, micaceous sands with numerous lines of small rounded "Burrs"—a greyish calcareous sandstone. The sands rest on an oolitic limestone containing *Gramm. striatulum*. In the "sand-burrs" of the sand just above this bed, *Gramm. fallaciosum* is found (Lyncombe Tunnel). Whether this or anything different is found in the upper part I cannot say, as my researches at Midford were negative in their results.

* At North Nibley two beds, about 40 feet from the base of the sands, and perhaps on a little lower level than the one at Coaley, contain *Haugia variabilis*, *Lytoceras sublineatum*, *Pseudolioceras compactile*, *Dactylioceras crassum*, *Nautilus Jourdani*, &c.

A bed of brown hardened marl in the sands at Chalford and Nailsworth, probably on about the same horizon, contains *Haugia variabilis*, *Dactyl. crassum*, and *Dactyl. mucronatum*.

In the Quart. Journ. Geol. Soc. vol. xvi. p. 5, Dr. Wright states that this bed (his bed *e*) contains *A. jurensis*, *A. insignis*, *A. radians*, and most of the Conchifera of the Cephalopoda-bed which he calls *a*. I particularly investigated this point, which was totally at variance with my experience on the escarpment, and I can positively say it is a mistake, so far as the Ammonites go. The bed in the sands and the Cephalopoda-bed contain only one species in common, viz. *Amm. compactilis*. The Ammonites he quotes are not found in this bed. The distinctness of the Ammonite-fauna at the two horizons is also conclusively shown by an investigation of a collection made by Mr. A. E. Smith of Nailsworth, to whom my thanks are due for liberty to inspect the same and for other information.

III. The Dorset-Somerset District (south of the Mendips).

The Yeovil Sands.—These may be said to average 150 feet in thickness, and are fine, yellow, micaceous sands with frequent bands of sand-rock. They rest on a bed of marl and clay containing *Lytoceras jurense*, *Lytoc. Germaini?*, *Lytoc. rubescens?*, *Pelecoceras serrodens*, *Oxynoticeras discoides*, *Hammatoceras insigne*, *Grammoceras dispansum*, fragment, *Grammoceras striatulum*, fragment, *Gramm.* sp. (White Lackington). In the yellow sands are found *Dumortieria rhodanica*, fragments (Ham Hill). Higher up we meet with about 50 feet of fine sandy freestone—a mass of comminuted shells—with *Rhynch. cynocephala* or *Beneckei*. Layers of sand and coarser freestone cover this for some thirty feet; and these, again, are capped by ten feet of fine yellow sands (Ham Hill). These freestone and higher beds are probably represented round Bradford Abbas, Stoford, &c. by bands of sandstone sometimes containing a mass of comminuted shells (see Section VIII.). In these rock-bands *Gramm. mactra*, *Dumortieria Moorei*, *Dum. subundulata*, &c. have been obtained. The topmost bed of the sand-series in this district is a hard blue-centred stone, the "Dew-bed" of Bradford Abbas.

At Broad Windsor, Stoke Knap, and other places, at the upper parts of the sand-series, are sandy grits containing *Lioc. opalinum*, *Terebratula infraoolithica*, *Rhynchonella cynocephala*, *Waldheimia Blakei*, &c. These sandy grits may possibly be partly on the same horizon and partly on a higher horizon than the Ham-Hill stone.

At Down Cliff, near Seatown, the yellow sands repose on a bluish marl passing into micaceous clay. There seemed to be no fossil-bed at the junction, and the blue marl appeared barren. Not improbably the *Striatulum*-beds may be found in this blue clay, possibly near its base. If so, this would be a very important point. At Burton Bradstock about 150 feet of yellow sand is exposed in a fine cliff. From fallen blocks *Gramm. mactra*, *Gramm. aalense*, and *Catulloceras Dumortieri* were obtained. In the road-cutting on the top of the cliff the sand-rock bands of the upper ten feet of the sands are characterized by *Lioceras opalinum*; so also is the lowest bed of limestone.

From the analysis of the various sand-deposits it will be seen that none of the different districts contain the same Ammonite-fauna. In every district—I. A & B, II., III.—the Ammonites which characterize the sands are not only specifically, but often generically, distinct from those of the others. If we now go back to the first district, and examine the strata which there repose upon the sands—that is, if we examine the so-called Cephalopoda-bed—we shall be able to find out the exact explanation of what these various Ammonites indicate.

The Cephalopoda-bed of Gloucestershire may be said to be fully developed only between the south side of the Stroud valley and Wotton-under-Edge inclusive. It consists of brown marls with dark-brown grains, separated at intervals by layers of hardened oolitic stone. The thickness of the series varies from about eight

to fifteen feet; and it may be divided into four stages. The lowest stage—the *Striatulum*-beds—contains *Gramm. striatulum*, *Gramm. Bingmanni*, *Pseudolioceras compactile*, *Haugia Eseri*, *Haugia illustris*, &c. The stage above this — the *Dispansum*-beds — contains *Gramm. dispansum* abundantly in some places, in others *Gramm. fallaciosum* takes its place; here belong also *Gramm. Sœmanni* (Dumortier), *Gramm. dœrntense*, *Hammatoceras insigne*, *Oxynoticeras discoides*.

The third stage—the *Dumortieria*-beds—obtains its name from the presence of several species of the extraordinary genus *Dumortieria*, of which *Dumortieria rhodanica* is the most abundant. Here also come *Dum. Levesquei*, *Dum. striatulo-costata*, Haug, *Catulloceras Dumortieri*, *Pelecoceras affine*, *Pelecoceras serrodens*, *Terebratula haresfieldensis*, *Rhynch. cynocephala*, &c.

The fourth stage—the *Moorei*-beds—completes the series known as the Cephalopoda-bed. It is characterized by some peculiar species, namely, *Dumortieria Moorei*, *Gramm. aalense*, *Gramm. Steinmanni*, *Gramm. fluitans*, *Gramm. subcomptum*, and occasionally *Lioceras opalinum*. In addition *Hamm. Alleoni*, *Lytoceras Wrighti*, *Dumortieria subundulata*, *Gramm. mactra*, *Terebratula haresfieldensis* and *Rhynchonella cynocephala* are found.

We have now reached the top of the so-called Cephalopoda-bed, and we pass into what was called by Mr. Witchell the "sandy ferruginous limestone"*. The lowest bed of this series is harder and darker than the others, and contains *Lioc. opalinum* in fine proportions, also *Pseudolioc. Beyrichi*, *Ludwigia* sp., &c. The rest of the series up to the white, oolitic "Lower Limestone" may be described as generally light-yellow, sandy, sometimes hardly oolitic stone, containing *Lioc. opalinum*, *Lioceras ambiguum*?, *Hammatoceras* sp., and *Parkinsonia scissa*. The whole of the "sandy ferruginous limestones" may be classed as another stage—the *Opalinum*-beds. They probably form the uppermost portion of the *Opalinum*-zone, and are evidently on exactly the same horizon as the bed of the Burton-Bradstock section.

Now, if we look at this whole series of beds and the fauna which they contain, we shall be at once struck with the difference, not only of species but of genera, which each stage exhibits from the one below or above it; and I can confidently say that, during the whole course of my collecting from these strata, I have invariably found that this order is most exactly, and even extraordinarily, maintained.

No one has yet, I believe, attempted to analyze and divide the Gloucestershire Cephalopoda-bed in this minute fashion. Two divisions at the most were made; but for our present purpose many divisions are necessary; and any one, when he becomes thoroughly acquainted with the different beds and their Ammonite-fauna, will be able to see that these divisions are fairly well characterized. It is, in fact, only by making such particular divisions that we are able

* "Basement-beds of the Inferior Oolites of Gloucestershire," Quart. Journ. Geol. Soc. vol. xlii. p. 264 *et seq.*

to trace the true correlation of the Midford and Yeovil Sands with the various strata in the Cotteswolds.

1st. The Midford Sands are on the same horizon as the *Dispansum*-beds, and perhaps as some of the higher divisions.

2nd. The Yeovil Sands are above the *Dispansum*-beds, are on the horizon of the *Dumortieria*-, the *Moorei*-, and part of the *Opalinum*-beds.

If I have been able to make my remarks clear, it follows that the sands were by no means contemporaneous in the various districts. The same horizon which in the Haresfield-Wotton district is noted for its sand is blue clay at Ilminster. What is sand at Burton Bradstock is an ironshot limestone in Gloucestershire. What are the consequences of this upon our nomenclature? The style of nomenclature in general use at present combines the Cotteswold Sands plus the Cephalopoda-bed, the Midford Sands, and the Yeovil Sands under one name "Midford Sands," and, placing them as the next stage above the Upper Lias, includes them in the Inferior Oolite Series *. As I have shown, however, the Cotteswold Sands and even part of the Cephalopoda-bed, and the Midford Sands so far as we know them, are absolutely contemporaneous with the Upper Lias of Ilminster. The diagram (fig. 1, facing this page) will exhibit this at a glance.

I may note the following facts to support my statement that the *Striatulum*-beds are in the Upper-Lias Clay of Somerset—that the top of this clay is, in fact, on the same horizon as the Cotteswold Sands and part of the Cephalopoda-bed of Gloucestershire.

Charles Moore, who always considered the Yeovil Sands to belong to the Inferior Oolite, has placed the following species in the Bath Museum as from the *Upper Lias* of Ilminster †:—

Hammatoceras insigne (Schubler), *Grammoceras striatulum* (Sow.), *Gramm. fallaciosum*, Bayle, *Gramm.*, sp. (called *radians*) ‡.

Oppel, 'Juraformation,' p. 250, footnote, says "Mr. Moore aus Bath sandte mir den *Amm. variabilis* aus den Umgebungen von Ilminster, mit dem besondern Bemerken, dass die Exemplare aus dem höchsten Bette des obern Lias stammen. Dies ist aber nichts anderes als die zone des *Amm. jurensis*."

With these facts before us how is it possible to treat the "Midford Sands" as of later date than the "Upper Lias," seeing that the greater part of two of their constituents are absolutely contemporaneous therewith?

* H. B. Woodward, 'Geol. England and Wales,' 2nd ed. p. 285 *et seq.*

† It is instructive to notice how Dr. Wright has interpreted this fact concerning the Ilminster strata, and brought it into accordance with Gloucestershire. In Quart. Journ. Geol. Soc. vol. xii. 1856, "Upper Lias Sands," p. 317, he states that in three horizons which he calls, beginning with the lowest, Upper Lias Clay, Upper Lias Sands, and Upper Lias Cephalopoda-bed, the following species of Ammonites have been found—*Amm. insignis*, *Amm. variabilis*, *Amm. radians*, *Amm. Raquinianus*, *Amm. concavus*, *Amm. striatulus*. Practically speaking, the statement is true enough; but they are not three horizons. They are one and the same horizon showing a lithology varying with the locality; this it is that has misled him.

‡ Compare also Moore, Proc. Somerset Arch. Soc. vol. xiii. p. 131 (1865–66).

On the other hand the "Midford Sands" have been defined as equal to the zones of *Amm. opalinus* and *Amm. jurensis* *; but, in all probability, the lower part of the Cotteswold Sands—the part containing *Amm. bifrons*—belongs to the *Commune*-zone. Then, too, it is just the opposite in Somerset, where it is the Upper-Lias Clay of Ilminster which contains the greater part of the *Jurense*-zone. Again, part of the Inferior-Oolite Limestone of Dorset and of the Cotteswolds is in the zone of *Amm. opalinus*. Therefore this latter definition does not coincide with the first.

According to either view we arrive at an absurdity, namely, part of the Upper-Lias Clay must be in the Inferior Oolite series; or beds containing several of the same species of Ammonites must be in the Lias in one place, and in the Inferior Oolite in another.

After all, the term "Midford Sands" is only used locally. The Dogger Sands of Yorkshire, and part of the Northampton Sands, are contemporaneous with the upper part of the Yeovil Sands; but they are not included in the term "Midford Sands." Is there the least advantage in retaining a term—a merely local term—which, as I have shown, includes deposits that are, by no means, contemporaneous? Its only advantage is that it does away with two names; but the result is absolute inaccuracy. The terms Cotteswold, Midford, and Yeovil Sands may be retained as merely local names for certain deposits, in the same way as Pea-grit, Oolite Marl, &c.; they should have no wider signification than the district to which they apply, and should not be used where strict scientific accuracy is required, but should give place to their zonal equivalents.

It would almost seem as if the sands between Liassic Clay and Oolitic Limestone were a somewhat singular deposit; but the fact of the matter is, that from a rather remote period until a much later one than we are treating of, sandy strata have been deposited—in no two districts contemporaneously, but generally first in one place and then in another. Why, then, is it desired to mark off the "Midford Sands" as a distinct series—not all across England, but only locally?

The *Jamesoni*- and *Capricornum*- zones are characterized by micaceous and sandy shales at Robin Hood's Bay in Yorkshire †.

The *Henleyi*-zone in Gloucestershire is largely made up of sandy strata very similar to the Cotteswold Sands.

The *Margaritatus*- and *Spinatus*-zones in Dorset contain sandy strata often undistinguishable from the Yeovil Sands.

The zone of *Amm. annulatus* in Yorkshire is represented by hard and compact, grey and micaceous sandy shale ‡.

What is probably the upper part of the *Commune*-zone is composed of micaceous sands in Gloucestershire.

The *Jurense*-zone is made up of sands at Bath, while, lastly, the *Opalinum*-zone at Burton Bradstock is chiefly sands.

Passing to the continent, Oppel § shows us that at Wasseralfingen

* H. B. Woodward, *op. cit.* p. 285.
† H. B. Woodward, *op. cit.* p. 269.
‡ H. B. Woodward, *op. cit.* p. 277.
§ Oppel. 'Juraformation.' p. 328.

the greater part of the *Murchisonæ*-zone consists of "Sandstein;" while, apparently, the Clays and Shales,—considered in England so distinctive of the Lias—continued to a much later period; because the zone of *Trigonia navis* is described as consisting of "Dunkle gegen oben glimmerreiche Thone"*.

Returning to the North Cotteswolds, we find yellow sands at the top of the *Murchisonæ*-zone; while, in the Banbury district, Northampton Sand continues without intermission from the *Opalinum*-zone until the lower part of the Great Oolite inclusive†.

The foregoing remarks will show that, putting different localities together, there exist, with but very few breaks—which breaks continental strata would perhaps bridge over—deposits of sands, sandy marls, or sandstone from the time of the *Jamesoni*-zone to the lower part of the Great Oolite inclusive. Thus the obvious inference is that the presence of sandy lithological conditions is no guide to the age of the deposits; consequently we ought not to be surprised at finding the Cotteswold, Midford, and Yeovil Sands upon three different horizons; the surprise would be to find them on the same horizon.

If we abolish the general name "Midford Sands," and retain the names Cotteswold, Midford, and Yeovil Sands as local names for deposits on three different horizons, what are we to do as regards the dividing line between Lias and Oolite, which has always been such a bone of contention? If we follow the method of Quenstedt, Oppel, and others, and draw the line of division between Oolite and Lias at the top of the *Jurense*-zone, we must draw a very arbitrary line through the middle of the Cephalopoda-bed in Gloucestershire, and through the middle of the Yeovil Sands in the district south of the Mendips. If we follow H. B. Woodward, and place the whole of the sands—and their horizontal equivalents, I suppose—in the Inferior-Oolite series, we must dive down into what is known as Upper Lias Clay in Somerset, to draw a very arbitrary line, and a line, too, totally unacceptable to continental geologists. If we follow Dr. Wright, and draw the line of demarcation above the *Opalinum*-zone, we find that it results in parting a series of thoroughly oolitic limestones from the Inferior Oolite, and it thus becomes an arbitrary line.

All these remarks will only show (1) that between the Lias and the Oolite there practically exists no constant lithological break anywhere in the region where it has usually been sought; (2) that the old idea, that the sands necessarily marked a transition period between the Lias and the Oolite, cannot be held. Such being the case, shall we adopt a perfectly arbitrary line of division irrespective of where it falls? Or is it possible to do without this?

Dr. Vacek‡ has proposed to extend the Lias up to the top of the *Murchisonæ*-zone; and, in the correspondence that we have had upon the subject, he would extend it to the top of our *Concavum*-

* Oppel, 'Juraformation,' p. 321. † Woodward, *op. cit.* p. 310.

‡ "Die Fauna der Oolithe von Cap San Vigilio," Abh. der k.-k. geologischen Reichsanstalt, Bd. xii. no. 3.

beds. To anyone acquainted with the Cotteswolds the idea of placing the greater part of the thoroughly oolitic strata there exhibited—the Pea-grit, Lower Freestone, Oolite Marl, Upper Freestone, Lower Trigonia-grit, and Gryphite-grit—in the Lias must seem very extraordinary; but anyone who visits Dundry in North Somerset, Corton Downs in South Somerset, and Sherborne in Dorset, and sees the *Concavum*-beds of those places, with their truly Liassic appearance, and remembers at the same time that clayey conditions prevailed on the continent until a much later date than with us, will begin to understand the motives which sway continental geologists when they wish to place these strata in the Lias *.

I was strongly opposed to Dr. Vacek's views at first, especially because he had made many errors in describing our English strata; and had then drawn inferences therefrom which I knew could not be sustained.

Now, instead of regarding them as Lias, I propose (being especially struck with certain palæontological features of the series) to describe all the strata from the *Falciferum*-zone to the top of the *Concavum*-beds by d'Orbigny's term "Toarcien"; but I would not place the strata so named as subsidiary to either Lias or Oolite. I cannot say that this idea is new. Prof. Eugène Deslongschamps (*op. cit.* footnote, p. 100) says of the same series: "Les marnes infrà-oolithiques représentent exactement l'étage Toarcien de M. d'Orbigny." Now he had already proposed the following classification for a portion of the Jurassic strata (pages 70, 71):—

"Système Oolithique inférieur.
1°. Les marnes infrà-oolithiques;
2°. L'oolithe inférieure;
3°. Le fuller's earth;
4°. La grande oolithe."

The first and lowest of these stages, namely, "*Les marnes infrà-oolithiques*," are stated to be composed as follows (pp. 73, 74):—

1°. Argiles à poissons.
2°. Marnes moyennes. { 1°. Couches à *Ammonites bifrons* et *serpentinus*; 2°. Id. à *Ammonites* et *Lima toarcensis*.
3°. Calcaires supérieures à *Ammonites Murchisonæ*. { 1°. Couches à *Ammonites primordialis*; 2°. Id. à *Terebratula perovalis*.

From this we see that d'Orbigny's "Toarcien" and Prof. Eugène Deslongschamps's "Marnes infrà-oolithiques" comprise what we now know as Upper Lias, together with what Mr. Hudleston calls the Lower division of the Inferior Oolite, namely, to the top of the zone of *Lioceras concavum* †.

* D'Orbigny placed these same beds in the Lias—Toarcien = Upper Lias. Eugène Deslongschamps was at first of the same opinion (Etudes jurass. inf. Normandie, p. 99, footnote, 1864).

† This horizon was formerly called the "*Sowerbyi*-zone." The reason for the present designation may be found in Mr. Hudleston's Monogr. Gast. Inf. Oolite, p. 44, Pal. Soc. (March 1887), and in my Monogr. Inf. Ool. Amm., Pal. Soc. p. 63, March (1889).

As soon as I clearly grasped the facts concerning the so-called "Midford Sands," and when I became aware of certain palæontological evidence which I shall have to mention presently, it occurred to me to propose that the "Toarcien" should be a separate and distinct division of the Jura-formation, or, if it be preferred, a distinct formation of the Jurassic system. I now find, however, that in this matter I have long ago been forestalled. Eugène Deslongschamps says his father considered the series I propose to call "*Toarcien*" as an intermediate subformation of very distinct character *, and I am inclined to agree with this opinion, rather than include these strata in the Inferior-Oolite series; because there exists a far more marked stratigraphical and palæontological break at the end of the "Toarcien" than at the beginning. Consequently, in my opinion, those who would relegate the "Toarcien" to the Lias have the weight of evidence upon their side; but I am opposed to this view, because to us, in England, it seems so entirely misleading and anomalous to call the *Murchisonæ*- and *Concavum*-zones—in the Cotteswolds nearly the whole Oolitic escarpment—by the term Lias. Again, there is quite a sufficient palæontological break at the beginning of the "Toarcien" to warrant our making it a distinct stage or formation; and probably stratigraphical evidence will also justify this proceeding. The term "Toarcien" commits us to nothing like the term "Inferior Oolite;" it does not say whether the strata are clay, sand, or limestone; and considering how unreliable a guide lithology is, I consider this a very important point. Those who are apt to defend the present divisions, especially Inferior Oolite, 1st, because of the Oolitic character of its rocks, composed, too, of a limestone, in distinction to the clay or sand below, 2nd, because this mass of limestone forms such an important and well-marked—easily recognizable—feature in the country, should remember that this is by no means always the case, even in England; while over the much greater area—the Continent—it is the exception; because clay, sand, or marl are wont to make up a large part of the *Murchisonæ*-zone and of the zones below it.

The term "Toarcien" will supersede a number of names which have been applied to its various constituents, namely, Upper Lias Clay, Upper Lias Sands, Supra-liassic Sands, Inferior-Oolite Sands, Midford Sands, Infra-oolitic marls, Lower division of the Inferior Oolite, Lower Bajocien, &c.

Prof. Deslongschamps (*op. cit.* p. 100, footnote) says that the name "Toarcien" was unfortunately chosen, because at Thouars many of the beds of this age are wanting; in Normandy the series is more complete, but thin and irregular; but in the Moselle department the strata are most complete.

In order to show this, he appends a Table of the strata in the different localities (p. 101), part of which I here reproduce (Table I., facing this page); but as the strata of Dorset are certainly more developed and show fewer lacunæ than even those of the Moselle, I place them, and also those of the Cotteswolds, side by side with

* See Eugène Deslongschamps, *op. cit.* p. 98.

the French localities for comparison. The only observation which I have to make upon this Table is that in the first column the "Calcaire à *Amm. jurensis*," placed below the *Bifrons*- and *Serpentinus*-beds, is totally at variance with all present knowledge, and is probably an error.

The great variation in the lithology of the different localities upon the same horizon should be noticed.

I will now proceed to consider the evidence in favour of the proposed Toarcian division and will in consequence begin with the palæontological aspects of the case.

The family Hildoceratidæ dominate this period. They appear suddenly with the *Falciferum*-zone, and die out abruptly with the exit of the *Concavum*-beds. Prior to the former, or subsequent to the latter, only a very few species are found. The annexed Table of the range of the species and genera of the family Hildoceratidæ will fully bear out these remarks.

TABLE II.†

Family HILDOCERATIDÆ.	*Jamesoni*-zone.	*Ibex*-zone.	*Henleyi*-zone.	*Margaritatus*-zone.	*Spinatum*-zone.	*Falciferum*-zone.	*Commune*-zone.	*Jurense*-zone.	*Opalinum*-zone.	*Murchisonæ*-zone.	*Concavum*-zone.	*Sauzei*-zone.	*Humphriesianum*-zone.	*Parkinsoni*-zone.
Hildoceras														
bifrons (*Brug.*)							*	*	*					
Levisoni (*Simps.*)							*	*						
Frantzi (*Reynès*)									*					
Douvillei (*Haug*)						*								
Kiliani, *Haug*						*								
boreale (*Seebach*)							*							
serpentinum (*Reinecke*)						*								
Lillia														
comensis (*Buch*)							*							
tirolensis (*Hauer*)				*										
Lilli (*Hauer*)							*							
erbaensis (*Hauer*)							*							

† For information concerning the position of many of these species (especially those of older authors), I must acknowledge myself indebted to Dr. Haug's memoir on *Harpoceras*: Neues Jahrbuch für Mineralogie &c. Beil. Bd. iii. 1885.

Many of Dumortier's species are given by him as from the zone of *Amm. bifrons* (=*Commune*- and *Jurense*-zones above). In such cases I have referred the species to the *Commune*-zone, unless I had knowledge or evidence to the contrary.

The zone of *Amm. Parkinsoni* does not, to my knowledge, contain any species belonging to this family; but certain members thereof (descendants of the genus *Ludwigia*) occur in the strata above. Other species in the same horizon perhaps belong to this family; but at present we are only concerned with those in the zones here given.

TABLE II. (*continued*).

	Jamesoni-zone.	*Ibex*-zone.	*Henleyi*-zone.	*Maryaritatus*-zone.	*Spinatum*-zone.	*Falciferum*-zone.	*Commune*-zone.	*Jurense*-zone.	*Opalinum*-zone.	*Murchisonæ*-zone.	*Concavum*-zone.	*Sauzei*-zone.	*Humphriesianum*-zone.	*Parkinsoni*-zone.
Lillia (*cont.*)														
rheumatisans (*Dumort.*)							*							
Escheri (*Hauer*)							*							
robusta (*Denckmann*)								*						
Bayani (*Dumortier*)							*							
sulcata, *Buckman*													*	
Pœcilomorphus														
Mercati (*Hauer*)							*							
macer, *Buckman*												*		
cycloides (*d'Orbigny*)													*	
Ludwigia														
Murchisonæ (*Sowerby*)										*				
Lucyi, *Buckman*											*			
costosa (*Quenstedt*)									*					
cornu, *Buckman*											*			
rudis, *Buckm.*											*			
Lioceras														
elegans (*Young & Bird*)						*								
opalinum (*Reinecke*)									*					
concavum (*Sowerb.*)											*			
fallax, *Buckm.*											*			
apertum, *Buckm.*											*			
bradfordense, *Buckm.*										*	*			
decipiens, *Buckm.*											*			
ambiguum, *Buckm.*										*				
Pseudolioceras														
lythense (*Young & Bird*)						*	*							
compactile (*Simpson*)							*	*						
lympharum (*Dumort.*)							*							
Beyrichi (*Schlönb.*)									*					
simile (*Simpson*)						*								
Hyperlioceras														
discites (*Waagen*)											*			
discoideum (*Quenstedt*)											*			
subdiscoideum, *Buckm.*											*			
Desori (*Mœsch.*)											*			
Walkeri, *Buckm.*											*			
Harpoceras														
falciferum (*Sow.*)						*								
exaratum (*Young & Bird*)						*								
subplanatum (*Oppel*)								*						
bicarinatum (*Zieten*)							*							
elegans (*Sowerby*)							*							
Strangewaysi (*Sowerby*)						*								
crassifalcatum (*Dumort.*)									*					
connectens (*Haug*)							*							
Harpoceras?														
Curioni, *Meneghini*				*										
boscense (*Zittel*)				*										

TABLE II. (*continued*).

	Jamesoni-zone.	*Ibex*-zone.	*Henleyi*-zone.	*Margaritatus*-zone.	*Spinatum*-zone.	*Raricostatum*-zone.	*Commune*-zone.	*Jurense*-zone.	*Opalinum*-zone.	*Murchisonæ*-zone.	*Concavum*-zone.	*Sauzei*-zone.	*Humphriesianum*-zone.	*Parkinsoni*-zone.
Harpoceras ? (*cont.*)														
pectinatum, *Meneghini*				*										
subconcavum, *Blake*							*							
Hildoceras ?														
algovianum (*Oppel*)				*										
retrorsicosta (*Oppel*)				*										
nitescens (*Young & Bird*)				*										
Grammoceras														
antiquum (*Wright*)	*													
Normanianum (*d'Orb.*)				*										
radians (*d'Orbigny*)								*						
striatulum (*Sowerby*)								*						
acutum (*Tate*)					*									
pseudoradians (*Reynès*)				*										
Kurrianum (*Oppel*)				*										
fallaciosum, *Bayle*								*						
Bingmanni (*Denckmann*)								*						
Struckmanni (*Denckm.*)								*						
Sæmanni (*Oppel*)								*						
Muelleri (*Denckm.*)								*						
capillatum (*Denckm.*)							*							
Ruthenense (*Reynès*)				*										
Bodei (*Denckm.*)								*						
quadratum (*Haug*)								*						
Cæcilia (*Reinecke*), (*Blake*)						*								
dœrntense (*Denckm.*)								*						
Emilianum (*Reynès*)							*							
dispansum (*Lycett*)								*						
latescens (*Simpson*)						*								
subcomptum (*Branco*)									*					
mactra (*Dum.*)									*					
costula (*Reinecke*)									*					
fluitans (*Dumortier*)									*					
aalense (*Zieten*)									*					
lotharingicum (*Branco*)									*					
Steinmanni (*Haug*)									*					
metallarium (*Dumortier*)								*						
Gruneri (*Dumortier*)							*							
ovatum (*Young & Bird*)							*							
sp.										*				
Haugia														
variabilis (*d'Orbigny*)								*						
navis (*Dumort.*)								*						
malagma (*Dumort.*)								*						
Ogerieni (*Dumort.*)								*						
illustris (*Denckm.*)								*						
Eseri (*Oppel*)								*						
occidentalis (*Haug*)								*						

I have tabulated herein 96 species of this family, and I believe that, with very few exceptions which I have not had opportunity to study, these include all the Ammonites which belong to this family in the zones mentioned. It will be noticed that, of all these species, only three survive the period known as the *Concavum*-beds, a fact which cannot but be regarded as extremely striking; while, on the other hand, only 13 of the species appeared prior to what I propose to name Toarcian. Thus we are left with 80 species of this one family as existing during the Toarcian period; and we may, I think, with propriety, define this period as the one which was dominated by the family Hildoceratidæ. Curiously enough, different portions of the Toarcian were dominated by certain genera of this family: thus *Hildoceras*, *Harpoceras*, and *Lillia* dominate the *Falciferum*- and *Commune*-zones; *Grammoceras* dominates the *Jurense*- and *Opalinum*-zones; *Ludwigia*, *Lioceras*, and *Hyperlioceras* dominate the *Murchisonæ*- and the *Concavum*-zones.

It would seem that the upper limit of the Toarcian is more sharply defined upon the continent than with us, owing to the absence, apparently, of the *Concavum*-beds from the continent. I fancy that the *Concavum*-zone helps to bridge over the hiatus between the *Murchisonæ*- and so-called *Sowerbyi*-zones of the continent, and therefore it gives a certain amount of difficulty. It is quite true that the Hildoceratidæ come to a sudden end within the *Concavum*-zone, as the Table shows; but we also meet with a number of species (as yet undescribed) of the genus *Sonninia*; and this genus is one which belongs especially to the strata above the *Concavum*-zone, and therefore helps to connect it therewith. It was the presence of these *Sonniniæ* (some of which are very similar to, though precursors of, *Sonninia Sowerbyi*) which caused me to call the *Concavum*-zone "the *Sowerbyi*-zone"; especially as they make a sudden and quite unexpected appearance in the *Concavum*-zone and are absent from the *Murchisonæ*-zone. Probably we must not expect to find any division where there is not some connexion with strata above; and the value of these *Sonniniæ* is again balanced by *Hammatoceras*, a genus which began in the *Jurense*-zone and ended, apparently rather abruptly, in the *Concavum*-zone, having been fairly persistent through the intermediate strata. The presence of members of the genera *Oppelia* and *Lissoceras* is evidence neither one way nor the other; it connects the strata no more with the *Oppeliæ* of the *Opalinum*-zone than with those of the *Humphriesianum*-zone. The presence of one or two small species of *Stephanoceras* perhaps tends rather to unite the *Concavum*-zone with the strata above them. But the presence of *Lytoceras confusum* (a member of the *Jurense*-group) unites the *Concavum*-zone very forcibly with the rest of the Toarcian by means of the following series:—*Lytoceras jurense*, in the zone of that name; *Lytoceras Wrighti*, in the *Opalinum*-zone; *Lytoc. amplum* in the *Murchisonæ*-zone; because we must remember that *Lytoceras Eudesianum* of the *Humphriesianum*-zone does not belong to the *Jurense*-group of the *Lytocerata*, but to the *Fimbriatum*-group. After all, the strongest palæontological

evidence in favour of a break above the *Concavum*-zone is that thirteen species of Hildoceratidæ occur in the *Concavum*-zone, while only one is found in the succeeding *Sauzei*-zone.

The geological evidence in favour of a break above the *Concavum*-zone is somewhat striking. The failure of the *Humphriesianum*- and *Sauzei*-zones in the majority of English localities affords us at once a very definite break, and leaves us with few, if any, places where there would be anything like drawing a really arbitrary line. At Dundry the *Humphriesianum*- and *Sauzei*-zones are present; at Milborne Wick and in the neighbourhood of Sherborne the same holds good; these are the places where we may expect opposition. At Burton Bradstock and in the Bridport neighbourhood the *Humphriesianum*-zone is feebly represented; but there is a hiatus, due to the absence of the *Sauzei*-zone and the *Concavum*-beds. At Halfway House and Bradford Abbas the *Humphriesianum*-zone is represented by a very thin band, of itself more like a dividing-line than anything else; while the *Sauzei*-zone is probably almost, if not entirely, absent. At Stoford, East Coker, Haselbury, Crewkerne, Broad Windsor, and around Beaminster the *Humphriesianum*-zone is entirely absent—the *Parkinsoni*-zone rests upon the *Murchisonæ*-zone or the *Concavum*-zone. Further north we find, at Cole, the *Parkinsoni*-zone resting on the *Sauzei*-zone, and this, again, on the *Murchisonæ*-zone—the *Concavum*-beds are absent; while at all other places, Castle Cary, Doulting, Cranmore, along the sides of the Mendips, at Radstock, at Midford, and at Bath the *Parkinsoni*-zone rests on sands and, in some instances, on Carboniferous Limestone. Throughout the whole of the Cotteswolds the *Humphriesianum*-zone is absent*; the *Parkinsoni*-zone (Upper Trigonia-grit) rests upon the *Concavum*-zone (Gryphite-grit), but in many parts there is a greater hiatus† than this. From Little Sodbury nearly to Stroud the Upper Trigonia-grit rests upon the Freestone or Limestone of the *Murchisonæ*-zone, and there is a lithologically marked hiatus. In the eastern extension of the Cotteswolds, namely, at Little Rissington, near Stow-on-the-Wold, the *Clypeus*-grit (*Parkinsoni*-zone) rests upon the Upper-Lias Clay, so that the hiatus is now very great.

* I would expressly note, in passing, that I am pleased to think my views upon the proper position of the Gryphite-grit &c. were published before anything of this kind had been thought of, at any rate by me (Proc. Cotteswold Club, vol. ix. 1887), so that it cannot be said that such views were manufactured to meet the exigencies of the situation. It can, however, be seen how extremely important such views have become in connexion with the present ideas. The zonal arrangements of the Cotteswolds, according to Dr. Wright and Prof. Judd, whereby the Upper Freestone &c. represented the *Humphriesianum*-zone, and the Oolite Marl the *Sowerbyi*-zone, would have greatly interfered with the working-out of the present views.

† In the North Cotteswolds this hiatus is marked lithologically by a bored bed covered with oysters. In the South Cotteswolds the junction of the Upper Trigonia-grit and the Gryphite-grit is not so distinguished; but this is paralleled by Castle Cary (p. 447). At the same time there is, singularly enough, a distinct lithologically-marked hiatus in this district, on a lower horizon, namely at the top of the Upper Freestone; but this hiatus means the absence of the Lower Trigonia-grit of the Cheltenham district, some 24 feet of strata.

So far I can speak almost entirely from my own knowledge of the various localities. To continue the subject:—Dr. Wright * notices that near Burford, and in the north-eastern parts of the Northleach district of the Cotteswolds, the *Parkinsoni*-zone rests upon the Upper Lias. Mr. Hudleston † says that further eastwards, namely, at Hook Norton, in Oxfordshire, the *Parkinsoni*-zone rests on the *Murchisonæ*-zone and that there is therefore a hiatus.

In a section of the Northampton district, very kindly sent to me by Mr. Thompson, an "Unconformity" is said to exist between the Lower Estuarine series (Northampton Sand, *Murchisonæ*- or *Opalinum*-zone?) and the Upper Estuarine series (Great Oolite).

At Rockingham, Stamford, and Grantham Prof. Judd ‡ depicts the Upper Estuarine series (Great Oolite) resting upon the Lincolnshire Limestone of the Inferior Oolite. In Middle and North Lincolnshire he shows the Great-Oolite Limestone resting on the Lincolnshire Limestone. Now he places the Lincolnshire Limestone in the *Sowerbyi*-zone, but at the same time on the level of the "Oolite-Marl" (page 8). In the latter case, the Lincolnshire Limestone would be in the *Murchisonæ*-zone, according to my views, and this is Mr. Hudleston's opinion of its proper position (*op. cit.* p. 72). Therefore we have the same hiatus at the top of the *Murchisonæ*-zone, only that it is now much greater, owing to the absence of all the upper beds of the Inferior Oolite.

In the Yorkshire basin we have the *Humphriesianum*-zone (Scarborough Limestone) resting upon the *Murchisonæ*-zone (Hudleston, *op. cit.* page 75), so that here, too, we have a palæontological hiatus (the *Sauzei*-zone and the *Concavum*-beds being absent), though there is no mention of any lithological one.

I have therefore shown that over nearly the whole of the English Inferior-Oolite area, and especially where the zones can best be distinguished, there already exists a well-marked, ready-made line of division, due to the absence, generally, of the *Humphriesianum*-zone, but very often to the absence of other zones also. In some cases this hiatus is marked stratigraphically by the presence of a bored bed, by the under rock being pitted or covered with oysters, and by other signs of a cessation of deposition; but in other cases a long interval may not be marked in this way, and the two periods may be actually cemented together into one stone (see page 447), so that we again find lithological features to be unreliable.

Dr. Vacek, who has worked this matter out very extensively in connexion with his proposal to include the *Murchisonæ*-zone in the Lias, finds, upon the continent, a very extensive hiatus between the *Murchisonæ*- and so-called *Sowerbyi*-zones. Possibly this *Sowerbyi*-zone, in its strict sense, is more correctly on the horizon of our *Sauzei*-zone; and in that case it seems to me that our *Concavum*-zone is possibly the stratum the absence of which the hiatus represents.

Eugène Deslongschamps (*op. cit.* p. 94) shows that this hiatus,

* "Subdivisions of the Inferior Oolite," Quart. Journ. Geol. Soc. vol. xvi. p. 18 (1860).

† "Gasteropoda of the Inferior Oolite," Palæont. Soc. 1887, p. 71.

‡ Memoirs of Geological Survey, "Geology of Rutland," plate i. (vertical sections).

accompanied by conglomerate and signs of erosion, is also very clearly marked in Normandy as indicated in his figure (No. 19) p. 95. In this is shown also the partial extent of the *Humphriesianum*-zone (the dotted stratum). Its absence at Falaise brings the *Parkinsoni*-zone in contact with the *Malière*, which is what we so frequently find in this country. In fact, if we omit from the above-mentioned diagram the conglomerate and the signs of erosion, if we substitute *Concavum*-beds for *Malière*, Sherborne for Bayeux, and Bradford Abbas for Falaise, and imagine Louse Hill situated a short distance from the latter place, we have exactly the position of the Inferior-Oolite strata in Dorset, as well as their extent and sequence. It may be remarked, however, that in Dorset the absence of any particular beds is not necessarily attended with signs of erosion. Lithologically there may be little to indicate the absence of even a considerable series (page 447).

How the matter stands lithologically for the commencement of the Toarcian I cannot say, because I have not studied the Liassic strata with that minute analysis necessary to grapple with such a task; but in the South-Western counties I know we have a marked lithological change from the hard Marlstone of the Middle Lias to the clays of the *Falciferum*-zone; and this line corresponds with a line of division at present in use. In passing I would note that in drawing dividing-lines we must have regard to what will suit Continental strata as well as our own; that whatever lines we adopt will certainly be bridged over more or less in some places; and that all that we can hope is to choose, as the limits of our divisions, lines which can be drawn with the most ease over the greatest extent of country. Such I claim for the Toarcian.

The following is a general description of the strata for which the term "Toarcian" is proposed.

A variable series of clay, sand, and limestone, during the formation of which the Ammonite-family Hildoceratidæ was dominant, and which series, practically speaking, corresponds in its duration with the beginning and ending of the majority of members of that family.

The series comprises the period from the *Falciferum*-zone to the *Concavum*-zone inclusive.

In England the series usually consists of clay at the base, yellow sands in the middle, and oolitic limestone at the top; but the sands may be absent; while clayey or marly conditions may be partially reproduced at the very top (Dundry, Corton Downs).

In the south-western parts of the Jurassic development (counties of Gloucester, Somerset, and Dorset) the duration of the clay is very variable. It may cease, giving place to sands, before the end of the *Commune*-zone, or may last into the middle of the *Jurense*-zone before it gives way. The period of sand-deposit is very variable; it may exist from the middle of the *Commune*-zone to the middle of the *Jurense*-zone, or from the middle of the latter zone to the middle of the *Opalinum*-zone. The oolitic limestone, too, may begin in the middle of the *Jurense*-zone, or may not begin till nearly the end of the *Opalinum*-zone. Argillaceous marl mixed with some limestone may reappear in the *Murchisonæ*- and *Concavum*-zones.

Table III., p. 469, compiled from my own observations, will show the variations in lithology in the different zones, and will

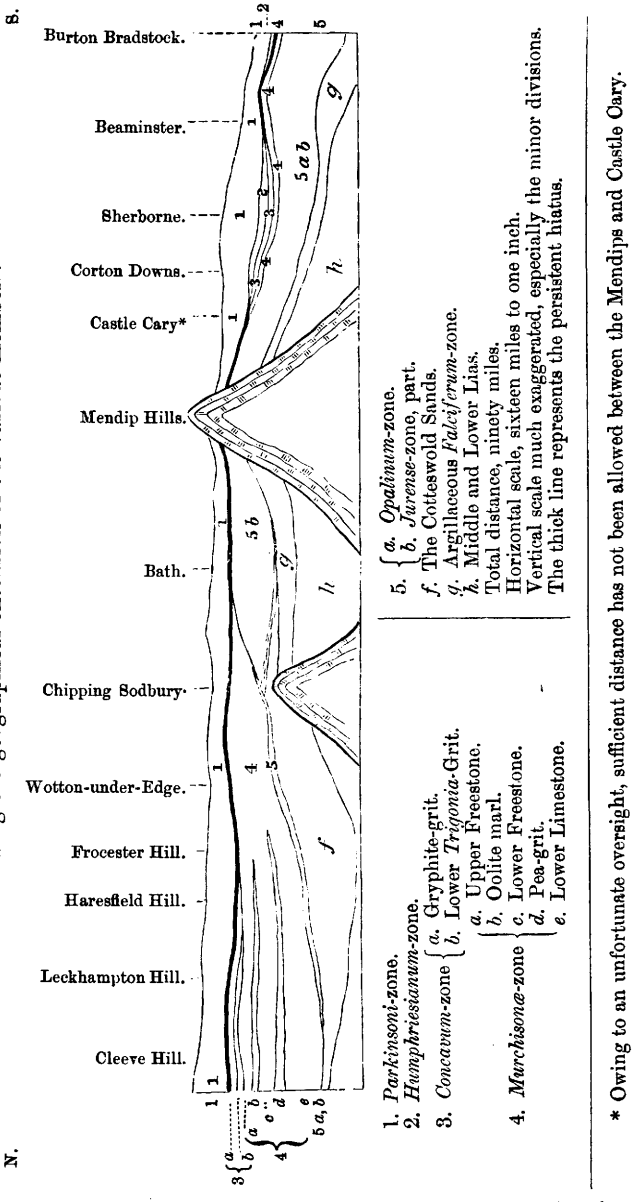

Fig. 3.—*Sketch of the Inferior-Oolite and Liassic Strata*, showing the geographical extension of the various members.

* Owing to an unfortunate oversight, sufficient distance has not been allowed between the Mendips and Castle Cary.

demonstrate how impossible it is, from a palæontological point of view, to class all "the sands" as a certain particular series.

TABLE III.*

	CHELTENHAM.	COALEY WOOD.	SODBURY.	BATH.	DUNDRY.	ILMINSTER.	HAM HILL.	CORTON DOWNS.	STOKE KNAP.	BURTON BRADSTOCK AND DOWN CLIFF.
Concavum-zone† ...	Oolitic grits (limestone). Micaceous yellow sands.	Absent.	Absent.	Absent.	Slate-coloured marl and limestone.	Denuded.	Denuded.	Bluish clay and limestone.	Ironshot limestone.	Absent.
Murchisonæ-zone	Freestone (limestone). Marl. Freestone (limestone). Pisolitic limestone. Oolitic limestone.	Freestone (limestone).	Freestone (limestone).	Absent.	Bluish-grey stone.	Denuded.	Denuded.	Yellow limestone.	Pale yellow limestone.	Thin band of limestone.
Opalinum-zone.....	Sandy limestone. Ironshot limestone.	Sandy limestone. Ironshot limestone. Hard, ironshot marl.	Sandy limestone. Ironshot limestone. Ironshot marl.	Absent.	Hard bluish-grey shale.	Denuded.	Yellow sands. Freestone. (Yellow shelly sandstone).	Part absent? Yellow sands.	Sandy grits and sands.	Grey limestone. Yellow sands.
Jurense-zone ...	Absent.	Ironshot marl and limestone. Yellow micaceous sands.	Ironshot marl. Yellow sands and sandstone.	Yellow sands. Oolitic limestone.	Bluish-grey sands.	Yellow sands. Brown marl (thin). Yellowish-grey stone (thin). Blue clay.	Probably as at Ilminster.	×	×	Yellow sands. Blue clay.
Commune-zone ...	Blue and yellow sands. Blue clay.	Yellow and blue micaceous sands. Blue clay.	×	Oolitic limestone (thin band).	Blue clay?	Bluish-grey clayey marl and stone.	Probably as at Ilminster.	×	×	Blue clay. Pink limestone (thin band).

× No definite details available.

* The designations denote different beds in their correct order, except when between brackets, when they are explanatory of the following sentence.

† See footnote, page 459.

Considering the very great development of the Toarcian limestone in the Cotteswolds it may be advantageous to give a comparison of the strata of that district with a section of the strata in Dorset (fig. 2, facing p. 456). This correlation is entirely founded on the position of the different species of Ammonites; and for further information on this matter the reader is referred to my Monograph on "Inferior-Oolite Ammonites," Palæontographical Society, p. 91.

The horizontal diagram (fig. 3, p. 468) is intended to represent the Inferior-Oolite strata north and south of the Mendips, with their geographical extension according to the correlation just given, on a line from Leckhampton Hill to Burton Bradstock. Apparently the Mendip range must have acted as a barrier between the areas on each side of it; but it is more curious to find that a change in lithology in the Sodbury district, a change which I have demonstrated in the case of the sands, should coincide with an outcrop of Carboniferous Limestone. This is part of a patch which extends to Charfield and reappears across the Severn and no doubt formed, at that period, a subsidiary range of hills joining the Mendip axis at right angles.

However, the character which this figure brings into greatest prominence is the remarkable persistence of a hiatus or lacuna, due to the absence of certain strata, in the middle of what is called Inferior Oolite. This is the same hiatus which Eugène Deslongschamps finds in Normandy, and which he proposes shall mark the uppermost limit of his Infra-Oolitic marls; this is the same hiatus which Dr. Vacek says occurs over the continent generally, and which he proposes as the uppermost limit of the Lias; this is the hiatus which I, following d'Orbigny, propose to take as the dividing line between the "Toarcien" and the "Bajocien"; this is the hiatus which is accompanied palæontologically by the sudden exit of nearly all the Hildoceratidæ, or 'true Falciferi.'

One last subject remains to be dealt with, namely, the matter of mapping. In connexion herewith the proposed classification would introduce some advantages, and would certainly get rid of such anomalies as the same zone being mapped as "*Midford Sands*" in one county and as Upper Lias Clay in another; or, again, as "*Midford Sands*" at one place and Inferior-Oolite Limestone somewhere else. It would probably be best for this purpose to divide the Toarcian into Upper and Lower, although there is between them, lithologically, no marked break at any point, and, palæontologically, only a small one. This palæontological break occurs at the end of the *Opalinum*-zone with the extinction of the genus *Grammoceras*—only one species of which, I believe, survives into the *Murchisonæ*-zone. Therefore, the *Falciferum*-, *Commune*-, *Jurense*-, and *Opalinum*-zones form the Lower Toarcian. They would require the following changes among others, namely the abolition of the dividing-line now drawn between Upper Lias* and "*Midford*

* Throughout a large part of Dorset and Somerset the Upper Lias Clay is not mapped, although to a great extent it overlies what is marked as "*g* 2, Middle Lias." For instance, at South Petherton, it is exposed to a depth of nearly seven feet on the top of the Marlstone; but nothing is said about it on the map.

Sands," which is erroneous, and the merging of these two divisions into one—*Lower Toarcian* *—with perhaps a marginal note as to the position of "*the Sands*" in the various localities.

On the other hand, the *Murchisonæ*- and *Concavum*-zones in Gloucestershire, from the Pea-grit, or perhaps from the Lower Limestone, to the Gryphite-grit, would form the "*Upper Toarcian*;" and this horizon might be marked as *g* 4. Wherever the Upper *Trigonia*-grit (*Parkinsoni*-zone) is absent in the Cotteswolds would be *Upper Toarcian* and would cause considerable alteration. Part of Cleeve Hill, part of the district round Andoversford, part of Leckhampton Hill, Crickley Hill, part of Birdlip Hill, part of Haresfield and Frocester Hills, and, in fact, most of the outer edge of the escarpment would be *Upper Toarcian*. Part of the country round Corton Downs, in Somerset, and some part of the escarpment as it passes along, now in Somerset, and now in Dorset, would also be distinguished as *Upper Toarcian*.

I may just say a word concerning the Northampton Sands, and the sands below the Yorkshire Dogger. Although partly on the same horizon as the strata which have been mapped as "*Midford Sands*," these sands have been mapped separately. Part of the Northampton Sand, however—that round Duston—belongs to the *Opalinum*-zone, as I have been able to determine by an inspection of its Ammonites †. Mr. Thompson ‡ has attempted to show that the Upper *Leda-ovum*-beds upon which this rests—the top of the Upper Lias Clay of the district—belong to the *Jurense*-zone. I should be glad to admit this, if possible, as it would be an additional argument against the artifical definition of the "*Midford Sands*" as equal to the *Opalinum*- and *Jurense*-zones; but I am unable to do so. The species of Ammonites which he quotes (p. 83) from the Upper *Leda-ovum* beds are all characteristic of the *Commune*-zone; none of the characteristic *Jurense*-zone species are mentioned—not a single species of the genus *Grammoceras* which dominated that period. The Dogger Sands of Yorkshire overlie the *Striatulum*-beds. From an examination of some species of Ammonites kindly forwarded to me by Mr. Hudleston, I am able to confirm his view that they, in part at any rate, belong to the *Opalinum*-zone; and in part they represent the *Dumortieria*-beds. It would be correct, looking at their zonal and stratigraphical affinities, to place together the Yeovil and the Dogger Sands under one name—far more correct than to combine the former with the Cotteswold and Midford Sands. Both the Yeovil and the Dogger Sands occupy a similar horizon, namely *above* the *Striatulum*-beds and *below* the *Murchisonæ*-zone; while the Cotteswold Sands are *below* the *Striatulum*-beds. According to the present proposed classification, the Yorkshire Oolites up

* The tops of Ham Hill and Chiselborough Hill in Somerset—at present marked *g* 5, Inferior Oolite, and which ought, at least, to have been marked *g* 4, "Midford Sands," the same as the sands with shelly beds at Stoford, Babylon Hill, Bradford Abbas, &c., which are on the same horizon—would be marked as *Lower Toarcian*.

† "Inferior-Oolite Ammonites," p. 52. Palæont. Soc. 1888.

‡ "The Upper Lias of Northampton: Part VI.." Journal of the Northamptonshire Natural History Field Club. p. 54 (1888).

to the top of the "Middle Shale and Sandstone" (Hudleston, *op. cit.* p. 75) would be in the *Toarcian*—the *Lower Toarcian* would end with the Dogger Sands, and thence would be *Upper Toarcian*.

In the Midland Counties the Toarcian would include the Lincolnshire Limestone; above that would come the Bathonian, the Bajocian being entirely absent.

Conclusions.

We arrive at the following conclusions in this paper:—

1. That the yellow-sand deposits of the counties of Gloucester, Somerset, and Dorset are on different horizons, earlier in the North, and later in the South.

2. That it is best to retain the names Cotteswold, Midford, and Yeovil Sands as local names merely, and not to extend these divisions beyond the yellow micaceous sands.

3. That the term "*Midford Sands*" for the whole series is inapplicable, since it gives an idea of contemporaneity, which does not exist.

4. That on account of the different horizons at which the sands are developed, and on account of the fact that they occupy only a small part of the duration of sandy deposits in various places, the idea of considering them as passage-beds between the Lias and the Oolite cannot be entertained.

5. That it is incorrect to assign all these sands either to the Lias or to the Inferior-Oolite series.

6. That there is no continuous and marked geological or palæontological break either at the beginning or end of these sand-deposits, or even at the end of either the *Commune*-, *Jurense*-, or *Opalinum*-zones.

7. That the strata from the *Falciferum*-zone to the *Concavum*-zone inclusive form a very continuous series dominated throughout by the Hildoceratidæ, and marked off palæontologically from its predecessors or successors; and that at the end of this period there is a ready-made break, often marked lithologically, due to the absence of one or other life-zone.

8. That the term *Toarcian* is applicable to this series; and it should be erected into a distinct formation.

9. That the term *Toarcian* is commendable because it does not commit us to any definite opinion concerning the constituents of the strata, whether Clay, Sand, Limestone, oolitic, or otherwise.

10. That the term is preferable to "*Infra-Oolitic Marls*;" because the term "Marls" is anomalous when applied to the majority of English localities.

11. That to call the whole series "*Toarcian*" is preferable to placing the *Falciferum*-, *Commune*-, and *Jurense*-zones in the Inferior-Oolite Series, or to uniting the *Opalinum*-, *Murchisonæ*-, and the *Concavum*-zones with the Lias; because both of these plans suggest an anomaly.

12. That the term "*Toarcian*," as thus defined, should be regarded

as a division of the Jura-formation, or a separate formation in the Jurassic system.

13. That the Toarcian can be conveniently divided into Upper and Lower Toarcian, the former including the zones from the *Falciferum*- to the *Opalinum*-zone, and the latter the *Murchisonæ*- and *Concavum*-zones; while the division between them practically corresponds to the disappearance of the genus *Grammoceras*.

14. That the term "Cephalopoda-bed of Gloucestershire" is unscientific. It does not embrace any particular zone, does not begin or end with any Ammonite period, and, if we think of Sodbury, is not referable to any uniform lithology.

Discussion.

The President said that the paper showed a large amount of field-work in conjunction with palæontological research, and helped to prove that much had yet to be done in the stratigraphy of England. He commented on the interest attaching to the Jurassic system, where the zonal divisions were so well marked. Neumayr had enumerated 33 zones. In the International Geological Map of Europe, the base of the *Opalinum*-zone had been adopted as the lower boundary of Middle Jurassic. He doubted the advantage of admitting intermediate subdivisions like "Toarcian," and would prefer a conventional arbitrary limit.

Mr. H. B. Woodward commented on the biological character of the paper. In England the entire Jurassic series (locally) was conformable, and the question was whether our divisional lines should be drawn on palæontological or stratigraphical evidence. A zone might be regarded as a particular assemblage of species; but when traced for any distance these zones were found running into each other. He instanced especially the inosculation of the zones of the Lias, as showing there were no rigid planes of division. He had adopted the term "Midford Sands" because it met an acknowledged difficulty; and so long as people knew what it meant, he could not see any valid objection to its use. The lower portion of the "Sands" in the Bridport Cliffs was inaccessible; but the beds passed downwards into the Upper Lias, while the upper parts were more nearly allied to the Inferior Oolite. He referred to the difficulties in connexion with the naming of Ammonites, and concluded that, taking the Cephalopoda-beds and the "Cotteswold Sands" together, and as stratigraphically equivalent to the "Yeovil and Bridport Sands," the term "Midford Sands" ought not to be changed.

Prof. Blake considered that the Author had thoroughly proved his case, in so far as showing that the different "Sands" were not on the same horizon. With respect to the "Toarcien," he thought the suggestion by no means new. As regards the dividing-line between Lias and Oolite, he observed that in South Europe limestones were more abundant in the Jurassic rocks. We ought to pay some attention to lithological distinctions as indicating physical changes. A new fauna, and that by no means Liassic, made its

appearance in the Cephalopoda-bed, although the same Ammonite-groups remained. The Author surmised that the *Striatulus*-beds disappeared towards Burton Bradstock, indicating a palæontological break. In Yorkshire, the *Striatulus*-beds were in Liassic shales. No doubt the family Hildoceratidæ constituted a bond of union between Lias and Oolite; but if this principle were generally adopted, this would help to divide the Lias also. Hence his objection to the proposed "Toarcian."

Rev. H. H. Winwood declared that lithology was cast to the winds if we accepted the conclusions of Mr. Buckman's paper. However, he was glad that the Author had done away with the misleading name "Cephalopoda-bed." In addition to *Amm. striatulus*, found in the Midford Sands in a cutting near Bath, he had found portions of another Ammonite, apparently too imperfect for Mr. Buckman to define, and also portions of a Brachiopod defined by Chas. Moore as *Rhynchonella spinosa*. He did not fully recognize Mr. Buckman's section at Lyncombe.

Mr. Hudleston was glad to hear a confirmation of the first part of Mr. Buckman's contention from so good a palæontologist as Prof. Blake. Lately, whilst examining the Inferior Oolite of the south-west for a particular purpose, he had come to the conclusion that the Yeovil Sands were on a different horizon from those of the Cotteswolds; hence he could not think it was advisable to describe them by the same name, except on very general grounds. When Phillips selected the term "Midford" for the "Sands" generally, it was probable that he had not an intimate knowledge of any of them. As regards the real Midford Sands the only thing clear about them was that they lay above the *Striatulus*-beds, and were consequently more allied to the Yeovil than to the Cotteswold Sands. If *Rhynchonella spinosa* had really been found the Midford Sands would belong to the uppermost zone of the Inferior Oolite. It was suggested that this might have been *Rhynch. cynocephala*. In the section near Midford the beds of the *Parkinsoni*-zone rested directly on the Sands, showing the absence of the *Murchisonæ*- and *Humphriesianum*-zones; hence there could be no question of passage where such a break existed.

Mr. Buckman's proposal to establish the "Toarcian" at the expense of the Upper Lias and the Lower Division of the Inferior Oolite was scarcely practicable, though we were indebted to the Author for specifying the particular genera of the Hildoceratidæ which characterized the several series. In Dorsetshire the palæontological hiatus between the Lower and Upper Divisions of the Inferior Oolite was undoubtedly very great, and by no means confined to the Cephalopoda. But this could not outweigh the many considerations on the other side. If Mr. Buckman's views on this point were accepted the Inferior Oolite would disappear, the Upper Division being thrown to the Bathonian.