13. JURASSIC CHRONOLOGY: II—PRELIMINARY STUDIES. *Certain* JURASSIC STRATA *near* EYPESMOUTH (DORSET); *the* JUNCTION-BED *of* WATTON CLIFF *and* ASSOCIATED ROCKS.

By S. S. BUCKMAN, F.G.S. (Read December 7th, 1921.)

CONTENTS.

I. INTRODUCTION.

THIS paper is to a certain extent a supplement to the communication on 'Certain Jurassic Strata of South Dorset' published by the Geological Society in 1910, in so far as it contains a study of another exposure of the Junction-Bed (Domerian, Whitbian, Yeovilian)[1] discovered farther east along the coast; but it also

[1] I, 5, pp. 61, 64, 82. These numerals in the footnotes throughout refer to the Bibliography, § VII, pp. 435–36.

gives a sketch of other Jurassic strata, the sequence of which should be of some importance in connexion with the chronology of the Oolite rocks.

About three-quarters of a mile east of Thorncombe Beacon[1] is Eypesmouth, a break in the cliffs where the little stream, the Eype (pronounced 'Eep,' to rhyme with sheep) runs into the sea. East of Eypesmouth is a lofty cliff of about a mile extending to West Bay—the harbour of Bridport.

The cliff is interesting geologically for three considerable faults: one, seen best about a quarter of a mile east of Eypesmouth is a fault of about 500 feet, bringing down Forest-Marble Beds to about the level of Yeovilian strata (*Dumortieria* hemera); another, about the same distance west of West Bay, brings down beds of Fullers' Earth almost vertically—it is a fault of about 120 feet; the third, immediately west of West Bay, shows Yeovilian strata of *Dumortieria* hemera or later—they are later than those on the west of the cliff—lying level with lower beds of Fuller's Earth: a drop as regards the latter of about 150 feet. So the middle and main portion of the cliff is let down by these faults. (See diagram 1, sketch-elevation of Watton Cliff, p. 383.)

The cliff faces about south-west by south and the faults run approximately west and east. The effect of the westerly fault is that destruction of the cliff has been hastened—there is a considerable recess from Eypesmouth to where the fault is now most visible, the cliff having been cleared back roughly along the line of fault, except for some more or less tumbled strata at its foot. The line of fault can be traced from what may be called 'the fault-corner' more or less towards Eypesmouth, where it disappears beneath the sand and shingle of the shore. This fault is shown on the 1-inch Geological Survey map, Sheet XVII, extending inland some 8 miles to the foot of the Chalk Downs—the Dorset Heights—near Long Bredy. It and the other faults run approximately parallel to, and are no doubt part of, the system of the Weymouth Anticline. A ground-plan of the cliff and the faults is appended (diagram 2, p. 384).

In the autumn of 1916 a large block lying on the platform of the fault-corner attracted my attention.[2] A portion that had been broken off exposed a weathered surface with *Thecidellæ*, and in some marl connected with them were unfamiliar ammonites in a fragmentary condition—Hildoceratids presenting almost the appearance of those which characterize the *discites*-beds of the Inferior Oolite. Further search showed specimens of *Tetrarhynchia thorncombiensis*, nom. nov.,[3] evidently derived.

Here was a case for investigation. The rock from which this block had fallen was subsequently located high up in the cliff-face, with also other tumbled blocks lying on a higher platform. Work

[1] I, 5, p. 59.
[2] This block has disappeared, buried perhaps by a slide of clay.
[3] See later, Palæontological Note, p. 435.

on these blocks showed that they were in the position of the Junction-Bed of Down Cliffs to Thorncombe Beacon, described in my former paper,[1] but that this exposure of the bed differed remarkably from what is found only about three-quarters of a mile away to the west. The Eype type consists mainly of strata with *Grammoceras striatulum* (*G. striatulum* sensu lato + *thouarsense* and other species)—a thin layer with these fossils was seldom present at the top of the Down Cliffs Junction-Bed; and here, at Eype, it is mainly a fine white lithographic stone, weathered faces of which show it to have been laid down as a fine white mud in paper-like layers: it is a very finely laminated bed. As I had, in my former paper, described at Burton Bradstock another white lithographic-stone bed, also associated with a fault and connected with Bridport Sands, the various interesting questions which arose will be readily understood.

Further work was done on this bed and the neighbouring strata during short holidays in the autumns of 1917, 1919, and 1920. A preliminary account of these investigations will, it is hoped, be equally interesting to the Society.

This paper was commenced on my return in 1917, but it was mainly written in the winters of 1918–19, 1919–20. During my visit to Eypesmouth in 1920, inspection of the bed showed that another investigator had taken details of it; a few days afterwards there came to Eypesmouth a letter from Mr. J. F. Jackson, enclosing a section. He kindly agreed to my suggestion that the account of his quite independent discovery and of his researches in the Junction-Bed of the western area should form an Appendix to this paper.[2] Therefore, I have divided this communication into two parts: the present paper, mainly concerned with these accounts of the Junction-Bed; and a proposed later paper, to give a fuller study of the main mass of Eype (Watton) Cliff—Fuller's Earth to Cornbrash—or the upper portion of the Lower Oolites.

II. Stratal and Faunal Details.

(A) Watton Cliff: the main mass.[3]

The following is a section of the beds exposed in Watton Cliff down to the '*margaritatus* bed,' showing the sequence, with

[1] I, 5, pp. 61, 64, 82.

[2] Mr. Jackson's account in his Section VIII does not seem to bear out my statement made above about *Grammoceras*; but then he might not feel sufficient confidence to identify *Grammoceras* by peripheries and cross-sections showing in a rock-mass. His Section IX would appear to deal with a block which I have not seen.

[3] The local name for the hill of which the cliff is the face is 'Fourfoot Hill' and for the cliff itself 'Clay Knapp.' E. C. H. Day has the name 'Fourfoot Hill' (III, p. 286). It may be suggested that the name is really 'Forefoot Hill,' from the tumbled platform at the base of part of the cliff, though this is to trespass dangerously near the usual error of folk-etymology. It seems advisable to distinguish it as Watton Cliff, from the name of the farm which lies behind it.

the position of the Junction-Bed. A consideration of the post Inferior-Oolite strata will be reserved for a later communication.

Section I—Watton Cliff, between Eypesmouth and West Bay (Bridport), Dorset.[1]

Beds 1–4 in the middle part of the Cliff.	Sequence of Strata.	*Thickness. (approximate) in feet*
1.	Forest Marble: massive shelly blocks with clay-partings	30
2.	Upper Grey Marls	30
3.	*a.* Micromorph *Ostrea* Bed: a mass of small oysters rarely 5 mm. long. Pedicle-valve of *Dictyothyris*; fragments of *Acanthothiris* (*A. bradfordiensis* Walker ?). *b.* The '*boueti*' or '*Rhynchonella* Bed': about 16 inches thick, mainly brown, crumbly, but white and compact for about 2 to 3 inches from the bottom. Full of specimens of *Goniorhynchia*,[2] often crushed; also occasional examples of *Ornithella* sp., crushed. Rarely *Terebratula langtonensis* Walker. *c.* Lower Grey Marl. *d.* White Marl.	5
4.	Large Conchoidal Bed: clays which break into large pieces. Measured up the cliff from 5 to 3 *d*	125
5.	*Ostrea-acuminata* Clays	20
6.	Brachiopod-Beds[3]: stone bands 6 to 12 inches thick separated by clays 18 to 30 inches thick. The contents of the stone-bands vary, and their sequence is somewhat supposititious	25
	a. *Ornithella* Bed.	
	b. Large *smithii* Bed: *Rhynchonelloidea* aff. *smithii*, rather large examples without other brachiopods.	
	c. *Acanthothiris* Bed: *A. powerstockensis*, *Rhynchonelloidea smithii*, and a large ammonite (*Parkinsonites* ?).[4]	
	d. The *globata* Bed or *Terebratula* Bed: *Stiphrothyris* spp. = *Terebratula* cf. *tumida* Davidson (*T. globata* auctt. *non* Sow.) + *T.* cf. *nunneyensis* S. Buckman. *Rhynchonelloidea* cf. *smithii*.	
	e. Shelly Bed: small forms of *Rhynchonelloidea* cf. *smithii*.	

[1] See diagram 1, p. 383.

[2] For these and other brachiopod names see Bibliography, I, 6.

[3] Details of the Brachiopod-Beds were mostly obtained from blocks scattered on the beach during 1916. In 1917 and 1919 these blocks were nearly all buried; towards the end of my visit in 1920 a high tide removed shingle, disclosing the upturned edges of some stone-bands along the line of fault immediately east of Eypesmouth. These gave some help in the interpretation of the succession; but, owing to faulting and dislocation, they are not too reliable. A detailed section will be given in a later communication.

[4] Now in the Museum of the Geological Survey, Jermyn Street, London.

		Sequence of Strata.	*Thickness (approximate) in feet.*
	6*.	*Ostrea-knorri* Clays: possibly Bed 6 *e* is a layer in these	5
		The following beds (7–9) are to be seen in the eastern part of the cliff beyond the second fault:—	
	7.	Umber Bed: umber-coloured clays with a nodular band	20
	8.	Small Conchoidal Bed: clays with conchoidal fracture, breaking into small lumps	40
	9.	Ochre Band: a yellowish marly band about 1 foot thick, seen near the top of the cliff, eastern end, resting on	
		Laminated Clays: with light bands of somewhat calcareous rock. Occasional lumps of pyrites.	50
		Of the following beds, details for 10 and 11 are furnished by Burton Bradstock. There are Inferior Oolite rocks, the Black Rocks, just out to sea west of the third fault (see later, p. 430). Then part of No. 12 is seen immediately east of the third fault, and the basal part of No. 13 is found with succeeding beds in the cliff west of the first fault:	
	10.	Belemnite-Clays	15
Bajocian / Aalenian	11.	Limestone-mass of the Inferior Oolite	16
Yeovilian	12.	Bridport Sands	130
	13.	Down-Cliff Clay	70
Whitbian	14.	Junction-Bed: fine creamy-white lithographic stone in paper-like laminæ (*Grammoceras* of *striatulum-thouarsense* types) and yellowish conglomerate, somewhat sandy, with derived *Tetrarhynchia thorncombiensis*. For detailed section, see later, p. 387	5
Domerian	15.	Thorncombe Sands[1]: yellow sands with doggers	35
	16.	Blue clay[2]	2
	17.	*Margaritatus* Bed: a prominent and easily recognized datum-line	1
	18.	Down-Cliff Sands.[3]	
		Approximate total	624

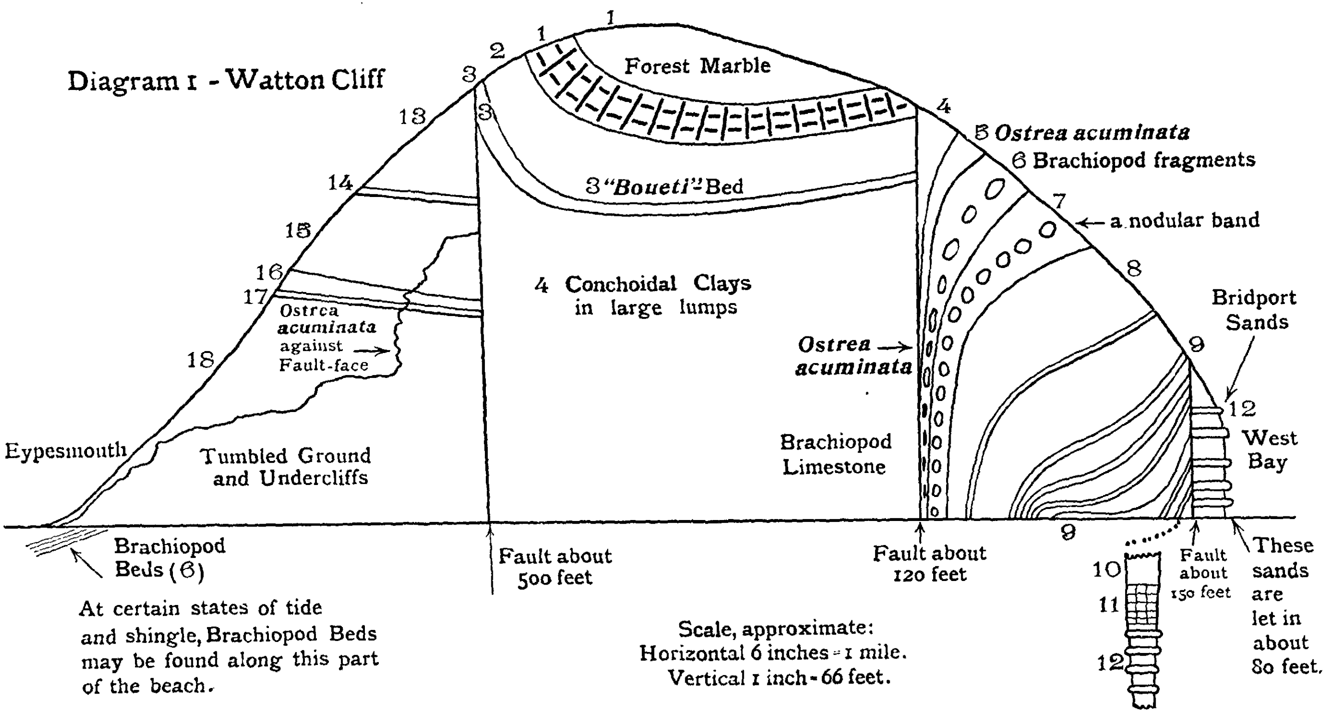
The accompanying diagram (1) embodies a general sketch of Watton Cliff.

[1] Name given from their occurrence at Thorncombe Beacon.

[2] The equivalent of this at Down Cliffs was wrongly placed in my section (I, 5, p. 66) copied from Day, and the thickness omitted. The *f* should be just above *g* there, and the thickness ($6\frac{1}{2}$ feet) should be put opposite; see E. C. H. Day, III, p. 285.

[3] From their occurrence at Down Cliffs; see Day, as above.

Diagram I - Watton Cliff



At certain states of tide and shingle, Brachiopod Beds may be found along this part of the beach.

Scale, approximate:
Horizontal 6 inches = 1 mile.
Vertical 1 inch = 66 feet.

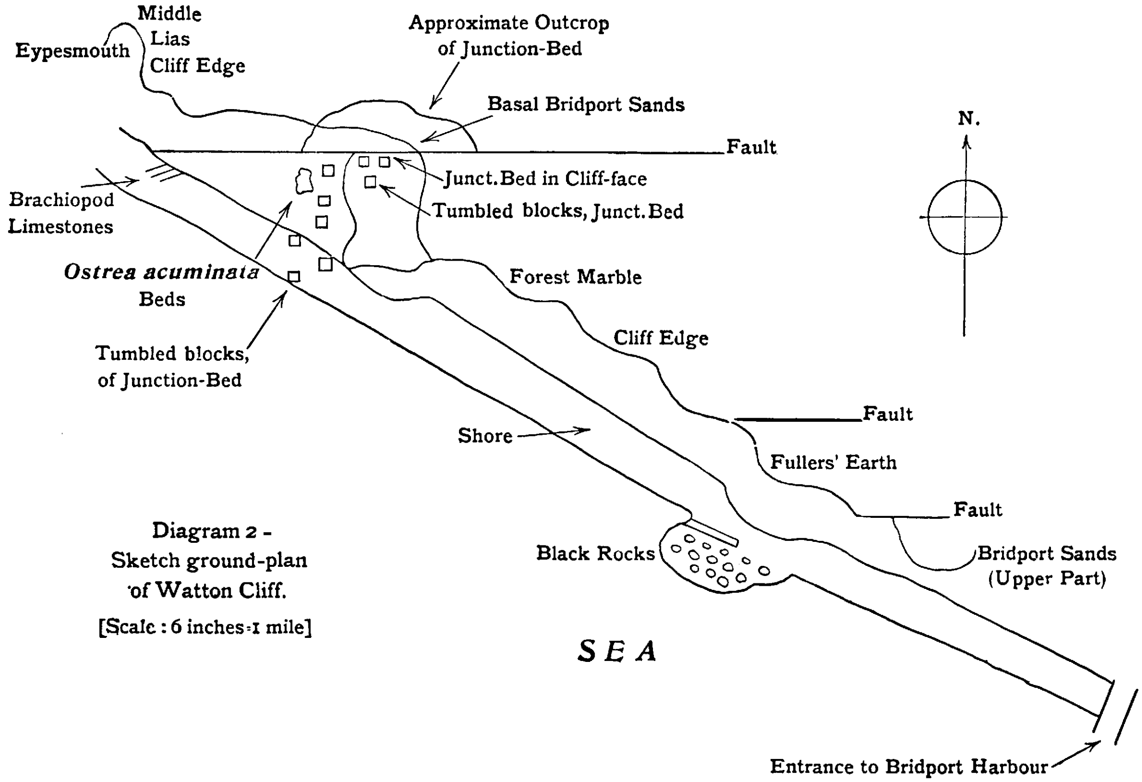


Diagram 2 -
Sketch ground-plan
of Watton Cliff.
[Scale : 6 inches = 1 mile]

The general features of the strata of this cliff will be discussed in a later paper. Now the Junction-Bed claims attention.

Diagram 3.—*Watton Cliff, near Bridport (Dorset), view of Junction-Bed (Watton Bed) in face, looking northwards.*

1.	Bluish sandy clay, with hard beds at intervals. Basal Bridport Sands or Down-Cliff Clay equivalent.	Difference in colour between Beds 1 & 3 very noticeable in the cliff-face.
2.	Junction-Bed. Hard compact block.	
3.	Yellow sands of Middle Lias, faced on a very steep batter by an irony conglomerate-bed, containing belemnites (slickensided), ammonites (*Dumortieria*, and some Whitbian species). Some 20 feet of fault-face visible.	
4.	Blue Clay. Under about a foot of clay is Day's *margaritatus*-bed—a bluish marly stone: fallen blocks may be seen under the cliff on the left.	

Diagram 4.

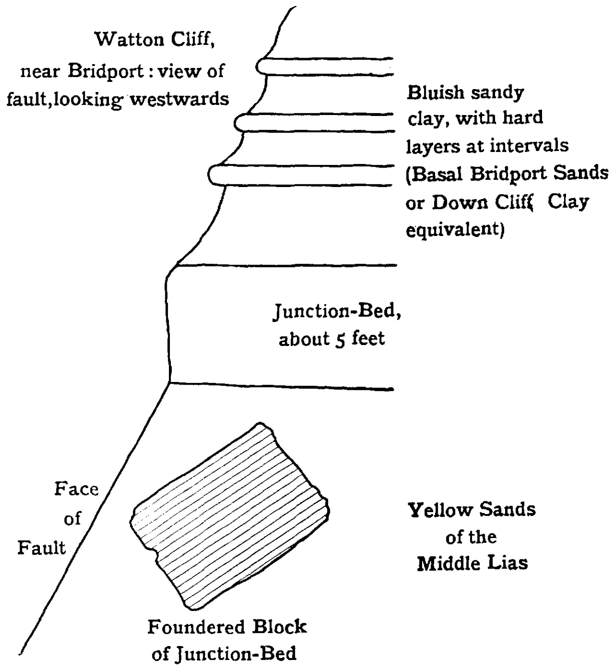
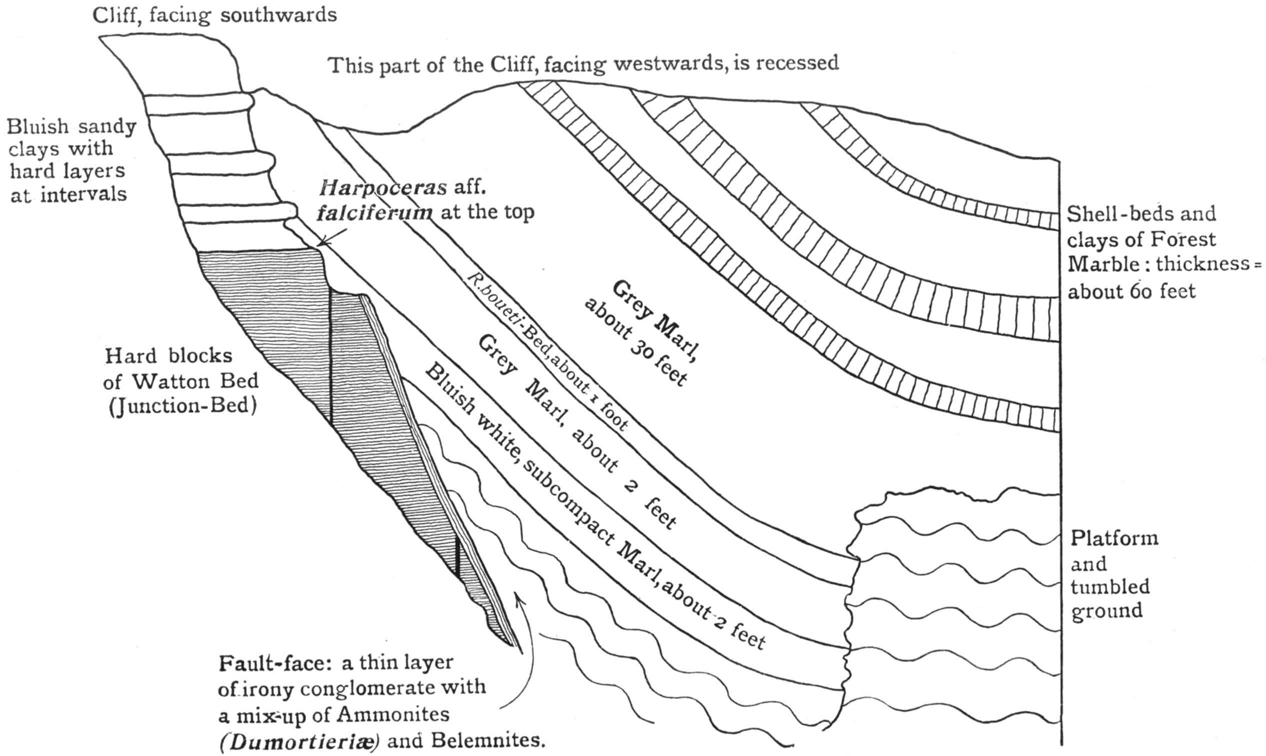


Diagram 5.—*Watton Cliff, near Bridport (Dorset) : view of fault looking eastwards.*



Diagrams 3, 4, & 5 are sketches to show the general position of the Junction-Bed. Of the face view it may be remarked that on the left, as the Junction-Bed runs out to the grassy slope of the cliff, it diminishes in thickness and seems to peter out at the surface: this is possibly due to solution by humic acid and the removal of the clayey capping, and it accounts for the bed not making any feature in the slope of the cliff. However, the bed was detected in the ploughed field immediately north of the fault-corner, a little way down the hill.

(B) The Junction-Bed of Watton Cliff, or, as it may more conveniently be called, the Watton Bed, is now described in detailed section, the result of my investigation. For the results of Mr. J. F. Jackson's examination Appendix I, p. 445, should be consulted.

Section II—WATTON CLIFF, NEAR BRIDPORT (DORSET). The Junction-Bed, generalized section with details from various fallen blocks.

		Thickness in feet	*inches.*
Layer 1.	Irony scale.[1] *Dumortieriæ* (*D.* aff. *regularis* S. Buckman, but more distant ribs, *D.* cf. *falcofila* Quenstedt sp.) and belemnites (of *tripartitus* style)......	0	1
2.	White lithographic stone, weathered at the edge to look like paper-shales. Peripheries of ammonites of the *Grammoceras-striatulum* type, but scarce. A Dactyloid (No. 3002) cf. *Ammonites crassus* Dumortier, *non* Young & Bird, 'Bassin du Rhône' vol. iv (1874) pl. xxvii, figs. 5–7, *non cæt.* Similar forms occur in the *variabilis* beds of the Cotteswolds	0	6
3.	Yellow conglomerate, whiter towards the base. Broken fragments of *Grammoceras-striatulum* type, belemnites, *Tetrarhynchia thorncombiensis.* About 2 inches from the base *Dumortieria* sp.[2], and about at the base *Hildoceras* of *bifrons* type	0	7
4.	White lithographic stone like No. 2, with a conspicuous line of *Grammoceras* of *striatulum* type in section, showing peripheries and partly weathered—mostly in the topmost 2 inches. Section of a small *Nautilus* in the rock—an unusual form with a large umbilicus, a cordate whorl-section, the periphery somewhat sharpened. *Hammatoceras* of *insigne* type: gastropods	0	4
5.	Similar to No. 4, sharply irregular at the base. At one place the bed is 9 inches thick, at another 14 inches. Many specimens of *Grammoceras thouarsense-striatulum* type, about 4 inches from the top, in a somewhat muddy yellowish seam		

[1] In one case, irony scale presumably lacking, fine yellow sands rest on layer 2. They contain small belemnites like *B. quadricanaliculatus* (Quenstedt), which are also cemented to the top of layer 2.

[2] A micromorph with rounded whorls, undeveloped as to keel, ribs coarse: like the inner whorls of *Dumortieria novata* S. Buckman, but the ribs rather more approximate.

		Thickness in feet	*inches.*
	resting on lithographic stone—some of them are in the lithographic stone. These ammonites are mostly lying horizontal, but not in all cases.[1] At the same horizon as these ammonites a reversed gastropod, *Cirrus* sp. cf. '*Turbo bertholeti?* D'Orbigny' Moore.[2] Nautilus with squared whorls.	9″ to 1′ 2″	
Layer 6.	Yellowish-brown shelly, more or less conglomeratic bed of variable thickness, running up into the bed above.[3] The variation in thickness seems to be due to a bodily transported block of the *Tetrarhynchia-thorncombiensis* Bed deposited in this layer; specimens of this species broken and whole; belemnites. This bed rests upon yellowish shales containing peculiar micromorph Hildoceratid ammonites (see p. 408)	1′ 1″ to 8″	
7.	Partly conglomerate, that is, broken up *T. thorncombiensis* Bed redeposited, and partly lithographic stone. Small Dactyloid ammonites; at the top *Rhynchonella* cf. *moorei* Davidson—a flattish form, subcircular, with coarse ribs, rectimarginate. This is the horizon yielding *T. thorncombiensis* in a fallen block on the lowest platform under the cliff, and *Thecidellæ* on the weathered top-face	0	8
8.	Lithographic stone	0	3
9.	More or less conglomeratic with a pink tinge, some yellow sand-rock	0	5
10.	Lithographic stone	0	6
	Total	5	5

Remarks on the above section.—Fallen blocks gave a thickness of about 5 feet 6 inches, and a block measured *in situ* in the cliff-face gave a similar thickness. Attached to the upper surface of some blocks there is a certain portion of sandy deposit which really belongs to the sandy marls above (see diagram 3).

The irony scale which forms the top of the Junction-Bed is very noticeable in the fault-face, where this is formed by a partly foundered block (see diagram 5, p. 386). In this scale were found fragments of *Dumortieria*, and there are slickensided belemnites. From this scale on a block in the cliff I obtained a broken and worn fragment of *Harpoceras* of *mulgravium* type, and another example came from this top irony scale of a fallen block.

Blocks of the Junction-Bed on the beach gave the following information. Towards the base of blocks, especially where polished by wave-action, the stone has a pink tinge very suggestive of the pink stone (*bifrons*) of the Western Cliffs.[4] Some matrix suggestive of *spinatum* marlstone was seen, but no fossils. A large *Harpoceras* of *mulgravium* type was obtained from the base of a block—the specimen was in fair condition, but was not lying

[1] From 'about middle of Watton Bed,' which would be this layer 5, two examples of *Stolmorhynchia bothenhamptonensis* (Walker) with a yellowish-white matrix.

[2] VII, p. 210 & pl. vi, figs. 7–8.

[3] From a loose block examples of *Stolmorhynchia bouchardi* Davidson, with a yellow matrix (presumably this bed), were obtained.

[4] I, 5, p. 64.

horizontally. A striate *Nautilus* of fair size was obtained from just below the [lower?] *striatulum* layer and a little *Zeilleria* (the so-called '*Waldheimia lycetti*') was obtained from this *striatulum* layer.

A comparison of this detailed section of the Watton Bed with that of the Junction-Bed in the cliffs west of Eypesmouth (Thorncombe Beacon, Doghus and Down Cliffs), as recorded in my previous paper,[1] will show how unlike the former is to the latter.

Thus the former is as much as 5½ feet thick, whereas the latter is about 2 feet, although it may amount to somewhat more occasionally. The former is mainly made up of a lithographic stone with *Grammoceras-striatulum* types, derived examples of *Tetrarhynchia thorncombiensis*, and derived lumps of this *Rhynchonella* Bed. The latter shows sometimes about 2 inches of the *striatulum* layer, while the *T.-thorncombiensis* Bed is, according to my measurements, some 8 feet below the Junction-Bed at Thorncombe Beacon: according to my interpretation of Day's measurements at Down Cliffs,[2] it is more than 18 feet below, about which something will be said later.

Further, the Watton Bed shows no sign of Marlstone,[3] which is, when present, a richly fossiliferous horizon in the Western Cliffs; nor did I find any strata with the *bifrons* type of ammonite—only examples redeposited along with *striatulum* forms.

In the Watton Bed there are certain peculiar Whitbian ammonites—unfortunately in fragmentary condition, mainly only body-chambers. Nothing of such forms has been noted for the Junction-Bed of the Western Cliffs; but, of course, all the ammonite fauna of that deposit has not been fully examined, for removal of this matrix is very tedious. In the Watton Bed, however, there were enough specimens to attract attention at once, and yet I imagine that they are unusual for Whitbian deposits of the South of England. About that it is inadvisable to speak too positively as yet—first, because these ammonites require study; and secondly, because the Whitbian ammonite fauna of the South of England has been very imperfectly illustrated. These ammonites have something of the appearance of certain small species from the Jet-Rock of Yorkshire—at any rate, they suggest an early date in Whitbian, about *exaratum*, or even before that.[4] The *Thecidellæ*, which are just below them, call to mind the micro-brachiopod horizon below the Fish- and Insect-Beds of the South-West of England.

These matters will require further study later, see p. 400.

[1] I, 5, p. 64. [2] III, p. 285.

[3] I, 5, p. 65. Later observations of a fallen block suggested some Marlstone matrix used up, but no fossils were found. Naturally, blocks may vary considerably in their constituents.

[4] Curiously enough, Mr. J. F. Jackson has found similar ammonites at a higher horizon in the Watton Bed; they are in a much better state of preservation, and have a white matrix.

III. The Dating of the Junction-Bed of Watton Cliff.

(A) Upper Lias Succession in other Areas.

In order to understand the evidence of the Junction-Bed of Watton Cliff, it is necessary to investigate the stratal and faunal sequences of other areas. And, as this Junction-Bed contains fauna belonging to dates which range from pre-*spinatum* to *Dumortieria*—in other words, contains fauna of Domerian, Whitbian, and Yeovilian ages—it is necessary to make a somewhat extended investigation (1) as to the sequence of the Upper Lias (Whitbian, Yeovilian); (2) as to the Middle Lias of about *spinatum* (Domerian) date in the Junction-Bed elsewhere; and (3) as to the Domerian pre-*spinatum* beds which are found in Thorncombe Beacon. First and most important, then, is the Upper Lias (Whitbian) succession, so far as the lower part of it is concerned. This is given in the following summaries.

I. Succession in Normandy (according to E. Eudes-Deslongchamps).[1]

[*bifrons-falciferum.*	Marnes moyennes. *Ammonites bifrons* [*Hildoceras* spp.] et *serpentinus* [=*Harpoceras falciferum* et aff.].
murleyi ?	Argile à poissons.
Leptæna. globulina.]	Couches à *Leptæna*: *L. moorei*, *L. liasina*, *Terebratula globulina*, *Rhynchonella pygmæa*.

II. Succession in the Early Part of the Upper Lias of Ilminster (according to Charles Moore, 1867).[2]

[*bouchardi-murleyi.*]	(6) 'Zone of *Rhynchonella bouchardii.*'	
	(5) 'The Saurian and Fish Zone.'	
'The *Leptæna* Beds.'	(4) 'Zone of *Leptæna* [*Pseudokingena*] *granulosa*, *Spirifera ilminsterensis*, and *Zellania liassica.*'	
	(3) 'Zone of *Alaria unispinosa.*' 'Zone of *Thecidium rusticum.*'	
	(2) 'Zone of *Leptæna bouchardii*, *L. moorei*' (the first abundant, the second rare).	'*Terebratula globulina. Rhynchonella pygmæa.*'
	(1) 'Zone of *Leptæna bouchardii*, *L. moorei*' (and several other *Leptænæ*), p. 170.	

For the time when it was written this is a remarkably detailed record, to our present advantage, and we may be grateful to Moore for it. But it is interesting to note that, although he gives so much detail with regard to these lower beds, he groups the sixteen beds above his Saurian zone under the one term 'The Upper Cephalopoda Beds,' making only one zone of the basal 2 inches, and leaving the rest unseparated. Yet now we have those beds separated out into some eight or nine zones. There is reason to suppose that the zone of *Rhynchonella bouchardi* was rightly separated from these by Moore, and, at any rate for recording purposes, it should be kept distinct. Moore shows that it is post-Saurian Bed—that is post-*murleyi*, if the Alderton Fish-Beds

[1] V, pp. 60 *et seqq.*
[2] VII, pp. 132, 170 *et seqq.*

are on the same horizon as his Saurian Bed, which seems likely, but is not yet definitely proved. From Moore's evidence it may be judged that the *Rhynchonella-bouchardi* Zone is pre-*falciferum*; but how much earlier? Was it pre-*exaratum*? Its absence from Yorkshire and the failure of *exaratum*-like ammonites from the South-West of England, where *Rhynchonella bouchardi* is not unusual, seem to indicate that it is not actually of *exaratum* date.

III. Succession in the Upper Lias of Stroud, Gloucestershire (according to E. Witchell).[1]

[*bifrons-falciferum.*	[*Ammonites*] *bifrons*, *A. serpentinus* [*Harpoceras falciferum* et aff.], *A. communis* [*Dactylioceras* spp.]. Fish-remains rare.
globulina.]	*Terebratula globulina* and *Rhynchonella pygmæa* in considerable numbers.

IV. Succession in the Upper Lias of Churchdown, Gloucestershire (according to F. Smithe, cited by E. Witchell).[2]

	'Crustacean' [Bed].
[*murleyi.*	'Fish-Bed.'
	'Alga-Bed.'
Leptæna.	'*Leptæna* Bed.'
globulina.]	'*Terebratula globulina*' [Bed].

V. Succession in the Upper Lias at Alderton (Dumbleton), summarized from various authorities[3] and from personal observations.

[*bifrons-falciferum.*	3.	Shales with *Hildoceras*, *Harpoceras*, *Dactylioceras*, 44 feet.
murleyi.	2.	Saurian, Fish- and Insect-Bed: Light-ochre Fissile Bed; *Ammonites murleyi*,[4] 1 foot.
globulina.]	1.	Paper-shales. '*Leptæna* Shales.' *Terebratula globulina*, *Rhynchonella pygmæa*, 15 feet.

This is the northernmost point, I think, at which the small *Terebratula* and *Rhynchonella* have been observed; but their range is wide, as it extends into Normandy. Therefore they are good for dating. It is doubtful whether *Leptæna* has been found at Alderton (Dumbleton). Moore mentioned the *Leptæna* Clays as 15 feet thick there; but he may have recognized them only by the presence of the *Terebratula* and *Rhynchonella*. H. B. Woodward's citation of *Leptæna* from these clays may have no other basis than Moore's remark. I have collected the *Terebratula* and *Rhynchonella*, but have seen no other brachiopods there, and Mr. Linsdall Richardson mentions the two former, though he does not cite *Leptæna*.[5] Witchell's evidence from Stroud is to the same effect.

[1] XIII, p. 25.
[2] XIII, p. 26.
[3] VII, p. 149; IX, p. 56; X, 1, p. 36; XIV, p. 267.
[4] The following species of 'Ammonites murleyi' have now been published. *Murleyiceras murleyi* (I, 8, ccxvi), *M. forte* (ccxlv), *M. aptum* (cccxvi).
[5] IX, 1, p. 57.

The point is that, if the various species of *Leptæna* are absent from the thick deposit of Alderton, which contains the minute *Terebratula* and *Rhynchonella*, it may be because the *Leptæna*-Beds are not really synchronous with the *globulina* beds, although in places (Ilminster and Normandy) the two may be mixed owing to paucity of sedimentation. Smithe's record at Churchdown supplies some evidence in this connexion, giving the *globulina*-bed below *Leptæna*. The data are insufficient, and further research is required. But they show that, in the case of Churchdown, records from the *Leptæna* Bed and from the *globulina* bed should be kept separate, and that while the strata of Alderton (Dumbleton) and Stroud are known to be of *globulina* date, they are not known to be of *Leptæna* date. The same may be the case with other localities whence *Leptæna* Clays have been cited.

The next piece of evidence for the separation of the *Leptæna* and *globulina* beds would be to find the former without the latter. Moore's records of his finds at Whatley come in here: he obtained three species of *Leptæna*, but makes no mention of *Terebratula globulina* nor of *Rhynchonella pygmæa*.[1] He gives a similar result for Sandford [Orcas, Somerset].

Therefore the faunal analysis works out as follows:—

	NORMANDY.	SOMERSET.			GLOUCESTERSHIRE.		
	Caen.	Ilminster.	Sandford Orcas.	Whatley.	Stroud.	Churchdown.	Alderton.
Leptæna	×	×	×	×	...	×	?
T. globulina ...	×	×	...	...	×	×	×

These records give at least sufficient reason for a theory of two deposits at two different dates. At any rate, it is necessary to keep them distinct for recording purposes, and not to credit a locality with the possession of the *Leptæna* Beds[2] merely on the evidence of the *Terebratula* and *Rhynchonella*.

Similar mistakes to this we have all made in the past—a relic of the old teaching, which consistently obstructed all increase in the number of names—of zones, of genera, or of species. That was a wrong doctrine; because it will now give much more trouble than the other course, and impairs the value of many old records. It is to be hoped that what may be called the 'analytical method' will be pursued in the future, even if it does involve the use of many names.

A consideration of these Upper Lias records suggests the following succession; but it is incomplete. There are gaps (non-

[1] VII, p. 157.

[2] The *Leptæna* Beds have a wide range—the South-West of England, Normandy, Würtemberg; also Sicily, according to the title of a paper by G. G. Gemmellaro, 'Sugli Strati con *Leptæna* nel Lias Superiore di Sicilia' Boll. Com. Geol. Ital. vol. xvii (1886) pp. 156, 341.

sequences), as is known from other areas, and where these really occur is a matter of some surmise :—

falciferum,
bouchardi,
murleyi,
granulosa,
Alaria,
Thecidella rustica,
Leptæna,
globulina,
spinatum.

(B) Additional Details concerning the Junction-Bed of Thorncombe Beacon.

One of the most remarkable features of the Junction-Bed is that it may always spring surprises in the matter of its faunal contents. This apparently arises from the fact that fragments of so many different beds have been preserved. These fragments are in many cases quite small, and in other cases it would seem that the fragments themselves were disintegrated, but that some of their contents became incorporated in other strata.

During one visit I was fortunate enough to find a small block in which were preserved various specimens of *Rhynchonella serrata* and like forms (*Prionorhynchia* spp.) in a sort of pale Marlstone-Rock matrix. This presumably is only a fragment of a once widespread bed. One may search many of the ordinary Marlstone blocks under Thorncombe without finding it. Walker found many specimens of *Rh. serrata* at the temporary exposure near Bothenhampton. Moore says that near Ilminster (Somerset) the species is found only at Moolham [1]; these Somerset and Dorset localities are, I think, the only places where the fossil is known in England, and consequently destruction of this bed must have been considerable. On the Continent a species allied to *Rh. serrata*—*Prionorhynchia quinqueplicata* (Zieten) is found in Würtemberg, indicating, perhaps, that an original spread of the bed was to that country. This species is also found in England with *Rh. serrata*.

From the same block I obtained a remarkable Terebratulid—somewhat of *Terebratula punctata* style, but anteriorly sulcate, and therefore an inverted form. Further search for other blocks to yield another example was quite unsuccessful. During my visit in 1920 I could not find a single block showing the *serrata* bed. Mr. Jackson, however, has another inverted example, though it is a different species. I hope to deal with these in a future palæontological portion of this paper.

Rhynchonellids, small, rather flat, with few coarse plicæ, were found in this bed: such forms have passed by the names *Rhynchonella egretta*, *Rh. fallax*, but the identifications are open to doubt. Also from this block I extracted examples of (or allied to)

[1] VII, p. 164.

Rhynchonella bouchardi (*Stolmorhynchia* spp.). As *Rh. bouchardi* was, according to Moore, of post Saurian-bed date, this seems to show that the *serrata* bed and the *bouchardi* bed were being destroyed together, and that some of their fossils were being mixed up. The *serrata* bed holds evidence of such a mix-up, for in this same block were *Rhynchonella* (*Homœorhynchia*) *acuta*, the large form, *Quadratirhynchia crassimedia*,[1] *Q.* aff. *sphæroidalis*,[2] and other species which properly belong to the lower bed—the brown marlstone. I have seen *Rhynchonella acuta* in the Upper Lias part of the Junction-Bed.

For successful collecting, it is important to note the distinction in matrix between the pale, rather soft *serrata* bed and the dark hard Marlstone below, as it is of little use to look in the latter for the special fossils of the former. The hard Marlstone is a fairly constant bed at the base of blocks of Junction-Bed: the *serrata* bed is rarely found, having been denuded from the Marlstone before the Upper Lias was cemented to it. The planed-off top of the Marlstone shows the denudation: it is also a guide as to which is the upper part of odd Marlstone blocks.

However, this lower Marlstone is not necessarily homogeneous, and may be compounded of beds of various dates. In my former paper I mentioned my lack of success in finding Day's *Pleurotomaria* Bed.[3] During my visit in 1920 I was successful. A Marlstone block about 1 foot thick gave the following :—

(*a*) Hard, finely ironshot, blue marlstone decomposing to a rusty brown, about 3 or 4 inches.

(*b*) Hard ironshot in the middle of the bed.

(*c*) Hard ironshot in the lower part of the bed, enclosing big blue sandstone-pebbles ; they look like fragments of the Starfish-Bed. See later, p 397.

The following is a rough sketch of the faunal contents :—

Upper 3 or 4 inches—*Pleurotomaria* spp. Specimens so crowded that, in the course of the extraction of one, others were broken. Mainly acuminate species, but one or two more depressed. See p. 400.

Just under the *Pleurotomariæ* various species of *Paltopleuroceras* and *Quadratirhynchia crassimedia* occur.

In about the middle of the block a fragment of *Ammonites* cf. *kurrianus* Oppel and various lamellibranchs were found.

In the lower part of the block, a depressed *Pleurotomaria* was seen.

In another small block—a rather soft brown matrix, quite unfamiliar—I found a single small example of another inverted Terebratulid: it is like *Terebratula bakeriæ* Davidson, which comes from the *acutum* bed (Transition-Bed) of Northamptonshire, but very rarely, only two or three specimens being known.[4]

[1] I, 6, pl. xiii, fig. 3 *a*. [2] I, 6, pl. xiii, fig. 2. [3] I, 5, p. 83.

[4] Its rarity may be due to the fact that it really comes in the bottom layer of the Transition-Bed—the *athleticum* horizon, which has been almost destroyed in Northamptonshire. The finding of a like form in the Junction-Bed supports this idea, for *Tiltoniceras* has not been found in this bed, although there are evidences of the *athleticum* fauna.

Edward Wilson found, in the Junction-Bed of the Dorset coast some 25 years ago, when in company with Mr. Tutcher, a similar species: the specimen is now in the Bristol Museum. Accompanying my example were some unfamiliar Harpoceratoid ammonites which will require further investigation. This bed possibly yielded those Dactyliocerates, of about Transition-Bed date, which have been obtained from the Dorset coast.[1]

We may now return to *Rhynchonella bouchardi*: three or four examples can sometimes be obtained from a small lump—from rock which belongs to the base of the Upper Lias: that is to say, it is to be sought for in the blocks immediately above the Marlstone, which is congruous with Moore's post-Saurian-Bed position. It also comes from the Watton Bed, from Ilminster, South Petherton, and other places. It is a form of fairly wide distribution: Thomas Davidson figures an example from Cromarty (Scotland); Eudes-Deslongchamps mentions it from Normandy. But all mention and figures of it are not to be trusted. I seem to recollect the name being applied to some figured examples which have nothing to do with Davidson's species. And I have my doubts about the Cromarty shell.

The widespread occurrence of strata with *Rhynchonella bouchardi* indicates a period of perhaps greater quiescence after their deposition than had been the case with some previous deposits. But the *bouchardi* deposit did not escape wholly, for there are some large areas without it—I think that the Cotteswolds might be cited; and in some cases where *Rh. bouchardi* is found, it has certainly been taken from its own bed and redeposited.

It is from such evidence as this—some of it particularly fragmentary—that a reconstruction of the course of events in the matter of deposition had to be made.

The Dorset coast, then, seems to supply evidence, by fossils and sometimes by fragments of strata, for the following sequence:—

(6) *Harpoceras-falciferum* Bed.
(5) *Rhynchonella-bouchardi* Bed.
(4) *Dactylioceras-athleticum* Bed.
(3) *Rhynchonella-serrata* Bed.
(2) *Pleurotomaria* Bed.
(1) *Spinatum* Bed.

(C) The Middle Lias (Domerian) of Thorncombe Beacon.

As the Junction-Bed of Watton Cliff contains Domerian strata of earlier date than those found in the bed under the Western Cliffs, it becomes necessary to give a short summary of these deposits. The information is required for several reasons, as will be seen later.

Blocks and pebbles scattered along the shore from under Thorncombe Beacon to Eypesmouth show various matrices, and contain many different fossils. In fact, some of the small pebbles

[1] I, 5, p. 83.

yield quite a rich harvest, and are well worthy of investigation. Only in certain cases have I been able to attack the beds in the cliffs, a very laborious and unsatisfactory task, and therefore my information is not so complete as it might be. But, with the help of Day's section, it may be possible to work out the main sequence—sufficiently, at any rate, for present purposes.

Table I, below, gives in the two left-hand columns a summary of Day's information, with my interpretation of his fossil names in square brackets, and in the two right-hand columns are the details which I have collected—the sequence and position in certain cases being supposititious.

TABLE I—DOMERIAN (PRE-*SPINATUM*) DEPOSITS, THORNCOMBE BEACON.

Day's Details.		S. S. Buckman's Details.	
Strata.	Fauna.	Strata.	Fauna.
Brown sands and sandstones. (Blocks of indurated sand.)	*Ammonites. spinatus* [*Amaltheus armiger ?*] *Ammonites bechei.* [*Anisoloboceras nautiliforme.*]	Thorncombe Sands with *Tetrarhynchia thorncombiensis* Bed. (The '*Rhynchonella northamptonensis*' Bed.) Compact brown marly rock with numerous Rhynchonellids, which weather out cleanly.	*Tetrarhynchia thorncombiensis* = '*Rhynchonella northamptonensis*' (auctt.) Walker in Davidson. A thin sharp-edged *Zeilleria.*
Margaritatus-Stone. (*Margaritatus*-Bed.)	*Ammonites margaritatus.* [*Amaltheus* cf. *amaltheus* and other species.] *A. fimbriatus.* [*Lytoceras fimbriatum* Wright (*non* Sowerby), Mon. Lias Amm. 1883, pls. lxxi, lxxii = *L. postfimbriatum* Prinz-Vadasz.]	*Margaritatus* Bed: Yellowish-brown, blue-centred, marly stone.	*Amaltheus* spp., and Lytoceratid, as cited in col. 2.
Grey and brown sands with nodules.	'Masses of *Rhynchonellæ* of small size.' 'In some places lumps composed chiefly of the stems and arms of *Pentacrinus johnsonii* Austin.'	Down-Cliff Sands with massive sandstone-bed. Pale yellow with blue centre. Mainly unfossiliferous, but fossils crowded in certain small portions which resist wave-action: these supply the fossiliferous pebbles. The yellow pebbles can be assigned to this bed with fair certainty; but the blue may be mistaken for Starfish-Bed or for Shell-Bed, or *vice versa*.	Numerous small *Rhynchonellæ* of cuboidal form, with sharp-cut ribs. Some small Amaltheids in the yellow stone. Many small Amaltheids in blue pebbles. Pebbles with numerous fragments of crinoids in a blue sandstone perhaps belong here.

Day's Details. Strata.	Fauna.	S. S. Buckman's Details. Strata.	Fauna.
The Starfish-Bed.	*Ophioderma.*	Blue somewhat marly sandstone.	*Ophioderma.*
The Shell-Bed immediately underlies the Starfish-Bed.	Rich in Conchifera. *Ammonites margaritatus.* [*Amaltheus* spp.] *A. thouarsensis.* [*Seguenziceras* cf. *algovianum.*]		
Mudstone, with nodular concretions and shells.		The black nodule-bed. (Bluish marly stone, with black nodules.) Light-blue clay.	Amaltheids.
Marls, with a layer of small nodules.	Ammonites of several species.	Dark blue conchoidal clay, with two lines of small nodules near the top.	Fragmentary Amaltheids in the nodules. Body-chambers of *Amaltheus* aff. *clevelandicus, Ammonites* cf. *boscensis* and like forms in the clay in line with the nodules (*Tragophylloceras* aff. *loscombei* J. Sowerby sp. [derived?]).
The Three Tiers.	*A. margaritatus.* *A. loscombii.* *A. fimbriatus.*	The Three Tiers form 'The Ledges,' which show on the foreshore under the eastern end of Thorncombe Beacon at low tide. (Hard blue sandstone.)	

Most of the hard beds mentioned in Table I are separated by thick masses of unfossiliferous or poorly fossiliferous sands or clays (see Day). From the Junction-Bed to his 'blocks of indurated sand,' which I take to be the *T.-thorncombiensis* Bed, Day makes 18 feet at Down Cliffs and from the Junction-Bed to the Marlstone-Bed 92½ feet; whereas my measurements at Thorncombe Beacon give 8 and 68 feet respectively. More will be said about this difference presently, for it is a rather interesting point.

In certain pebbles of blue sandy matrix I found small Amaltheids, which are very similar, if not identical, with *Amaltheus lævis* (Quenstedt), and their matrix certainly recalls that of the Scalpa Sandstone. In my first paper on Jurassic Chronology I proposed a zone of *Amaltheus lævis*,[1] placing it directly beneath that of *Paltopleuroceras spinatum*. Recent researches have tended to confirm the value of the zone, but have raised considerable doubt as to its position. According to the Thorncombe evidence the first zone below that of *P. spinatum* is that of the so-called *Rhynchonella northamptonensis* (*Tetrarhynchia thorncombiensis*) and the next is that of the *margaritatus* bed with large examples of *Amaltheus.* The specimens supposed to be *A. lævis* may come from the

[1] I, 7, p. 262.

massive sandstone-beds of the Down-Cliff Sands at the latest, but may come from the Starfish-Bed or the Shell-Bed. No sign of the rest of the fauna which was found in the Scalpa Sandstone in the same matrix as that of *Amaltheus lævis* was seen at Thorncombe.

If *A. lævis* comes from the Starfish-Bed and *Seguenziceras* from the immediately subjacent Shell-Bed, while there seems to be some 200 feet between *A. lævis* and *Seguenziceras* at Raasay in the Scalpa Sandstone,[1] a very interesting position would be reached, but one quite analogous to what is found in other cases. Some 200 feet would have to be added where now is little or no deposit. The already thick strata of the Domerian on the Dorset coast would still lack representatives of a time-interval equal to some 200 feet of deposit. The length of time required for the deposition of the Domerian is thus likely to increase to a large figure: it is already considerable.

These points cannot be pursued now, but they show where further work is required. It is obvious that the complication of the Domerian succession will be much greater than has been expected, and that the dating of the Scalpa Sandstone may have to be considerably modified. But that will not be at all a simple matter: it will immediately raise many other questions, among them perhaps that of local denudation of the Scalpa Sandstone—and that presents difficulties.

The Domerian succession disclosed by Thorncombe may be stated as follows:—

(7) *Paltopleuroceras spinatum.*
(6) '*Tetrarhynchia thorncombiensis.*'
(5) Lytoceratid (the *margaritatus* bed).
(4) Cuboidal Rhynchonellids.
(3) Starfish-Bed (=? *Amaltheus lævis*).
(2) *Seguenziceras.*
(1) *Amaltheus clevelandicus.*

This sequence is, in all probability, incomplete for the Domerian strata of Thorncombe Beacon—because, for one thing, it has not yet been possible to extract from their matrix all the specimens collected,—and it is certainly incomplete so far as the full Domerian sequence is concerned. Faunal elements of the Hebrides and Yorkshire are missing, and will have to be accounted for; but, more important still, faunal elements of the Ilminster district and of Normandy—that is, faunal elements immediately north and south of Dorset—are lacking.

Some interesting examples of this are the following:—*Aulacothyris resupinata* and *A. moorei* occur at Ilminster and in Normandy. The absence from the Dorset-coast sections of *Terebratula* [*Aulacothyris*] *resupinata* (including *T.* [*A.*] *moorei* presumably) is particularly noted by Day.[2] Walker mentions this, and says nothing to the contrary.[3] My experience is the

[1] I, 7, p. 261. [2] III, p. 293. [3] XII, p. 442.

same. Yet Walker found eight specimens of the first and one of the second at Bothenhampton. Now, it is fairly certain that these forms occupy a rather low position in the *spinatum* zone—may even indicate a deposit which is actually of pre-*spinatum* date. If so, the explanation of the geographical record is easy—this earlier bed, or some of its contents, is preserved at Bothenhampton; and the bed is certainly present at other places, but it and its contents have been lost from the coast-sections.

On the other hand, Walker notices particularly that not a fragment of *Rhynchonella acuta* rewarded his work at Bothenhampton. Considering that it is a not uncommon fossil at the coast-sections in certain cases, and that it is a usual fossil of Marlstone localities, this is rather remarkable—more especially as what seem to be its customary associates were found by Walker. Here further analyses may be particularly interesting, with this additional reason—that there are two forms of *Rh. acuta*—a small form, to which the name was originally applied, and a large form. There is reason to think that the small form is not actually the young (the brephomorph) of the large form, but that it is earlier in date—is an earlier stage (an anamorph) of the large form. If so, small forms and large could be used as chronological indices, the small form possibly marking a fairly early Marlstone (*spinatum*) date; while the large form certainly marks a particularly late date, although it must be earlier than *Rh. serrata*, for it occurs where the *serrata* deposit has been lost. Is it to be assumed that there was no record of either of these two dates at Bothenhampton?

It is, I think, correct to say that the small form ranges from the Dorset coast to the Hebrides; but, before such a statement could be made positively, a critical study would be necessary: for there must be a true brephomorph of the large form, and this must be so similar to the presumed adult small form that they would only be distinguishable by what would be regarded as very trivial features. This shows why it is so necessary in palæontology to be precise in noting and naming quite small details, if the full value from the different forms is to be obtained, so as rightly to apprehend what they indicate regarding the history of deposition and denudation. If small biological details be passed over without notice, much of considerable chronological value may be lost.

It follows, then, that if the idea be correct that the two differently-sized forms of *Rhynchonella acuta* indicate different dates, the finding of the large form may be taken as fair evidence for the later date; but the finding of the small form is not necessarily good evidence for the earlier date—not unless we work out precisely whether the small form is a brephomorph or an anamorph, a labour only to be accomplished when the respective distinguishing characters have been properly ascertained. Proof that the anamorph and the large form lived at different dates should be found by faunal analysis, as well as by direct observation. The former should reveal areas where the anamorph existed by itself without any trace of the large form;

while the latter would find small forms occupying strata at a lower horizon than the large forms. This shows how much scope there is for further work.

Mr. J. W. Tutcher has kindly supplied the following identifications of gastropods and scaphopods which I have been able to give him, as the result of chance collecting during various years at and near Thorncombe Beacon. Some of the labels require a little interpretation, because in earlier years I was necessarily less conversant with the details of the sequence or the matrices of odd blocks:—

'Junction-Bed, *bifrons* layer.'
Discohelix dunkeri Moore.
'Junction-Bed.'
Trochus nodulatus Moore.
'*Rhynchonella-serrata* Bed.'
Trochus lineatus Moore.
'*Pleurotomaria* Bed.' [See p. 394.]
Pleurotomaria mirabilis Deslongchamps.
Pleurotomaria cf. *subnodosa* Goldfuss = possibly the form recorded by Day as *P. precatoria* Deslongchamps.
'Marlstone' [= *spinatum* ?].
Amberleya cf. *gaudryana* A. d'Orbigny.
'*Spinatum*.'
Trochus cf. *flexicostatus* Moore.
'Lower part of Marlstone' [see p. 394].
Pleurotomaria mirabilis Deslongchamps.
'*Margaritatus* zone' [= possibly the *T.-thorncombiensis* Bed].
Cryptænia cf. *solarioides* (J. Sowerby).
'*Margaritatus*' [possibly *margaritatus* bed].
Cerithium liassicum Moore.
Ataphrus cinctus Moore.
'Massive Sandstone-Bed.'
Turbo aciculus (Stoliczka).
Dentalium elongatum Moore.
'With *Amaltheus* cf. *lævis*, pebble on beach, near Eypesmouth.'
Dentalium elongatum Moore.
'Pebble on beach, Eypesmouth, below *margaritatus* [bed], possibly Starfish-Bed.'
Actæonina ilminsterensis Moore.

(D) Analyses of the Junction-Beds, and Theories as to the Watton Bed.

From the faunal sequences arrived at in the foregoing studies, and from the results which have been already obtained and published elsewhere,[1] it is possible to present a detailed list of successive hemeræ, noting at the same time which of these hemeræ are represented by the fauna of the Junction-Bed at various places. But, as a preliminary, it is advisable to present an epitome of Walker's section at Bothenhampton.

About 2 miles somewhat east by north of Watton Cliff was the site of an exposure of the Junction-Bed at Shipton Long Lane,

[1] I, 7, p. 276.

Bothenhampton, described by J. F. Walker in 1892.[1] The following may be constructed from his description :—

Section III—SHIPTON LONG LANE, BOTHENHAMPTON (J. F. Walker).

			Thickness in feet.
	1.	'White stone. *Ammonites germani* [*germaini*] (D'Orbigny)'	1
[*striatulum.*]	2.	'Brown stone. *Ammonites (Grammoceras) thouarsensis* (D'Orbigny), *Rhynchonella jurensis* var. *bothenhamptonensis*'	1
[*bifrons.*] *falciferum.* *bouchardi.*	3.	'Brown conglomerate, often with pink stone at the base. *Ammonites (Hildoceras) bifrons*, worn specimens of *Harpoceras falciferum*, *Rhynchonella bouchardi*'	2
Harpoceratoid (*serrata*). [*spinatum*].	4.	'Marlstone. *Rh. serrata*' in the upper 3 inches. '*Rh. tetrahedra*' and many other brachiopods in the lower part	1

The possible faunal sequence ascertained by the foregoing studies may now be given and results compared.[2]

TABLE II—FAUNAL CONTENTS OF THE JUNCTION-BED.

	Hemeræ.	Localities. Western Cliffs, Thorncombe, etc.	Bothenhampton.	Watton.
YEOVILIAN.	*moorei*			
	Catulloceras			
	Dumortieria	...	...	×
	Hammatoceras	...	?[3]	×
	dispansum			
	struckmanni			
	pedicum			
	eseri			
	striatulum	×	×	×
WHITBIAN.	*variabilis*			
	lilli	?		
	braunianum			
	fibulatum			
	bifrons	×	×	×
	subcarinata	...	...	×[4]
	pseudovatum			
	falciferum	×	×	×
	bouchardi	×	×	×
	exaratum	...	...	?[5]
	murleyi			
	tenuicostatum			
	Leptæna	...	...	?[6]
	globulina			
	acutum			
	athleticum	×		
	Harpoceratoid (*serrata* bed)	×	×	
DOMERIAN.	*Pleurotomaria*	×		
	spinatum	×	×	
	T. thorncombiensis	...	...	×

[1] XII, p. 441.

[2] See also the hemeral table given in Appendix II.

[3] *Ammonites germaini.*

[4] Mr. Jackson's discovery.

[5] Small Hildoceratid ammonites.

[6] *Thecidellæ.*

Diagram 6.—*Lithology of the Junction-Bed (vertical scale : 1 inch = 2 feet).*

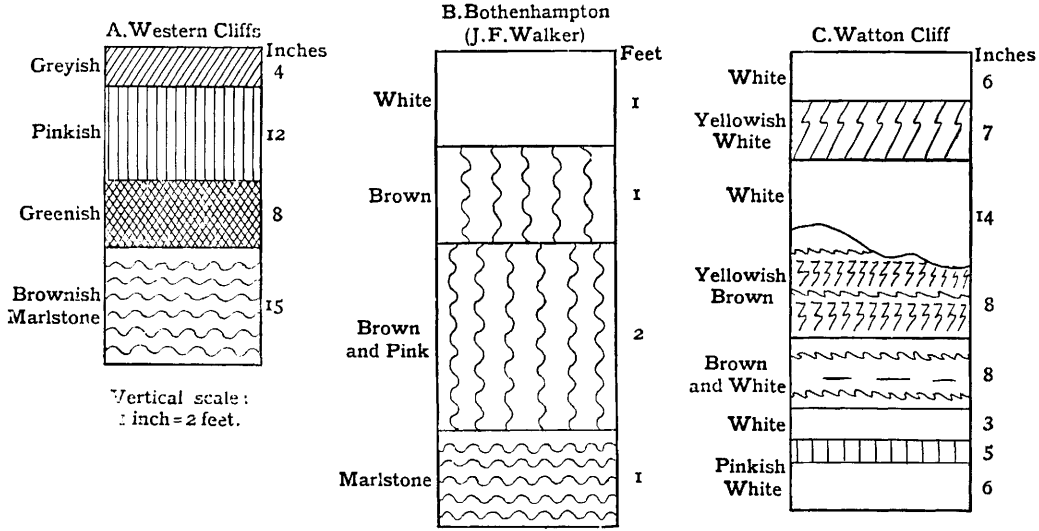


Table II records the faunal contents of the Junction-Bed at three places—I have drawn upon Mr. Jackson's evidence for one date (*subcarinatum*) in regard to Watton Cliff,—and it shows that, while there is substantial agreement between sections of the Western Cliffs and of Bothenhampton, yet that Watton Cliff differs considerably from both. This divergence is more noticeable than a mere list of fossil contents would indicate; for the points that are most strikingly in contrast between Watton Cliff and the other sections are, so far as Watton Cliff is concerned,

(1) The continuity through most of the Watton Bed of white-stone deposits.
(2) The considerable thickness of strata in which forms of *Grammoceras-striatulum* type are found.
(3) The presence of the *Thecidellæ* and unfamiliar Hildoceratids.
(4) The absence of the Marlstone-Rock bed—*serrata* and associated beds.
(5) The presence of the *Tetrarhynchia-thorncombiensis* Bed and many derived examples of that fossil.

These points are illustrated in Table II and diagrams 6 & 7.

The section at Bothenhampton is near a line of fault, parallel to and north of the Watton Cliff (Eype) Fault, heading in the direction of Thorncombe Beacon. The Junction-Bed of Bothenhampton reproduces the Thorncombe type, and shows Marlstone at the base. The Junction-Bed of Watton Cliff is closer to the axis of the Weymouth Anticline, and shows not only denudation and destruction of the Marlstone, but denudation carried down many feet lower—to below the *Tetrarhynchia-thorncombiensis* Bed (diagram 6, p. 402).

Now, Day's measurements (see above, p. 397) were made at Down Cliffs,[1] and by the increase in thickness it can be estimated that his exposure was some 4250 feet—approximately 6 furlongs—to the west of mine; it would, owing to the trend of the coast, take him some distance farther away from the axis of the Weymouth Anticline, and this would account for the greater thickness which he obtains between the Junction-Bed and the *margaritatus* bed. The following sections (diagram 8, p. 404) are placed in order from west to east, which direction, though not at true right angles to the anticlinal axis, is sufficient to illustrate the effect of it.

Thus in the Down-Cliffs section, as there are some 92 feet between the Junction-Bed and the *margaritatus* bed, in the middle section about 68 feet, and at Watton Cliff about 40 feet, the *Tetrarhynchia-thorncombiensis* Bed must have disappeared in the post-Marlstone denudation immediately east of Thorncombe Beacon, and the denudation has, at Watton Cliff, been carried down into the pre-*Tetrarhynchia-thorncombiensis*-Bed Sands (diagrams 8 & 9, pp. 404, 405).

The Marlstone Rock is only preserved at Thorncombe Beacon—

[1] There is reason to think that he took details, if not measurements, from Doghus as well as from Down Cliffs—the latter name originally covered both.

Diagram 7.—*Faunal comparison.*
(Vertical scale : 1 inch=2 feet.)

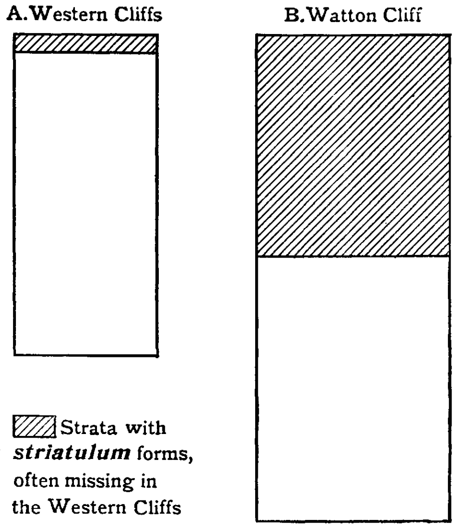


Diagram 8.—*Comparative sections at Thorncombe Beacon and Watton Cliff, on the scale of 30 feet to the inch.*

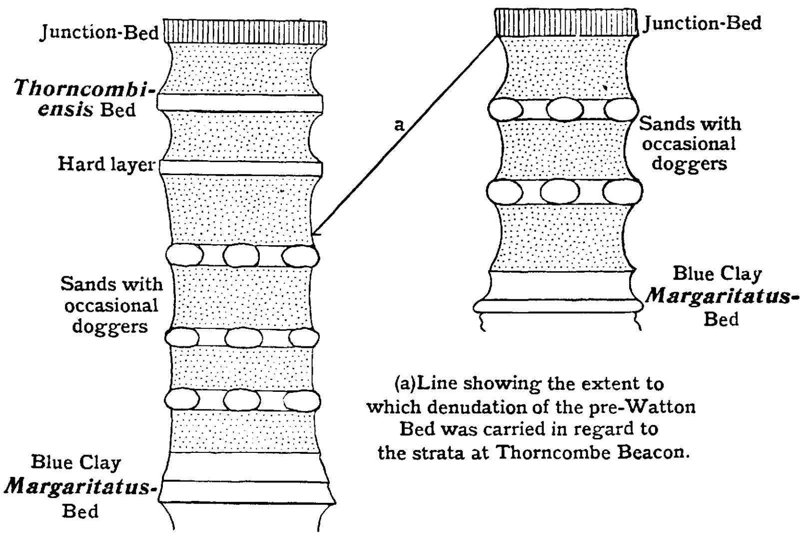
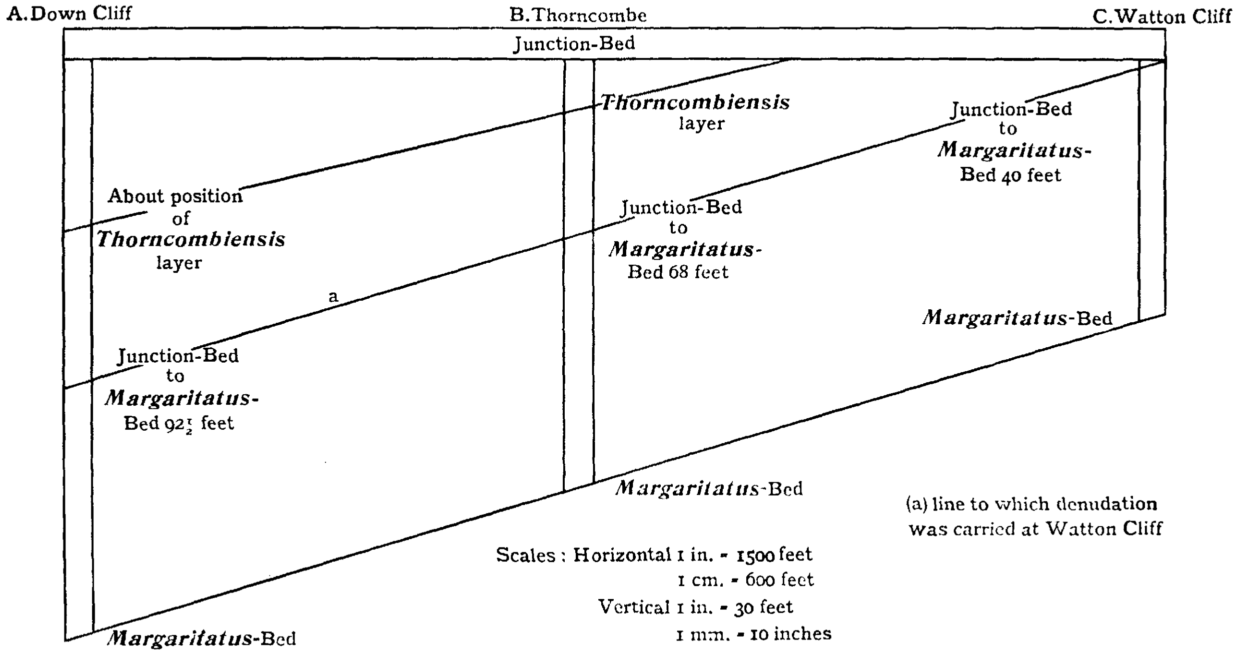


Diagram 9.—*Late Domerian denudation (or denudations), showing the effect of the Weymouth Anticline.*



not at Down Cliffs nor at Watton Cliff; this implies slight synclination of the Thorncombe area at the time of post-Marlstone denudation, just sufficient to preserve the thin bed. But there was a pre-Marlstone denudation—the presence of big blue sandstone-pebbles in the marlstone of the Junction-Bed of Thorncombe Beacon is evidence for that. The matrix of these pebbles suggests that they come from the Starfish-Bed; they certainly did not come from the *margaritatus* bed. Taking the data of denudation ascertained in the above sections—that is, about 30 feet to a mile,—then the Starfish-Bed was elevated to the line of erosion some 5½ miles from Thorncombe Beacon. The main axis of the Weymouth Anticline runs out to sea some 7 miles south of Thorncombe Beacon. Another mile and a half would involve a further 45 feet, which would be insufficient to bring the Three Tiers—the next hard bed—to the surface along the axis.

The fact that the *margaritatus* bed is not found in pebbly condition, while the *Tetrarhynchia-thorncombiensis* Bed is found as pebbles in Watton Cliff (and probably it is the Starfish-Bed that furnished the pebbles for the Junction-Bed of Thorncombe Beacon), may suggest that movements of post-*margaritatus*-bed time allowed that bed to be covered up and protected by *thorncombiensis* or pre-*thorncombiensis*-bed deposits.

It will thus be seen that the Watton Bed is a deposit of exceptional interest geologically: it would also be rich palæontologically, if one had the means of breaking up the massive blocks. That it is different from the Thorncombe Beacon Junction-Bed, only about 7 furlongs away to the west, is due to the fact that it really belongs to a different piece of territory—to what was some half-mile nearer the anticlinal axis. This little transverse difference is more important than a considerable lateral distance, as is shown by the similarity of the Down Cliffs (Thorncombe) and Bothenhampton Junction-Beds, which are from 2½ to 3 miles apart, but along the same line of fold.

The movements of the Weymouth Anticline and the distribution of strata which they produced in the English Channel suggest an interesting line of enquiry—as to the present-day distribution of strata out to sea. Some 20 years ago I collected certain data on the subject; but there has not yet been any opportunity of working out details, and the enquiry must be deferred for the present. However, such an enquiry should have a certain practical bearing. The distribution of areas of hard rocks—that is, areas of sandstone or limestone—is important to fishermen, as affording good ground for the setting of their lobster-pots. A geological investigation should indicate likely places to sound for such areas, and might lead to the discovery of some which are not yet known to the fishermen: they had, at the time I speak of, just made a chance discovery of a new ground.

To return to the Junction-Bed—it is evident from the various sections that the Weymouth Anticline was in a state of constant movement with consequent denudation making non-sequences.

Yet the non-sequences are not always synchronous in the different sections.

The main feature of the Watton Bed is the amount of deposit containing forms of *Grammoceras-striatulum* type, which, however, there is reason to suppose, are redeposited specimens. Yet the main mass of the Watton Bed is a hardened paper-shale—thin laminæ of very fine mud,—indicating a slowly-accumulating tranquil deposit. These statements appear to conflict: so does the statement about tranquillity with the observation that some ammonites are found more or less on edge, and that fairly large blocks of *Tetrarhynchia-thorncombiensis* Bed have been redeposited in the Watton Bed.

The reason for supposing that the forms of *striatulum* type are redeposited are the following:—At Bothenhampton J. F. Walker found *striatulum* forms in a brown bed, and a species of later date (*Ammonites germaini*) in white stone. The *striatulum* forms of the Watton Bed show evidence of a yellowish-brown matrix, although they are found in a very white lithographic stone. Associated with the *striatulum* forms are species of *Hammatoceras*—one form of the *H. insigne* type found in the rock itself and another (a rare and peculiar form somewhat removed from *insigne*, but certainly a *Hammatoceras*) was found on the lower platform loose: the matrix of the Watton Bed, however, is unmistakable. Now, *Hammatoceras* is of considerably later date than the *striatulum* forms, as may be seen from the synopsis on p. 401 (Table II). It is presumably of about the same date as the *Ammonites germaini* quoted by Walker, but is of pre-*Dumortieria* age. Therefore, the evidence appears to show that the forms of *striatulum* type which are found in Bed 4 are redeposited in strata of *Hammatoceras* date.

In the layer above, No. 3, is found evidence of a still later horizon, *Dumortieria*. The specimen belongs to a species with coarse, rather distant ribs, and is closely allied to *Dumortieria novata* S. Buckman (p. 387). But in this layer there is very plain evidence of redeposition apart from the *striatulum* forms: there is *Hildoceras* of *bifrons* type, which is a species some five hemeræ earlier than *striatulum* forms and some eleven hemeræ earlier than *Dumortieria*; and there are specimens of *Tetrarhynchia thorncombiensis*, which is some twenty hemeræ earlier than *striatulum* and some twenty-six earlier than *Dumortieria*.

It is evident, then, that the fossils which the Watton Bed yields are not to be trusted as evidence of the date of its deposition. And there is further evidence on this head in the finding of *Harpoceras* aff. *falciferum* (*mulgravium*) in the top of the bed (p. 388). Therefore, it is only possible to date the bed by the latest fossils which it contains.

What is, however, of considerable interest is the faunal inversion:—

Harpoceras at the top of the bed.
Hildoceras aff. *bifrons* in layer 3.
Grammoceras of *striatulum* type in layers 4 & 5.

This is an exact reversal of their true sequence. The possibility of such inversion had been already surmised from consideration of other cases.[1]

The important point is, however, that the evidence of ammonites is not to be trusted too implicitly in certain cases: it shows that special care has to be taken in reading records. That there was such an inversion might be explained on the supposition that, as the latest bed (that of *striatulum* date) was destroyed, its removal exposed an earlier bed (*bifrons*) which, in turn being removed, gave opportunity for the denudation of *falciferum*. But this is only a part of the history: it is fairly evident that strata of these dates and of others were all exposed to denudation at the same time. Thus *falciferum* contributed to the fauna of the lower part of one fallen block; *bifrons* (so far as the evidence of pink matrix goes) was laid under contribution for layer 9; *thorncombiensis* provided materials for layer 3, and for various earlier layers. While the middle and upper part of the bed was being laid down, however, a stratum which yielded *striatulum* forms was being considerably raided to provide materials, though it was not the only bed from which they were obtained.

The latest date for the deposition of the Watton Bed is determined by the date of the superimposed areno-argillaceous stratum (No. 13)[2]: the Watton Bed was laid down before that date. This sandy stratum is, from its position, presumably a less argillaceous representative of the Down-Cliff Clay which caps the Junction-Bed in the cliffs west of Eypesmouth; or it may be the equivalent of the basal part of the Bridport Sands, which in Burton Cliff assume a bluish colour in their lower part. But, again, these basal Bridport Sands may be really a less argillaceous condition of Down-Cliff Clay.

The Down-Cliff Clay has yielded *Dumortieria*,[3] the irony scale at the base of the Watton-Cliff sandy stratum has also yielded *Dumortieria*, the basal Bridport Sands at Burton have given no evidence. The Watton Bed is, therefore, earlier than the *Dumortieria* hemera, in the main. But an early form of *Dumortieria* occurs in the Watton Bed, layer 3; the irony scale which caps that bed and the complete lithic change between the Watton Bed and the sandy stratum point to a non-sequence of greater or less duration. It is to be concluded that the *Dumortieria* hemera contains really more episodes than our present time-scale allows for: first, an episode of early *Dumortieria*, during which calcareous conditions of lithographic-stone deposition obtained—a tranquil deposition of fine sediment resembling paper-shales; secondly, an episode of possible denudation while a lithic change was accomplished; thirdly, the episode of argillaceous or areno-argillaceous conditions of the Down-Cliff Clay and its equivalents, passing higher up into

[1] I, 9, p. 74, footnote 1.
[2] Section I, p. 382.
[3] I, 2, p. 519; I, 5, p. 64.

the completely arenaceous conditions of the middle part of the Bridport Sands. In this third episode *Dumortieria* ranges up some 60 feet in the Down-Cliff Clay,[1] and it may range as far again into the Bridport Sands before *Catulloceras* appears, while there is about 170 feet before evidence of *moorei* is obtained.[2]

The other supposition is that the upper part of the Watton Bed was deposited contemporaneously with the Down-Cliff Clay. This is possible, but it follows that a curiously limited horizontal extension of the lithographic-stone deposit in a westerly direction would have to be allowed, and, moreover, would have to be accounted for; because north-eastwards, so far as the Bothenhampton evidence goes, there is reason to suppose considerable horizontal range of lithographic-stone conditions.

On this theory the non-sequence between the Watton Bed and the sandy stratum might correspond to the time of deposition of the upper part of the Down-Cliff Clay.

So far, then, as our present time-scale allows, the three upper layers of the Watton Bed were deposited in the earliest part of the *Dumortieria* hemera. The layer below, which contains *Hammatoceras*, could be dated as *Hammatoceras* hemera, which precedes *Dumortieria*. The layer below (No. 5), which contains *striatulum* forms, can be dated as certainly later than *striatulum* hemera; but whether it can be dated as contemporaneous is a question for consideration later.

In this layer I obtained a reversed gastropod (*Cirrus*), thinking it to be a new record; but Moore has already figured and described[3] a similar form as *Turbo bertholeti* from the 'Upper Lias at Compton [near Sherborne, Dorset] . . . from the highest bed of that place in association with *Ammonites walcottii*.' There is reason to suppose at Compton and the neighbourhood a close association of *Grammoceras-striatulum* forms with *A. walcottii* [cf. *bifrons*], owing to paucity of sediment, erosion, or both; therefore the evidence is not necessarily against this gastropod being a contemporary of *striatulum* forms.[4]

The peculiar Hildoceratid ammonites of layer 6 have some resemblance to species which occur in the Jet-Rock of the Yorkshire Upper Lias (*exaratum* hemera), as, for instance, *Ammonites rugatulus* and *A. multifoliatus* Simpson; there is also likeness to *A. similis* Simpson, but this is perhaps from the *falciferum* horizon. The species of *Elegantuliceras*, *E. elegantulum* and *E. ovatulum* (Simpson), 'Yorkshire Type-Ammonites' ii, pls. xciii & cvi, may also be cited as similar, but they are thicker: they are from Jet-Rock, *exaratum* hemera.

[1] I, 5, p. 64. [2] I, 5, p. 64.

[3] VII, p. 210 & pl. vi, figs. 7–8.

[4] There is little doubt that, at Compton, Moore worked a higher (later) deposit of Upper Lias than at Ilminster. Analysis of his finds should show this. The forms common to Ilminster and Compton would presumably be from the lower bed; those peculiar to Compton might be expected to indicate the higher bed.

It is rather tempting to assign to the rock that date, because it would bring the *Thecidellæ* of the top of layer 7 into line with Moore's zone of *Thecidium rusticum* (p. 390). But there seem to be difficulties in this course:—(1) there is lithographic stone in layers 8 & 10 below; (2) there is pink rock suggestive of *bifrons* date in layer 9; and (3) the possibility that the *Harpoceras* aff. *mulgravium* found in a fallen block (p. 388) came from about the horizon of layer 8 or even below it.

The ammonites of layer 6 may have been derived, especially as Mr. Jackson has found similar peculiar Hildoceratid ammonites in far better condition nearly in the top of the bed (corresponding to layer 3, or possibly 4). His specimens are in quite unworn condition, showing no signs of derivation, yet it seems quite impossible to imagine that they were contemporaries of *Hammatoceras*—that is contrary to all our experience: there is admittedly a difficulty here. As to *Thecidellæ*, they can only have been derived if the whole slab to which they are attached had been derived. This is possible; but it is also possible that the *Thecidellæ* are a different species and of a different date from *Thecidella rustica*: they are too much weathered to make any determination of species satisfactory. And, even if such were made, our knowledge of the range of *Thecidellæ* is admittedly very incomplete: possibly several Whitbian horizons yield *Thecidellæ*, but there has been, since Moore's time, too little systematic search for them. The washing process, by which alone they can be obtained in satisfactory condition, is particularly tedious; and there are cases, as their occurrence in this calcareous Watton Bed shows, where it could be applied only with much difficulty.

If it be supposed that the peculiar Hildoceratids are *in situ* in the lower part, or not much removed from their original position, that they were at least deposited originally in a lithographic-stone matrix, then we are confronted with a difficult position, and the following theories may be put forward to account for the facts. A recapitulation of the facts may be helpful: they are:—

(1) A laminated lithographic-stone bed about $5\frac{1}{2}$ feet thick shows in the face of Watton Cliff, separating Yeovilian from Domerian sandy deposits.

(2) It is in the same position as the Junction-Bed of Down-Thorncombe Cliffs; but it is quite different in lithic character, and disagrees greatly in its fauna.

(3) The white-stone matrix runs through the bed, but there are other matrices mixed up with it.

(4) *Striatulum* forms occur in a yellowish matrix, but are redeposited in lithographic stone; they are associated with *Hammatoceras* and *Dumortieria*.

(5) There is faunal inversion.

(6) Certain small species of Hildoceratids of pre-*falciferum* aspect are found at two levels, towards the base and towards the top; those at the top are in the best condition and in a white-stone matrix.

(7) A white-stone matrix is not found in the Junction-Bed of the western cliffs; but it occurs at Bothenhampton and is post-*striatulum* in date.

These are the facts which have to be accounted for, and the following theories may be put forward:—

(1) The lithographic or white-stone matrix began to be deposited in pre-*falciferum* time, and its deposition continued until the time of early *Dumortieria*, although there were various breaks in the record due to penecontemporaneous erosions.

(2) The whole of the Watton Bed was laid down at about one date, *Hammatoceras* (that is, the base of the Watton Bed corresponds in date with the upper part of Walker's Bothenhampton section—it is post-*striatulum* wholly): therefore, it is altogether later in date than any part of the Junction-Bed of the Western Cliffs, and than all but the last layer of the Bothenhampton section. So far as agreement in lithic character is concerned, this would appear to be correct. So far as faunal contents are concerned, nothing that has been found lower than layer 4 is in favour of it.

(3) The Watton Bed consists of two similar deposits of rather widely different dates; there was a deposit of, say, pre-*falciferum* date which had the characters of white lithographic stone, and made up the lowest part of the bed, then there was a break, possibly with denudation, while *falciferum* and post-*falciferum* deposits were being laid down in surrounding areas, as for instance in that of Thorncombe; then followed a time of deposition at Watton Cliff, for which materials were obtained from *falciferum* and later deposits, from the pre-*falciferum* white-bed deposit, and even from the *thorncombiensis* rock. Afterwards came another period of definite lithographic-stone deposition beginning in *Hammatoceras* hemera (laid down not only at Watton Cliff, but at Bothenhampton), and continuing to the earliest part of the *Dumortieria* hemera. In other words, two deposits of similar character, but of widely different dates, have coalesced.

Let us consider these theories: the first theory carries various difficulties. That a homogeneous deposit existed for many hemeræ, and at the same time shows various non-sequences, is not a difficulty; for such a deposit, lasting through more than thirty hemeræ with various non-sequences, is illustrated in my last paper.[1] But the difficulty is to suppose that during all the long time of about eighteen hemeræ which the fauna of the Watton Bed would require for its deposition (that is, from pre-*falciferum* to early *Dumortieria*), the white-stone conditions had so remarkably restricted a geographical range—not extending to the cliffs west of Eypesmouth, about 7 furlongs westwards, where different conditions of deposit obtained, nor to Bothenhampton, about 2 miles away to the north-east, until the time of *Hammatoceras* hemera, when white-stone conditions did come in at that locality.

Next there is evidence that white-stone conditions were not really continuous. Some small Dactyloids are in a brownish

[1] I, 9, p. 100.

matrix, and the *Grammoceras-striatulum* forms are in a yellowish deposit.

The second theory requires that *Hammatoceras* or some contemporary should be found low in the Watton-Cliff Junction-Bed. This theory does not account for the white matrix of the presumed pre-*falciferum* Hildoceratids, found by Mr. Jackson towards the top of the bed. And it involves the following corollaries: (*a*) that any strata deposited in the Watton-Cliff locality during the making of the Junction-Bed of the Western Cliffs and elsewhere were broken up and redeposited during *Hammatoceras* time; (*b*) that all such strata were removed, and then that the *Hammatoceras* sea had access to exposed strata of *thorncombiensis*, pre-*exaratum*, *falciferum*, *bifrons*, *striatulum*, and other hemeræ, in order to gather materials for the making of the bed—to a certain extent layers 2, 3, & 4 give evidence that some portions of such strata were available for supplies; (*c*) that all the faunal contents of the Watton Bed which are of older date than *Hammatoceras* have been derived.

The third theory sounds rather elaborate, but it seems helpful in many ways: (*a*) it will account for the pre-*falciferum* Hildoceratids having a white-stone matrix, so that they have the same matrix after derivation as that in which they are enclosed; (*b*) it synchronizes this presumed pre-*exaratum* deposit of fine-grained lithographic stone with the paper-shales of North Gloucestershire—as, for instance, Alderton-Dumbleton : and such synchronization of two fine-grained, thinly-laminated deposits is rather an interesting point; (*c*) it accounts for the absence, except as derivatives, of deposits of post-*falciferum* to pre-*Hammatoceras* hemeræ, and also for their irregularity; (*d*) it brings into accord the commencement of the second white-stone deposit at Watton Cliff with the same deposit at Bothenhampton—there it is post-*striatulum*, presumably *Hammatoceras*; at Watton Cliff it is post-*striatulum* certainly *Hammatoceras*, so far as layer 4 is concerned.

If, however, this theory be correct, then there will be the following corollaries awaiting acceptance:—

(*a*) The presumed pre-*falciferum* Hildoceratids should be found in the basal part of the blocks: unfortunately, this basal part is the most difficult portion to attack; (*b*) this pre-*falciferum* white-stone deposit has been removed by denudation from the Junction-Bed of the Western Cliffs and of other places: there certainly is a non-sequence in the required position—both stratal and faunal failure; this is not asking too much, because denudation of the pre-*falciferum* deposits occurs over a considerable area—south of North Gloucestershire they are only preserved in patches, and in stratal sequence those are often incomplete; (*c*) that the main constituents of the Junction-Bed of the Western Cliffs were not deposited in the Watton Bed in a regular order, but are only represented by chance faunal and stratal elements in disorder; (*d*) that the second white-stone deposit has practically come into contact with the first one, giving the Watton Bed a false appearance of stratal continuity, whereas it masks a considerable non-sequence—say, some dozen or more hemeræ; (*e*) that the second white-stone deposit which is of two dates at Watton Cliff—*Hammatoceras* and earliest *Dumortieria*—has been partly removed, so far as the *Dumortieria* portion is concerned, from Bothenhampton, and has been wholly removed from the Thorncombe area: there, indeed, removal has gone further—it has taken off the deposit of *striatulum* date from Thorncombe Beacon, and yet left it as witness for original deposition at the neighbouring Doghus and Down Cliffs, in places.

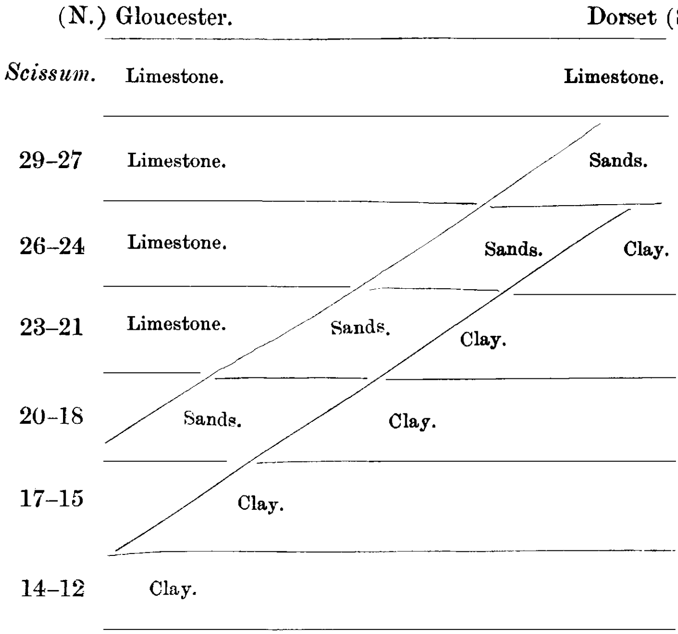
The phenomenon of what may be called stratal repetition—the occurrence of like deposits after greater or less intervals of interruption by deposition of strata unlike them—is quite well known. It occurs in two forms which may be called local and non-local—the first is stratal repetition in the same district, the second is stratal repetition, but not in the same district; there is stratal repetition in time, although what may be called the depositional focus has shifted. In the first case the like deposits are superimposed, in the second case they are not.

Those Jurassic sands of the South-West of England which makes a first appearance in Middle Lias (Domerian), and continue with various changes of locality until early Inferior Oolite (Aalenian), illustrate remarkably well stratal repetition, both local and non-local, as Table III (p. 415) will show.

Before illustrating this point I may say just a word about the so-called 'Midford Sands' or 'Oolite-Lias Sands' (Cotteswold, Midford, Yeovil, etc. Sands). From what one may read concerning lithological [lithic] evidence about change of deposit producing change of ammonite fauna, and when one sees assumptions made that the same formation stretching across country may be taken as evidence for the same date, I fear that the lessons to be gathered from the 'Midford Sands,' the secret of which I unravelled some years ago,[1] have not yet been learnt. Here is a formation of sand stretching across country for some 90 miles, from near Gloucester to the Dorset coast, resting upon clay below and capped by limestone rocks above. But the sand formation is not uniform in date—as it passes from north to south it gradually becomes later in time. Diagram 10 (p. 414) will illustrate this—the numbers refer to the hemeræ in Table III; but, of course, the diagram does not illustrate all the complexities due to differential thickening of deposits, to penecontemporaneous erosions, and so on. But it shows how unreliable a guide the lithic character may be. In this case clay, sand, and limestones are all being deposited synchronously during several hemeræ without, so far as is known, any effect on the ammonite faunas. But it can

[1] 'On the Cotteswold, Midford, & Yeovil Sands, &c.' Q. J. G. S. vol. xlv (1889) p. 440.

Diagram 10.—*Non-local stratal repetition.*



hardly be supposed that these simultaneous depositions of different strata form an isolated case—in fact, there is every reason to think that the phenomenon is rather frequent. It may, however, be masked by paucity of exposures and by hemeral sequences not having been so fully worked out. In the case of paucity of exposures, faunal analyses of the contents of a formation should be made. If they reveal notable discrepancies at certain localities, the explanation may be sought in the phenomenon of synchronous deposition of different strata—the similar lithic character as evidence of date should be regarded with suspicion.

It is not surprising that, in the Midford Sand case, observers disputed fruitlessly for many years as to the position of the Sands. But the palæontology of these observers was much at fault—a name like *Ammonites variabilis* was applied to species of such diverse genera as *Haugia*, *Phlyseogrammoceras*, *Pleydellia*, *Hammatoceras*, *Sonninia*, and *Fissilobiceras*.

I hope to be able to illustrate the phenomena of these Sands and synchronous deposits more fully in some subsequent paper of this series—much of it is written. Meanwhile, I return to the subject of stratal repetition, as illustrated by the geographical shifting of the focus of deposition (see Table III, p. 415).

TABLE III—DATES AND LOCALITIES OF SANDS.

Dates. Hemeræ.	Localities. Dorset Coast.	North Dorset.	Bruton.	Bath.	Sodbury.	Cottes-wolds.		
29. *venustula*	×						Bridport Sands.	Midford Sands *sensu lato*.
28. *digna*	×							
27. [*Cotteswoldia*]	×							
26. *moorei*	×	×					Yeovil Sands.	
25. *Catulloceras*	×	×						
24. *Dumortieria*	×	×						
23. *Hammatoceras*	...	...	×				Bruton Sands.	
22. *dispansum*								
21. *struckmanni*	...	...	...	×			Midford Sands, *sensu stricto*.	
20. *pedicum*								
19. *eseri*								
18. *striatulum*	...	...	...	...	×		Sodbury Sands.	
17. *variabilis*	...	...	...	...	...	×	Cotteswold Sands.	
16. *lilli*	...	...	...	...	...	×		
15. *braunianum*								
14. *fibulatum*								
13. *bifrons*								
12. *subcarinata*								
11. *pseudovatum*								
10. *falciferum*								
9. *exaratum*								
8. *tenuicostatum*								
7. *acutum*								
6. *athleticum*								
5. Harpoceratoid								
4. *spinatum*							Thorn-combe Sands.	
3. *thorncombiensis*	×							
2. *margaritatus* bed.								
1. pre-*margaritatus* bed	×	×	?	?	?	×	Down-Cliff Sands.	

So far as the Dorset coast is concerned, there are three sets of sands which are remarkably alike—so much so, in fact, that it is matter of common knowledge how difficult it is to be sure of the date (even in a general way) of a chance opening, especially as the strata are rather barren in a fossiliferous sense. The three sets of sands are those of pre-*margaritatus* bed (Down-Cliff Sands), separated by a thin calcareous and by a thin argillaceous bed from a post-*margaritatus* sand-deposit (*thorncombiensis*, the Thorncombe Sands), which is in some cases separated from the third sandy deposit (Bridport Sands) only by the thin Junction-Bed. This is local stratal repetition. Non-local stratal repetition is illustrated by the other areas, which show the depositional focus of sands travelling northwards into Gloucestershire and then returning southwards to the Dorset coast again.

In Table III the interval between the Thorncombe Sands and the Bridport Sands seems to be very great, and so it is in the time-scale as well, if the full thickness of deposits made contemporaneously elsewhere were brought in—250 feet or so in *lilli-variabilis* hemeræ of the Cotteswold Sands alone; but in actual section on the Dorset coast the break is a very small matter, sometimes only about 2 or 3 feet—so little, indeed, that it may reasonably be inferred that the movements of the Weymouth Anticline have resulted in places in such small upheaval as was necessary to bring about the removal of the Junction-Bed and the superposition of Bridport Sands on Thorncombe Sands in one bed, with a wholly false appearance of sequence.

In argillaceous deposits stratal repetition is shown in Fuller's Earth, Upper Lias, Lower Lias—to name only a few. And in calcareous rocks the phenomenon occurs—certain strata of especially similar appearance may be named:—

Minchinhampton Stone (Great Oolite).

Notgrove Oolite. Upper Freestone. Lower Freestone. Lower Limestone.	Inferior Oolite.

These are strata of white freestone with oolitic grains: they are separated by deposits having other characters.

But to ask for a stratal repetition of a fine-grained white lithographic stone of two dates, one pre-*falciferum* and the other *Hammatoceras*, to be deposited in the same area so as to form one bed masking a non-sequence of considerable duration, is to make a somewhat extravagant demand, because of the great degree of similarity involved. There are two phenomena to consider—the first is repetition, and the second is coalescence. It will greatly strengthen the case to bring forward evidence of the first phenomenon in regard to lithographic stone, and of the second in regard to another stone; because, although the phenomena occur separately, there is obviously only one further step towards finding them occurring together.

Remarkable confirmation in regard to stratal repetition of a like deposit comes from a neighbouring place, Burton Bradstock [1]; there is found a white bed (which it will be necessary to discuss presently) of much later date, so similar to the white bed of Watton Cliff that, if portions without their fossils were mixed, separation could doubtfully be made. Now, the greater will include the less. Here is definite evidence that white-stone—lithographic-stone—conditions

[1] I, 5, p. 69.

recurred in the same area after the lapse of some fifteen to twenty hemeræ, so there is ground for surmising that the same phenomenon occurred at Watton Cliff after the lapse of some ten to fifteen hemeræ. But the two beds of presumed different dates at Watton Cliff have coalesced. Yet coalescence of unlike deposits separated by more than twenty hemeræ in time is well known; rarer, of necessity, is the coalescence of two like deposits of different dates, because the chances against it are greater: but it is known, and was commented upon in my last paper.[1] Possibly, other cases of such coalescence have been overlooked, because they were not understood. If only such coalescence of the Burton and Watton white beds had taken place, it would have provided a problem and a crop of ingenious surmises before it was understood. And there is just the possibility that such coalescence did occur—somewhere out to sea, in the neighbourhood of the axis of the Weymouth Anticline.

The third theory seems to have the greatest weight of probability in its favour; but, at present, that is all that can be said for it. If correct, it makes the Watton Bed contemporaneous, so far as its earliest part is concerned, with the pre-*falciferum* paper-shales of the North Gloucestershire Whitbian, and, so far as its later part is concerned, contemporaneous with the top layer of the Bothenhampton section, with the Yeovilian Sands of Cole, near Bruton (Somerset), and with the middle part of the Gloucestershire Cephalopod-Bed. It will be noticed that at present there is no ammonite evidence for any of the hemeræ between *Hammatoceras* and *striatulum*—in descending order: *dispansum, struckmanni, pedicum, eseri*. They have not been found at Bothenhampton nor in the Western Cliffs—at the former place towards the top of the Junction-Bed there is, consequently, a gap of four hemeræ; at Doghus and Down Cliffs, between the Junction-Bed and the overlying Down-Cliff Clay, there is a gap of five hemeræ; at Thorncombe Beacon there is a gap of six hemeræ. At Shoot's Lane, Symondsbury (Dorset), evidence for *eseri* has been found—*Haugia fascigera*[2] (now *Esericeras*).[3]

Stress has been laid on stratal repetition and coalescence, because this may possibly explain some of the Continental deposits which are puzzling, on account of inclusion in the same matrix of species of very widely different dates.

In the Red Ammonite-Limestone of Lombardy are species of various dates, from Domerian through Whitbian to Yeovilian, with certain notable omissions. The dates of the species are fairly obvious, and the deposit possibly represents a continuity of like conditions with erosions. But were the gaps—the portions

[1] I, 9, p. 86.

[2] I, 5, p. 57.

[3] I, 8, pl. clxxxii. Since this was written, examination of Mr. Jackson's finds gives evidence for fauna of *eseri* and *pedicum* (or *struckmanni* hemera, perhaps) in the Western Cliffs. Such finds are always possible, and do not invalidate my statements; they stand good for many exposures of the Junction-Bed of the Western Cliffs.

unrepresented by fauna — filled by strata of like or of unlike character? There is no evidence.

The stratum of *Posidonomya alpina* of Sette Comuni (Italy) contains a fauna described and figured by Parona[1] which appears to show considerable mixture of Bajocian (and early Vesulian) with Callovian species. Parona notes that such an admixture has been recognized by E. Böse & H. Finkelstein for the same stratum in Southern Tyrol and by E. Jüssen for the Klaus Beds of the Northern Alps.[2] In Parona's case the admixture seems to be greater than he supposes, even allowing for the well-known and deceptive homœomorphy of certain Bajocian-Vesulian and Callovian species, and therefore the following remarks on some of his faunal elements may be of service. It is interesting to note how many of them have a distinctly Bajocian-Vesulian aspect. Before claiming them as Callovian species it would be very necessary to show that they, or very similar forms, occur in deposits which are unquestionably Callovian. If that could be done, then they would still remain of much interest, as illustrating heterochronous homœomorphy. But at present the majority of the forms about which the following notes are made appear to be strangers to Callovian, though not to Bajocian-Vesulian deposits.

TABLE IV—REMARKS ON PARONA'S FIGURED SPECIES OF BAJOCIAN-VESULIAN ASPECT.

Reference.	Species.	Remarks.
PL. I, fig. 11.	'*Oppelia subtilicostata*.'	Similar to Oppelids of *niortense* date.
12.	'*Œcotraustes minor*.'	Possibly a catamorph of *Cadomoceras*. Cf. *C. costatum*, I, 8, pl. clxxxix: *niortense*.
13.	'*Cadomoceras nepos*.'	Good evidence for *niortense* date.
14, 15.	'*Sphæroceras pilula*.'	Possibly catamorph of *Labyrinthoceras*, I, 8, pls. cxxxiv, cxxxv; c. *sauzei*.
16.	'*Sphæroceras auritum*.'	Like species of *blagdeni-niortense* dates.
17.	'*Sphæroceras? disputabile*.'	Like species of *niortense* date.
18.	'*Stephanoceras rotula*.'	Like the coronate stage of Perisphinctids of *niortense-truellei* date.
19.	'*Stephanoceras gibbum*.'	Very like *Trilobiticeras*, I, 8, pl. cxl; *Discites*.
21.	'*Stephanoceras venetum*.'	Remarkably similar to *Polyplectites* sp of the *truellei* bed of Burton Bradstock.
22.	'*Parkinsonia bonarellii*.'	Not a *Parkinsonia*, as the furcation is on the edge of the periphery; it should be about medio-lateral. A phaulomorph Perisphinctid; *truellei?*
PL. II, fig. 1.	'*Cosmoceras pollux*.'	Like certain forms of *Strenoceras* of *niortense* date. But there is a great resemblance between the Bajocian-Vesulian genera *Strenoceras*, *Baculatoceras*, *Garantiana*, and the Callovian *Cosmoceras* in certain cases.

[1] VIII.

[2] VIII, p. 5.

Reference.	Species.	Remarks.
PL. II, fig. 2.	'*Cosmoceras* n. f.'	Much like *Baculatoceras* of *niortense* date.
3.	'*Perisphinctes subtilis*' Neumayr.	Not *P. subtilis*. Very like *P. pseudomartinsii* Siemiradzki—*Prorsisphinctes*, I, 8, pl. cc; *garantiana*.
9.	'*Peltoceras chauvinianum*' A. d'Orbigny.	More like *Caumontisphinctes*, I, 8, pls. clxix & cxcii; *niortense*.
21–23.	'*Waldheimia bœhmi*.'	'Has the most remarkable likeness to *Waldheimia brodiei* S. Buckman (in Davidson, Mon. Brit. Jur. Brach. App. to Suppl., Palæont. Soc. 1884, p. 266 & pl. xix, figs. 14–15, which is a species from the Irony Bed (*blagdeni* zone) of Louse Hill.'[1]
24.	'*Waldheimia concava*.'	An anamorph of *Waldheimia haasi* S. Buckman in Davidson as above, p. 265 & pl. xix, fig. 12; *blagdeni* zone of Louse Hill.
19.	'*Waldheimia beneckei*.'	A catamorph of *Zeilleria ferruginea* S. Buckman, I, 4, p. 260 & pl. xiii, fig. 4; from the Irony Bed (*blagdeni* zone) of Louse Hill.

The stratum in question appears from Parona's description[2] to be homogeneous. It is making a rather large, though not impossible, demand on credulity to believe that this homogeneous deposit was persistent without alteration, through all the great number of hemeræ which are contained in Upper Inferior Oolite, Fuller's Earth, Stonesfield Slate, Great Oolite, Forest Marble, Cornbrash, Kellaways Rock to basal Oxford Clay. Continental authors, it is true, have failed to realize the great time-interval that exists between post-Bajocian and Callovian—being inclined to look upon them as merely a part of one deposit, because on the Continent so many of the stratal constituents are lacking. Quenstedt, for instance, placed such strata just in one division, Braun Jura ϵ, as if they all made up quite a minor episode. But I shall have more to say on that point in a sequel to this paper.

What concerns us now is the difficulty of thinking that the homogeneous deposit lasted persistently through all this time. There is perhaps no evidence against it in the shape of different deposits in the neighbourhood; but the great non-sequence suggests that a change of conditions occurred, that different deposits were laid down and were entirely swept away again—then that there was stratal repetition and coalescence.

The interesting point about the Burton White Bed and the Watton Bed is the definite evidence given for about 230 feet of strata, different from them and differing among themselves—sands and various limestones—separating two like deposits. But it is not difficult to picture another condition—a difference of geological and geographical history—sea where now is land, the

[1] I. 5, p. 105. [2] VIII, p. 3.

Dorset–Somerset evidence of these intervening strata swept away; land where now is sea, with coalescence instead of separation of the two White Beds. Then we might be examining a rock of white matrix obtained some miles off the Dorset coast which would puzzle us, because it showed in a homogeneous deposit Whitbian and Yesulian ammonites. Given sufficient destruction of evidence, and we might be long in arriving at the solution—erosion, stratal repetition, and then coalescence. Yet such, I think, is the explanation of sundry Continental deposits, and also of the Watton Bed itself: stratal repetition for the Yeovilian deposit and coalescence with a like Whitbian deposit—some of the intervening strata, of different lithic composition, being deposited in the Junction-Bed of the Western Cliffs and elsewhere.

The subject of stratal repetition and coalescence must receive further attention at another time.

IV. THE WHITE BED OF BURTON BRADSTOCK.

The likeness of the Watton Bed to that which I described as found at Burton Bradstock naturally attracted attention.[1] That bed is in Bridport Sands and also connected with faulting. Accordingly, in the autumn of 1919, I paid another visit to Burton. The first blow of the hammer fortunately hit a block disclosing examples of the same latesulcate '*Garantiana*' as that which I mentioned before.[2] It is not properly a 'Garantiana'; but it is a well-known form of the *niortense* bed of Louse Hill,[3] the *Astarte* or Rotten Bed[4] which lies above the Irony Bed. A fine-ribbed Perisphinctid was also obtained.

Subsequent labour, however, proved unproductive of more evidence for date. But a *Garantiana*-like form and a Perisphinctid in this bed are sufficient to show that, like as these two lithographic strata are in composition, yet they are of widely different dates—the Watton Bed is pre-Bridport Sands, the Burton Bed is on the border-line of Bajocian-Vesulian, not only post-Bridport Sands, but subsequent to the early and middle Inferior Oolite. What is interesting, however, is that the same fine muddy sedimentary conditions must have obtained at these two different dates: but, in the Burton case, it is only by the accident of faulting that a fragment of the later deposit has been preserved; in the Watton-Cliff case the accident of faulting has doubtless preserved the southern extension of the Bed, although that must be buried at a steep angle some 300 feet below Watton Cliff. What has been preserved is the unfaulted part which lies practically horizontal in the cliff-face, in position between Middle Lias and basal Bridport Sands.

[1] I, 5, p. 69. [2] I, 5, pp. 70–71.

[3] I, 5, p. 71. [The Louse-Hill species has, since this was written, been figured and named *Hlawiceras platyrrymum* (I, 8, pl. ccxl).]

[4] I, 3, p. 488, Section VI, Bed 3.

Mr. Linsdall Richardson has said that the Burton White Bed is *in situ* in Bridport Sands formed by percolation subsequently [1]; but while such an explanation might account for a deposit, it is quite inedaquate to account for the presence of fossils in that deposit. It seems hardly sufficient to account for such a deposit as this: percolation should produce calcite-veins (the so-called 'beef'), not a finely-laminated lithographic stone. The difficulty about the fossils in the deposit Mr. Richardson avoids by a suggestion which ignores my statements, and is totally at variance with the facts; he says:

'It was probably from this horizon [the top of the Red Beds] that the piece of "lithographic" stone came that yielded to Mr. Buckman fossils indicative of late *niortensis* or *garantianæ* hemera. Prof. S. H. Reynolds has very kindly examined microscopically one of the two pieces of "lithographic" stone that Mr. Buckman gave to the Director [Mr. Richardson]. These two particular pieces probably come from the top of the Red-Bed horizon.' [2]

My statements were

'The White Bed .... only occurs .... in the bank at the beach opposite the villas .... It is particularly exposed on the sort of pathway leading from the road to the beach, and just to the right hand as one reaches the beach.... The blocks on the beach were broken. The yield was several specimens [of fossils] .... and a piece of a *Garantiana* sp. nov.... known as a species from the *niortensis* beds of Louse Hill, near Sherborne.' [3]

The fossils and the rock-specimens were both obtained from the same place, from those blocks which are on the beach below the villas, blocks detached from the Bridport Sands, into which they have been faulted. The latest finds (1919)—similar ammonites, a Perisphinctid, and a *Nautilus*—were all extracted from the bank in the pathway below the villas.

Why Mr. Richardson made the assumption that the fossils and specimens came from the Red Bed it is difficult to imagine, especially as the cliff-section with the Red Bed is from a quarter to half a mile away; and I had remarked that [4]

'there is [in the cliff-section] practically no sign of any deposit of a thick white bed of the character of the one that has just been described.'

But the assumption was necessary to fit the percolation theory, in pursuance of which Mr. Richardson remarks that 'the lithographic stone might be found associated with fossils of any hemera.' [5] The difficulty here is that the fossils would show internally the different matrices formed during the hemeræ to which they rightly belonged. But these fossils from the white bed show inside and outside a white-bed matrix—they are evidently synchronous with the White Bed. Another objection is that the fossils of the White Bed are not found in any other of the Burton deposits. And there is a still further objection which may be taken to the percolation theory—that percolation would not produce a fine-grained, laminated lithographic stone.

[1] IX, 2, p. 56. [2] IX, 2, pp. 56–57. [3] I, 5, pp. 69–71.
[4] I, 5, p. 71. [5] IX, 2, p. 57.

It is now known that a similar lithographic stone was deposited horizontally and normally at an earlier date at Watton Cliff, of which the unfaulted part is preserved and the faulted part rendered inaccessible: it is reasonable to conclude that the Burton White Bed was deposited in a normal manner, but that the unfaulted part has been destroyed and only the faulted part preserved. A somewhat complicated series of events which involves faulting and penecontemporaneous erosion must be postulated, but nothing that is not already known in other cases.

Thus, in regard to the White Bed, there are the following facts:—

(i) That the White Bed is of later date than the Red Bed, and earlier than the *Astarte* Bed.

(ii) That the White Bed is not now found resting upon the Red Bed.

(iii) That the White Bed is not found separating the Red Bed from the *Astarte* Bed.

(iv) That the White Bed is a finely-stratified laminated deposit—in part, at any rate.

(v) That the White Bed is let down in a fault some 50 to 60 feet below the top of the Red Bed: that is, below its original position.

(vi) That it is mixed up with Bridport Sands.

(vii) That hard rocks of dates subsequent to that of the White Bed—that is, strata of the hemeræ *Garantiana* to *zigzag*—are not found associated with broken-up masses of the Red Bed.

Next, the following inferences may be drawn:—

(i) That the White Bed was deposited discontinuously on a surface of the Bridport Sands to the east, but with fair continuity on the surface of the Red Bed to the west.

(ii) That the White Bed is a deposit of slow accumula'ion, laid down under conditions similar to those of the lithographic stone of the Watton Bed.

(iii) That the White Bed deposited on the Bridport Sands must have been protected from the denuding agency.

(iv) That the preservation of the White Bed is apparently due to a small syncline in the Bridport Sands.

(v) That the White Bed was removed from the top of the Red Bed before the commencement of the deposition of the *Astarte* Bed.

(vi) That the hard rocks of the strata of hemeræ *Garantiana* to *zigzag* must have been either not deposited on the top of the White Bed of the Bridport-Sands tract, or, if deposited, they must have been completely removed again, otherwise they would be found associated with fallen blocks of the White Bed.

(vii) That non-deposition of these strata on the top of the White Bed would mean the elevation of the sand tract above the water, and would therefore expose it to denudation, which would bring about the total loss of the White Bed.

(viii) That deposition of these strata on the White Bed is a necessary supposition; but that this requires a postulate as to their subsequent removal.

(ix) That it is necessary to suppose that a soft rock easily yielding to denudation—a rock like the clays of the Fuller's Earth—was the immediate covering of the White Bed at the time when faulting occurred, as such a rock could easily disappear from the face of the White Bed without leaving any traces.

To account for these facts and inferences, the following history of events may be suggested. Diagram 11 (I–V), pp. 424–25, which illustrates the different events is merely a sketch, only approximately to scale. Vertical scales are, of course, greatly exaggerated in relation to horizontal:—

(i) Towards the end of the deposition of the Red Bed there was elevation of the tract of Bridport Sands on the east.

(ii) There was denudation of this tract, and then the White Bed was deposited on a surface consisting of Red Bed in the west, passing across strata down to Bridport Sands in the east (I in diagram 11).

(iii) Subsequent to the deposition of the White Bed, and before the deposition of the *Astarte* Bed, there was a renewed elevation of the Bridport Sands. Then there was denudation of the White Bed and its complete removal off the Red Bed, but its preservation in the Bridport-Sand area in a small fold east of the anticlinal axis (II in diagram 11).

(iv) Following this was the deposition of the *Astarte* to *zigzag* strata non-sequentially upon the various denuded surfaces (II).

(v) Renewed elevation of the Bridport-Sand tract came next, with a denudation which removed from that tract all the *zigzag* to *Astarte*-Bed strata and possibly some more of the White Bed; because the supposition that the later denudation should cease at the same place as the earlier makes too much demand upon coincidence (III in diagram 11).

(vi) On such a denuded area Fuller's Earth was deposited (III).

(vii) At some date subsequent to the deposition of the Fuller's Earth—perhaps at the same date as the faulting in Watton Cliff—the strata of the Bridport-Sand tract bearing the White Bed were let down considerably, and at as steep an angle as are the Junction-Bed and Fuller's Earth of the faults in Watton Cliff.

(viii) That the soft Fuller's Earth would be rapidly removed, and would then leave the White Bed exposed. IV (diagram 11) gives a view of this condition of affairs, in profile at right angles to the supposed fault-face, the elevation of the rocks inland being of course greatly exaggerated in relation to the horizontal scale, and V gives a picture of the same looking on to the fault-face, omitting the rocks which lie directly inland, but showing those of the cliff which lie to the westward. In this case it should be noted that really, from the fault westwards along the cliff to where the Fuller's Earth is preserved, is a distance of about half a mile.

(ix) While the White Bed was being eroded from the surface of the Red Bed, there is the possibility that portions of it may have been broken off and cemented on to the top of the Red Bed with ground-up paste of the Red Bed; and there is always the possibility that pockets of the White Bed may yet be found in hollows of the Red Bed. A recent discovery of a possible White-Bed block in the *Astarte* Bed will be noticed presently.

This theory of the course of events is, at any rate, superior to the percolation theory, in that it does not commence with an incorrect assumption as to the facts. The only real call that it makes on probability is in postulating two elevations and erosions, the second elevation being so adjusted that all the hard rocks of *Garantiana* to *zigzag* hemeræ are removed from the surface of the White Bed, but that some portion of the White Bed is left intact. Yet this is only asking for a phenomenon on a small scale, such as is exhibited on a large scale over a considerable area of the Cotteswolds. There the strata which intervene between those of *bradfordensis* and *Garantiana* hemeræ were deposited after a period of

Diagram 11.—*Presumed history of the White Bed of Burton Bradstock (Dorset).*

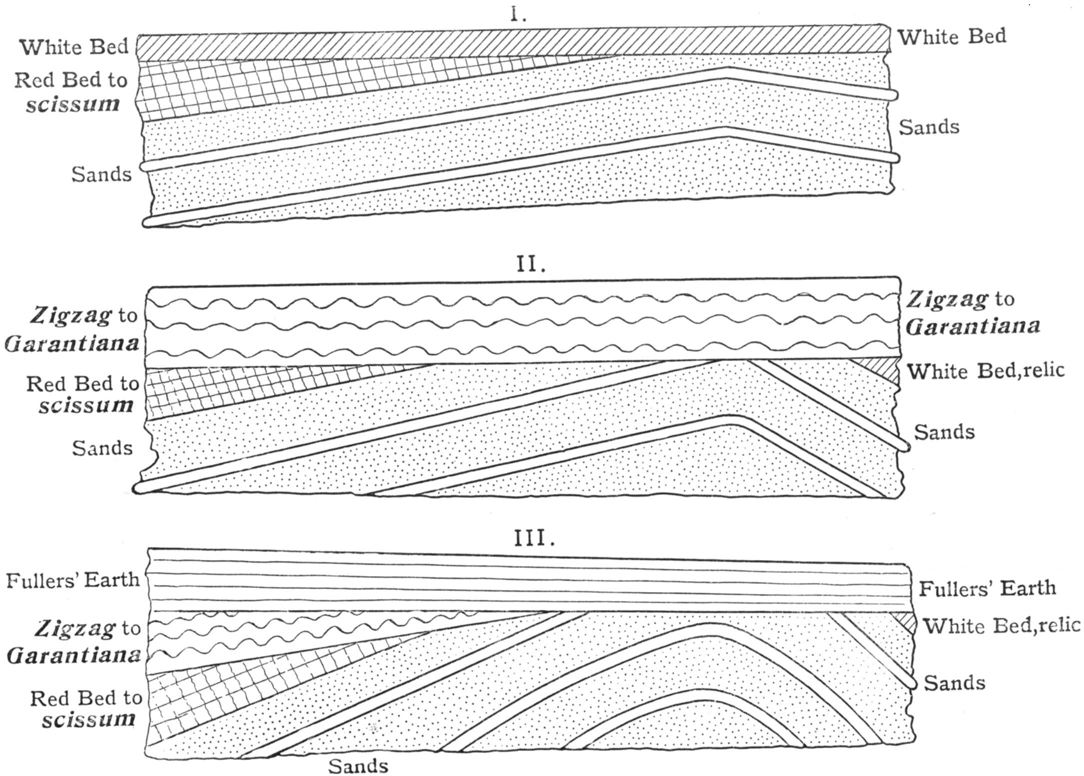
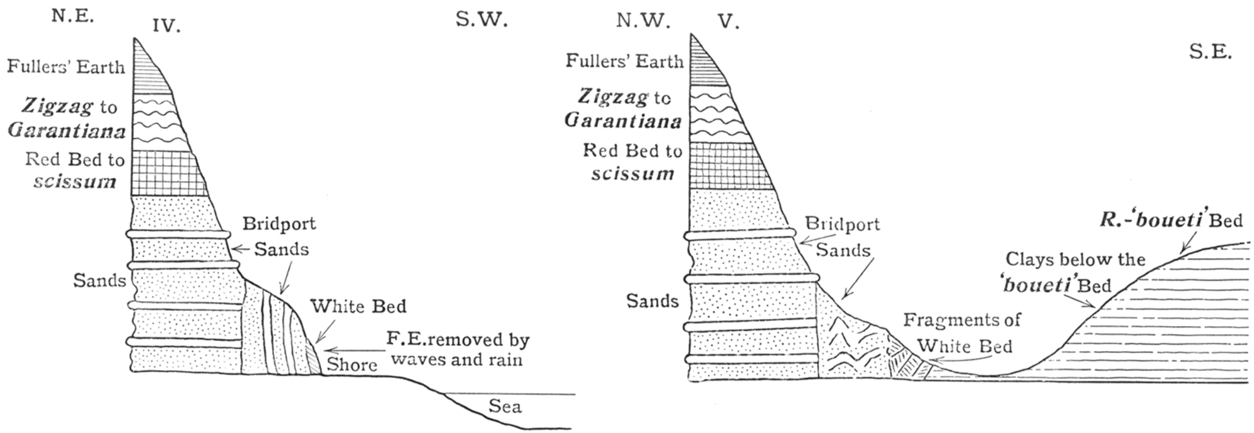


Diagram 11 (continued).



elevation and erosion, yet prior to another period of elevation and erosion. The second erosion obliterated all these intervening strata from certain places, yet was so adjusted that they were preserved in other places. But the latest bed of all is only preserved over a rather limited area—Cleeve Hill,—and strata which ought to follow on this bed, preceding those of *Garantiana* hemera, have been completely destroyed.

It is not necessary to assume that a fault was present until the date which let down the White Bed to its present position—long after Fuller's-Earth date presumably.[1] All that need be assumed is a gentle fold bringing Bridport Sands first to the level of the Red Bed, and then to the level of the *Zigzag* Bed: the actual anticlinal axis being about on the present line of fault, which would give a syncline just beyond it sufficient to let in the White Bed.

We do not know how thick the White Bed was originally. Say that there is now some 2 or 3 feet of it preserved. It may have been deposited to a thickness of 20 feet, of which only this small portion is preserved, and that by an accident. It is true that the other Inferior-Oolite rocks of Burton Bradstock are quite thin; but this is no measure of their original thickness—it is the result of the constant denudation that they underwent, being removed almost as fast as they were deposited. Some of them thicken considerably only a short distance inland—away from the axis of the Weymouth Anticline.

For instance, at Vetney (Vinney) Cross, which lies about 3 miles north-east by north of Burton Bradstock (or about 8 miles from the axis of the Weymouth Anticline), the *Garantiana* Bed is 18 inches thick as against 4 inches at Burton or an increase of $4\frac{1}{2}$ times, while the *truellei* bed is about 6 feet as against less than 2 feet at Burton; this, however, is not the full thickness, for really the deposit of 6 feet corresponds to about the lower 6 inches of the Burton *truellei* bed, or an increase of 12 times as much. Then at Nettlecomb, near Powerstock Station (about 5 miles north-north-east of Burton Bradstock), a rather poorly-fossiliferous quarry shows some 20 feet of *schlœnbachi* deposit, as against less than 5 feet at Burton; and yet there is no sign of the subjacent or superjacent beds, either in the quarry or in the stones of the fields around.

We speak of the sequence *blagdeni*, *niortense*, *Garantiana*; but we have no certainty that this is the complete sequence. It may be that, between the hemeræ *niortense* and *Garantiana*, strata were deposited of which no trace has yet been discovered.[2]

[1] The Forest Marble of Watton Cliff contains pebbles of a White-Bed matrix. It is an interesting speculation whether these have been derived from destruction of the Burton or from that of the Watton White Bed. They appear to be rather too soft for either: but this is a case where chemical analysis might yield some evidence.

[2] The most likely place in this country for such a discovery is near Sherborne (Dorset), in the neighbourhood of the quarries of Frogden and Lower Clatcombe. Seeing how little distance at Burton Bradstock is required to bring in a bed not found in the other neighbouring sections, there is no telling what an excavation at 100 or 200 yards in certain directions near Sherborne might not reveal. This subject may be more fully worked out in a later paper.

It is fairly certain that, when the fauna of the strata now dated as *niortense* are submitted to analysis, several episodes will be found covered by the one name—deposits of one episode have been preserved at one place, and those of others in other places. And yet the sequence may not be complete.

These remarks are made to show that, on theoretical grounds, there is reason to claim plenty of time between the dates of the deposition of the Red Bed and the *Astarte* Bed for the various events of elevation, denudation, deposition, to have occurred even in repetition. And there is actual evidence in support: in the Hebrides, according to the researches of Dr. G. W. Lee, some 70 feet of strata separate deposits which are respectively the equivalents of the Red Bed and the *Astarte* Bed. Unfortunately, they are unfossiliferous, and so their dating as *niortense* rests only on the fact that they are between *blagdeni* and *Garantiana* hemeræ. Then in the Sherborne district there are poorly fossiliferous strata—the Building-Stones—which are post-*niortense*: they are reckoned as belonging to the *Garantiana* hemera, and so is the *Astarte* Bed of Burton Bradstock; but that they are strictly contemporaneous is possibly doubtful—the various *Garantiana*-like forms in the two deposits show certain differences, and therefore, at any rate, the species are not altogether identical. Possibly the *Astarte* Bed is, in part at least, of somewhat earlier date than the Building-Stone of Sherborne; but it is unadvisable to speak positively on this point, until the *Garantiana*-like forms can be worked out in detail—a long task with such a mass of material as the strata yield.

The point to be emphasized is the necessity of knowing whether our chronological datum-lines are strictly contemporaneous; because, as it is only possible to estimate time by the amount of work performed during stated periods, it is necessary to be certain that the periods are identical. For instance, was the thickness of 70 feet in the Hebrides laid down only prior to the Building-Stone of Sherborne, or was it laid down prior to the *Astarte* Bed of Burton, or, as is possible, was it laid down even prior to the White Bed of Burton? These possible differences make considerable difference to the time-estimate; for, in the last case, the 70 feet represent work done in a time-interval between the Red Bed and the White Bed, which was a period of upheaval and erosion at Burton; then between the Red Bed and the *Astarte* Bed, which reposes upon it, one could place a time-interval represented by work done in depositing 70 feet in the Hebrides, and, in addition, an unknown original thickness of White Bed. It is rather interesting to note that the White Bed, which is the sole representative at Burton of the time-interval between the Red Bed and the *Astarte* Bed, should not be found separating them, and has only been preserved by an accident.

Bearing on the remarks about the possible original thickness of the White-Bed deposit, there is this to be said further: in the Sherborne district the pre-*Garantiana* zones of the Inferior

Oolite are thin deposits, averaging about a foot or so, but the *Garantiana* deposit is a thick one—running up to 40 or 50 feet, perhaps more. The paucity of fossils accounts for such horizons as there may be not being followed out in the different quarries of Building-Stone, for these quarries may be really on various levels—if so, the thickness would be much greater. Therefore, a surmise of a possible 20-foot deposit for the original White Bed is not necessarily a gross overestimate.

It is interesting to note that these lithographic-stone beds of the Yeovilian of Watton Cliff and of the late Bajocian of Burton Bradstock have a great likeness to the Continental strata termed White Jura, *diphya*-kalk or Alpenkalk, which form so conspicuous a feature of the Upper Jurassic over wide areas. It has, before now, been claimed for this country that its special geological interest lies in the fact that, small though its area be, yet it contains strata so fully representative as regards all the different dates and all the different structures. Yet it is correct, I think, to say that before the date of my discovery of the lithographic stone of Burton, it showed nothing to compare with strata laid down under those conditions which produced the Alpenkalk. Now, however, the Watton Cliff discovery adds another representative of such conditions—a deposit made at a still earlier date: so it is now unnecessary to travel outside England to obtain samples of strata like those of the Alpenkalk. And there will be this additional interest attached to them, that these beds of Watton Cliff and Burton indicate Alpenkalk conditions of deposition prevailing in Western Europe long prior to the date when they held good in Central Europe.[1] How long these conditions endured in the English cases, and what respective thicknesses of strata were laid down, can only be matters of surmise; for penecontemporaneous erosion has removed so much, and came near to removing all. How wide an area was occupied by such deposits is also matter for surmise—they may have spread far over the area now occupied by the English Channel. Some parts of the deposits may now lie buried beneath its waters, other parts of them have certainly been destroyed by those waters. Only a very few cubic yards of deposit in the Burton case are now left available for investigation. In the case of the earlier deposit, there may be a good deal more. There is certainly not much in Watton Hill itself: for the bed is cut off on the south by the Watton Fault, and on the west, north, and east by the landward slope. There is, perhaps, no more than an area of some 250 to 300 square yards preserved. But this White Bed has been detected in Shipton Long Lane, Bothenhampton—say, about three-quarters of a mile inland from the east-and-west line of Eype—and there is a possibility that it can be found farther inland, as around Allington Hill.

[1] Mr. J. W. Tutcher rightly draws my attention to the Sun-Bed in the White Lias of the Radstock-Bristol district as being an earlier deposit of similar character. Therefore in the South-West of England there was a threefold repetition of this kind of rock.

Now, Bothenhampton is some 7 miles from the main anticlinal axis of the Weymouth Anticline. If it be a legitimate surmise that the conditions producing Alpenkalk extended as far south of the axis of the anticline as they do north of it, then a north-to-south stretch of the White Bed was some 14 miles. To put the east-to-west stretch at the same distance would be reasonable: this would give nearly 200 square miles of area as the original extent of White-Bed deposit. To put the east-to-west stretch at some three times the distance would not be really so very unreasonable: this would imply some 600 square miles of area—by no means an inconsiderable extent.

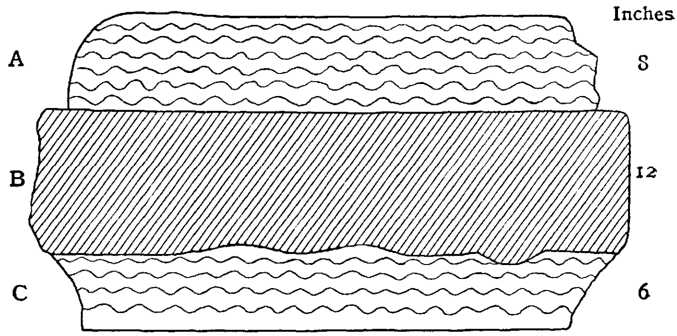
The exploration north of Bridport of what is marked as the contact-line between Lias Marlstone (G 2) and Lias Sand (G 4) would certainly be desirable, as giving a chance of finding further evidence of the Yeovilian White Bed. But there is little chance of exploration in such an area giving more evidence for the Burton White Bed, as there are plenty of quarries opened at the necessary horizon and they have received much attention. However large may have been the surface over which the Burton White Bed was deposited, it seems unfortunately to be only too true that it has been wholly removed from all that area. If such removal did not wholly take place, as at Burton Bradstock, prior to the deposition of the *Garantiana* Bed, it was accomplished later, when it shared the fate which in some localities was meted out to the *Garantiana* or subsequent deposits. But there is reason to suppose that the main accomplishment of its destruction was a pre-*Garantiana* episode, for, unlike the strata of *niortense* date which are preserved only at a few isolated localities, the strata of *Garantiana* date have a remarkably wide spread.

An observation made at the Black Rocks, west of West Bay, tends to confirm the theory that the White Bed was an original stratified deposit, broken up and redeposited later, where it was not preserved by being let down in the fault. At the Black Rocks, about the middle, close to the beach of pebbles, was found a big block (diagram 12, p. 430)—4 feet long, 18 inches broad and 26 inches thick—consisting of the *Astarte*-Bed (*Garantiana*) matrix, recognizable by its lithic characters and the great number of various fossils shown in section. About in its middle it carries a large mass (1 foot thick), extending rather beyond the length and breadth of the block, because of its superior hardness. This mass is a very compact, close-grained, grey rock, apparently quite unfossiliferous. It differs from all other local Inferior-Oolite rocks except the White Bed; that it resembles in texture, hardness, and paucity (if not absence) of fossils. In colour it differs somewhat, but not more, perhaps, than the difference of locality—it is nearly 2½ miles from the Burton White Bed—might explain. It certainly seems as if this included mass might be a local portion of the White or *Nautilus* Bed redeposited in the *Astarte* Bed. If such be the case, then, as the Black Rocks lie at the foot of Watton Cliff, we should have evidence of the second White Bed deposited in the same locality as the first.

Mr. Richardson says with regard to the Burton White Bed: ‘the very white aspect of the stone was due to weathering of the surface.’[1] This is not my experience—the true lithographic stone is beautifully white, inside as well as outside.

The Black Rocks which lie out to sea immediately west of the first fault from West Bay, should repay investigation. Hitherto they seem to have been neglected; but this may be due to the fact that they are inaccessible, except during certain low tides. It was only during my last visit to Eype (1920) that I found them sufficiently uncovered for a short examination, which enabled me to collect certain specimens, indicative of the *Astarte*-Bed (*Garantiana*) of Burton Bradstock, from some masses well

Diagram 12.—*One of the Black Rocks (Dorset).*



A = Ironshot fossiliferous (*Garantiana*) rock.
B = Very hard, fine-grained grey rock (White Bed equivalent).
C = Ironshot, like the hard portion of the Vetney Cross *Astarte* Bed (*Garantiana*).

off shore, but just landward of the big rock. At my next visit at low tide these rocks were not accessible; but, nearer the beach and among the shingle of the beach, were found certain blocks which could be recognized as *scissum* bed, Red Bed, *schlœnbachi* and *zigzag* beds, besides the mass of *Astarte* Bed just mentioned. At certain states of the shingle these beds are buried; but, given favourable conditions of tide and shingle, the Black Rocks should yield a good harvest. However, heavy tools are a necessity.

To return for a moment to the *niortense* bed: there is reason to suppose that this bed was originally of wide geographical extent—possibly from the Hebrides to Italy and the Carpathians, certainly from Sherborne (Dorset) through France to Würtemberg. But, although it was originally deposited over so vast an area, the bed is now preserved only at a few widely-distant localities and is lacking from intermediate areas—much of it was wholly destroyed

[1] IX, 2, p. 56.

prior to the deposition of strata of the *Garantiana* hemera, much of what may have escaped that destruction perished in later erosions along with the whole of the Inferior Oolite. I have made a rough calculation that possibly not 1 part in 30,000 of the bed as originally deposited has been preserved. I do not pledge myself to the figures; they may be thought to be an under-estimate, but there is also reason to think that they may be an over-estimate. But to give an idea of what such destruction means: there are about 30,000 post-offices in the British Isles enumerated in the Postal Guide. If we were to destroy all these names but that of Sherborne (Dorset), we should thereby obtain a picture of the destruction of the *niortense* bed. Then consider how small a part a quarry or two forms of the preserved portion, and that, when such quarries are in work, many years may pass without anyone visiting them. On such a basis, it is easy to understand that the collected material may form no more than one part in a million of the entombed originals.

Which deposit of the Jurassic hemeræ has suffered the most in regard to destruction may be a matter for future research, but the *niortense* bed will, I expect, be one of those which make the greatest claim to such distinction. It is not proposed to enter into details on this subject here—the accumulation of evidence is no light task; but it is hoped to initiate in a sequel to this paper a geographical enquiry as to the original extent of the *niortense* bed and as to its present preservation, which may fit in suitably with some other geographical studies suggested by stratal and faunal phenomena of the rocks to be dealt with in that sequel.

V. Certain Chronological Studies.

(A) Milborne Wick and the Green-grained Marl.

In the Table[1] of his paper on the Doulting-Milborne-Port district, Mr. Linsdall Richardson places opposite *blagdeni* hemera, and under Milborne Wick, the following 'Marl with green grains, S. S. Buckman.' The placing of it within inverted commas makes it appear like a statement taken from my paper,[2] or given on my authority. But this is incorrect: reference to my section of Milborne Wick will show that I divided the beds in more detail than did Mr. Richardson. I recorded

Humphriesiani. [*blagdeni*].	2. Soft white chalky limestone, 4 inches.
	3. Grey limestone with iron grains, 6 inches.
sauzei.	4. White limestone, 6 inches.
	5. [Soft limestone] speckled with green grains. *Astarte spissa*.

Here I have said nothing about any green grains in the limestone of *blagdeni* hemera: at the top that is white, without coloured

[1] IX, 3, facing p. 518. [2] I, 3, p. 502.

grains, lower it has grains which are noticeably pink; at a still lower level, which I dated as *sauzei*, are the green grains.

The point is of considerable importance for dating specimens. In the 'seventies (at the time, I understand, when the road-cutting was made at Milborne Wick), very extensive collections of fossils were obtained from this place: many are in my collection, and it is rare to see a public or private collection without noting fossils which have the characteristic Milborne-Wick matrices. If my observations are correct, the lithic differences afford a means of ascertaining the sequence of these fossils. I have examined many ammonites in my collection, and they certainly tend to confirm this opinion. The very common fossil of the *blagdeni* zone is *Pœcilomorphus cycloides*—common, because the name really covers a multitude of different forms; but Mr. Richardson does not mention this species.

Not only is he incorrect in citing my authority for this dating of the marl with green grains; but I think that he may be incorrect in his dating of the beds which he saw. My 'Bed 2' is given by me as 4 inches thick, and Beds 3 & 4, as 1 foot, total = 16 inches. Mr. Richardson's Beds 2 to 4 total 13 inches. So on that basis he may have hit a place where Bed 2 was only 1 inch thick. But there is a lack of 14 inches in the rest of his section—under Bed 6. I think it possible that where he took his section he saw, at the top, Bed 5—where I noted the green grains—with just some small portions of the higher beds and their fossils in more or less derived condition mixed up with the disturbed green-grained marl. This point might be settled by an examination of the matrix inside the fossils, not that outside.

There are two further points for consideration:—

That in this section local removal of the beds below the non-sequence—Beds 2–4—is possible, with the corollary that, at favourable places, Bed 2 may be thicker than is recorded in my section; and that there may be local variation in the thickness of any of the beds. Therefore, if Mr. Richardson found green-grained rock at the top of the section, whereas I found it at 16 inches below, the explanation may be local thickening at the top of Bed 5 and/or local denudation.

One point I would add about this section, from examination of ammonites from old collections—specimens of *Witchellia* show a matrix with green grains and *Astarte spissa*; wherefore it is possible that the top of Bed 5 should be reckoned as *Witchellia* and not as *sauzei*, as it is in my paper.[1] Actually I cannot recollect any example of '*Ammonites sauzei*' *(Otoites)* from Milborne Wick. The species '*Sphæroceras perexpansum*' *(Labyrinthoceras)*[2] cited for Bed 4 may really indicate a somewhat different date. But whether just before or just after cannot be said yet: this is a matter possibly to be considered in future faunal analyses.

[1] I, 3, p. 503.
[2] I, 8, pt. 19, pls. cxxxiv & cxxxv.

(B) Haselbury and Hammatoceratids.

In his paper on the Crewkerne district[1] Mr. Linsdall Richardson reproduces W. H. Hudleston's profile[2] of the now disused quarry near the church of Haselbury. When he was preparing his paper he asked my opinion as to the possible date of Bed 3: at that time I could only suggest *bradfordensis* hemera, adding, however, that I did not recollect any *bradfordensis* specimens from Haselbury. Since then the possible solution of the date has occurred to me. The keeled ammonites which Hudleston mentions from this Bed 3 are perhaps represented by the species of *Hammatoceras* and *Erycites*, which have been obtained from Haselbury and the immediate neighbourhood—*H.* cf. *planinsigne* Vacek and *Erycites* aff. *gonionotum* (Benecke): similar forms have been figured by Vacek[3] & De Gregorio[4] from the strata at Cape San Vigilio, Lago di Garda (Italy).

In the Bradford-Abbas district occur many species of these two genera[5]: they have come from strata mainly dated as *murchisonæ* hemera, though partly or occasionally as *bradfordensis*. But, when faunal analysis comes to be applied, it is seen that the synchronization of such species with *murchisonæ* (that is, the Ludwigoids), on the one hand, or with *bradfordensis* (that is, *Brasilia* spp.), on the other, becomes rather doubtful. At the Italian locality are few or no species that can be properly reckoned as either Ludwigoids[6] or *Brasilia*, but Hammatoceratids are abundant. In the Hebrides the Ludwigoids are especially abundant, but the Hammatoceratids are unknown. In Dorset–Somerset Ludwigoids associated with the characteristic brachiopod, the so-called *Waldheimia anglica*, are of fairly wide distribution and not uncommon, but Hammatoceratids are localized and particularly rare. At Haselbury both Ludwigoids and Hammatocerata are rare, for the quarry was not a productive one so far as ammonites are concerned; but Hudleston notices for Bed 4 *Ammonites murchisonæ* and *Waldheimia anglica*, and for Bed 3 he records keeled ammonites: evidently they were unfamiliar to him—had they been of *murchisonæ* or *concavus* (that is, *bradfordensis*) type,

[1] IX, 4, p. 165. [2] VI, p. 41.
[3] XI. [4] IV. [5] I. 1, p. 661.

[6] So far as the Ludwigoids are concerned, this statement may seem particularly rash, for De Gregorio says (IV, p. 11) 'L'*Harpoceras Murchisonæ* est très-commun à S. Vigilio, et c'est une des espèces les plus caractéristiques de cette faune.' This illustrates the necessity for precision in palæontological identification. The specimens which he figures (IV, pl. iii) as *Harpoceras murchisonæ* with various qualifying terms show no species agreeing strictly with *Ammonites murchisonæ* itself, possibly no Ludwigoids at all, certainly not the *murchisonæ* fauna of the Hebrides nor of Dorset–Somerset, nor of other areas; while the list of species of widely different dates which he gives as possible varieties or mutations of *A. murchisonæ* show how greatly outward similarity may mislead. His *Harpoceras murchisonæ* includes a variety of types, some indicative of *Ancolioceras* date and perhaps of earlier hemeræ, some more or less suggestive of *bradfordensis* date, some perchance indicative of strata of even later dates.

it may be presumed that he would have appended some less general term.

On the assumption that at Haselbury the *Hammatocerata* occupy a higher bed, and are of later date than the Ludwigoids, which would lead to a theory of a Hammatocerate-Erycite horizon as distinct, that is, of later date than that of Ludwigoids, the facts of distribution could be explained. In Italy strata of *murchisonæ* hemera are absent or only represented in part, but those of a Hammatocerate-Erycite hemera are present. In the Hebrides, the former was very conspicuous, but there is as yet no evidence for the latter. In Dorset–Somerset the strata of the *murchisonæ* hemera are developed over a wide area; but those of the Hammatocerate date are wholly destroyed in some places, and partly removed in others. At Haselbury a bed assumed to be that of Hammatocerate date is preserved in sufficient thickness to attract attention as a deposit superior to that yielding '*Ammonites murchisonæ.*'

More analysis on these ines may suitably come later, and will be of greater value if and when some of the species of Hammatocerates can be figured. But, meanwhile, it may be advisable to consider the possibility of a Hammatocerate-Erycite date, as intermediate between those of *murchisonæ* and *bradfordensis*, and to date Bed 3 of Haselbury in Hudleston's (and Mr. Richardson's) communications as Hammatocerate-Erycite? rather than as '*bradfordensis?*'

The Cotteswold evidence seems in favour of this view. There between the Pea Grit (*murchisonæ* hemera) and Oolite Marl (*bradfordensis*) is a thick mass of poorly fossiliferous, perhaps non-ammonitiferous freestone with a more or less eroded surface: this deposit, in part at any rate, and the subsequent erosion (prior to *bradfordensis*) would mark the time required for laying down a Hammatocerate-Erycite stratum in other areas.

A short record of the chronological succession and geographical occurrences of some of the principal Hammatoceratid forms shows the faunal repetition and the limited extent—in some areas—over which the particular strata have been preserved: it is the earliest of these horizons that has come so much into discussion in connexion with the Watton Bed (see p. 387).

TABLE V—HAMMATOCERATIDS: CHRONOLOGICAL SUCCESSION AND GEOGRAPHICAL OCCURRENCE.

——— Intervening hemeræ omitted.

Hemeræ.	Fauna and Localities.
Eudmetoceras. [*discites*/*concava*].	*Eudmetoceras* spp.[1], *Euaptetoceras.*[1] Bradford Abbas district; Beaminster district (Dorset); Lago di Garda (Italy).
———	
'Hammatocerate'-Erycite. [*bradfordensis*/*murchisonæ*].	'*Hammatoceras,*' *Erycites, Abbasites,*[2] *Ambersites.*[3] Dorset and Somerset; Normandy; Lago di Garda; Lombardy (Italy); Monte Grappa (Italy); Bakony (Hungary).
———	

[1] I, 8, pls. clxxix, clxxx, ccxcix. [2] I, 8, pl. ccxxxvi. [3] I, 8, pl. ccxxxvii.

Hemeræ.	Fauna and Localities.
scissum.	*Bredyia* spp.
[*Ancolioceras opaliniforme*].	Burton Bradstock (Dorset); Cotteswolds (Gloucestershire) in the Sandy Ferruginous Limestone; Normandy; Rhone Basin?
Hammatoceras (*insigne*). [*Dumortieria dispansum*].	Watton Cliff, Eype (Dorset), Junction-Bed; Cole (Somerset), Bruton Sands; Cotteswolds, Cephalopod Bed; widespread on the Continent.

VI. A Palæontological Note—*Tetrarhynchia thorncombiensis*, nom. nov.

J. F. Walker identified specimens of this characteristic fossil from the Thorncombe bed as his *Rhynchonella northamptonensis*, and it is presumably the same form from the same deposit at North Allington, near Bridport, that he called '*Rhynchonella tetrahedra*, var. *northamptonensis*.'[1] But the Thorncombe form certainly is not the same species as that from Northamptonshire,[2] for that has clean-cut, sharp ribs; whereas the Thorncombe fossil has blunt, somewhat rounded-off ribs, and has a general smoothed-off appearance. As the two forms are certainly not contemporaries, as the Thorncombe fossil marks a particularly distinctive horizon on the Dorset coast, and as it has been frequently necessary to cite the name, it seems preferable to give it a distinct appellation rather than to perpetuate one which will require changing. I have selected a type to be figured in the proposed palæontological sequel to this paper, where it is also hoped to figure and describe various ammonites and brachiopods, which have special bearing on the chronology of Lias-Oolite rocks as well as giving evidence for widespread deposition of certain deposits.

VII. Bibliography.

I, 1. Buckman, S. S. 'The Descent of *Sonninia* & *Hammatoceras*' Q.J.G.S. vol. xlv (1889) p. 651.
2. Do. 'On the So-called "Upper-Lias Clay" of Down Cliffs' Q.J.G.S. vol. xlvi (1890) p. 518.
3. Do. 'The Bajocian of the Sherborne District: its Relation to Subjacent & Superjacent Strata' Q.J.G.S. vol. xlix (1893) p. 479.
4. Do. 'Homœomorphy among Jurassic Brachiopoda' Proc. Cotteswold Nat. Field-Club, vol. xiii. pt. 4 (1901) p. 231.
5. Do. 'Certain Jurassic (Lias-Oolite) Strata of South Dorset, & their Correlation' Q.J.G.S. vol. lxvi (1910) p. 52.
6. Do. 'The Brachiopoda of the Namyau Beds, Northern Shan States (Burma)' Palæontologia Indica, n.s. vol. iii, No. 2, 1917.
7. Do. 'Jurassic Chronology: I—Lias' Q.J.G.S. vol. lxxiii (1917–18) p. 257.
8. Do. 'Type-Ammonites' III & IV, 1919-22.
9. Do. 'Jurassic Chronology: I—Lias: Supplement 1, West England Strata' Q.J.G.S. vol. lxxvi (1920) p. 62.

II. Davidson, Thomas. 'Monograph of the British Fossil Brachiopoda' (Pal. Soc.) iv, pt. ii, no. 1, Suppl. to the Jurassic & Triassic Species, 1876; no. 2, 1878; Appendix to Suppl., 1884.

---

[1] XII, p. 438.
[2] II, 1878, p. 199, Suppl. pl. xxix, figs. 7–12: fig. 7 may be taken as lectotype of the species.

III. DAY, E. C. H. 'On the Middle & Upper Lias of the Dorsetshire Coast' Q. J. G. S. vol. xix (1863) p. 278.
IV. DE GREGORIO, A. 'Monographie des Fossiles de S. Vigilio' Ann. Géol. Pal. livr. 5, 1886.
V. EUDES-DESLONGCHAMPS, E. F. G. 'Études sur les Étages Jurassiques inférieurs de la Normandie' 1864.
VI. HUDLESTON, W. H. 'A Monograph of the British Jurassic Gasteropoda: Part I—Gasteropoda of the Inferior Oolite' (Pal. Soc.) 1887–1896.
VII. MOORE, CHARLES. 'On the Middle & Upper Lias of the South-West of England' Proc. Somerset Arch. Soc. vol. xiii (1867) p. 119.
VIII. PARONA, C. F. 'Nuove Osservazioni sopra la Fauna & l'Età degli Strati con *Posidonomya alpina* nei Sette Comuni' Palæont. Italica, vol. i (1895) p. 1.
IX, 1. RICHARDSON, L. 'A Handbook to the Geology of Cheltenham & Neighbourhood' 1904.
2. Do. 'Report of an Excursion to Bridport, Beaminster, & Crewkerne' Proc. Geol. Assoc. vol. xxvi (1915) p. 47.
3. Do. 'The Inferior Oolite & Contiguous Deposits of the Doulting-Milborne Port District (Somerset)' Q. J. G. S. vol. lxxi (1915–16) p. 473.
4. Do. 'The Inferior Oolite & Contiguous Deposits of the Crewkerne District (Somerset)' Q. J. G. S. vol. lxxiv (1918–19) p. 145.
X. STRICKLAND, H. E., & BUCKMAN, J. 'Outline of the Geology of the Neighbourhood of Cheltenham, by R. I. Murchison' new ed. 1844.
XI. VACEK, M. 'Fauna der Oolithe von Cap San Vigilio, &c.' Abhandl. K. K. Geol. Reichsanst. vol. xii (1886) p. 57.
XII. WALKER, J. F. 'On Liassic Sections near Bridport (Dorsetshire)' Geol. Mag. 1892, p. 437.
XIII. WITCHELL, E. 'The Geology of Stroud & the Area drained by the Frome' 1882.
XIV. WOODWARD, H. B. 'The Jurassic Rocks of Britain: vol. iii, The Lias of England & Wales' Mem. Geol. Surv. 1893.

VIII. APPENDICES.

Appendix I—SECTIONS OF THE JUNCTION-BED AND CONTIGUOUS DEPOSITS. By JAMES FREDERICK JACKSON.

[In brackets remarks on ammonites and brachiopods, by S. S. Buckman.]

(1) Introduction.

My acquaintance with the Junction-Bed dates from 1912; and, in the course of a number of visits to the sections between that date and 1920, several interesting facts bearing on the stratigraphy and palæontology of the bed have come under observation. Some of these facts appear to be new, and others, while not strictly new, have proved to possess a greater significance than had previously been recognized.

(2) Characters of the Junction-Bed (Western Cliffs).

In 1910 Mr. Buckman[1] recognized six separate layers in the Junction-Bed, and referred them to the hemeræ *striatulum*, *lilli (?)*, *bifrons*, *falciferum*, and *spinatum*. Day's '*Pleurotomaria* Bed' was not certainly identified. I have now noted, in addition to the above subdivisions: (i) a lenticular development of clay (O) between the *falciferum* and *spinatum* layers at Down Cliffs;

[1] 'Certain Jurassic (Lias-Oolite) Strata of South Dorset, & their Correlation' Q. J. G. S. vol. lxvi (1910) pp. 57 *et seqq.*

(ii) a thin ferruginous layer (N) with *Harpoceratoides* spp. below the limestones of the *falciferum* layer at Thorncombe Beacon; and (iii) a marly layer (N_1) at the top of the *serrata* bed, also at Thorncombe Beacon.

The blue sandy 'Upper Lias' clays everywhere rest non-sequentially upon the limestones of the Junction-Bed with a remarkably sharp line of division; and, owing to the impersistence of the several layers of the Junction-Bed, the clays may rest upon any layer from the *striatulum* to the *falciferum* zone. Usually, the basal 6 to 12 inches of the clays become more sandy and ferruginous than the main mass above, and this lower portion contains a good many coarse-ribbed *Dumortieriæ* in the condition of friable casts—mostly too rotten to be preserved. A long slender *Belemnites* sp. occurs, but is uncommon.

The lithic character of the *striatulum* layer varies much. In parts it is a hard, rubbly, greyish-yellow limestone; in other sections it is a soft earthy marl, with harder lumps and many limonitic nodules and rolled fossils in a perished condition. At the base is a very thin, impersistent seam of dense laminated limestone showing an obscure mammillated structure, suggestive of 'Cotham Marble.' Whenever the top of the *striatulum* layer can be examined *in situ*, it supplies plain evidence of long-continued quiet erosion, prior to the deposition of the 'Upper Liassic' clays, being planed off perfectly level and displaying ammonites in section—the lower or embedded side well preserved, the upper removed by the erosion. From a fallen block below Down Cliff I collected a large alticarinate *Haugia*, 5322[1] [*Esericeras* aff. *eseri* (Oppel), more umbilicate], almost as accurately cut through as if sliced on a lapidary's wheel: the erosion has removed the shell down to within a few millimetres of the thin high keel almost equally around the greater portion of the circumference of the shell. The *striatulum* layer reposes upon the smoothed top of the *bifrons* layer with a well-marked plane of division, but in perfect conformity. There is no obvious indication of the extensive non-sequence known to exist—a good illustration of the kind of deceptive conformity that has led to so many under-estimates of the importance and real time-value of attenuated deposits.

The *bifrons* layer is a hard tough limestone, usually mottled pinkish-yellow and red. Sometimes the stone is wholly fine-grained and massive; generally it abounds in pebbles of a similar rock, together with derived *Hildoceras bifrons*.[2] The derived ammonites are often reduced to mere limonitic pebbles showing traces of the sutures, etc. Unworn examples of *H. bifrons* occur among the redeposited specimens. The upper 2 or 3 inches of the *bifrons* layer is a greyish-yellow rubbly limestone, abounding in small specimens of *H.* aff. *bifrons* and *Dactylioceras* cf. *commune*;

[1] These numerals refer to my register of specimens.
[2] Trivial names of species are used *sensu lato*.

two or three species of small, thick-ribbed, involute Dactyloids are not uncommon. The *bifrons* layer is separated into two or three minor seams by impersistent planes of erosion, and occasionally the ammonites subjacent to these planes are in a similar condition to those at the top of the *striatulum* layer. Some of the ammonites are embedded in a vertical or highly inclined position, and in one or two instances which came under my observation the ammonite was seen to be truncated by a plane of erosion: a portion having been removed while the remainder continued firmly fixed in the rock, which must have been completely consolidated previous to the erosion. The division between the *bifrons* and *falciferum* layers is often rather obscure, and falsely suggestive of a passage.

The *falciferum* layer is a very hard tough limestone of a yellowish-pink colour, often mottled with red blotches; occasionally it is rather greenish. Sometimes the rock is fine-grained and compact; more often it is highly conglomeratic, containing broken and rolled *Harpocerata* and pebbles of a similar limestone. As in the *bifrons* layer, there are minor layers separated by planes of erosion. Apart from *Harpoceras falciferum*, fossils are uncommon, and all are very difficult to extract on account of the intense hardness of the stone.

The *falciferum* layer frequently rests directly upon a planed-off surface of 'marlstone,' but in places it appears to be transitional from a thin, earthy, ferruginous seam with *Pleurotomariæ* and other gastropods—presumably the '*Pleurotomaria* Bed' of Day.[1]

That writer's description is so vague that it is difficult to determine whether he considered the '*Pleurotomaria* Bed' to be a separate layer at the base of the 'Upper Lias' limestones, or merely the highest portion of the 'marlstone.' Mr. Buckman has observed an impersistent seam with nests of *Pleurotomariæ* at the top of the lower or *spinatum* layer of 'marlstone,' which he considers to be the true '*Pleurotomaria* Bed.' I have not noticed any very definite '*Pleurotomaria* Bed,' although *Pleurotomariæ* are fairly common in the *serrata* bed and rare in the main mass of the lower or *spinatum* layer. It is, perhaps, doubtful whether there is any particular horizon especially entitled to the term '*Pleurotomaria* Bed.'

At Down Cliff a lenticular deposit of clay intervenes between the *falciferum* layer and the 'marlstone'; but, since no fossils were obtained, it is impossible to say anything as to the exact date of this clay-band. The occurrence of a lenticle of clay within the Junction-Bed is noteworthy.

The *spinatum* layer or 'marlstone,' when fully developed, is divisible into two seams. The upper, Mr. Buckman's *serrata* bed, is usually a fine-grained oolitic limestone with a rich assemblage of well-preserved fossils: occasionally it is conglomeratic. The

[1] 'On the Middle & Upper Lias of the Dorsetshire Coast' Q. J. G. S. vol. xix (1863) p. 288.

lower portion of the 'marlstone' is a harder and much coarser rock, and is often highly conglomeratic. Most of the pebbles are made up of a similar coarse 'marlstone'; but pieces of a compact blue limestone and micaceous sandstone occur. Many large flat pebbles are thickly encrusted with a small *Serpula* and riddled by *Lithophagus* borings, the shells sometimes remaining in the crypts. There does not appear to be any definite line of division between the two layers of 'marlstone.' The base of the 'marlstone' is always highly irregular, on account of the presence of large branching and tuberous concretions of calcareous micaceous sandstone. The 'marlstone' rests upon an impersistent stratum of blue sandy clay, or directly upon the underlying Yellow Sands.

(3) Details of Sections (Western Cliffs).

I think that it will be convenient to describe the sections from Down Cliff to Thorncombe Beacon before dealing with the exposure at Watton Cliff, east of Eypesmouth, which exhibits so remarkably abnormal a facies as to call for special consideration.

The following scheme of lettering of the several layers of the Junction-Bed and the contiguous deposits will be utilized throughout the sections to be described below:—

SCHEME OF LETTERING.

Dumortieria	A.	*lilli (?)*	K.
	B.	*bifrons*	L.
	C.	*falciferum*	M.
Hammatoceras	D.	pre-*falciferum*	N.
dispansum	E.	clay within Junction-Bed	O.
struckmanni	F.	*serrata*	P.
pedicum	G.	*Pleurotomaria (?)*	Q.
eseri	H.	*spinatum*	R.
striatulum	I.	clay below Junction-Bed	S.
variabilis	J.	yellow sands	T.
thorncombiensis	U.		

SECTION I—THE JUNCTION-BED AND CONTIGUOUS DEPOSITS, MEASURED *in situ* NEAR THE WESTERN END OF DOWN CLIFF.

Hemeræ.		Strata and Fauna.	*Feet*	*inches.*
Dumortieriæ.	A+B.	Blue sandy 'Upper Lias' clay. Coarse-ribbed *Dumortieriæ.*		
		Impersistent irony scale.	0	0½
Lilli?— *Bifrons.*	K+L.	Pale conglomeratic limestone, with a very smooth top.	0	2
		Hildoceras bifrons, Dactylioceras cf. *commune, Rhynchonella.* [5217, a fissicostate Rhynchonellid, gen. et sp. nov.; 5211 *a*, *Stolmorhynchia* cf. *bothenhamptonensis* (Walker); 5211 *b*, *St.* cf. *bouchardi* (Davidson), but with too strong a fold.]	0	9
		Faintly-marked parting.		
Falciferum.	M.	Yellowish limestone with red blotches. *Harpoceras falciferum, Dactylioceras* sp.	0	7-8
Spinatum.	R.	Oolitic conglomeratic 'marlstone,' with a very smooth top. *Belemnites* spp., *Pseudopecten æquivalvis.*	0	6-9
	T.	Soft, yellowish, clayey sands.		

On the coast the westernmost exposure of the Junction-Bed is near the western end of Down Cliff, where the *falciferum* layer rests directly upon the 'marlstone.' A few yards east of this first exposure a clay-band comes in between these layers, and continues almost to the eastern extremity of Down Cliff, where it passes into a band of earthy marly stone. Section I shows the sequence near the western end of Down Cliff.

Section II shows the sequence near the eastern end of Down Cliff. Here the *striatulum* layer is present, and the inter-*falciferum-spinatum* clay-band reaches its maximum thickness.

SECTION II—THE JUNCTION-BED AND CONTIGUOUS DEPOSITS, MEASURED *in situ* NEAR THE EASTERN END OF DOWN CLIFF.

Hemeræ.		Strata and Fauna.	*Feet*	*inches.*
Dumortieriæ.	A.	Blue, sandy, 'Upper Lias' clay. Coarse-ribbed *Dumortieriæ* in friable condition; *Belemnites* sp.		
		Transitional from		
	B.	Yellowish sandy clay with ferruginous streaks.	1	0
Striatulum. [Traces of *pedicum* and *eseri* faunas].	I [G + H].	Grey earthy limestone, with many rotten limonitic nodules and rolled fossils. *Grammoceras* spp. common. Top planed off very smooth.	0	2
		[5317, *Grammoceras* aff. *audax* S. B.; 4989, *G.* aff. *comptum* Haug; 5320 *a*, *G. penestriatulum* S. B.; 5319, *G.* aff. *penestriatulum* S. B.; 5315, 5318, *G.* aff. *penestriatulum* S. B., but coarsely-ribbed; 5320, *G.* aff. *striatulum*; 5317 *a*, *G.* aff. *thouarsense*, rather strongly ribbed; 5316, *Pseudogrammoceras* cf. *pachu* S. B., but more finely ribbed (*pedicum* fauna); 5322, *Eseriiceras* aff. *eseri* (Oppel), but more umbilicate.]		
		Strong parting.		
Lilli (?)	K.	Whitish rubbly limestone. Small *Hildoceras bifrons*, *Rhynchonella* sp.	0	4
		[5211 (2 examples), *Stolmorhynchia bouchardi/bothenhamptonensis*.]		
		Obscure parting.		
Bifrons.	L.	Pinkish-yellow conglomeratic limestone. *Hildoceras bifrons.*	0	7
		Obscure parting.		
Falciferum.	M.	Similar limestone, but showing bright red blotches. *Harpoceras falciferum.*	0	6
Pre-*falciferum.*	O.	Very stiff, greyish-yellow, mottled clay. No fossils observed.	0	10
Spinatum.	R.	Oolitic conglomeratic 'marlstone,' with a markedly planed-off top. *Belemnites* spp. common, *Pseudopecten æquivalvis, Rhynchonella tetraëdra.*	0	7
		Resting with very irregular base upon		
	T.	Yellowish clayey sands.		

The 'marlstone' of the Down-Cliff sections is almost certainly only the lower layer of that deposit. No evidence of the upper or *serrata* bed was found at Down Cliff, and the planed-off top of the 'marlstone' points to a considerable non-sequence.

The 'marlstone' at Down Cliff rests directly upon the Yellow Sands, without the intervention of the clay-bed seen in Doghus Cliff and Thorncombe Beacon. At the eastern end of Down Cliff a thin layer of sandy clay is beginning to come in beneath the 'marlstone,' and it thickens rapidly towards Doghus Cliff.

Section III illustrates the thinning-out and change in lithic character of the lenticle of clay O.

SECTION III—THE JUNCTION-BED, MEASURED IN A BLOCK ON THE TALUS AT THE EASTERN END OF DOWN CLIFF.

Hemeræ.		Strata and Fauna.	Feet	inches.
Bifrons.	L.	Massive mottled limestone. *Hildoceras bifrons.*	1	2
		Obscure parting.		
Falciferum.	M.	Whitish and pink, conglomeratic, mottled limestone; ferruginous near the base.	0	7
		Apparently transitional from		
Pre-*falciferum?*	O.	Greyish-white, nodular, earthy stone, with marly streaks and patches.	0	3–5
		Apparently transitional from		
Spinatum.	R.	Oolitic conglomeratic 'marlstone.' *Belemnites* spp., *Paltopleuroceras* sp. [5168, *Paltopleuroceras* cf. *pseudocostatum* Hyatt, but more spinose.] Seen to	0	8

The 'marlstone' here is almost certainly the lower or pre-*serrata* layer, and the '*Pleurotomaria* Bed' Q is undoubtedly absent: hence the appearance of a transition from R to M must be considered illusory. In formations where 'contemporaneous' erosion has been active (especially if the materials be at all soft) so much intermixture of matrices has taken place along the line of contact of

SECTION IV—THE JUNCTION-BED, MEASURED IN A BLOCK ON THE TALUS BELOW DOGHUS CLIFF.

Hemeræ.		Strata and Fauna.	Feet	inches.
Bifrons.	L.	Pinkish-yellow mottled limestone. *Hildoceras bifrons*, rolled fragments of *Harpoceras* sp., *Rhynchonella* cf. *moorei.*	0	8
		Obscure parting.		
Falciferum.	M.	Similar, but harder, limestone. Very large *Harpoceras falciferum*, *Dactylioceras* spp., '*Aulacothyris*' sp.	0	7
		[An inverted Terebratulid (5218) a little like *T. aspasia* Meneghini & Zittel, but rounder, not nearly so sulcate, and possessing a smaller beak.]		
		Obscure parting.		
Pleurotomaria ?	Q.	Impersistent earthy ferruginous seam. *Pleurotomariæ*, *Amberleya*, *Cylindrites*, *Trochus*; *Plicatula* cf. *spinosa.*	0	1–2
		Resting upon a rather irregular surface of		
Spinatum.	R.	Rough conglomeratic 'marlstone.' *Paltopleuroceras spinatum*, *Discohelix sinister*, *Pteria* '*inæquivalvis*,' *Pseudopecten æquivalvis*, *Modiola*, *Ostrea*, etc.; *Rhynchonella acuta*, *Rh. furcillata*, *Rh. tetraëdra*, *Terebratula punctata*, *Zeilleria cornuta*, *Z. quadrifida*, *Spiriferina oxygona.*	0	9
		[5137, *Paltopleuroceras* cf. *pseudospinatum* Hyatt, but has many more ribs; 5689 (2 ex). *Homœorhynchia acuta*, medium size; 5361, *Furcirhynchia furcata* S. B.; 1830, *Tetrarhynchia* cf. *tetraëdra.*]		

newer with older deposits, which may be perfectly 'conformable,' that a false appearance of transition results: and such pseudo-sequences may give rise to very erroneous views as to the real importance of formations such as the Junction-Bed or the Inferior Oolite.

I was unable to measure a satisfactory section *in situ* at Doghus Cliff; but some blocks on the talus showed features of considerable interest. Section IV (p. 441), which is taken from one of these blocks, is important, in that it shows what Mr. Buckman considers to be the '*Pleurotomaria* Bed.' The 'marlstone' here does not appear to include any representative of the *serrata* bed. The '*Pleurotomaria* Bed' (?) is impersistent—it is absent from the great majority of the blocks on the talus.

As an illustration of the remarkably variable characters of the Junction-Bed, the following section (V) of another block on the talus of Doghus Cliff is of some interest.

SECTION V—THE JUNCTION-BED, MEASURED IN A BLOCK ON THE TALUS BELOW DOGHUS CLIFF.

Hemeræ.		Strata and Fauna.	Feet	inches.
Lilli (?).	K.	White rubbly limestone, with ochreous nodules. Worn *Hildoceras* aff. *bifrons*, *Dactylioceras* spp.; *Rhynchonella* sp.	0	3
		[1763, 4994, 5279, 5308, micromorph Dactyloids presenting the aspect of *Ammonites dayi* Reynès; 5278, micromorph Dactyloid of *Cœloceras* aspect; 1777, 4991, 5212 (2 examples), 5309, *Stolmorhynchia bothenhamptonensis* Walker.]		
		Very obscure parting.		
Bifrons.	L.	Pinkish-yellow mottled limestone. *Hildoceras bifrons.*	0	10
		Resting upon the markedly planed-off top of		
Serrata-spinatum.	P+R.	Light-brown oolitic 'marlstone,' becoming rough and conglomeratic towards the base. Many small gastropods (*Amberleya*, *Cerithium*, *Pleurotomaria*, *Trochus*, etc.) near the top. *Rhynchonella acuta*, *Rh.* spp., *Zeilleria cornuta*, *Spiriferina* sp., *Serpulæ*, etc.	1	2
		[5155 (2 ex.), 5687, *Homœorhynchia acuta* (large); 5163 (2 ex.), *Rudirhynchia* sp. = *Rhynchonella fallax* (Deslongchamps) Walker, but presumably new; 5360, *Quadratirhynchia* cf. *crassimedia* S. B.; 5686, *Stolmorhynchia buchardi*; 5159, *Spiriferina oxygona* Davidson *non* Deslongchamps, cf. *Sp. signensis* Buvignier.]		

Here the *falciferum* layer and the '*Pleurotomaria* Bed' (?) are absent, while the *serrata* bed is present. The lower layer of the 'marlstone' appears to pass up into the *serrata* bed without any break; probably this false appearance of transition is due to a mingling of matrices along the line of junction.

Scattered about on the talus of Doghus Cliff are several large slabs of (presumably) 'Upper Lias' limestone, showing a worn and pitted surface covered with the adherent valves of a small species of *Ostrea* and, more rarely, a large cristate *Serpula*. No satisfactory evidence sufficient to date the non-sequence thus indicated was observed, and the question must be left open to future research.

The clay which was noted as coming in beneath the 'marlstone' at the eastern end of Down Cliff thickens rapidly under Doghus Cliff, where a thickness of over 10 feet can be seen. The maximum is at Thorncombe Beacon, where the thickness of clay is not less than 16, nor more than 20 feet.

The 'marlstone' attains its maximum thickness in the central portion of the Thorncombe-Beacon cliffs; but, unfortunately, owing to the steepness of these cliffs, it can scarcely be reached *in situ*. However, a very large recent slip has brought down to the shore an abundance of blocks: these yield a rich fauna, and show most of the subdivisions of the Junction-Bed, with the exception of the *striatulum* layer, which, as Mr. Buckman has pointed out,[1] is probably absent from Thorncombe Beacon. Section VI shows two layers N, N_1 not previously noticed.

SECTION VI—THE JUNCTION-BED, MEASURED IN A VERY LARGE BLOCK ON THE TALUS BELOW THE CENTRAL PORTION OF THORNCOMBE BEACON.

Hemeræ.		Strata and Fauna.	Feet	inches.
Falciferum.	M.	Massive limestone, mottled greenish and pink. *Harpoceras falciferum*, *Belemnites* sp.	0	9
		Transitional from		
Pre-*falciferum.*	N.	Earthy ferruginous seam. *Harpoceras* spp., *Phylloceras* sp., *Pteria* '*inæquivalvis*,' *Trapezium* sp., small gastropoda.	0	2-3
		[5220*a*, *Harpoceratoides kisslingi (?)* Haug; 5219, 5220, *H.* cf. *kisslingi* Haug, but very finely ribbed; 5169, a micromorph *Phylloceras*, like *Ammonites calypso* D'Orbigny, 'Terr. Jurass.' 1845, pl. cx, but with straighter constrictions and a smaller umbilicus.]		
		Obscure parting.		
Pre-*falciferum.*	N_1.	Hard, greyish-white, nodular, earthy limestone with *Harpoceras* spp. at the top of the bed. The lower portion of the bed is a soft yellowish-white rock with scattered oolitic grains, which appears to pass imperceptibly into the earthy limestone at the top. *Rhynchonella acuta (?)*, *Rh.* sp. in the lower portion. A layer of large *Belemnites* spp. near the base.	0	3–5
		From the top of the bed: [5222, *Harpoceratoides?* aff. *fellenbergi* Haug; 5221, *Harpoceratoides?* sp.]		
		Very obscure parting.		
Serrata.	P.	Finely oolitic, light-brown 'marlstone.' *Paltopleuroceras spinatum*, large *Harpoceras* sp., large *Belemnites* spp., *Cerithium* sp., *Pleurotomariæ* spp., *Trochus* sp., etc.; *Pseudopecten æquivalvis*; *Rhynchonella acuta*, *Rh. furcillata*, *Rh. serrata*, *Rh.* '*tetraëdra*,' *Rh.* spp., *Terebratula punctata*, *Zeilleria* spp., *Spiriferina* sp.	1	0
		[5167, a brephomorph of *Paltopleuroceras* cf. *spinatum* (D'Orbigny), showing the coronate stage strongly spined, before the advent of a carina; 5231, Harpoceratoid = *Harpoceras radians* Wright, Mon. Lias Amm. (Pal. Soc. 1882) lxxvi, 4–6.		

[1] Q. J. G. S. vol. lxvi (1910) p. 82.

Hemeræ.	Strata and Fauna.	Feet	inches.
	1827, 5191 (4 ex.), *Homœorhynchia acuta* (large); 5156, *Furcirhynchia furcata* S. B.; 5192, *Prionorhynchia serrata*; 5195, *P. quinqueplicata*; 5157 (2ex.), *Quadratirhynchia* cf. *crassimedia* S. Buckman; 5196, *Stolmorhynchia* cf. *bothenhamptonensis*; 5197, *S. bouchardi*; 5192 *a*, *Rudirhynchia (?)* sp.=*Rhynchonella fallax* (Deslongchamps) Walker, but presumably new; 5194, *Rudirhynchia ?* cf. *Terebratula triplicata fronto* Quenstedt; 5160, *Lobothyris punctata*; 1845, *Zeilleria cornuta*; 1844, *Z.* aff. *cornuta*; 5343, *Z.* cf. *quadrifida*; 5161, *Z.* sp.]		
	Apparently transitional from		
Spinatum.	R. Rough conglomeratic 'marlstone,' with large irregular concretions of calcareous sandstone at the base. *Rhynchonella* '*tetraëdra*,' *Rh.* spp., *Terebratula punctata*, *Zeilleria* sp., *Spiriferina* sp., etc. [3726, *Tetrarhynchia media tetraëdra*; 4956, *Quadratirhynchia* aff. *crassimedia*; 5359, *Q. crassimedia sphæroidalis*; 4523, *Q.* aff. *sphæroidalis*; 5199, *Lobothyris punctata*; 4951, *L. subpunctata*; 1843, 5190, *Aulacothyris florella*; 1838, 5201, *Zeilleria mariæ*; 5202, *Z. subnumismalis*; 5200, an inverted Terebratulid (gen. nov.); 5331, *Spiriferina oxygona* (Davidson); 1841, 5158, *Sp.* sp. like *oxygona* Davidson, but with a costate fold; 1840, *Sp.* sp. (smooth)—cf. *Spirifer rostratus* Davidson, Mon. Brit. Ool. Lias. Brach. III, 1851, ii, 3.]	0	4-6

The presence of *Harpoceratoides* and the absence of *Paltopleuroceras* indicate that at least the upper portion of layer N_1 belongs to the 'Upper Lias.' The date of the lower portion of N_1 is very doubtful; no fossils of zonal importance were observed, and there are only very obscure indications of any break at the base.

The presence in the *serrata* bed of a large Harpoceratoid bearing a superficial resemblance to *Harpoceras falciferum* is of some interest, in that it enables us to understand how early observers came to record '*Ammonites serpentinus*,' etc., from the 'marlstone' portion of the Junction-Bed. No real credence can be given to the alleged occurrence of typical 'Upper Lias' species in the 'marlstone.'

Pleurotomariæ occur in the *serrata* bed, but no indication of any definite '*Pleurotomaria* Bed' was observed.

The brachiopoda are the most abundant fossils of the two 'marlstone' layers. *Rhynchonella serrata* is fairly common in the *serrata* bed, to which it would appear to be confined. Large specimens of *Rhynchonella acuta*, often in a fine state of preservation, are common in the *serrata* bed; *Rh. acuta* is very much rarer in the basal 'marlstone' layer, so much so that an abundance of that form in a block is strongly suggestive of the *serrata* bed. *Rh. acuta* is markedly rare at Down Cliff, where the *serrata* bed is considered to be absent.

Section VII was measured *in situ* near the eastern end of Thorncombe Beacon, only a short distance east of the position from which the block measured in Section VI must have fallen. It shows the most attenuated facies of the Junction-Bed yet observed on the coast.

SECTION VII—THE JUNCTION-BED AND CONTIGUOUS DEPOSITS, MEASURED *in situ* CLOSE TO THE EASTERN END OF THORNCOMBE BEACON.

Hemeræ.		Strata and Fauna.	*Feet*	*inches.*
Dumortieria.	A + B.	Blue sandy 'Upper Lias' clay. Coarsely-ribbed *Dumortieria* sp. in friable condition.		
		Thin irony scale (impersistent).	0	$0\frac{1}{4}$
Bifrons.	L.	Earthy conglomeratic limestone, with a markedly-smooth top. *Hildoceras bifrons.*	0	5–6
		Strong parting.		
Serrata.	P.	Light-brown, finely oolitic 'marlstone,' yielding *Rhynchonella acuta.* Top planed off very smooth.	0	6–7
		Resting upon		
	S.	Blue sandy clay.		

Sections I to VII will have served to illustrate some of the extraordinary complexities of the Junction-Bed; a larger number of sections would show still further variations.

A few yards east of Section VII the outcrop of the Junction-Bed leaves the cliff-face, and turns inland; when the Junction-Bed reappears at Watton Cliff, east of Eypesmouth, the whole facies is remarkably changed.

(4) The Watton-Cliff Section.

From the last appearance of the Junction-Bed at the eastern end of Thorncombe Beacon to its reappearance at the western end of Watton Cliff, east of Eypesmouth, there is a gap of some three-quarters of a mile.

At Watton Cliff the Junction-Bed is exposed in a particularly inaccessible position. It forms a kind of projecting cornice, high up in the precipitous face of the cliff, on the upcast side of the great fault that throws 'Fuller's Earth' and 'Forest Marble' against the 'Middle' and 'Upper Lias.' According to the Geological Survey,[1] the downthrow is 'at least 425 feet.'

The only published reference to the existence of the Junction-Bed at Watton Cliff that I have been able to find is the following short and inconclusive note by the Geological Survey *(loc. cit.)*:

'East of Eype the cliff again exhibits a portion of the Middle Lias. At the base there are blue clays with *Ammonites margaritatus*, and these are succeeded by the Starfish Bed, the Laminated Beds, and Yellow Sands. These are capped by grey shaly beds, that include a hard band that may be the Junction-Bed of Middle and Upper Lias, with perhaps some portions of the overlying Upper Lias. The higher strata were, however, difficult of access.'

It seems somewhat remarkable that this unique section should have escaped general notice for so many years. It is quite easy to observe from the talus that the Junction-Bed is much thicker here than in the Western Cliffs.

[1] 'The Jurassic Rocks of Britain: the Lias of England & Wales' Mem. Geol. Surv. vol. iii (1893) p. 200.

Section VIII—The Junction-Bed, measured on a Block on the Talus at the Western End of Watton Cliff, East of Eypesmouth.

Hemeræ.	Strata and Fauna.	Feet	inches.
Dumortieria.	A. Traces of blue sandy 'Upper Lias' clay.		
	Transitional from		
	B. Hard, sandy, ferruginous clay with ochreous veins. Coarsely-ribbed *Dumortieriæ* in friable condition; obscure gastropod-remains, fragments of *Isocrinus* sp.	0	3–5
	Transitional from		
	C. Whitish earthy limestone in two irregular layers. A seam of small slender *Belemnites* sp.	0	2–5
	Non-sequence.		
[*Hammatoceras ?*]	D. Intensely hard, finely laminated, lithographic limestone; the laminæ are of various shades of pale brown and bluish grey. The lower portion splits readily into thin platy slabs, covered with fine dendrites; the upper portion is more massive, and breaks with a sub-conchoidal fracture. Many finely-preserved ammonites; no other fossils observed.	0	7–8
	[5323, *Alocolytoceras* cf. *germaini* (D'Orbigny), a smooth cast, ornament almost obliterated; 5684, *Frechiella* aff. *subcarinata* (Young & Bird), a brephomorph, beautifully preserved, with white matrix in the body-chamber: this shows the transition from *Cymbites* to the *Paroniceras* stage, but has not got to the *Frechiella* stage of bisulcate periphery; 5324, 5325*a* & *b*, 5680, 5682, costate forms, more than one species, like *Ammonites rugatulus* Simpson, also like *A. multifoliatus* Simpson, but more costate; 5325, 5679, 5679*b*, costulate to capillate forms, like *A. similis* Simpson, but thinner; 5325*c*, a micromorph of, presumably, *Grammoceras-striatulum* type.]		
	Impersistent earthy parting: non-sequence.		
	D_1. Intensely hard, greyish-yellow, non-laminated, sandy limestone. No recognizable fossils, except fragments of a small *Rhynchonella* sp.	0	5–6
	Apparently transitional from		
	D_2. Massive cream-coloured limestone. *Belemnites* sp.	0	4–5
	Apparently transitional from		
	D_3. Cream-coloured shelly limestone, crowded with *Grammoceras* sp. [5326, *G.* aff. *thouarsense*], especially at the base. Many minute gastropoda: *Amberleya*, *Ataphrus*, *Cerithium*, *Cryptænia*, *Trochus*, etc.; *Rhynchonella* sp., *Isocrinus* sp., echinoid radiole.	0	3–4
	Apparently transitional from		
	D_4. Pale cream-coloured laminated limestone.	0	3
	Distinct parting.		
	D_5. Compact, cream-coloured, laminated limestone, somewhat false-bedded on a minute scale. Fragment of *Nautilus* sp., *Ataphrus* sp.	0	2–10
	Resting unconformably upon		
[*Thorncombiensis.*]	U. Hard yellowish-brown ferruginous rock of 'marlstone' type, almost identical in lithic characters with the *T.-thorncombiensis* Bed of the Western Cliffs. *Rhynchonella* sp. [*Tetrarhynchia thorncombiensis*] common; *Belemnites* sp.; fragment of large *Harpoceras* on the top of the bed, but probably not belonging to it.	0	0–10
	Very irregular base.		
Falciferum ?	M ? Massive, pinkish and yellow mottled limestone.	0	8–9
	Very obscure parting.		
	M_1 ? Similar, but harder limestone. Seen to	0	9–10

There is only one place where it is at all possible to reach the Junction-Bed *in situ* with any degree of safety—a kind of shallow gully or slide, descending from the top of the cliff along the line of fault to the top of the extensive overgrown talus between the inner cliff and the foreshore. I measured a section in the Junction-Bed immediately above a group of three very big fallen blocks on the talus. The total thickness was 4 feet 7 inches; but the only part that could be reached was a joint-face, covered with stalactitic matter which prevented me from recording any detailed measurements. Another section, measured *in situ* a few yards farther east, will be described later on. The accompanying section (VIII) was taken from one of a group of three immense fallen blocks. Other blocks show a very similar development of the Junction-Bed, but with minor variations.

The whitish earthy limestone (C) forms a kind of capping to the lithographic stone (D); but a close examination shows that there is no transition. The base of C fills shallow hollows in D, and cuts across the planes of lamination. The thickness of C is very variable. No fossils of zonal importance were seen.

Little more can be said concerning layer D. Mr. Buckman writes (*in litt.*, February 1921): 'the date of D is very uncertain.' Layers D to D_5 are closely associated, and form a group with very similar lithic characters, but there are small non-sequences. The abundance of minute gastropoda in D_3 is noteworthy.

Below layer D_5 the sequence is very doubtful, and difficult to determine. The rock resembling 'marlstone' (U) is a wedge-shaped mass, about 3 feet long, presumably a portion of a large slab or lenticular cake of stone derived from some lower horizon. Mr. Buckman has determined the *Rhynchonella* to be *Tetrarhynchia thorncombiensis*, which is abundant in a bed some little distance down in the Yellow Sands of the Western Cliffs. Presumably, therefore, this redeposited mass was derived from the *T.-thorncombiensis* Bed. Other blocks show similar lumps of stone, and derived specimens of *T. thorncombiensis* and *Belemnites* sp. are common.

The age of layers M (?) and M_1 (?) is doubtful. In lithic characters they remind one of the more massive portions of the *falciferum* layer of the Western Cliffs, and are very similar to layer M_1 (?) of Section IX (which yielded some big specimens of *Harpoceras falciferum*). In some blocks pieces of the *T.-thorncombiensis* Bed and redeposited *Rhynchonellæ* are enclosed in the limestone layers M (?) and M_1 (?).

At Watton Cliff the clay below the Junction-Bed is absent, and the presence of derived masses of the *T.-thorncombiensis* Bed indicates that erosion has removed some thickness of the upper portion of the Yellow Sands.

Section IX (p. 448) was measured *in situ* immediately west of the point where the Lias is finally cut off by the faulted Bathonian rocks, and only some 30 feet east of the position from which the block measured in Section VIII must have fallen.

SECTION IX—THE JUNCTION-BED AND CONTIGUOUS DEPOSITS, MEASURED *in situ* AT THE WESTERN END OF WATTON CLIFF.

Hemeræ.		Strata and Fauna.	Feet	inches.
Dumortieria.	A + B.	Blue sandy 'Upper Lias' clay.		
		Marked non-sequence.		
Falciferum ?	M (?).	Very hard mottled limestone, with large *Harpoceras falciferum* common at the top. [5230, *Harpoceras* cf. *mulgravium*.] Top much iron-stained and planed off smooth.	0	8–9
		Transitional from		
	M_1 (?).	Harder, conglomeratic, mottled limestone. Small *Harpoceras ?* sp. near the top. [Micromorph, not *Harpoceras*.]	0	10–11
		Irregular parting.		
[*Thorncombiensis*.]	U (?).	Soft, earthy, yellowish 'marlstone.' *Belemnites* sp., *Syncyclonema* sp., *Rhynchonella* sp. [5232, *Tetrarhynchia thorncombiensis*].	0	6
		Apparently transitional from		
	U_1 (?).	Rough lumpy 'marlstone,' soft and highly ferruginous.	0	6
		Apparently transitional from		
	U_2 (?).	Soft earthy 'marlstone' crowded with crinoid fragments.	0	2–3
		Apparently transitional from		
		Lumpy ironshot marlstone, somewhat oolitic.		
	U_3 (?).	Obscure fragment of *Harpoceras* in friable condition. Seen to	0	7
		(About 1 foot obscured by slipped material.)		
	T.	Soft yellow sands.		

The most interesting feature of this section is the absence of the lithographic and other limestones of layers D to D_5. That all these beds should have disappeared in so short a distance is a good example of the remarkably sudden variations to be met with in the Junction-Bed.

Layers M (?) and M_1 (?) are almost certainly the continuation of layers M and M_1 (?) in Section VIII. Presumably layer M (?), at least, is of *falciferum* date—unless the specimens of *Harpoceras falciferum* are redeposited.

Layers U (?) to U_3 (?) are only separable with uncertainty, as the deposit is very irregular, lumpy, and confusedly mingled. The fossils characteristic of the 'marlstone' of the Western Cliffs appear to be absent, and much of the rock is more like the *Tetrarhynchia-thorncombiensis* Bed and other hard bands in the Yellow Sands than the true 'marlstone.' Mr. Buckman considers that the whole of layers U (?) to U_3 (?) is pre-*spinatum* material redeposited.

[During further work in 1921 I discovered a block of the Junction-Bed (about 8 feet long) lying partly embedded in talus some few feet west of the group of three blocks measured in Section VIII. At the eastern end, the 'Upper Lias' clay A+B rests upon the earthy limestone C (4 to 5 inches) and the lithographic stone D (7 to 8 inches); at the western end it rests upon the grey limestone D_1, C and D having been removed by denudation prior to the deposition of the 'Upper Lias' clay.]

Appendix II—THE UPPER LIAS SUCCESSION. By LEONARD FRANK SPATH, D.Sc., F.G.S., JOHN PRINGLE, F.G.S., ANDREW TEMPLEMAN, and S. S. BUCKMAN, F.G.S.

(A) Introduction. (S. S. B.)

Some time after my paper had been sent in to the Society, some important excavations were made in the Upper Lias of Somerset, which throw much light on the points discussed in pp. 390–395. Dr. Spath sent me a summary of the results that he had obtained from a study of a collection made by Prof. D. M. S. Watson: this communication is placed first, because it enters into considerable detail as regards the genera and species of ammonites. Later, Mr. Pringle and Mr. Templeman forwarded a summary of the results of their collecting—particularly important because the beds were collected from almost inch by inch, with extremely happy results. They did not attempt much particularization of ammonites, because their finds were placed in my hands for detailed work. But, although such detailed work cannot be undertaken for some time, it has been possible to make a general survey of the faunal succession. From this information and the study of some Northamptonshire specimens submitted by Mr. Pringle at the same time, it has been possible to construct succession and correlation tables, which, although necessarily imperfect in certain respects, will (it is hoped) become useful bases for further work.

(B) Upper Lias Succession near Ilminster, Somerset. (L. F. S.)

This succession is based on material collected and submitted by Prof. D. M. S. Watson, to whom grateful acknowledgments are tendered. Beds 13 to 15 were collected from at Barrington, beds 4 to 12 at Stocklinch. The highest bed ('Top-Rock' 13) at the latter locality did not yield any ammonites; but Prof. Watson has reasons for considering beds 13–15 to follow on bed 12, as in the succession tabulated below.

Strata.	Horizons.
(a) *Barrington.*	
15. 'Basement Bed of Yeovil Sands' (*Phlyseogrammoceras dispansum*, *Dumortieria ?* sp., *Alocolytoceras ?* sp. juv.)	*Dumortieria ?* to *dispansum.*
14. 'Black Clay,' 6 inches (fauna derived) (*Hammatoceras* cf. *insigne*; *Grammoceras* spp.; *Pseudogrammoceras ?* cf. *grunowi* (Dumortier,[1] *non* Hauer); *Haugia* sp.; v-script *Hildoceras.*)	*struckmanni ?* to *striatulum.*
13. 'Top-Rock' (*Phymatoceras ?* cf. *werthi*)	*variabilis ?*

[1] 'Études Paléontologiques sur les Dépôts Jurassiques du Bassin du Rhône: Lias Supérieur' vol. iv (1874) pl. xiv, figs. 6 & 7.

(b) *Stocklinch.*

Strata.	Horizons.
12. Top 3 feet. (Zones not separated in collecting.) ... (*Hildoceras bifrons*, *H. walcottii* etc.; a stout Dactyloid *(Porpoceras?)* and vermiform *Dactylioceras.*)	*bifrons*, etc.
11. Above Fish-Bed 7 feet 6 inches .... (*Ammonites levisoni*, auctt. *non* Simpson; a stout Dactyloid, more finely costate than '*Cœloceras*'[1] *crassoides*, below.)	*Hildoceratoides.*
10. Above Fish-Bed 7 feet .... (Many young *Harpoceras*; *Hildoceratoides* sp. (of *Mercaticeras* aspect); *Dactylioceras* cf. *vermis*; '*Cœloceras*' cf. *fonticulum.*)	*falciferum* B.
9. 'Brown Bed' (above Fish-Bed 6 feet 6 inches) ... (Main development of *Harpoceras falciferum* sensu stricto; '*Cœloceras*' cf. *crassoides.*)	*falciferum* A.
8. Above Fish-Bed 5½ to 6 feet .... (*Hildaites levisoni* Simpson and *Hildaites* cf. *chrysanthemum* Yokoyama sp.[2]).	*Hildaites.*
7. Above Fish-Bed 4½ to 5 feet .... (*Dactylioceras anguinum* (Reinecke) and other, more vermiform, *Dactylioceras.*)	*anguinum.*
6. Above Fish-Bed 18 inches to 4½ feet (no yield) ...	?
5. Above Fish-Bed 18 inches .... (*Harpoceratoides*, large form, more finely costate than those below.)	?
4. Above Fish-Bed 1 foot .... (*Harpoceratoides alternatus*, *H. kisslingi*, etc.; *Dactylioceras helianthoides* Yokoyama, '*Cœloceras*' sp. juv.; *Phylloceras* sp.; *Elegantuliceras* sp.)	*Harpoceratoides.*
3. Fish-Bed (Clay 18 inches), no yield	?
2. *Leptæna* Bed (1 foot), no yield	?
1. Marlstone.	

(Beds 7–11 with *falciferum*-like *Harpoceras* throughout.)

(C) Two New Sections in the Middle and Upper Lias at Barrington, near Ilminster, Somerset. (J. P. & A. T. Notes in brackets by S. S. B.)

During the year 1920 a quarry was opened in a field on the west side of the cross-roads between Barrington and Stocklinch, and 650 yards south-west of Barrington Church. In the excavation, which was carried down to the base of the Marlstones, about 14 feet of Upper Lias clay and limestones are exposed. An abstract of these beds, numbered in ascending order from 1 to 26, is set forth in the appended section (p. 451). Fuller details await a critical examination of the ammonites.

In the same year a smaller quarry was opened on the west side of Shelway Lane, Barrington; it shows a similar sequence of Middle and Upper deposits on the eastern side of the pit. Beds 1–26 of the Upper Lias can again be seen; but in the roadside above the quarry and in the bank above the adit on the east side of the road additional strata are exposed, carrying the section up

[1] *Cœloceras* sensu stricto, restricted to the *pettos* group, in L. F. Spath, 'Notes on Ammonites' Geol. Mag. 1919, p. 28.

[2] 'Jurassic Ammonites from Echizen & Nagato' Journ. Coll. Sci. Tokyo, vol. xix, No. 20 (1904) pl. ii, fig. 1.

to the brown sands, which are believed to be of *dispansum* date. These higher beds are numbered in continuation with the larger quarry. It should be noted here that the Shelway-Lane quarry also shows a remarkable local wash-out, probably of recent geological date. On the west side of the pit all of the beds above the Marlstone have been broken up to the depth of 14 feet, and re-arranged.

Section I—LIAS, BARRINGTON (EPITOME).

(A) SHELWAY LANE, BARRINGTON.

No.	Strata.	Thickness. *Feet*	*inches.*	Horizon.
Upper Lias.				
32.	Sand	6	0	*dispansum.*
31–29.	Clays and limestones, unfossiliferous	2	6	
28, 27.	Do. fossiliferous	3	8	

(B) BARRINGTON QUARRY.

No.	Strata.	Feet	inches	Horizon.
26–24.	Clays and limestones, *Hildoceras*	3	8	*bifrons* [12, 11, Spath].
23.	Reddish-brown clay, pinkish-grey limestone	0	7	[10, Spath.]
22.	Whitish clayey limestone	1	0	
21.	Olive-grey clay, with *Crania* = *Crania*-Clays of Moore	0	5	
20.	Pink-tinged, grey, clayey limestone. *Hildoceras* [Not *Hildoceras*; a new form.]	0	5	[pre-*bifrons*.]
19.	Clay and limestones. Large Harpoceratids, *Cœloceras*	0	8	[9, Spath.] *falciferum*
18.	Do.	0	3	[8, Spath.]
17.	Do., *Dactylioceras*	0	3	[7, Spath.]
16–12.	Do.	1	1	[6, Spath.]
11.	Do., *Harpoceras*	0	5	
10–8.	Do.	0	10	[5, Spath.] }
7.	Do., *Rhynchonella bouchardi*, *Harpoceratoides*	0	7	[Moore's zone of *Rh. bouchardi*.] }
6.	Do., *Harpoceratoides*	0	3	[4, Spath.] }
5.	Laminated clay, *Harpoceratoides*	0	5	[4, Spath.] }
4.	Fish-Bed	0	3	*exaratum.*
3.	*Leptæna* Clays of Moore	2	0	
2.	Top bed of Moore's Middle Lias: bed F of his Ilminster section. *Dactylioceras* spp.	0	4	*tenuicostatum.*
1.	Sandy marl; large belemnites, finely ribbed Dactyliocerates [Impression of *Paltopleuroceras* cf. *hawskerense*.]	0	7	
Middle Lias.				
2.	Marlstone Rock-Bed, 7 feet thick. A layer of sandy marl 6 to 9 inches from the top [contains degenerate Paltopleurocerates, cf. *Paltopleuroceras regulare* Simpson sp.]	7	0	*acutum.* [*regulare*.] *spinatum.*
1.	Sands.			

(D) Upper and part of the Middle Lias Succession, and Correlation. (S. S. B.)

In his examination of Prof. Watson's collection Dr. Spath was able to make certain notable additions to the recognizable horizons of the Upper Lias: he was able to place as chronological indices two new genera which I had recently named and illustrated in 'Type-Ammonites'—*Hildaites* (pl. ccxvii) and *Hildoceratoides* (pl. ccxviii). Further, he distinguished a horizon by the name *anguinum*, and placed *Harpoceratoides* as marking a distinct date: species of this genus had been obtained by Mr. J. F. Jackson from the Junction-Bed of the Dorset Coast (see p. 443); but on that evidence alone it had not been considered advisable to distinguish *Harpocerotoides* as a separate time-term. Now all this evidence falls nicely into line.

Adopting Dr. Spath's terms, and using information otherwise obtained, it is possible to present the following sketch of the chronological sequence in the Upper Lias (and top of the Middle Lias) —Table VI, p. 453. At the same time, a series of stratigraphical terms are appended which may be useful to the memory, as well as indicating where certain beds are well exposed. It is not intended to say that the beds are only exposed at the places which give their names: it is known, for instance, that Whitby possesses far more than the strata of the three hemeræ which stand opposite 'Whitby Beds.' But, on the other hand, deposits of certain hemeræ seem only to have been preserved at the localities which give their names: thus the strata of *pseudovatum* date are only known in Yorkshire.

A similar phenomenon attends *exaratum*: this species has not been recognized outside of Yorkshire. Several of the associates of *exaratum* in the Jet-Rock of Yorkshire have now been found in other localities—for instance, in the *Leptæna* Bed of Somerset, where the inch-to-inch collecting gives them a certain sequence, which, however, must be taken with some reserve: first, because the present examination is necessarily rather cursory, and, secondly, because the specimens are somewhat crushed and ill-preserved. But the important fact is that, while the *Leptæna* Bed yields these *exaratum* associates, another of the Jet-Rock genera (*Harpoceratoides*) is found in a bed of different lithic character at a distinctly higher level—separated from the *Leptæna* Bed by the Fish-Bed. Therefore, it may be argued that the Yorkshire Jet-Rock is not a deposit of one date, but is polyhemeral.

The exact chronological position of *exaratum* is, then, uncertain. There is little doubt that it has some affinity with the forms now spoken of as 'Grantham ammonites,' and it is therefore concluded that its date is either just before or just after those forms. If placed before the Grantham ammonites, a non-sequence in the *Leptæna* Bed is produced, and a considerable non-sequence in the

TABLE VI—SKETCH OF THE CHRONOLOGICAL SEQUENCE IN THE UPPER LIAS.

Ages.	Bed Nos.	Hemeræ.	Strata.
YEOVILIAN.		9. *moorei.*	Yeovil Sands.
		8. *Catulloceras.*	
		7. *Dumortieria.*	
		6. *Hammatoceras.*	Bruton Sands.
	U.L. 28.	5. *dispansum.*	Frocester Beds.
		4. *struckmanni.*	Midford Sands.
		3. *pedicum.*	Stinchcombe Beds.
		2. *eseri.*	
		1. *striatulum.*	Sodbury Sands.
WHITBIAN.	U.L. 27 *c*.	26. *variabilis.*	Cotteswold Sands.
		25. *lilli.*	
	U.L. 27 *b*.	24. *semipolitum.*[1]	
	U.L. 27 *a*.	23. *subplanatum.*	Northampton Beds.
		22. *braunianum.*	
		21. *fibulatum.*	
	U.L. 26.	20. *bifrons.*	Whitby Beds.
	U.L. 25 ?	19. *subcarinata.*	
		18. *pseudovatum.*	
	U.L. 24.	17. Gen. and sp. nov. (small Harpocerate.)	Barrington Beds.
	U.L. 23.	16. *Hildoceratoides.*	
	U.L. 19.	15. *falciferum.*	
	U.L. 18.	14. *Hildaites.*	
	U.L. 15.	13. Cf. *Pseudolioceras.*	
	U.L. 11.	12. *anguinum.*	
	U.L. 7.	11. *Harpoceratoides.*	
		10. *murleyi.*	Dumbleton Insect-Bed.
		9. *exaratum.*	Boulby Bed.
	U.L. 3.	8. biform Harpocerates.	Grantham Bed.
		7. *Eleganticeras.*	Yorkshire Jet-Rock.
		6. *Elegantuliceras.*	
		5. *tenuicostatum.*	Yorkshire Grey Shales.
		4. *Tiltoniceras.*	Tilton Beds.
	U.L. 2.	3. *athleticum.*	
	U.L. 1.	2. fine-ribbed Dactyloids.	Stocklinch Bed.
		1. Harpoceratoid.	Chideock Bed.
DOMERIAN.	M.L. 1.	2. *hawskerense.*	Hawsker Beds.
		1. *spinatum.*	South Petherton Beds.

Jet-Rock; if placed afterwards, the former is avoided at the expense of a double non-sequence in the Jet-Rock. Further evidence is required.

As the evidence for the chronology of the earlier hemeræ of the Upper Lias is somewhat imperfect, the correlation-table (VII, facing p. 454) has been drawn up, chiefly in order to compare Somerset with Yorkshire. The lacunæ in the intervening areas are not all to be read as non-sequences: they arise from lack of evidence, collection-failure, exposure-failure, nomenclature-failure, and so on. It is doubtful whether anything like the full sequence of the early hemeræ of the Whitbian has yet been obtained.

[1] *Hildoceras semipolitum*, S. Buckman, is the particular species of the lower part of the Cotteswold Sands; evidence for *Lillia lilli* and its associates in that deposit is lacking, but there is plenty of room for them. Very little collecting has been done in this deposit, which sometimes is 250 feet thick.

A last word may be added concerning the Japanese species *Dactylioceras helianthoides* Yokoyama. Dr. Spath quotes this from above the Fish-Bed: I quote something like it from well below. The Dactyliocerates are a very difficult group, occurring in the Upper Lias in seemingly endless variety. When it was thought that the Upper Lias was laid down at about three different dates, such endless variety of apparently contemporaneous forms was difficult to understand. When it is seen that the dating of the Upper Lias (the Dactyliocerate part—the Whitbian) has to be multiplied some eight times and, therefore, the number of contemporaneous species has to be divided eight times, the diversity of the Dactyliocerates becomes more comprehensible: they represent waves of more or less closely-allied lineages, which develop and tail-off (degenerate) in somewhat similar fashion, producing homœomorphous forms.

It was necessary to be satisfied, in regard to the finely-ribbed Dactyliocerates below the Fish-Bed, that they were not *D. tenuicostatum* of the Yorkshire Grey Shales: they are not, but they have a likeness to *D. helianthoides*. When really systematic research-work on the Dactylioceratidæ can be undertaken—at present such work is only in its infancy,—it will doubtless be found that the points of difference between similar-looking forms are more important than is now suspected. When these differences can be recorded and brought to bear on species of known date in an extended time-scale, one may expect the Dactylioceratidæ to become very useful chronological indicators.

IX. Summary.

(1) The body of the paper deals with certain Jurassic strata near Eypesmouth on the coast of Dorset; but, as it forms part of a series of preliminary studies in connexion with Jurassic chronology, certain details connected with other localities are noticed.

(2) A general section of the main mass of Watton Cliff east of Eypesmouth is given.

(3) A detailed section is recorded of a remarkable white lithographic bed in Watton Cliff, one in the same position as the Upper and Mid-Lias Junction-Bed of the Thorncombe-Beacon area, but differing much in faunal and stratal details.

(4) This bed shows faunal inversion, presumably due to redeposition of material from older deposits.

(5) The dating of this Watton Bed is discussed, after preliminary investigations into the sequence of horizons in the Upper Lias of various areas, in the Junction-Bed and pre-Junction-Bed strata of Thorncombe Beacon.

(6) A theory of stratal repetition and coalescence is discussed in regard to the Watton Bed. Its main date is taken to be Yeovilian, *Hammatoceras* hemera.

(7) The white lithographic bed of Burton Bradstock is cited as evidence of stratal repetition, and a theory as to the deposition and almost complete destruction of this Burton bed is put forward.

(8) The Watton and Burton lithographic beds are cited as evidence of Alpenkalk conditions prevailing in Western Europe during two well-separated Jurassic dates, both of them far earlier than the times of Alpenkalk deposits in Central and Eastern Europe.

(9) Certain remarks are made upon sections at Milborne Wick and Haselbury (Somerset) with regard to the dating of their deposits, and a table of the succession and distribution of Hammatoceratids is given.

(10) A palæontological note describes a new species of Rhynchonellid—*Tetrarhynchia thorncombiensis* (*Rhynchonella northamptonensis* auctt., passim)—a species marking a particular deposit at Thorncombe Beacon.

(11) An Appendix by Mr. J. F. Jackson gives the result of his studies of various sections of the Junction-Bed (including the Watton Bed) on the Dorset coast,

(12) A second Appendix gives studies by Dr. L. F. Spath and by Mr. J. Pringle & Mr. A. Templeman of the stratal and faunal (ammonite) succession revealed by certain new exposures in the Upper and Middle Lias near Barrington (Somerset)—the collecting of specimens having been done almost inch by inch.

(13) The evidence thus obtained, added to that gleaned elsewhere, some of it set out in the body of the paper, enables the Author (S. S. Buckman) to put forward a tabular sketch of Upper Lias chronology more detailed than has yet been attempted—dividing the ages (Yeovilian and Whitbian) of the Upper Lias into thirty-five hemeræ—more divisions than were originally made by Oppel for the whole of the Jurassic.

Discussion.

Mr. J. Pringle said that, as joint author of one of the Appendices, he would refer to the salient features of the work done by Mr. A. Templeman and himself on the Upper Lias exposed in certain quarries at Barrington. These beds had been described by Charles Moore, and the reopening of the sections after a long period of disuse had provided an opportunity of examining the Upper Lias, with a view to the correlation of the deposits with those of the Banbury district. The section was carefully collected over bed by bed, and more than a thousand specimens of ammonites were secured. The value of the results obtained had been much enhanced by Mr. Buckman's co-operation.

Dr. A. Morley Davies said that the deposits in a shallow sea transgressing over an area where folding and faulting movements were still in progress, might very well show such anomalies as the Author described. He found it difficult to believe, however, that the beautifully preserved ammonite exhibited, with similar matrix within its body-chamber and around it, could be a derived fossil. He enquired whether the *bifrons* ammonites which appeared in inverted sequence in this new junction-bed showed the same pink colour as that which characterized their matrix in the well-known Junction-Bed.

Dr. W. D. LANG asked whether a simpler explanation than that suggested by the Author might not be applicable to the inverted sequence of ammonites in the Junction-Bed at Eype, namely, a long period of very slow deposition coinciding with an oscillation of surface at about sea-level, allowing wave-action to mingle the fossils of successive faunas, and even to remove a certain amount of sediment; the whole deposit being subsequently consolidated by a segregation of calcium carbonate. If the last-mentioned process took place, it would be unnecessary to consider, as the Author apparently did, that the Junction-Bed was a deep-water deposit. That such segregation would not necessarily do away with the bedding-planes could be seen in the concretions of the *birchi* nodular deposit, occurring in the Lower Lias of the same district. Bedding was very apparent in these nodules.

Prof. P. G. H. BOSWELL said that, among the many interesting questions raised by the Author, that of the evidence of shallowing conditions and instability in the area during the period covered by the hemeræ from *lilli* to *opaliniformis* deserved emphasis. The sandy facies which stretched from the Cotteswolds to the Dorset coast, and included the uppermost zones of the Lias and lowermost zones of the Inferior Oolite, was characterized throughout by the constancy of its peculiar lithological and petrographical characters. As the Author had proved many years ago, this sandy and silty phase transgressed as a wave of shallowing conditions to successively higher horizons as the observer travelled southwards, thus providing an admirable example of the transgression of time-planes by lithological planes.

Mr. G. W. LAMPLUGH thought it improbable, on the evidence adduced, that the comparatively large and well-preserved ammonites found in the narrow band of fine-grained laminated material at Watton Cliff could have been derived at recurrent intervals from older strata and redeposited in inverted order. Judging from the specimens exhibited, he suggested that the bed might be a 'condensed' deposit, very slowly accumulated and covering a long period. In such beds the rare accident of preservation at intervals was likely to bring about the juxtaposition of forms not truly contemporaneous. The further accident of collecting-chances in beds of this kind rendered the basis for the hypothesis still narrower.

The AUTHOR, in reply, said that the Watton-Cliff bed presented a mass of puzzles, and the point raised by Dr. Davies—the difficulty of derivation in the case of well-preserved fossils—was a problem already noted, not only for this instance. The solution in some cases was that specimens had been redeposited inside lumps of original matrix. Big lumps of derived matrix were in the Watton bed, but there arose the difficulty of reconciling such lumps with a fine-grained laminated deposit—the former indicated violent action, the latter very tranquil conditions and, possibly, deep water. The tranquil conditions seemed to be inconsistent with the wave-action suggested by Dr. Lang.

The Author agreed with Mr. Lamplugh that the Watton Bed was a highly condensed deposit: it had taken the whole of the time of the Upper Lias—some thirty hemeræ—to deposit 5 feet; but the question was whether the deposit as seen now represented anything like the original mass laid down. The Author supposed not. How much had been removed by penecontemporaneous erosion without leaving a trace behind?

With reference to Mr. Pringle's remarks, the Author wished to acknowledge how greatly he was indebted to his collaborators for their Appendices, representing a mass of new observations supplementing his paper. The most interesting point, perhaps, was that the system of many chronological divisions, which the Author might claim to have originated, had been extended by his collaborators: that testimony to his moderation was welcome; because his original number of subdivisions had often been condemned as excessive. He had always been compelled to go on asking for more, and now other investigators went farther still. This constant lengthening of the Earth's chronology was particularly interesting.

In noting that palæontological planes did not coincide with lithological planes, Prof. Boswell had, as he said, drawn attention to the Author's work of many years ago. It was a vindication of the subdivisional method that it had given these results so clearly, and had shown the uselessness of lithology as a guide to date.