

18. *The RHÆTIC and CONTIGUOUS DEPOSITS of GLAMORGANSHIRE.*

By LINDSALL RICHARDSON, F.G.S. (Read May 24th, 1905.)

[PLATE XXXIII—FOSSILS.]

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I. INTRODUCTION.

IN the autumn of 1904 I made, in company with my friend, Mr. E. Talbot Paris, a detailed examination of the Rhætic and contiguous deposits of Monmouthshire and Glamorganshire. The results of my investigations in the former county have already been made known,<sup>1</sup> and it now remains to record those in the latter.

Less than four years have elapsed since the officers of the Geological Survey completed the re-survey of the Secondary rocks of Glamorganshire; and that part of the memoir on 'The South-Wales Coalfield' which deals with the Bridgend district was only issued to the public last January. This being the case, it might be thought that but little of interest would have remained to be noticed in the present communication. However, whereas the officers of the Survey were mainly concerned in the mapping of the deposits, my attention was directed in most cases to the accumulation of facts bearing upon the physical geography of the Rhætic Epoch.

On a previous occasion I communicated to this Society a theory, to account for the geographical distribution in North-West

<sup>1</sup> Quart. Journ. Geol. Soc. vol. lxi (1905) pp. 374-84.

Gloucestershire and Worcestershire of certain beds at the base of the Rhætic Series. I then stated that

‘there is evidence to suggest that there were earth-pressures at work at the close of the Keuper Epoch, which caused the deposits to be thrown into slight synclinal and anticlinal flexures. In the depressed areas the earlier deposits of the Rhætic were laid down, and successive overlap on to the marls seems to have taken place.’<sup>1</sup>

My reasons for suggesting this explanation for the phenomenon were as follows. Throughout North-West Gloucestershire and Worcestershire the component deposits of the Rhætic are remarkably persistent. There were slight earth-movements towards the close of the *Pteria (Avicula)-contorta* age, it is true, which affected the persistency of one or two beds; but the cause for their irregularity is so obvious, that it does not influence the matter under discussion. Once below a certain stratum, however, such persistency is not to be observed. That stratum happens to be full of saurian- and fish-remains at certain localities, on which account it has been denominated the ‘Bone-Bed.’ Therefore I employed this term, or that of ‘Bone-Bed equivalent,’ according as the circumstances demanded. The geographical distribution of these infra-Bone-Bed deposits appears to me to be, at present, satisfactorily explained only by the theory that I have formulated.

For some years previous to the publication of the above-mentioned paper, I had come to the conclusion that

‘when the Rhætic ocean gained access to the British area it spread over an undulating expanse of Keuper Marls. In some areas, however, . . . lakes probably existed, and it would be in these areas that the complete sequence from the Keuper to Rhætic deposits should be looked for. The section of deposits formed under the conditions stated would be essentially of transitional nature, as at Watchet; but where the Rhætic ocean spread over the surrounding ground a non-sequence would result. Thus, at the present time, the junction-line would appear sharply defined; there would be no transitional signs, and practically no erosion.’<sup>2</sup>

A stretch of water, probably of considerable dimensions, extended into the Lavernock district, and therefore, according to my theory, transition-beds should be present. Such is the case: the transition-beds are the ‘Grey Marls’ (*pars*) of the late Robert Etheridge. This term would have been a convenient designation for the beds, had it not been generally misinterpreted. But, as such is the case, it appears desirable to replace it by the term ‘Sully Beds,’ after the locality where the most interesting development can be studied.

## II. THE SULLY BEDS.

In his very interesting memoir of Robert Etheridge, Mr. H. B. Woodward, F.R.S., drew attention to the fact that the ‘Grey Marls’ and ‘Tea-Green Marls’ of Etheridge were distinct deposits.

<sup>1</sup> Quart. Journ. Geol. Soc. vol. lx (1904) p. 356,

<sup>2</sup> *Ibid.* p. 337.

'Etheridge,' he wrote, 'originally placed them [that is, the 'Tea-Green Marls'] in the Keuper, and distinguished them from the Grey Marls which frequently form the base of the Rhætic.'<sup>1</sup> In support of this interpretation of Etheridge's remarks, Mr. Woodward quoted from the paper published by Etheridge in the Proceedings of the Cotteswold Naturalists' Field-Club. In that paper, Etheridge recorded this sequence:—'alternating bands of grey and red fissile and conchoidal marls (No. 1 in section), apparently here containing no fossils';<sup>2</sup> and then, above these 'Tea-Green Marls' a series of Grey Marls. The point upon which Mr. Woodward naturally laid stress was that Etheridge denominated the lower of these two series the 'Tea-Green Marls': not the upper, which he distinguished by the name of 'Grey Marls.' As will be seen by referring to his section at Garden Cliff, the beds that he wished to be called the 'Tea-Green Marls' are not those to which the term has been restricted by most authors. Etheridge's suggestion with regard to these 'Tea-Green Marls' of his at Garden Cliff was, that although they did differ lithically, they nevertheless corresponded to certain beds at Watchet, Penarth, and Puriton,

'at which places,' he wrote, 'I have termed them "Tea-Green Marls," from the peculiar hue of the freshly-fractured shales when exposed, and the constancy of their conditions.'

The 'Grey Marls' (the upper strata of which are here designated the Sully Beds) above he regarded as belonging to the Rhætic, because they contained fish-remains.

Mr. Woodward's explanation of Etheridge's conclusions is very satisfactory, because I had been compelled to adopt the view that there were marls which were Rhætic, and again such as were Keuper. But, while agreeing with Etheridge that this was the case, I fail to see any evidence, either palæontological or stratigraphical, why the marls below what I have called the 'Tea-Green Marls' at Garden Cliff (which there come immediately below the Rhætic Black Shales)<sup>3</sup> should be regarded as the equivalent of certain beds which Etheridge admitted were lithically different at Penarth, Watchet, and Puriton. Is it not much more probable that the 'Grey Marls'—certainly that the fossiliferous portion of them, namely, the Sully Beds—of the Lavernock and Watchet districts—are not represented in North-West Gloucestershire and Worcestershire; and that they are only found within the limits of those areas which were submerged at the time when the Rhætic ocean gained access to the British low-lying country?

These Sully Beds will be again dealt with after the sections in Glamorganshire have been described.

<sup>1</sup> Proc. Bristol Nat. Soc. ser. 3, vol. x (1903-04) p. 183.

<sup>2</sup> Vol. iii (1865) pp. 220, 221.

<sup>3</sup> Proc. Cottesw. Nat. F.-C. vol. xiv (1903) table iii, facing p. 174.

### III. DESCRIPTION OF SECTIONS.

#### i. The Penarth District.

In the Penarth district are included the outliers of Leckwith, Penarth, Lavernock, and Cross: all capped by Lower Liassic deposits.

The Penarth section, it is almost superfluous to state, is a classic one, as the name of the locality suggested to Murchison an alternative denomination for the Rhætic—the Penarth Beds. It is unnecessary, for the present purpose, to discuss all that has been written on this far-famed section; but, for the convenience of those who desire to study the literature, references are given in a footnote.<sup>1</sup>

The cliff-section at Penarth is disappointing. It is true that there is a faulted syncline which has brought the Rhætic to the foot of the cliff, but recently (August 1904) a slip has obscured the greater part of the section which was available. Accordingly, if anyone wishes to obtain details of value, it is necessary (to quote Mr. H. B. Woodward) 'to climb an almost perpendicular cliff.' Fragments of the several hard beds can be seen on the beach, and from an examination of their lithic structure it is often possible to state that such and such a bed is present in the cliff-section; but that is about all. The details recorded by Bristow and Etheridge were obtained in a railway-cutting; and at the present time several such exposures are available, especially at Penarth Docks.

It is not necessary, however, to climb Penarth Head, for at Seven Sisters' Bay the base of the Rhætic is within 3 feet of the beach; while at Lavernock Point the beds are even more accessible and convenient to examine than at Garden Cliff, Westbury-on-Severn. The section at Seven Sisters' Bay is very similar to that at Lavernock; if anything, the beds are a little thicker, and continue to increase in thickness until Penarth Head is reached. At Penarth Head Mr. Woodward has noticed a band of limestone, which reminded him of the Cotham Marble; and I have observed a similar bed—which probably represents the Sun-Bed of the White Lias—at Lavernock (p. 393) and Barry (p. 398). On the beach at Seven Sisters' Bay were pieces of limestone, probably from the same horizon, that had been bored by *Lithophagus* (*Lithodomus*, Cuvier) and encrusted with *Plicatula intus-striata*, Emmrich.

<sup>1</sup> H. T. De la Beche, Mem. Geol. Surv. vol. i (1846) p. 253; T. Wright, Quart. Journ. Geol. Soc. vol. xvi (1860) pp. 381–82; W. V. Guise (Presidential Address, 1863), Proc. Cotteswold Nat. F.-C. vol. iii (1865) pp. 117, 118; H. W. Bristow, Geol. Mag. vol. i (1864) p. 236, & Rep. Brit. Assoc. 1864 (Bath) Trans. Sections, p. 50; R. Etheridge, Trans. Cardiff Nat. Soc. vol. iii (1870–71) pt. ii, p. 39; Bristow & Etheridge, Geol. Surv. Vertical Sections, 1873, Sheet 47; T. Wright, 'Monogr. Lias Ammon. Brit. Is.' Pal. Soc. 1878, p. 10; J. Storrie, Trans. Cardiff Nat. Soc. vol. xiv (1882–83) p. 100; H. B. Woodward, Proc. Geol. Assoc. vol. x (1888) p. 529, & Rep. Brit. Assoc. 1888 (Bath) p. 900; J. Storrie, Trans. Cardiff Nat. Soc. vol. xxvi (1894) p. 105; A. Strahan & T. C. Cantrill, 'The Geology of the South-Wales Coalfield: Part iii—The Country around Cardiff' Mem. Geol. Surv. 1902, pp. 59–63.

(A) Lavernock.

The section at Lavernock is certainly one of the finest in the country of the beds under consideration. The Rhætic can be studied in the foreshore and cliffs of the deeply-indented little bay immediately to the north of Lavernock Point; the White Lias and the *Ostrea*-Beds succeed; while round the Point, and as far as St. Mary's-Well Bay, Sully, are the *planorbis*-, *angulata*-, and *Bucklandi*-beds (*pars*), arranged in a gentle syncline. At St. Mary's-Well Bay, the Rhætic again makes its appearance. North of Lavernock Point the strata rise into a gentle anticline, with the result that the Keuper makes its appearance. Thus Keuper, Rhætic, and Lower Lias can all be examined in this unrivalled coast-section.

Although brief reference has been made to the section by several authors,<sup>1</sup> it has not received sufficient attention. The most complete record is that given by Bristow; but he mentioned comparatively few fossils. For several reasons, a very detailed section has been appended to the present paper (facing p. 392).

The Keuper Red Marls are of the usual type: dark-red marls, with greenish-grey zones. Above come the 'Tea-Green Marls,' having, according to my measurements, a total thickness of 33 feet 4 inches. The most interesting feature in connection with these marls is the occurrence in them of gypsum—a mineral that is particularly rare in North-West Gloucestershire and Worcestershire. Indeed, I have not found it in the marls of the sections which I have studied in that district in any appreciable quantity.

Above the 'Tea-Green Marls' come the Sully Beds—a portion of Etheridge's 'Grey Marls.' The line of demarcation between the two series of deposits is necessarily an arbitrary one. The peculiar lithic characters of the Sully Beds at Lavernock, and the fact that John Storrie found '....some remains of the great Labyrinthodon, *Mastodonsaurus*....', in association with a number of small teeth of *Sphærodus*, a mandible believed to belong to *Paleosaurus*, two teeth belonging to the same dinosaur, and remains of *Trematosaurus*, about 6 feet below the Rhætic 'fish-bed,'<sup>2</sup> all support the conclusion that the Sully Beds are more intimately connected with the Rhætic than with the Keuper. The most useful evidence in support of this contention, however, was obtained at St. Mary's-Well Bay (Sully), Cross, and Cadoxton; as will be shown later (pp. 395, 396, & 399).<sup>3</sup>

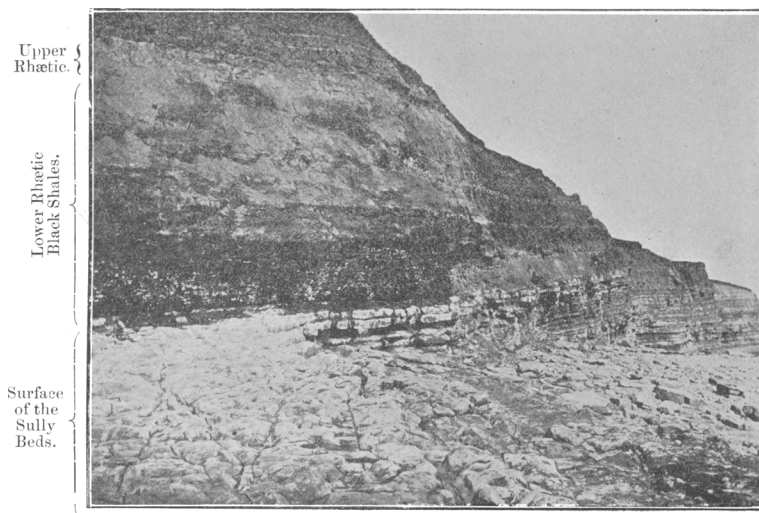
The uppermost marlstone of the Sully Beds is conspicuously waterworn, some of the irregularities projecting at least 5 inches

<sup>1</sup> R. Etheridge, Trans. Cardiff Nat. Soc. vol. iii (1870-71) pt. ii, p. 39  
H. W. Bristow, (Geol. Surv.) Vert. Sect. Sheet 47.

<sup>2</sup> Trans. Cardiff Nat. Soc. vol. xxvi (1893-94) pp. 105-106 & pl.

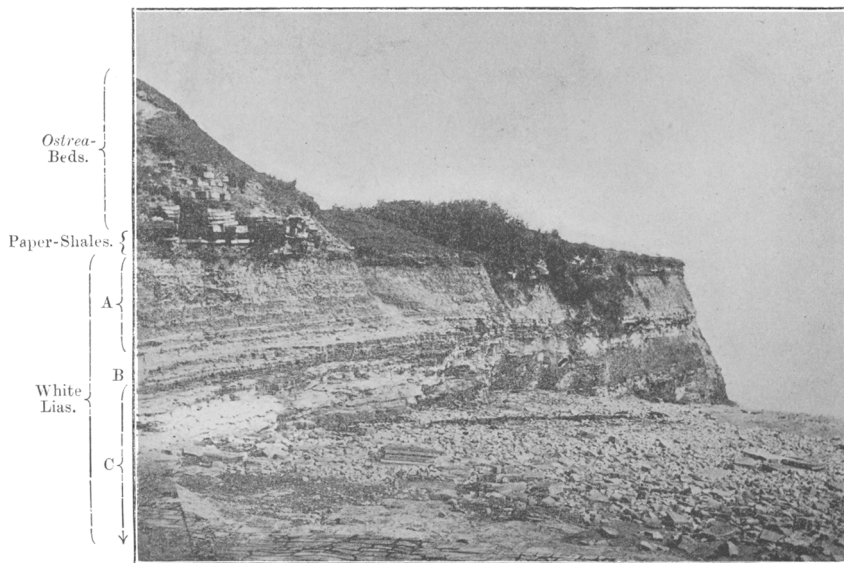
<sup>3</sup> [Since this paper was written I have made a detailed examination of the Watchet district; and it appears desirable to state here that organic remains are numerous in that district, in marlstones corresponding to these Sully Beds.—June 16th, 1905.]

Fig. 1.— *View showing the upper surface of the Sully Beds and the Black Shales, Lavernock Point.*



J. Storrie fotogr.

Fig. 2.— *View showing the White Lias and its junction with the Lower Lias at Lavernock Point.*



J. Storrie fotogr.



above the average level (see fig. 1). Frequently a black-shale deposit is found filling-in these irregularities; but it is occasionally replaced by a soft yellowish-green marl, which passes up gradually into a blackish marl. At that part of the cliff where these notes were made, a layer of grey argillaceous nodules, with quartz-pebbles and fish-remains, rested upon the above-mentioned marl or shale. Doubtless this band of nodules is intimately connected with the 'fish-bed' for which the locality is celebrated. The fact that black shale is intercalated between the 'fish-bed' and Sully Beds in places, is commented upon by Mr. F. T. Howard, F.G.S., who, like most observers, had regarded the 'fish-bed' as the lowest Rhætic deposit in the Cardiff district.

'I was therefore,' he wrote, 'surprised, on removing a block of the conglomerate ["fish-bed"] from its natural position on the foreshore opposite Lavernock Point, to see beneath it and lying directly on a worn surface of Tea-Green Marls, a thin band of black shale, not more than  $\frac{1}{4}$  inch thick, containing numerous crushed specimens of typical Rhætic shells—*Cardium rhæticum*, *Avicula contorta*, and *Pecten valoniensis*. Others may have been represented, but were badly preserved. The band of shale was very irregular. . . .'<sup>1</sup>

There are places where the 'fish-bed' rests directly upon the marlstone of the Sully Beds. As noticed by John Storrie, the 'fish-bed' is not continuous, but occurs in patches, and the best of these will be found protected by seaweed between low- and high-tide marks:—

'The patches in which it occurs vary from the size of a sixpence to pieces 5 or 6 yards square, and at some places are comparatively close together—at others a considerable distance apart. The bed may be best described as a conglomerate of pure white quartz-pebbles, from the size of a hen's egg downward, all waterworn, and mostly crusted with a greenish-copper tinge, jasper-like pebbles, and also some waterworn pieces of limestone (unfossiliferous, but probably Silurian, from their general texture).'<sup>2</sup>

I am inclined to agree with Mr. Howard that the last-mentioned pebbles are more likely to be of marlstone derived from the Sully Beds. A fine piece of this 'fish-bed,' not altogether of the usual lithic structure, since the greater mass of it consisted of quartz-sand cemented together mainly by carbonate of lime, contained in great abundance the teeth of *Acrodus minimus*, *Gyrolepis Alberti* (?), *Saurichthys acuminatus*, *Sargodon tomicus*, and *Lepidotus* (?),<sup>3</sup> and less commonly of *Hybodus minor* and *H. cloacinus*. Rich as this deposit is in vertebrate-remains, it has not been regarded by our chief authorities as the Bone-Bed. It may be suggested that this basal bone-bed at Lavernock is the equivalent of a deposit of a

<sup>1</sup> Trans. Cardiff Nat. Soc. vol. xxix (1896-97) p. 66.

<sup>2</sup> *Ibid.* vol. xiv (1882-83) p. 100.

<sup>3</sup> The teeth thus denominated are those described by Agassiz as *Sphærodus minimus*, and by Meyer & Plieninger as *Psammodus orbicularis*. They may belong to the same animal (*Sargodon tomicus*) as the chisel-shaped teeth, but at present it appears desirable to keep the records separate. Charles Moore thought that the knob-like teeth probably belonged to *Lepidotus*, and such teeth are recorded in this paper as '*Sargodon tomicus*' (*Lepidotus*?). See Quart. Journ. Geol. Soc. vol. xvii (1861) p. 499, footnote.

similar nature at Garden Cliff, Westbury-on-Severn. At Garden Cliff, 16 inches above the basal bone-bed is the 'Lower Pullastra-Sandstone.' At Lavernock, 18 inches above the presumed equivalent deposit, is a thin layer composed of hundreds of teeth of *Acrodus minimus* and scales of *Gyrolepis Alberti*. At Garden Cliff a deposit of shale, 2 feet thick, separates the Lower from the Upper Pullastra-Sandstone; at Lavernock the deposit intervening between the beds that may be regarded as the equivalents of the sandstones measures only 13 inches. Bed 17 is also a 'bone-bed,' and frequently contains vertebræ of *Plesiosaurus*. Black shales with a grey limestone-band separate this bed from a series of sandstone-layers with shale-partings, and frequently full of fish-remains, usually comminuted. If the correlation of the Rhætic deposits (20 to 16) enumerated above be correct, then the next bed in ascending order should be the equivalent of the Bone-Bed (15) of Garden Cliff. This was thought to be the case by Etheridge, and it certainly seems probable. John Storrie wrote:—

'The bone-bed proper . . . is a continuous bed through the whole [Penarth-Lavernock] section, and is described by Etheridge as "a dark-grey grit, or hard indurated pyritic limestone, 2 or 3 inches thick (oftener about 1 inch), made up of minutely-comminuted fragments of fish-teeth, scales, and bones." This bed . . . is accessible in the whole Penarth section, and is always constant in character, except at Lavernock, where it is more pyritized than elsewhere. This bed very rarely contains large bones or spines; on one occasion only have I found such.'<sup>1</sup>

The most persistent strata in the *Pteria (Avicula)-contorta* Zone are the *Pecten*-Beds (7 & 5 b), especially the lower of the two. At Lavernock, they can be easily traced across the foreshore. Bristow observed that the lower bed was full of *Pecten (Chlamys) valoniensis*; but, according to my investigations, it was of rather rare occurrence in the actual limestone, and in neither of the *Pecten*-Beds did I find lamellibranchs to be abundant, as is usually the case. However, the Black Shales, for 2 or 3 inches below Bed 5 b, are extremely fossiliferous, containing *Pecten (Chlamys) valoniensis*, *Pteria (Avicula) contorta*,<sup>2</sup> scales of *Gyrolepis Alberti*, and coprolites (of fishes chiefly). In places immediately below this shale is a thin earthy limestone-layer with a layer of 'beef' on the under surface. At 5 inches below 5 b is a seam full of *Pteria (Avicula) contorta*; and in the shales below that again, numerous examples of *Pecten (Chlamys) valoniensis*, and *Schizodus Ewaldi*, *Gervillia præcursor*, *Protocardium Philippii*, *Orbiculoidea Townshendi*, *Pleuromya (?)*, *Placunopsis alpina* (small and large forms), scales of *Gyrolepis Alberti*, teeth of *Acrodus minimus* (rare) and *Saurichthys acuminatus*, and coprolites. The vertebrate-remains occur mostly in a thin layer at 8 inches below 5 b. This is certainly the most fossiliferous horizon in the Rhætic at this locality; and fortunately the deposit is easy to investigate. Black

<sup>1</sup> Trans. Cardiff Nat. Soc. vol. xiv (1882-83) p. 100.

<sup>2</sup> *Pteria*, Scopoli, = *Avicula*, Brug. I am at present engaged in the revision of the representatives of the Pteriidae from the Rhætic, Liassic, and Inferior-Oolite rocks; and also those of the Mytilidae from the same rocks.



SECTION AT LAVERNOCK, NEAR CARDIFF.

		Thickness in feet inches.	
HEMERA ROTIFORMIS(?)		Limestone-beds and clay-partings: estimated at.....	25 0
HEMERA MARMOREA.		Marly clays and nodular limestones: about.....	40 0
LOWER LIAS.	PLANORBIS-ZONE (Hemere planorbis and megastomatos).	1. Limestone .....	0 2
		2. Shale .....	0 3
		3. Limestone, nodular .....	0 6
		4. Shale, with three beds of rather nodular limestone.....	1 8
		10. Limestone, nodular: 0 to 2 inches .....	0 1
		11. Shale, with three beds of limestone.....	2 6
		12. Limestone, massive: 4 to 8 inches .....	0 6
		13. Shale .....	0 5
		14. Limestone: 3 to 5 inches.....	0 4
		15. Shale .....	1 3
		16. Limestone .....	0 4
		17. Shale .....	0 7
		18. Limestone, massive, with large nodules below; and beneath these are shales, with numerous specimens of Ostrea at the base .....	1 10
		19. Limestone, massive .....	2 7
		20. Shale-parting, indistinct in places.....	0 1
		21. Limestone, nodular .....	0 4
		22. Shale .....	0 2
		23. Limestones, five beds, interstratified with shale .....	4 2
		24. Shale, hard, imperfectly laminated .....	1 10
		25. Limestone.....	0 7
		26. Shales, very much indurated in places, forming almost a limestone at the base .....	2 2
		27. Limestone, massive .....	0 7
		28. Shale-parting often indistinct, Bed 44 often adhering to 46.....	0 1
		29. Limestone, somewhat nodular .....	0 4
		30. Shales .....	0 3
		31. Limestone, hard .....	0 8
		32. Shales, with hard nodules .....	1 0
		33. Limestone, massive, very irregular surface, sometimes with nodules adhering to it.....	0 9
		34. Shales .....	1 1
		35. Limestone .....	0 4
		36. Shale: 3 to 5 inches .....	0 2
		37. Limestone .....	0 5
		38. Shale: 2 inches .....	0 11
		39. Limestone, nodular, impersistent: 2 inches .....	0 6
		40. Shale: 7 inches .....	0 2
		41. Limestone, somewhat nodular .....	0 3
		42. Limestone, nodular, impersistent .....	0 3
		43. Shales .....	0 4
		44. Limestone .....	0 6
		45. Shales, bluish .....	1 5
		46. Limestone, in two massive beds, but sometimes conjoined .....	0 10
		47. Shales, bluish, with one or two layers of impure limestone .....	1 0
		48. Limestone .....	0 2
		49. Shale-parting .....	0 1
		50. Limestone .....	0 4
		51. Shale or limestone .....	0 3
		52. Limestone .....	0 4
		53. Shale or limestone .....	0 3
		54. Limestones, five beds, with shale-partings.....	2 0
		55. Shales .....	0 4
		56. Limestone .....	0 2
		57. Shale-parting .....	0 0½
		58. Limestone .....	0 2
		59. Shales .....	0 4
		60. Limestone .....	0 6
		61. Shale, dark, thinly laminated.....	0 8
		62. Shale and thin limestone .....	1 4
		63. Limestone, hard .....	0 7
		64. Shale, hard, thinly laminated .....	0 6
		65. Limestone, in places giving way to a tough shale .....	0 3
		66. Paper-Shales, hard, brown .....	1 0
		WHITE LIAS *	OSTREA-BEDS.
B. Limestone, hard, grey, weathering into two beds, the upper one being probably the representative of the Sun-Bed .....	0 4		
1. Shale-parting: indistinct.....	0 0½		
2. Limestone, hard, grey: half an inch to 2½ inches.....	0 2		
3. Shale, grey, parting .....	0 0½		
4. Limestone, greyish-green.....	0 2		
5. Shale, dark-grey.....	0 1		
6. Limestone, greyish-green: 2 to 3 inches.....	0 2		
7. Shale, hard, dark-grey, with pyritic, gritty, ripple-marked layers.....	0 5		
8. Limestone, very gritty, ripple-marked .....	0 2½		
9. Shale analogous to 7, with similar gritty ripple-marked layers .....	0 7		
10. Limestone, impure, gritty, ripple-marked: 3 to 6 inches .....	0 4		
* The White Lias is provisionally grouped with the Lower Lias.			
RHÆTIC.	UPPER RHÆTIC.	4. Marls, greyish-green. The gritty material from the overlying bed has filtered down cracks in this deposit .....	2 9
		5a. Shales, black .....	5 6
		5b. Limestone, sometimes in two layers with a very thin parting of shaly matter. 'Beef' sometimes occurs above, and when the bed is in two layers it often occurs between them .....	0 3
		6. Shales, black, laminated .....	1 8
		7. Limestone, hard, bluish: 5 to 11 inches .....	0 8
		8a. Shales, black, laminated .....	1 8
		8b. Shales, black, earthy. Beds 8a and 8b are 4 feet thick at Seven Sisters' Bay .....	1 10
		9. Limestone, hard, bluish, with one or two shelly layers immediately below. In places the limestone becomes thin, and is then replaced by grey earthy shales full of shell-debris: 2 to 6 inches .....	0 4
		10. Shales, black, somewhat thinly laminated .....	2 0
		14. Shales, black, tough, throwing off water .....	1 1
		a. Limestone, grey, micaceous, arenaceous, and occasionally replaced by a more shaly deposit with many Schizodus (?). The lower portion is often very pyritic and of bone-bed nature .....	0 3
		b. Hard sandstone, slightly pyritic: 1 to 2 inches .....	0 1
		c. Shale-parting .....	0 1
		d. Two beds of sandstone, with shale-parting and 'beef' in between .....	0 4
		a. Shales, black, laminated .....	0 3
		b. Limestone, dark grey, slightly pyritic .....	0 1
		c. Shales, black .....	0 7
		17. Thin 'bone-bed', intermittent: 0 to 1½ inches .....	0 0½
		18. Shales, black .....	1 1
		19. Thin 'bone-bed' .....	0 1
LOWER RHÆTIC.	SULLY BEDS.	20. Shales, black, laminated .....	1 6
		21. 'Fish-bed', sometimes resting directly upon the top stratum of the Sully Beds, and at others separated therefrom by black shale or marl .....	0 5
		(1. Two somewhat massive beds of hard greyish-blue marlstone, weathering yellowish. Upper surface extremely irregular.....	1 4
		2. Series of blackish-blue marls, with harder zones, passing gradually upwards into harder irregular limestone .....	6 6
		3. Series of bluish limestones, with dark marly partings. The middle and most massive bed is conglomeratic, and can be traced across the foreshore.....	2 2
		4. Series of blackish-blue and yellowish marls, with hard zones, two of which are near the centre .....	4 0
KEUPER.	I. 'TEA-GREEN MARLS.' (33 feet 4 inches.)	1. Marlstone, rather broken up, yellowish-grey, thin layer of gypsum on the top.....	0 9
		2. Green marl, much broken up, and containing near the top an irregular zone of gypsum .....	1 4
		3. Marlstone, greyish-yellow .....	0 6
		4. Green marl, grey zone near the top.....	2 4
		5. Marlstone, hard, greyish-yellow, one of the most conspicuous beds in the section .....	0 6
		6. Greenish marl .....	1 4
		7. Marlstone, laminated at the top .....	0 3
		8. Greenish-grey marls, with hard zone near the centre .....	2 5
		9. Marlstone, earthy, with gypsum in cavities .....	1 3
		10. Greenish-grey marls .....	2 4
		11. Series of five bands of reddish marlstone, parted by thin, green, and less-compact layers of marl. Some of the bands are not altogether red .....	4 2
II. RED MARLS.		12. Greenish marl .....	0 6
		13. Thin impersistent band of marlstone .....	0 2
		14. Greenish marl .....	0 4
		15. Marlstone .....	0 5
		16. Greenish marl, somewhat laminated in places, compact at the base where it fits into .....	0 6
		17. Deposit of gypsum, pink .....	0 9
		18. Greenish-grey and whitish marls, white marl usually in hard layers .....	11 0
		19. Gypsum, usually white .....	0 6
		20. Hard grey marl: 6 to 9 inches .....	0 8
		21. Greenish-grey marl, shaly in places, nodular in others .....	0 11
Red marls, with zones of greenish-grey marl.			

shales complete the Lower Rhætic Stage, and pass up gradually into a greyish-green marl.

This marl-deposit was much fissured, previous to the deposition of the superincumbent gritty limestone. Into these fissures gritty material was washed. We have here a non-sequence caused by a slight upheaval; and, as a result, certain beds which are found elsewhere, are not to be seen at Lavernock. The beds that are missing at Lavernock measure at Garden Cliff about  $13\frac{1}{2}$  feet. Gradual subsidence, again, in the Lavernock area allowed of the formation of the White Lias (fig. 2, p. 390). At Penarth, Etheridge failed to discover '*Ostrea intus-striata*, so common in Somersetshire and Warwickshire';<sup>1</sup> but at Lavernock it is not uncommon, and is very abundant at Coldknap, Barry. The probable equivalent of the Sun-Bed completes the series of limestone-beds; and it is of this stratum that I found bored pieces (crypts of *Lithophagus*), on the beach at Seven Sisters' Bay. The specimens of *Ostrea liassica* (two) from this stratum were on the upper surface. The light-coloured shales above the White-Lias limestones are grouped with the White Lias; they contain *Ostrea liassica* abundantly in the lower portion. These are capped by the Paper-Shales, concerning which there has been some debate as to whether they should be classed with the Rhætic or with the Lias.<sup>2</sup> I think that there is little doubt but that they should be grouped with the Lias.

The deposit between these shaly beds and the Lavernock Shales requires no particular comment; but there has been some doubt as to the exact age of the last-named. However, as surmised by Mr. H. B. Woodward, they belong to the *angulata*-zone, having been laid down during the hemera *marmoreæ*. *Cardinia ovalis* (Stutchbury) did not exist after this hemera. In the Lavernock Shales it is abundant at certain horizons, both at Lavernock and at Leckwithbridge, near Cardiff. At the latter locality *Schlotheimia angulata* (Schlotheim) and *Cardinia ovalis* occur in association; consequently there can be no doubt as to the date of the beds. As the Lavernock Shales are difficult to examine minutely at the typical locality, the section at Leckwithbridge is appended:—

Thickness in feet inches.

Limestone, two beds mixed with marly clay ..... about	0	8	
Clay, marly, blue and yellow ...	0	8	
Limestone .....	0	2	
Clay, marly: 4 to 6 inches .....	0	5	
Limestone .....	0	3	{ <i>Ostrea irregularis</i> , Lima ( <i>Plagiostoma</i> ) aff. <i>gigantea</i> .
Clay and limestone-bands .....	1	10	
Limestone, dark grey .....	0	3	
Clay, hard, marly, reddish blotches	0	5	

<sup>1</sup> Trans. Cardiff Nat. Soc. vol. iii (1870-71) pt. ii, p. 50.

<sup>2</sup> H. B. Woodward, 'The Jurassic Rocks of Britain' Mem. Geol. Surv. vol. iii (1893) p. 119.

[Leckwithbridge Section (*continued*).]

		Thickness in feet inches.		
LAVERNOCK SHALES.	Limestone .....	0	4	<i>Ostrea irregularis</i> .
	Clay, with three bands of lime- stone, totalling 7 inches .....	4	0	{ <i>Ostrea irregularis</i> , <i>Lima</i> <i>gigantea</i> , <i>Cardinia</i> <i>ovalis</i> , <i>Schlotheimia</i> <i>angulata</i> (Schloth.). <i>Cardinia ovalis</i> (Stutch- bury); <i>Ostrea irregu-</i> <i>laris</i> , Münster; <i>Lima</i> <i>gigantea</i> (Sowerby); <i>Pholadomya fortu-</i> <i>nata</i> , Dumortier; <i>Littorina</i> cf. <i>minuta</i> , Terq. & Piette; ossicles of <i>Pentacrinus</i> , radioles of <i>Cidaris</i> ; <i>Rhynchon-</i> <i>ella</i> aff. <i>calciocosta</i> , Dav.; <i>Dentalium eta-</i> <i>lense</i> , Terq. & Piette.
	Limestone .....	0	3	
	Clay and limestones .....	12	0	
	Clay, blue; <i>Cardinia ovalis</i> abundant .....	3	0	
	Clay and limestones. Some of the limestone-bands become nodular .....	22	4	

Concerning the higher beds at Lavernock no details can be given; they are inaccessible, but limestones predominate. Proceeding farther westward along the coast, the other side of the syncline is entered upon, and the strata are soon passed over in descending order, until at St. Mary's-Well Bay, Sully, the Rhætic reappears.

(B) St. Mary's-Well Bay, Sully.

At this locality the whole of the Rhætic Series can be studied; but, since the Lavernock section has been dealt with in such detail, it will be sufficient for our present purpose to describe the basal portion only of the exposure. The beds are very much disturbed, owing to a fault—that which starts at Dinas Powis. The result is that the Rhætic Beds are faulted against the littoral Keuper, and in the downward course that portion of the series which I have denominated the Sully Beds has been prettily contorted.

The Bone-Bed seen in this section, although consisting of several layers, as at Lavernock, is nevertheless lithically distinct. The main band is a hard gray limestone, seldom pyritic, but usually crowded with fish-remains, although no quartz-pebbles were observed. Below the Bone-Bed are black shales with intermittent hard layers, as noticed in the appended section:—

<i>Thickness in feet inches.</i>			
15. A series of sandstone- and lime- stone-layers, with partings of shale.....	1	0	<i>Gyrolepis Alberti</i> (teeth ? & scales); a lamellibranch ( <i>Schizodus</i> or <i>Pullastra</i> ) not uncommon
16. Shales, black.....	1	5	
17. Limestone; intermittent.....	0	1	
18. Shales, black.....	0	5	
19. Limestone, earthy; intermittent	0	1	
20. Shales, black.....	1	4	
21. Rust-coloured layer.....	0	0½	<i>Gyrolepis Alberti</i> (rare).



Thickness in feet inches.

SULLY BEDS.	{	{	Marlstone, hard, greenish-grey, massive at the top, but nodular and mixed with black and yellow marl below .....	4	6	{	{	<i>Ostrea Bristovi</i> (very com- mon); <i>Pteria (Avicula)</i> <i>contorta</i> (abundant in a thin layer at the top); <i>Sargodon</i> (?), <sup>1</sup> <i>Lepidotus</i> (?); <i>Modiola</i> .
			Marls and marlstones.....					

Large masses of marlstone from the Sully Beds, scattered about on the beach, are crowded with *Ostrea Bristovi*, Etheridge, MS. (see p. 422), and the beds also frequently contain traces of the mineral baryto-celestine. These strata do not appear to have attracted any attention; they must have been observed, because Mr. E. T. Newton, F.R.S., informed me that an *Ostrea*, similar to that which I had submitted to him for examination from this locality, was preserved in the Museum of Practical Geology, Jermyn Street, and bore the legend '*Ostrea Bristovi*, Etheridge, MS. From near Penarth.' In a thin layer at the top of the Sully Beds, *Pteria (Avicula) contorta* is very abundant.<sup>2</sup> Their fossil contents render it incumbent that these beds should be classed with the Rhætic, but an arbitrary line of division must be drawn between them and the 'Tea-Green Marls,' which will be subject to alteration according to the records of fossils.

### (C) Cross Farm, near Dinas Powis.

In the memoir descriptive of the geology of the Cardiff district it is observed that

'To the west of the Lower Penarth or Lavernock outlier there is a considerable tract just high enough to take in some of the Rhætic shales and limestones, but nowhere high enough to touch the Lias.'<sup>3</sup>

Since the district was geologically surveyed between the years 1892

<sup>1</sup> Concerning this specimen, Dr. A. Smith Woodward, F.R.S., wrote (*in litt.*):—'Premaxilla with cutting-teeth. Might be *Sargodon*, or perhaps a Pycnodont fish.' It is preserved in the collection of Mr. E. Talbot Paris.

<sup>2</sup> The abundance of *Pteria contorta* in the uppermost layer of the Sully Beds here, and the record by Mr. F. T. Howard, F.G.S., of 'numerous crushed specimens of typical Rhætic shells—*Cardium rheticum*, *Avicula contorta*, and *Pecten valoniensis*'—in a thin layer of shale below the 'fish-bed,' Trans. Cardiff Nat. Soc. vol. xxix (1896-97) p. 66, is interesting in connection with a statement made by Prof. S. H. Reynolds & Dr. A. Vaughan in a footnote to their admirable paper on 'The Rhætic Beds of the South-Wales Direct Line' Quart. Journ. Geol. Soc. vol. lx (1904) p. 200. In that footnote they remarked:—'We have ventured to dissent somewhat from Mr. Richardson's correlation of the beds at Garden Cliff. Seeing that *Avicula contorta* and *Schizodus* occur plentifully below his Bone-Bed (Bed 15), it does not appear to us that this bed can be considered to be on the same horizon as that at Sodbury, which is well below the level at which these mollusca commence to occur in any abundance.' As to whether the Sodbury Bone-Bed was on the same horizon as that numbered 15 at Garden Cliff was a question for them to decide, and the evidence which led to their answer in the negative is quoted above. In view of the details obtained in Glamorganshire (and also in the Watchet district), this hardly seems conclusive.

<sup>3</sup> 'The Geology of the South-Wales Coalfield: Pt. iii' Mem. Geol. Surv. 1902, p. 63.

and 1896, a large quarry has been opened out in the Lower Liassic limestones of this outlier, near Cross Farm, and the junction of these beds with the White Lias (A of Lavernock) exposed to view. The section is as follows :—

		Thickness in feet inches.		
LOWER LIAS.	{	Marl and limestone-fragments .....	seen 0 10	
		Three bands of limestone, with marly partings .....	2 10	{ <i>Ostrea liassica</i> and radioles of <i>Pseudodiadema</i> .
		Limestone .....	0 7	
		Limestones and shales .....	5 2	
		Shale .....	0 8	{ <i>Ostrea liassica</i> common.
		Limestone in two conspicuous beds .....	0 8	
		Shale .....	0 4	
		Limestone .....	0 5	
		Limestone and shales .....	9 5	
		Three beds of limestone, with very thin partings of shale. Locally called 'the Washers' .....	0 7	<i>Ostrea liassica</i> .
		Clay .....	0 1	
		Limestone .....	0 6	<i>Ostrea liassica</i> .
		Shale, thinly laminated in the upper portion, clayey in the lower .....	0 6	
		Limestone, blue-centred .....	0 3	
		Paper-Shales, as at Lavernock .....	1 0	
WHITE LIAS.	{	Shales, bluish, marly .....	seen 3 6	

Unfortunately, the sequence downwards cannot be ascertained; but in the lane-side near the buildings at Cross Farm the following details may be observed :—

		Thickness in feet inches.		
		Shales, black, with soft gritty layers at the base .....	seen 3 0	{ In the limestone <i>Pullastra arenicola</i> is abundant: wood and fragments of fish-scales occur. In the quartz-sand <i>Acrodon minimus</i> , <i>Saurichthys acuminatus</i> , and <i>Gyrolepis Alberti</i> are common.
		15. Limestone, hard, grey, micaceous, with quartz-sand immediately below .....	0 5	
		16. Shales, black .....	0 4	
		17. Sandy layer, chocolate-coloured ...	0 1	<i>Gyrolepis Alberti</i> .
		[Gap]		
SULLY BEDS.	{	Marlstone, hard, greenish-grey: 4 to 15 inches .....	0 9	<i>Ostrea Bristovi</i> .
		Marly shales, dark greenish-grey and brown, with sandy seams .....	2 0	
		Marlstone, hard, greenish-grey .....	0 11	<i>Ostrea Bristovi</i> .

The lamellibranchs in Bed 15 are, on the whole, well-preserved and extremely abundant. As I did not recognize the fossil, I submitted specimens to Mr. E. T. Newton, who replied :—' This is the shell which is known as *Pullastra arenicola*, Strickland.' *Ostrea Bristovi* abounds in the Sully Beds at this locality; but, in a deep wheel-track some 350 yards to the north-east, the equivalent beds

are found to have changed, both as regards faunal and lithic characters:—

		Thickness in feet inches.		
SULLY BEDS.	Shales, black, clayey .....	seen	2 0	
	a. Limestone and quartz-sand .....	0	4	<i>Gyrolepis Alberti</i> ; <i>Ostrea</i> (?)
	b. Limestone, earthy .....	0	3	
	c. Clay .....	0	1	
	d. Limestone, irregular masses: 0 to 9 inches.....	0	5	<i>Gyrolepis Alberti</i> .
	e. Marl, black and brown .....	0	6	
	f. Limestone, hard, crystalline in the upper portion: the lower simulates Carboniferous Limestone .....	0	7	Fishes (scales and teeth).
	g. Marl, hard, shaly .....	seen	0 10	

In a road-cutting between Merch and Cogan Hall certain Rhætic beds are exposed, including a bone-bed:—

		Thickness in feet inches.		
10 to 14 ?	Shale, black, clayey: possibly about	4	5	[ <i>lepis</i> .
15.	Limestone, hard, grey: 0 to 2 inches	0	1	<i>Schizodus</i> (?); <i>Gyro-</i>
16.	Shale, black, clayey .....	0	6	<i>Saurichthys acumina-</i>
17.	Arenaceous rust-coloured deposit ...	0	1	<i>tus</i> , <i>Gyrolepis Alber-</i>
18 to 21.	Shale, black .....	estimated at	3 0	<i>ti</i> ; quartz-pebbles.

It is impossible to correlate these beds with certainty, and so the numbers affixed to them must be regarded merely as suggestive.

About halfway between the foregoing section and the place where this lane joins the Cogan road, fish-remains are not uncommon in the Sully Marls. Although these beds are well-developed in this outlier, it is recorded in the Geological-Survey Memoir that, whereas a certain zone occurs 26½ feet below the Rhætic Black Shales at Lavernock, in this outlier it occurs only 14 feet below that datum-level.<sup>1</sup> This may point to some overlap of the Sully Beds (see p. 413).

## ii. Barry to Cowbridge.

In the district between Barry and Cowbridge there are three important sections of the beds under consideration, namely, at Barry (Coldknap), Cadoxton, and Tregyff (near Cowbridge).

Two small outliers of Rhætic Beds occur on Barry Island. The northernmost patch has been investigated by Mr. F. T. Howard, F.G.S., who has recorded a number of fossils.<sup>2</sup>

### (A) Coldknap, Barry.

In the low cliff near Coldknap Farm, and facing Barry Island, is a section of much interest and importance. In the Geological-Survey Memoir on the Cardiff district it is recorded that

‘Rhætic shales are exposed again as an inlier near Coldknap. They form a

<sup>1</sup> ‘The Geology of the South-Wales Coalfield: Pt. iii—The Geology of the Country around Cardiff’ Mem. Geol. Surv. 1902, p. 54.

<sup>2</sup> Trans. Cardiff Nat. Soc. vol. xxvii (1894–95) p. 42.



small anticline running rather south of east, and are traversed by several small faults, all probably branches from the Coldknap Fault.'

A sketch-section is given by Mr. Strahan (*op. cit.* p. 64). Beneath the *Ostrea*-limestones are the following beds:—

		Thickness in feet inches.		
WHITE LIAS.	Paper-Shales.			
	Marl, bluish-grey, with harder bands	5	6	<i>Modiola minima</i> , Moore
	Calcite-layer	0	0½	[ <i>non</i> Sowerby.
	Band of indurated marl	0	2½	
	A. Marl, bluish-grey	0	2	
	Layer composed of the valves of an <i>Ostrea</i>	0	2	<i>Ostrea</i> sp.
	Marl, bluish-grey	2	10	
	B. Limestone in two beds, bluish-grey weathering yellow. The lower bed in particular resembles the Sun-Bed, and exhibits a conchoidal fracture	0	6	
	1. Shales, bluish-grey, calcareous.	0	5	
	2. Rubbly limestone, with more compact limestone immediately below, weathering yellowish. Fossils most abundant in the upper portion	0	5	{ <i>Plicatula intus-striata</i> , <i>Pl. hettangiensis</i> , and <i>Lima (Plagiostoma)</i> <i>valoniensis</i> , common; <i>Protocardium Philip-</i> <i>pianum</i> , <i>Pleuropho-</i> <i>rus</i> (?), <i>Modiola mini-</i> <i>ma</i> (?) (large) Moore, <i>Ostrea</i> sp.; an ostracod.
	3. Shale	0	2	<i>Pleurophorus</i> (?) & <i>Pro-</i> <i>tocardium</i> (?) as casts,
	4. Limestone, yellowish	0	1½	<i>Plicatula intus-</i> <i>striata</i> .
	5. Shale, blue and yellow, indurated	0	9	<i>Lima (Plagiostoma)</i> <i>valoniensis</i> .
	6. Gritty layer	0	2	Shell-débris; <i>Plicatula</i> <i>intus-striata</i> .
	7. Shale, greenish-grey, thinly laminated	0	2	
	8. Limestone, blue-centred	0	3	
	9. Shale, greenish-grey ... about	0	3	
	10. Grit, pyritic, ripple-marked: 0 to 3 inches.	0	2	
UPPER RHÆTIC. 4. Shales, greenish-grey.				

The White-Lias Beds (C) in the foregoing section are extremely fossiliferous, and it is remarkable that they have not attracted attention on this account. The strata between the Paper-Shales and the Upper Rhætic marl or shales (4) at Lavernock measure 8 feet 10½ inches, and at Barry 12 feet 3½ inches, the increase in thickness at the latter locality amounting therefore to close upon 3 feet 6 inches.

Mr. H. B. Woodward has observed a bone-bed in crevices of the top-bed of marl, at the base of the Black Shales at Cadoxton.<sup>1</sup>

<sup>1</sup> Proc. Geol. Assoc. vol. x (1888) p. 531.

The most interesting exposure in this neighbourhood is in the sides of a field-road, near the brook, about three-fifths of a mile in a direction a little to the south of west of Cadoxton Church.

(B) Cadoxton.

		Thickness in feet inches.	
SULLY BEDS.	a. Marls, yellow and black .....		
	b. Limestone, hard, dark, in masses mixed with dark-brown clay : 3 to 9 inches .....	0 6	<i>Lepidotus</i> (?), <i>Acerodus</i> <i>minimus</i> , <i>Gyrolepis</i> <i>Alberti</i> ; boné ( <i>Laby-</i> <i>rinthodon</i> ?) ; <i>Ostrea</i> <i>Bristovi</i> (see Pl. XXXIII, fig. 4), <i>Pteria</i> ( <i>Avicula</i> ) (?) <i>contorta</i> ; <i>Natica</i> (?) <i>Ostrea Bristovi</i> (rare).
	c. Shales, black, earthy .....	1 8	
	d. Limestone, hard, dark .....	0 6	
	e. Shales, black and brown, with yellow streaks.		

The necessity for grouping the Sully Beds with the Rhætic will be obvious from the foregoing section, although it should be mentioned that the fossils are not individually numerous. Here it will be noticed that *Ostrea Bristovi* is associated with *Pteria* (*Avicula*) *contorta* and other Rhætic lamellibranchs.

*Pteria* (*Avicula*)-*contorta* Black Shales, with an extremely fossiliferous *Pecten*-Bed, are to be seen in the deeply-cut lane three-fourths of a mile north by east of Cadoxton Church : the limestone-bed yields *Pecten valoniensis*, *Pteria* (*Avicula*) *contorta*, *Schizodus Ewaldi*, and a *Placunopsis* similar to that which occurs in Bed I of the Redland (Bristol) section.<sup>1</sup>

Between the last section and Redland (near Bonvilston) the Rhætic deposits are but seldom exposed. Black shales with thin *Pecten*-Limestones have been observed in a brook on the north side of Bears Wood, south of Wenvoe Castle, and again west of St. Nicholas, 'on both sides of the valley and in Coed-y-Cwm.'<sup>2</sup>

In a road-section at Redland (Sheets 261, 262) some interesting details can be observed. In the Geological-Survey Memoir on the country around Bridgend is the following passage :—

'A small quarry 100 yards south of Redland shows the *Avicula-contorta* Shales overlying a hard yellow dolomitic rock of Tea-Green Marl age, while Carboniferous Limestone, apparently in place, crops out on the opposite side of the road. Here, then, we can fix a point on the Keuper coast-line, for the limestone-ground to the north was still above water at the close of the Keuper-Marl period.' ('Geology of the South-Wales Coalfield : Pt. vi' 1904, p. 30.)

In August 1904, the section on the west side of the road exposed a boss of Carboniferous Limestone wrapped round by Black Shales. This boss, at the road-level, measured 2½ feet across, and stood 2 feet high. A little farther in the direction of Blackland the Black

<sup>1</sup> A. Rendle Short, Quart. Journ. Geol. Soc. vol. lx (1904) p. 171.

<sup>2</sup> 'The Geology of the South-Wales Coalfield : Pt. iii' Mem. Geol. Surv. 1902, p. 65.

Shales were more in evidence, and pieces of a *Pecten*-Limestone containing the characteristic lamellibranch, fragments of a *Placunopsis*, and fish-scales, were lying about. Still nearer Blackland higher beds were exposed, including thin bands of pale limestone intercalated in similarly-coloured shale, altogether 3 feet 4 inches thick, and resting upon grey and yellow shale (belonging presumably to the Upper Rhætic), of which a thickness of 6 inches was visible. Where the *a* in Redland comes on the 1-inch Geological-Survey map there is a large quarry in the Carboniferous Limestone. In one place some green marl has been washed down a fissure, but on the whole, as noticed by Mr. Cantrill,

the Rhætic soil can be recognized so close to the brow of a large quarry in Carboniferous Limestone, as to suggest that the Keuper is here wholly overlapped, as shown on the map.<sup>1</sup>

A pond to the east of the ancient camp at Leige Castle is in the Black Shales, and from pieces of *Pecten*-Limestone were obtained Labyrinthodont-bones (small pieces), scales of *Gyrolepis*, coprolites (fish), and fragments of *Pecten* (*Chlamys*) *valoniensis*. A section showing the junction of the Rhætic and Carboniferous-Limestone deposits can be studied in the roadside 200 yards north-west of Ty'n-y-coed, but here—as at Redland—the Rhætic Beds exhibit no littoral facies, such as might be at first expected.

The finest section in the Cowbridge district is in a road-cutting at Tregyff, near the St. Mary-Church Road Station on the Cowbridge & Aberthaw Railway. It is dealt with in the Geological-Survey Memoir (*op. cit.* p. 40) in the following short passage:—

‘They [the Rhætic deposits] emerge south-east of Wren Castle, and here for the first time exhibit signs of the oncoming of a more arenaceous type, in the intercalation of bands of greenish-grey sandstone. These may be traced southwards along the valley, but are especially well-shown in a road-cutting at Tregyff, though the beds undulate gently down the road westwards at such an angle that only a few feet are exposed. They consist of sandstone with *Protocardium Philippiannum* and *Avicula contorta*, blue sandy marls, a thin conglomeratic band containing pebbles of Carboniferous Limestone and chert and black limestone with *Pecten valoniensis*.’

### (C) Tregyff, near Cowbridge.

Thickness in feet inches.

LOWER RHÆTIC.	{	Limestone, pieces not <i>in situ</i> .			
		Shales, brown (several feet).			
		Limestone, dark .....	0	1	
		Shales, brown .....	1	3	
		Shales, black, with several bluish gritty layers .....	1	6	
		Limestone, brown and blue.....	0	1½	
		Shale, weathering brown .....	0	6	
		Sandstone, fine-grained, calcareous	0	1	Casts of worm-burrows
		Shale, black, weathering brown ...	0	7	[on the underside.
		5a {			

<sup>1</sup> ‘The Geology of the South-Wales Coalfield: Pt. vi.—The Geology of the Country around Bridgend’ Mem. Geol. Surv. 1904, p. 39.

		Thickness in feet inches.		
LOWER RHEIFIC.		Sandstone, light-grey, fine-grained, calcareous.	0 3	<i>Pteria (Avicula) contorta</i> (two specimens).
		Shales, black, thinly-laminated, weathering brown, and containing thin gritty layers	1 2	{ <i>Pecten (Chlamys) valoniensis</i> , <i>Schizodus Ewaldi</i> ; <i>Acrodon minimus</i> , teeth and scales of <i>Gyrolepis Alberti</i> .
		5b. Limestone, grey, massive, with muscovite-flakes	0 10	
		6. Parting, usually of shale, sometimes impure limestone	0 1	{ <i>Pecten (Chlamys) valoniensis</i> , <i>Placunopsis alpina</i> (large).
		7. Limestone, grey, massive	0 6	
		8. Shale, black, weathering brown, thinly laminated, with a few gritty layers	0 4	Much shell-débris.
		9. Limestone, grey, thinning out in places, often arenaceous	0 1	{ <i>Pecten (Chlamys) valoniensis</i> , <i>Pteria (Avicula) contorta</i> , coprolite. <i>Acrodon minimus</i> (common), <i>Saurichthys acuminatus</i> , 'Sargodon tomicus' ( <i>Lepidotus</i> ?), ichthyodorulite of <i>Hybodus</i> ; casts of a lamellibranch of <i>Schizodus</i> -type; wood. <sup>1</sup> <i>Schizodus</i> ? (casts).
		10 to 14 { Shales, black, laminated, with several gritty layers near the top, and at the base, towards the eastern end of the section, a	2 5	
		15 { Massive bed of conglomerate (see p. 402): 0 to 8 inches		
		Hard band of grit: 1 to 3 inches	0 2	
		16. Shales, black, with gritty layers containing a few fish-scales (indeterminable)	0 9	
		17. Limestone, hard, grey, slightly sandy in places, usually in two beds with a little shaly matter intervening between them	0 7	{ <i>Pteria (Avicula) contorta</i> ; a few fish-scales ( <i>Gyrolepis</i> ?) and coprolites (fish). <i>Hybodus minor</i> (1 tooth), <i>Gyrolepis Alberti</i> (scales, rare); <i>Pteria (Avicula) contorta</i> , <i>Modiola</i> , fragments of lamellibranchs, and carbonaceous matter.
		18. Marl, greenish-grey and bluish, imperfectly laminated. Near the top are little lumps of a hard limestone simulating Carboniferous Limestone.	1 4	
	SULFUR BEDS.	{ Limestone, hard, compact, greyish-green, sandy, resembling from a distance, Carboniferous Limestone: containing occasionally fragments of a white earthy marlstone and small quartz-pebbles	0 10	{ <i>Acrodon minimus</i> (common), 'Sargodon tomicus' ( <i>Lepidotus</i> ?), fish-scales (fragments common).
		Marlstone, yellowish-green; visible in the gutter		

From a lithological standpoint the Tregyff section presents many features of interest. At the base are hard marlstones which are best

<sup>1</sup> All from the Conglomerate-Bed.

grouped with the Sully Beds. The fossils recorded from the limestone-bed were observed mostly in the uppermost portion. Above is a deposit of soft marl, which yielded single examples of *Pterin* (*Avicula*) *contorta*, *Modiola* (indeterminable), and *Hybodus minor* (tooth).

The most interesting stratum in the foregoing section is the Conglomerate-Bed distinguished as 15.

In a series of deposits such as the Rhætic, it is often difficult to correlate with certainty the various component deposits seen at different localities. In certain districts, however, as in North-West Gloucestershire and Worcestershire, the same lithic characters are preserved by a bed over a considerable area; but in Glamorganshire such is not the rule, and as the beds are traced westwards there is increasing evidence of the proximity of land. Here, at Tregyff, the Lower Rhætic was deposited close to a shore-line composed of Carboniferous rocks, and as a result the Secondary rocks became what Charles Moore would have termed 'abnormal.' Therefore, it will be understood that when in the foregoing record, and in those of sections farther west, a bed is distinguished by a certain number, that number suggests rather than implies contemporaneity with a similarly-notated deposit elsewhere.

Mr. E. B. Wethered, F.G.S., has kindly supplied me with the following notes on certain limestone- and chert-pebbles from the Conglomerate-Bed:—

'Limestone-pebble from the Conglomerate-Bed, Tregyff, near Cowbridge.—An impure limestone containing a number of organic remains, but so altered by molecular change that it is very difficult to determine them beyond a few spines, crinoid-ossicles, fragments of polyzoa and mollusca. The main feature of the slide is the presence of a large number of crystals of salt and gypsum, which are apparently of secondary origin.'

'Chert-pebble from the Conglomerate-Bed, Tregyff, near Cowbridge.—Looked at in a hand-specimen this appears to be a chert enclosing oolite-granules. The sections of this chert seen under a microscope show it to contain a number of ovoid bodies, some of which include a nucleus, but the usual form of concentric structure characteristic of oolite-granules is not apparent. Originally the rock was probably a limestone, which has been transformed into chert by the gradual replacement of the carbonate of lime by silica.'

The *Pecten*-Beds (7 & 5*b*) are well-developed; but the superincumbent deposits are difficult to correlate, both on account of the lack of distinctive fossils and the growth of vegetation, which obscures the upper portion of the section to a large extent.

In the neighbourhood of Ty-ganol the lower portion of the Lower Rhætic consists mainly of a sandstone-deposit. This sandstone is well exposed by the roadside, 180 yards north-east by north of Ty-draw, and therefrom were obtained a specimen of *Hybodus minor* and a few scales of *Gyrolepis Alberti*. The whole of the lower stage, however, is not replaced by an arenaceous deposit, because

Mr. Cantrill has noticed some *Pecten*-Limestones between Ty-ganol and Pentre.

At Pentre certain White-Lias beds have been preserved as an outlier; also a few Rhætic beds, as proved by pieces of *Pecten*-Limestone with fragments of *Pecten* (*Chlamys*) *valoniensis*. This outlier is situated 200 yards east of the road, and owes its preservation to faulting, whereby the beds composing it have been let down on the north against the Carboniferous Limestone. Formerly there was a quarry here, but now the excavation is filled with water. On the south side of this pond the following beds are exposed:—

		Thickness in feet inches.	
WHITE LIAS.	Clay, yellow, shaly at the base: visible .....	1	0
	Limestone, brown and dark-coloured; <i>Plicatula intus-striata</i> common <sup>1</sup> .....	0	5
	Clay .....	0	3
	Limestone .....	0	2
	Clay, yellow .....	0	5
	Limestone; <i>Modiola minima</i> common .....	0	2
	Shales, dark, hard, with thin beds of limestone .....	seen 1	6

The uppermost limestone in the foregoing record exactly resembles the bed bearing a similarity to the Sun-Bed at Barry (p. 398).

The account of these Rhætic beds given by Mr. Cantrill shows that, in the St. Hilary district, few if any exposures escaped his attention. But there are one or two interesting facts not as yet recorded. By the side of a pond, indicated by the arrow on the Geological-Survey Map, and some 300 yards to the west of Garn, is a limestone-bed very much resembling, lithically, a certain development of the *Estheria*-Bed of North-West Gloucestershire. This stratum contains *Pseudomonotis fallax*, and dips gently to the north-east by north: it is, therefore, most probably on the same horizon as the *Pseudomonotis*-Bed.

In the floor of the lane between St. Hilary and St. Hilary Common, there is a quite fossiliferous bone-bed. The deposit is a pale, slightly-arenaceous limestone, containing obscure casts of a lamellibranch (*Schizodus* ?), scales and teeth of *Gyrolepis Alberti*, *Acerodus minimus*, and a few indeterminable fragments of bone.<sup>2</sup>

In the roadside at The Cross, south of St. Hilary, the Rhætic sandstones are exposed. There is, however, a considerable amount of black shaly matter present, and in the sandstone-layers intercalated in this shale—especially in that about an inch thick towards the middle (vertical) of the exposure—‘plant-remains’ are abundant.

<sup>1</sup> A rock crowded with this lamellibranch, but not found *in situ*, is assigned to this horizon, owing to the similarity of lithic structure.

<sup>2</sup> See also Buckland & Conybeare, Trans. Geol. Soc. ser. 2, vol. i (1824) p. 301; and ‘The Geology of the South-Wales Coalfield: Pt. vi.—The Geology of the Country around Bridgend’ Mem. Geol. Surv. 1904, p. 41.



Between How Mill and The Herberts a road-section shows sandy beds and shale:—

Thickness in feet inches.			
RHÆTIC.	a. Shale, black .....		
	b. Sandstone, fine-grained, calcareous: 1 to 2 inches .....	0	1
	c. Shale, grey .....	0	5
	d. Limestone, arenaceous, nodular: 1 to 2 inches .....	0	1
	e. Shale, black .....	0	1
	f. Sandstone, hard and dark-grey bands near the base, but otherwise some- what soft .....	6	0
<div style="display: flex; justify-content: space-between; align-items: flex-start;"> <div style="width: 60%;"> <p><i>Gyrolepis Allerti</i>, and some other fish- remains, but indeter- minable.</p> <p>In the hard por- tions were noted casts of a lamelli- branch and numerous small pieces of wood.</p> </div> <div style="width: 35%; font-size: 2em;">}</div> </div>			
KEUPER. I. Hard, grey, rocky marls .....			

As no distinctive fossils were obtained from these rocks, it is only possible to say that they belong to the Lower Rhætic.<sup>1</sup>

The sections in the railway-cuttings north and south of St. Mary-Church Road Station have been described in detail in the Geological-Survey Memoir on the district<sup>2</sup>; and, in both cases, below the representative of the Paper-Shales of the Lavernock Section, is the White Lias—shaly and marly matter constituting the greater mass of the deposit. Owing to the ample details recorded in the memoir just cited, it is unnecessary to discuss these sections here; and the same remark applies to the sections of the Rhætic Beds at both ends of the railway-cutting at Cowbridge.<sup>3</sup> That at the southern end is the more satisfactory of the two. The Paper-Shales are 8 inches thick, and the Rhætic and White-Lias deposits between them and the Keuper measure 19 feet.

Having dealt with the sections of the Rhætic deposits in the district between Barry and Cowbridge, I may now direct attention

<sup>1</sup> Higher up, in a field on the south side of the road, there is a quarry in blue-limestones with shale-partings—the upper beds full of *Psiloceras Johnstoni*. They are crowded with gasteropods, the commonest form of which is *Cerithium gratum*, Terquem. In the quarry on the north side of the road, as noticed by Mr. F. T. Howard, Trans. Cardiff Nat. Soc. vol. xxx (1897-98) p. 41, are several limestone-beds crowded with *Thecosmilia* cf. *irregularis*, Duncan. Halfway between Llandough-juxta-Cowbridge and Llanfihangel are two quarries, one on each side of the valley. In that on the north side is a bed full of the same species of *Thecosmilia*, while the other fossils included *Pteria* (*Avicula*) *inequivalvis*, *Lima valoniensis*, *L. tuberculata*, *Modiola minima* (?), *Pinna*, *Ornithella sarthacensis*, and radioles of an echinoid. The quarry on the opposite side yielded *Psiloceras planorbis*, *Lima gigantea* (small), *Pecten* aff. *calvus*, *Pinna*, *Ostrea*, *Modiola minima*, Sow., and a gasteropod.

<sup>2</sup> 'The Geology of the South-Wales Coalfield: Pt. vi' (1904) pp. 41-44.

<sup>3</sup> *Ibid.* pp. 44-48 and Trans. Cardiff Nat. Soc. vol. xxx (1897-98) pp. 36 et seqq.

to the outliers in the neighbourhood of Pendoylan, at Peterston, and St. Fagans.<sup>1</sup>

In the Pendoylan outlier, Mr. Cantrill discovered pieces of *Pecten*-Limestone at a pond 100 yards south-east of the vicarage; and I found fragments of a similar rock at a pond immediately west of the footpath running from Pendoylan to Ty'n-y-cae, at a point due west of the Tre-sfoch. Mr. Cantrill obtained spines and tubercles of an echinoid (queried as an *Acrosalenia*), from a *Pecten*-limestone thrown out from a well-excavation, 80 yards north-west of Pendoylan School. The fact is interesting, because, except for the records of an echinoid (which may be a species of *Pseudodiadema*) at Coomb Hill near Cheltenham,<sup>2</sup> and at Church Lench (Worcestershire),<sup>3</sup> I am not aware that such remains have been noticed in beds of *contorta*-age.<sup>4</sup> Mr. Cantrill, moreover, observed Rhætic limestone in the soil of a field, at about 150 yards along the footpath running south-eastward from Ty'n-y-cae. Near the hedge at the same spot are shallow excavations, in which fragments of sandstone containing *Acrodus minimus*, and bits of fish-scales, can be seen.

In the Peterston outlier Black Shales and *Pecten*-Limestones have been noticed in a brook between Maendy and Allt-isaf, but the only exposure of any interest is at the village of St. Bride's, in a shallow road-cutting near the church. On the west side a considerable thickness of black shale occurs, together with a bed of sandstone crowded with the teeth of *Acrodus minimus*; while on the east the 'Tea-Green Marls' (Keuper) are visible. There is no evidence of the Sully Beds.

In the sides of a pond about 200 yards west of Pen-hefyd, St. Fagans, Black Shales and a *Pecten*-Limestone (containing *Pecten valoniensis* and fragments of a *Placunopsis*?) are visible. These

<sup>1</sup> The occurrence of Rhætic deposits has been noted by the officers of the Geological Survey at certain localities which have not been touched upon in this paper, because, although I visited these localities, I did not obtain any additional information. The results of the official investigations are chronicled at the following pages of the memoir on 'The Geology of the South-Wales Coalfield: Pt. iii'—p. 66 (St. George's); p. 66 (Coed-y-gof); p. 66 and in Pt. vi (1904) p. 39 (Castell-y-Mynach); p. 65 (Saintwell); and p. 65 (Vishwell).

<sup>2</sup> 'Handbook to the Geology of Cheltenham' 1904, p. 210.

<sup>3</sup> Proc. Cotteswold Nat. F.-C. vol. xv (1904) p. 40.

<sup>4</sup> In that part of the memoir on 'The Geology of the South-Wales Coal-field which deals with the Cardiff district (pt. iii, 1902, p. 56) there is the following passage:—'The fauna includes scarcely any examples of the four great marine orders, Actinozoa being unknown in the *Avicula-contorta* beds, Echinodermata being represented by one form of feather-star, Brachiopoda by one form of *Discina*, Cephalopoda by a *Beloteuthis*, the horizon of which, however, there is reason to doubt.' Later discoveries require this statement to be modified somewhat: in addition to the occurrence of an echinoid in the *Pteria* (*Avicula*)-*contorta* Beds, a compound coral has been described by the late R. F. Tomes (Quart. Journ. Geol. Soc. vol. lix, 1903, p. 403); and the same author found an imperfectly-preserved *Montlivaltia*, parasitic on a *Modiola* in the Black Shales, during the construction of the Penarth Docks (*ibid.* vol. xl, 1884, p. 363). Charles Moore obtained from his 'Flinty bed' at Beer Crowcombe, Somerset, a single specimen of a coral, probably a species of *Montlivaltia* (*ibid.* vol. xvii, 1861, p. 511).

Rhætic beds are preserved between two faults, as recorded in the Geological-Survey Memoir, but they have been omitted—no doubt inadvertently—from my copy of the map.

### iii. Cowbridge to Pyle.

At most localities between Cowbridge and Pyle the Black Shales and intercalated sandstone-bands, which usually constitute the deposit laid down during the *contorta*-age, are replaced by massive sandstones containing few fossils; while, during the time when the Upper Rhætic was deposited, a greenish marl with red streaks was formed.

What details concerning the Rhætic can be obtained in the neighbourhood of St. Mary Hill have been recorded by Mr. Tiddeman<sup>1</sup>; it is, therefore, sufficient to state here that the arenaceous element predominates over the argillaceous.

The road between the railway near Coychurch and Coity runs along the outcrop of the Rhætic, of which there are several exposures; as, for instance, seven-tenths of a mile north-west by west of Coychurch Church, and again in the road at Simondston. In the village of Coity itself, sandstones and shales of a greenish tint (but mottled red in places), and full of *Modiola minima* (?) Sow., are seen in a road-cutting near the Castle.

### (A) Hendre, near Pencoed.

Between Hendre and Pencoed the Rhætic has been disturbed by two faults, that on the north letting it down against clayey shales belonging to the Millstone Grit. The Hendre brick-kilns are situated on the Keuper Marls. At a slightly-higher level to the north are the Rhætic sandstones, faulted against the Millstone Grit. A passage driven from the brickworks to the bottom of the clay-pit passes through the Rhætic sandstone, and from such fissile rock numerous ill-defined casts, of a lamellibranch of *Schizodus*-facies, were obtained. The Keuper Marls are excellently exposed in a pit adjoining the works.

A little to the east of the Hendre brickworks are two quarries in which massive Rhætic sandstone is worked. *Pullastra arenicola* and scales and fragmentary bones of *Gyrolepis Alberti* have been collected in this neighbourhood by Mr. Tiddeman, who has also given the following record of the sequence of deposits<sup>2</sup>:—

		Thickness in feet.
LOWER RHÆTIC.	Sandstone, white, fine-grained, massive below and more thinly-bedded and yellowish above .....	seen 30
	<i>a.</i> Sandy beds .....	3
UPPER KEUPER.	<i>b.</i> Green and yellow marl.....	15
	<i>c.</i> Hard marl, with 'race' and gypsum .....	2
	<i>d.</i> Clayey red marl.....	2
	<i>e.</i> Clay and marl; proved in a well .....	30

<sup>1</sup> 'Summary of Progress of the Geological Survey for 1899' (1900) p. 129 and 'The Geology of the South-Wales Coalfield: Pt. vi—The Geology of the Country around Bridgend' Mem. Geol. Surv. 1904, pp. 50, 51.

<sup>2</sup> 'Summary of Progress of the Geological Survey for 1899' (1900) p. 129 and 'The Geology of the South-Wales Coalfield: Pt. vi—The Geology of the Country around Bridgend' Mem. Geol. Surv. 1904, p. 50. See also his pamphlet on the 'Quarella Quarries,' Bridgend, 1893.

(B) Quarella Quarry, Bridgend.

North of Bridgend are the well-known Quarella Quarries, where pale-green and white Rhætic sandstones are worked, the rock being very suitable for building-purposes. A single block from Bed *c* (of the sandstone-deposit) of the appended record measured  $72 \times 53 \times 44$  inches, and must have weighed about a ton and a half. The deeper quarry, and that which yields the more satisfactory section, is situated on the south side of the lane:—

		Thickness in feet	inches.
OSTREA- BEDS.	Limestone, grey .....	0	6
	Shale-parting .....	0	1
	Limestone .....	0	3
	Shales, bluish-grey and brown .....	0	4
RHÆTIC.	1. Shales, hard, passing into hard bluish-grey limestones with conchoidal fracture .....	0	7
	2. { <i>a.</i> Shale, black and brown, clayey .....	0	4
	<i>b.</i> Shale, hard .....	0	4
	<i>c.</i> Marls, greenish and yellowish .....	1	8
	3. Limestone, argillaceous, nodular: 3 to 5 inches .....	0	4
	4. Green and yellow sandy marls; almost a fine sandstone in places .....	6	6
	5 <i>a</i> { <i>a.</i> Sandstone, pale-green and white, rather broken up ...	4	4
	<i>b.</i> Sandstone .....	3	4
	<i>c.</i> Sandstone .....	4	0
	15(?) { <i>d.</i> Sandstone .....	4	0
		<i>e.</i> Sandstone, more flaggy, and therefore in thinner layers, seen	8 6

The first notice of this section is contained in Tawney's paper 'On the Western Limit of the Rhætic Beds in South Wales & on the Position of the "Sutton Stone."' He regarded the sandstone-beds as belonging to the Keuper, while '6 feet of green sandy marls' he doubtfully referred to the Rhætic.<sup>1</sup> Charles Moore observed (Quart. Journ. Geol. Soc. vol. xxiii, 1867, p. 513) that

'in the valley west [north?] of Bridgend the Keuper Sandstones are largely worked, but their succession upwards into the Lias is not well exposed.'

H. W. Bristow, however, corrected this error (*ibid.* p. 205):

'the sandstones quarried for building and grindstones . . . are not situated at the base of the Keuper, as stated by Mr. Tawney, but are in the upper part of the Rhætic Series, overlain by Lias crowded with the characteristic *Ostrea liassica*.'

Whichever subdivisions of the Rhætic are represented here, and in the absence of fossils (except for a *Lima*) it is difficult to decide, it is obvious that we have the equivalents of nearly the whole series. The stratum distinguished as 1 much resembles the Cotham-Marble equivalent; while the nodular limestone (3) is very suggestive of the *Estheria*-Bed. From the limestones capping the section Mr. Tiddeman obtained *Ostrea liassica* and *Pleuromya*.<sup>2</sup>

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxii (1866) p. 72.

<sup>2</sup> 'Summary of Progress of the Geological Survey for 1899' (1900) p. 130 and 'The Geology of the South-Wales Coalfield: Pt. vi.—The Geology of the Country around Bridgend' Mem. Geol. Surv. 1904, p. 51.

Sandstone, from which Rhætic fossils have been obtained, has been worked near the Angeltown Asylum, and (more recently) for building the church at Pen-y-fai.

The section in the railway-cutting at Cwrt-Colman is now for the most part overgrown, but the details recorded by Tawney show (1) that there is an increase in the proportion of the shale-deposit to the sandstone as compared with the Quarella section, and (2) the presence of a recognizable bone-bed (Quart. Journ. Geol. Soc. vol. xxii, 1866, p. 70). Massive sandstone-beds, however, are still to be seen on the south side of the line. Near this cutting, in a road-section south of Melin Cwew, certain information concerning the upper portion of the Rhætic has been obtained by Mr. Tiddeman.<sup>1</sup>

### (C) Stormy Down.

The picturesque and breezy moorland known as Stormy Down is covered with large masses of Rhætic sandstone, and is broken with many scattered openings, most of which have been made in search of sand for silica-bricks. In a long line of excavations the following sequence may be observed:—

	Thickness in feet inches.	
a. Sandstone with an uneven base: 10 to 12 feet seen .....	11	0
b. Marl, green and yellow, clayey. Soft and hard layers alternate. They appear to have been slightly contorted previous to the deposition of the superincumbent sandstone, as soft arenaceous matter fills up the miniature synclines. A little lignite occurs near the base .....	1	10
c. Marl, greyish-green; full of plant-remains .....	1	0
d. Clay, brown .....	0	2
e. Marl, grey and brown .....	0	6
[Apparently this deposit extends some feet deeper.]		
f. Sandstone of considerable thickness ['Tea-Green Marls' ?].		

Tawney (*op. cit.* pp. 70, 71) has recorded *Pteria* (*Avicula*) *contorta* from the marls intervening between the sandstone-deposits on Stormy Down; while from the sandstone (but not *in situ*) I have obtained casts of *Schizodus*, *Myophoria*, *Natica pylensis*, Tawney, and *Cylindrites oviformis*, Moore, together with a fragment of the ichthyodorulite of a *Hybodus*.<sup>2</sup> By the roadside near Llangewdd Court large masses of sandstone were found to contain numerous plant-remains.

### (D) Stormy-Down Cement-Works.

At the time of my visit to the Stormy-Down Cement-Works water had accumulated in the pit, and so it was only possible to examine certain of the Lower Liassic beds. The lower beds are, therefore, tabulated on Mr. H. B. Woodward's authority.

<sup>1</sup> 'The Geology of the South-Wales Coalfield: Pt. vi—The Geology of the Country around Bridgend' Mem. Geol. Surv. 1904, p. 53.

<sup>2</sup> See also 'Summary of Progress of the Geological Survey for 1899' (1900) p. 131; 'The Geology of the South-Wales Coalfield: Pt. vi' Mem. Geol. Surv. 1904, p. 56; and Quart. Journ. Geol. Soc. vol. xxii (1866) p. 71.

		Thickness in feet inches.	
Lower Lias.	1. Clay, with yellow and hard grey limestone-nodules; <i>Pentacrinus</i> -ossicles, <i>Pseudodiadema</i> -radiole?; <i>Lima</i> ( <i>Plagiostoma</i> ) <i>gigantea</i> , <i>L. (Radula) pectinoides</i> , <i>Uni-</i> <i>cardium cardioides</i> , <i>Modiola minima</i> , <i>Ostrea cf. liassica</i> , <i>Pholadomya glabra</i> ; <i>Dentalium etalense</i> , gasteropods; <i>Psiloceras Johnstoni</i> ..... seen	3	6
	2. Limestone.....	0	5
	3. Shale, dark.....	0	7
	4. Limestone, yellowish, nodular; <i>Psiloceras Johnstoni</i> .....	1	8
	5. Shale, dark.....	0	3
	6. Limestone, bluish, mixed with shaly matter.....	2	7
	7. Shale, dark, usually persistent ..	0	6
	8. Hard blue limestone, with a little shaly matter; <i>Ostrea</i> <i>liassica</i> , <i>Psiloceras planorbis</i> [seen in 1905, 8 feet; add 10]	18	0
	9. Conglomerate-bed .....	0	10
	10. Limestone-shales .....	0	8
Hard compact limestone (resembling the Sun-Bed) .....		0	10
Shaly parting.			
Hard, compact, and rather shaly limestone.....		0	8
Black shales, with thin bands of limestone: <i>Pecten valoni-</i> <i>ensis</i> .....		1	0
Grey and greenish marls, with hard nodules (formerly used for cement)..... seen to a depth of		3	6
[A specimen of <i>Coloceras intermedium</i> (Portlock) was found, but not <i>in situ</i> .]			

In addition to Mr. H. B. Woodward,<sup>1</sup> several other authors have described this section. H. W. Bristow wrote:

‘The section at the Stormy Cement-Works . . . shows about 20 feet of ordinary Lias limestone and shale, resting upon 2 feet of a hard, siliceous, and shelly blue conglomerate, under which occur from 12 to 15 inches of pale argillaceous limestones, breaking with a smooth conchoidal fracture, and which I believe to represent the “White Lias” or uppermost member of the Rhætic Series.’ (Quart. Journ. Geol. Soc. vol. xxiii, 1867, p. 204.)

Charles Moore, in his valuable contribution to our knowledge of the Mesozoic littoral deposits, commented upon the fact that

‘When compared with the West-of-England section, the Rhætic beds at this spot are very insignificant. A single bed of black marl containing *Pecten valoniensis* and other Rhætic shells succeeds the variegated marls, and upon this a dark limestone 4 inches, and next a bed (in texture very similar to the “White Lias”) 2 feet thick. The *Ostrea*-beds then follow . . .’ (*Ibid.* p. 520.)

In 1884 the late R. F. Tomes recorded in the pages of the Quarterly Journal (vol. xl, p. 359) the following details of the strata below the *Ostrea*-Beds:—

		Thickness in feet inches.	
‘Hard conglomerate, in all respects like the “Guinea”-Bed of Binton.....		2 to 3	0
Fine-grained nodular limestone, with a conchoidal fracture, and very much resembling the <i>Estheria</i> -Bed.....		1 to 2	0
Dark-grey Rhætic shale.....		1	6
Greenish, compact Keuper Marl, forming the bottom of the pit.’			

<sup>1</sup> ‘The Jurassic Rocks of Britain’ Mem. Geol. Surv. vol. iii (1893) p. 114.



There is obviously some peculiarity about the stratigraphical sequence in this section. Observers are agreed that at the base there are greenish marls: Tomes mentioned them as belonging to the Keuper; Mr. H. B. Woodward as belonging to the Rhætic. If they belong to the latter, then they must correspond either to the green marls above the sandstone at the Quarella Quarry (p. 407), or to some bed occupying the stratigraphical position of that which is lettered *b* in the section on Stormy Down (p. 498). If it be considered that they correspond to the former, the presence of 'black shales, with thin bands of limestone; *Pecten valoniensis*,' in the foregoing section at Stormy-Down Cement-Works (p. 409), needs explanation; and again, if to the latter, the absence of the sandstone-deposit, such as that seen on Stormy Down (Bed *a*) requires accounting for. Charles Moore, as already mentioned, commented upon the insignificance here of the equivalent of the Rhætic of the West of England. Tomes thought that the greenish marls belonged to the Keuper, and if his surmise be correct the Rhætic Black Shales probably rest thereupon non-sequentially, for the *Pecten*-Beds occur at some height above the base of the series, where the sequence is complete.

Not having had the opportunity of examining the beds which may possibly correspond to those that compose the greater portion of the Upper Rhætic at other localities, I think that it is undesirable to offer any suggestions.

The Rhætic Beds in the neighbourhood of Pyle are largely represented by sandstones. In the recently-published Geological-Survey Memoir on the district, there is an excellent account of the sections available, and to that account I have nothing to add.<sup>1</sup> Attention, however, may be directed to the fact that Tawney appears to have studied beds higher in the series than any seen of late years, because he makes mention of limestones 'which . . ., from their appearance and conchoidal fracture, remind one of the Cotham Marble . . .'.<sup>2</sup> He prefaced his observations on this tract with the remark that 'The above-mentioned patch [was] sufficiently described by Mr. Bristow,' and referred the reader to Rep. Brit. Assoc. 1864 (Bath) Trans. Sections, p. 50. In the place cited there is no mention made of this Pyle, but Pylle Hill (Bristol) is referred to as a locality visited by Bristow, for the purpose of making a detailed section of the Rhætic Series.

#### IV. ADDITIONAL OBSERVATIONS ON THE SULLY BEDS.

It is generally admitted that, towards the close of Keuper times, there was a great inland sea covering a large part of England, which by degrees evaporated. As Mr. A. Rendle Short has pointed out, the conditions were probably desertic, and therefore over that area there would be a more or less uniformly-horizontal surface, with gently-shelving shores, and occasional deeper pools and

<sup>1</sup> 'The Geology of the South-Wales Coalfield: Pt. vi.—The Geology of the Country around Bridgend' Mem. Geol. Surv. 1904, pp. 54-55.

<sup>2</sup> Quart. Journ. Geol. Soc. vol. xxii (1866) p. 70.

channels.<sup>1</sup> This inland sea, at the close of the epoch, had been reduced by evaporation to a few comparatively-shallow lakes surrounded by flats of marl.

One of these lakes certainly existed in the Lavernock district, and, as I have already pointed out, it would be in such areas that transition-beds between the Keuper and the Rhætic should be sought for.<sup>2</sup> This lake was deepened, and its limits further restricted, by earth-pressures which occurred at the close of the Keuper Epoch.

It is difficult, at present, to decide whether the earth-pressures were more intense at the commencement or at the close of the time when the Sully Beds were deposited.

It is well-known that towards, or at the close of, the Carboniferous Period, earth-pressures affected the Palæozoic rocks of most parts of the world, and among them Glamorganshire, and caused the strata to be thrown into a number of anticlines and synclines. The folds in Glamorganshire have been mapped and admirably described by Messrs. Strahan & Cantrill, the main axis being distinguished by these authors as the Cardiff-Cowbridge anticline. As observed by Mr. Strahan, this anticline as far west as Pendoylan was simply a broad arch, but in that neighbourhood became compound. Mr. Cantrill has shown the position of the subsidiary anticlinal fold: it trends a little north of east and south of west, and brings to the surface at Stalling Down, near Cowbridge, quartzitic and pebbly beds belonging to the Old Red Sandstone.

The movements which occurred at the close of the Keuper Epoch, and affected the newly-formed conglomerates and marls, were probably of upheaval along old anticlinal axes, although of course they need not, and it would appear did not, agree with these precisely in position in every case. One of the main axes of elevation at this time, however, was apparently along the line of country traversed by the subsidiary pre-Triassic anticline referred to above. On the hillside to the south of Aberthin, near Cowbridge, rock thought to be Lower Lias is shown in the Geological-Survey Map to rest directly upon the Keuper; and between this outlier and Cowbridge there is another outlier of the same rock, which is depicted as resting upon the littoral Keuper. The Rhætic has been shown by the railway-cuttings at Cowbridge to intervene at those particular localities between the littoral modifications of Keuper and Lower Lias; but usually in the Cowbridge outlier the Lower Lias rests directly, and therefore non-sequentially, upon the Keuper. Similar phenomena are observed at Llanbleiddian—a village near Cowbridge.

Now, if deposition had continued unchecked from Keuper to Liassic times, then everywhere the sequence would have been—Keuper, Rhætic, and Lias; we should not have seen Lias resting directly upon Keuper. Only two explanations can be suggested: either the Rhætic has been deposited and subsequently removed (but in

<sup>1</sup> Quart. Journ. Geol. Soc. vol. lx (1904) p. 186.

<sup>2</sup> *Ibid.* p. 357.

Fig. 3.—Diagrammatic section showing the relationship of the *Pteria* (*Avicula*)-contorta Black Shales to the subjacent deposits. (See p. 414.)

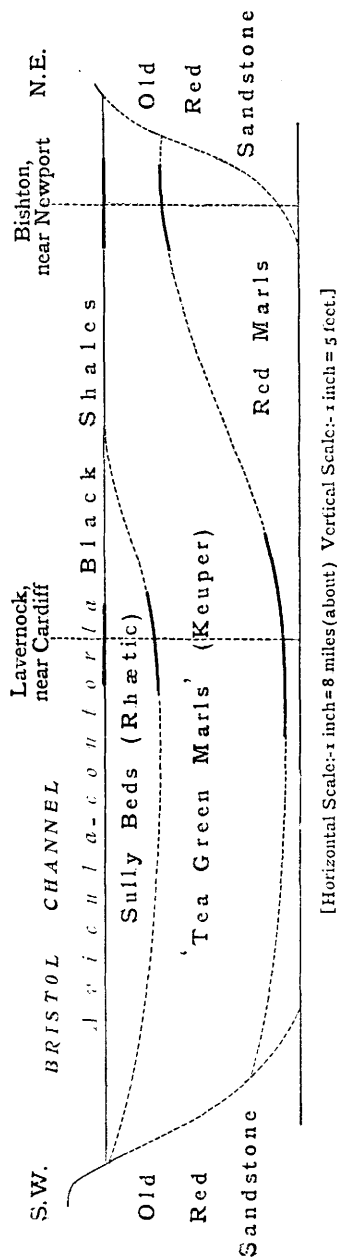
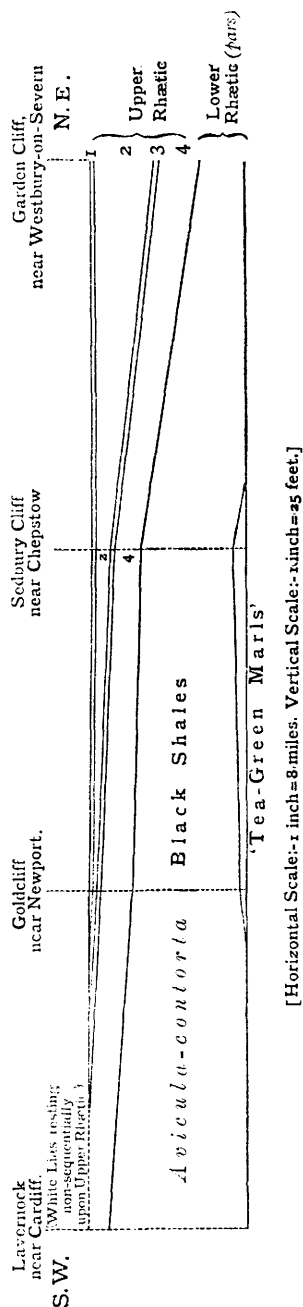


Fig. 4.—Diagrammatic section showing the relationship of the Lavernock White Lias to the Upper Rhætic, etc. of Gloucestershire. (See p. 415.)



pre-Liassic times), or the Rhætic has not been deposited. In either case, it seems to me that it is necessary to invoke the assistance of earth-movements to explain matters; but, taking all the facts available into account, it would certainly seem that at the localities in question the Rhætic had not been deposited, owing to an elevation which was initiated about the time of the deposition of the Sully Beds. On the westerly continuation of the Cardiff-Cowbridge anticline at Bevos, near Tythegston, it is interesting to notice that the relations of the Lias to the Keuper also suggest that the above is the correct interpretation of the phenomena; while at Sutton again it is very doubtful whether the Keuper Conglomerate was ever parted by a Rhætic deposit from the Sutton Conglomerate.<sup>1</sup>

In the stretch of water which extended into the Lavernock district, and the outlines of which had been modified by the earth-pressures referred to above, the Sully Beds were formed, while the 'Tea-Green Marls' at certain other localities were undergoing subaërial denudation. When the Rhætic ocean gained access to the British region it spread over the Lavernock area; its waters mingled with those of the Lavernock lake; the sediment too was commingled, and the resultant deposit has the peculiar lithic structure which characterizes Etheridge's 'Grey Marls' and the upper portion now denominated the Sully Beds. The appended diagram (fig. 3, p. 412) will help to elucidate my views as regards the relationship of the *Pteria* (*Avicula*)-*contorta* Black Shales to the subjacent marls and Sully Beds. Throughout the period during which the Sully Beds were in process of formation, earth-pressures may have affected the rocks, and it is especially desirable that exact records should be kept of any sections showing the junction of these beds with the overlying Black Shales, in order to see whether there is definite evidence of any overlap of the upper strata of the Sully Beds on to the 'Tea-Green Marls.'

It appears imperative that these Sully Beds should be grouped with the Rhætic, and consequently a certain portion of the 'Tea-Green Marls,' as defined during the re-survey of the district (1892-1901), must be assigned to that series and removed from the

<sup>1</sup> The debated question as to the age of the Sutton Stone is now a thing of the past: 'the whole of these beds may be regarded as the basement-beds of the Lower Lias, representing the *Osrea*-Beds and other portions of the zone of *Ammonites planorbis*, and including perhaps portions of the zone of *A. angulatus*' (H. B. Woodward, 'The Geology of the South-Wales Coalfield: Pt. vi' Mem. Geol. Surv. 1904, p. 62). I concur with this view. A little to the west of the Caves, below West, near Southerndown, a quarry (now disused) had been opened out in beds about the junction of the Sutton Conglomerate and Stone, and from the spoil-heap were collected *Chemnitzia* (fragment), *Anomia* (with *Serpula*), *Astarte* (*Cardita*? *rhomboidalis*, Tawney), *Cardinia regularis*, Terq. (= *C. suttonensis*, Tawney), *Gryphæa*, *Lima* (*Ctenostreon*) *tuberculata*, Terq., *Lima* (*Plagiostoma*) sp. (small), *Lima* (*Radula*) *hettangiensis*, Terq. (juv. = *L. subduplicata*, Tawney), *Ostrea multicostrata*, Münster, *Plicatula intus-triata*, Emmerich, *Pecten valoniensis*, DeFrance, *Mytilus imbricato-radiata*, Tawney, *Lithophagus* sp., *Serpula* (?), and *Astrocenia gibbosa* (Duncan). *Lima Terquemi* is not uncommon, and this fossil alone demonstrates the non-Rhætic and the non-White Lias nature of the deposit in which it occurs.

Keuper. No mention is made in the Geological-Survey publications of the abundant occurrence of *Ostrea* in the 'Tea-Green Marls' at St. Mary's-Well Bay, Sully: it is observed that these marls

'are distinguished from the Rhætic formation by the fact that they have hitherto proved to be totally unfossiliferous in South Wales, except for the occurrence of a bone-bed at Goldcliff.'<sup>1</sup>

This statement, however, is modified in a subsequent part of the same memoir,<sup>2</sup> but the same classification is adhered to. Although I have been compelled, from the palæontological evidence, to suggest that the Sully Beds be classed with the Rhætic, I nevertheless quite agree that the line of demarcation between Keuper and Rhætic decided upon by the officers of the Geological Survey is the most satisfactory for their purpose, because it is then possible to indicate on the map where the lithic change takes place.<sup>3</sup>

Renewed earth-movements occurred before the deposition of the Rhætic Black Shales, and brought about conditions suitable for a slight erosion of the uppermost stratum of the Sully Beds. In the Penarth-Lavernock section, indications of such an erosion are most apparent.

I would here direct attention to the fact that Mr. F. T. Howard, F.G.S., is of opinion that

'in South Wales, at least, there was a slight upheaval instead of a subsidence just at the close of the Trias Period (immediately preceding the subsidence of Rhætic and Liassic times, about which the evidence is indisputable). We see at once that the newly-formed Trias beds might be raised into dry land, and immediately attacked by the various agents of denudation.'<sup>4</sup>

#### V. CONDITIONS OF DEPOSITION OF THE RHÆTIC BLACK SHALES.

So far as is known at present, while the Black Shales or sandstones containing *Pteria* (*Avicula*) *contorta* were being deposited in the Glamorganshire district, no appreciable earth-movements occurred.

<sup>1</sup> 'The Geology of the South Wales Coalfield: Pt. i.—The Country around Newport, Mon.' Mem. Geol. Surv. 1899, p. 70.

<sup>2</sup> *Ibid.* Pt. iii.—'The Country around Cardiff' 1902, p. 41.

<sup>3</sup> Since this paper was written, that dealing with the Rhætic rocks of Monmouthshire has been communicated to the Geological Society. In the discussion which ensued (Quart. Journ. Geol. Soc. vol. lxi, 1905, p. 384) Mr. Strahan said that he had been unable to identify the 'Grey Marls' of Etheridge, and doubted whether any such subdivision of the 'Tea-Green Marls' could be made. The palæontological evidence set forth in the present paper requires such a division; but, of course, the actual line of demarcation between the Sully Beds and the 'Tea-Green Marls' must be more or less arbitrary, and governed solely by palæontological considerations. Mr. Strahan also doubted whether there was any overlapping of the 'Tea-Green Marls' by the *Avicula-contorta* Shales, and remarked that they varied but little in thickness over the whole region. According to the Geological-Survey publications, the 'Tea-Green Marls' at Lis-Werry measure 13 feet ('Geology of the South Wales Coalfield: Pt. i.—The Country around Newport, Mon.' Mem. Geol. Surv. 1899, p. 74) and at Lavernock 42½ feet (*ibid.* Pt. iii.—'The Country around Cardiff' 1902, p. 54)—a difference of 31½ feet.

<sup>4</sup> Trans. Cardiff Nat. Soc. vol. xxix (1896-97) pp. 65-66.

In the neighbourhood of Bridgend, a considerable deposit of sandstone was made while black sediment was being laid down around Lavernock. The very different nature of these contemporaneous deposits is to be accounted for, mainly by the fact that there was only imperfect connection between the two areas of deposition: land, composed of Palæozoic rocks, intervened.

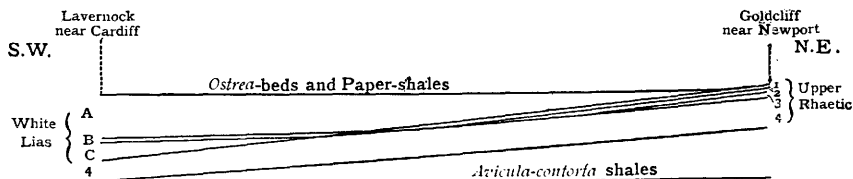
There is evidence (which will be quoted shortly), however, to show that near the commencement of the Upper Rhætic 'Age' the deposits in the Lavernock area were elevated, and a stretch of water separated-off to the north. Theoretically, this stretch of water may be regarded as having been connected with that in which the Upper Rhætic beds now visible at Bishton, near Newport,<sup>1</sup> were deposited. This view explains the similarity noticed between the beds distinguished as 3 at the Quarella Quarry, Bridgend, and Bishton, and likewise between the remaining similarly-notated deposits.

The effects of these earth-movements were not merely local; by the elevation of certain areas, shallow lagoons were formed in others, initiating conditions suitable for the existence of *Estheria*. While the Upper Rhætic Beds 3 to 1 were in the course of formation, the Lavernock area was above sea-level; the marl-deposit (4) was subjected to subaërial denudation and somewhat fissured (fig. 4, p. 412).

#### VI. ON THE WHITE LIAS OF GLAMORGANSHIRE, AND ON THE STRATIGRAPHICAL POSITION OF THE WHITE LIAS.

A gradual subsidence in the Lavernock area, accompanied by the reverse movement to the north, allowed again of deposition, and into the fissured marls (4) gritty material was washed. The relations of the White Lias and the Upper Rhætic Beds may be represented as shown in fig. 5, below.

Fig. 5.—Diagrammatic section showing the relationship of the White Lias to the Upper Rhætic in the Cardiff district.



In the Bath district, the sea in which the well-known White Lias was deposited was deeper than at Lavernock. At the latter locality, the various lamellibranchs are usually found grouped upon the surfaces of the limestone-bands: *Plicatula intus-striata*,

<sup>1</sup> Quart. Journ. Geol. Soc. vol. lxi (1905) pp. 377-78.

*Pl. hettangiensis*, and *Lima valoniensis* being especially abundant. A stratum which probably represents the Sun-Bed completes the equivalent of the White Lias of the Bath district: the representative of Bed A of the Lavernock and Barry sections is only found over a restricted area, and probably indicates a deepening of the sea in this neighbourhood, caused by renewed earth-pressures.

During the period when the White-Lias limestones and shales (A & B, Lavernock) were being deposited, the Cotham Marble in certain localities was hardened, broken up, and cemented into a conglomerate—for example, at Sedbury Cliff, near Chepstow. As remarked by Dr. Arthur Vaughan,

‘The time occupied by the hardening of the Cotham layer [at Sedbury Cliff], its destruction, and subsequent cementation into a conglomerate may be considered to correspond roughly to the time of deposition of the White Lias in the areas on the south and east.’ (Quart. Journ. Geol. Soc. vol. lix, 1903, p. 397.)

It is interesting to observe also that the same author thought that

‘At Sedbury Cliff the deposition of the Cotham Marble must have been succeeded by an elevation of the floor, which produced the breaking-up of the Cotham-Marble layer *in situ*.’ (*Ibid.* p. 398.)

At the time when the Lower Liassic ‘Paper-Shales’ were formed, the bathymetric conditions were about the same in the West of England.

In the description of the various sections in this shire, reference has been made to the stratigraphical position of the White Lias, and it will have been noticed that this deposit is considered to come above the Cotham Marble. Recent work accomplished by several geologists in the Bristol district has demonstrated that such is its correct stratigraphical position.

As long ago as 1864, Bristow & Etheridge, in their account of the Rhætic beds at Penarth, referred to ‘bands of limestone and indurated marl (in brown shale),’ which they considered might be ‘equivalent to the “White Lias.” . . . The place of the Cotham Marble (not observed here),’ they added, ‘is at the base of this group of beds.’ (Geol. Mag. vol. i, p. 237.)

It has been remarked recently that the denomination White Lias is a useful stratigraphical term for the Upper Rhætic Beds in the region extending southwards from Bath (Geol. Mag. 1905, p. 79).

Since the term Upper Rhætic has been applied by different authors to obviously non-contemporaneous strata, it is desirable to define exactly to what beds it has been applied in the present paper. The ‘Upper Rhætic’ of my records of the sections in North-West Gloucestershire, and those at Wood Norton (near Evesham), Sedbury Cliff (near Chepstow), and elsewhere, is not the equivalent of the White Lias.



At Wainlode Cliff, on the banks of the Severn between Gloucester and Tewkesbury, no White Lias is present: the Paper-Shales rest directly upon the *Pseudomonotis*-Bed, as shown in the following section:—

		Thickness in feet inches.		
OSTREA-BEDS. Limestone, hard, blue.....		0	4	<i>Ostrea liassica</i> , <i>Modiola minima</i> .
Paper-Shales, brown and grey, finely laminated, with an intermittent limestone-band .....		1	3	<i>Pseudomonotis fallax</i> , <sup>1</sup> <i>Darwinula liassica</i> , <i>D. liassica</i> var. <i>major</i> (teste Brodie & Prof. T. R. Jones).
UPPER RILETIC.	1. Limestone. <i>Pseudomonotis</i> -Bed, 'Insect-Limestone.' Hard, dark-grey and blue .....	0	5	<i>Modiola minima</i> , <i>Ostrea</i> (teste Brodie); insects; fish-scale.
	2. Shales, blue and brown, laminated, weathering into a marly clay .....	5	2	<i>Lycopodites lanceolatus</i> ; <i>Estheria minuta</i> var. <i>Brodiana</i> ; ostracoda (teste Brodie); fish-remains and shell-débris.
	3. Limestone. <i>Estheria</i> -Bed, 'Cypris'-Bed. Hard, yellow, nodular; arborescent markings; irregular fracture...	0	6	<i>Modiola minima</i> , <i>Schizodus Ewaldi</i> , <i>Cardium cloacinum</i> .
	4. Shales, pale, greenish-yellow, coarsely laminated, marly .....	6	0	
LOWER RILETIC. } <i>Pteria</i> ( <i>Avicula</i> )- <i>contorta</i> Zone.				

Near Chase Hill, Wickwar, the thin flaggy limestones of the *Ostrea*-Beds rest directly upon the Cotham Marble,<sup>2</sup> and in that neighbourhood the bed frequently contains *Pseudomonotis fallax* in abundance. But to the south, in the railway-cutting at Lilliput, near Chipping Sodbury, the sequence is as follows:—

		Thickness in feet inches.		
OSTREA-BEDS. Thin flaggy limestones, separated by thin shales .....		3	0	<i>Ostrea liassica</i> , <i>Modiola minima</i> , and <i>Pleuromya</i> .
WHITE LIAS. B. Compact cream-coloured limestone .....		1	0	
UPPER RILETIC.	1. Cotham Marble .....	0	5	
	2. Grey shale, containing plant-beds at 15 and 18 inches from the top.	2	3	<i>Darwinula</i> & <i>Estheria</i> .
	3. Brown, unfossiliferous shale .....	1	0	
	4. Argillaceous limestone.....	0	6	
UPPER RILETIC.	3. Brown or grey shale, with lenticular beds and concretions of argillaceous limestone at two or three levels .....	5	0	Fragmentary shells, <i>Cardium cloacinum</i> , <i>Modiola</i> .
	4. Argillaceous limestone.....	0	6	
LOWER RILETIC. } <i>Pteria</i> ( <i>Avicula</i> )- <i>contorta</i> Zone.				

In the foregoing section, the position of the White Lias is clearly shown: it occurs above the Cotham Marble.

Some 5 miles south-south-west of Lilliput the White Lias is seen to have increased in thickness; for, in a quarry by the side of the

<sup>1</sup> *Pseudomonotis decussata* of my previous papers.

<sup>2</sup> Geol. Mag. 1904, p. 534.

drive at Blue Lodge, near Siston, the White-Lias beds exposed are as follows:—

		Thickness in feet inches.			
OSTREA-BEDS.	Limestones, thin, with clay-partings.			{ <i>Ostrea liassica</i> , <i>Protocardium Philippi- anum</i> .	
	Clay .....	0	2		
	Limestone, in two beds with clay-parting.	0	3½	{ <i>Pholadomya glabra</i> , <i>Ostrea liassica</i> .	
	Clay, full of <i>Ostrea</i> : ½ to 1½ inches ...	0	1	{ <i>Protocardium Philippi- anum</i> common.	
	Limestone, sometimes in two beds .....	0	4		
	{ Clay or limestone .....	0	1		
	{ Limestone, often inconspicuous .....	0	1		
WHITE LIAS.	{ Brown and dark clay: 3 to 6 inches .	0	4		
	B. Sun-Bed.....	1	1		
	Clay .....	0	0½		
	Limestone, thin.....	0	2		
	Limestone .....	0	7		
	Clay-parting .....	0	0½		
	Limestone .....	0	2	{ <i>Ostrea liassica</i> , <i>Lima valoniensis</i> , <i>Modiola minima</i> , <i>Protocardium Philippi- anum</i> , <i>Plicatula intus- striata</i> .	
	Shaly deposit .....	0	1		
	C. Rubbly beds .....	seen	1		

[COTHAM MARBLE.]

The Sun-Bed is exposed in the quarry, but it will be observed that below it is a deposit of which a thickness of 2 feet 2 inches is seen, without any evidence of the Cotham Marble. But no doubt that stratum would be found, if the excavation were a little deeper; and then, below again, would occur the grey marls of the Upper Rhætic, such as those seen in close proximity to the Carboniferous Limestone seven-tenths of a mile south by 5° east of Abson Church.<sup>1</sup>

The rubbly beds (C in the foregoing section) are interesting. They seem to be present, as a rule, in the Bath district, but are rarely exposed as they are of no industrial value, and quarrying operations are therefore not prosecuted so deep down. These beds are not present in the Lilliput section, but I recently (May 1905) obtained evidence, from débris thrown out of a well, to show that they do extend farther north than Blue Lodge, Siston, where they

<sup>1</sup> At an ochre-working, at the cross-roads near Gathcrnam Farm, Wick Rocks, the following interesting section is exposed:—

		Thickness in feet inches.			
RHÆTIC.	{ Light-coloured, grey and yellow clay seen	2	9		
	{ Peculiar deposit of black and brown sandy clay, with impure limestone in places.....	0	3		
	{ Sandy bed, with more or less angular pieces of grit (the biggest measuring 2×1½×1 inch): ½ to 2 inches.....	0	1	{ <i>Sargodon tomicus</i> ( <i>Lepidotus</i> ?), <i>Acro- dus minimus</i> (rare), <i>Gyrolepis Alberti</i> , & fragments of bone.	
KAUPER (including 'Tea-Green Marls').	{ Light-yellow and grey clay, with hard masses of marlstone containing small quartz-pebbles..... about	2	6		
	{ Reddish deposit, with yellow streaks...	1	6		
	{ Yellow stone .....	1	0		
	{ Reddish stone, with yellow streaks.....	1	3		
	{ Hard, yellow stone: 5 to 7 inches .....	0	6		
	{ Working for ochre .....				

are seen at the bottom of the quarry noticed above (p. 418). Unfortunately, this well, which is situated in the orchard at the back of the inn in the village of Codrington, had been sunk some weeks previous to my visit to this part of the country, and the greater mass of the rock which had been excavated had been carted away.

The well is 70 feet deep, and the water-supply good. Those blocks of Lower Lias which were sufficiently compact had been used for walling the sides of the well, so that very little of the rock was lying about. The limestone which could be examined contained small specimens of *Lima gigantea* and *Ostrea liassica*. How great a thickness of Lower Lias was penetrated could not be ascertained. Pieces of a compact cream-coloured limestone showed that the White-Lias Sun-Bed had been proved, together with the sub-jacent, rubbly, fossiliferous White Lias, which contained *Plicatula hettangiensis* (one specimen), *Lima valoniensis*, *Protocardium Philippianum*, *Modiola minima*, Moore, and gasteropoda. Masses of a hard limestone (with a mammillated surface and faint arborescent markings) showed that the Cotham Marble was present, if not in its quite typical form. The remaining Upper Rhætic deposits are apparently similar to those which were exposed in the railway-cutting at Lilliput, and some of the indurated portions contained fish-scales and teeth not uncommonly. Black shales were very much in evidence, and contained a hard dark limestone with *Pecten (Chlamys) valoniensis*, *Pteria (Aricula) contorta*, *Placunopsis alpina* (large), and *Schizodus (?)*: also dark, calcareous, very micaceous, and occasionally pyritic sandstone-layers. A number of pieces of Bone-Bed were found. They indicated that the Bone-Bed here was not of the same lithic structure as that at Lilliput, doubtless owing to the fact that it does not rest upon any member of the Carboniferous System or the Old Red Sandstone. This is known from arenaceous 'Tea-Green Marl' having been found among the débris. The Bone-Bed is a dark-grey, micaceous, sandy limestone, with *Gyrolepis Alberti* (scales and teeth?), *Acrodus minimus*, and coprolites of fishes; but it passes into a thin pyritic sandstone containing a few vertebrate-remains. The excavation was terminated in the Carboniferous Limestone.

Just 2 miles in a direction a little east of south of Blue Lodge the White Lias is quarried near Barton Farm, Upton Cheney, the following section being exposed:—

		Thickness in feet inches.	
OSTREA-BEDS.	Clay .....	0	0
	Limestone, rubbly .....	0	3
	Clay .....	0	3
	Limestone: four beds, with clay between the middle two.....	0	7
	Clay .....	0	4
	Limestone: five beds, with clay-partings .....	1	0
WHITE LIAS.	Clay .....	0	4
	B. Sun-Bed, capping hard cream-coloured limestones .....	4	0
	[White-Lias rubbly beds.]		
	[Cotham Marble.]		

As I have indicated above, the rubbly beds of the White Lias probably occur not far below the floor of the quarry, and rest upon the Cotham Marble. The strata below the Sun-Bed and above the rubbly deposits at Blue Lodge are 2 feet 2 inches thick (see p. 418): here, however, the equivalent deposit must be of double that thickness, since White-Lias limestones, 4 feet thick, are exposed without any indication of the rubbly beds.<sup>1</sup>

Some 4 miles distant from the Barton-Farm Quarry is the instructive section at Newbridge Hill, on the outskirts of Bath. When I visited the section, the Cotham Marble was the lowest bed that could be studied *in situ*. The following record is compiled from details noted by the Rev. H. H. Winwood, F.G.S.,<sup>2</sup> my own notes being in square brackets:—

		Thickness in feet inches.		
WHITE LIAS.	B. Sun-Bed .....	0	9½	Gasteropoda; <i>Lina</i> ,
	Limestones, with an occasional			<i>Pecten</i> , <i>Plicatula</i>
	parting of clay .....	5	1½	<i>intus-triata</i> , <i>Modiola</i>
	C. Rubbly limestone with clay-			[ <i>aff. minima</i> , Moore],
	partings, passing downward	5	0	<i>Myacites</i> [ <i>Pleuro-</i>
	into bluish bands. Very fossiliferous towards the base ...			<i>mya</i> ], <i>Axinus</i> , <i>Cardium rheticum</i> [ <i>Pro-</i>
UPPER RHÆTIC.	Blue clay .....	0	1½	<i>tocardium</i> <i>Philippinum</i> ], [ <i>Ostrea</i> ].
	Limestone .....	0	4	
	Reddish-brown clay .....	0	6½	
	[1] Landscape Stone [or Cotham Marble] .....	0	6½	<i>Avicula</i> [ <i>Pseudomonotis</i> ] <i>fallax</i> .
	[2] Light-blue or grey shales .....			{ <i>Esteria minuta</i> and traces of vegetable matter in the band about the centre.
	[3] Darker-shaded band about the centre .....	3	8	
	[4] Light-blue or grey shales .....			

From these few sections it will be observed, (1) that the White Lias comes above the Cotham Marble and below the *Ostrea*-Beds; and (2) that it increases in thickness, as it is traced from north to south. The component beds of the White Lias successively overlap one another, and this implies elevation in the north, depression in the south: a conclusion also arrived at from investigations in Glamorganshire.

## VII. SUMMARY.

(i) The Sully Beds, or the upper portion of Etheridge's 'Gréy Marls,' belong to the Rhætic Series, as shown by the fossils, and are distinct from the 'Tea-Green Marls' of the Keuper, which do not contain fossils.

<sup>1</sup> The White Lias is exposed in road-sections at Barrow Hill, about a mile north of the Barton-Farm Quarry; while the junction of the Rhætic and Keuper is seen in the road-cutting a short distance to the west, or some 300 yards east of Wick Forge. A thin deposit of red sand, containing *Acrodus minutus*, *Saurichthys acuminatus*, *Gyrolepis Alberti* (scales), '*Sargodon tomicus*' (*Lepidotus*?), fragments of bones, and small quartz-pebbles, probably represents the Bone-Bed.

<sup>2</sup> Proc. Bath Nat. Hist. & Antiq. F.-C. vol. ii (1871-73) pp. 204-11.

(ii) Descriptions are given of sections, the most important of which are at Lavernock (near Cardiff), Barry, Tregyff (near Cowbridge), Quarella (Bridgend), and Stormy Down.

(iii) Earth-pressures affected the rocks during the formation of the Sully Beds. The *Pteria (Avicula)-contorta* Black Shales rest with perfect parallelism, but, nevertheless, non-sequentially, upon the Sully Beds.

(iv) Owing to a local upheaval of the Lavernock district, early in the age during which the Upper Rhætic Stage was deposited, only a portion of the lowest bed of that stage is found, and this deposit was subjected to subaërial denudation during the accumulation of the remaining Upper Rhætic beds elsewhere.

(v) Subsidence in the Lavernock district allowed of the deposition of the White Lias. As a result, the White Lias rests non-sequentially upon a portion of the lowest Upper Rhætic deposit.

(vi) The White Lias at certain localities in Glamorganshire contains in abundance *Plicatula intus-striata*, *Pl. hettangiensis*, and *Lima valoniensis*. The deposit intervening between the Sun-Bed and the Upper Rhætic near Bath (Newbridge Hill) is over 11 feet thick: at Lavernock the equivalent deposit measures but 2 feet  $2\frac{1}{4}$  inches. At the last-named locality, above the probable equivalent of the Sun-Bed, are marls 6 feet 4 inches thick, which are grouped with the White Lias. Above come the Lower Liassic Paper-Shales, succeeded by the *Ostrea*-Beds.

(vii) The Upper Rhætic of North-West Gloucestershire and Worcestershire is not the equivalent of the White Lias of the Bath district: the White Lias comes above the Cotham Marble (the topmost bed of the Upper Rhætic) and below the Paper-Shales, which occur immediately below the *Ostrea*-Beds.

I am much indebted to a number of geologists and others for kind assistance. For the trouble which he took in procuring photographs of the Lavernock sections I have to record a debt of gratitude to Mr. John Storrie (son of the late John Storrie), of Cardiff; while, in obtaining the literature on the Rhætic of the county I have received much help from Mr. H. B. Woodward, F.R.S., Mr. F. T. Howard, F.G.S., Mr. J. Storrie, and Mr. G. H. Dutton, F.G.S. Valuable assistance with regard to some of the fossils has been most courteously accorded to me by the Rev. J. F. Blake, F.G.S., Mr. S. S. Buckman, F.G.S., Mr. E. T. Newton, F.R.S., Mr. A. C. Seward, F.R.S., and Dr. A. Vaughan, F.G.S.; while to Mr. E. B. Wethered, F.G.S., and Dr. C. G. Cullis, F.G.S., I acknowledge my indebtedness for help in certain petrological matters. For assistance in the field-work I tender my best thanks to Mr. E. Talbot Paris; while I feel that any expression of thanks inadequately conveys my gratitude to Mr. J. W. Tutchter for preparing the excellent photographs of fossils from which the figures in Pl. XXXIII were reproduced.

VIII. PALÆONTOLOGICAL NOTES.

*OSTREA BRISTOVI*, Etheridge, MS. (Pl. XXXIII, fig. 4.)

Right valve.—The dimensions of an average-sized specimen are: length 45 millimetres, breadth 55 mm. The greatest length seems to be attained (as a rule) at 23 mm. from the most extended portion of the ventral margin. The valve is flat or slightly convex; the ventral margin regularly convex; while the anterior and posterior margins converge regularly in the direction of the beak, which unfortunately is not preserved in the specimens collected. The test is somewhat thin for an *Ostrea*, and composed of numerous considerably-imbricating layers.

Unfortunately, the preservation of the specimens of this lamelli-branch does not admit of a very exact diagnosis. Mr. E. T. Newton, F.R.S., informed me (*in litt.*) that specimens of this oyster are preserved in the Museum of Practical Geology, Jermyn Street, London, and bear the MS. name of *Ostrea Bristovi*, Etheridge.

Like most of its tribe, this form is difficult to describe; but, on account of its frequent occurrence in the Lavernock area, it seems desirable to have some name wherewith to record it when obtained.

The specimen figured is from the upper portion of the Sully Beds (Rhætic) at Cadoxton (Glamorganshire).

*CARDIUM CLOACINUM*, Quenstedt. (Pl. XXXIII, fig. 5.)

1858. 'Der Jura' Tübingen, p. 30 & pl. i, fig. 37.

1856. Oppel, A., & Suess, E., 'Ueber die muthmasslichen Äquivalente der Kössener Schichten in Schwaben' Sitzungsber. k. Akad. Wissensch. Wien, vol. xxi, p. 540 & pl. ii, fig. 2.

1904. Vaughan, A., 'The Rhætic Beds of the South-Wales Direct Line' Quart. Journ. Geol. Soc. vol. lx, pp. 207-208 & fig. 6.

In the immature forms of this shell the costæ are rounded or subacute, and increase in breadth towards the ventral margin; while the intercostal spaces exceed the breadth of the costæ. In the adult forms, however, the costæ are usually broader and flat-topped, while the intercostal spaces are reduced to mere linear grooves.

The first definite record of this shell was at Wainlode Cliff<sup>1</sup>; but since then it has been found at many localities, and was especially abundant at Lilliput, near Chipping Sodbury, on the South-Wales Direct Line. Dr. Vaughan has given an excellent description of the species, elucidated by figures in the text (Quart. Journ. Geol. Soc. vol. lx, pp. 207-208), and has drawn attention to the *Cardita*-like aspect of the shell, which is especially noticeable in the specimens figured in the present paper. Charles Moore, indeed, referred this shell (which he obtained from the railway-cutting at Willsbridge, near Bitton) to the genus *Cardita*, and entered it as such in his section (Quart. Journ. Geol. Soc. vol. xxiii, 1867, p. 498). His specimen is now in the Bath Museum, and came from the Upper Rhætic.

<sup>1</sup> Proc. Cottesw. Nat. F.-C. vol. xiv (1903) table i, facing p. 174.

The specimen figured in Pl. XXXIII was obtained from Bed 5b (3), Lower Rhætic. Section by the roadside near Bishton, near Newport (Monmouthshire).<sup>1</sup>

*PLICATULA INTUS-STRIATA*, Emmrich. (Pl. XXXIII, fig. 1.)

1853. 'Geognostische Beobachtungen aus den östlichen bayerischen & den angrenzenden österreichischen Alpen' Jahrb. der k.-k. geol. Reichsanst. vol. iv, p. 376.  
1853. Hauer, F. Ritter von, 'Ueber die Gliederung der Trias-, Lias- und Juragebilde in den nordöstlichen Alpen' Jahrb. der k.-k. geol. Reichsanst. vol. iv, p. 738.  
1864. Dumortier, E., 'Études paléontologiques sur les Dépôts jurassiques du Bassin du Rhône: pt. i.—Infralias' pp. 74-77 & pl. i, figs. 13-16.  
1861. *Ostrea interstriata*, Moore, C., 'On the Zones of the Lower Lias & the *Avicula-contorta* Zone' Quart. Journ. Geol. Soc. vol. xvii, p. 501 & pl. xvi, fig. 25.

This lamellibranch is too well-known to require any additional description, but it has not been recorded previously from the Penarth or Barry districts; only from beds of later date to the west, as at Bridgend and near Sutton. At Lavernock it is fairly common, while at Barry it is very abundant in the White Lias. I have not recorded it from the Lower Rhætic in Glamorganshire; but that it does occur abundantly in that stage at certain localities (Watchet, for example) I have been able to satisfy myself only recently (June 1905). At Blue Anchor, near Watchet, it is associated with *Pteria (Avicula) contorta*.

*PLICATULA HETTANGIENSIS*, Terquem. (Pl. XXXIII, fig. 2.)

1855. 'Paléontologie de l'Étage inférieur de la Formation liasique de la Province de Luxembourg, Grand-Duché (Hollande), et de Hettange' Mém. Soc. Géol. France, ser. 2, vol. v, p. 326 & pl. xxiv, figs. 3-4.  
1864. Renevier, E., 'Notices géol. & paléont. sur les Alpes vaudoises: I.—'Infralias & Zone à *Avicula contorta* (Étage Rhétien)' pp. 38-39 & pl. iii, fig. 4.  
1864. Dumortier, E., 'Études paléontologiques sur les Dépôts jurassiques du Bassin du Rhône: pt. i.—Infralias' pp. 73-74 & pl. xii, figs. 4-7, 10.

*Plicatula hettangiensis* has not been recorded previously, to my knowledge, from the White Lias of this county. It is very common at Coldknap, Barry, and Lavernock, and it is difficult to understand how this *Plicatula* has managed to escape detection for so long a time. It is quite possible, however, that it has been recorded under another name (*Ostrea multicostata*?). A specimen submitted for examination to the Rev. J. F. Blake was at once identified with Terquem's fossil.

As remarked by Terquem (*op. cit.* p. 326), and later by Prof. Renevier (*op. cit.* p. 77), this shell presents several varieties in form. One specimen from Barry agreed precisely with the figure given by the latter author.

*LIMA VALONTIENSIS* (Defrance). (Pl. XXXIII, fig. 3.)

1825. 'Mémoire géologique sur quelques Terrains de la Normandie occidentale par M. de Caumont, Mém. Soc. Linn. du Calvados [*postea* de Normandie] vol. ii, p. 507 & Atlas, pl. xxii, fig. 7.

This fossil is of frequent occurrence in the White Lias at Lavernock and Barry. A specimen submitted to Dr. A. Vaughan for

<sup>1</sup> See Quart. Journ. Geol. Soc. vol. lxi (1905) p. 378.



comparison with those of the same genus from 'the main *Pecten*-horizon' at Lilliput, near Chipping Sodbury,<sup>1</sup> was returned with the remark—'typical clavellate form.'

EXPLANATION OF PLATE XXXIII.

[The fossils figured in this plate are preserved in the Author's collection.]

- Fig. 1. *Plicatula intus-striata*, Emmrich.  $\times 2$ .  
White Lias; Coldknap, Barry (Glamorganshire).  
2. *Plicatula hettangiensis*, Terquem. Natural size.  
White Lias; Coldknap, Barry (Glamorganshire).  
3. *Lima valoniensis*, DeFrance.  $\times$  about  $1\frac{1}{2}$ .  
White Lias; Coldknap, Barry (Glamorganshire).  
4. *Ostrea Bristovi*, Etheridge, MS. Natural size.  
Sully Beds (Lower Rhætic); St. Mary's-Well Bay, Sully (Glamorganshire).  
5. *Cardium cloacinum*, Quenstedt. Natural size.  
Bed 5 b (Lower Rhætic); roadside section, four-fifths of a mile north-north-east of Bishton Church, near Newport (Monmouthshire).

<sup>1</sup> Quart. Journ. Geol. Soc. vol. lx (1904) p. 202.

[For the Discussion, see p. 430.]

FIG. 1.  $\times 2$ .



FIG. 2. NAT.  
SIZE.



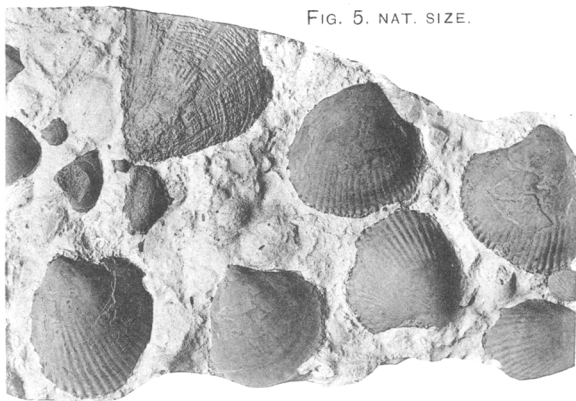
FIG. 4. NAT. SIZE.



FIG. 3.  $\times$  ABOUT 11.



FIG. 5. NAT. SIZE.



RHÆTIC LAMELLIBRANCHIATA.