THE LIASSIC ROCKS OF GLAMORGAN.

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I. INTRODUCTION.

THE Liassic rocks of Glamorgan occur in several small outliers west of Cardiff, and in a broad tract stretching between Bridgend and Cowbridge and southwards to the sea (fig. 55). This area is known as the Vale of Glamorgan, and is a beautiful agricultural district, which has not shared the industrial development of the adjacent coalfield.*

The "Vale" is a low plateau, generally a little over one hundred feet above sea-level, but ranging to three hundred feet above sea-level in several tracts of Carboniferous Limestone.

The northern margin is crossed near Bridgend by the main South Wales line of the Great Western Railway, while the only other railway of importance, the Vale of Glamorgan Railway, which runs near the coast and connects Barry and Bridgend, affords the easiest means of reaching many of the exposures to be described.

Liassic rocks, with very low dips, crop out over the greater portion of the Vale. In the east of the area near Cardiff, and elsewhere, they are underlain by the Rhætic and Keuper Marls, but at many places further west these formations are overlapped by the Lias, which then rests unconformably on the underlying Palæozoic rocks, chiefly Carboniferous Limestone.

The Triassic and Liassic rocks of the Vale of Glamorgan were laid down near a shore line in a region of steady and fairly rapid subsidence. As the sea encroached on the land, which lay to

* A. E. Trueman, "Population Changes in the Eastern Part of the South Wales Coalfield," *Geographical Journal*, 1919, p. 410.

FIG. 55.—GEOLOGICAL SKETCH MAP OF THE VALE OF GLAMORGAN.

(Adapted from the one-inch maps of the Geological Survey, Nos. 261-2, 263, New Series.)

the north and north-west, there were at various stages groups of islands, generally composed of Carboniferous Limestone, situated near the mainland. Around such islands, and along the shore of the mainland, littoral deposits of various kinds accumulated.

Two chief types of littoral deposits have been described among the Liassic rocks of the area, the Sutton Stone, a whitish conglomeratic limestone, and the Southerndown Beds, which are usually darker in colour and often consist of limestone and cherty breccias. Oolites and cherty limestones also occur in some parts of the area.

The Liassic rocks of Glamorgan represent only the lowest few zones of the Lower Lias, but these are of more than usual thickness, and owing to the gentle dips which prevail over the greater part of the area, the rocks have an extensive outcrop.

These rocks form the cliffs which stretch almost continuously from Sutton to near Barry, a distance of about twenty miles. Such a great extent of almost horizontal rocks is somewhat monotonous, but undoubtedly these cliffs offer an unrivalled opportunity to study the sequence of faunas in the lower portions of the Lower Lias and also to investigate the relations of the littoral deposits. Indeed, it is doubtful whether anywhere in Britain there are similar sections in any formation which show such rapid lateral changes in lithology, or in which the various stages of a marine transgression can be so completely studied.

II. HISTORY OF RESEARCH.

The Liassic rocks of littoral character in Glamorgan attracted the notice of geologists at a very early date, and more attention has been paid to them than to the larger areas of normal Lias. De la Beche pointed out that various limestones become conglomeratic in the west and that on the coast near Sutton there is at the base of the series a white limestone, known as the Sutton Stone.*

In 1863 and for several years later the Sutton Stone and the associated beds were studied by numerous workers. A summary of their views has been given by the late H. B. Woodward† in "The Lias of England and Wales," and it does not appear to be necessary to discuss them in detail here. R. F. Tomes‡ and E. B. Tawney§ maintained that the conglomerate series of the Sutton and Southerndown district was of Rhætic age, while C. Moore,|| W. H. Bristow,¶ and R. Tate** held that the fossils were characteristic of the lowest zones of the Lias. Tate, in particular, showed that the fossils considered by Tawney as

* 3 (see Bibliography, p. 283).

† 31 p. 99 (reprinted in 17 p. 61.)

‡ 10

§ 20

|| 12.

¶ 2.

** 19.

new species, are relatively common in Hettangian rocks in this country and on the Continent, and proved the Liassic age of the deposits. P. M. Duncan studied the corals from the Sutton Stone and his account of the age and relations of these littoral deposits is more accurate than subsequent writers have realised.*

Since that time the Liassic rocks have been examined by H. B. Woodward† and by other officers of the Geological Survey.‡ In the Cardiff and Bridgend Memoirs a summary of their observations is given; but as no detailed examination of the fossils was made at that time, and as very few, if any, accurate records of ammonites within the area are available, further investigations appeared desirable. Before the exact age and relations of the littoral deposits could be satisfactorily determined, it has been necessary to obtain more detailed and exact information of the faunal succession in those parts of Glamorgan where the Liassic rocks are of normal character. The writer has already published an account of the succession in the lowest zones, as seen in the cliffs of Lavernock and Penarth.§ In the present paper some additional facts concerning the faunal sequence are recorded, and the relations of the littoral deposits are examined.

III. GENERAL SEQUENCE IN THE LIAS OF GLAMORGAN.

The Liassic rocks of Glamorgan are probably not less than 350 feet in thickness, and consist, where normally developed, of nodular limestones and shales. The following are the only divisions that have hitherto been recognized:—

Nodular limestones with some shales	..	about 200 feet.
Shales with some nodules. (The lower part are called Lavernock Shales)	..	„ 100 feet.
Alternating limestones and shales	..	„ 45 feet.

The lower divisions were described and the faunal sequence in them was discussed in the Cardiff paper. The upper series is not seen in the outliers near Cardiff, but in the cliffs westwards from Barry they are clearly exposed. Frequently they form the upper portion of the cliffs, and only at a few localities are even the lowest beds of these limestones accessible. It has proved to be almost impossible to subdivide this limestone series by any lithological characters. Throughout most of the two hundred feet the limestones are nodular and thickly-bedded, and the interbedded shales are usually thin. At some localities a few limestone bands of more massive type form a horizon that

* 4, 5. (See especially the Appendix to 5).

† 29, 31.

‡ 16, 17. These will be referred to in this paper as the *Cardiff* and *Bridgend Memoirs* respectively.

§ 23, 25. The first paper will be referred to as the *Cardiff paper*.

can be traced along the coast, sometimes for a few miles, but it is rarely possible to trace such a band unless there are continuous exposures unbroken by faults. On the whole, the series is more calcareous in the west, and nodular limestones with interbedded shales become more massive in appearance as they are traced westwards. Further, what appears to be a massive limestone band when exposed in a freshly-broken cliff face is usually seen to be made up of nodular limestones when it is weathered in the cliff or on the beach (see Plate 8A).

About 80 feet above the base of the upper limestone series the limestones are less massive and the series becomes more argillaceous, and it is usually possible to identify this horizon in the cliffs. Similar changes at other levels, however, are much less constant when traced along the cliffs for a few miles. The changes are indicated in the vertical sections in figure 56. Even approximate correlation by lithological characters is thus rarely possible in Glamorgan. In these circumstances it is, therefore, unfortunate that ammonites and other fossils are by no means common in these beds. It is particularly difficult to collect fossils "in place"; and fallen material obviously is of little use, for the horizon in the cliff from which it has come cannot be determined, owing to the uniform appearance of the limestone bands. Many of the ammonites that are to be found are of large size, but they are poorly preserved; in most cases the fossils are silicified, partly or wholly, and even the details of ornamentation may then be obscured. In not a single ammonite from the *bucklandi* zone of Glamorgan has the writer been able to make out a suture line. Accurate work on these specimens is thus extremely difficult. Ammonites are still more scarce in the beds of littoral origin, the Sutton and Southerndown Beds.

In correlating the Lias in this area, considerable attention has been paid to species of *Ostrea* and *Gryphæa*. The method of using these in determining the horizon approximately has already been described.* *Gryphæa* occurs in most of the limestones of the *bucklandi* zone throughout the district and gryphæate forms have proved very useful in correlating these deposits and in relating them to the littoral deposits.

THE AMMONITE SEQUENCE.

Notwithstanding the difficulty of collecting identifiable specimens of ammonites in place in the *bucklandi* zone, some information has been obtained concerning the succession of faunas within that zone in Glamorgan; exposures of the *angulata* zone are more accessible, and specimens are fairly abundant, and thus more details of the ammonite sequence have been ascertained.

Before considering the succession that has been determined in Glamorgan, it will be convenient to summarize the horizons

FIG. 56.—GENERALISED SECTIONS OF THE LIAS OF GLAMORGAN.
A, near Southerndown ; B in the cliffs east of Dunraven ; C, in the cliffs
between St. Donats and Llantwit Major. Approximate scale, one inch to
60 feet.

[ai-aiu and bi-bvi indicate the zonal sub-divisions (see pp. 252, 253) ; the
a-e in section C correspond with those in figures 62 and 63.]

in the lower part of the Lower Lias, which have recently been noticed by Mr. S. S. Buckman* and Mr. J. W. Tutchet.† It may be recalled that Mr. Buckman has shown that within each of the Liassic zones as defined by Oppel and others, it is possible to recognize several horizons characterised by distinct ammonite species. These faunas are rarely all to be found in one locality, and Mr. Buckman considers that the absence of a fauna in any district is generally due to a non-sequence. Other geologists have suggested that the differences in the sequence of faunas in various localities may result from the migration of the ammonites, and may be related to slight changes in the physical conditions and the food supply.‡ At present, in the writer's opinion, the bulk of the evidence is strongly in support of Mr. Buckman's view, though it is not unlikely that certain ammonite species were of restricted horizontal distribution.

It is clear, however, that the meaning of these various faunal sequences can only be understood when information from other areas is available, and when other elements of the fauna have been investigated as carefully as have the ammonites.

It may be urged, therefore, that the names given to some of these various horizons should be used with considerable caution as *zonal terms* in discussing correlation. In this paper they are referred to as sub-zones; this procedure is open to serious objections, but it has the advantage of allowing the continued use of the names of the zones that are generally known.§

The following divisions will be referred to :—

semicostatum zone

	{	<i>Agassicerias (sauzeanum)</i> sub-zone.	
		<i>scipionianum</i>	”
<i>bucklandi</i>		<i>gmüendense</i>	”
zone	{	<i>bucklandi</i>	”
		<i>rotiforme (rotator)</i>	”
		<i>conybeari</i>	”
	{	<i>angulata</i>	”
<i>angulata</i>		<i>liasicus</i>	”
zone	{	<i>Wæhneroceras</i>	”
		<i>johnstoni</i>	”
<i>planorbis</i>		<i>planorbis</i>	”
zone	{	<i>Ostrea</i> Beds	”

PLANORBIS ZONE.

The exposures of the *planorbis* zone in the main area of Lias are not good, and west of Barry the writer has only seen the ammonites of this zone in quarries near Laleston; no addi-

* "Jurassic Chronology; I., Lias." *Quart. Journ. Geol. Soc.*, vol. lxxiii., 1918, for 1917, p. 274.

† *Ibid.*, p. 278.

‡ See for example, W. D. Lang, *Quart. Journ. Geol. Soc.*, vol. lxxiii., pp. 325-6, and F. A. Bather, *Abst. Proc. Geol. Soc.*, No. 1079, 1922, p. 31.

§ The author proposes to make some suggestions concerning zonal terms in another paper.

tional information concerning the succession within this zone has been obtained since the Cardiff paper was written.*

ANGULATA ZONE.

The following sequence has been observed within the *angulata* zone :—

aiiv	Shales with <i>Schlotheimia</i> spp., including	
	<i>S. angulata</i>	about 50 ft.
aiii	Shales with <i>Schlotheimia</i> spp. and <i>Alsatites</i>	
	spp.	„ 30 ft.
aii	Shales with <i>Schlotheimia</i> spp. and <i>Caloceras</i> spp.	„ ? 20 ft.
ai	Shales with <i>Wahneroceras</i> spp. and <i>Caloceras</i>	
	spp.	„ 6 ft.

The lower beds (ai, aii and aiii) are seen at Lavernock and Penarth and were described in the Cardiff paper. It was pointed out there that the lower portion of the beds with *Schlotheimia* contain no species of *Alsatites*,† and it was suggested that the *Alsatites* occupied a higher horizon than Mr. J. W. Tutchter had indicated in Somerset.‡ It is now apparent, however, that the sequence given by Tutchter for Somerset is quite correct, but the division aii, with *Schlotheimia* and *Caloceras*, does not seem to be well represented there.§

These beds (aii) contain rather lowly forms of *Schlotheimia*, such as *S. cf. acuticosta* Strickland-Buckman, *S. gallica* S. Buckman, and *S. cf. equalis* (Simpson). Raricostate *Caloceras* are also found, and in one bed at Lavernock there occurs abundantly a small simple *Schlotheimia* that is here described as *Schlotheimia cf. hagenowi* (Dunker). These beds contain numerous lamellibranchs, especially at Lavernock.

The next division (aiii) is not very accessible at Lavernock, but is particularly well seen on the coast just east of Dunraven. The shales there contain *Schlotheimia cf. gallica* S. Buckman, *S. cf. thalassica* (Quenst.), *S. prometheus* (Reynès), *S. cf. marmorea* (Opp.), and *S. aff. angulata* (Schloth.).

Various forms of *Alsatites* are present, but they all appear to be more closely related to *A. laqueolus* (Schlon.) than to *A. liasicus* (d'Orb.).

As lender-whorled ammonite, in appearance something like *Caloceras longipontinum* (Opp.), has also been found in these beds near Cwm Bach.|| *Ornithella sarthacensis* (d'Orb.), which characterizes this horizon in Somerset, was not noted near Cardiff, but has since been found at Whitmore Stairs and near Porthkerry; it is, however, by no means common in Glamorgan.

* 23, pp. 99-101.

† 23, pp. 102, 107.

‡ J. W. Tutchter, *Quart. Journ. Geol. Soc.*, vol. lxxiii., p. 279.

§ The absence of the *Wahneroceras* sub-zone in Somerset was noted by Mr. Tutchter (*op. cit.*, p. 280).

|| The Cwm Bach referred to in this paper is north of Whitmore Stairs, and must be distinguished from the Cwm Bach further south, near Marcross.

The uppermost portion of the *angulata* zone (aiv) appears to contain no ammonites except species of *Schlotheimia*. These include *S. cf. acuticosta* Strickland-Buckman, *S. angulata* (Schloth.) with some large smooth forms resembling *S. greenoughi* (Sowerby).

The writer has not found any horizon characterized by an association of *Schlotheimia* and slender *Arietids*, such as occurs at the junction of the *angulata* and *bucklandi* zones at Keynsham, Somerset. The species of *Vermiceras* found near the base of the *bucklandi* zone in Glamorgan are, however, identical with those found in Somerset, and the absence of *Schlotheimia* at this horizon in Glamorgan, either is a result of the limited horizontal distribution of *Schlotheimia* at that time, or (more probably) indicates that this bed in Somerset contains elements that were not quite contemporaneous.

BUCKLANDI ZONE.

The following horizons of *Arietids* appear to be represented in Glamorgan; others are probably present but the evidence of the ammonites in the higher parts of the zone, as has been already noted, is very unsatisfactory.

	Feet.*
bvi Limestones with <i>Arnioceras bodleyi</i> and ? <i>Agassicerias sauzeanum</i> .	
bv Shales of uncertain date	? 30
biv Shales with <i>Coroniceras cf. gmuendense</i> ..	? 30
biii Limestones with <i>Coroniceras rotiforme</i> , &c., and <i>Arnioceras cf. spirale</i>	about 20-30
bii Limestones with large <i>Vermiceras</i> -like forms (<i>V. cf. conybeari</i> Wright)	40
bi Limestones with large stout non-tuberculate <i>Arietids</i> and small <i>Vermiceras</i> (<i>V. cf. rouge- monti</i> Reynès)	15

It will be noted that, on the whole, the sequence of faunas determined here agrees with that already recorded in Somerset and elsewhere (see p. 251). The abundance of slender *Arietids* of *Vermiceras* aspect in the lower part of the zone, followed first by a horizon rich in the large heavy-whorled *Coronicerates* and later by a horizon with forms of *gmuendense*-aspect conforms, on the whole, with the sequence found in Somerset.

The absence of the true *Coroniceras bucklandi* (Sow.) is not surprising, since this species is only known, at present, from the Keynsham neighbourhood; *C. bucklandi* may, indeed, occur among the many species found in and near horizon biii, but the evidence available is insufficient to justify a record of the species.

It is not unlikely, indeed, that the majority of the horizons which have been determined in Somerset are present in Glamor-

* The thicknesses given in this table are only approximations.

gan; the continuous series of *Gryphæas*, and the thickness of the deposits, suggest that the sequence may be almost complete. On the other hand it is probable that several horizons found in Glamorgan are not represented in Somerset. There appears to be repetition at least of *Vermiceras* (*bi* and *ii*) and of *Arnioceras*; the horizon with the slender *Arnioceras* referred to *A. cf. spirale* Fucini, which would appear to be included within the *rotiforme* sub-zone, is apparently unrecorded elsewhere in this country.

SEMICOSTATUM AND HIGHER ZONES.

Previous observers have noted ammonites that indicate the presence in Glamorgan of horizons above the *bucklandi* zone; the most important species named is *Arnioceras semicostatum*. There is little doubt, however, that this name has been misapplied.

The ammonite which occurs is *Arnioceras bodleyi* (J. Buckman). At Fretherne, south of Gloucester, this species occurs with *Agassicerias* and in Dorset species of *Arnioceras* aspect occur with *Agassicerias*.* There is, therefore, difficulty in defining the limits of the *semicostatum* zone and the upper part of the *bucklandi* zone.† The writer has not found *Agassicerias* in Glamorgan, although it has been recorded,‡ and it is uncertain where the zonal boundary should be placed. The *Gryphæas* indicate, however, that the lower portion of the *Agassicerias* sub-zone of Somerset and Gloucester is represented. *Gryphæa* is not generally common in the beds with *A. bodleyi*.

It is uncertain what zones are present above this horizon, for exposures of higher beds are not found along the coast. At one locality, however, in a small quarry 150 yards S.S.E. of the church, Llantwit Major, an ammonite which has been named *Arietites* aff. *plotti* (Reynès) has been found, and this presumably represents a horizon somewhat higher than the *semicostatum* zone.

IV. STRATIGRAPHICAL DETAILS.

A. COAST SECTIONS NEAR DUNRAVEN.

The littoral Lias exposed in the cliffs from Sutton eastwards to Witches Point (Trwyn-y-Witch), near Dunraven, has been investigated by numerous workers, as already noted (p. 247). The sections are clear, and although fossils are not usually abundant, the relations of the various rock-types may readily be observed.

The Carboniferous Limestone forms the lower part of the

* See W. D. Lang, "Shales-with-Beef, a Sequence in the Lower Lias of the Dorset Coast, Pt. 1," *Abst. Proc. Geol. Soc.*, No. 1079, 1922, p. 30. C. Moore recorded an association of *Arnioceras* and *Agassicerias* in South Wales (12, p. 515).

† Since this paper was written Dr. L. F. Spath has dealt briefly with this problem: "On Lower Lias Ammonites from Skye," *Geol. Mag.*, vol. lix., 1922, p. 170.

‡ 12, pp. 513-517

cliff near Sutton, in the north-west, and is there overlain in turn by the white conglomeratic Sutton Stone and the darker Southerndown Beds, the latter passing upward gradually into Lias of more normal type. The same sequence of rock-types is also seen in the Witches Point, while in the small bay at Sea Mouth, Southerndown, the shore and cliffs are made up of normal Liassic limestones and shales. These facts were noted by several workers during the last century, and are summarized in sections by H. B. Woodward* and others. Woodward also pointed out that the Sutton Beds and Southerndown Beds are not sharply separated and that there is a continuous passage between the two types.†

It is important to notice, however, that these two types of littoral deposit do not mark definite horizons, but have apparently been formed at various stages as the islands of Carboniferous Limestone became submerged. The palæontological evidence shows that the littoral deposits at Dunraven are older than those near Sutton, while as several earlier workers noticed, they are thicker under Southerndown than at Dunraven, and unusually thick still further to the west, in Pant y Slade.

Indeed, the relations of the littoral deposits to the normal Liassic rocks on the one hand, and to the Carboniferous Limestone on the other, are precisely such as would be expected under these conditions of deposition. The littoral deposits pass laterally into normal limestones and shales within a comparatively short distance, and are thickest in the north-west, where they are banked up against the islands of Carboniferous Limestone.

The relations of these rocks are shown on Plate 10, p. 284, and diagrammatically in fig. 60. It may be noted here that in these and all other figures in this paper the same conventional signs are used for the various rock-types.

As already stated, the littoral Lias of this coastal region is of two types, the Sutton Stone below and the Southerndown Beds above.

THE SUTTON STONE SERIES.

The Sutton Stone typically is a white or pale cream massive limestone. Near the base it is frequently conglomeratic. Where it is banked against steep-sided masses of Carboniferous Limestone, as on the coast east of Pant y Slade, some of the included boulders of limestone are several feet in diameter and the conglomeratic beds are thick. The boulders and pebbles are mainly of Carboniferous Limestone, but some pebbles and small sub-angular fragments of a yellow or brown sandstone are also found near the base of the Sutton Stone east of Sutton.

* 31, fig. 45, p. 101, and 17, fig. 5, p. 63.

† 31, p. 100.

The source of this sandstone material is unknown. Some portions of the Sutton Stone are shelly, while corals are abundant at several localities.

Galena is found fairly frequently in the Sutton Stone, particularly in the old quarries above Black Rocks, between Sutton and Southerndown. It generally occurs in isolated well-formed crystals, but sometimes forms strings and small irregular aggregates.

The greater part of the Sutton Stone, and the matrix of the conglomeratic bands, appears to consist mainly of a white crystalline limestone. Frequently it is hard and massive, and is not readily distinguished at a distance from the underlying Carboniferous Limestone. The higher beds, which merge into the Southerndown Series, are generally less compact and more thinly-bedded.

Many massive beds of Sutton Stone show pressure "sutures" or stylolites (fig. 57).^{*} These were noticed by Tawney† and are particularly well seen in the cliffs under Southerndown, near

FIG. 57.—STYLOLITE OR SUTURE FROM A LIMESTONE OF THE SUTTON STONE SERIES, NEAR FAIRY CAVE, SOUTHERNDOWN.

One-quarter natural size.

Fairy Caves. The Sutton Stone is frequently eroded with the formation of caverns under the more resistant Southerndown Beds.

Microscopically, the Sutton Stone varies in character. Dr. Flett described a section with little crystalline calcite, the rock consisting largely of rounded shell fragments.‡ In many places, however, the rock is made up largely of crystalline calcite in a fairly coarse mosaic. Apparently this has resulted from a recrystallisation of the original material, for in a section examined by the writer, there are traces within the calcite mosaic of included fragments, marked by cloudy rings (fig. 58), and it may be suggested that these represent Carboniferous Limestone pebbles which have undergone recrystallisation.

It is interesting to note, as observed by several workers,

^{*} See A. W. Grabau "Principles of Stratigraphy," 1913, p. 786. G. Wagner, "Stylolithen etc." *Geol. u. Paläont. Abhand (Köln)* N.F., Bd. XI., 1913, p. 101. Similar sutures are often seen in other massive limestones, such as the Carboniferous Limestone (Merthyr-Tydfil, *Mem. Geol. Survey*, 1904, p. 20).

† 20, p. 73.

‡ 17, p. 60.

that where the Lias rests on Carboniferous Limestone in Somerset it frequently resembles the Sutton Stone in lithology.* These white Liassic limestones of littoral character are well developed north of Shepton Mallet, and are exposed in several quarries near the viaduct immediately to the north of that town. In parts of Somerset also it has been noted that there is often a remarkably rapid passage laterally from littoral Lias to the more normal deposits.

THE SOUTHERNDOWN SERIES.

The Southerndown Beds vary considerably in constitution, as they are traced outwards from the Carboniferous Limestone islands. They merge downwards into Sutton Stone and upwards

FIG. 58.—A LIMESTONE FROM THE SUTTON STONE SERIES, NEAR PANT Y SLADE.

Magnified about 12 diameters.

into the Lias of normal characters, so that it is difficult to measure thicknesses.

Typically, the Southerndown Beds are dark blue limestones, weathering to a dull brown, with thin shale bands; they are somewhat irregularly bedded and not infrequently exhibit a feeble nodular structure. The Southerndown Beds are generally more or less conglomeratic or brecciated, and contain angular or sub-angular fragments of Carboniferous Limestone, of chert (from the Carboniferous Limestone) and, occasionally, of yellowish sandstone. The fragments are small, rarely exceeding one inch in length, and they are usually not more than half that length.

* *31*, p. 109.

In some beds in Pant y Slade, and more frequently further east, near Fairy Caves, the included fragments are less abundant and of smaller size, and the Southerndown Beds pass imperceptibly into dark fine-grained limestones with occasional layers of fine chert fragments. In the Southerndown Beds on the beach under Southerndown large nodules and irregular masses of dark Liassic chert are common, and the fossils in this series are frequently silicified.

The abundance of chert fragments in these beds is clearly due to the fact that the Carboniferous Limestone, undergoing denudation somewhere in the neighbourhood was rich in chert. It is noteworthy that the limestone seen underlying the Lias near Sutton and Southerndown is the *Caninia* zone (C₁ and C₂), while

FIG. 59.—A CHERT AND LIMESTONE BRECCIA FROM THE SOUTHERNDOWN SERIES AT PANT Y SLADE.

C = Chert. Magnified 12 diameters.

the γ -beds, from which Dr. T. Franklin Sibly informs me the chert has probably been derived, are not now exposed between Sutton and Southerndown.*

The limestone fragments in the Southerndown Beds at Southerndown are generally oolitic and appear to be in large part *Caninia* Oolite.

Microscopic examination shows that the Southerndown Beds consist of angular and sub-angular fragments in a matrix of cloudy material, largely calcareous and probably consisting of

* The γ -beds of the Carboniferous Limestone are exposed in Witches Point, but the beds now exposed were covered by deposits of *planorbis*-zone; there may, however, be more extensive tracts of these beds not far inland.

a fine mud resulting from the denudation of the Carboniferous Limestone (fig. 59). There appears to be little recrystallisation either of the matrix material or the limestone fragments, although in some bands near the Fairy Cave, where the lowest Southern-down Beds somewhat resemble the Sutton Stone, a tendency to recrystallisation has been noticed.

SUTTON AND PANT Y SLADE.

In the most westerly of the cliff exposures Sutton Stone rests with little apparent discordance on Carboniferous Limestone. The Sutton Stone was formerly well seen in the numerous quarries along the cliff-top from Slon to Sutton, but these are not now worked and the exposures are not good. Fossils are abundant in an old quarry on the cliff above Black Rocks, and in the base of the Lias in the cliff at Pant y Slade.

FIG. 60.—DIAGRAM SHOWING THE RELATIONS OF THE LITTORAL DEPOSITS IN THE LIAS NEAR SUTTON AND DUNRAVEN.

Horizontal distance about 1 mile; thickness about 250 feet.

(The conventional signs are explained in figure 56.)

In this gully (Pant y Slade) the littoral beds may be examined more conveniently than at any other place. The Sutton Stone is not more than 20 feet in thickness; the lower 4 feet is conglomeratic, but some cherty bands occur in the higher portion. The Sutton Stone at this point is fairly fossiliferous, and casts of lamellibranchs are found in great numbers. *Ostrea* sp. cf. *liassica* is abundant, with *Ostrea multicostata*, *Cardinia suttonensis*, *Pecten suttonensis* and casts of "*Chemnitzia*" (*Zygopleura*) sp. About 10 feet above the base, *Schlotheimia* cf. *thalassica* (Quenstedt) has been found, indicating the *liasicus* sub-zone, and with it are found other fossils typical of the *angulata* zone, such as *Lima hettangiensis* Terquem, *Hinnites* sp., *Pinna* cf. *semistriata* Terquem, and *Pleurotomaria* cf. *anglica* Sow. Corals are commonest a few feet above the base of the Lias at Pant y

Slade, and the following species have been collected :—*Isastrea latimeandroidea* Duncan, *I. globosa* Duncan, and *Montlivaltia* cf. *murchisonæ* Duncan. Duncan named many other corals from the Sutton Stone, but these doubtless include species from other localities and therefore (presumably) from other horizons.*

Above the Sutton Stone in the gully are the Southerndown Beds, which are here probably quite 100 feet in thickness. They are not very fossiliferous, but *Gryphæa dumortieri* Joly has been found near the base, probably indicating the *angulata* sub-zone, and *Gryphæa* aff. *obliquata* Sow. at a higher horizon (indicating the *Vermiceras* sub-zone). Certain bands contain large turriculate gastropods in considerable numbers.

Several authors have called attention to the unusual thickness of the Southerndown Beds at this point,† but the thickness is due to a lateral change from the normal Lias a few furlongs to the south-east, and not to a local thickening of the deposits of any zone (fig. 60). The littoral character of the Lias of Pant y Slade (and the cliffs further west) may perhaps be due to its deposition on the terraced shore of a large island of Carboniferous Limestone; the lowest terraces are exposed on the foreshore, and the Carboniferous Limestone also crops out a few hundred yards inland, at 200 feet above sea-level. The probable relations of the littoral deposits to the shore of the island are represented diagrammatically in figure 61.

West of Pant y Slade the Sutton Stone is seen in the quarry mentioned above, near Black Rocks. Numerous fossils have been found, chiefly lamellibranchs, the commonest being *Ostrea* cf. *liassica*, *O.* cf. *irregularis* (Munster), *Lima hettangiensis* Terquem, *Lima succincta* Schl., *Pecten texturatus* Munster. The thickness of Sutton Stone here and at Sutton cannot be accurately estimated, but it is certainly much more than the 20 feet seen at Pant y Slade, and even allowing for a slight south-easterly dip it is probable that the lower parts of the Southerndown Beds change in character westwards and assume the Sutton Stone type of lithology.

THE SOUTHERNDOWN CLIFFS.

From Pant y Slade eastwards, for a short distance, the rocks are almost horizontal; about a hundred yards from the gully the terrace of Carboniferous Limestone ends abruptly, and the Sutton Stone is seen banked against a Carboniferous Limestone cliff. There is, therefore, a sudden increase in the thickness of the Sutton Stone at this point to approximately 40 feet. The lowest beds are conglomeratic, and include large boulders exclusively of Carboniferous Limestone. In this conglomerate no fossils have been found, but doubtless horizons below the

* 6, 7

† 31, p. 103.

liasicus sub-zone are represented. In the section (Plate 10) the *planorbis* zone is indicated but no palæontological evidence for this has been found.

For some distance along the coast the Carboniferous Limestone floor forms the foreshore, but it does not reappear in the cliffs for several hundred yards, until it is brought up in a small anticline. Here it is overlain with a distinct unconformity by Sutton Stone, some 40 feet in thickness. Hereabouts, only the lowest part of the Sutton Stone can be examined in place, the upper portion of the cliff being quite inaccessible. As the beach is rough, and can only be reached for a short period at low tide, opportunities for examining the higher beds are few. It appears, however, that the Sutton Stone passes gradually upwards into the Southerndown Series. The prominent brown bands which resemble the Southerndown Beds in appearance, are much thinner than at Pant y Slade, being probably not more than 50 feet. They are succeeded by nodular limestones and shales. The highest of these were examined in a small quarry on the

FIG. 61.—DIAGRAM SHOWING THE PROBABLE RELATIONS OF THE LITTORAL LIAS TO THE CARBONIFEROUS LIMESTONE AT PANT Y SLADE.

[Tr, Triassic Breccia (probably of Tea Green Marl age) ; Su, Sutton Stone ; So, Southerndown Beds ; C.L., Carboniferous Limestone ; shading as in figure 56.]

cliff-top, near Cwm y Gawei, south-west of West Cottage, and impressions of a slender Arietid (*Vermiceras*) were found. The horizon is probably the *Vermiceras* sub-zone (*bii*), which at Pant y Slade is represented by conglomeratic limestones.

East of Fairy Cave the whole series begins to dip gently south-eastwards, and this continues except for some minor folding and faulting as far as Dunraven. The littoral beds are thus carried below beach-level, and the various horizons may be examined on the foreshore. The whole of the Southerndown Series is exposed and the relations to the overlying limestones and shales are clearly seen as Sea Mouth is approached. It is in this portion of the cliffs that most of the earlier workers examined the Southerndown Beds, and the name, perhaps, ought strictly to be kept for these strata.

Measured sections of the series at this point have been

published by several workers,* but the beds vary so much, as might be expected, that such sections only serve to illustrate the general character of the group. Horizons mentioned by other workers can rarely be identified in the field. Under Southerndown itself the Southerndown Beds are 45-50 feet in thickness. Viewing the cliffs from low-water mark, near Dancing Stones, the change of lithology laterally from limestones and shales to brownish beds of Southerndown Bed type is apparent, and the passage from one type to the other may be noted at higher horizons as Pant y Slade is approached.

Fossils are fairly common in parts of the Southerndown Series. At several horizons large gastropods (*Zygopleura* sp.) are abundant, but it is almost impossible to extract specimens. Impressions of ammonites are rarely seen, but *Gryphæa* is abundant and it is on a study of these forms that correlation is based. About 10 feet from the top of the Southerndown Beds the *Gryphæas* are wide, and closely resemble the smaller forms found in the *callicosta*-limestone at Keynsham; † these beds presumably represent the lowest part of the *Vermiceras* sub-zone (b₁), but no ammonites have been found. Nearer the top of the series the *Gryphæas* are more distinctly incurved. The greater part of the Southerndown Beds under Southerndown therefore represents the *angulata* zone; in this lower portion *Gryphæa* is not generally so common, but specimens resembling *G. dumortieri* Joly have been found.

The succeeding limestones and shales are not very accessible in this part of the cliffs and will more conveniently be described in the next section.

SOUTHERNDOWN BEACH AND DUNRAVEN.

The cliffs as far as Witches Point are made up of limestones and shales of normal character. These dip gently southwards as far as Dunraven, where the series is faulted and is brought up against the Carboniferous Limestone and littoral Lias of Witches Point. In this faulted zone are exposed some of the highest beds of Lias seen anywhere along the coast of Glamorgan, but they are quite inaccessible and the sequence is only inferred from fallen material.

The succession in the cliffs under Dunraven is shown in A, figure 56. Overlying the Southerndown Beds north-west of Sea Mouth are nodular limestones with thin shale bands. Some 60 feet above the Southerndown Beds is a prominent bed, which was noticed by H. B. Woodward as one of the few characteristic horizons that can be traced along the cliffs.‡ It appears to be a massive limestone about 8 feet in thickness, but when weathered

* 22, p. 357.

† 24, p. 259, fig. 1c.

‡ 31, p. 105, and 17, p. 78.

it is seen to be made up of ten or more layers of irregular nodules, with thin contorted shale bands (Plate 8A). The position of this bed is indicated in the sections in fig. 60 and on Plate 10. It comes down to the beach at the most northern fault under Dunraven, and appears in the foreshore south of the fault. Above this bed are 8 feet of limestones and thick shales, followed by 70 feet of shales with a few bands of nodular limestone and some scattered nodules. The highest beds in the cliff are more calcareous, and include some massive limestones.

Ammonites are fairly common in the limestones below the prominent bed referred to. Ten feet below it is a limestone band forming the lowest reef in the bay under Dunraven; this limestone contains some large slender Arietids and a number of small silicified ammonites (? *Arnioceras* cf. *spirale*, etc.). At this horizon occur *Coroniceras* cf. *rotiforme* and *Coroniceras* cf. *rotator*. The limestones 10 feet below this form ledges near the base of the cliff E.N.E. of Dunraven Castle, and in these ammonites are also to be found. Large slender Arietids nearly two feet in diameter are common, but the specimens are crushed and accurate identification is not usually possible. They include *Vermiceras* cf. *conybeari* (Wright) and *Vermiceras* cf. *cæsar* (Reynès). These beds thus represent part of the *Vermiceras* sub-zone (bii). Similar ammonites are found in the limestones 30 feet lower, west of Sea Mouth. In these beds other fossils are not usually common; large specimens of *Gryphæa* aff. *obliquata* occur and occasionally large *Lima gigantea*. In one bed which forms a reef south of Sea Mouth (north-east of Dunraven Castle), great numbers of *Montlivaltia haimeii* occur.

The prominent band is at horizon biii, and in it and in the beds immediately overlying it stout tuberculate Arietids are found along with a slender ammonite which may be *Arnioceras* cf. *spirale*.

Just above these beds there occur remarkable numbers of *Gryphæas*; in some of the shales specimens are so numerous that they make up fully one half of the rock. The deposit is comparable with the *Ostrea* Beds at the base of the Lias in many areas. The *Gryphæas* are silicified and are fairly incurved, resembling those of the *rotiforme-gmuendense* sub-zones of Somerset, and may be called *G.* aff. *incurva*.* *Pleuromya* sp., and *Pleurotomaria* cf. *anglica* Sow., also occur.

In the succeeding shales (biv on A, fig. 56) *Gryphæa* aff. *incurva* is common, but no ammonites have been recorded. The fallen *Gryphæas* indicate that the *gmundense* sub-zone is represented in the cliffs, but no ammonites of this zone have been collected; indeed, the only ammonite that has been found, from the highest limestone (bvi), is a well-preserved specimen of *Arnioceras bodleyi* (J. Buckman).

* 24, p. 259, 1d.

In the cliffs on the northern side of Witches Point littoral Lias (Sutton Series and Southerndown Series types) is seen resting on Carboniferous Limestone (γ). The littoral beds are not very accessible, but their relations to the Carboniferous Limestone are well shown (Plate 8B). The Sutton Series varies in thickness from 25 to 40 feet, and is overlain by dark conglomeratic limestones (Southerndown Series) about 14 feet thick. Above these, in the eastern corner of the bay, are thinly-bedded limestones and shales.

These beds are equally well exposed and are easily examined on the south of the headland, where the littoral Lias may be conveniently studied at the foot of a cliff path leading down from the castle grounds.* The Sutton Series is massive and some beds, where worn on the beach, closely resemble Carboniferous Limestone. The lower beds are frequently conglomeratic and contain few fossils, but in the higher beds of Sutton Stone type, *Ostrea multicostata* and *Pecten suttonensis* are abundant. The Southerndown Series is thin here, not exceeding 14 feet (figs. 60 and 56B), but several bands are fairly fossiliferous. *Pecten suttonensis*, *Ostrea* cf. *irregularis*, *O.* cf. *liassica*, *Lima gigantea*, *L. acuticosta* and *Astarte* sp. are frequently found, while in a band about four feet from the top of the series is a bed rich in gastropods; these include *Katosira* cf. *trivia*, *Bourguetia* sp., and *Trochus* sp. Judging from the lamellibranchs, and particularly from the *Ostreus*, the horizon is the lowest part of the *angulata* sub-zone, a conclusion which is supported by the evidence obtained from the fossils of the overlying shales (see page 265). It is interesting to note how this compares with the horizon of the Southerndown Beds at Pant y Slade and Southerndown (fig. 60). In the section the Southerndown Beds are represented as merging laterally into the shales with nodules of the *angulata* zone; it must be noted, however, that the actual passage is not seen in the cliffs, as this zone is not exposed between Southerndown and Dunraven. Nevertheless, the palæontological evidence clearly indicates that quite 100 feet of littoral deposits pass laterally into normal Liassic deposits within a distance of little more than half-a-mile.

Except for a small exposure at Whitmore Stairs the littoral Lias is not seen in the coast sections east of Witches Point.

B. COAST SECTIONS EAST OF DUNRAVEN.

It is not the author's intention, in this paper, to describe fully the normal Lias in the cliffs between Dunraven and Barry. It will be useful, however, to summarize the succession for comparison with the littoral deposits and to indicate the positions of the fossil bands which have been of service in establishing the sequence in the area.

* The author is indebted to J. M. Randall, Esq., for permission to use these paths.

Photo by A. Stuart.

A.—CLIFFS AND FORESHORE NEAR DUNRAVEN.

Photo by A. E. Trueman.

B.—NORTHERN SIDE OF WITCHES POINT, DUNRAVEN.

[S. Sutton Stone ; C.L. Carboniferous Limestone.]

To face p. 264.

DUNRAVEN TO NASH POINT.

The littoral beds seen under Dunraven are succeeded by a series of shales with many nodule bands which may readily be examined in the cliffs and in the reefs in the beach. In the lowest nodules *Alsatites* cf. *laqueolus* (Schlön.), *Schlotheimia* cf. *gallica* S. Buckman, *S.* cf. *thalassica* (Quenst.), *S. prometheus* (Reynès), *S.* cf. *marmorea* (Opp.), and *S.* aff. *angulata* (Schloth.) are found commonly. With them are *Ostrea* aff. *irregularis* and other semi-gryphæate forms, *Nautilus striatus*, *Ornithella sarthacensis*, *Pleurotomaria anglica*, *Pleuromya* cf. *liasina* Sch. and several species of *Lima*.

Only this division (aiii) of the *angulata* zone is seen on the beach for over a mile (Plate 10), but the higher portions of the *angulata* zone and part of the *bucklandi* zone are easily examined along the cliff path below Cwm Bach, and in the sides of this Cwm, and also in the cliffs at Whitmore Stairs. In the beach at the latter place, as pointed out by Mr. R. H. Tiddeman, littoral beds of the Southerndown Series are seen in the crest of a low anticline.*

The beds dip south-east from this point as far as Cwm Nash, and in the beach called Traeth Mawr the several divisions of the *angulata* zone are fairly well exposed. The *angulata* sub-zone (aiv) may be more conveniently examined near Cwm Nash than in any other district. Ammonites are moderately common and include small specimens resembling *Schlotheimia acuticosta* and *S. angulata*. In one or two beds a few feet below the top of the zone, large smooth ammonites (*S.* cf. *greenoughi*) are found. Other fossils are not common, but *Gryphæa* aff. *dumortieri* and somewhat more incurved varieties are found, with small specimens of *Lima gigantea*.

Along this part of the coast (from Dunraven to Nash Point) the *angulata* zone is more argillaceous than the overlying *bucklandi* zone, the base of which generally projects in the cliff and forms a fairly conspicuous horizon. The difference in lithology between the two zones, however, is not perhaps so marked as would appear from the conventional signs used in the diagrams; the *angulata* zone consists of shale with numerous bands of small nodules, while the nodular limestones of the *bucklandi* zone are often thicker. At Cwm Nash and at Nash Point the limestones of the lower part of the *bucklandi* zone come down to the beach, and give rise to the small headlands there. Fossils are fairly plentiful in the reefs in the beach, but they are usually silicified and it is rarely possible to extract specimens.

In the lowest beds (bi) occur large stout Arietids a foot or more in diameter, and some more slender species. In a limestone which is just at the base of the cliffs at Cwm Nash are numerous well-

* 17, p. 85.

preserved specimens of *Vermiceras*, including *V. cf. rougemonti* (Reynès). *Gryphæa* aff. *obliquata*, often of large size, is frequently found, but other fossils are rare in these lower beds. Blocks of limestone fallen from the cliffs (bii) contain *Montlivaltia haimeii*, *Pleuromya* sp. and *Lima gigantea*.

Between Cwm Nash and Nash Point is a gentle anticline and the *angulata* zone is exposed in the beach for a considerable distance.

NASH POINT TO ABERTHAW.

From Nash Point to Cwm Col Hugh, south-west of Llantwit Major, the *bucklandi* zone forms the cliffs and beach. The sequence is complicated by numerous faults, and several bays, notably St. Donat's Bay and Stradling Well (fig. 62), result from the more rapid denudation of higher and more argillaceous beds that have been brought down by trough faulting.

Between Nash Point and St. Donat's the rocks are almost

FIG. 62.—DIAGRAM TO ILLUSTRATE THE STRUCTURE OF THE CLIFFS AT STRADLING WELL, NEAR ST. DONAT'S.

[The letters are explained under figure 63.]

horizontal and a limestone band, rich in slender *Arnioceras* (*A. cf. spirale*, etc.), *Montlivaltia* and *Lima*, forms an extensive platform (biii). Twenty feet below this, at St. Donat's, are great numbers of *Gryphæa obliquata*, of which this is the type locality; the horizon is probably the upper part of the *Vermiceras* sub-zone (bii). Some 30 feet above the *Arnioceras*-reef is a group of massive limestones which may correspond to the prominent limestone at the same horizon at Dunraven; above this are more argillaceous beds.

Arnioceras is again found, in beds with *Coroniceras* cf. *rotiforme*, on the west of Stradling Well, and about 200 yards west of Reynard's Cave. Higher beds are seen in Stradling Well, with *Gryphæa* aff. *incurva* (probably biv). The *Vermiceras* sub-zone is exposed frequently west of Stradling Well, but is

not very fossiliferous. *Montlivaltia haimeri* occurs west of Reynard's Cave, though not so abundantly as at the same horizon at Dunraven, Cwm Nash and Nash Point.

The cliffs near Cwm Col Hugh are in the *Vermiceras* sub-zone, but between this point and Stout Point, and again to the east of Stout Point, the argillaceous beds of the *angulata* zone are brought up in gentle anticlines. The *bucklandi* zone is brought to the beach between two sharp monoclinal folds near Stout Point (fig. 63).* Here, as at Cwm Nash and Nash Point, the harder limestones of this zone form a headland. The cliffs are low near these headlands because the limestones are succeeded by more argillaceous beds (*biv*).

Beyond Stout Bay the dip is east, and the *Vermiceras* and *rotiforme* sub-zones of the *bucklandi* zone are seen in the beach. The most fossiliferous band is a nodular limestone forming a reef a hundred yards west of Summerhouse Point, where *Arnioceras* cf. *spirale* is very plentiful. *Gryphæa* is fairly common

FIG. 63.—THE CLIFFS NEAR STOUT POINT, SOUTH OF LLANTWIT MAJOR. a, Lavernock Shales; b, *angulata* sub-zone and *Vermiceras* sub-zone; c, *Vermiceras* and *rotiforme* sub-zones; d, e, upper *bucklandi* zone. M, sharp monocline.

Horizontal scale, 6 inches to 1 mile; Vertical scale, 1 inch to 200 feet.

in these cliffs, but almost all the examples are silicified. The softer beds above the *rotiforme* sub-zone are brought to the beach east of Summerhouse Point, but there are no cliffs from this point to Aberthaw.

ABERTHAW TO BARRY.

In the cliffs between Aberthaw and Porthkerry, west of Barry, various horizons of the *bucklandi* zone are exposed. Fossils are rare in these cliffs, and even *Gryphæa* is not common. From Aberthaw westwards to Font y Gary and Roose, the beds are almost horizontal and the *Vermiceras* sub-zone is exposed on the foreshore; *Vermiceras* cf. *rougemonti* is abundant near the base of the cliff at Font y Gary. The limestones are worked in extensive quarries at Aberthaw and Roose, and in a large quarry east of the Lime Works at Aberthaw are massive lime-

* In figure 63 these monoclines (marked M) are shown as faults; the sharp folds are not apparent when the cliffs are viewed from the sea.

stones with *Coroniceras* cf. *gmuendense*, though it is likely that beds higher than the *gmuendense* sub-zone are also represented.

East of Porthkerry, in the Bull Cliff, is a section showing the *Ostrea* Beds of the *planorbis* zone in the beach, overlain by Lavernock Shales and limestone of the *angulata* zone.

C. INLAND EXPOSURES OF NORMAL LIASSIC ROCKS.

There are very numerous small exposures of normal Lias in many parts of the Vale, but the information obtained from

FIG. 64.—SKETCH MAP OF THE BRIDGEND DISTRICT TO SHOW THE POSITIONS OF EXPOSURES.

(Scale, 6 inches to 1 mile.)

their study is too incomplete to afford a useful summary, and it is not proposed to offer a detailed account of them here. It may be noted that over the greater part of the area the high ground is made up by the higher beds of the *bucklandi* zone; the *rotiforme-gmuendense* sub-zones are exposed very frequently in the cuttings of the Vale of Glamorgan Railway.

In the Bridgend neighbourhood, however, the numerous

quarries and railway cuttings have made it possible to obtain fuller information of the *bucklandi* zone and it will be useful to summarize the sequence in that area for comparison with the sequence noted on the coast.

THE BRIDGEND DISTRICT.

The limestones of the *bucklandi* zone are worked in several large quarries in and around Bridgend, and the higher beds are also shown in the railway cutting near the station. Quite the best exposure, however, is in a cutting of the Coity Branch Line of the Vale of Glamorgan Railway, a few hundred yards east of the town. The positions of these sections are indicated in figure 64. The rocks as a whole dip southward and the angle of dip is high in some places; the limestone series is folded into east-west folds, and is repeated by faulting (figure 65).

The succession in the *bucklandi* zone in this district is summarized in figure 66, and further detail concerning the lithology does not appear to be necessary. In the lowest beds of the *bucklandi* zone (bi) which are now exposed in quarries 2 and 3, in the Coity Cutting, and in the deeper part of quarry 5, occur wide *Gryphæas* resembling those from the lowest part of the *Vermiceras* beds at Keynsham,* and large Arietids. The suc-

FIG. 65.—SECTION OF THE *BUCKLANDI* ZONE, CUTTING OF THE COITY BRANCH RAILWAY NEAR BRIDGEND.

ceeding beds are seen in quarries 4, 5 and 6, and are the beds chiefly quarried in the neighbourhood. They are nodular, but the bands are usually a foot thick and little shale is present. Chert, often with traces of sponge-spicules, is fairly abundant,† and the fossils are often beekitised. Ammonites are rare, but large specimens of *Coroniceras* cf. *bisulcatum* (Brug.) and, in the upper part, of *C.* cf. *rotiforme* (Sow.), occur. Good specimens of *C. rotiforme* are found in quarry 1. Numerous other mollusca, including *Gryphæa obliquata* Sow. (from the lower part) and *G.* aff. *incurva* Sow., have been recorded from these beds.

These massive nodular beds are succeeded by a more argillaceous series, the base of which is seen on the south-western face of quarry 5 and on the east of quarry 4. At the base of this division occur many *Gryphæas* closely comparable with those from horizon *biii-iv* on the coast. It is interesting to note that at Southerndown and at Llantwit Major, as at Bridgend, the

* 24, fig. 1c, p. 259.

† 17, p. 72.

series becomes more argillaceous near this horizon (see figure 56). Above this more argillaceous group are thick, evenly-bedded limestones, alternating with thick beds of shales; this series is best exposed in the railway cutting immediately south of the station. Higher beds, which have yielded *Arnioceras* cf. *bodleyi* (Buckman), are seen in the north side of the cutting on the Great Western Railway, east of the junction with the Vale of Glamorgan Railway.

In brief, it may be pointed out here that there is a close similarity between the lithological sequence at Bridgend and at various places on the coast, notwithstanding that during part of the time at least they were separated by rather extensive islands.

D. INLAND EXPOSURES OF LITTORAL LIAS.

The Liassic rocks usually become littoral in character when they rest on Carboniferous Limestone. Such littoral deposits, frequently resembling closely those of the Dunraven and Sutton Coast, are found in various parts of the Vale, but chiefly in the west. Unfortunately, there are comparatively few exposures of these beds, as many of the old quarries are now overgrown, and it is not always possible to supplement the information given in the Survey Memoirs. It is only in isolated areas that the relations of the various littoral deposits can be determined, but it is useful to consider some of these and to compare the littoral deposits with those of South-erndown.

MERTHYR MAWR.

Merthyr Mawr is about two miles south-west of Bridgend, and three miles north of Southerndown, and is on the northern margin of the tract of Carboniferous Limestone which rises behind Southerndown. The Lias crops out northwards from Merthyr Mawr to

FIG. 66.—DIAGRAM ILLUSTRATING THE SEQUENCE IN THE LIMESTONES OF THE *Bucklandi* ZONE NEAR BRIDGEND.

Vertical scale about 1 inch to 36 feet.

Bridgend, and is of littoral type where it comes against the Carboniferous Limestone. Near Merthyr Mawr and east of Tythegston the Lias overlaps Rhætic and Keuper.*

The best series of exposures at present is to be seen in Cwm Quintin, a narrow valley between Tythegston and Merthyr Mawr. At the northern end of this valley, and about one mile from the outcrop of the Carboniferous Limestone, are several small quarries in Lias of normal character. Further south, in a small opening on the east of the Cwm, about a quarter of a mile east of Whitney, are seen blue fine-grained limestones and thin bands of chert, with *Nautilus striatus*, *Lima gigantea*, *Cardinia* cf. *ovalis*, and *Gryphæa* aff. *dumortieri*; probably these represent the upper part of the *angulata* zone (aiv). Further south, within the woods in the Cwm, are several small exposures showing conglomeratic limestones, but no fossils have been found in these. The littoral beds are best seen, however, at the southern end of the Cwm under Candleston, where they are nearly horizontal and appear to be banked against a terraced cliff of Carboniferous Limestone, as they are at Pant y Slade. The Lias limestones are more thinly-bedded than the Sutton Stone, but like it they weather white. There are some bands of whitish crystalline limestone, while other beds are conglomeratic. The included fragments are usually small, and consist almost entirely of Carboniferous Limestone, but some chert is also present. The only fossil recorded is a *Gryphæa* intermediate in form between *G. obliquata* and *G. dumortieri*; it is, of course, impossible to decide the horizon from a single specimen, but it probably is upper *angulata* or lower *bucklandi* zone.

In the old quarries in Coed Slaies, north of Merthyr Mawr House, and in a roadside quarry 500 yards east of Ysgubor Quintin, are thick nodular limestones and shales. These do not include any conglomerates, although the quarries are scarcely 200 yards from the outcrop of the Carboniferous Limestone. *Gryphæa* aff. *obliquata* occurs, and it appears likely that at least the neighbouring portion of the Carboniferous Limestone island was submerged by the *rotiformis* hemera.

East of the River Ogmore there are now no exposures showing the relations of the Lias for several miles. It is worthy of note, however, that there are evidences of red and green Keuper Marl in fissures in the Carboniferous Limestone 600 yards S.S.W. of Ewenny Bridge (two miles south of Bridgend), both in the quarry east of the railway, and in the railway cutting. It is not likely that the Keuper sea extended far over the Carboniferous Limestone here, and it is probable that the Keuper is overlapped by Rhætic and Lias.† It may be suggested that there was a

* 17 p. 73.

† In a quarry about 850 yards S.S.W. of the bridge are several veins in the Carboniferous Limestone filled with a white crystalline limestone; the writer believes this to be of Liassic age, but no fossils have hitherto been found in it.

narrow inlet at this place (fig. 67), and that the greater part of the Triassic deposits has been removed by the Afon Alun. In this instance, as near Sutton and elsewhere, the river apparently has made its course along pre-Triassic valleys.*

Near the north-eastern corner of this tract of Carboniferous Limestone is the old quarry which was called Brocastle, by Duncan, Moore and others.† Great numbers of corals were collected at this spot from limestone resembling Sutton Stone, which was seen resting on Carboniferous Limestone, but the quarry is now overgrown. A few *Gryphæas* found near suggest that the horizon represented is somewhat higher than that at Sutton, probably upper *angulata* zone or lower *bucklandi* zone.

ST. BRIDE'S MAJOR.

Along the southern margin of the same Carboniferous Limestone tract there are several exposures east of Dunraven, showing Liassic conglomerates. The best are near the Southerndown Road Station of the Vale of Glamorgan Railway (nearly three miles east of Southerndown). Massive whitish limestones resembling the Sutton Stone are exposed near the stream under Castle-upon-Alun; the Carboniferous Limestone against which this was deposited is seen only a few hundred yards to the north-west. Farther from the Carboniferous Limestone, in a large quarry just west of the station, are dark blue limestones which are slightly conglomeratic; they are somewhat of the type of the Southerndown Beds but contain fewer and smaller fragments of Carboniferous Limestone, and chert fragments are rare. *Gryphæa* aff. *obliquata* has been found, indicating a horizon low in the *bucklandi* zone. On the western side of the quarry the limestones weather to a whiter colour, and in the neighbouring railway cutting (west of the station) the Lias is whiter as the Carboniferous Limestone is approached. The actual junction of Lias and Carboniferous Limestone is not exposed.

WICK.

Between one and two miles south of the Southerndown Road Station, near Wick and St. Andrew's Minor, the Geological Survey have mapped several small areas of Carboniferous Limestone. Around only one of these are good exposures of the Lias; this is about half a mile west-north-west of Wick. Mr. R. H. Tiddeman pointed out the rag-like character of the Lias at this locality and noted that corals are abundant in several bands;‡ on the Geological Survey map a coral reef is indicated.§ In several exposures about 350 yards west of Beacon Tower, a pale crystalline limestone is seen, often with casts of compound corals

* But compare 17, p. 25.

† 4, p. 17; 12, p. 521; 31, p. 112; 17, p. 73.

‡ 17, p. 88.

§ Sheet 262 (New Series).

resembling *Thecosmilia michelini* Terquem. Several specimens of *Gryphæa* have been found which indicate that the horizon is probably lower *bucklandi* zone. Under the microscope the limestone is seen to consist of a coarse mosaic of calcite, with cloudy bands and patches, and it closely resembles some coral bands found in the Sutton Stone. No conglomerates have been noticed in these exposures, and presumably the island of Carboniferous Limestone against which these rocks were deposited was very small.

THE COWBRIDGE DISTRICT.

About four miles north of Cowbridge, at St. Mary Hill, littoral Keuper and Rhætic are found bedded against a tract of Carboniferous Limestone which stretches to Cowbridge. Along the margin of this tract are littoral Liassic rocks of the *planorbis* zone, near St. Mary Hill; in these beds fragments of limestone and chert are found, with white quartz pebbles.* Southwards to near Llangan and Pen-llin, higher zones are represented, but the exposures are poor and there is no indication of beds higher than the upper part of the *angulata* zone. Near Llangan, at Gelli-araul, 150 feet of conglomerates were proved in a trial shaft; these were *under* limestones that were considered by Moore to be Sutton Stone and no evidence of their age was found.† It should be noted, however, that the sinking was near the Carboniferous Limestone and probably there is a thickening of the littoral beds similar to that occurring at Pant y Slade.

In the immediate neighbourhood of Cowbridge there are several exposures of Liassic rocks, but their relations are not always clear and few fossils of zonal value have been found. It is not, therefore, proposed to describe in detail the sections in this district, as excellent accounts have been given by Mr. T. C. Cantrill,‡ Mr. F. T. Howard,§ and Mr. L. Richardson,|| who were able to observe many of the sections when they were in better condition. The littoral deposits include oolitic limestones, sandy limestones, limestone conglomerates and beds resembling the Sutton Stone. In the outlier south of Cowbridge and around Llanbleiddian the littoral deposits are mainly referred to the *planorbis* zone, while normal Lias of higher zones is seen south and west of the River Daw.

Along the southern margin of the area of Carboniferous Limestone that extends eastwards from Cowbridge, to St. Hilary and Llantrithyd, the Lias occasionally overlaps Rhætic and Keuper and rests directly on the Limestone, but here also the littoral deposits appear to be confined to the *planorbis* zone. It is probable, therefore, that the whole of this limestone tract

* 17, p. 71.

† 12, p. 533.

‡ 17, p. 62.

§ 9.

|| 13.

was submerged before the commencement of deposition of the *angulata* zone.

This is supported by the information obtained from the extensive Liassic plateau further north, between Cowbridge and Welsh St. Donats, where the littoral deposits are referred to the *planorbis* zone and are followed by limestones and shales of more normal type which represent the *angulata* and *bucklandi* zones. Near Welsh St. Donats are several large quarries in limestone resembling Sutton Stone, with *Ostrea liassica*, indicating *planorbis* zone, and an assemblage of lamellibranchs similar to that found in the Sutton Stone near Sutton and elsewhere.

ST. FAGAN'S AND PETERSTON-SUPER-ELY.

The writer called attention, in the Cardiff paper, to the outlier of Lias near St. Fagans, four miles west-north-west of Cardiff.* The Lias here is poorly exposed and little additional information has been obtained. It is now clear, however, that the limestones with chert bands seen in the quarry 600 yards east-south-east of Pentrebanau, belong to the lower *bucklandi* zone (*Vermiceras* sub-zone), judging from the *Gryphæa* aff. *obliquata* found there.

In the Peterston outlier farther west, the best exposure at present is a quarry west of Palau. This shows about fifteen feet of nodular limestones with thin bands of flattened chert nodules, closely resembling the exposure at Pentrebanau. Fossils are very rare but the few *Gryphæa* found probably indicate the lower *bucklandi* zone.

It is important to note, however, that the Lias of these outliers, though occasionally oolitic, is not really littoral in character; the coast line at the time of deposition of the *bucklandi* zone must have been at least four miles to the north, and the Carboniferous Limestone now exposed to the south must have been submerged in Rhætic or early Liassic times. It is also noteworthy that the lowest Lias and also the Rhætic in this neighbourhood are of normal character.

V. THE ORIGIN OF THE NODULAR LIMESTONES.

Attention has recently been drawn to the mode of origin of nodular limestones such as those that are so well exhibited along the Glamorgan coast. The origin of these and similar limestones has been considered by numerous workers, and it was discussed at some length by H. B. Woodward.† He concluded that while some of the Lias limestones are undoubtedly of directly sedimentary origin, the nodular and lenticular masses of limestone have been formed by the segregation of the calcareous matter from the more argillaceous portion of the deposit.

* 23, p. 103; see also 16 (2nd Edition), p. 71, etc.

† 31, pp. 27-32. See also W. D. Lang, *Proc. Geol. Assoc.*, vol. XXV, 1914, p. 297.

In his petrological notes on some Liassic strata in Dorset, Mr. W. A. Richardson recently discussed this question and suggested that the nodular limestones are of secondary origin and were precipitated rhythmically during the initial stages of desiccation and drainage of the deposits.* It is interesting to examine the Liassic limestones of Glamorgan in the light of this suggestion since they show several features that are not seen in Dorset.

Some of the limestones in Glamorgan are clearly of organic origin and others show a distinct lamination that suggests a sedimentary origin, but most of the limestones where the Lias is of normal character are nodular in form. Some thin beds are less nodular than others and on the beach form flat-topped reefs, but they generally show some tendency to nodular form. In the more argillaceous divisions (such as the *angulata* zone) the nodule bands may be separated by some thickness of shale and the nodules are themselves separate, but in the more calcareous portions of the *bucklandi* zone the nodule bands are closely packed and the interbedded shales are thin. These nodule bands generally form continuous beds and the nodular character of the limestone is shown by rapid changes in the thickness of the band; as a result the shales also vary in thickness and appear to follow the irregularities of the nodules (plate 8A). The shales are contorted in this way both above and below the nodules.

The nodular limestones of the Lias of South Wales appear to be of subsequent origin since they show the following characters:—

1. The nodules in form are flattened ellipsoids.
2. They are frequently unfossiliferous, or contain fewer fossils than the shales.
3. The lamination of the shales is displaced conformably to the nodules, both above and below.
4. The spacing of the nodule bands from the base of the Lias to the top of the *angulata* zone on the whole agrees with a rhythmic banding.

[The limestones of the *bucklandi* zone can only be explained by supposing a further period of rhythmic precipitation.]

The limestones of South Wales illustrate several facts more clearly than those Mr. Richardson has investigated. For, since they were accumulated near a shore-line and in several parts of a sea separated by islands, the rocks were deposited under different conditions in different parts of the area; thus, calcareous material was being worn from the Carboniferous Limestone of the islands while, presumably, more argillaceous material

* See W. A. Richardson, "Shales-with-Beef, etc. Part III." *Abst. Proc. Geol. Soc.*, No. 1079, 1922, p. 30; and "The Relative Age of Concretions," *Geol. Mag.*, vol. lviii., 1921, p. 114.

was derived from the mainland. Yet, except that the series of non-littoral limestones and shales is more calcareous near some of the islands, the same general sequence obtains over a great part of the area. It is unlikely that similar deposits would be formed simultaneously in these separate areas under these differing conditions, and it appears to the writer that these facts support the view that the limestones were precipitated subsequently to the deposition of the material.*

VI. CONCLUSIONS AND GENERAL CONSIDERATIONS.

PRE-LIASSIC GEOLOGY OF THE VALE OF GLAMORGAN.

It has already been pointed out that the Mesozoic rocks were laid down on an irregular floor of Carboniferous Limestone and Old Red Sandstone. In the east, between Cowbridge and Cardiff, sufficient of the Mesozoic rocks have been removed to show some of the characters of the pre-Keuper topography; the Carboniferous Limestone forming the limbs of the Cardiff-Cowbridge anticline gave rise to ridges with the lower country made by the Old Red Sandstone in between. Further west, between Cowbridge and Bridgend, there is less evidence of the nature of the Palæozoic floor, but it is clear that Carboniferous Limestone formed a large part of it, and that the pre-Keuper surface was irregular with, in particular, a belt of lower country on the north extending along the outcrops of the Millstone Grit and Lower Coal Series.

This region was submerged gradually during Keuper times, subsidence taking place at short intervals, between which platforms were cut around the shores of the islands. The distribution of land and sea in early and late Keuper times has been indicated by Sir A. Strahan;† the geography of the western part of the area during these times is represented in figure 67A. It will be noted that the shore of the mainland coincides to some extent with the coalfield margin; in the east, near Taff's Well, the Carboniferous Limestone was completely submerged before the end of the Triassic period, and presumably in this region the higher ground of the Pennant Grit formed the shore line. Before the end of Keuper times the islands near Barry were covered, but an extensive island stretched south-westwards between Cowbridge and Bridgend (fig. 67A). No evidence concerning the coast-line south of Cowbridge is available, but it is not unlikely that several islands existed there, as in earlier and

* Professor A. H. Cox has stated that in his view the limestones are contemporaneous, being formed by the precipitation of calcite-mud under varying conditions of salinity. (*Abstracts Proc. Geol. Soc.*, No. 1079, 1922, p. 31). If similar physico-chemical conditions applied over the whole area it is conceivable that similar deposits might be produced under *outwardly* different conditions. But it is not proposed to discuss Prof. Cox's suggestion until further details of his theory are published.

† 17, fig. 2, p. 24.

A

B

FIG. 67.—A—MAP SHOWING THE OUTLINES OF THE TRIASSIC GEOGRAPHY OF THE VALE OF GLAMORGAN.

(partly after Sir A. Strahan)

B—MAP SHOWING THE OUTLINES OF THE LIASSIC GEOGRAPHY OF THE VALE OF GLAMORGAN (DURING THE DEPOSITION OF THE *Angulata* ZONE).

Scale, approximately 1 inch to 5 miles.

subsequent times. There was a further slight extension of the sea during the deposition of the Rhætic.

LIASSIC GEOGRAPHY.

At the close of Rhætic time there was probably a sharp subsidence; this is indicated by a change in the character of the deposits in many areas, as from the sandstones of the littoral Rhætic deposits near Bridgend to the normal Lias which overlies them.* The sea presumably encroached on the mainland, but direct evidence for this is lacking; the large island between Cowbridge and Bridgend became steadily submerged, smaller islands being formed, as at Wick. Before the deposition of the *angulata* zone a strait had been formed west of Cowbridge (fig. 67B), and during the deposition of the *bucklandi* zone probably all the islands south of Bridgend disappeared. The plateau of the Carboniferous Limestone at Ogmore Down and Ewenny Down were probably planed off about this time. It is significant that in parts of the Gower peninsula a similar plateau feature is often developed some two hundred feet above the littoral Keuper deposits, and although no Lias is known in that region the writer believes this Gower plateau to mark a stage in the subsidence in the area below the Liassic sea. In this connection it may be noted that in the Museum of the Royal Institution of South Wales, there are several Liassic oysters allied to *Ostrea irregularis* from "stalactite in the Carboniferous Limestone at Mumbles." It is assumed that they were collected from a Liassic vein similar to those described by Moore at Holwell and various other localities in Somerset.†

In general, it may be suggested that the pre-Liassic (and to a large extent the pre-Keuper) landscape of South Wales is being re-exposed by the removal of the softer Mesozoic cover. It must be noted, however, that extensive land areas may have existed to the south of the present coast; from such land the abundant chert and the sandstones found in the Southerndown Beds, for instance, were probably derived.

FAUNAL REGIONS.

The faunal assemblages to be noticed at various horizons in the Liassic rocks of Glamorgan are of some interest. Compound corals, usually extremely rare in the Lias of this country, are often abundant in the Sutton Stone, and at all horizons where this type of lithology is developed. In the more argillaceous beds of the normal Lias *Montlivaltia* is the only coral found, and it may be inferred that there was clear water favourable to coral growth near the shores of many of the islands. In other portions of the Sutton Stone there is found an assemblage

* 12, p. 407.

† C. Moore, 12, pp. 454, 481, &c.; "On Abnormal Geological Deposits in the Bristol District." *Quart. Journ. Geol. Soc.*, vol. xxxvii., 1881, p. 67.

of ribbed *Ostrea*, *Lima* spp. and *Pecten suttonensis*, a similar series of fossils being found in beds of this character in other parts of Glamorgan and in Somerset.*

In the shallow water only a few hundred yards from some of the islands, *Gryphæa* and ostræiform lamellibranchs were exceedingly plentiful. With them in several areas occurred numerous ammonites, often of large size.

It is noteworthy that near the islands in the Liassic sea, both in Glamorgan and in Somerset, the ammonites frequently attain a great size.†

THE LITTORAL DEPOSITS.

The various types of lithology among the littoral Liassic rocks have already been described, but it appears desirable to summarize several considerations of more general interest.

1. The littoral deposits of Glamorgan include materials that have mostly been derived from Carboniferous Limestone; in view of the extensive areas of Coal

FIG. 68.—DIAGRAM SHOWING THE RELATION OF THE MESOZOIC ROCKS TO THE PALÆOZOIC FLOOR.

Littoral deposits are dotted.

Measures undergoing denudation to the north there is a remarkable scarcity of argillaceous and arenaceous material.

2. The littoral deposits in all areas in Glamorgan frequently resemble Sutton Stone and Southerndown Beds in lithology.
3. In almost every exposure where the Lias is seen actually resting against Carboniferous Limestone the littoral deposits are of Sutton Stone type; this kind of deposit is found at various horizons in the Lias, and more rarely in the Rhætic. The high percentage of calcareous material in the Sutton Stone indicates that it includes very little sediment except that from the islands.

* 31 p. 88.

† Compare S. S. Buckman, *op. supra cit.*, 1918, p. 315.

4. The limestones of Sutton type often pass laterally, at a short distance from the islands, into breccias and conglomerates of Southerndown type.
5. Deposits of littoral character in South Wales are rarely found more than half-a-mile from the shore lines. This is probably because they are usually associated with small islands which presumably had no large streams. There is evidence that the pebbles were carried along the shores by currents.
6. In the Lias of more normal character, deposited several miles from a shore line, there are frequently oolitic limestones and chert nodules, and the fossils are commonly silicified.

VII.—NOTES ON THE AMMONITES.

The following notes on the ammonites are appended in order to facilitate more exact correlation with the ammonite sequence in other areas. Satisfactory determination of ammonite species from Glamorgan is rarely possible; several new species are doubtless represented, but as the specimens are not well preserved no new names are proposed here, the forms being compared with species already figured.

ALSATITES cf. LAQUEOLUS (Schlön.)

Compare *Amm. hettangiensis* Terquem.*

Amm. laqueolus Schlön.†

Amm. liasicus A. d'Orbigny.‡

Specimens of *Alsatites* found in Glamorgan range up to 400 mm. in diameter, and several species are represented. *A. liasicus* (d'Orb.) has not been found, a form resembling *A. laqueolus* (Schlön.) being more abundant. *A. liasicus* has a fairly round whorl with nearly straight ribs, while *A. laqueolus* has a round whorl with ribs curved almost in a semicircle. All the specimens hitherto found in Glamorgan have this rib-curve, although in several where the costæ are only prominent on the sides of the whorl, the curve at first sight appears to be less marked. The latter specimens are generally confined to the higher portion of the *liasicus* sub-zone.

Some of the Glamorgan specimens agree with *A. laqueolus* in whorl form, but a number have a depressed whorl (resembling in this character *A. hettangiensis* Terq. sp.). Forms with this whorl shape are closely related to *A. laqueolus* however, and in some specimens the round whorl becomes depressed in the adult stages, the change taking place very rapidly.

The writer is indebted to Mr. J. W. Tutchet for opportunity to compare his Somerset specimens of this genus. These appear

* *Mem. Soc. Geol. France*, 2nd Ser., vol. v., 1855, pl. xiii., fig. 1.

† *Palæontographica*, xiii., 1865, p. 152, Taf. xxvi., 1.

‡ *Palæont. franc. T. jurass.*, t.i., p. 199, pl. xlviii.

to include the typical *A. liasicus* (d.'Orb.) from Filton, as well as *A. cf. laqueolus*.

SCHLOTHEIMIA cf. HAGENOWI (Dunker), fig. 69 and Plate 9A.

Compare *Amm. hagenowi* Dunker.*

Amm. hagenowi Schlön.†

Psilophyllites hagenowi Spath.‡

These remarkable little specimens resemble Triassic or Palæozoic forms rather than Jurassic ammonites. Generally they are quite smooth and evolute, with the following dimensions :

	Diameter.	Whorl height. per cent.	Whorl thickness. per cent.	Umbilicus. per cent.
a.	10.5 mm.	33	25	43
b.	16 mm.	31	21	40

The whorl shape changes very little during development as the following dimensions show :

Diameter.	Whorl height. per cent.	Whorl thickness. per cent.	Umbilicus. per cent.
4 mm.	34	35	41
3.5 mm.	38	40	—
2.7 mm.	38	43	38
1.7 mm.	38	48	41
1.2 mm.	40	50	45

Most of the specimens found are septate throughout. The sutures are simple and in the most advanced specimens are ceratitic. Until the diameter of about 15 mm. is reached they are simple and without denticulations, but in the adult sutures denticulations are present in the chief lobes, the saddles remaining entire in every case. Usually the external saddle is somewhat smaller than the first lateral saddle ; the auxiliaries are frequently but not invariably reclined.

One large fragment at about 22 mm. diameter has low sub-costæ with the curve typical of *Schlotheimia*, and these ammonites are therefore referred, somewhat doubtfully, to that genus.§ It may be suggested that the superficial resemblance to *A. hagenowi* (and to other specimens that have been figured previously and referred to that species) does not necessarily mean that the species are identical, or even related. This could only be decided by a re-examination of the type of *A. hagenowi*, which may not be a species of *Schlotheimia*, but quite possibly is a reduced member of another genus.

* *Palæontographica*, I., 1847, p. 115, Taf. xiii., 22.

† *Ibid.*, xiii., Taf. xxvi., 2.

‡ L. F. Spath, *Quart. Journ. Geol. Soc.*, vol. lxx., 1914, p. 351, footnote 1.

§ *S. cf. hagenowi* occurs at Lavernock in the lower part of the *angulata* zone, with several other species of *Schlotheimia*.

ARNIOCERAS cf. SPIRALE Fucini.* (Plate 9B).

This *Arnioceras* is found abundantly on the beach in several localities. Probably several species are included, but all agree in having a slender whorl, with straight ribs somewhat reclined. Usually the keel is sharp, and is flanked by shallow and fairly wide grooves. No specimen hitherto collected shows any trace of the suture line.

FIG. 69.—SUTURES OF *Schlotheimia* cf. *hagenowi* (DUNKER).

a, from the specimen shown in Plate 9a, b, c, d, e, several stages from another specimen, at the diameters indicated.

The dimensions agree closely with those of Fucini's species, as will be seen below :

	Diameter.	Whorl height. per cent.	Whorl thickness. per cent.	Umbilicus. per cent.
Fucini's specimen No. I.	51 mm.	19	18	65
Figured specimen a.	51 mm.	20	19	65
Figured specimen b.	24 mm.	23	22	52

In a few specimens the whorl thickness is much less than whorl height, and some specimens closely resemble *A. tardecrescens* Fucini (non Hauer, Reynès, etc.)

The relation of these forms from the lower part of the *bucklandi* zone (*rotiforme* sub-zone) to later *Arnioceras* cannot be satisfactorily discussed in the absence of sutural details.

* A. Fucini, *Palæont. ital.* viii., 1902, T. xix., 10.

A.—*Schlotheimia* cf. *hagenowi* (Dunker).

B.—*Arnioceras* cf. *spirale* Fucini.

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EXPLANATION OF PLATES.

PLATE 8A.—Cliffs and foreshore near Dunraven, looking north from near the more northerly fault under Dunraven. The bed in the foreground is the prominent bed referred to on pages 262 and 275, and shows the nodular character of the limestones. This bed is seen in the cliff beyond and is succeeded by more argillaceous beds.

B.—The northern side of Trwyn y Witch (Witches Point), Dunraven, showing thinly-bedded Carboniferous Limestone (Y-beds) overlain unconformably by littoral Lias of Sutton stone type.

PLATE 9A.—*Schlotheimia* cf. *hagenowi* (Dunker), from the *liasicus* sub-zone, near Lavernock Station, Glam. (Slightly enlarged).

B.—*Amioceras* cf. *spirale* Fucini, from the *rotiforme* sub-zone, Summerhouse Point, near Llantwit Major, Glam. (Natural size).

PLATE 10.—Diagrams showing the structure of the cliffs between Sutton and Cwm Nash, to illustrate the changes in lithology within the various Liassic zones.

Index to shading of Liassic zones:

? *planorbis* zone

angulata zone

bucklandi zone

semicostatum zone

Carboniferous
Limestone

Index to shading of rock-types:

Sutton Beds

Southerndown Beds

Shales with
nodules

Nodular limestones

CLIFF SECTIONS IN THE LIASSIC ROCKS OF SOUTHERNDOWN, GLAM.

By A. E. Trueman.

Horizontal Scale, 6 inches to 1 mile. Vertical Scale, 1 inch to 200 feet.