# NON-MARINE LAMELLIBRANCH ASSEMBLAGES FROM THE COAL MEASURES (UPPER CARBONIFEROUS) OF PEMBROKESHIRE WEST WALES

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ABSTRACT. Assemblages of non-marine lamellibranchs are described from twelve horizons in the Ammanian and four in the Morganian strata of the Pembrokeshire coalfield. In the case of the Ammanian assemblages it is usually possible to indicate the approximate correlative fauna in one or more of the major British coalfields.

## INTRODUCTION

THE first records of non-marine lamellibranchs from this part of the South Wales coalfield are contained in two Memoirs of the Geological Survey and refer to the more conspicuous faunal horizons which are low in the Coal Measure succession (Strahan *et al.* 1914, pp. 161, 179; Cantrill *et al.* 1916, p. 116). Davies and Trueman (1923) related these occurrences to similar ones in the Gwendraeth and Amman Valleys of the main coalfield. Further details of the lamellibranch succession in east Pembrokeshire were given by George and Trueman (1925). The fauna from the roof of the Lower Level Vein, at Bonville's Court Colliery, Saundersfoot, received biometric attention from Davies and Trueman (1927). The zonal scheme of these authors was applied by Dixon (1933) to the eastern, or Saundersfoot, district, and subsequently Trueman (1934) diagnosed the presence along the St. Bride's Bay coast in the west of Pembrokeshire of strata belonging to the Modiolaris, Phillipsii, and Tenuis Zones.

Dix (1933; 1934) revised the palaeobotany, previously investigated by Goode (1913) and Kidston (*in* Strahan *et al.* 1914; Cantrill *et al.* 1916), and established the presence in Pembrokeshire of her floral zones C, D, and G. Dix (1942) referred the Monkstone Grit to the Lenisulcata Zone but unfortunately much other detailed work was left unpublished.

This paper describes and illustrates some assemblages of non-marine lamellibranchs from the Pembrokeshire coalfield. The faunas discussed were selected for their palaeontological interest and stratigraphical significance and most are here newly recorded. Correlations of the Pembrokeshire Coal Measures (fig. 1), to be discussed in a later paper, rest in large part on comparisons of the composition and distribution of these non-marine faunas among others.

Measurements of shells were made in the manner introduced by Davies and Trueman (1927) and the tabulation of dimensional data follows the pattern used by Eagar. In many cases, however, the preservation does not allow the thickness measurement (T) to be made and sometimes, as with the *Anthraconauta* faunas, the indefinite nature of the umbo makes inadvisable the measurement of the anterior end (A). The limitations of imperfect preservation and subjective orientation are, however, not such as invalidate

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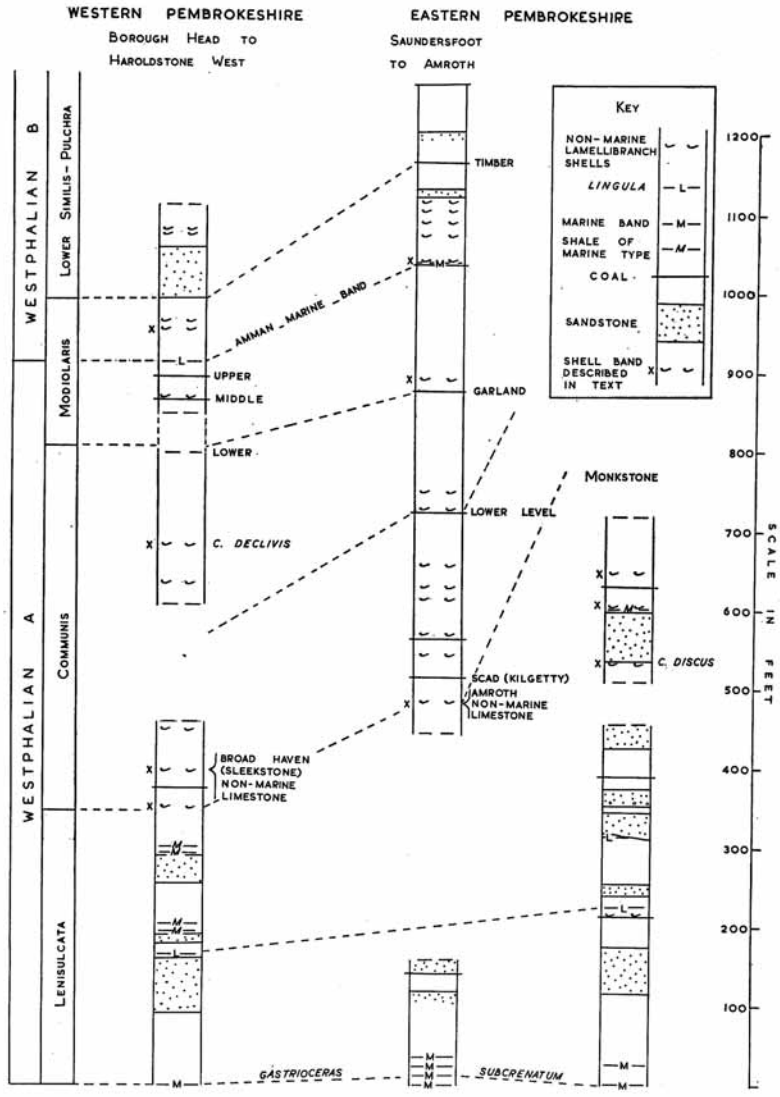


TEXT-FIG. 1. Some natural sections of the Ammanian in Pembrokeshire.

this method of measuring, and certain of the collections are susceptible to more detailed statistical treatment than any here attempted.

The specimens illustrated are in the author's collection at the Department of Geology, University College, Swansea. The figures are natural size.

The authorship of the species mentioned in this paper is as follows: *Anthraconaia bellula* (Bolton), *A. glotae* (Weir and Leitch), *A. lenisulcata* (Trueman), *A. pringlei* (Dix and Trueman), *A. pruvosti* (Chernyshev), *A. pruvosti* (Weir and Leitch *non* Chernyshev), *A. pulchella* Broadhurst, *A. williamsoni* (Brown). *Anthraconauta calcifera* (Hind), *A. minima* (Auctorum), *A. phillipsii* (Williamson), *A. subovata* Dewar, *A. tenuis* (Davies and Trueman), *A. trapeziforma* Dewar. *Anthracosia aquilina* (J. de C. Sowerby), *A. aquilinoides* (Chernyshev), *A. concinna* (Wright), *A. lateralis* (Brown), *A. ovum* Trueman and Weir, *A. phrygiana* (Wright), *A. planitumida* (Trueman), *A. regularis* (Trueman), *A. rectrotracta* (Wright). *Anthracosphaerium affine* (Davies and Trueman), *A. bellum* (Davies and Trueman), *A. turgidum* (Brown). *Carbonicola acuta* (J. Sowerby), *C. bipennis* (Brown), *C. browni* Trueman and Weir, *C. cristagalli* Wright, *C. communis* Davies and Trueman, *C. declivis* Trueman and Weir, *C. discus* Eagar, *C. embletoni* (Brown), *C. fallax* Wright, *C. limax* Wright, *C. martini* Trueman and Weir, *C. obliqua* Wright, *C. obliquissima* Trueman and Weir, *C. oslancis* Wright, *C. pilleolum* Eagar, *C. protea* Wright, *C. pseudorobusta* Trueman, *C. pyramidata* (Brown), *C. rhomboidalis* Hind, *C. similis* (Brown), *C. subconstricta* Wright (*non* J. Sowerby), *C. venusta* Davies and Trueman. *Naiadites carinatus* (J. de C. Sowerby), *N. flexuosus* Dix and Trueman, *N. modiolaris* (J. de C. Sowerby), *N. productus* (Brown) *N. quadratus* (J. de C. Sowerby), *N. triangularis* (J. de C. Sowerby). Where ambiguity exists the authorship is indicated in the text.

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## LENISULCATA ZONE

Nine horizons yield non-marine lamellibranchs between Saundersfoot and the Trevane anticline just south of Monkstone and it is likely that they all fall within this zone.

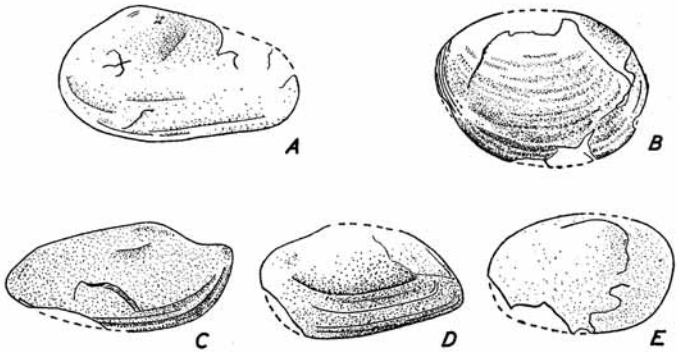
(*a*) *Band with* Carbonicola discus *Eagar* (fig. 2). Crushed shell impressions occur in the uppermost 3 feet of fine, dark platy shale outcropping 200 yards south of Swallowtree stream in the section north of Monkstone Point. The collection of twenty shells consists mainly of posteriorly tapered examples of *Carbonicola* (fig. 2A, C, D) some being referable to *C.* cf. *protea* (fig. 2D), *C.* cf. *obliqua* (fig. 2C), *C.* cf. *browni*, and *C.* cf. *pseudorobusta*. A minority of the shells are orbicular and include *C. discus* sensu stricto (fig. 2B), and *C.* aff. *discus* (fig. 2E). Variation within the sample may be discontinuous but it is impossible to demonstrate this with the small collection available. Dimensions for the *Carbonicola* assemblage are given below. One large specimen of *Naiadites* cf. *flexuosus* was found.

| *Length* (L) *in mm.* | *Height* (H) / *Length* (L) | *Anterior end* (A) / *Length* (L) |
|---|---|---|
| Range 28·5–39·6 | 47·2–75·6[1] | 26–43 |
| Mean 33·0 (12) | 65·7 (11) | 32·5 (10) |

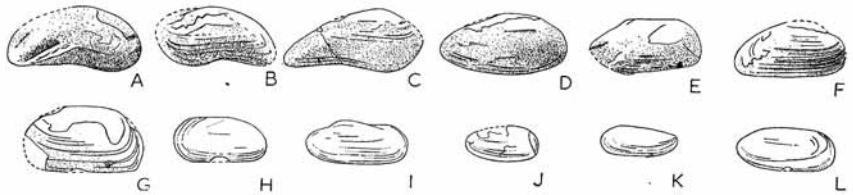
[1] Omitting one shell with H/L ratio of 91 per cent.

The figures in brackets in this and similar subsequent tables refer to the number of shells measured.

These specimens are comparable with shells described by Eagar (1947) from 16 ft. 3 in. to 18 ft. 9 in. above the Soft Bed Coal at Honley, near Huddersfield, and reported by him to occur very widely in the Pennine region at a constant horizon within the middle division of the strata between that coal and the Middle Band Coal (Eagar




TEXT-FIG. 2. Shells from a band with *Carbonicola discus* Eagar, ×1. Lenisulcata Zone, cliffs 200 yards south of Swallowtree Stream, near Saundersfoot. Author's Coll.; *a* A, M2/9; B, M2/10; C, M2/3; D, M2/13; E, M2/18b.




TEXT-FIG. 3. Shells from the Lenisulcata Zone, ×1. A–E, about 116 feet above the band with *Carbonicola discus* Eagar, cliffs between Swallowtree Stream and Monkstone Point, south of Saundersfoot. Author's Coll.; A, M31/1a; B, M32/12; C, M32/6; D, M40/8; E, M40S/1. F–L, from about 65 feet above the band with *C. discus*. Locality as above. F, M42/18; G, M42/33a; H, M42/2; I, M42/15; J, M42/37e; K, M42/37b; L, M42/1.

1951; 1952, pp. 25–29, 51). At localities between Honley and Halifax successive assemblages in this Soft Bed–Middle Band sequence are respectively characterized by the presence of *C.* cf. *pseudorobusta* and similar forms and by the brief acme of the distinctive *C. discus* fauna. Unfortunately the sparseness of the Swallowtree collection and other factors prevent a comparison of the dimensions of the Pembrokeshire and Yorkshire assemblages. It appears, however, that the known range of variation of the *C. discus* fauna in the Pennine province is comparable with that shown by the Pembrokeshire members of this short-lived species (Eagar 1952, table 8).

(*b*) *Shells from about 65 feet above the band with* C. discus (fig. 3F–L). In the Monkstone–Swallowtree section the top of the shale carrying the fauna with *C. discus* is eroded at the base of a partly cross-bedded sandstone approximately 65 feet thick which is capped

by 3 ft. 4 in. of dark fine shale. The base of this shale is of marine type and yielded *Planolites*; at 6 to 12 inches above the base lamellibranch impressions occur fairly abundantly and persist less frequently through the upper part of the band.

The lamellibranchs are all small and 68 per cent. are expanded (dorso-ventrally) posterior to the umbo. Such anthraconaioid shells (fig. 3H–L) are elongate or only moderate in relative height and about half have a postero-ventral angulation; this character is more prevalent in the larger specimens (e.g. fig. 3M, the umbonal region of which is probably distorted); in the smaller anthraconaioids (e.g. fig. 3I, K) the angulation is completely suppressed. *C.* aff. *pilleolum* (F), *C.* cf. *protea* (small form) (G), *C.* aff. *fallax*, *C.* cf. *limax* and an elongate–oval form are represented among the minority of shells lacking anthraconaioid character. Dimensions appear in Table 3.

One specimen is referred to *Naiadites*?

(*c*) *Shells from about 116 feet above the band with* C. discus (fig. 3A–E). At this horizon in the cliffs just north of Monkstone small crushed shells (fig. 3A–E) were found, sparsely preserved in hard, grey silty mudstone.

*C.* cf. *fallax* (fig. 3E) and *C.* cf. *protea* occur together with several shells characterized by recurved ventral margins, some of which may be referred to *C.* cf. *pilleolum* (fig. 3A, B). No anthraconaioid shells were found.

| | *L in mm.* | *H/L %* | *A/L %* |
|---|---|---|---|
| Range . | 14·1–20·7 | 45·0–55·6 | 22–33 |
| Mean . | 18·7 (8) | 51·2 (8) | 28 (7) |

This assemblage is similar to some of the *fallax–pilleolum* faunas described by Eagar (1947; 1951; 1952) from the Bassy Mine succession of the Pennine coalfields.

(*d*) *Shells from the eastern Cleddau.* In this section fine, dark grey-green shale forms the roof of a 4-inch coaly layer and comprises the lowest of five pene-marine bands; its base contains *Planolites* which persists less frequently into the 9 inches of similar shale bearing impressions of small (L<20 mm.) lamellibranchs. Of fifteen almost complete shells one only is posteriorly tapered, the remainder being posteriorly expanded and, mostly, anthraconaioid; they are determined as *A.?* aff. *bellula*. Dimensions are given in Table 3 which shows the correspondence in H/L per cent. values of anthraconaioid phase faunas in and just below the Lenisulcata Zone in Pembrokeshire and the north of England. The Welsh shells are smaller in absolute size.

TABLE 1

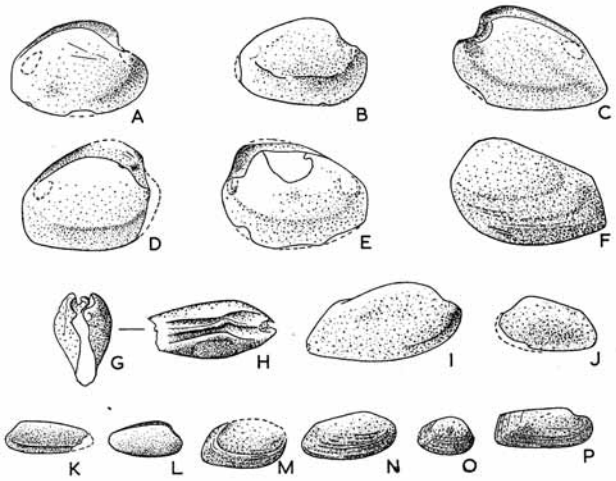
| *Locality text reference* | *Mean length in mm.* | *H/L%* | | *Number of shells measured* | *Percentage posteriorly expanded* |
|---|---|---|---|---|---|
| | | *Mean* | *Range* | | |
| Monkstone (*b*) . . | 17·4 | 44·5 | 36·5–65·1 | 26 | 68% |
| Eastern Cleddau (*d*) . . | 12·5 | 44·2 | 33–51 | L 10 | 93% |
| Honley, Yorkshire . . | 32·1 | 44·6 | 37·8–57·2 | 26 | 65% |
| Parbold, Lancashire . . | 23·0 | 42·8 | 37·3–47·6 | 15 | ?66%[1] |
| Midhopestones, Lancashire . | 23·44 | 40·92 | 35·3–46·8 | 71 | 65% |

[1] '. . . *Anthraconaia*-like forms are at least twice as abundant as those referable to *C. limax* and elongate *C.* aff. *fallax*.'

The sources of the data on the north of England faunas are: Honley—shells from 10 ft. 9 in. to 11 ft. 3 in. above the Soft Bed Coal, i.e. base of the Middle Division of Soft Bed Succession (Eagar 1947, table i, p. 21). Parbold—shells from 0 to 3 in. above the base of band marking base of Upper Division of Bassy Mine Succession (Eagar 1951, table iii, p. 32). Midhopestones—shells from just below the *Gastrioceras subcrenatum* marine band (Eagar 1953, p. 173).

## COMMUNIS ZONE

At Amroth and Broad Haven the basal beds of this zone contain two almost identical non-marine limestones but their lamellibranch faunas (*a* and *b* below) are dissimilar.



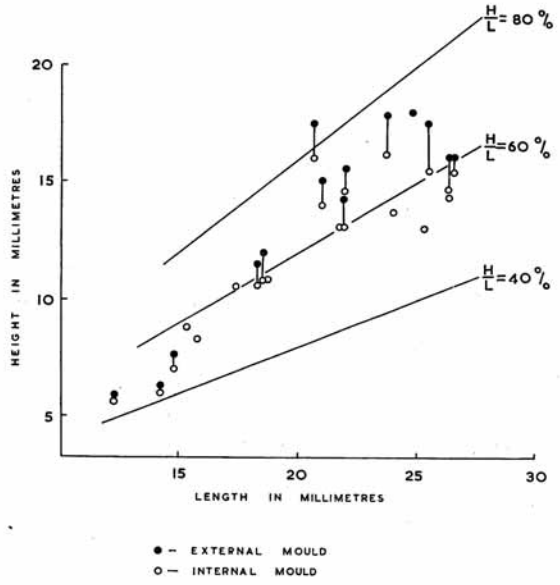

TEXT-FIG. 4. Shells from the basal beds of the Communis Zone, × 1. A–L, Amroth non-marine limestone, 30 feet below Kilgetty (Scad) Vein, cliffs west of Amroth, Pembs. Author's Coll., A, FWL/34b; B, FWL/7b; C, FWL/8; D, FWL/18a; E, FWL/35b; F, FWL/34a; G, H, FWL/40; I, FWL/33; J, FWL/36; K, FWL/18b; L, FWL/22a. M–P, about 47 feet below the non-marine limestone near the Sleek Stone, Broad Haven, Pembs. Author's Coll., M, H2/1a; N, H2/6; O, H2/20; P, H2/10.

The Amroth band is probably represented in St. Bride's Bay by a black, mainly non-calcareous, shale yielding very small shells (*c*). Another assemblage of small *Carbonicola* is described from the upper Communis Zone south of Little Haven.

(*a*) *The Amroth non-marine limestone* (figs. 4A–L; 5). Near Amroth a blue silty limestone, 2½ feet thick, weathering to an ochreous rottenstone, outcrops 30 feet below the Kilgetty (or Scad) Vein. First recorded by Strahan *et al.* (1914, pp. 161–2), it has also been mentioned by Jones (*in* Cantrill *et al.* 1916, p. 117), Trueman and Davies (1923), and by George and Trueman (1925, p. 411) who referred the abundant shells to *C.* cf. *acuta*.

The fauna consist of small shells and exhibits an exceptionally wide range of H/L per cent. values (Table 4). The scatter diagram (fig. 5) shows apparent clustering of (i) the relatively larger shells having high H/L per cent. values, (ii) small shells of low or moderate height; but there are insufficient specimens to prove discontinuity from the

measurements of standard parameters. Specimens referable to *C.* aff. *bipennis* (fig. 4J). and *C.* cf. *declivis* (fig. 4K) are included in the (ii) group while *C.* aff. *subconstricta* Wright (*non* J. Sowerby) (fig. 4I), *C.* cf. *obliquissima* (fig. 4F), and *C.* cf. *martini* appear among the larger shells. But the distinguishing character of this fauna derives from the




TEXT-FIG. 5. Height plotted against length of *Carbonicola* shells from the Amroth non-marine limestone.

strong representation of shells having H/L ratios over 65 per cent. in external mould measurement and which are referable to cf. *Anthracosia regularis*. Dimensions are as follows:

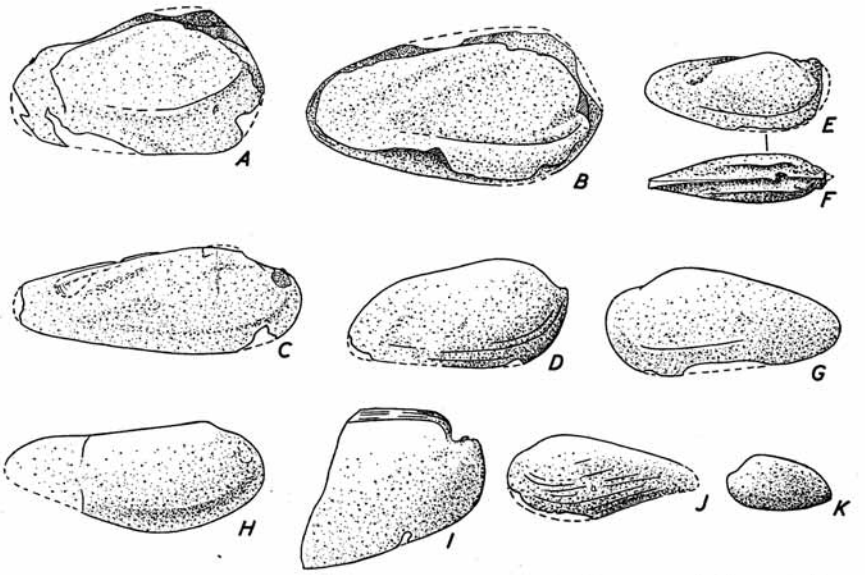
| | *External moulds* | | *Internal moulds* | |
|---|---|---|---|---|
| | *Range* | *Mean* | *Range* | *Mean* |
| L in mm.[1] . | .. | .. | 12·3–26·5 | 20·6 (22) |
| H/L% . . | 44·2–85·3 | 64·2 (14) | 42·0–77·9 | 58·0 (20) |
| A/L% . . | 9–24 | 18 (11) | 16–39 | 26 (20) |

[1] Since the shells are marginally very thin at the extremities the internal and external lengths are assumed to be equal and are tabulated under the former heading.

Some of the specimens (fig. 4C, especially) have a deep lunular hollow which suggests that, given restricted umbonal resorption, the early growth-lines were probably inclined appreciably to the mid-ventral commissure.

This fauna resembles in several respects that occurring about 60 feet below the Arley

Mine–Better Bed Coal horizon in the Pennine coalfields (Wright *in* Tonks *et al.* 1931, p. 134; Eagar 1954, p. 56; 1956, pp. 356–60; Calver 1956, p. 32) and is probably an approximate correlative of that band.




TEXT-FIG. 6. Shells from the Broad Haven (or Sleekstone) non-marine limestone, × 1. Communis Zone, just north of the Sleekstone, near Broad Haven. Author's Coll.; A, H3/10; B, H3/14; C, H3/20; D, H3/29; E, F, H3/6; G, H3/13; H, H3/16; I, H3/24a; J, H3/18; K, H3/19.

(*b*) *The Broad Haven* (*or Sleekstone*) *non-marine limestone* (fig. 6). Just north of the Sleekstone fold a non-marine muddy limestone 3 ft. 3 in. thick outcrops at about 20 feet above the lowest worked coal and weathers to a rottenstone from which Jones (*in* Cantrill *et al.* 1916, p. 116) recorded *C. acuta*; Trueman and Davies (1923) have inferred it to be equivalent to the Amroth limestone. The assemblage consists mainly of *Carbonicola* with sparse *Naiadites* and *Anthraconaia*. The possibly homogeneous *Carbonicola* fauna includes a large proportion of *C. browni* (fig. 6C, E–H) and *C.* aff. *bipennis* (K), *C. pseudorobusta* (cf. A), *C.* aff. *cristagalli*, *C.* aff. *rhomboidalis*, and *C.* cf. *martini*. Elongate, posteriorly tapered forms like *C. browni* comprise more than 40 per cent. of the collection; shells with higher H/L ratios, comparable with *C. pseudorobusta* and *C. rhomboidalis*, comprise a further 40 per cent. The latter group is not unexpected here but the occurrence of completely typical *C. browni* extends its known range downwards to a low horizon in the Communis Zone and the abundance of this species renders doubtful the statement that 'the species probably never formed the majority in any assemblage' (Trueman and Weir 1946, p. 12).

*Anthraconaia* is represented by a part of a large internal mould (fig. 6I) showing an

edentulous, striated, posteriorly widening, straight hinge-plate. *N.* cf. *flexuosus* also occurs.

TABLE 2

| | *External moulds* | | *Internal moulds* | |
|---|---|---|---|---|
| | *Range* | *Mean* | *Range* | *Mean* |
| L in mm.[1] . | .. | .. | 9·8–56·9 | 31·4 (21) |
| H/L% . . | 39·4–61·4 | 50·1 (9) | 36·0–62·0 | 49·1 (18) |
| T/L% . . | .. | 16·1 (1) | 16·7–40·7 | 27·8 (10) |
| A/L% . . | 13·4–28·9 | 20·2 (5) | 11·2–31·4 | 24·1 (17) |

[1] See table of dimensions on p. 106.

*External and internal measurements.* A quantitative statement of the systematically important differences between internal and external measurements of specimens from the limestones appears as Table 3.

TABLE 3

| | *Differences of means in Tables 1 and 2* | | *Means of simultaneous differences*[1] | |
|---|---|---|---|---|
| | *Amroth* | *Broad Haven* | *Amroth* | *Broad Haven* |
| H/L% (E–I) | 6·2 | 1·0 | 4·9 (13) | 3·8 (5) |
| A/L% (I–E) . | 8·0 | 3·9 | 7·8 (10) | 7·5 (2) |

[1] 'Simultaneous difference' is that obtained from a specimen which allows the measuring of both internal and external characters: effectively a direct measurement of peri-umbonal relative thickness of shell matter in H and L directions. Figures in brackets refer to the number of such specimens measured. H/L per cent. (E–I) values give excess of external over internal ratios; A/L per cent. (I–E) conversely.

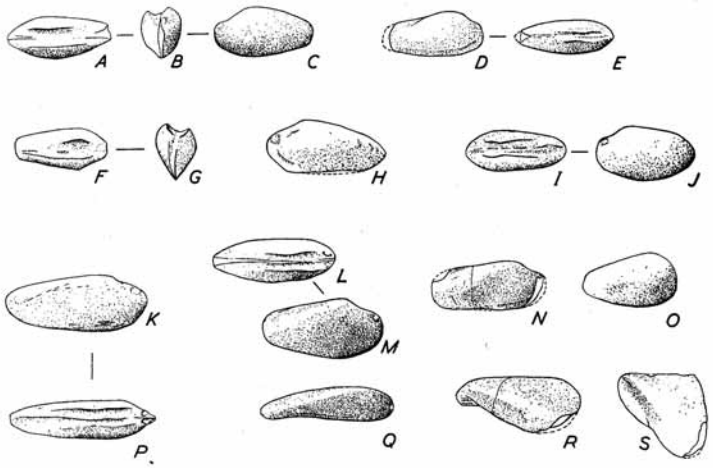
The frequent shells with high H/L ratio having damaged umbones in the Broad Haven limestone cannot be externally measured with any precision and the mean value for external relative height in Table 2 is thus almost certainly too low. Consequently the value of 1 per cent. in Table 3 is probably also much too low and the corresponding means of simultaneous differences may well be nearer the true average for the assemblage. The four comparisons of peri-umbonal shell-thickness shown in Table 3 indicate that the Amroth specimens have relatively stouter shells.

(*c*) *Shells from about 47 feet below the non-marine limestone near the Sleekstone, Broad Haven* (fig. 4M–P). Small shells occur as impressions in dark-grey shale and sandy shale at this horizon. *Anthraconauta* and *Carbonicola* are moderately abundant and there is one specimen of *Anthraconaia* among a total of twenty-five shells.

*Carbonicola* (fig. 4M–O) exhibits wide variation but the specimens are invariably small or very small, eleven measurable specimens giving the following dimensions:

| *L in mm.* | | *H/L%* | | *A/L%* | |
|---|---|---|---|---|---|
| *Mean* | *Range* | *Mean* | *Range* | *Mean* | *Range* |
| 14·9 | 9·4–19·5 | 52·7 | 41·9–70·4 | 27 | 20–30·4 |

Elongate, obliquely truncate forms (e.g. fig. 4N) and higher almost orbicular forms (e.g. fig. 4O) occur. There are no closely comparable named species of *Carbonicola* of this diminutive size. It should be noted, however, that the Amroth limestone fauna shows certain resemblances, e.g. in the presence of small high shells and the frequency of oblique posterior truncation. Also, individual specimens can be matched fairly closely: compare I with N, and O with D in fig. 4.




TEXT-FIG. 7. Shells from 116 feet below the Lower (Coal) Vein of Little Haven. Communis Zone, ×1. Author's Coll.; A, B, C, H51/40; D, E, H51/15; F, G, H51/17; H, H51/33; I, J, H51/27; K, P, H51/13; L, M, H51/8; N, H51/41; O, H51/6; Q, H51/1; R, H51/43; S, H51/44.

Badly preserved *Anthraconauta* of the *subovata* group generally lie on bedding planes different from those on which *Carbonicola* are found. *A. subovata*, *A. trapeziforma*, and a form similar to that figured by Dewar (1939, pl. 4, fig. 2A) occur.

The specimen referred to *Anthraconaia* (fig. 4P) appears to be of a new species which Mr. D. G. Jones has also found at about 10 feet below the Cnapiog (or Garw) Coal of Glynneath, Glamorgan. Eagar (1956, fig. 9*k*) has figured a shell from about the same horizon which may well be of the same group.

(*d*) *Shells from 116 feet below the Lower* (*Coal*) *Vein of Little Haven* (fig. 7). The specimens, ironstone internal moulds, are enclosed in grey shale which carries much other ironstone. *Carbonicola* is strongly represented by an assemblage of small shells (fig. 7A–Q), mainly elongate and invariably posteriorly tapered, which includes *C. declivis* s.s. (fig. 7K–P, N) in association with *C.* aff. *declivis* (fig. 7D–E, H) and a number of relatively high (H/L> 55%) forms (e.g. fig. 7J, *C. martini* juv.?). Umbonal moulds are mainly of a single kind—diminutive, gaping *C. communis*-type (fig. 7B, G). The assemblage is probably homogeneous and the specimen figured at 7Q may be an aberrant variant.

Trueman and Ware (1932) recorded somewhat similar material from the alleged Millstone Grit of Clyne Common, Gower. Dimensions of the present collection are:

| | *L in mm.* | *H/L%* | *T/L%* | *A/L%* |
|---|---|---|---|---|
| Range | 12·3–23·2 | 34·1–56·7 | 25·9–47·3 | 18–41 |
| Mean | 16·8 | 46·3 | 33·9 | 28·9 |
| Number of shells measured | 15 | 15 | 14 | 15 |

*Naiadites* (fig. 7R, S) are variable in outline and are provisionally referred to *N.* cf. *flexuosus*.

## MODIOLARIS ZONE

(*a*) *The basal band* (fig. 8A–K). Shells are found abundantly in the roof shales of the Garland Vein at Lloyd's Patch, near Wiseman's Bridge, and identical specimens are found about 18 feet below the base of the thick sandstone near Hean Castle, east Pembrokeshire; very similar shells occur near the south wall of The Settlings (near Little Haven) in St. Bride's Bay. The specimens are preserved as partially crushed impressions in dark, fissile shale. *Carbonicola* predominates and is associated with *Anthraconaia* cf. *williamsoni* and *Naiadites spp. Carbonicola* cf. *pyramidata* and *C.* cf. *rhomboidalis* occur but most of the *Carbonicola* are small (L<20 mm.): in characters other than size, however, many resemble *C. oslancis* s.l.

Dimensions of *Carbonicola:*

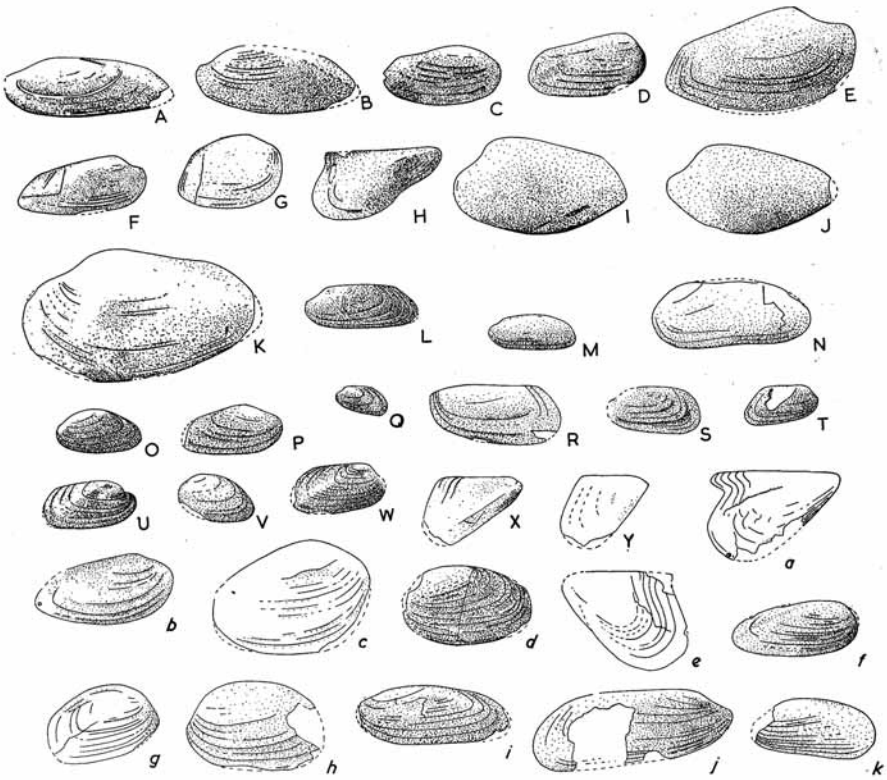
| | | *Number of shells* | *Mean* | *Maximum* | *Minimum* |
|---|---|---|---|---|---|
| Lloyd's Patch, near Wiseman's Bridge, east Pembs. | L in mm. | 59 | 16·1 | 30·2 | 7·1 |
| | H/L% | 49 | 49·3 | 73·0 | 30·8 |
| | A/L% | 48 | 24·1 | 34·8 | 8·5 |
| The Settlings, Little Haven, west Pembs. | L in mm. | 10 | 14·3 | 20·0 | 10·4 |
| | H/L% | 9 | 44·8 | 51·1 | 35·7 |
| | A/L% | 7 | 20·2 | 26·4 | 16·7 |

Most of the small forms of *Carbonicola* are of moderate relative height. Evenly convex ventral margins, high rounded anterior lobes, inconspicuous umbones, and obliquely truncate posterior ends are common features. A small proportion of the shells are referable to *C. oslancis* s.s. (fig. 8E) and most of the others are comparable with this form. More elongate shells (fig. 8A, B, F) are numerous. *C. similis* (fig. 8G) and *C. embletoni* are rare. *C.* aff. *venusta* occurs *inter alia* in uncrushed internal ironstone moulds (fig. 8I, J, K) from shale closely associated with that yielding the *C. oslancis* fauna at Lloyd's Patch.

*Anthraconaia* cf. *williamsoni* is represented by two imcomplete specimens. *Naiadites* occurs fairly frequently and *N.* cf. *modiolaris* (fig. 8H), *N.* cf. *productus*, and *N.* cf. *flexuosus* are present.

In the main basin of the South Wales coalfield the fauna most closely resembling this *C. oslancis* fauna is that from the roof of the Stinking Vein of the Gwendraeth Valley (Dix 1928, pp. 460–2). There seems little doubt that the fauna here recorded is a stunted

equivalent of that described by W. B. Wright (1931) from the roof of the Trencherbone in Lancashire.




TEXT-FIG. 8. Shells from the Modiolaris Zone, ×1. A–K, the basal band, roof shales of the Garland Vein at Lloyd's Patch, near Wiseman's Bridge. Author's Coll.; A, M9/20a; B, M20/2; C, M20/5; D, M20/6; E, M20/15; F, M20/37a; G, M20/39; H, M20/1a; I, M7/27; J, M7/31; K, M7/13. L–Y, the mussel-band immediately overlying the Amman Marine Band at Lloyd's Patch, near Wiseman's Bridge. L, M12/35; M, M21/11; N, M12/28; O, M21/21c; P, M12/32; Q, M21/13; R, M21/21d; S, M12/16; T, M21/21b; U, M12/24; V, M21/10; W, M21/6; X, M12/18; Y, M21/17. *a–k*, from 42 feet above the Amman Marine Band, Falling Cliff, near Little Haven. *a*, H25/42b; *b*, H25/1a; *c*, H25/24f; *d*, H25/42a; *e*, H25/1e; *f*, H25/35; *g*, H25/33b; *h*, H25/44f; *i*, H25/8; *j*, H25/23a; *k*, H25/33a.

(*b*) *The mussel-band immediately overlying the Amman Marine Band* (fig. 8L–Y). Dark-grey fissile shale directly overlying the Amman Marine Band yields non-marine lamellibranchs abundantly at Lloyd's Patch, near Wiseman's Bridge in east Pembrokeshire, but the equivalent stratum near Little Haven, on St. Bride's Bay, is only very sparsely fossiliferous. At the former locality the mussel-band is 21 inches thick and yielded over

a hundred impressions. *Anthracosia* predominates and is accompanied by *Naiadites spp.* and *Belinurus sp.* Of the shells referred here to *Anthracosia* about 90 per cent. are posteriorly expanded and all are of small size. No hinge characters are preserved and the generic assignment is based on the observed grading of anthraconaiiform shells with undoubted specimens of *Anthracosia.*

*Anthracosia* cf. *aquilinoides* (fig. 8M, N), *A.* aff. *ovum* (fig. 8O), and *A.* sp. nov. cf. *aquilinoides* (fig. 8L) are frequently represented. The assemblage gives the following values:

| | *L in mm.* | *H/L%* | *A/L%* | *V/H%* |
|---|---|---|---|---|
| Upper limit . . . | 24·5 | 65·4 | 32 | 97·0 |
| Lower limit . . | 5·5 | 40·1 | 15 | 63·2 |
| Mean . . . . | 14·0 | 50·1 | 22·4 | 82·0 |
| Number of observations | 70 | 64 | 50 | 45 |

V of the right-hand column is the measurement of subumbonal depth (v of Leitch 1940).

Most of the shells are oblique and some are closely comparable with the indicated species except in size. A frequent character is a flatly curved ventral margin and in some specimens this is straight or even slightly recurved (fig. 8N). Many shells exhibit greater posterior expansion than is seen in the type of *A. aquilinoides* and this expansion is occasionally accompanied by an accentuation of the posterior superior angulation, to give an anthraconaioid outline (compare fig. 8N, M, L). Such forms appear to intergrade with the rest of the assemblage and are referred to *Anthracosia* sp. nov. cf. *aquilinoides*, following Trueman and Weir (1951, p. 129). The minority of shells lacking posterior expansion include forms referable to *A.* cf. *retrotracta* and *A.* cf. *concinna.*

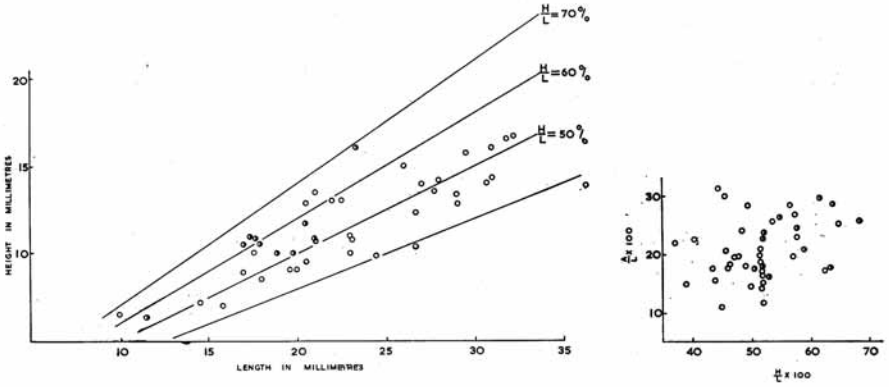
This occurrence of a fauna dominated by small, posteriorly expanded non-marine lamellibranchs (belonging, presumably, to a genus which normally shows no such expansion) in a band which directly overlies a marine stratum recalls the similar phases bearing anthraconaioid faunas in the Lenisulcata Zone and lower. The resemblance doubtless stems from adaptation to similar environments.

*Naiadites* is characterized by an absence of a distinct 'wing' and forms referable to *N.* cf. *triangularis* (fig. 8Y) and *N.* cf. *modiolaris* occur.

(*c*) *The mussel-band 42 feet above the Amman Marine Band at Falling Cliff near Little Haven* (figs. 8*a–k*, 9A, B). This locality and horizon yielded about eighty specimens, more or less completely crushed in dark fissile shale overlying a thin coal. *Anthracosia* is the dominant genus; *Naiadites* and probably *Anthracosphaerium* also occur; the imperfect preservation sometimes makes it difficult to assign with confidence certain specimens to either *Anthracosphaerium* or to the species of *Anthracosia* having relatively great height. The following table of dimensions, therefore, refers to the entire Anthracosiidae assemblage; the scatter diagrams (fig. 9A, B) illustrate the proportion of generically doubtful shells present and an apparent clustering of such shells is seen from fig. 9A.

| *L in mm.* | | *H/L%* | | *A/L%* | |
|---|---|---|---|---|---|
| *Range* | *Mean* | *Range* | *Mean* | *Range* | *Mean* |
| 10·0–36·3 | 23·0 (45) | 37·2–68·5 | 51·9 (45) | 11–32 | 21·0 (43) |

*Anthracosia* exhibits a wide range of variation between representatives of the following species, which are in order of abundance: *A. aquilina*, *A.* aff. *ovum* (fig. 8*d*), *A.* aff. *retrotracta*, *A.* aff. *regularis* (fig. 8*c*), *A. lateralis* (fig. 8*f*), *A.* cf. *phrygiana*, *A.* cf. *planitumida*, *A.* cf. *aquilinoides* (fig. 8*j*), and *A.* cf. *duponti*. Some of the anthracosiids may be cf. *Anthracosphaerium turgidum*, cf. *A. affine*, and cf. *A. bellum*. *Naiadites quadratus*, *N.* cf. *modiolaris*, *N.* cf. *carinatus*, and *N.* cf. *triangularis* (fig. 8*a*, *e*) also occur, but no *Anthraconaia* was seen at this horizon. This assemblage is characterized by the wide variation in the dominant genus *Anthracosia*.




TEXT-FIG. 9. A, Height plotted against length of Anthracosiidae shells from a band 42 feet above the Amman Marine Band, Falling Cliff, near Little Haven. B, relative length of anterior end plotted against relative height. Loc. hor. and symbols as A. The symbol ○ denotes an *Anthracosia* shell; ◑ denotes a specimen which could, on form, be assigned to either *Anthracosphaerium* or *Anthracosia*.

Other mussel-bands in Pembrokeshire near or slightly above the one just described also show wide variation among the many species of *Anthracosia*. *Anthraconaia* is always rare, if present at all, and no homogeneous assemblages of *Anthracosphaerium* are known in Pembrokeshire. *Leaia* occurs at one horizon.

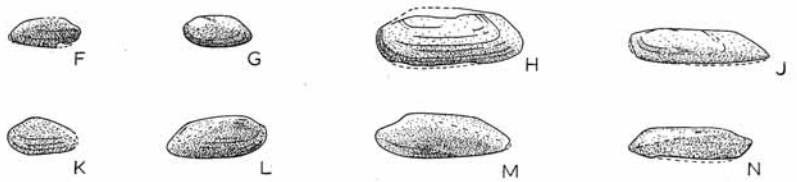
## SIMILIS–PULCHRA ZONES

The Upper and Lower Similis–Pulchra Zones are sparsely represented in the collection and only one assemblage merits description.

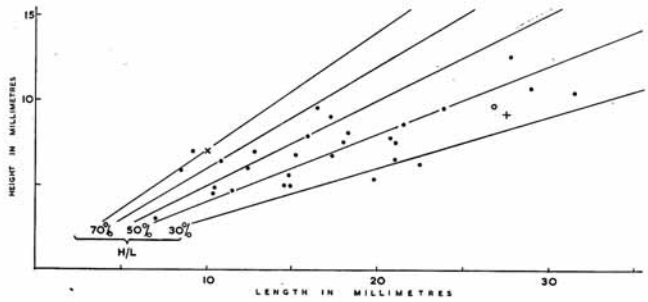
(*a*) *Band outcropping near Landshipping Quay* (figs. 10, 11). Shell impressions occur in highly disturbed dark shale repeated at 173 and 200 yards south of Landshipping Quay on the eastern bank of the Deugleddyf estuary. *Planolites* occurs nearby in similar sediment but its exact relation to the mussel-band could not be ascertained. The lamellibranchs lie along the bedding-planes and are crushed, usually laterally but some dorsoventrally. *Anthraconaia* is the dominant genus. Badly preserved *Anthraconauta* of the *subovata* group also appears to be present.

Elongate *Anthraconaia* (fig. 10H, J, M, N) referable to *A.* cf. *pruvosti* (Weir and Leitch

*non* Chernyshev) are associated with forms of moderate height (fig. 10F, G, L) including *A.* cf. *pulchella* and rather rare small sub-quadrate shells, not illustrated, comparable with *A. glotae*.




TEXT-FIG. 10. Shells from near Landshipping Quay, × 1. Upper? Similis-Pulchra Zone, bed outcropping 173 and 200 yards south of Landshipping Quay. Author's Coll., F, C5/28b; G, C5/19b; H, C5/20; J, C5/19a; K, C5/31a; L, C5/31b; M, C5/30; N, C5/32.




TEXT-FIG. 11. Height plotted against length of *Anthraconaia* shells from near Landshipping Quay. Upper? Similis-Pulchra Zone; 173 and 200 yards south of Landshipping Quay. Symbols show the positions which would be occupied by the holotype of *Anthraconaia glotae* (Weir and Leitch) — ×; by the type of *Anthraconaia pruvosti* (Chernyshev), —o, dimensions of the left valve from Pruvost 1919, pl. 26, fig. 1; and by a specimen illustrated by Weir and Leitch 1936, fig. 15a, —+.

Dimensions of *Anthraconaia* yield the following values:

| *L in mm.* | | *H/L%* | | *A/L%* | |
|---|---|---|---|---|---|
| *Range* | *Mean* | *Range* | *Mean* | *Range* | *Mean* |
| 7·0–31·5 | 16·9 (34) | 26·8–76·1 | 44·6 (29) | 15–42 | 28·0 (26) |

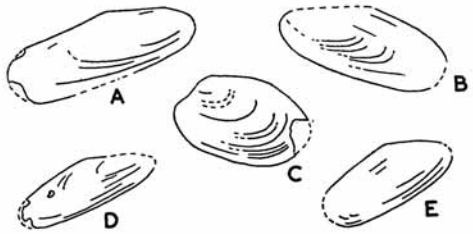
Posterior expansion occurs in only about 17 per cent. of these *Anthraconaia*, subparallelism of upper and lower margins being common, especially in the longer specimens. The upper posterior angulation is usually wide (about 140°) and in some shells is replaced by a rounded margin. In many specimens an almost flat area lies dorsal to a low ridge extending postero-ventrally from the umbones. Slight lateral constriction often affects the mid-ventral area but it is possible that this feature is related to the crushing of carinate shells.

The scatter diagram (fig. 11) suggests a marked negative correlation between size (as measured by length) and the H/L ratio.

This association of an extremely elongate species with a sub-quadrate *Anthraconaia* recalls the *A. glotae–A.* cf. *pruvosti* fauna described by Weir and Leitch (1936) from Bothwell, Scotland.

## PHILLIPSII AND TENUIS ZONES

(*a*) *Between Druidston and Nolton Haven* (figs. 12 and 13). The lowest and topmost of four fossil bands in this section exhibit interesting differences of composition. The lowest band (I) is exposed only in the core of the anticline at North Haven, 6 feet above beach




TEXT-FIG. 12. Shells from between Druidston and Nolton Haven, ×1. Tenuis Zone, band IV, uppermost of four horizons with lamellibranchs, in cliffs between Druidston and Nolton Haven. Author's Coll., A, H45/3b; B, H45/18b; C, H45/18a; D, H45/2a; E, H45/4d.

level, but the topmost band (IV), some 300 feet higher in the sequence, is accessible at four points, being repeated by strong folding. The second and third bands lie within 30 feet of the lowest and yielded only indifferent material referable mainly to *Anthraconauta* aff. *phillipsii* and rarely to *A.* cf. *tenuis*.

The lowest band provided over a hundred impressions in grey shale. Forms referable to *A. phillipsii* predominate, while *A.* cf. *tenuis* is rare and *A. tenuis* s.s. is absent. One specimen of *Anthraconaia* cf. *pringlei*, several insect wings and many specimens of *Euestheria* cf. *dawsoni* (Jones) were found.

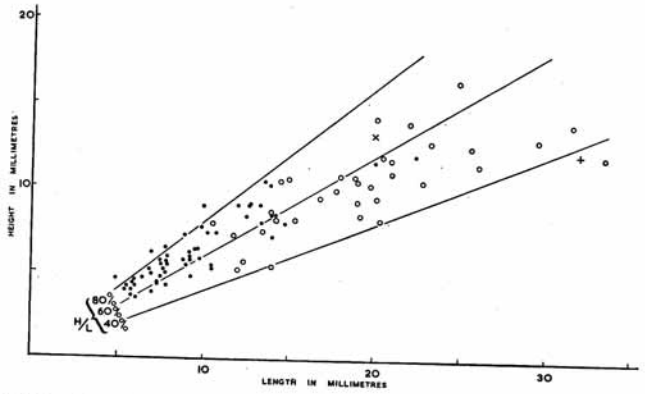
In band IV *Anthraconauta*, *Euestheria*, and *Spirorbis sp.* are found crushed in tough dark shale overlying a thin unnamed coal. *A. tenuis* (fig. 12A, B, D, E) is typically represented and as frequently as *A. phillipsii*. A more ovate form referable to *A.* aff. *phillipsii* also occurs (fig. 12C); similar variants have previously been found high in the Tenuis Zone in Glamorgan (Dix and Trueman 1931, p. 191) and near its base in Monmouthshire (Sullivan and Moore 1956).

The dimensions of the *Anthraconauta* shells yield the following values:

| Band | *L in mm.* | | *H/L%* | | | |
|---|---|---|---|---|---|---|
| | *Range* | *Mean* | *Range* | *Mean* | *Range* | *Mean* |
| I . . . | 4·9–22·4 | 9·3 (61) | 50·4–96·0 | 67·5 (58) | 123°–165° | 142° (82) |
| IV . . | 9·8–33·5 | 19·1 (37) | 40·5–76·4 | 54·2 (34) | 140°–170° | 153° (46) |

The specimens having rounded posterior angles are not suitable for measurement of angle $\beta$.

The scatter diagram (fig. 13) illustrates the differences in dimensions exhibited by these faunas and shows that within the region of size overlap ($10<L<23$ mm.) the dimensional characters of the assemblages are discernibly different. This suggests that the differences of proportions are not entirely due to the evident contrast in size distributions. The faunal change is taken to mark the boundary between the Phillipsii and Tenuis Zones.



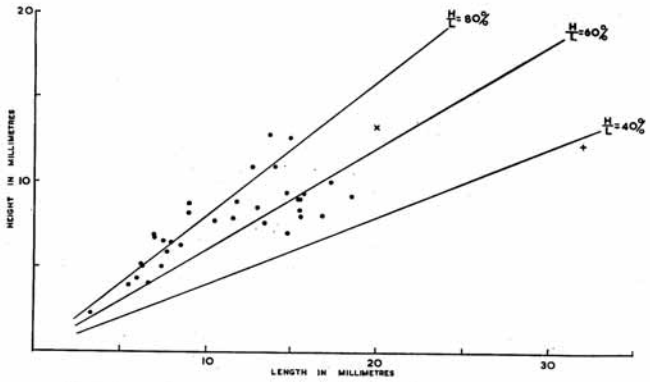

TEXT-FIG. 13. Height plotted against length of *Anthraconauta* shells from the lowest and highest bands between Druidston and Nolton Haven, Phillipsii and Tenuis Zones. Dots represent specimens from the lowest band (I), circles those of the uppermost band (IV). The positions which would be occupied by the holotypes of *Anthraconauta phillipsii* and *A. tenuis* are shown by the symbols × and + respectively.

(*b*) Anthraconauta *from Rickets Head* (fig. 14). Trueman (1934) recorded *Anthraconauta tenuis*, *A. phillipsii*, and some small forms which resemble *A. calcifera* from shales at Rickets Head. Overlying a seat-earth 93 feet below the base of the Rickets Head sandstone is a dark much sheared shale which contains crushed *Anthraconauta*, *Spirorbis*, insect wings, and plant fragments. The lamellibranchs are mainly small *A. phillipsii* and *A.* aff. *phillipsii*; about 15 per cent. are referable to *A.* cf. *tenuis* but only one specimen is *A. tenuis* s.s. (this specimen is incomplete: it is omitted from the table of dimensions and is not shown in fig. 14). The dimensions of the *Anthraconauta* give the following values:

| *L in mm.* | | *H/L%* | | *β* | |
|---|---|---|---|---|---|
| *Range* | *Mean* | *Range* | *Mean* | *Range* | *Mean* |
| 3·3–18·5 | 10·8 (33) | 47·7–99·0 | 70·9 (33) | 125°–170° | 144° (47) |

It will be noted that the mean H/L value exceeds that of the relatively high *A. phillipsii* and the scatter-diagram (fig. 14) shows that the dimensions of *A. tenuis* are not attained. This assemblage cannot be held to indicate the Tenuis Zone and it is preferably assigned to the Phillipsii Zone.

(*c*) Anthraconaia *from Rickets Head* (figs. 15, 16). The upper of two shell bands in the shales associated with the Rickets Head Veins lies 12 feet below the Rickets Head sandstone. The lamellibranchs are preserved as 'solid' ironstone moulds in dark shale. *Anthraconauta phillipsii* occurs rarely with the *Anthraconaia* shells. Some specimens show both




TEXT-FIG. 14. Height plotted against length of *Anthraconauta* from Rickets Head. Phillipsii Zone, 93 feet below the sandstone at Rickets Head, Pembs. The positions which would be occupied by the holotypes of *Anthraconauta phillipsii* and *A. tenuis* are shown by the symbols × and + respectively.

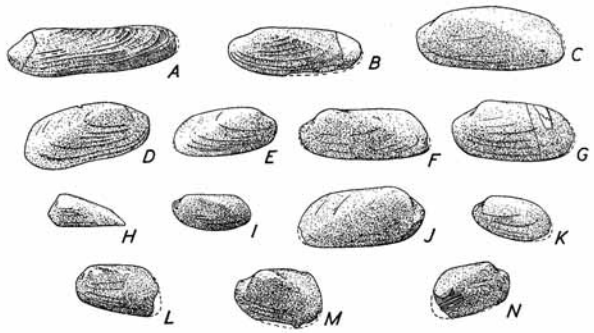
growth-lines and muscle-scars; consequently in the following table of *Anthraconaia* dimensions no distinction is made between internal and external measurements.

| | *L in mm.* | *H/L%* | *T/L%* | *A/L%* |
|---|---|---|---|---|
| Upper limit . . | 25·0 | 72·0 | 51·9 | 29·2 |
| Lower limit . . | 8·7 | 39·0 | 27·4 | 16·4 |
| Mean . . . . | 16·3 | 53·8 | 36·8 | 23·2 |
| Number of observations | 45 | 43 | 39 | 41 |

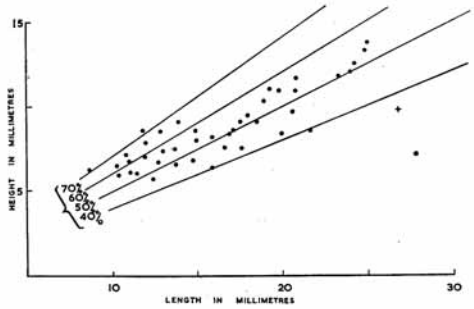
The *Anthraconaia* shells are small and 98 per cent. are posteriorly expanded with respect to both umbonal height and thickness; hinge-lines are long and straight to moderately arched (fig. 15C, D), and a carina of varying definition runs postero-ventrally from inconspicuous umbones.

In other characters the assemblage is extremely variable. The original of fig. 15A is a very long shell, probably slightly crushed dorso-ventrally; its dimensions are omitted from the table. Shells such as those illustrated in fig. 15E, F, J can be regarded as normal representatives and are referable to *Anthraconaia* sp. nov. cf. *pruvosti ?* (Chernyshev); the high shells ($H/L \geqslant 60$) are also unlike any named species (fig. 15L, M, N). Sinuation of the ventral margin (fig. 15D) is uncommon; one of the two specimens found lacking posterior expansion is illustrated (fig. 15H). The assemblage exhibits a tendency to diminished H/L values with increasing length (fig. 16). The only closely comparable shells which the writer has seen are derived from the roof of the Gwscwm Vein

(Phillipsii Zone) of Burry Port, Carmarthenshire, and were thought by Dix and Trueman (1931) to be probably related to *A. pringlei*.




TEXT-FIG. 15. *Anthraconaia* from Rickets Head, ×1. Phillipsii Zone, 12 feet below the sandstone at Rickets Head. Author's Coll., A, H34/19; B, H34/32; C, H34/2; D, H34/12; E, H34/3; F, H34/10; G, H34/104; H, H34/6; I, H34/8; J, H34/47; K, H34/34; J, H34/61; M, H34/69; N, H34/48.




TEXT-FIG. 16. Height against length of *Anthraconaia* from Rickets Head, Phillipsii Zone, 12 feet below the sandstone at Rickets Head, Pembs. The symbol + indicates the position which would be occupied by the type of *A. pruvosti* (Chernyshev), dimensions of the valve from Pruvost 1919, pl. 26, fig. 1; the specimen represented by the open circle is incomplete and may be distorted.

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