

NEW NON-MARINE BANDS AND *CARBONICOLA* BURROWS IN LOWER WESTPHALIAN A MEASURES OF THE BRITISH PENNINES

R.M.C. EAGAR

SUMMARY: At Elland, Yorkshire, midway between Huddersfield and Halifax, a fine quarry section shows newly recorded bands of *Carbonicola* and *Curvirimula* near the top of the Zone of *Carbonicola lenisulcata*. In the Burrs district of Bury, 11 km north-north-west of the centre of Manchester, material collected in 1860 by the Geological Survey of Great Britain has led to the discovery of three 'lost' horizons of non-marine bivalves within the basal part of the Zone of *Carbonicola communis*. A fourth horizon, of *Carbonicola* and burrows, has been discovered above these, and burrows have been found on a fifth horizon, in the Raistrick area, near Huddersfield, about 30 feet below the Better Bed. Similar burrows, all referred to *Pelecypodichnus* SEILACHER, are also directly or indirectly associated with several other of the newly found bands of *Carbonicola* in both the Bury and Huddersfield areas, and form part of the evidence for classifying these non-marine bivalve faunas as 'invading' and 'established'. Aspects of the palaeoecology and stratigraphy of these horizons are discussed briefly. Invasion of the Pennine delta took place in late Namurian time when marine bivalves pushed upward, with their long axes vertical, to escape sediment from advancing delta lobes.

I. Introduction

The association of elongate *Carbonicola* of the *C. bellula* group with the trace fossil *Pelecypodichnus* SEILLACHER has recently been recorded by EAGAR (1971) from Pennine horizons ranging from the Haslingden Flags (upper Namurian C) to the Crutchman Sandstone, near the top of the *Carbonicola lenisulcata* Zone of lower Westphalian A. It has been suggested that faunas of elongate *Carbonicola*, including the species *C. bellula* (BOLTON), *C. lenisulcata* (TRUEMAN), *C. extima* EAGAR including varieties trending to *C. declinata* EAGAR, and finally the larger shelled group of *Carbonicola extenuata* EAGAR, were all steep-burrowing invaders of the Pennine prodeltaic area; furthermore that the invaders which moved up vertically to survive, gave rise to the prolific better known faunas of oval highly variable *Carbonicola* characteristic of the more carbonaceous bands of the same measures. The latter have been called

'established' faunas. Further evidence bearing on this theme from bands of *Carbonicola* on other horizons, and data from observations on some comparable Recent faunas, are recorded elsewhere (EAGAR 1973, 1974). The following notes deal with some stratigraphical details of newly recorded sections which have yielded 'invading', 'established', and a few intermediate and mixed faunas.

For assistance in the field in the Burrs district of Bury I am grateful to Mr William PEACOCK. I have received some help in this area from Mr. Peter A. DICKSON, Research Assistant under a grant from the Natural Environment Research Council, to whom I am also grateful for help in defraying some of the cost of the field work.

II. Elland district Yorkshire (Fig. 1).

(a) Measures beneath the Norton (Tonge's) Marine Band:

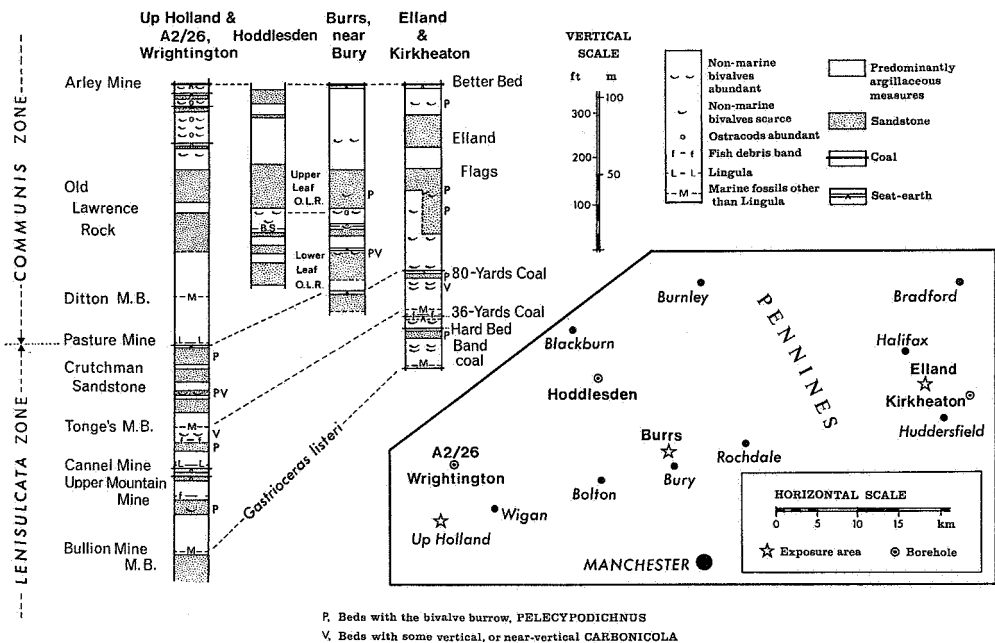


Fig. 1. Generalised sections of parts of the Lower Coal Measures (lower Westphalian A) and their location in the British mid-Pennine region. Localities west of the Pennine arch lie in east Lancashire, those east of it in west Yorkshire.

Sections and certain palaeontological detail after EAGAR (1974), the succession from the Pasture to the Arley Mine being taken from the record of Borehole A2/26, after MAGRAW (1957). The Hoddlesden borehole section was drawn from records of the Institute of Geological Sciences, the cores being examined and the fauna collected by Mr R.H. PRICE; but the sparse shells found immediately above 'B.S.', a brecciated surface comparing with the seat-earth in the Burrs section, were not collected. In the Elland section the succession between the 80-Yards Coal and the Better Bed is drawn after WRAY & TRUEMAN (1934), but the Lower Leaf of the Elland Flags, as developed at Elland Upper Edge (see p. 207), is also shown in the right half of the section.

At Storth (Sharratt's) Brickworks Quarry (abandoned), Elland (SE 118 203), just over 27 m of measures are exposed and accessible from immediately above the Hard Bed Band Coal to near the top of the Eighty Yards Rock (EAGAR 1956, fig. 2, Huddersfield district). In this quarry the Norton (Tonge's) Marine Band lies 3.65 m above the Thirty-six Yards Coal (5-6 cm thick). The dark intervening shales and shaly mudstones are unfossiliferous except to 10 cm above the Coal, where palaeoniscid fish scales and debris suggestive of fish coprolites may be found abundantly on certain bedding planes. Ostracods are also fairly common locally within these measures, but are badly preserved.

From 0.55 to 2.16 m below the Coal recent collecting has shown that *Carbonicola* occurs in some profusion, with occasional *Curvirimula* cf. *belgica* (HIND), in grey silty mudstones which also yield rootlets throughout. *Carbonicola proxima* EAGAR includes associated variants showing every gradation to *C. extenuata* EAGAR, but the fauna has a modal length of little over 30 mm and no shell reaches the size of these morphotypes. A few specimens appear referable to the group of *Carbonicola crispa* EAGAR, but they are not clearly separable from the remainder of the fauna which includes *C. cf. pontifex* EAGAR grading to *C. aff. declinata* EAGAR, *C. cf. fallax* WRIGHT and *C. aff.*

artifex EAGAR, the more elongate varieties being common only towards the base of the band. Conjoined, closed valves predominate and lie approximately parallel to bedding planes in leaves a few millimetres to about 4 cm apart. No unquestionable shell burrows were seen. This band of shells therefore, whilst showing the lithological facies and several of the morphological trends characteristic of the slightly higher horizon of *Carbonicola proxima*, *C. pontifex* and *C. crispa* (see below, p. 208), differs from the latter both in its range of shell variation and also in the absence of any separable bio-species.

(b) Measures between the Norton (Tonge's) Marine Band and the Eighty Yards Coal.

At Storth Brickworks Quarry, Elland, small *Pelecypodichnus* with *Planolites* and *Cochlichnus kochi* (LUDWIG) (cf. EAGAR 1971, p. 75, Bed 8) lies on the under surface of the Eighty Yards Rock and large specimens of *Pelecypodichnus* are also common 22 — 25 cm above this horizon. The underlying non-marine shell band extends from 3.66 to 6.44 m below the base of the Rock, with the following section: —

BED THICKNESS IN METRES

- 13. Grey silty ochreous-weathering mudstone with a sparse fauna of *Carbonicola extenuata* (cf. EAGAR 1956, fig. 6 e, including more elongate varieties than this) and a small-shell fauna of *C. cf. fallax* WRIGHT (*ibid.*, fig. 6 g), grading towards but not reaching *C. extima*, and with occasional *C. aff. crispa* (EAGAR 1962, t-fig. 8B) 0.21
- 12. Leaf of very abundant *Curvirimula* spp., including *C. aff. belgica* (HIND), and shells trending towards *C. subovata* (DEWAR), in silty mudstones, very slightly darker than those of Bed 13 . . c. 0.03
- 11. Sediment and fauna as for Bed 13, but the small-shell fauna is more abundant, running in leaves, and includes more elongate varieties grading to *C. aff.*

- extima*, near the type, and *C. declinata*. Large shells of *Carbonicola* cf. *communis* TRUEMAN & WEIR are occasional on certain bedding planes and do not grade with shells of the *C. extenuata* group. Rare obscure *Naiadites* is present and uncommon *Spirorbis* 0.63
- 10. Leaf of abundant *Curvirimula* spp., as for Bed 12. but including *C. aff. tessellata* (JONES) c. 0.03
- 9. As for Bed 11, but shells are very sparse and include *Carbonicola aff. crispa* 0.26
- 8. Leaf of abundant *Curvirimula*, as for Bed 12 0.05
- 7. Grey silty mudstone with a rather sparse fauna in which large elongate *Carbonicola extenuata* (cf. EARP *et. al.* 1961, pl. x, fig. 11) is dominant, occurring mainly in iron-rich carbonate nodules as articulated closed valves, but including also smaller shells of this group, many of them originally broken. A small-shell group of *C. cf. fallax* (as for Bed 13) includes varieties comparing with *Carbonicola crispa* EAGAR but between 15 and 20 mm long . . 0.46
- 6. Leaf of abundant *Curvirimula* spp. with many fragmentary shells. Some varieties compare with the shell of PRICE *et al.* (1963, pl. IV, fig. 8) 0.03
- 5. Grey shaly mudstone with a very sparse fauna of elongate small shells including *C. cf. bellula*, *C. aff. declinata* and occasional small *C. cf. bipennis*. Broken fragments of larger shells are present 0.11
- 4. Leaf of abundant *Curvirimula* spp. as for Bed 6, with a sparse fauna of elongate *C. cf. extima* and *C. aff. bellula* lying immediately below it 0.12
- 3. Barren grey slightly silty mud-

stone	0.15
2. Leaf of abundant <i>Curvirimula</i> . Varieties lie between <i>C. belgica</i> and <i>C. tessellata</i> without including these species <i>sensu stricto</i> (cf. TRUEMAN & WEIR 1960, pl. XXXIII, fig. 49). The band immediately overlies a sparse small-shell fauna of <i>C. cf. extima</i> , as in Bed 4	c. 0.03
1. Mainly barren rather coarse-grained silty grey mudstone with ironstone lenticles 0.12 m from the base. Small elongate shells, <i>C. cf. fallax</i> , with well curved ventral margins, are confined to a leaf 0.20 m from the top. <i>Carbonicola</i> aff. <i>proxima</i> , including shells closely comparing with forms characteristic of the <i>C. communis</i> group, run in two thin courses, at the base of the Bed and in the top 0.08 m	0.56
Total	2.67

The alternations of *Curvirimula* with *Carbonicola* extend along the whole face of the quarry, some 300 m. Within the bands of *Carbonicola*, the dimensions of the smaller and larger shell groups, both mostly articulated, correspond with those of two main sizes of burrow in the overlying Eighty Yards Rock if a steep position of moving upwards was assumed. From available material it appears that amongst the larger shells those of the *C. extenuata* group do not show gradation with any of those apparently related to the *Carbonicola communis* group, which enter the succession of Westphalian A for the first time at this horizon. By comparison with members of the *Carbonicola communis* group found some 43 m higher, in the lower Leaf of the Elland Flagstones, these early members have large Height/Length ratios. Their general appearance resembles faunas of this group elsewhere found to belong to 'established' faunas, although it is stressed that most of these larger shells were originally broken before burial.

The succession therefore appears to be one mainly of invading faunas in which there is some admixture of derived material from an 'established' fauna. This interpretation receives some support from the small-shell faunas which are of the type often directly associated elsewhere with steep burrowing and which precede bands of the near-marine genus *Curvirimula* in Beds 2, 4, 5 and 11. However it should be noted that in the middle and upper parts of the band, especially in association with ferruginous carbonate, these small shells include a minority of variants with Height/Length ratios slightly in excess of 50 per cent and grade with *Carbonicola crispa*.

This 2.7-metre band is a representative of the Norton Mussel Band of the south-east Pennine coalfield. Closely comparable long shells of the *Carbonicola extenuata* group have been figured from about this horizon near Bradford, Yorkshire (EAGAR 1956, p. 351, fig. 7 a-f). The strikingly large, long shells of the *C. extenuata* group in Bed 7 also invite comparison with the fauna above the supposed Cemetery Mine, near the middle of the Crutchman Sandstone (Fig. 1) of the Cockden Bridge Borehole, near Burnley, Lancashire (EARP *et al.* 1961, p. 146). Nearer Elland — at Kirkheaton — shells below the 80-Yard Rock, and apparently related to *Carbonicola proxima*, have already been tentatively referred to the *C. communis* group (EAGAR 1956, p. 350; 1974, p. 227).

The *Carbonicola proxima-crispa-pontifex* band is an important marker horizon, having been recognised in borings in Derbyshire (EDEN 1954, EAGAR 1956), in Glynneath, South Wales (EAGAR 1962) and in south-eastern Ireland (EAGAR 1963).

The Elland section is therefore of particular interest in that it demonstrates the early appearance of *Carbonicola proxima* in continuous variation with *C. extenuata* below the Norton Marine Band and its later occurrence above the latter, as part of a biospecies which was distinct from that including *C. extenuata*, and which may have been closely linked with the earliest known faunas of the group of *C. communis*.

III. *Burrs district, Bury, Lancashire* (Fig. 1).

In October 1860 Richard Gibbs, of the Geological Survey of Great Britain, collected non-marine bivalves from the Burrs area of Bury, recording "Calcareous sandstone. Bottom Beds of the section", "Sandstone and ironstone. Middle Beds", and "Black shales, Top Beds". Although his collected material has survived, no further details of the provenance of these shell bands has been found in the Institute of Geological Sciences, nor are references to them known elsewhere.

Measures exposed on the banks of the River Irwell, between the Weir above Burrs (Fig. 2, top left centre) and the southern viaduct of the railway crossing, have recently revealed that these three horizons lie within and between sandstones mapped as the Old Lawrence Rock, divided into an Upper and Lower Leaf in this region. The measures of the following section lie near the base of the Zone of *Carbonicola communis*, between sandy measures mapped as the Upper and Lower Leaves of the Old Lawrence Rock. The following section is nearly all accessible.

BED NO. THICKNESS IN METRES

14.	Two-metre massive, buff, medium-grained sandstone with siltstone pellets at the base, lying with slight discordance on Bed 13 and succeeded by a variable development of sandstone and sandy measures	seen to 12.0 (NW)
13.	Mainly banded siltstones, flaggy siltstones and thin flags, with subordinate silty mudstones and with several ripple-marked horizons (which include flaser silt sandstone facies). A thin band of <i>Carbonicola bellula</i> (Bolton) lies above abundant <i>Pelecypodichnus</i> 5, 18m from the base, which is taken as the base of the Upper Leaf of the Old Lawrence Rock	6.80 (SE)

12.	Grey slightly silty mudstones	2.90 (SE)
11.	'Top Bed'	
D.	Grey slightly silty mudstones with ostracods including <i>Geisina arcuata</i> (BEAN) and with occasional fish debris	0.04
C.	Grey silty to shaly mudstones with courses of poorly preserved <i>Carbonicola</i> spp. (as for Bed B, below), ostracods, fish scales including <i>Rhabdoderma</i> , and occasional <i>Naiadites</i> sp.	0.41
B.	Dark grey shaly mudstones with carbonate bands up to 9 cm thick. Shells of <i>Carbonicola</i> are nearly all articulated and lie parallel to the bedding planes in prolific quantity within courses 2 to 5 cm apart. They include <i>C. torus</i> EAGAR, varying to <i>C. subconstricta</i> WRIGHT, <i>C. cf. bipennis</i> (BROWN), <i>C. cf. martini</i> TRUEMAN & WEIR, with less common <i>Naiadites</i> aff. <i>flexuosus</i> DIX & TRUEMAN, <i>Curvirimula</i> cf. <i>subovata</i> (DEWAR), rare <i>Anthraconaia</i> cf. <i>fugax</i> EAGAR, abundant <i>Geisina</i> and less common <i>Spirorbis</i> and fish scales	0.45
A.	Fairly dark grey shaly mudstone, grading in colour into Band B above, and with the same fauna as this Band, but sparsely represented and with smaller <i>Carbonicola</i> spp. The fauna is scarce or absent locally in the basal 0.37 m	0.76
Total		1.66
10.	Medium to dark grey shaly mudstones	3.70
9.	Pale grey rather soft mudstones with harder sandy mudstones at 0.6 to 1.2 m and 1.63 to 1.80 m from the top	2.00
8.	Pale grey mudstones with root-	

lets having a basal 0.65 m of silty ganistroid rock with irregular carbonate concretions, the whole constituting a typical seat-earth profile

1.85

7. Pale grey to blue-grey shaly and silty mudstones weathering greenish grey and containing carbonate nodular bands and

fairly common pteridosperms. A well marked carbonate band 1.5 m from the top probably lies near the 'Middle Bed', below which shaly siltstones and fine-grained sandstones with abundant stems of *Calamites* show gradation with Bed 6, up to

4.70

6. Massive medium-grained buff

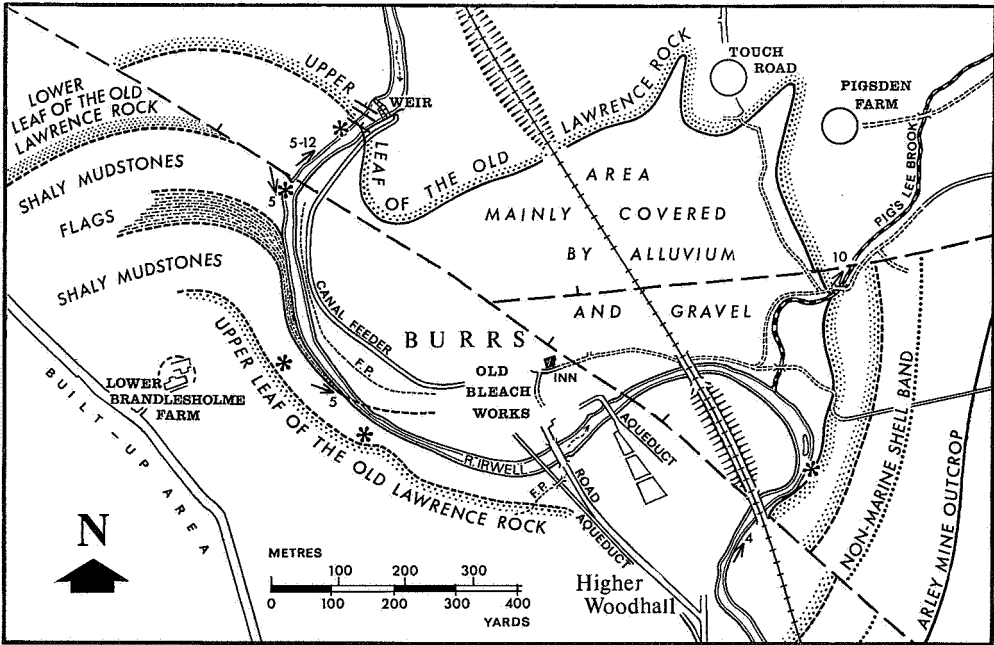


Fig. 2. Sketch-map of the Burrs area, 2 km north-west of Bury, Lancashire (Fig. 2). The solid geology is based on Six-Inch Geological Survey Sheets Lancs 88NW and 87NE, by permission of the Director, Institute of Geological Sciences. New fossil localities are shown by asterisks. The area is fairly heavily covered by Drift, including boulder clay, so that the outcrops shown by broken lines west of the banks of the River Irwell are conjectural. To the south-west of the latter area the base of the Upper Leaf of the Old Lawrence Rock has been extrapolated in accordance with the section given on p. 209, where it lies about 3.5 m above Gibbs 'Top Bed'. To the east of the Irwell it has proved more convenient to take the base in accordance with Geological Survey mapping, at the base of a 2-metre massive sandstone which lies locally about 9 m above the 'Top Bed' and thus within the Upper Leaf of the Rock as herein defined. The top of the Lower Leaf of the Old Lawrence Rock was formerly taken at the top of the 'Flags', with crop shown towards the north-western corner of the map, and has been lowered in accordance with the correlation of the Burrs section with part of the succession proved in the Hoddesden borehole (Fig. 1). In the south-east corner of the map the outcrop of a non-marine shell band 1.14 m thick and about 18 m below the Arley Mine rests on the succession proved in Fern Hill Borehole (1924), situated 411 m south of the point where the railway line crosses the southern limit of the map. It is highly probable that this shell band, which was not collected, is the local representative of the *Carbonicola torus* Band of mid-Lancashire.

sandstone, about 2 m thick.		sition	25.40 cm
overlying flagstones	3.60	Total	c. 0.60
	-4.70		
5. Pale grey silty mudstones with plant debris towards their base .	2.00	Flags with interlaminated ripple-marked mudstones constitute the top of the Lower Leaf of the Old Lawrence Rock and are seen to	0.20
4. Fine-grained silty sandstones and siltstones with laminae of ripple-marked mudstones in the lower 0.35 m	1.20	Total	c. 29.00
3. Soft grey mudstones grading down to darker shales which are poorly exposed in their basal 1 m. The sequence is interrupted by a 0.6 m band of hard ferruginous fine-grained sandstone immediately overlying 0.85 m of silty grey ripple-marked mudstones	4.30		
2. Poorly exposed light grey mudstones with rootlets seen in the top 0.3 m	2.10		
1. 'Bottom Bed'			
C. Light brown to buff calcareous siltstone with fairly abundant <i>Carbonicola</i> of the <i>C. bellula</i> and <i>C. extenuata</i> groups, with occasional small <i>Naiadites</i> and rare <i>Anthraconaia</i> . Shells are mostly disarticulated and about 10 per cent were broken before burial. <i>Pelecypodichnus</i> is occasional	6.25 cm		
B. Very hard siltstone carbonate with three courses of shells, mainly articulated and randomly orientated .	27.94 cm		
A. Light buff calcareous fine-grained flaggy sandstone with very abundant <i>Pelecypodichnus</i> throughout. Disarticulated and opened conjoined valves occur sparsely down to 18 cm from the top, lying parallel to bedding planes and mainly convex up. A few small shells of the <i>C. bellula</i> group lie in <i>Pelecypodichnus</i> structures, orientated in steep-burrowing po-			

Gibbs' 'Bottom Bed' proves to be a typical 'invading' fauna of elongate shells closely associated and occasionally within steep burrows and has been more fully described elsewhere (EAGAR 1974). The band has a high carbonate content throughout its extent and, as is typical on other horizons where 'invading' faunas have been found, it contains *Naiadites*, whereas *Curvirimula* is absent. The horizon may be represented in a 0.9 m band of "highly calcareous ironstone" met in the middle of the New Hey Mudstones, 85.3 m above the Upper Foot Mine in Thorpe Borehole, near Oldham, about 12 km to the east-south-east of Burrs (TONKS *et al.* 1931, fig. 23, p.71).

Since Gibbs' Middle Bed yielded several *Calamites* with preservation and matrix identical with those found in parts of Bed 7 of the Burrs succession, it is likely that his single slab (I.G.S. Coll. B. 1388) came from a 'pocket' in this Bed now no longer exposed. Out of six more or less complete shells associated with rootlets and *Calamites*, five are comparable with *Carbonicola crispa*, and all have relatively large Height/Length ratio. This association of shells and rootlets invites comparison with that of the fauna, which includes *C. crispa* (s.1), below the seatearth of the Thirty-six Yards Coal at Elland (p. 206).

Gibbs' 'Tob Bed' is a typical established fauna. It compares closely with the well known fauna of *Carbonicola torus* EAGAR and *C. subconstricta* WRIGHT (*C. aff. bipennis* TRUEMAN & WEIR, 1947, pl. XI, fig. 10) characterising measures about 20 m below the Arley Mine, of the lower part of the *communis* Zone in the Lancashire coalfield. However it differs from this fauna, as devel-

oped in the western Lancashire area, in lacking the trend towards *C. pseudorobusta* TRUEMAN (EAGAR 1956, fig. 9 e); nor does it include shells trending towards the outlines of *Anthracosphaerium* and *Anthracosia* (*ibid.*, p. 360). The 'Top Bed' is identical however with the band of shells found 72 m below a thin coal underlying the Arley Mine in the Huddlesden Borehole, situated 13 km north-west of Burrs (EAGAR 1954, p. 17; 1956, p. 354; MAGRAW 1957, p. 20). This latter bed lies immediately beneath a thick sandstone at Huddlesden, just as at Burrs. Moreover the seat-earth at Burrs (Bed 8) is apparently represented at Huddlesden by a brecciated surface about 90 m below the thin coal. A few shells were noted immediately above this horizon but were not collected by the Geological Survey.

The Upper Leaf of the Old Lawrence Rock is well exposed in several quarries at Tottington, 3 km west of Burrs, where search has failed to reveal any bivalve burrows; nor have such burrows been found in Bed 14, where it is accessible in the region of the Weir (Fig. 2, north, centre). However at the fossil locality shown 100 m north-east of the southern viaduct crossing the Irwell (*ibid.*, south-eastern corner) a block fallen from the upper part of Bed 13 yielded a pair of open valves of small *Carbonicola bellula* (Bolton), associated with *Planolites* and lying about 10 mm above a 15 mm band of small *Pelecypodichnus* (EAGAR 1974, p. 230). It was then noted that shell and burrows fit well if burrowing was near the vertical. Investigation of Bed 13, subsequently carried out by Mr P. A. DICKSON, using climbing tackle, has revealed the precise horizon of the band, recorded in the section above. Mr. DICKSON has also found rare *Carbonicola* of the *C. bellula* group immediately overlying occasional and questionable *Pelecypodichnus* locally 0.13 m above the base of Bed 13, and *Arenicolites* in thin sandstones and siltstones 3.5 m above its base. Facies and fauna of Bed 13 are thus similar to those of certain phases in the Elland Flagstones of Yorkshire (*ibid.*, p. 231). It should also be noted that there are two new main phases with *Carboni-*

cola bellula and *Pelecypodichnus* (Fig. 1, Burrs section), both representing invading faunas, in the basal measures of the *communis* Zone of part of the mid-Lancashire coalfield. They compare with a similar distribution of the *C. bellula* group, above and below the Jarrow Coal, in the basal *communis* Zone of the Leinster coalfield of south-eastern Ireland (EAGAR 1964, text-fig. 2, see also p. 213).

IV. Lancashire and Yorkshire: measures below the Arley Mine — Better Bed.

In Lancashire the 'established' fauna of *Carbonicola torus*, consisting of fairly large oval shells with relatively high, inflated umbones, characterises some 12 m of dark shaly mudstones rich in ostracods about midway between the Arley Mine and the top of the Old Lawrence Rock (Fig. 1). In Yorkshire, in the region around Huddersfield, the measures below the Better Bed (correlated undoubtedly with the Arley Mine) and the top of the Elland Flagstones include a thin band of elongate *Carbonicola* aff. *communis* and *Naiadites*. At Kirkheaton, 4 km north-west of Huddersfield, this band was found to lie in calcareous siltstone 18.3 m below the Better Bed (EAGAR 1956, p. 354). A similar non-marine fauna including the elongate variety *Carbonicola antiqua* (BROWN) was found in carbonate-rich sandstone at Raistrick, 4.8 km north of Huddersfield, probably on about the same horizon (*ibid.*, p. 355). More than 90 per cent of the shells collected from these Yorkshire localities consist of single valves, of which an appreciable proportion were broken before burial. Post-mortem conditions in this region were therefore turbulent and appreciable transport of shells may have taken place. However the fauna is of 'invading' type, as seen by its associations with *Pelecypodichnus* elsewhere, as in the Lower Leaf of the underlying Elland Flags (EAGAR 1974, p. 231). It therefore appears significant that at the only section where this band is now exposed in continuity with underlying and overlying measures, in a stream near Raistrick, 4.8 km north of

Huddersfield, *Pelecypodichnus* has been found. The trace fossil has been seen in loose material which appears to have come from just below the horizon of the *Carbonicola* band, in Bradley Park Dyke, on the northern margin of Bradley Wood, immediately below its junction with Deep Dyke and about 330 m east of Firth House, 1.6 km south-east of Raistrick Bridge (SE 156 215). No trace of the *Carbonicola bellula* group has been seen above the top of the Elland Flags, but very small elongate shells lying immediately above exceptionally small *Pelecypodichnus* have been noted in the Lower Leaf of the Elland Flags at Elland Upper Edge, where they lie about 25 m above the base of the flagstones (EAGAR 1974, p. 232). There therefore appear to have been two groups of 'invading' faunas in the Pennine area at this time, the first of *Carbonicola bellula* (BOLTON) and its associates, which is first seen in Namurian C beds and continues throughout the *lenisulcata* Zone into the basal beds of the *communis* Zone, and the second and later fauna of elongate *Carbonicola* aff. *communis* TRUEMAN & WEIR, including *C. antiqua* (BROWN). Both invading faunas appear to have belonged to distinct groups of shells. Although there is stratigraphic overlap between them in the basal measures of the *communis* Zone, no morphic transitions between shells of the two groups have been seen by the writer. Both groups of shells moreover appear to have given rise to 'established' faunas, several instances of this being well documented in the case of the *Carbonicola bellula* faunas (EAGAR 1974). In the measures below the Arley Mine — Better Bed the Lancashire 'established' faunas of low-energy organic-rich environments were probably contemporaneous with the Huddersfield area 'invading' faunas of shallow water, high energy environments.

As noted earlier, two horizons with 'invading' faunas of the *Carbonicola bellula* group are present in the basal *communis* Zone of the Burrs (Bury) area. A third fauna of the

same group was found about 25 m above the base of the Lower Leaf of the Elland Flags in the Elland area, where it similarly overlies *Pelecypodichnus* and this may represent a third slightly higher horizon. The disposition of these bands in the Pennines is similar to that of three bands of the *Carbonicola bellula* group found in the basal *communis* Zone of the Leinster coalfield, south-east Ireland (EAGAR 1964, text-fig. 2). The Irish horizons occur below and above the Jarrow Coal, the upper two above it being within 10 m of one another. Both the latter are recorded with or immediately above "worm-burrows" which may well refer to *Pelecypodichnus*.

V. Deltaic invasion by *Carbonicola*

Recent work on marine bivalve faunas and *Pelecypodichnus* in the upper Namurian (R_{1c} to R_{2h}) of Ireland and the Pennines (EAGAR *in prep.*) indicates that late Namurian *Carbonicola* evolved from assemblages of highly variable shells provisionally referred to cf. *Sanguinolites* HIND non M'COY. Since delta lobes move seaward comparatively fast in relation to speeds of locomotion of bivalves (*ibid.*), it appears that survival of marine bivalves in the path of an advancing delta front of late Namurian time would have depended primarily on the bivalves' ability to push upward with the foot, with long axis near the vertical (EAGAR 1974, fig. 12a), in order to escape burial. In this mode of movement advantage would have lain with the more elongate varieties, as with the later invading faunas, perhaps of inter-distributory lakes, of the Westphalian. Whereas in 'established' faunas of *Carbonicola* the bivalves tended to burrow down shallowly, or to plough, with their long axes more or less parallel to the substrate and their commissures vertical. In brief, the delta invaded the bivalves, not *vice versa*.

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