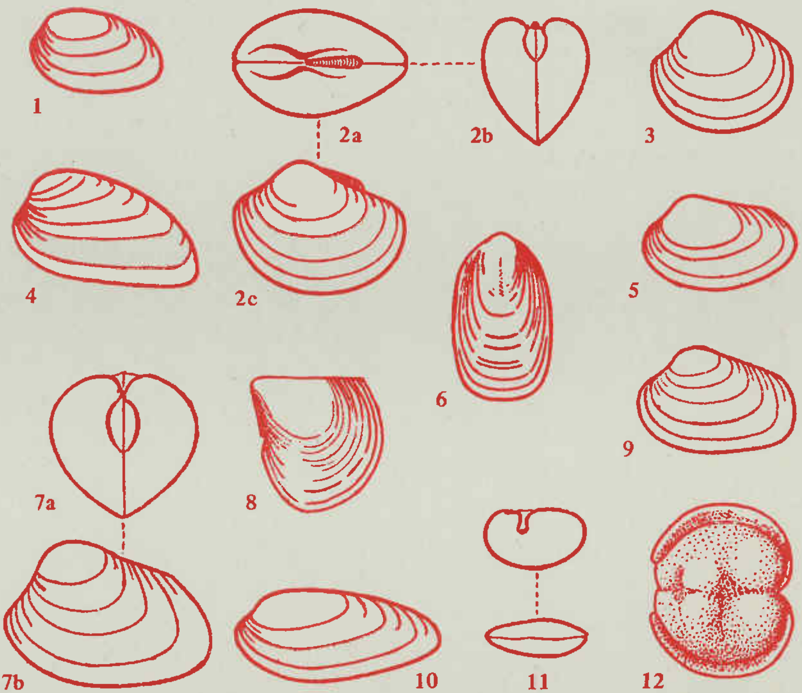
DERBYSHIRE NATURALISTS TRUST

20p

The W. H. Wilcockson Nature Reserve

Duckmanton Railway Cutting

Geological Trail



FOREWORD

The Derbyshire Naturalists' Trust, one of the County Trusts for Nature Conservation, was formed in 1961. A voluntary organisation and a registered charity, one of its principal functions is to acquire and manage representative types of wildlife localities within the County, and, to date, it has management interests in 35 sites throughout the County, totalling over 800 acres. Although some of the existing reserves have geological interest, and the protection and conservation of geological sites is included in the Trust constitution, Duckmanton Railway Cutting represents the first specific acquisition of a major geological site.

The site was acquired from British Rail in 1976, and a decision was made at an early stage to rename the site the Wilcockson Reserve. William Howson Wilcockson become Honorary Secretary of the Trust at the time of its foundation in 1961, and played a leading part in its affairs until his death in 1976. He had a distinguished academic career and was, for many years, Reader in the Geology Department at the University of Sheffield, and the renaming of the Reserve seemed particularly appropriate in view of his interest and expertise in Carboniferous stratigraphy.

The assistance of Dr. M. A. Calver and Dr. B. Owens of the Institute of Geological Sciences, who provided details of the fauna and lithologies present at each of the localities, is gratefully acknowledged. The originals of the fossil sketches (Figure 7) were prepared by Dr. R. M. C. Eagar of the University of Manchester, and permission to reproduce them is acknowledged. Publication of this guide was made possible by a grant from the Nature Conservancy Council.

THE W. H. WILCOCKSON NATURE RESERVE
DUCKMANTON RAILWAY CUTTING GEOLOGICAL TRAIL

INTRODUCTION

Duckmanton Railway Cutting, now disused, lies midway between Chesterfield and Bolsover, in the South Derbyshire coalfield, and exposes a series of Carboniferous rocks laid down some 300 million years ago. The locality, which is situated approximately 4km east of Chesterfield and 18km south-south east of Sheffield, has been designated the international boundary stratotype for the junction of two major units of geological time, the Westphalian A Stage and the Westphalian B Stage, and is consequently of international geological importance. By purchasing the locality, the Derbyshire Naturalists' Trust is ensuring that this vital site will be protected in perpetuity, for study by geologists. The science of geology attempts to elucidate the history of the earth by study of rocks. Within the Duckmanton Railway Cutting, examples of several of the main types of sedimentary rocks, including mudstones, siltstones, sandstones and ironstones. may be seen, together with good examples of various sedimentary features, including cyclothems (see below) with coal seams, cross-bedded sandstones, nodular ironstones, and cone-in-cone structures. By relating these deposits and structures to modern deposits of mud, silt and sand, it is possible to determine the environmental history of the Duckmanton area during the time when the Coal Measures were being laid down.

The various beds of rock were originally deposited in horizontal layers on the surface of a huge delta-swamp complex, but have since been affected by earth movements which has raised them above sea-level, and tilted them eastwards, so that the rocks now dip gently towards the east at an angle of about 20°. As a result, the lowest rocks present occur at the extreme western end of the cutting, and progressively higher beds occur towards the east. Fossils are abundant at certain horizons in the cuttings the most common being non-marine bivalves, commonly known as "mussels". The presence of these fossils, together with studies of the sediments, show that deposition occurred mainly in fresh- or brackish-water lagoons and swamps. However, the presence at one level of marine fossils, including the brachiopod *Lingula,* indicates that the sea invaded the area for part of the time. Plant fragments and trace fossils (i.e. burrows or markings indicating the presence of fossil animals) are locally common.

The geological trail visits seven trenches, each about two metres wide, cut into the walls of the cutting, and reaching nearly to the top. Because of the gentle easterly dip of the rocks within the cutting, a large part of the sequence on either side of the Clay Cross Marine Band (the lowest unit of Westphalian B) may be examined in these trenches. Details of what may be seen in each trench are to be found below, in the description of the trail itself. The sequence of rocks and fossils within the cutting provides the geologist with representative examples of most of the main depositional environments present within the Coal Measures, without the access problems met with when trying to visit National Coal Board opencast sites.

GEOLOGICAL SETTING

The Carboniferous period in England is clearly divisible into three main parts. At the base are the marine limestones of the Carboniferous Limestone, followed by the largely deltaic sandstones and shales of the Millstone Grit, which are in turn succeeded by the coals, siltstones, sandstones and mudstones of the Coal Measures; lithologically, the Coal Measures have similarities with the underlying Millstone Grit, but are characterised by the presence of many economically valuable coal seams. Within the Coal Measures the rocks can be subdivided either on the basis of lithology or on the fossils which they contain, giving rise to two systems of nomenclature. The details of these classifications, with particular reference to Duckmanton are shown in Figure 1. In this figure, the second column lists the basic units used for correlation by fossils in these rocks, the non-marine bivalve zones, which are based on the distribution of assemblages of bivalves, the most characteristic group of fossils occuring widely within the Coal Measures. These zones are *biostratigraphic units,* defined as the thickness of strata characterised by a particular species or assemblage of species. Groups of zones are grouped together into larger units, known as stages, and these in turn into series. The Coal Measures lie within the Westphalian Series, which is subdivided into A, B and C Stages. The rocks seen in the Duckmanton Railway Cutting represents the highest 75m of Westphalian A, and the lowest 50m of Westphalian B. Column 3 shows the *lithostratigraphic units* into which the Coal Measures are usually divided, and which are based on major similarities between the rock-types within various parts of the Coal Measures. The final column identifies the marine bands which are used as boundaries between the stages or lithostratigraphic units, and places the Duckmanton cutting in its relative position.

The environmental history of the later part of the Carboniferous Period records the gradual southwards-spread of large-scale deltaic complexes over much of the European area, a process that started during the Namurian. By Westphalian times, the growth of the Namurian deltas had produced a low-lying, widespread delta-top plain, occupied by swamps with brackish and freshwater lagoons, in which considerable thicknesses of largely non-marine sediments were laid down. Irregular overall subsidence of the area, continued during the Westphalian, resulting in the accumulation of delta-top sediments in cyclic sequence, to give the well-known Coal Measures cyclothems (see below). At times, due probably to world-wide rises in sea-level, the low-lying plains were invaded by the sea, producing marine horizons which can be traced over very wide areas. Most marine transgressions are represented by mudstones yielding marine faunas, many of which can be traced right across northern Europe, making the horizons extremely useful for correlation purposes. These marine bands are either named after a locality at which they are particularly well-developed (e.g. the Clay Cross Marine Band) or they may be known by the name of their characteristic goniatite (e.g. the *Anthracoceratites vanderbeckei* Marine Band, the alternative name for the Clay Cross Marine Band).

Particularly characteristic of the Coal Measures is the rhythmic sedimentation which occurred because of the periodic subsidence of the delta-top, which produced a sequence of different types of sediments, collectively known as

STAGE	ZONE	LITHOSTRATIGRAPHY		MARINE BANDS
WESTPHALIAN C	phillipsii	UPPER COAL MEASURES		
			-M–M–M-	Top Marine Band
	UPPER similis-pulchra	MIDDLE COAL MEASURES	-M–M–M-	Mansfield Marine Band
WESTPHALIAN B	*LOWER* similis-pulchra			
	modiolaris		-M–M–M-	First Ell Coal Clay Cross Marine Band Chavery Coal
WESTPHALIAN A	communis	LOWER COAL MEASURES		
	lenisulcata		-M–M–M-	Pot Clay Marine Band
NAMURIAN		MILLSTONE GRIT		

Figure 1. The stratigraphic sequence of the Upper Carboniferous rocks of England. Not to scale. The part of the sequence seen at Duckmanton is shown between the wavy lines.

cyclothems. Most cyclothems are of fairly restricted occurrence, but those which contain a marine band are usually relatively uniform over a wide area, presumably as a consequence of the widespread effect of the rise in sea-level. In a fully-developed cyclothem, with a marine band at the base, the sequence one would expect to find would be: dark mudstone, with a marine fauna at or near the base, passing up into a fauna of non-marine bivalves; this passes up into grey mudstones, which become silty towards the top, and may pass into siltstones or sandstones; these are then capped by a seatearth, above which is a coal seam. Within such a cycle, animal remains are mainly confined to the dark mudstones, whilst plant remains occur throughout and are usually most abundant, and best-preserved, in the grey mudstones, silty mudstones and siltstones. Seatearths consist of unbedded fireclays, mudstones, silty mudstones, siltstones and sandstones, and normally contain abundant rootlets; they are usually capped by a coal seam, although it may not always be well-developed. The lower parts of the seatearths are often enriched in ironstone nodules, due to leaching of iron from the upper parts.

Not all cyclothems display the idealised sequence described above. In particular, the sandstone unit is often absent, largely because the sandstones which do occur within the Coal Measures tend to be lensoid in shape, due to their having been deposited in river channels, and thus they frequently pass laterally, through siltstones, into mudstones. Many cycles, especially those in the Middle Coal Measures of Derbyshire, are dominated by mudstones and sandstones are not prominent. The average thickness of cyclothems in the Middle Coal Measures is about 9 to 12m in Derbyshire and Nottinghamshire, although those which contain marine bands are usually substantially thicker, as are those which commence with a thick coal.

Non-marine bivalves are abundant at many levels within the rocks of the Duckmanton Cutting, and characteristically occur crushed flat in the dark shales and mudstones near the base of cyclothems. In view of the abundance of specimens which occur at any one level, it is possible to study the great range of variation which occurs within a single species. As a result, Coal Measures non-marine bivalves tend to be identified by means of the overall characteristics of a whole population of specimens, rather than by the characters of a single one. It can also be shown that successive populations in a sequence of rocks demonstrate progressive changes in character, and so it is possible to recognise gradual evolutionary development, or response to environmental changes. On a broad scale, this provides a means for very fine subdivision of the rocks, since each successive population can be readily identified, and used for correlation with populations elsewhere.

The following publications have special relevance to Duckmanton cutting or to features which may be seen within it:-

1. Smith, E. G., G. H. Rhys & R. A. Eden, 1967. The Geology of the Country around Chesterfield, Matlock and Mansfield. *Memoir Geol. Surv. G.B.*, for sheet No. 112.
2. Edwards, W. & C. J. Stubblefield, 1948. Marine bands and other faunal marker-horizons in relation to the sedimentary cycles of the Middle Coal Measures of Nottinghamshire and Derbyshire. *Quart. Journal Geol. Soc. London, 103,* 209–260, pls. 13–15.
3. Neves, R. & C. Downie (Eds.), 1967. *Geological Excursions in the Sheffield Region.* Sheffield.
4. Calver, M.A., 1968. Distribution of Westphalian marine faunas in Northern England and adjoining areas. *Proc. Yorks. Geol. Soc., 37,* 1–72, pl. 1.
5. Goossens, R. F., E. G. Smith & M. A. Calver, 1974. Westphalian. *In* Rayner, D. H. & J. E. Hemingway (Eds), *The Geology of Yorkshire,* 87–114. Yorkshire Geological Society.
6. *"British Palaeozoic Fossils".* British Museum (Natural History).
7. I. G. S. British Regional Geology, *"The Pennines and Adjacent Areas"* H.M.S.O.

ADVICE TO VISITORS

Permission to visit

Since the railway cutting is owned and managed by the Derbyshire Naturalists' Trust as a nature reserve, application should be made well in advance for a permit to visit the locality. Applications should include information on the number of intending visitors to the site, together with an indication of their academic level, and should be sent to:- Dr. A. J. Deadman, Conservation Officer, Derbyshire Naturalists' Trust, Estate Office, Twyford, Barrow-on-Trent, Derby, DE7 1HJ. Telephone Burton on Trent 703219.

Personal Safety

Exposures of rock, whether natural or artificial, are rarely safe. Therefore, visitors who follow the trail do so entirely at their own risk. Some of the rock faces, especially those in the coals, may be rather unstable, especially after frost, and must be approached with great caution, especially when children are in the party. The Derbyshire Naturalists' Trust cannot accept any liability or responsibility for loss, damage or injury to persons or property.

Use of the trail

The localities to be visited are not marked by any posts or boards in the cutting, but are clearly visible on the cutting walls, where they take the form of vertical trenches. Their distance from the footings of the Deepsick Lane overbridge are given in the text and if there is any doubt as to which is which, this distance can be paced out.

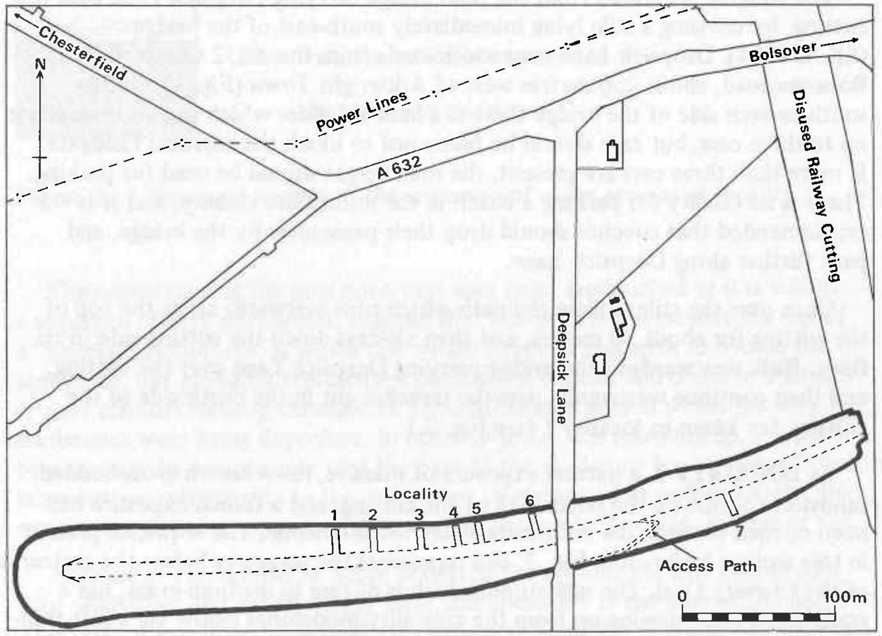


Figure 2. **Plan showing the location of Duckmanton Railway Cutting, and the position within it of the localities described in the text.**

Collecting

The exposures within the Duckmanton cutting are an exceptionally prolific source of fossils, but please remember that they are not limitless. The best areas are already well picked over, and choice items are difficult to find. Large numbers of students could quickly deplete what is left. With a large number of visitors every year, the demonstration value of the trail could largely be ruined if each visitor is over-enthusiastic in using his or her hammer. In addition, it should be remembered that this locality is of international importance for geological research and that over-use or misuse could severely compromise that interest.

The Derbyshire Naturalists' Trust discourages individual collecting, and the only legitimate practice should be to build up small teaching collections. In this way the educational value of the trail may be maintained for many years. Aimless hammering at important faces destroys features or fossils that others may wish to see. The trail is designed to train people to observe, not to satisfy any short-sighted instinct to collect – many good educational sites have already been made useless through uncontrolled collecting. On the other hand, to derive maximum benefit from the trail, it is useful to compare faunal assemblages from the various localities. Wherever possible the requisite small specimens should be collected from scree; if it is necessary to hammer the exposures, the minimum disturbance should be caused.

GEOLOGICAL TRAIL

The Reserve is entered from the road bridge carrying Deepsick Lane over the cutting, by crossing a stile lying immediately south-east of the bridge (SK 424704). Deepsick Lane runs southwards from the A632 Chesterfield to Bolsover road, about 250 metres west of Arkwright Town (Fig. 2). On the south-eastern side of the bridge there is a hard shoulder which can accommodate up to three cars, but care should be taken not to block the adjacent fieldgate. If more than three cars are present, the road verges should be used for parking. There is no facility for parking a coach in the immediate vicinity, and it is recommended that coaches should drop their passengers by the bridge, and park further along Deepsick Lane.

Once over the stile, follow the path which runs eastwards along the top of the cutting for about 30 metres, and then zig-zags down the cutting side to its floor. Walk westwards to the bridge carrying Deepsick Lane over the cutting, and then continue westwards, past the trenches cut in the north side of the cutting, for 146m to locality 1 (see Fig. 2.)

1 At **LOCALITY 1**, a natural exposure of massive, fawn-brown cross-bedded sandstone occurs on the north wall of the cutting, and a trench exposure has been opened through the sediments above the sandstone. The sequence present in this section is shown in Fig. 3, and represents the measures below the seatearth of the Chavery Coal. The sandstone, which is of fine to medium-grain, has a gradational base, passing up from the grey silty mudstones below via a soft thin-bedded silty sandstone. The basal and upper parts of the sandstone unit are rippled, but apart from weak cross-bedding, the bulk of the sandstone is largely devoid of sedimentary structures. Resting on the sandstone is a 15cm band of

red-weathering sideritic clay-ironstone nodules, with a sparse clay matrix, passing up into soft grey-brown silty mudstones with ironstone nodules scattered throughout; plant fragments are fairly common in the lower 25cm of this unit. Capping these silty mudstones are light grey-fawn clays with rootlets forming the seatearth of the Chavery Coal, seen at the top of the section. Measures above this are best seen at the next locality.

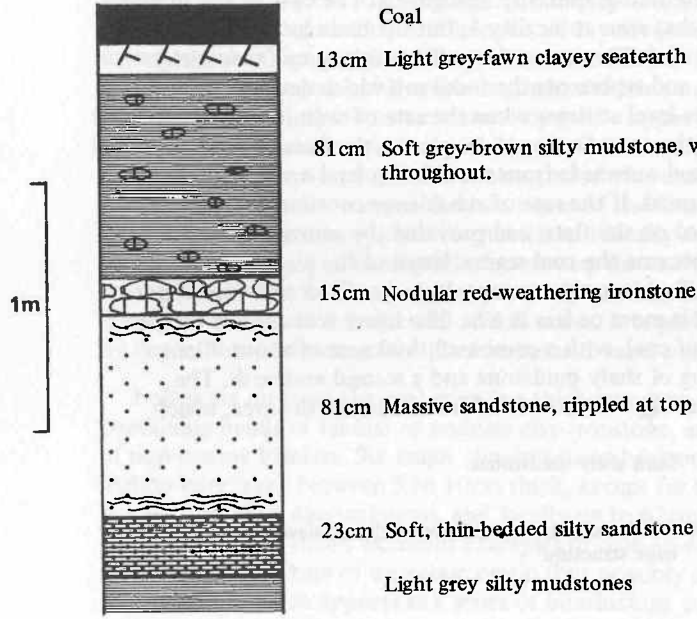


Figure 3. Measured section of the sequence of rocks present at locality 1.

The occurrence of the sandstone unit seen here, sandwiched as it is within a sequence of silty mudstones, suggests that this does not represent the top of a "normal" cyclothem, in which one would expect a seatearth to overlie the sandstone, but probably represents a channel-fill deposit laid down in a stream or river channel running through the lagoonal swamp area in which the silty mudstones were being deposited. In order to prove this relationship, it would be necessary to demonstrate that the base of the sandstone has an unconformable cross-cutting relationship to the underlying mudstones, but unfortunately, the exposure is not clear or extensive enough to show whether this the case or not.

Nodules of clay-ironstone occur scattered throughout the soft grey-brown silty mudstone, and are especially large and abundant at the base of the unit. This type of ironstone is particularly characteristic of the non-marine mudstone units within the Coal Measures, and often occurs as lenses, or as more continuous bands. These are usually composed largely of siderite, an iron carbonate, and are thought to have formed by concentration and precipitation of iron-rich carbonate fluids moving through the sediments after depositon. However, they must have been formed before the sediments were compacted, since they often contain uncrushed mussels.

2 Twenty-five metres east of locality 1, and 121m west of the Deepsick Lane bridge, is **LOCALITY** 2, a long scar on the north face of the cutting, exposing the Chavery Coal, and some of the measures above it. The sequence of rocks seen at this locality is presented graphically in Figure 4. The base of the section overlaps with the top of that seen at locality 1, but the main interest here begins with the seatearth of the coal. The seatearth itself is a light grey-fawn sticky clay, containing rootlets, and represents the fossil soil which developed on the wide flats at or near water-level at times when the rate of sedimentation exceeded the rate of subsidence of the area. During these phases, the flats became colonised by land-plants which spread outwards from the existing land areas, and rootlet beds (seatearths) were formed. If the rate of subsidence continued to be low, extensive forests developed on the flats, and provided the source of the plant debris which eventually became the coal seams. Much of the plant material forming the coal seams was drifted into the swampy lagoons of the coal forest, but it is likely that some of it is more or less *in situ.* The lower seatearth at locality 2 is overlain by two seams of coal, with a combined thickness of about 70cm, separated by a thin parting of shaly mudstone and a second seatearth. The presence of this central parting indicates a sudden sinking of the area, which

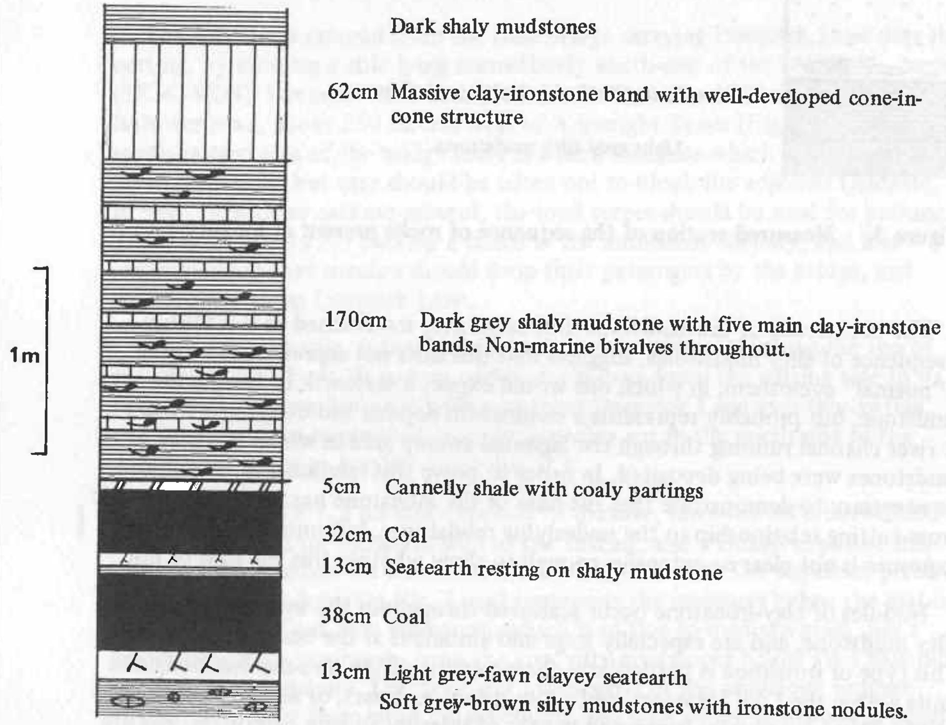


Figure 4. Measured section of the sequence of rocks present at locality 2.

caused flooding of the coal forest, and in the shallow lagoons which formed, 5cm of shaly mudstones were deposited before coal forest conditions were re-established with the deposition of the second seatearth and the upper leaf of the coal. The two coal seams are here known jointly as the Chavery Coal. It is possible, however, that if the seam was to be traced away from the Duckmanton cutting, the two leaves of the seam would become more widely separated, and it might then be more appropriate to give each leaf a separate name. The two leaves of the coal seem to differ slightly in composition and purity, with the lower leaf being rather dirty and impure, with yellow-weathering patches marking areas rich in decomposed iron pyrite, and relatively few layers of bright coal, whilst the upper leaf is much brighter, and has a much better-developed "cleat". Lenses of pyrite occur commonly in the upper leaf. "Cleat" is the term given to the well-marked jointing which often develops in coals, giving regular patterns of intersecting joint planes along which the coal breaks into small pieces. The seatearth between the two leaves of the Chavery Coal consists of a light grey clay containing plant fragments, and locally contains small lenses of bright coaly material. The upper leaf grades up into a thin unit of cannelly shale consisting of dark shaly mudstone with coaly partings and yielding drifted plant remains, together with fragments of fish scales. It is probable that it accumulated by deposition of disintegrated plant remains in local small pools or lakes.

Following on from the coal seam is a thick sequence of dark shaly mudstones containing bands of tabular or nodular clay-ironstone, and yielding a rich fauna of non-marine bivalves. Six major clay-ironstone horizons may be seen in the section here, each between 5 to 10cm thick, except for the uppermost (sixth) horizon, which is discontinuous, and locally up to 62cm thick. This band, where thickened, shows excellent examples of cone-in-cone structure, a sedimentary structure of uncertain origin (but possibly caused during compaction), which appears as a series of interlocking cone-shaped structures with annular rings. Do not hammer this band, since it is only locally developed, and could rapidly be destroyed. Where this horizon is particularly thickened, the sedimentary laminae in the shaly mudstones above and below it appear to have been forced outwards, suggesting that the thickening took place after the surrounding sediments had been deposited. Cone-in-cone structures are only present in the thickened portions of the ironstone band, and are not seen in the thinner units. Both the shaly mudstones and the clay-ironstone bands contain abundant non-marine bivalves, which are crushed flat in the mudstones, and are usually uncrushed in the ironstones. In addition the bivalves from the ironstone horizons usually have the shell material replaced by siderite, whilst those from the shaly mudstones have no shell material remaining, and the bivalves occur merely as impressions on the bedding planes of the rock. The bivalves are abundant up to the base of the sixth ironstone band, and occur in all the shale units and most of the ironstones. However, they do not appear to be present where cone-in-cone structure has developed, and it is likely that they were destroyed during its growth. The abundance of bivalves on many bedding planes within the mudstones allows studies of morphological variation within species to be undertaken, and it is suggested that collections may be made for that purpose. The fauna is dominated by *Anthracosia regularis,* (Figure 7) but rare *Anthraconaia modiolaris* and *Anthracosphaerium* sp. also occur. The occurrence of *A. modiolaris* is indicative of the Modiolaris Zone (see Figure 1), but since it is used as a zonal index fossil, it is a widespread form, and throughout the zone it is accompanied by a succession of other, more rapidly-evolving, bivalve species. At certain horizons, some of the bivalves have been colonised by the epifaunal attached annelid worm *Spirorbis,* which secretes and cements a small coiled shell. Since spirorbids can only live above the sediment surface, and since most Coal Measures bivalves represented here are thought to have lived as burrowers within the sediment, it is necessary to assume that the spirobids did not colonise the bivalve shells until after the bivalves had died, and had been winnowed out of the sediment. However, it is thought that in some of the burrowing bivalves the posterior part of the shell protruded above the sediment surface, and this could have provided suitable sites for colonisation by *Spirorbis.* The occurrence of the bivalve fauna, as plasters of crushed shells along bedding planes, rather than in life position, tends to support this view. The ostracod *Geisina arcuata* (Figure 7) occurs sporadically at certain horizons within the shaly mudstones.

3 Thirty metres to the east, and 91m west of the bridge, is **LOCALITY** 3, a trench on the north side of the cutting. At this locality there are two main features of interest; the Tankersley Ironstone occurs at the top of the trench,

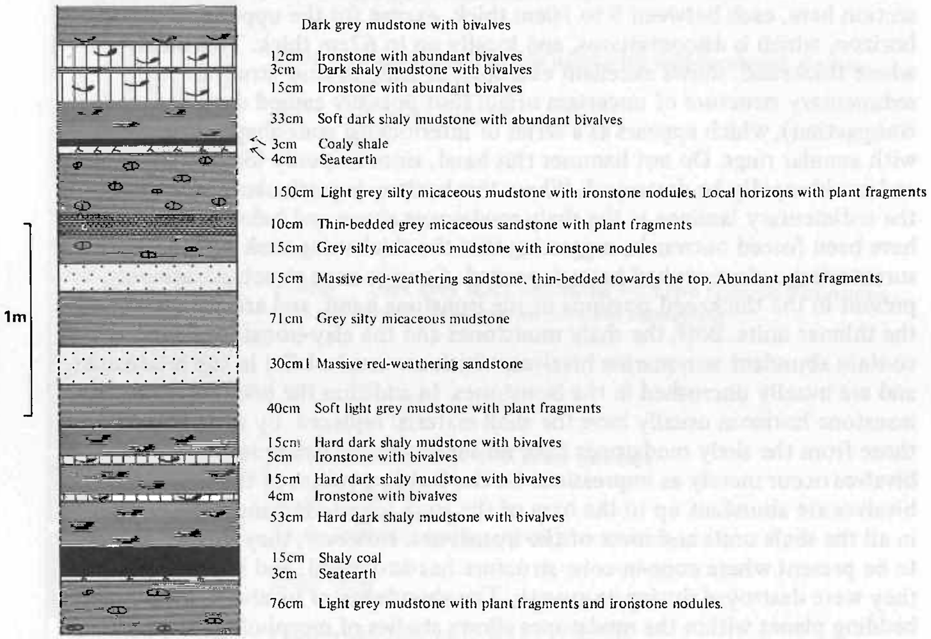


Figure 5. Measured section of the sequence of rocks present at locality 3.

yielding abundant uncrushed non-marine bivalves, and below this is a series of deposits which demonstrate the sequence of faunas and lithologies present within a Coal Measure cyclothem (Figure 5). By standing on the cutting floor and looking at the rocks exposed in the trench, it is apparent that the lower part of the section is composed mainly of dark grey shaly mudstones, and that this is overlain by a thicker series of lighter grey mudstones, with sandstone bands and ironstone nodules. The dark grey shaly mudstones, here about 90cm thick, yield abundant crushed non-marine bivalves, again mainly *Anthracosia regularis* (Figure 7), and contain two prominent ironstone bands containing uncrushed examples of the same species. The dark mudstones rest on a thin low-grade coal, which in turn overlies a sticky light grey clay with plant fragments, representing the seatearth of the coal. Beneath this is a sequence of light grey mudstones with plant fragments and ironstone nodules. By convention, the basal unit of a cyclothem is taken as the base of the mudstone unit forming the roof shales of a coal seam, and by taking a measured section upwards from the thin coal seen here, a good example of the composition of a cyclothem may be seen. The dark mudstones pass up into softer light grey mudstones with plant fragments, but without bivalves, which in turn grade into micaceous siltstones, sandstones and mudstones, often with plant remains, which were laid down in shallower water, closer to shore. The three prominent sandstone bands may represent channel-fill deposits, or else may merely indicate phases of more rapid sedimentation in a near-shore environment, later followed by a slight deepening of the water which renewed the deposition of the light grey mudstones. Plant fragments are abundant throughout these upper deposits. At the top of the light grey mudstone is a sticky clay rich in plant fragments, which is overlain by a thin low-grade coal representing the top of the cycle. The sediments between this coal and the previous one are a good example of the sequence of lithologies and faunas present in a cyclothem, and may be used to demonstrate the principle of cyclic sedimentation.

Above the upper thin coal is a series of dark grey shaly mudstones yielding abundant crushed non-marine bivalves, and containing, at the top, two massive clay-ironstone horizons with uncrushed well-preserved bivalves. These ironstone bands are collectively known as the "Tankersley Ironstone", and are probably equivalent to the "Pinder Park Rake", which may be traced over a wide area of the Derbyshire coalfield. They consist of shelly ironstones, in which the bivalves are preserved largely uncrushed, and with the shells replaced by siderite. At some horizons, individual bivalves occur in a loose ironstone matrix, and may easily be collected, while elsewhere, the ironstone consists of a well-developed tabular horizon, containing abundant bivalves on its surface. Since the bivalves are uncrushed, the ironstone must have developed in the early stages of diagenesis, before sedimentary compaction led to crushing of the shells. Again, the bivalve fauna consists largely of *Anthracosia regularis.* Dark mudstones with bivalves continue above the ironstones but are deeply weathered, and can be better seen at the next locality.

4 **LOCALITY** 4 lies 25 metres further east, and 66m west of the bridge, and is another trench section on the north side of the cutting. The marker horizon to be seen near the base of this section is a hard micaceous sandstone with plant fragments, which is probably equivalent to the sandstone lying about 2 metres

below the Tankersley Ironstone at locality 3. However, because of the easterly dip of the rocks in the cutting, the Tankersley Ironstone is here at a much lower level in the trench, and this greater accessibility makes it much easier to examine. In consequence, however, the Ironstone at this locality is not as deeply weathered, and it is much more difficult to collect material from it. Above the Ironstone are about 50cm of dark grey shaly mudstones with ironstone nodules and non-marine bivalves, which pass up into light grey mudstones and clay without bivalves. These mudstones contain small ironstone nodules scattered throughout about 140cm, and are characterised by a very unusual ironstone horizon about 50cm from the base. This is a tabular ironstone with a regular joint pattern which splits the band into long lath-shaped rectangular pieces, up to 5cm square and up to 60cm long. The major joint pattern runs more or less east-west, and is intersected by a weaker and much more distantly-spaced north-south set of joints; there is no horizontal joint system, since the major and minor joint systems run through from the top to the bottom of the ironstone band. The light grey mudstones containing this ironstone band are capped by a 23cm band of fine-grained silty micaceous micro-cross-laminated sandstone yielding plant fragments, and there then follows a thick sequence of similar light grey mudstones containing harder silty bands.

5 Some sixteen metres to the east (50m west of the bridge) lies **LOCALITY 5**, again occurring as a trench on the northern side of the cutting. The Tankersley Ironstone may sometimes be visible at the base of the trench, but is usually obscured by scree and vegetation. The visible part of the section (Figure 6) comprises a hard micro-cross-laminated sandstone at the base, followed by an alternation of about 140cm of silty mudstones and silty sandstones with plants. This would appear to represent the topmost part of the cycle containing the Tankersley Ironstone, since it is overlain by some 76cm of dark shaly mudstones with crushed non-marine bivalves; an ironstone band containing uncrushed bivalves occurs near the centre. Again, the fauna is dominated by *Anthracosia regularis*, and it is a worthwhile exercise to compare assemblages of this species from the different horizons at which they occur at localities 2, 3, 4 and 5. Comparative studies of measurements of specimens at each horizon will give an indication of the variation which can be seen at each horizon, and may allow conclusions on the evolution of the species through this part of the Coal Measures to be drawn. It is noteworthy that this cycle is not underlain by a coal seam, although the basal part of the mudstone is very dark and shaly and contains much mica; this may represent a cannelly horizon consisting of drifted plant material which accumulated in small pools.

6 **LOCALITY 6** occurs 36m further east (14m west of the bridge) and is another wide trench on the north side of the cutting. The sequence seen here has a thick seatearth at the base, comprising over 30cm of yellow-weathering clay, purplish-grey when fresh, containing plant fragments, and also contains a good deal of yellow weathering iron minerals. Leaching, which tends to concentrate iron minerals near the base of seatearths, can be well-demonstrated here. The seatearth is overlain by a thin (6cm) splintery coal (the Joan Coal), which contains obvious large pieces of woody material, forming a locally-bright coal, with a good deal of yellow-weathering pyrite and secondary iron minerals.

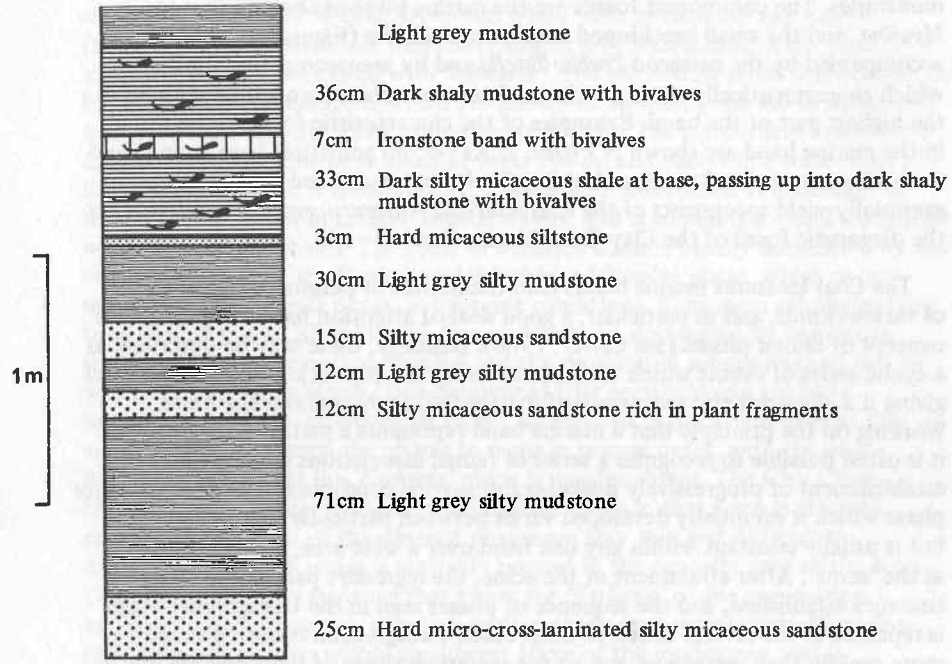


Figure 6. Measured section of the sequence of rocks present at locality 5.

Above the coal is a thick sequence of dark grey shaly mudstones, with occasional thin ironstone bands. Marine fossils occur sporadically throughout the lower 340cm (approximately 11 feet) of this mudstone, and this horizon is known as the "Clay Cross Marine Band". This marine band is known to extend over much of north-western Europe, and is one of the most important marker horizons to occur in the Coal Measures, lying as it does at the base of the Middle Coal Measures, and in the middle of a thick series of economically workable coals. It can readily be identified, both at surface and in borehole cores, by virtue of its fauna, and is of wide use for correlating within and between coalfields. In addition, it is taken as the horizon which marks the junction of two major portions of geological time, and is defined as the basal unit of geological time known as the Westphalian B Stage (Figure 1). In order to attain uniformity of usage between geologists of all nationalities, geological time units are defined by their bases, and a type-locality is designated for the base of each particular unit. The type-locality is thus the unique reference locality with which all rocks of equivalent age are compared. The exposure of the Clay Cross Marine Band seen at locality 6 in the Duckmanton Railway Cutting is defined as the international boundary stratotype for the base of Westphalian B, and is consequently of the greatest international geological importance. For this reason, hammering should be kept to a minimum, and great care taken so as not to obscure the lower parts of the section. Marine fossils are scattered sporadically throughout the lowest 340cm of the dark grey mudstones, but are nowhere abundant, although they may usually be found fairly easily in the ironstone bands in the lower part of the mudstones. The commonest fossils are the marine bivalves *Dunbarella* and *Myalina,* and the small brachiopod *Lingula mytilloides* (Figure 7), which are accompanied by the ostracod *Praehollinella* and by arenaceous foraminifera, which characteristically occur on the surface of weathered ironstone nodules in the highest part of the band. Examples of the characteristic fossils to be found in the marine band are shown in Figure 7. As yet, no goniatites have been found at this horizon at Duckmanton, but it is likely that continued study will eventually yield speciments of the characteristic *Anthracoceratites vanderbeckei,* the diagnostic fossil of the Clay Cross Marine Band.

The Coal Measures marine bands lend themselves to palaeoecological studies of various kinds, and in particular, a good deal of attention has been paid to the concept of faunal phases (see Calver, 1968). Basically, these may be described as a cyclic series of events which took place during the deposition of a marine band giving it a characteristic succession of marine faunas throughout the band. Working on the principle that a marine band represents a marine transgression. it is often possible to recognise a series of faunal associations which reflect the establishment of progressively deeper-water marine conditions. The deepest water phase which is eventually developed varies between particular marine bands, but is usually constant within any one band over a wide area, and is known as the 'acme'. After attainment of the acme, the regressive part of the cycle becomes established, and the sequence of phases seen in the transgressive stage is repeated in the reverse order. In most cases, transgression occurred much more rapidly than regression, and so the regressive stages of the cycle are much thicker and better developed. In an idealised Westphalian cycle, the sequence seen would be:-

Non-marine bivalves	
Planolites ophthalmoides phase	
Foraminifera phase	Retreat
Lingula phase	
Cephalopod/Brachiopod/Bivalve phase	ACME
Lingula phase	
Foraminifera phase	Advance
Planolites ophthalmoides phase	
'Estheria'	
Non-marine bivalves	
Fish	
COAL SEAM	

The fish remains are usually fragments of scales, which often occur in the cannelly roof of a coal seam, and are sometimes followed by a thin band of non-marine bivalves, indicating the initial flooding of the coal swamp area, when mudstone deposition began. As the transgression become established, occasional incursions of brackish water penetrated the areas inhabited by the bivalves, and thin bands of mudstone containing the crustacean *'Estheria'* were laid down. The ostracod *Geisina* is sometimes found associated with *'Estheria',* suggesting that it too could tolerate more saline environments. Further advancement of the sea led to the deposition of mudstones containing the trace-fossil *Planolites ophthalmoides,* thought to be produced by a burrowing worm.

analogous in habit to Recent *Arenicola,* which lives in estuaries and marine flats. *Planolites* occurs most frequently in soft grey mudstones, often slightly silty, and is never associated with *'Estheria'.* The succeeding phase is characterised by arenaceous foraminifera, which are known to be wholly marine in habit, and so indicate the establishment of marine conditions. The inarticulate brachiopod *Lingula* dominates the next phase of most cycles, and occurs in a wide range of lithologies, although it is commonest in dark silty mudstones. It is thought to represent deposition in shallow coastal waters, and is sometimes found associated with other faunal phases. The acme of a marine band is usually dominated by one of the subphases of the Cephalopod/Brachiopod/Bivalve phase, which occurs seaward of the *Lingula* phase, in open-sea conditions. Four main subphases have been described by Calver (1968), two of which are dominated by benthonic (bottom-living) species (the *Myalina* and the productoid subphases) and two of which are more planktonic (free-swimming) (the pectinoid and goniatite subphases), and are consequently rather widespread. After attainment of the acme, regression caused the phases to recur in reverse order, with the only difference being that the *'Estheria'* phase is usually absent. The Clay Cross Marine Band is similar to many other marine bands in that acme is attained rapidly, and so most of the advance phases are very thin and difficult to distinguish. The fish phase is probably present in the cannelly roof of the Joan Coal, but there is no evidence that either the *'Estheria'* or the non-marine bivalve phases are present, although further study may reveal them. *Planolites ophthalmoides* occurs within the lowest 10cm of the mudstones, and is succeeded within another 10cm by mudstones with *Lingula mytilloides;* the foraminifera phase appears to be absent from the transgressive sequence here. Following the *Lingula* phase, the acme fauna seems to be developed within about 25cm of the Joan Coal, and is here in the *Myalina* sub-facies, containing *Myalina* and *Dunbarella.* These are found most commonly in the thin tabular and lenticular ironstone bands which occur within the mudstones, where they are often well-preserved, and occur as uncrushed valves preserved in pyrite. Because of the difficulty of collecting large quantities of material from this locality, it is not known with certainty at which stages of the regression most of the phases reappeared, but no marine fossils have been found higher than 340cm above the Joan Coal. In addition, bands of non-marine bivalves become abundant at about this level, and it is clear that the marine regression is complete. However, a characteristic feature of the uppermost part of the Clay Cross Marine Band, and one well-seen at Duckmanton, is the alternation of layers rich in non-marine bivalves with layers containing marine fossils. Sometimes these fossils occur together on the same bedding planes, but usually they are interbedded, leading to the supposition that the non-marine bands represent incursions of fresh or brackish water into the predominantly marine conditions. The bivalves which occur usually belong to the genus *Anthracosia,* and are invariably stunted, due to their introduction into an essentially marine environment, and never occur together with the acme fauna, which is clearly too deepwater to be affected by non-marine incursions.

The re-establishment of freshwater conditions is seen in the mudstones about 340cm above the Joan Coal, where non-marine bivalves become abundant again. This level still lies within the Modiolaris Zone, but *Anthracosia regularis* has now been replaced by species of the *Anthracosia aquilina / A. ovum* group. The dark mudstones overlying the marine band contain lenses and nodules of ironstone, in which bivalves are both abundant and well-preserved. A collection of bivalves from this locality can be made, to compare with the collections of *A. regularis* made previously, and with the collections to be made at the next locality.

7 The final locality, **LOCALITY** 7, lies 106m east of the bridge, on the south side of the cutting, and is an outcrop of coal in the cutting side, underlain by a trench section cut through to the underlying sandstone. The coal seam here is known as the First Ell Coal and lies about 33m above the Clay Cross Marine Band, from which it is separated by two well-developed cycles, the lower being capped by the Second Ell Coal and the upper by the First Ell. There are many similarities between the sequence seen here and that seen at localities 1 and 2, where the Chavery Coal and its underlying measures are seen. Probably the most striking are the presence of a massive sandstone unit lying about 1 metre below the coal, and separated from it by a series of soft mudstones and a thick seatearth, and the occurrence above the seatearth of a well-developed coal seam, here about 65cm thick. It is suggested that the sequence between the sandstone and the coal is measured and compared with the sequence seen at locality 1, to give an indication of the variability of the depositional history of the Coal Measures. The First Ell Coal is too thin to be economically worked, but it is nevertheless a good quality bright coal with a low ash content; it shows a well-developed cleat. The feature of greatest interest here is the measures immediately above the coal, which are different from all the other roof measures seen at Duckmanton. The top of the coal is sharply defined, and is overlain by dark, very shaly mudstones containing nodules and irregular tabular bands of ironstone at the base, which yield an abundant, diverse and extremely well-preserved fauna of non-marine bivalves. The distribution of bivalves within the ironstone is rather patchy, but they tend to be concentrated within the nodular, rather than the tabular, parts of the band. The ironstone is a deep reddish-purple colour, and appears to be considerably richer in iron, and less rich in carbonate, than most of the other ironstone horizons seen in the cutting. Many of the concretions are rich in pyrite. The fauna is extremely diverse, and over 14 species of bivalves have been recorded, including *Anthracosia beaniana, A. ovum, A. phrygiana A. retrotracta, A. aquilina,* the zonal index *Anthraconaia modiolaris,* and several species of *Anthracosphaerium* and *Naiadites.* Examples of some of these may be found in Figure 7.

Immediately above the shelly ironstone, and locally resting directly on the roof of the coal, are a series of dark, very fissile shaly mudstones containing a sparse fauna of crushed bivalves. The mudstones are very thin-bedded and sometimes approximate to the consistency of a paper shale; their fauna is much less abundant than in any of the other roof-measures to be seen in the cutting, suggesting that environmental conditions were less favourable.

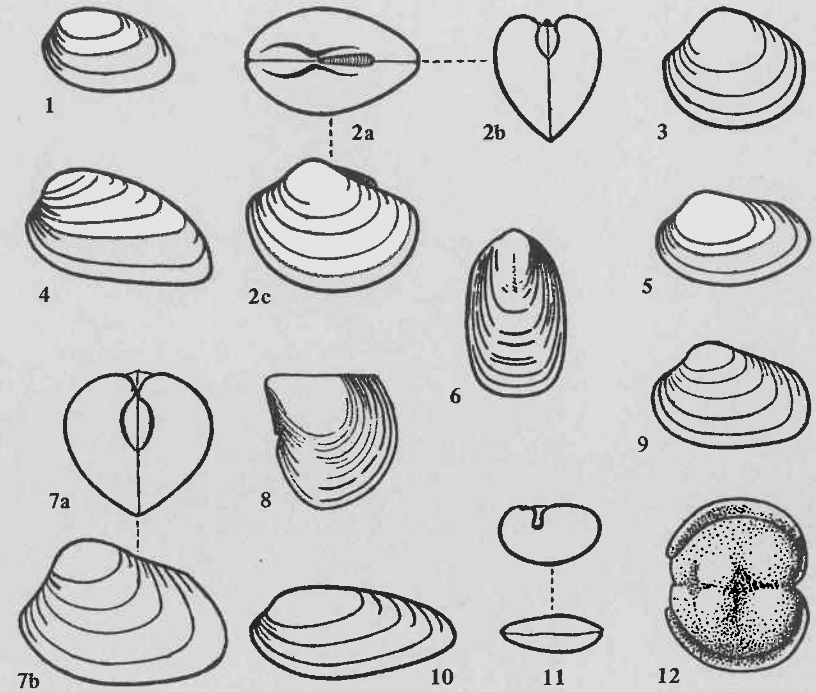


Figure 7. **Sketches of some of the commoner Coal Measures fossils.**

1, *Anthracosia regularis* (Trueman);
2a-2c, *Anthracosphaerium exiguum* (Davies & Trueman), dorsal, anterior and lateral views;
3, *Anthracosphaerium boltoni* (Wright);
4, *Anthracosia phrygiana* (Wright);
5, *Anthracosphaerium affine* (Davies & Trueman);
6, *Lingula mytilloides* J. Sowerby, x 3;
7a-7b, *Anthracosphaerium gibbosum* (Hind) anterior and lateral views.
8, *Myalina compressa* Hind, x 1;
9, *Anthracosphaerium turgidum* (Brown).
10, *Anthracosia atra* (Trueman);
11, *Geisina arcuata* (Bean), x 20;
12, *Praehollinella* cf. *bassleri* (J. B. Knight), x 20;
All sketches x 2/3 unless otherwise stated.