THE SEDIMENTS AND TRACE FOSSILS OF THE ROUGH ROCK GROUP ON CRACKEN EDGE, DERBYSHIRE

by

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Summary

The sediments of the Yeadonian GI Rough Rock Group on Cracken Edge in north Derbyshire include basal silty mudstones, the Rough Rocks Flags and the Rough Rock. Three Facies Associations are identified and possible sedimentological origins are considered.

Trace fossils in the Rough Rock Flags are described. They include *Pelecypodichnus* resting traces, escape shafts and possible bivalve trails, with minor *Planolites, Cochlichnus* and *Didymaulichnus?*, in the lower levels. In higher beds *Didymaulichnus?, Planolites* and *Cochlichnus* are found, together with large concretions. Four ichnocoenoses are suggested, and their distribution is discussed.

Introduction

Cracken Edge (SK 038837) runs along the eastern face of Chinley Churn, a 451 m high hill near Chinley in the High Peak of Derbyshire (Stevenson and Gaunt, 1971, plate XVIIIB). The north-south trending Edge lies on the eastern limb of the Goyt Trough syncline, with the strata dipping to the west at angles of between 8 degrees and 20 degrees. The sequence to the east of Chinley Churn starts with Namurian shales and the *Reticuloceras gracile* marine band in the valley bottom, and moves upwards through the Chatsworth Grit and Simmondley Coal to the Rough Rock Flags and Rough Rock which have been extensively quarried (and in places, mined) along Cracken Edge itself (Fig. 1). Above these come shales and the *Gastrioceras subcrenatum* marine band forming a boggy depression, and then the Lower Westphalian Woodhead Hill Rock makes the summit of the Churn itself.

The Rough Rock Group

Somewhat surprisingly the Yeadonian G1 (N11 cycle of Ramsbottom 1977) Rough Rock Group has not received as much detailed study as other Namurian formations, although as Shackleton (1962) pointed out, it covers some 6,400 km^2 in the north of England. The area in which it is found can be divided into three principal sectors. The first—the axial zone—stretches from Bradford and Huddersfield to the Peak District and then on to Macclesfield and north Staffordshire. The Group attains thicknesses of 67m in the north, 106m in the centre, and 58m in the south. The corresponding figures for the Rough Rock Flags and Rough Rock are 36, 42 and 28m. The succession (with many local variations) above the *Gastrioceras cumbriense* marine band can be summarised as follows–

Pot Clay or Six Inch Mine Coal (present locally).
Seat-earth or shale.
The Rough Rock (medium to coarse-grained sandstones, commonly pebbly, with occasional shale lenses).
Shales (in places) with *Carbonicola, Naiadites, Spirorbis, Pelecypodichnus.*
The Rough Rock Flags (fine to coarse-grained micaceous sandstones, occasional grits, and shale partings), in several areas, with rare *Carbonicola, Pelecypodichnus*, and *Cochlichnus.*
Shales and occasional sandstones, with *Carbonicola, Naiadites, Spirorbis, Cochlichnus* and *Planolites.*

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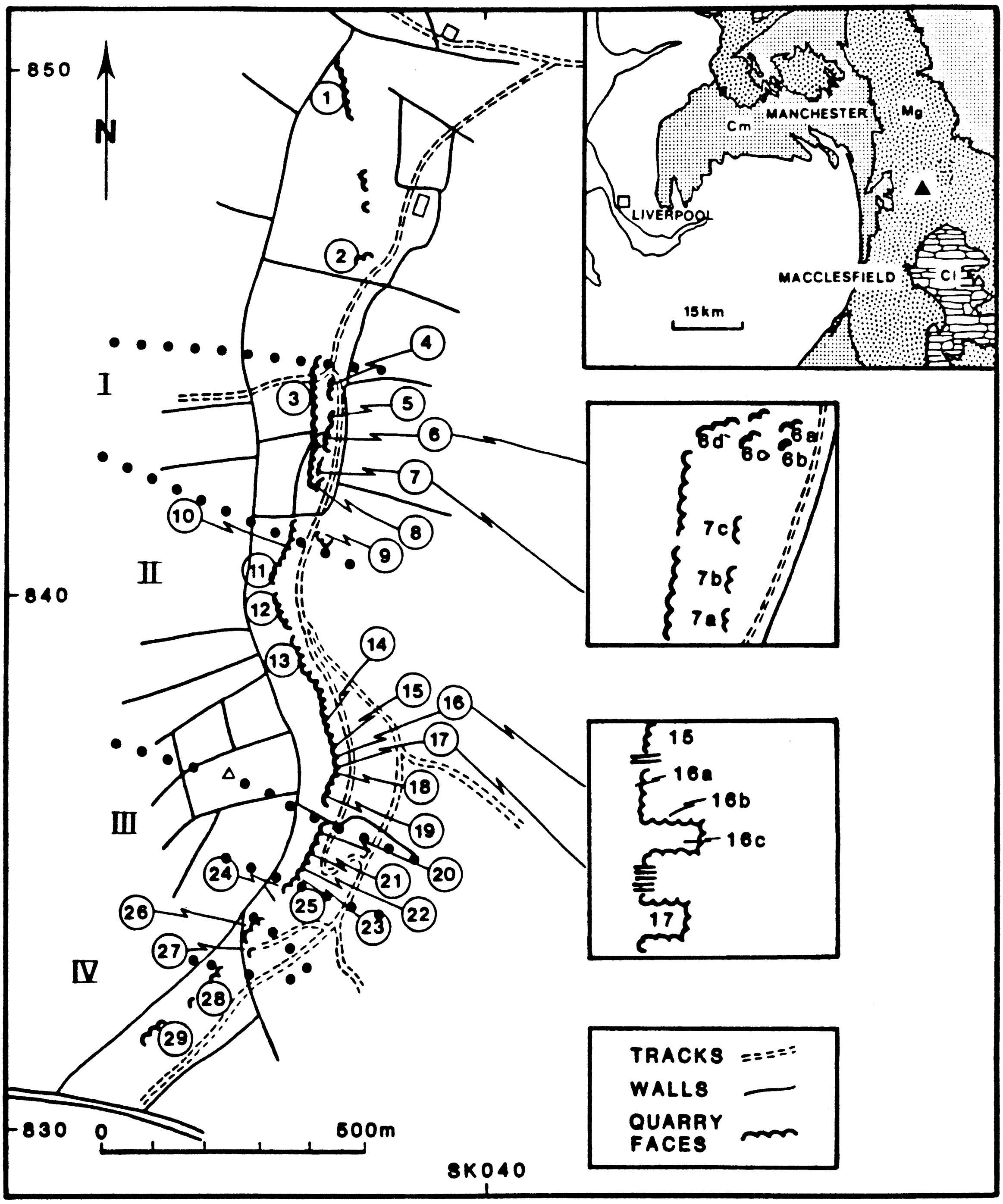


Fig. 1. Map of the location, outcrop and localities studied in the Rough Rock Group at Cracken Edge, Derbyshire.

The second sector forms the western flank of the first and is bounded by a line running from Colne through Blackburn to Parbold in central Lancashire, then east through Bury to the north-east and east of Manchester. Here the Rough Rock Group reaches thicknesses of 122m, and the Rough Rock itself 40m. The succession is distinctive–

Six Mine Coal (largely present).
Shales (in places).
Rough Rock upper leaf (shaley sandstones, very rare pebbly sandstones, and shales with *Carbonicola*).
Sand Rock Mine Coal.
Seat-earth or mudstone.
Rough Rock lower leaf (coarse and pebbly sandstones with a finer-grained flaggy base in the south).
Mudstones with *Carbonicola, Naiadites, Pelecypodichnus, Cochlichnus*, and *Limulicubichnus*.
The Haslingden Flags (in the north) or mudstones (in the south).

The remaining sector forms the eastern flank of the axial zone from the Leeds area through Barnsley and Sheffield to Chesterfield and south-east Derbyshire. The Rough Rock Group attains thicknesses of 70m in the north and 36m in the south, with the Rough Rock itself diminishing from 24 to 12m in the same direction. The succession is–

Pot Clay Coal.
Seat-earth or shales with *Carbonicola, Spirorbis*, and *Geisina*.
Rough Rock (non-pebbly sandstones, mudstone partings, very rare seat-earth or ganister).
Shales with *Carbonicola, Anthraconaia, Naiadites, Spirorbis*, and *Geisina*.

In lithological terms the Rough Rock Flags are fine-grained quartz arenites resembling the Shale Grit but with a substantial amount of mica. The Rough Rock is coarse, somewhat pebbly, subatkosic to arkosic, and broadly comparable with the Chatsworth Grit. On Cracken Edge, for example, the Flags are described by Harrison (in Stevenson and Gaunt, 1971) as well-sorted with igneous quartz, chert, feldspars and 13–21% micas. In contrast the Rough Rock is fairly well-sorted with igneous quartz, rock particles, feldspars (4.5—17%) and some mica (Stevenson and Gaunt, 1971, plate XX, fig. 1).

Ripple marks and primary current lineations are found in the Rough Rock Flags generally, and cross-bedding (mainly planar) is ubiquitous in the Rough Rock. According to Shackleton (1962) the palaeocurrent direction changes from southwards in the lower Rough Rock to south-westwards in the upper. As with other Namurian sandstones, large calcitic or ferruginous concretions—the 'mare's balls' or 'red horses' of the quarrymen—are common in the Rough Rock. The fauna of the Group above the marine bands—*Carbonicola, Anthraconaia, Naiadites, Spirorbis* and *Geisina* with the trace fossils *Pelecypodichnus, Cochlichnus, Planolites* and *Limulicubichnus*—are characteristic of the brackish to freshwater assemblages of the uppermost Namurian and Lower Westphalian in the Pennines (Calver 1968).

Interpretations of the origins of the Rough Rock Group sediments differ. The majority of authors have ascribed them to a shallow-water delta sheet (Collinson 1976), consisting of coarsening-upwards mudstone/siltstone slope deposits (without turbidites) topped by the sheet sandstones of migrating distributaries. On the other hand Shackleton (1962) concluded that the Rough Rock at least was deposited not by a large river system but by many relatively small rivers, aided by flash flooding, carrying sand and gravel over a slightly elevated continental margin very near sea level. Although Reading (1969) considered that Shackleton "underestimated the importance of lateral accretion by rivers", the latter's views have received support recently from Eagar et al (1985) who describe the Rough Rock as the sediments of "a complex of probably braided distributary channels flowing in general from the north-east and establishing the broad paralic basis of the subsequent Westphalian Coal Measures".

The southernmost extremities of the Rough Rock Group province present something of a puzzle. The Yeadonian deltas or river systems must ultimately have established a connection with the sea (or seas) responsible for the marine incursions of the *Gastrioceras cancellatum, cumbriense* and *subcrenatum* bands. But instead of marine sediments, the scanty borehole evidence from south Staffordshire and north Warwickshire (Mitchell 1954; Stevenson and Mitchell 1955; Taylor and Rushton 1971) suggests that the province dribbled away into marshland and lacustrine siltstones and mudstones with thin coals, seat-earths and very subordinate sandstones before the Mercian Highlands were reached. Did the deltas or rivers turn north-west into what is now the Cheshire Basin, or north-east into what is now the North Sea? An earlier north-westerly diversion has certainly been proposed for both the Roaches (Jones 1980) and Ashover (Chisholm 1977) deltas in the Marsdenian.

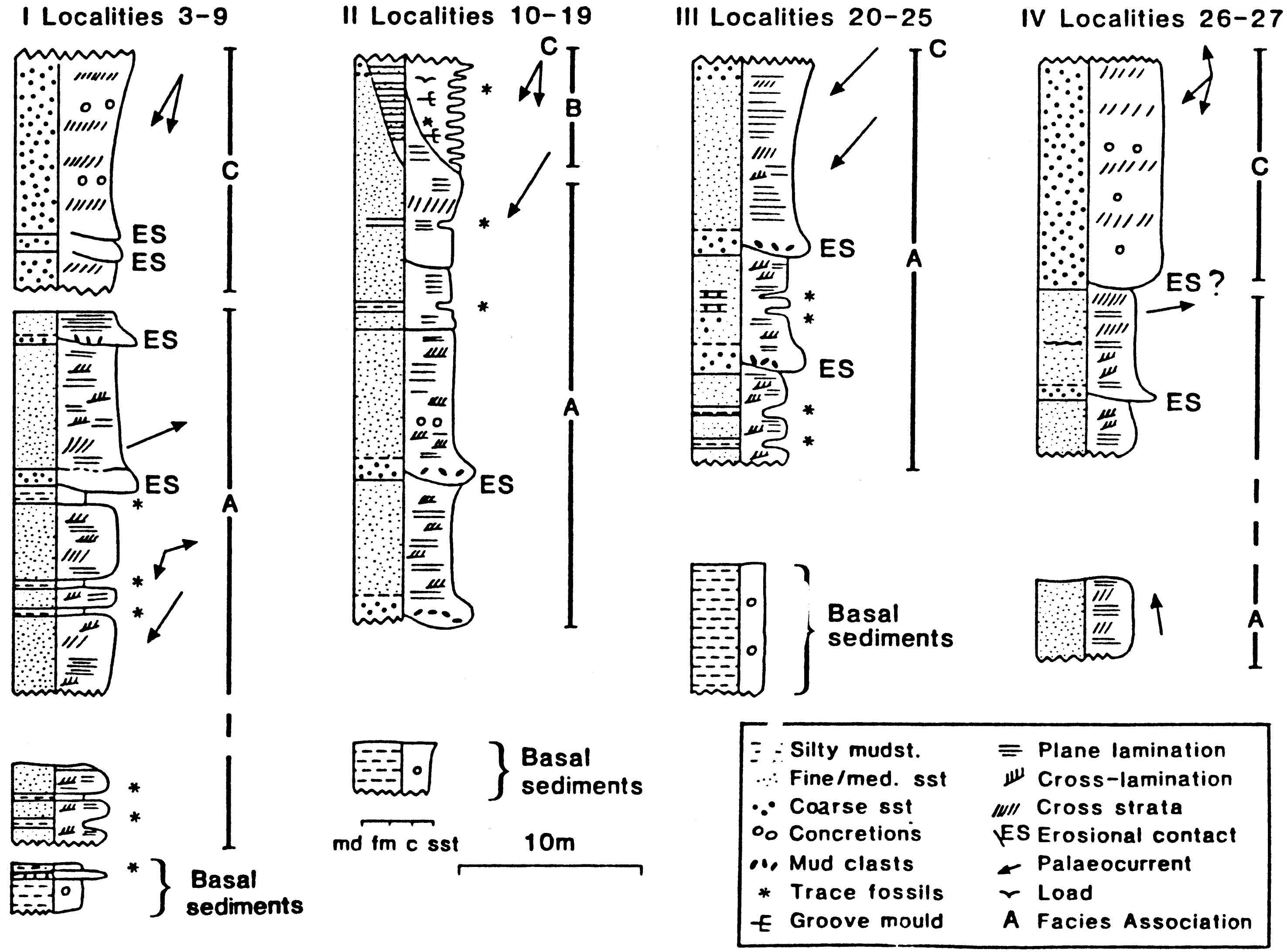


Fig. 2. Generalised graphic log of sediments and trace fossil horizons shown on Figure 1 (for discussion see text).

A. The Rough Rock Group Sediments on Cracken Edge

Introduction

Although the Cracken Edge quarries (see Fig. 1) extend for some 1500m from north to south, the detailed succession is not easily established. There are occasional hiatuses in the exposures, several changes in levels and relief, landslips and small faults. More important are the absence of good three-dimensional sections and the lack of persistent marker bands. The basal sediments of the Group are exposed at locality 25 and two smaller localities, although never in the full thickness seen a little further north at Foxhole Clough (SK 036859). They consist of dark grey to black mudstones and silty mudstones with horizons of small nodules, and weather to rusty iron hues. Their contact with the Rough Rock Flags is not visible at Cracken Edge. But at Foxhole Clough thin sandy laminae become increasingly frequent in the uppermost micaceous silty mudstones, and these are succeeded without an erosional break by an alternation of thin laminated and cross-laminated fine-grained sandstones with thin micaceous silty shales.

The lithofacies

In the succeeding Rough Rock Flags and Rough Rock five lithofacies can be recognised and arranged in three types of facies associations.

Facies 1. Silty mudstones and mudstones.

These are dark grey silty mudstones and mudstones containing some plant fragments. They form beds of 70–270mm thickness (generally 70–100mm) in the lower part of the succession and become infrequent thin lenses in the middle of it. Towards the very top, however, they occur again interbedded with sandstones in two areas and are thinner (mostly in the 30–80mm range).

Facies 2. Fine-grained laminated and cross-laminated sandstones.

These sediments—most of which probably indicate upper flow regime conditions—are found as follows:

(a) in the lower part of the Rough Rock Flags as sharp based sandstones, micaceous (with darker, more micaceous laminae alternating with lighter, less micaceous ones), and containing plant fragments. Amalgamations are locally present, some tops are cross-laminated, and loose slabs display poorly preserved ripple marks, 'rib-and-furrow' patterns and primary current lineations. A horizon of cross-laminated sandstone balls in siltstones at one locality resembles the ball-and-pillow structures of Reineck and Singh (1980), indicative of rapid sedimentation. Bed thicknesses vary considerably from 50mm to 1.5m, but the majority fall within the 100–300mm range.

(b) in the middle and upper parts of the Rough Rock Flags as thick (.5–1.5m) units, sharp based, weakly laminated, with some cross-laminated lenses and a number of large concretions.

(c) in two areas at the top of the Rough Rock Flags as thin (mostly 30–80mm), sharp based and weakly laminated sandstones alternating with lithofacies 1 silty mudstones in rhythmic sequences. They weather to distinctive colours—rusty brown, reddish, even purple—from their contact with the (presumably) iron-rich silty mudstones. They amalgamate and 'pinch-and-swell', and carry grooves and small loads as bottom structures. Some increase in size upwards is evident, and they appear to pass laterally into thicker sandstone units.

Facies 3. Fine-grained cross-bedded sandstones.

These are found locally as isolated units in the Rough Rock Flags. In the lower part of the succession they have been located at six localities, as single planar sets generally separated by laminated or cross-laminated beds. Forests dip at only 5–10 degrees, and set thicknesses vary from 200 to 400mm. Higher in the succession the sets become much larger on average. At locality 26 there are three trough cross-bedded sets up to 1m in thickness with tangential foresets dipping at 5 degrees, and separated from each other by thin units of laminated or cross-laminated sandstone. Similar trough cross-beds, incidentally, are to be found below an erosion surface at the Black Rocks (SJ 987830) a few kms away across the Goyt Trough.

Facies 4. Coarse pebbly sandstones above erosion surfaces.

Such sandstones with mud flakes, plant remains and large *Calamites* casts (up to 1.4m long and 270mm in diameter) occur at different levels throughout the succession. In the southern sector of the quarries there are two erosion surface units traceable for 140m, each 1-2m thick and some 4m apart. One such surface is found intermittently in the central sector, underlain in places by subsidiary erosion surfaces. In the northern sector two erosion surfaces are traceable in the Rough Rock Flags, and a number are scattered through the Rough Rock exposures (one with underlying subsidiaries). The bases of these surfaces undulate gently. Unfortunately no channel margins are visible, but in the southern part of the quarries the upper erosion surface appears to end abruptly as it is cut out by an overlying sandstone bed.

It is possible that the erosion surfaces in the Rough Rock Flags reflect two main erosional episodes. But with so many gaps in the exposures such a conclusion can only be speculative.

Facies 5. Coarse-grained bedded and cross-bedded sandstones.

These make up the Rough Rock at the top of the quarries. The beds have pebbly horizons and are generally thin (60–70mm). The cross-beds are mainly planar with rare trough sets; set thicknesses vary from 150 to 610mm, with most in the 200–300mm range, and foresets dip at low angles. Individual sets are more common than cosets. But at locality 1 a coset of three much larger planar sets (.9–1.8m in thickness) must constitute the megaripple beds of Wright (1964) with straight foresets inclined at an angle of nearly 30 degrees. Large concretionary masses are ubiquitous in this lithofacies, but no silty mudstone interbeds have been found.

Facies associations

Three associations appear to be present:

Type A. Consists of lithofacies 1 (silty mudstones) and 2a and b (fine-grained laminated and cross-laminated sandstones), together with occasional facies 3 (fine-grained cross-bedded sandstones) and facies 4 (coarse sandstones above erosion surfaces).

Type B. Facies 1 (silty mudstones) and 2c (fine-grained weakly laminated sandstones) alternating in rhythmic sequences. 19 sandstone beds are seen at locality 11, 38 at locality 12, and 19 at locality 15.

Type C. Facies 5 (coarse-grained bedded and cross-bedded sandstones) with locally facies 4 (coarser sandstones above erosion surfaces).

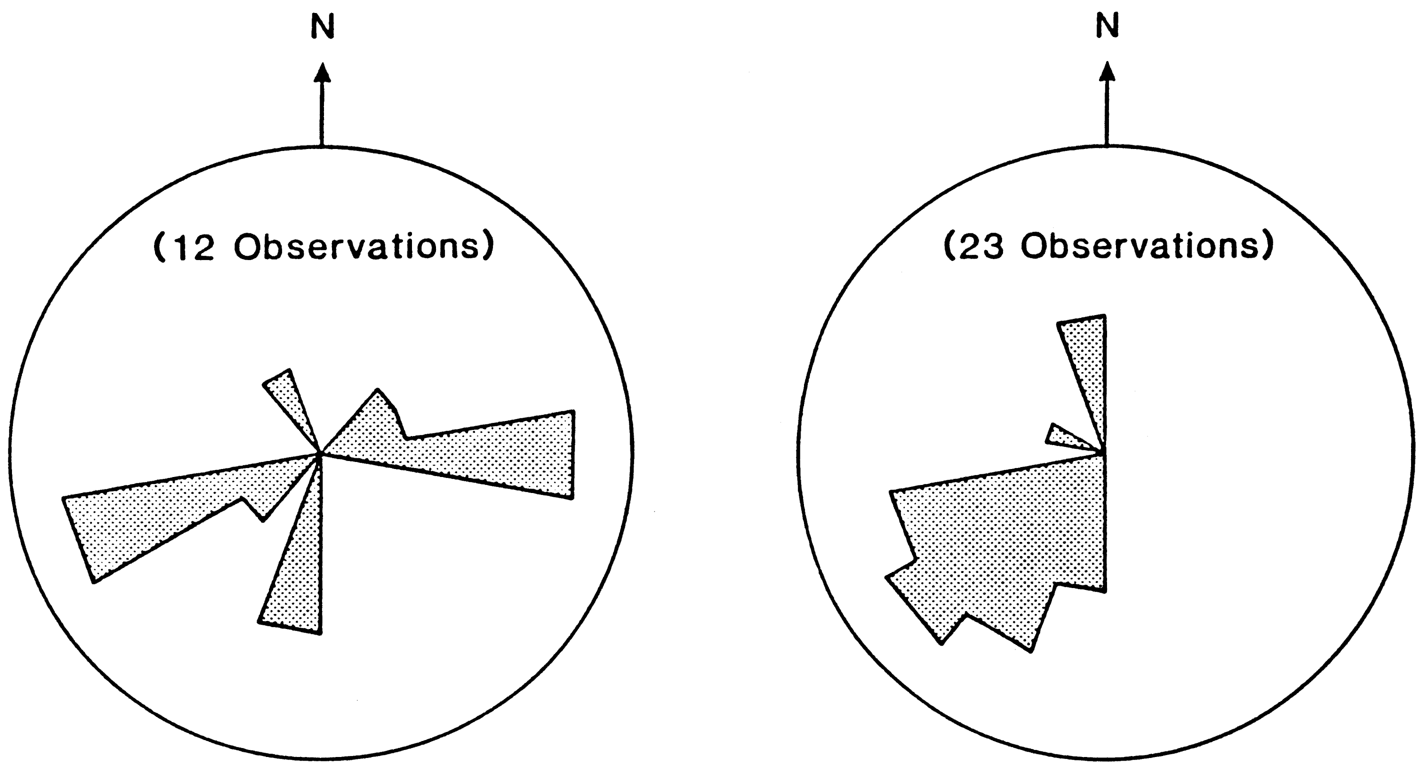
Distribution of facies associations

Working from north to south, the quarry at locality 1 (see Fig. 1) shows the top of Association A together with Association C. The crags to the south are in Association C, while locality 2 below is in the bottom of Association A. Localities 3–9 (Fig. 2, column I) display a much more complete section with almost the full thickness of Association A represented in the lower and middle exposures, and Association C at the top.

Localities 10–19 (Fig. 2, column II) show the upper part of Association A, Association B in two areas, and rare exposures (at the very top) of Association C. At localities 20–24, the line of crags to the south, and localities 26–27 (Fig. 2, columns III and IV) a fuller representation of Association A is present, together with Association C at the top. Finally, the crags to the south of locality 26 (see Fig. 1) are all in Association C.

The palaeocurrent evidence

The data for Facies Association A is unfortunately too scanty to warrant firm conclusions. The small numbers of cross-beds, however, indicate (see Fig. 3) a distinctly polymodal current pattern. There are indications that currents to the NE-E were dominant in the lower Rough Rock Flags, and changed to the SW-W higher up in the succession. Only one groove has so far been found in situ in Association B, giving a current direction of either SW or NE. For Association C more data is available (Fig. 3) and this suggests that palaeocurrent flows were mainly to SSW-WSW, with a few flows to the NNW.



(a) Facies Association A

(b) Facies Association C

Fig. 3. Palaeocurrent data from cross-bedding for Facies Associations A and C.

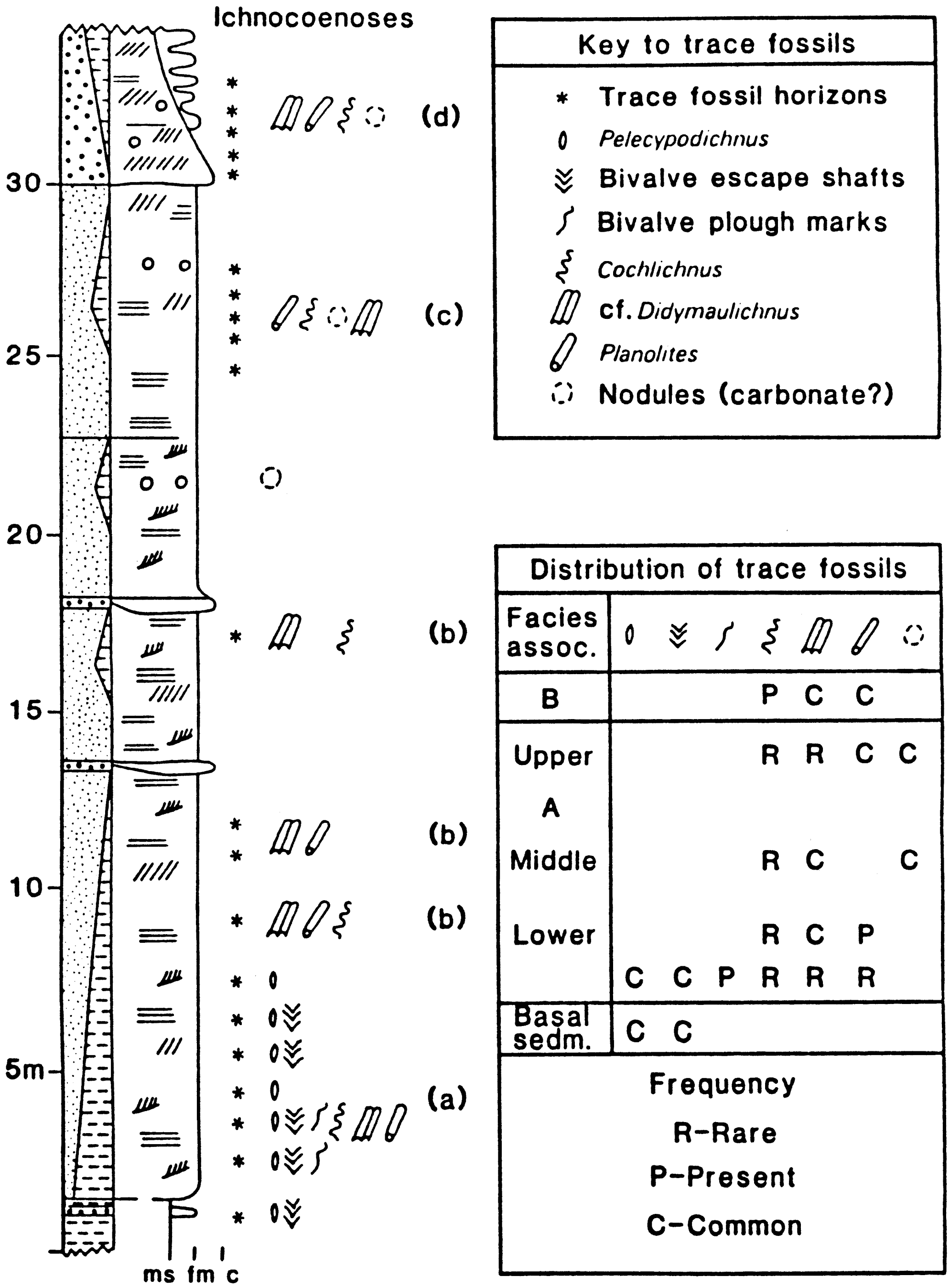


Fig. 4. Occurrence and diversity of trace fossils recorded from the Rough Rock Group at Cracken Edge.

Discussion—the sedimentary environment

In the broadest terms the Cracken Edge succession is a regressional, coarsening-up sequence. Silty mudstones of a probably brackish water environment are invaded by distal sandstones and silty mudstones as a consequence of hinterland uplift and/or climatic change. There are brief but violent influxes of much coarser sediments; silty mudstones become rare and isolated units of larger scale cross-bedding appear. Finally, the advancing fluvial system brings in coarser proximal sediments with many small channels before a final period of brief emergence.

Any attempt to provide a more detailed sedimentological interpretation encounters a number of problems. First, in Facies Association A. How do these laminated and cross-laminated fine-grained sandstones, with rare planar cross-beds, fit into the various Namurian delta models? Similar sandstones do make up the classical turbidites of Walker (1966) in the deep water deltaic sequences of Collinson (1976). But such deltas do not persist into the Yeadonian, and the Rough Rock Flags lack the grading, Bouma divisions, flutes and grooves of the classical turbidites; cross-bedding is very rare in the latter, and the mudstone/siltstone proportion is higher there.

In the shallow water sheet delta sequences of Collinson (op. cit.) fine-grained parallel—and cross—laminated sandstones appear to be restricted to the uppermost parts of some channel fills, as levees, or in interdistributary bay environments (Benfield 1969; Chisholm 1977; Jones 1980; Okolo 1983). But there is no evidence in the Rough Rock Flags of the large-scale channelling (with fills of coarse-grained sand-stone), the dominant trough cross-bedding, the significant proportions of mudstones and occasional seatearths that characterise the shallow water sheet delta sequences. Nor do the Rough Rock Flags compare well with the deposits of Collinson's shallow water, elongate delta type of sequence. In the Haslingden Flags (Collinson and Banks 1975) parallel-laminated sandstones are rare, and the dominantly cross-laminated bar finger sands of the delta front are backed by trough and planar cross-bedded sediments of migrating distributary channels.

Of the alternative fluvial models, the deposits of the large sandy, braided systems described by Collinson (1978) and Walker (1979) differ substantially from those of the Rough Rock Flags. Parallel-and cross-laminated sandstones are only a minor constituent in the former and are confined to bar tops in sequences made up of trough cross-bedded under planar cross-bedded sandstones. A more promising comparison is with the products of sheet floods—for example, the Bijou River type of sandy, braided river system (Miall 1977), although this has a semi-arid upland setting. Here repeated flash flood cycles produce a sequence which is dominated by fine to coarse, horizontally laminated sands with primary current lineations, but which also includes rippled sands, planar cross-bedded sands, erosion surfaces with some pebbles, and rare thin silt or clay beds.

Possible ancient examples of such sediments are not common. But in the United Kingdom they include the ORS Trentishoe Formation of North Devon (Tunbridge 1981). Here the main facies (A) consists of multistorey sand bodies of fine- to medium-grained laminated beds with erosive bases, primary current lineations and some ripples, together with occasional intra-formational conglomerates and some siltstones. These are interpreted by Tunbridge as the products of main (high energy) sheet floods, and they sometimes thin laterally and split into facies B sediments (thin-bedded, laminated sandstones alternating rapidly with siltstones) which represent lateral or distal floods. Cross-bedding, however, has not been found in the Trentishoe Formation.

Abroad, the braided river sediments in the lower Palaeozoic of the Cape Basin in South Africa (Vos and Tankard, 1981) suggest some comparisons with the Rough Rock Flags of Cracken Edge. Facies Association 6 (the distal alluvial plain sheet flood facies) consists of thick sequences of medium to coarse-grained laminated sandstones (with primary current lineations) and rare isolated sets of small-scale trough cross-beds. These are interpreted as the sediments deposited by sheet floods on a broad, distal alluvial plain with low gradients—a setting probably parallelled in the Yeadonian of the Pennines.

Next Facies Association B with its rhythmic alternations of fine-grained sandstones and silty mudstones. These have many of the characteristics of beds ascribed to levees or crevasse splays in the Namurian and indeed the Lower Westphalian (Broadhurst, Simpson and Hardy, 1980) delta complexes. But on Cracken Edge the setting is entirely different. There the rhythmic sequences appear to pass laterally into thicker sandstones and very thin silty beds of Association A, or on one flank into Association C. No deep channels are apparent at this level and there are no signs of flood plain silt-stones and mudstones. It seems more likely that the rhythmic sequences represent the distal or lateral accumulations of the repeated sheet floods which were responsible for Association A sediments. These floods did not necessarily cover the whole area with an even flow of sediments, and the strength of the palaeocurrents would vary from place to place, as in the Trentishoe Formation (Tunbridge, op. cit.).

Lastly there is the Facies Association C assemblage of coarse-grained bedded and cross-bedded sandstones with local erosion surfaces but no silty mudstones. Examples of this assemblage can be found in most of the shallow water sheet delta sequences of the higher Namurian. But the Rough Rock of Cracken Edge appears to lack many other features of such delta sequences—large concave-up channels, silty interbeds or lenses, a strong element of trough cross-bedding, and evidence of adjacent inter-distributary bay mudstones and siltstones. This is puzzling, and it is perhaps possible that the Rough Rock sediments are closer to those of the Platte type of sandy braided rivers (Miall, 1977) although here too the environment is a semi-arid upland one. In this very shallow, virtually non-cyclic flows produce a succession dominated by coarse (sometimes pebbly) sandstones with rare massive sandstones, horizontal gravels and sandstone/siltstone interbeds. An ancient relative of this type is perhaps the middle to distal braided alluvial plain facies association in the Cape Basin of South Africa (Vos and Tankard, op. cit.). This consists mainly of planar cross-bedded, coarse-grained and pebbly sandstone units with erosion surfaces and thin conglomerate lenses—all deposited by sedimentation within the transverse to linguoid bars of many small channels.

But perhaps the final word on the Cracken Edge problems must lie with Bridge (1985)–

> "we must ... be prepared to accept partial solutions to palaeogeographic reconstructions if exposure is inadequate".

B. Trace fossils from Cracken Edge

These were first discovered and described by Hardy (1970) who attributed the majority to the activities of bivalves under the ichnogenus *Pelecypodichnus*, including resting traces, escape shafts and plough marks. The resting traces—*Pelecypodichnus amygdaloides* Seilacher (or *Lockeia*)—occurred as hypichnial casts and epichnial depressions, between 5 and 30mm long. Escape shafts were commonly associated with them, varying from a few centimetres to 1m in height, normally vertical but sometimes slightly inclined. The plough marks sometimes led into, or from, the resting traces, and were preserved as hypichnial ridges and epichnial grooves. They varied from "a few" to 20–30cm in length, straight to irregularly and slightly curved, unbranched (but occasionally meeting), and at Cracken Edge showing evidence of both lateral and vertical movement. A preferred orientation was detected in both the resting traces and plough marks, parallel with the direction of prevailing currents.

In addition to bivalve trace fossils Hardy found a possible *Limulicubichnus* arthropod trace, and several *Cochlichnus* trails—mainly hypichnial, sinuous and unbranched, with a diameter of 1—4mm and a common association with *Pelecypodichnus*. Lastly, the concretions of the area were described as carbonate (usually ankeritic)—cemented and were interpreted as the product of the accumulated shells of dead bivalves.

Details

Trace fossils have been found as hypichnia at several horizons on Cracken Edge where sandstones and silty mudstones are juxtaposed (Fig. 2) in Facies Associations A and B. Their broad distribution is shown in Fig. 4 on a composite section through the succession. The ichnofauna consists of *Pelecypodichnus* resting traces, escape shafts and possible plough marks; *Cochlichnus, Planolites* and *Didymaulichnus*?

Ichnogenus *Pelecypodichnus* Seilacher 1953.

Plate 12A

1. *Resting traces*

The characteristic almond-shaped bivalve resting traces are present at the top of the basal sediments in Foxhole Clough and in the lowest part of Facies Association A at localities 4–9 on Cracken Edge itself. Loose slabs from above locality 25 show that they were also present at the same level in the southern sector of the quarries. Resting traces in the lowest exposures are moderate sized—up to 15mm in length, 10mm in width and 3mm in height. They are irregularly distributed but sometimes paired, without a preferred orientation. Most show a steeper slope down one side than the other, and one end is commonly facetted. Some have a short 'tail'—resembling a tadpole—and are similar to the *Lockeia siliquaria* James 1879 shown in Pickerill (1977, plate 2a).

Higher in the succession the beds of localities 6a and b show a profusion of classic resting traces, up to 25mm long, 20mm wide and 5mm high. There are indications of a preferred orientation with long axes aligned 120–300 degrees T. Higher still, resting traces of moderate size have been found at localities 7b and 8, and small ones at 6c (lower beds).

2. *Escape shafts*

These vertical structures perforating and downturning laminations in the sediments have been found in the Foxhole Clough exposures and at localities 9, 4, 6a and 7b. They are especially plentiful at 6a and are up to 210mm in height.

3. *Plough marks*

Straight to slightly sinuous ridges and grooves, crossing but not branching, up to 15mm in length and 2mm in width, have been found at locality 4. These are only rarely connected to resting traces, and indeed are sometimes overlain by the latter. They compare closely with those of Unit 2, Standedge Cutting (Eagar et al, 1985, Plate 7A) and are therefore interpreted as possible bivalve plough marks. No similar traces have been identified at locality 6a or in any of the higher *Pelecypodichnus*-bearing beds. But two loose sandstone slabs from the general area of localities 15–18 carry slightly sinuous median furrows and cylindrical lateral ridges (cf Hardy 1970, figure 3.6). The least weathered trail is 130mm long and 6mm wide. It displays more than a hint of transverse striations on the lateral ridges, suggesting a comparison with *Chevronichnus* Hakes (Hakes, 1976) interpreted as a bivalve trail.

Ichnogenus *Cochlichnus* Hitchcock 1857

Plate 12B

Typical sinuous trails up to 18mm long and 1mm wide are present at locality 4, sometimes clustered together and associated with *Pelecypodichnus* (see Eagar et al, 1985, Plate 12 E, F). They have also been found higher up in Facies Association A at 6c and 21, and still higher at locality 16. They are commoner in Facies Association B at localities 11, 12 and 15.

Ichnogenus *Planolites* Nicholson 1873

Plate 13A

The sandstones of locality 4 carry several horizontal hypichnial traces, up to 80mm long and 5mm wide, which are straight to slightly sinuous and occasionally cross. They have no apparent connection with the *Pelecypodichnus* resting traces, and probably belong to the *Planolites* group of Pemberton and Frey (1982) who tentatively identify them as the feeding or foraging burrows of deposit-feeding polychaete worms. *Planolites* also occurs in the middle of 6c and is there associated with nodules and with more substantial traces of bold relief, up to 65mm long, 15mm wide and 5mm in height.

Planolites burrows are found in Facies Association A at localities 20–24 in the southern sector of the quarries. They are also present higher up at locality 16–a medium-sized type, and also a profusion of delicate, very thin and short (4–9mm) traces which resemble the *Planolites montanus* of Pemberton and Frey (op. cit.). Medium-sized *Planolites* are found in Facies Association B at localities 11, 12 and 15.

Ichnogenus *Didymaulichnus* Young 1972

Plate 13A, B

A few of the horizontal hypichnial ridges of locality 4 are bilobed with a median furrow, straight to slightly sinuous in direction and up to 140mm long. These trails are tentatively included in *Didymaulichnus*, endogene trails of a gastropod or arthropod (Young 1972). Higher up in Facies Association A several similar trails have been found at localities 20–24. They are straight to slightly sinuous, crossing but not branching, and on average 120mm long, 5mm wide and 3mm high. They have a preferred orientation–N-S in lower beds, ENE-WSW in higher ones. Associated with these trails are nodules, often large and irregularly circular in shape, and in some cases with trails radiating away from them.

Such trails and nodules are also found still higher at localities 20–21 with an ENE-WSW orientation, and they may also be present at localities 16 and 17. They have been identified in Facies Association B at localities 11–12 and 15. Here they are bold with a pronounced relief, and attain 150mm in length, 9mm in width and 8mm in height. Only a small number display the median groove, but all attain the same dimensions. They cross only occasionally, and most show the 'pinch and swell' variation in width and height noted by Pickerill, Romano and Melendez (1984). A preferred orientation is usual, varying from bed to bed but mostly aligned ENE-WSW. There are many nodules, sometimes connected to the trails.

The ichnocoenoses

The distribution of the traces through the succession (Fig. 4) appears to justify recognition of four trace fossil assemblages or ichnocoenoses–

Ichnocoenosis a.

This is found in the basal silty mudstones and in the lowest beds of Facies Association A. It is dominated by *Pelecypodichnus* (peaking at the level of localities 6a and b, and declining thereafter) with rare *Cochlichnus, Planolites* and *Didymaulichnus*?.

Ichnocoenosis b.

Found in higher beds of Facies Association A. Dominated by *Didymaulichnus?*, with some *Planolites* and rare *Cochlichnus*.

Ichnocoenosis c.

Found towards the top of Facies Association A. Dominated by *Planolites* with rare *Cochlichnus* and *Didymaulichnus?*.

Ichnocoenosis d.

Found in Facies Association B. Dominated by *Didymaulichnus?*, with *Planolites* and *Cochlichnus*.

Discussion—the trace fossil distribution

The most surprising outcome of the present inquiry has been its failure to find the *Pelecypodichnus* assemblage present throughout the Cracken Edge succession. Resting traces, escape shafts and possible plough marks are certainly there, but only, it would appear, at the lowest levels. In higher beds they are absent and the traces of *Planolites* and *Didymaulichnus?* are dominant.

A similar separation (in space and time) between the traces of suspension feeders like *Pelecypodichnus* and those of internal sediment feeders such as *Planolites* is not without parallel in other Rough Rock exposures. At Millbrow quarry (SJ 97908954) not far away a sequence of thin sandstones and silty mudstones is exposed towards the middle of the section. *Pelecypodichnus, Cochlichnus* and rarer horizontal linear traces are found beneath the two lowest sandstones. *Pelecypodichnus* then disappears and is replaced by *Cochlichnus*, short trails of the *Planolites* type, and nodules which become more frequent upwards. But under the seventh sandstone large resting traces with excellent escape shafts reappear. Billinge Hill quarries (SJ 955777), also in the Rough Rock, seem to tell much the same story with bivalve shells, resting traces and escape shafts in the lower levels and *Planolites*-type traces at the top.

Further down in the Namurian distinct levels for *Pelecypodichnus* and *Planolites*, with little overlapping, are the general rule in the Grindslow Shales—as for example, in the excellent exposures at Torside Clough (SK 070971), Yellowslacks Brook (SK 074954), Crooked Clough (SK 0944), and Blackden Brook (SK 119883). As Eagar et al (1985) say, "the two trace fossils are mutually exclusive in terms of their host lithology, but can alternate in an interbedded sequence" with *Planolites* flourishing in organic-rich muds and the bivalves only in fine to medium-grained sandstones.

But what could have caused the separation on Cracken Edge between the *Pelecypodichnus* assemblage and that of *Didymaulichnus?/Planolites?*. No dramatic change in the sedimentary regime appears to have taken place since the laminated sandstones and silty mudstones which provided the host sediments are indistinguishable (macroscopically at least) at the relevant levels. The ratio of silty mudstone to sandstones does not increase upwards but in fact decreases as the bivalves disappear and the internal sediment feeders take over. Overall the thickness of individual beds and lenses of silty mudstones shows little increase upwards. There is some increase in the thickness of sandstone beds, but this is interrupted from time to time by sequences of thinner beds. Sedimentological control, therefore, does not seem to have operated in this case at least.

All that the available exposures apparently indicate is that the characteristic traces of the bivalves appear with the early influxes of sand into the muddy environment. As Broadhurst et al (1980) point out, this suggests "either that the bivalves gained some advantage from an environment subject to the periodical arrival of flood detritus, or that the bivalves arrived with the floodwater, survived and re-established themselves". They reach a moderate size; tolerate the presence of *Cochlichnus* and a few other internal sediment feeders; disappear at some levels but with restocking reappear at higher ones. Then a little higher up, very large bivalves take over the whole environment. No pause in sand sedimentation can be found to explain their growth. Some environmental change in channel fill may have been responsible; and the presence of complex cross-bedded sandstones below the *Pelecypodichnus*-rich horizon might suggest more variable and turbulent currents bringing larger food supplies for the new generation of bivalves.

This generation was able to survive further influxes of sand—perhaps 620mm in thickness on the evidence of the escape shafts at locality 6a. But the resting traces are noticably fewer and smaller at the top of this section, and with a further 1.5 m of sand (with very thin mudstone intercalations) these large bivalves died out. With restocking a new generation of moderate size established itself at slightly higher sandstone/silty mudstone interfaces, but it could not survive further substantial influxes of sand and died out. The supply of bivalves and/or their food supplies dried up—perhaps because of changes in current directions or the advance of more proximal, sand-laden water—and the environment was left to the more adaptable, internal sediment feeding arthropods and worms. Bivalves might well have been expected to reappear, as at Millbrow quarry, in the rhythmic sandstone-silty mudstone sequences of Facies Association B. But perhaps the muds here carried too much iron to allow of their establishment.

Finally, something should be said about the large concretions in the Cracken Edge quarries. These appear for the first time in the middle of Facies Association A (see Figs. 2 and 4). They are well above the *Pelecypodichnus* horizons; they are only rarely close to silty mudstone lenses (in which presumably bivalves could flourish); and those accessible for testing give no definite calcareous reaction. It seems unlikely, therefore, that they are the product of the accumulation of dead bivalve shells (Hardy 1970).

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References

Benfield, A.C., 1969. The Huddersfield White Rock cyclothem in the central Pennines. Report of Field Meeting. *Proc. Yorks. Geol. Soc.* 37, 181–187.

Bridge, J.S.P., 1985. Palaeochannel patterns inferred from alluvial deposits: a critical evaluation. *J. Sed. Petrology*. 55, 579–589.

Broadhurst, F.M., Simpson, I.M. and Hardy, P.G., 1980. Seasonal sedimentation in the Upper Carboniferous of England. *J. Geology*. 88, 639–651.

Calver, M.A., 1968. Coal Measures invertebrate faunas. *In*, Murchison, D., and Westoll, T.S. (Eds.), *Coal and Coal Bearing Strata*. Edinburgh, Oliver and Boyd, pp. 147–177.

Chisholm, J.I., 1977. Growth faulting and sandstone deposition in the Namurian of the Stanton syncline. *Proc. Yorks. Geol. Soc.* 41, 305–323.

Collinson, J.D., 1976. Deltaic evolution during basin fill—Namurian of Central Pennine Basin (abstract) *Bull. Am. Assoc. Petroleum Geol.* 60, 52.

Collinson, J.D., 1978. Alluvial sediments. *In*, Reading, H.G. (Ed). *Sedimentary Environments and Facies*. Oxford: Blackwell, pp. 15–60.

Collinson, J.D., and Banks, N.L., 1975. The Haslingden Flags (Namurian GI) of south east Lancashire: bar finger sands in the Pennine Basin. *Proc. Yorks. Geol. Soc.* 40, 431–458.

Eagar, R.M.C., Baines, J.G., Collinson, J.D., Hardy, P.G., Okolo, S.A., and Pollard, J.E., 1985. Trace fossil assemblages and their occurrence in Silesian (Mid-Carboniferous) deltaic sediments of the Central Pennine Basin, England. *In*, Curran, H.A. (Ed), *Biogenic structures: their use in interpreting depositional environments. Society of Economic Paleontologists and Mineralogists Special Publication* No. 25. Tulsa, Oklahoma, pp. 347.

Hakes, W.G., 1976. Trace fossils and depositional environments of four clastic units, Upper Pennsylvanian megacycolthems, north east Kansas. *Univ. Kansas Paleont. Contributions*, 63, 1–46.

Hardy, P.G., 1970. *Aspects of Palaeoecology in the arenaceous sediments of Upper Carboniferous age in the area around Manchester.* Unpub. Ph.D. dissertation, University of Manchester.

Jones, C.M., 1980. The Roaches Grit. *Proc. Yorks. Geol. Soc.* 43, 39–67.

Miall, A.D., 1977. A review of the braided river depositional environment. *Earth Sci. Revs.* 13, 1–62.

Mitchell, G.H., 1954. The Whittington Heath Borehole. *Bull. Geol. Surv.* G.B. 5, 1–60.

Okolo, S.A., 1983. Fluvial distributary channels in the Fletcher Bank Grit (Namurian R2b) at Ramsbottom, Lancs. *In*, Collinson, J.D. and Lewin, J. *Modern and Ancient Fluvial Systems*. Oxford: Blackwell, pp. 575.

Pemberton, S.G. and Frey, R.W., 1982. Trace fossil nomenclature and the *Planolites-Palaeophycus* dilemma. *J. Paleontol.* 56, 843–881.

Pickerill, R.K., 1977. Trace fossils from the Upper Ordovician (Caradoc) of the Berwyn Hills, Central Wales. *Geol. J.* 12, 1–16.

Pickerill, R.K., Romano, M., and Melendez, B., 1984. Arenig trace fossils from the Salamanca area, Western Spain. *Geol. J.* 19, 249–269.

Ramsbottom, W.H.C., 1977. Major cycles of transgression and regression (mesothems) in the Namurian. *Proc. Yorks. Geol. Soc.* 41, 261–391.

Reading, H.G., 1969. Sedimentation sequences in the Upper Carboniferous of N.W. Europe. *C.R. 6me Cong. int Carb. Strat. Geol.*, Sheffield 1967, vol IV, 1401–1411.

Reineck, H.E. and Singh, I.B., 1980. *Depositional Sedimentary Environments*. Berlin: Springer-Verlag. pp. 549.

Shackleton, J.S., 1962. Cross-strata of the Rough Rock (Millstone Grit series) in the Pennines. *Geol. J.* 3, 109–118.

Stevenson, I.P. and Gaunt, G.D., 1971. Geology of the Country Around Chapel-en-le-Frith. *Mem. Geol. Surv. U.K.* HMSO, London. 444pp.

Stevenson, I.P. and Mitchell, G.H., 1955. Geology of the Country between Burton upon Trent, Rugeley and Uttoxeter. Mem. Geol. Surv. U.K. HMSO, London. 178pp.

Taylor, K. and Rushton, A.W.A., 1971. The pre-Westphalian geology of the Warwickshire coalfield. *Bull. Geol. Surv. G.B.* 35, 1–150.

Tunbridge, I.P., 1981. Sandy high-energy flood sediments—some criteria for recognition, with an example from the Devonian of South West England. *Sedimentary Geology*. 28, 79–95.

Vos, R.G. and Tankard, A.J., 1981. Braided fluvial sediments in the Lower Palaeozoic Cape Basin, South Africa. *Sedimentary Geology*. 29, 171–193.

Walker, R.G., 1966. Shale Grit and Grindslow Shales: transition from turbidite to shallow water sediments in the Upper Carboniferous of northern England. *J. Sed. Petrology*. 36, 90–114.

Wright, M.D., 1964. Cross bedding in the Millstone Grit of the Central Pennines and its significance. *Geol. Mag.* 101, 520–530.

Young, F.G., 1972. Early Cambrian and older trace fossils from the Southern Cordillera of Canada. *Can. J. Earth Sci.* 9, 1–17.

Plate 12A

Pelecypodichnus resting traces and bivalve plough marks. Ichnocoenosis (a). Locality 4, Cracken Edge, Derbyshire (specimen MGSF 96. Dept. Geology, University of Manchester Special Collections).

Plate 12B

Cochlichnus sp. associated with *Planolites* burrows. Ichnocoenosis (c). Locality 16, Cracken Edge, Derbyshire (specimen MGSF 97).

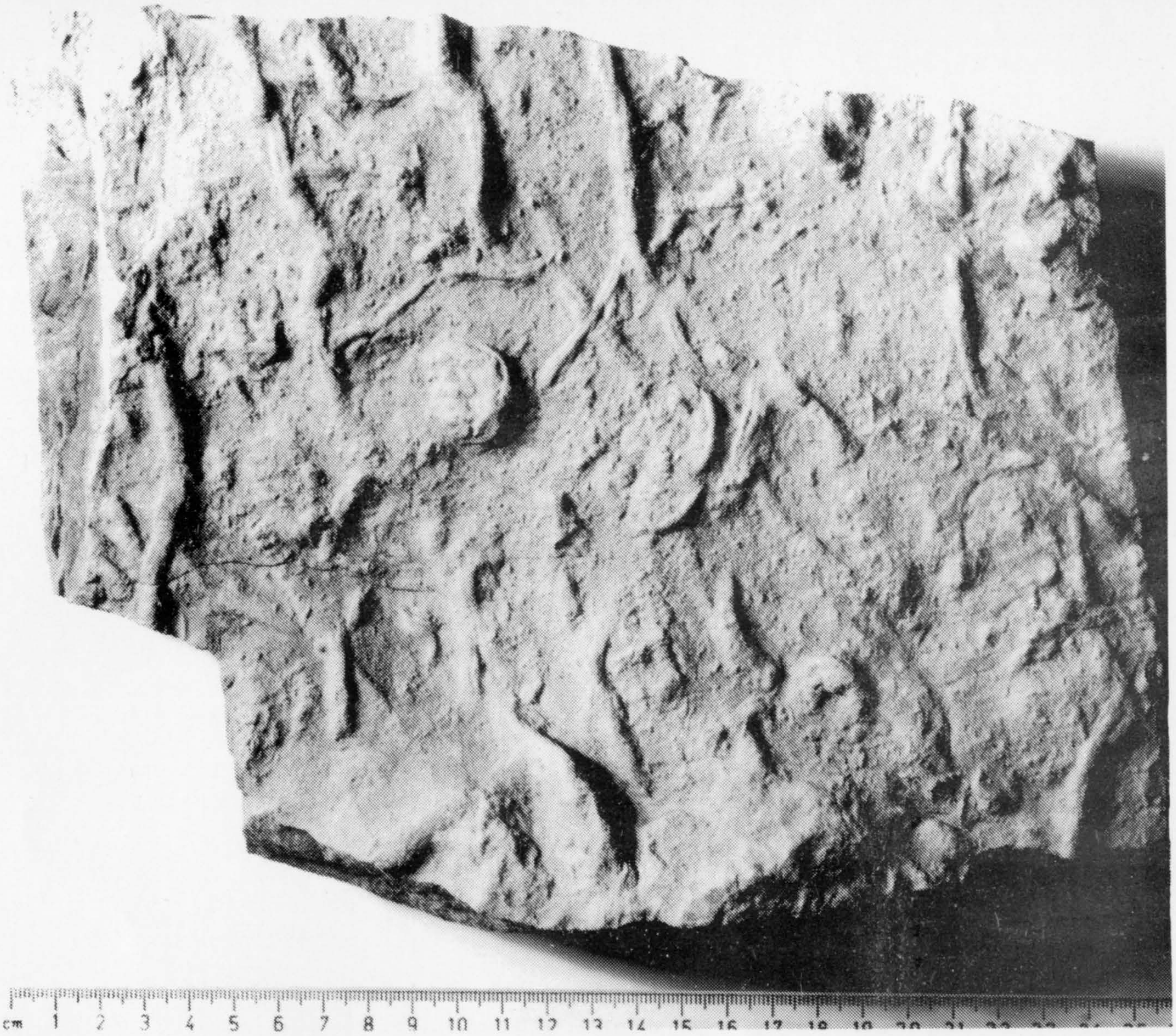

Plate 13A

Didymaulichnus? (bilobed hypichnial ridges) and *Planolites* (horizontal curved burrows). Ichnocoenosis (b). Locality 24, Cracken Edge, Derbyshire (specimen MGSF 98).

Plate 13B

Didymaulichnus? (variable length, parallel bilobed hypichnial ridges) and cross cutting *Planolites*. Ichnocoenosis (d). Locality 11, Cracken Edge, Derbyshire (specimen MGSF 99).