Precambrian Rocks of England and Wales

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Palaeontology Chapter by

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Chapter 8

Precambrian palaeontological sites

INTRODUCTION

J.C.W. Cope

Precambrian palaeontology is a subject that less than half a century ago could have been dismissed in a few paragraphs. Palaeontologists had long been perplexed by the major faunal break at the base of the Cambrian and the Precambrian rocks below were regarded as non-fossiliferous. There was, however, a general recognition that the early Cambrian faunas, which are very diverse and of sudden and cosmopolitan appearance, must have had Precambrian ancestors. There were undoubtedly large areas of late Precambrian sedimentary rocks that appeared to have suffered no high degree of subsequent metamorphism, but they proved to be always unfossiliferous. The first Precambrian fossils to gain credence as truly organic in origin were stromatolites, now recognized as structures produced by cyanobacteria (blue-green algae). These were found in considerable numbers in the Proterozoic rocks of the Canadian Shield, and subsequently in other areas of the world, but there was little if any trace of remains that could be ascribed to animals. In fact when the first Precambrian animal fossils were found, they were initially dismissed as pseudofossils by most palaeontologists.

The first accounts of Precambrian fossils were those of Salter (1856, 1857) who described a series of impressions found in the late Neoproterozoic Longmyndian Supergroup rocks of the Long Mynd, Shropshire. Some of his figures and descriptions are over-optimistic interpretations of inorganic impressions and these have been rightly dismissed. But dismissal of all of Salter's material, such as was done by the Geological Survey (Greig *et al.*, 1968) and by other authors, is no longer tenable. Although many of the impressions are of unknown origin, their organic nature is emphasized by the fact that similar impressions are known from other parts of the world. They nevertheless appear always to be restricted to late Neoproterozoic and early Cambrian rocks and this provides the most convincing argument for their organic affinities.

The first records of Precambrian body-fossils were similarly dismissed as inorganic structures. The earliest of these was the discoid *Aspidella*, described by Billings (1872) from the late Proterozoic of Canada. *Aspidella* has been discussed by many authors and most have concluded that it was a pseudofossil; this view persisted until very recently following a major review by Hofmann (1971), but recently specimens have been found from the Avalon Peninsula of Newfoundland that show that the genus bears considerable similarities to *Cyclomedusa*, and *Aspidella* has been re-interpreted as a benthic medusoid (Narbonne and Gehling, 1998) thus confirming Billings' (1872) original contention that it was an animal fossil.

The Nama Group of Namibia was the next to yield Precambrian animal remains. Three genera of frondose organisms were initially described by Gürich (1929, 1933) as coelenterate grade animals. These fossils were subsequently redescribed by Richter (1955) who concluded that although the fronds of the genus *Pteridinium* were rather like a marine alga, they were more likely to be a colonial animal and possibly a gorgonoidean octocoral. However, this was not the view of the next to work on these specimens, Pflug, who concluded that these organisms could not be ascribed to any known group of animals, but instead belonged to an extinct phylum that he named the Petalonamae (Pflug, 1972). This group was regarded as metazoan, but totally separate from other metazoan phyla. Runnegar (1995) has shown that there are major problems with Pflug's interpretation of these fossils, and what appear to be nothing more than associations of pseudofossils and irregular granular structures were used by Pflug to construct hypothetical models of evolution of petalonaman colonies.

The most widely known Precambrian animal fossils are those that later came to be known as constituting the original Ediacaran Fauna. The first fossils were found in the Ediacara Hills in the Flinders Ranges of South Australia, some 450 km north of Adelaide. Sprigg (1947) recorded a fauna of medusoid fossils from the Pound Quartzite of Ediacara that he likened with those of the Lower Cambrian in other parts of the world. Sprigg's fossils were accepted as well-preserved Cambrian medusoids and were described as such in Volume F of the *Treatise on Invertebrate Paleontology* (Moore, 1956); it was not until some years later that Glaessner decided to look in more detail at these fossil remains. One of his first conclusions (Glaessner, 1959) was that these fossils occurred a considerable stratigraphical distance beneath the earliest trilobites (Atdabanian), and the Pound Quartzite that yielded them was separated from the rocks above by a profound regional unconformity. The fossils were therefore unlikely to belong to the earlier (pre-trilobite) part of the Cambrian and instead must be of latest Precambrian age. Glaessner and his colleagues went on to describe other fossils from the Ediacaran sites including, in addition to a wide range of coelenterates that includes 'medusoids' and pennatulids, a diverse assemblage of polychaete worms, rare arthropods, and a range of other fossils of uncertain affinities (e.g. Glaessner and Wade, 1966). New fossils are still being found at Ediacara, the latest being sponges, which being among the most primitive multi-cellular animals had been long expected to have existed in Neoproterozoic times (Gehling and Rigby, 1996).

One of the next areas to yield Precambrian fossils was Charnwood Forest, Leicestershire, where a local schoolboy, Roger Mason, discovered a frondose impression in 1957. Ford (1958) subsequently described this as *Charnia masoni*. Initially the specimen was believed to be a complex marine alga, but later was re-interpreted as a pennatulacean coelenterate. This discovery prompted renewed interest in the Charnwood Forest Precambrian rocks and there have subsequently been many more discoveries in the area (see section on the Charnwood Forest GCR sites below for details).

Precambrian rocks of other areas of the world also began to yield fossils, and faunas were recorded from Sweden (Strand and Kuhling, 1972), the Ukraine (Palij, 1969), Siberia (Sokolov, 1973) and Newfoundland (Misra, 1969). Faunas discovered in the White Sea area of northern Russia (Keller *et al.*, 1974) included several species in common with Ediacara. The discovery of an Ediacaran fauna in South Wales (Cope, 1977) appears to be unique in that it was the Ediacaran fossils that proved the Precambrian age of the rocks, which had been mapped by the Geological Survey (Strahan *et al.*, 1909) as of early Ordovician (Arenig) age (see below).

By the late 1970s knowledge of Ediacaran faunas was extensive and with it came recognition that this was a cosmopolitan fauna that had existed shortly before the 'Cambrian explosion'. No biozones have been erected for these fossils, although there appear to be some differences between the 'early' faunas of Wales (Coed Cochion GCR site) and Newfoundland, and the 'late' faunas of the White Sea and Ediacara, which contain a greater diversity of forms. Differences between the Charnwood Forest Precambrian faunas and those found worldwide are discussed later in this chapter. With the renewed interest in early Cambrian fossils there arose the question of the relationship between Ediacaran animals and Cambrian forms. Was it correct to ascribe the Ediacaran fossils to extant groups of coelenterates and annelids, for instance, or did the Ediacaran faunas represent a short-lived experiment in animal design? Views became polarized on these questions and the whole subject came in for renewed controversy following Seilacher's (1989) hypothesis that many of the Ediacaran animals were totally unrelated to modern phyla; the 'Vendozoa' were represented as unique quilt-like organisms that were filled with plasmodial fluid and that were immobile. Other Ediacaran organisms he did relate to extant phyla, but interpreted the worm-like forms as producing medusoid-like trace fossils, whereas others were sand-filled polyps (Psammocorallia of Seilacher, 1992). Retallack (1994), however, proposed an entirely different hypothesis, namely that the Ediacaran fossils were lichens. Neither of these hypotheses has gained wide acceptance and Runnegar (1995) concluded that the Ediacaran fauna was a sample of Neoproterozoic biodiversity. This view was reinforced by Conway Morris' (1993) description of Ediacaran-like fossils from the Middle Cambrian Burgess Shale, thereby dispelling the belief that Ediacaran organisms were confined to the Vendian. Subsequently Jensen *et al.* (1998) described Ediacaran fossils from what undoubtedly are early Cambrian rocks in South Australia. Despite this extension of Ediacaran faunas into the Cambrian, it is not always possible to construct evolutionary paths, linking them to Cambrian organisms. Some authors have nevertheless concluded that certain Ediacaran taxa, such as *Charniodiscus*, may have direct Phanerozoic counterparts (Conway Morris, 1993; Crimes and McIlroy, 1999). The essential feature of these latter assemblages, setting them apart from Ediacaran forms, is the abundance of exoskeletons in trilobites, brachiopods, molluscs etc..

Examination of the organizational level of the Ediacaran fauna leaves no doubts that there must have been earlier animals. Reliable dates of the Ediacaran faunas are few, but include 565 ± 3 Ma (Benus 1988) from Newfoundland down to younger than 543 ± 1 Ma from southern Namibia (Narbonne *et al.*, 1997). We thus have a range of some 22 Ma virtually up to the base of the Cambrian, with the more complex Ediacaran assemblages believed to all lie close to the latter date (Narbonne *et al.*, 1997). Several earlier Precambrian animal fossils have been occasionally recorded from various localities worldwide, but on investigation these have thus far mainly proved to be either incorrectly dated animal remains, or to be inorganic. However, predictions of the divergence of animal phyla based on the evidence of molecular work (e.g. Knoll, 1994) suggest that this may date back to 1000 Ma. This date is appropriate too, as it coincides with a decline in stromatolite diversity that is widely attributed to the effects of extensive metazoan grazing (e.g. Walter and Heys, 1985).

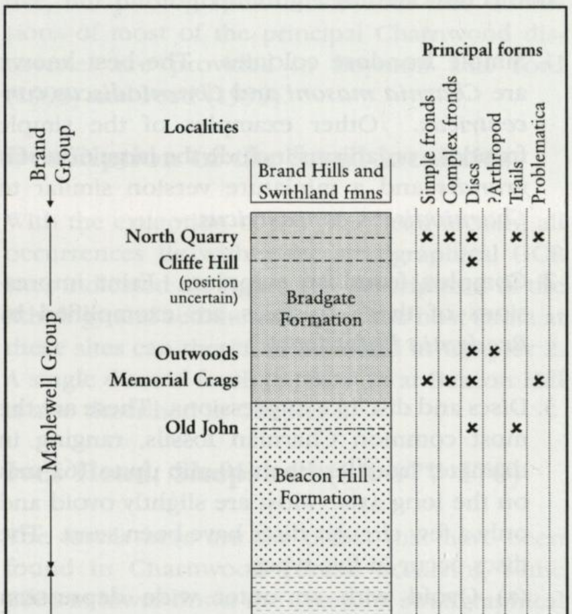

Figure 8.1 The range and stratigraphical distribution of fossil forms in Charnwood Forest (the stratigraphical thicknesses shown are not to scale).

Thus of particular interest are examples of the trace fossil *Neonereites uniserialis* recorded from the Dalradian Bonhaven Formation of Islay, Scotland, by Brasier and McIlroy (1998). This ichnofossil was interpreted by those authors as being the faecal pellets of a coelomate animal capable of peristalsis. This is of significance since the age of the rocks that yielded the fossils is 600 Ma, so these fossils, suggested Brasier and McIlroy, could represent one of a series of animals that was responsible for removing suspended organic material from the sea water. This would allow deeper submarine penetration of sunlight, which in turn promoted oxygenation of the water. With the enormous current research interest in the Proterozoic, it can be confidently predicted that further traces of pre-Ediacaran animal fossils will be found in the near future.

All of the Precambrian fossils known from England and Wales are from the upper part of the Neoproterozoic. When one considers the scale of the outcrops of the Precambrian rocks of England and Wales and the generally poor exposure of the rocks in inland outcrop, it is perhaps remarkable that three areas have yielded Precambrian fossils, and these from both shallow- and deep-water environments. Furthermore, the amount of palaeontological information obtained from them is considerable and there is clearly more to come.

CHARNWOOD FOREST

T. D. Ford

Introduction

The fossils of Charnwood Forest are the only examples of a truly diverse late Precambrian fauna known in Britain and Western Europe, and as such they represent a unique and important aspect of the history of life on Earth. The fossils are from six stratigraphical levels in the Charnian Supergroup (Figure 8.1), and the geographical distribution of the fossil-bearing localities is shown on Figure 2.1. The main horizons are in the Bradgate Formation, near the top of the Maplewell Group. Not far below this horizon a few fossils have been recorded at a further level in the Beacon Hill Formation. The oldest fossils are in the Ives Head Formation of the Blackbrook Group, towards the base of the exposed sequence. Burrows of *Teichichnus* type have been found in the Swithland Formation, which is the youngest unit in the Charnian sequence, but these are Cambrian forms and thus constitute a specialized occurrence, the significance of which is discussed in the section on 'The Brand' GCR site (Chapter 9). The sedimentology of the Charnian Supergroup was outlined by Moseley and Ford (1989) and further sedimentological descriptions of many fossil-bearing sites are given in Chapter 2.

Although ring-like markings were noted in the mid-19th century and were sufficiently well-known to give the local name of 'Ring Pit' to one of the quarries (Ramsay *et al.*, 1858; Harrison, 1877), they were generally regarded as of inorganic origin. The possibility that they could be trace fossils was overlooked until the first frondose organisms, *Charnia masoni* and *Charniodiscus concentricus* were discovered by Roger Mason in 1957 (Ford, 1958). This find stimulated a search of rocks at the equivalent horizon throughout Charnwood Forest and five further localities were found with more trace fossils. Later, different trace fossils were found at a much lower horizon (Boynton and Ford, 1995). Dubio-fossils have been found at other localities but are not discussed further herein (Boynton, 1978).

With the exception of the *Teichichnus* burrows, the fossils are regarded as members of the Ediacara fauna, named from the localities near Ediacara in the Flinders Ranges of South Australia. Apart from the rich assemblages in the latter (Glaessner, 1984; Glaessner and Wade, 1966), examples of the Ediacara fauna have since been found in many parts of the world, as discussed in the introduction to this chapter.

The age-range of Ediacaran fossils is currently the subject of much investigation, but unfortunately there is as yet no precise age date for the Charnian Supergroup, as discussed in the introduction to Chapter 2. Indirect correlations with radiometrically dated rocks in Nuneaton suggest that its fossiliferous beds could be older than 603 million years. However, the Ediacaran fossils, which are usually assigned to the Vendian Stage of the late Proterozoic (Glaessner and Wade, 1966), are presently believed by many to be no older than 580 Ma (e.g. McIlroy *et al.*, 1998). At the outside, a lower age limit of 600 Ma is considered by Narbonne (1998). At the other end of the time-scale, Ediacara-type fossils have been found in strata younger than 543 Ma (Narbonne *et al.*, 1997), this being the currently accepted age for the base of the Lower Cambrian (Bowring *et al.*, 1993).

Summary of the main fossil forms

The Precambrian fossils of Charnwood Forest are preserved as impressions on the upper bedding surfaces of fine-grained volcaniclastic siltstones, i.e. in hyporelief. The impressions have resulted from moderately soft-bodied organisms coming to rest on the silts, with fairly rapid burial pressing them down into the sediment. Counterparts on the under surfaces of overlying beds have not yet been found. Little is seen of the fossils' three-dimensional shape and no hard parts are preserved. A leathery integument (or covering) was probably present in at least some cases. The fossils fall into the six principal categories below and their stratigraphical distribution is indicated by Figure 8.1.

1. Simple frondose colonies. The best known are *Charnia masoni* and *Charniodiscus concentricus*. Other examples of the simple frondose organisms include the large *Charnia grandis* and a miniature version similar to *Charniodiscus concentricus*.

2. Complex frondose colonies. Faint impressions of these colonies are exemplified by *Bradgatia linfordensis*.

3. Discs and disc-like impressions. These are the most common Charnian fossils, ranging in diameter from less than 10 mm up to 162 mm on the long axis. Most are slightly ovoid and only a few circular discs have been seen. The discs occur in five types:
(a) Ovoid with an outer wide depression around a raised central boss. They include *Cyclomedusa cliffi*, Boynton and Ford (1995).
(b) Circular to ovoid discs with clusters of faint lobes in the centre. They include *Ivesheadia lobata*, *Shepshedia palmata* and *Blackbrookia oaksi*.
(c) Ovoid discs with many concentric rings and with only faint indications of a central boss. These include *Cyclomedusa* cf. *davidi*.
(d) Ovoid discs with a few gently arched concentric rings.
(e) Ovoid with a raised rim but no central boss or concentric rings.

4. Arthropod-like impressions. Only one of

these has been seen, named *Pseudovendia charnwoodensis*.

5. Trails. A few isolated examples, which appear to be 'worm' trails, have been found (Boynton and Ford, 1995), though their identification must be viewed with some doubts as only single individuals have been found. They bear some resemblance to *Planolites*.

6. Problematica. Faint traces of what may be fragments of stems with branches have been found on the Memorial Crags in Bradgate Park and the North Quarry of Charnwood Golf Course near Woodhouse Eaves. So little detail is visible that at present it is not possible to assign them to any biological group.

The descriptions that follow are not exhaustive, but photographic illustrations and discussions of most of the principal Charnwood discoveries are provided in Boynton and Ford (1995) and Ford (1999).

Description of the fossil localities

With the exception of the Ives Head locality, all occurrences lie within the stratigraphical GCR sites indicated on Figure 2.1; descriptions of the lithology and sedimentology of the host strata at these sites can therefore be found in Chapter 2. A single discoid fossil impression at Beacon Hill is also described in Chapter 2.

Ives Head, Shepshed (SK 477 170)

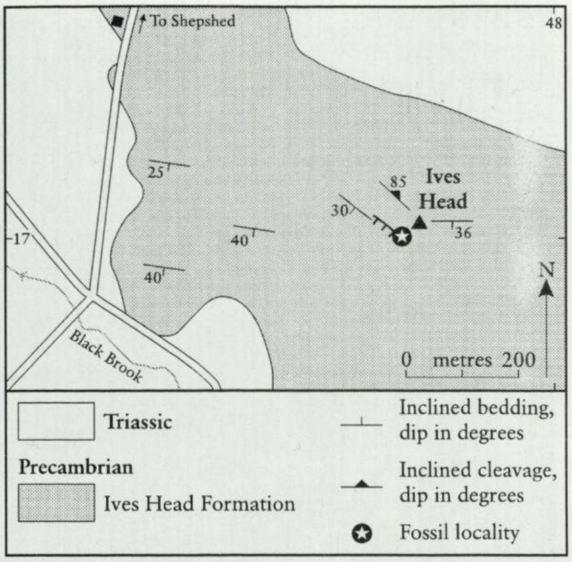

Figure 8.2 Simplified geological map of the Ives Head fossil locality.

The fossils here are the oldest that have been found in Charnwood Forest, occurring some 2000 m lower down the Charnian stratigraphical succession than the fossil-bearing localities of Bradgate Park. They occur immediately above the crags that are located to the west of the Ives Head trigonometric point (Figure 8.2). These exposures show a varied sequence of graded volcaniclastic mudstones, siltstones and sandstones typical of the Ives Head Formation, Blackbrook Group, as seen at the Morley Quarry GCR site (Chapter 2). The highest graded sandstone-siltstone package is 2.5 m thick (Carney, 1999) and is surmounted by a single very prominent bedding plane, capped only by remnants of the overlying medium- to coarse-grained sandstone. It is this surface that contains the several impressions once regarded as dubio-fossils (Boynton, 1978) but later re-interpreted (below) as medusoids (Boynton and Ford, 1995, 1996). They are characterized by forms with circular to ovoid discs with irregular rims and clusters of faint lobes in the centre. The fossils include *Ivesheadia lobata*, an associated form with a short stem named *Shepshedia palmata* (Figure 8.3), and *Blackbrookia oaksi*, which appears to have three fairly large 'discs' in contact. In addition to these, a new form consisting of a drooping head on a long stem (*Shepshedia* aff. *palmata*) has recently been recognized by Boynton (1999), who also described an associated frondose organism sharing some similarities with *Charnia masoni*. It should be noted that the Ives Head occurrences are both bizarre and unique, and their affinities are not fully understood at the time of writing (H. E. Boynton, pers. comm.).

Old John, Bradgate Park (SK 525 113)

The fossiliferous beds here belong to the Old John Member of the Beacon Hill Formation, low down in the Maplewell Group, and their location is shown on the map for the Bradgate Park GCR site report (Figure 2.8). The walled enclosure some 8 m to the south of the Tower contains a single steeply dipping bedding plane bearing several faint discoid impressions, interpreted as medusoids. There are also faint traces of 'worm' trails. The crags to the north of the

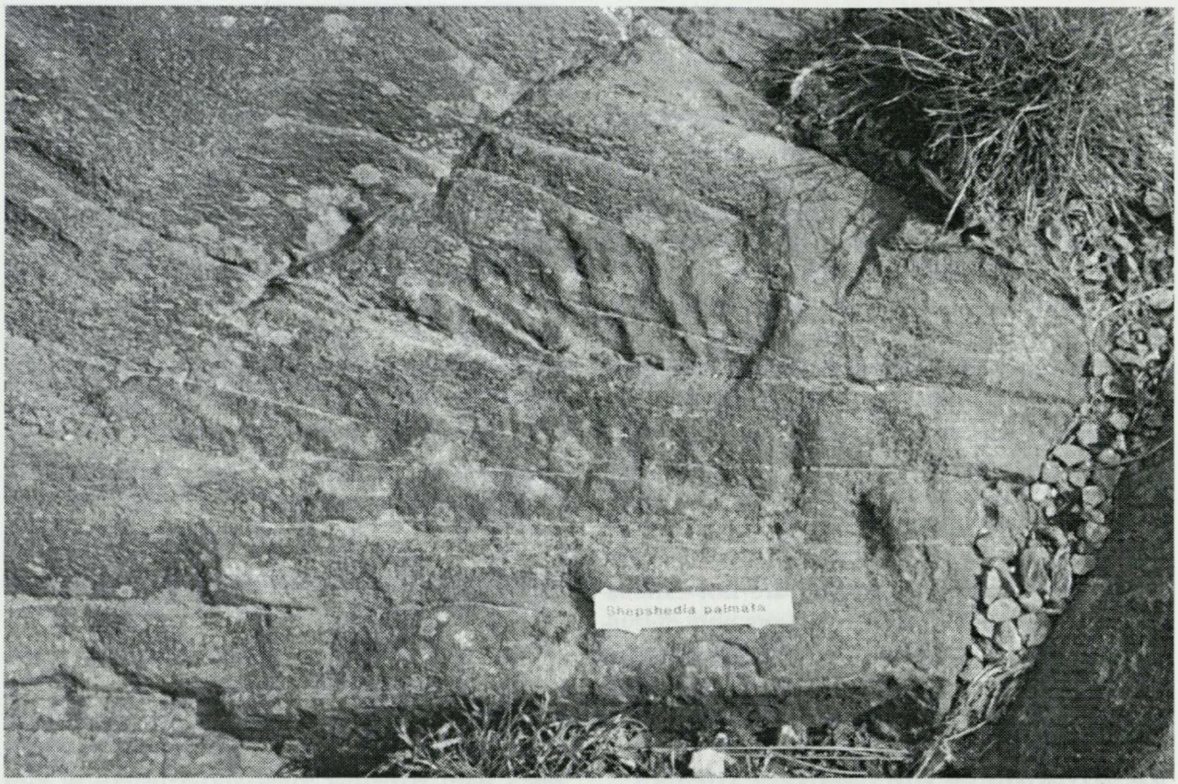

Figure 8.3 The possible medusoid fossil, *Shepshedia palmata* at Ives Head. The impression is about 120 mm wide. (Photo: T.D. Ford.)

Tower have some small but quite well-preserved discs and possible trails consisting of ovoid-shaped, raised impressions.

Memorial Crags, Bradgate Park (SK 524 110)

These crags are located near the Leicestershire Yeomanry Memorial (Figure 2.8). The fossil-bearing bedding plane (Figure 2.9) is in volcaniclastic mudstone or silty mudstone and represents the highest part of a graded sedimentary package in the Hallgate Member. About 10 m lower down, on the eastern side of these crags, are coarse-grained lithologies of the Sliding Stone Slump Breccia, which marks the base of the Bradgate Formation. The bedding plane covers an area of about 25 m^2 and on it some 50 fossil impressions have been found (Boynton and Ford, 1995). Some of these are very faint and difficult to see except in good oblique light provided during late afternoons in September. The fauna includes several impressions of complex frondose organisms, designated as *Bradgatia linfordensis* (Figure 8.4; see also, the North Quarry site report). At first sight they resemble tangled balls of seaweed but on close examination they appear to be radiating bundles of *Charnia*-like fronds. These colonies are up to 40 cm in diameter and individual parts are preserved well enough to show the characters of *Charnia* fronds (plaster replicas of the type specimens from here are in Leicester City Museum). Other fossils on this bedding plane include an incomplete impression of a large more complex frond, *Charnia grandis* (Figure 8.5), now 60 cm long but possibly a metre long when complete, as well as a minute cf. *Charniodiscus concentricus* only 15 mm long (and including a disc at the base). There are several types of discs, some of which may be holdfasts, or floats.

The Outwoods (SK 516 161)

The fossil bed occurs in strata inferred to lie immediately above the Outwoods Breccia Member (equated with the Sliding Stone Slump Breccia, see description of the Outwoods

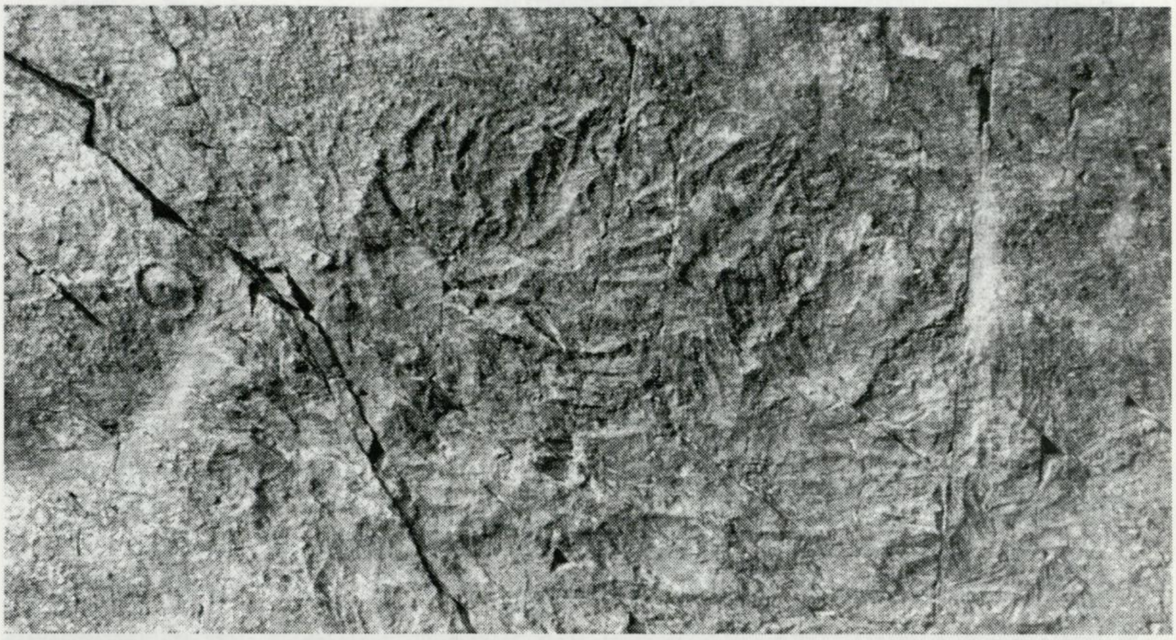

Figure 8.4 Impression of the complex frondose organism, *Bradgatia linfordensis*, at the Memorial Crags locality. This specimen is about 100 m wide. Note also, the small ovoid disc-like impression on the left of the photo. (Photo: T.D. Ford.)

–Hangingstone Hills GCR site). It may be the close contemporary of the fossil-bearing bed at Memorial Crags, Bradgate Park. A few square metres of bedding planes have yielded several ovoid impressions with multiple, sharp-edged ridges concentric about a poorly defined boss. The larger one shows faint traces of possible tentacles from the centre. They have been identified as the medusoid *Cyclomedusa* cf. *davidi* (Ford, 1968; Boynton, 1978; Figure 8.6). A single incomplete medusoid specimen of the same type was found on a loose block. Several small oval-shaped, single-ringed discs have also been found. Another loose block yielded an impression interpreted tentatively as part of a primitive arthropod *Pseudovendia charnwoodensis* (Boynton and Ford, 1979), now in Leicester Museum.

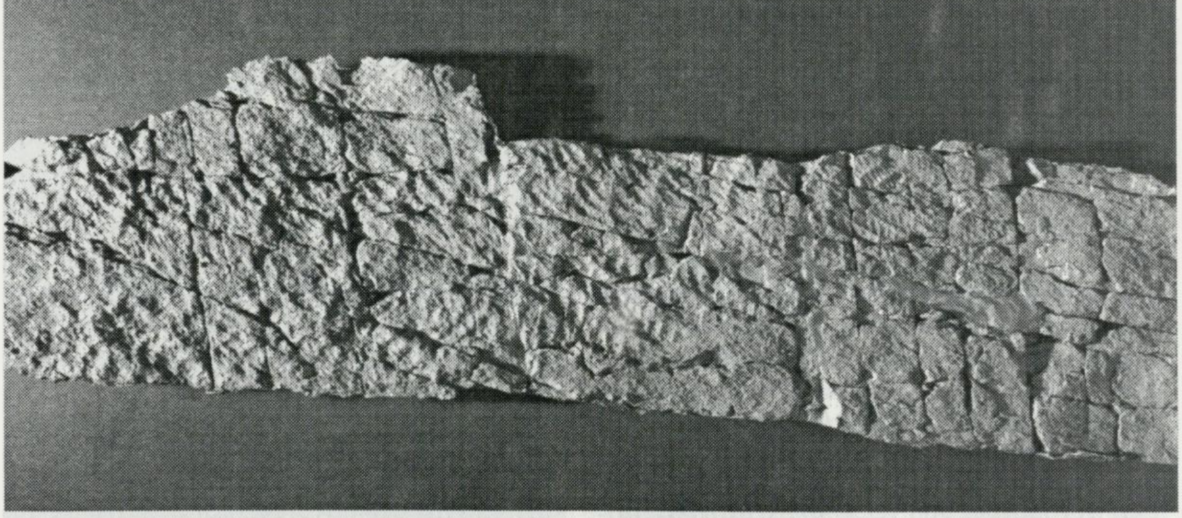

Figure 8.5 Incomplete specimen of a large simple frond, *Charnia grandis*, from a cast taken at Memorial Crags. The specimen is 600 mm long. (Photo: T.D. Ford.)

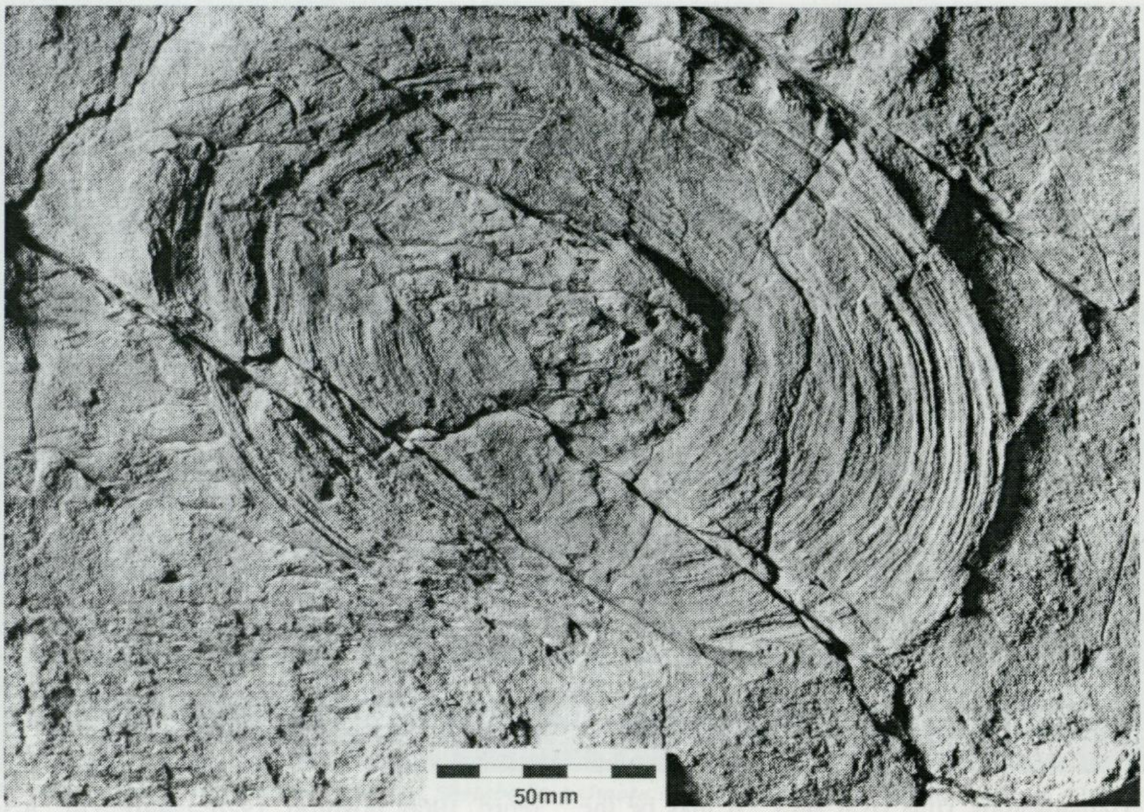

Figure 8.6 Specimen of the possible medusoid fossil, *Cyclomedusa* cf. *davidi*, from the Outwoods locality. The fossil measures 220×160 mm. (Photo: T.D. Ford.)

North Quarry, Charnwood Golf Course (SK 522 155)

This small and long-disused quarry lies close to the north-eastern edge of the golf course (Figure 2.15). It reveals the largest bedding plane exposure to be seen anywhere in Charnwood Forest (Figure 2.17). The fine-grained volcaniclastic mudstones and siltstones here show excellent parallel lamination and are correlated with a distal turbidite or suspension-sedimentation event in the Bradgate Formation (Hallgate Member), higher up in the Maplewell Group than the otherwise comparable fossil locality at the Memorial Crags. Ring-like markings were noted here over a century ago, hence the name of 'Ring Pit' for this quarry, but were dismissed as of inorganic origin. In 1957, the first frond-like impressions were found by Roger Mason (Ford, 1958). These were the first macrofossils of Precambrian age to be recognized in Britain and were named *Charnia masoni* and *Charniodiscus concentricus* (Ford, 1958, 1963, 1968). Both consist of fronds 25–30 cm long with a series of lobes on each side obliquely divergent from an ill-defined median axis, which suggests that the supporting structure lay outside the plane of the impression. *C. masoni* has lost its basal disc (Figure 8.7) but *Charniodiscus concentricus* still shows the disc at its base (Figure 8.8). The lobes on the fronds are divided into segments, which could have held small polyps though no direct evidence is preserved (the type specimens are now in Leicester City Museum).

Faint impressions of the complex *Bradgatia linfordensis* occur on the same bedding plane (see also, Memorial Crags site report). A similar very large form named *Bradgatia* aff. *linfordensis*, with a prominent disc near the centre, has recently been discovered on a bedding plane 3 m higher (Boynton, 1999). Several other less well-preserved fronds are present on this higher bedding plane. The ring-like markings have been interpreted as the detached holdfasts, or floats, of the frondose organisms. A single short length of 'worm' trail has also been found.

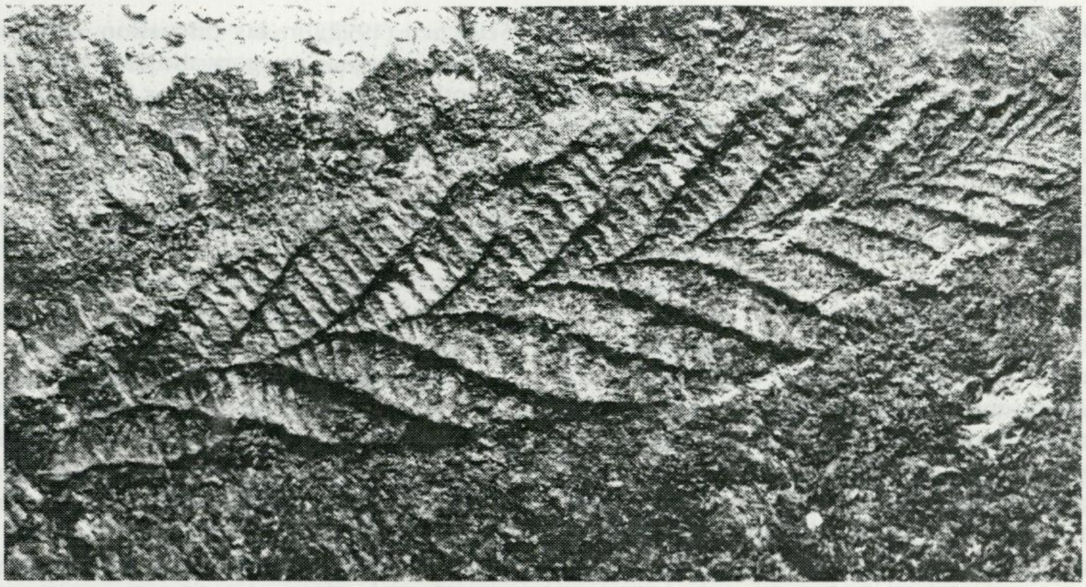

Figure 8.7 The simple frondose organism, *Charna masoni* at North Quarry on Charnwood Forest Golf Course. The specimen is 210 mm long. (Photo: T.D. Ford.)

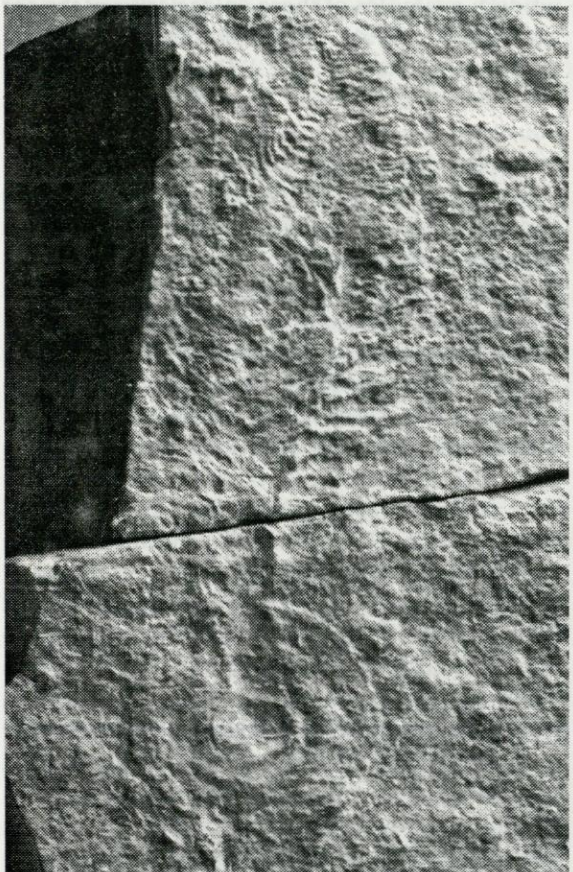

Figure 8.8 *Charniodiscus concentricus* from North Quarry. It shows a frond attached to a basal disc, which may either be a 'holdfast' or a float. This specimen is 250 mm long and the disc is 64 mm in diameter. (Photo: T.D. Ford.)

Cliffe Hill Quarry, Markfield (SK 476 107)

The north-east face of this now disused and partly flooded quarry consists of strata equated with the Bradgate Formation. Due to the isolated position of this site (Figure 2.1) the precise correlation of these strata with the other fossil beds of the Bradgate Formation is uncertain. The beds dip steeply to the south-west and are intruded by the South Charnwood Diorites (Figure 2.19); this relationship has important implications for the maximum age of the Bradgate Formation and other parts of the Charnian Supergroup, as discussed in the introduction to Chapter 2. A single bedding plane has yielded several discoid impressions, which are ovoid with an outer wide depression around a raised central boss. Although the lack of internal detail raises doubts, Boynton and Ford (1995) have referred them to *Cyclomedusa cliffi*, the type specimen of which is now at Leicester Museum. Most occurrences have been quarried away or are hidden in quarry debris.

Interpretation

The fossils of Charnwood Forest occur in turbidite-facies volcaniclastic strata, which are generally devoid of structures attributed to tidal or storm-influenced wave or current action and thus were probably deposited in moderate to deep waters. As discussed in the introduction to Chapter 2, the dominant sedimentation mechanism involved sediment gravity flowage, which was in part driven by tectonic and/or volcanic events. The beds with fossil impressions seem to represent relatively quiescent periods, characterized by the settling out of suspended fine-grade material, and commonly occur at the very tops of major graded sedimentary packages. This type of environment has been recognized in a minority of the other Ediacaran fossil occurrences around the world, and is regarded as representative of a deep-water slope or sedimentary fan environment (Jenkins, 1992; Narbonne, 1998). It is in contrast to the shallow shelf, tide- or storm-dominated conditions in which the faunas described from the Ashes Hollow (Long Mynd) and Coed Cochion (Camarthenshire) sites evidently flourished.

When simple frondose fossils such as *Charnia masoni* were first discovered at the North Quarry locality, their assignation to some form of complex seaweed was considered (Ford, 1958). They were later interpreted as probably the traces of organisms comparable with the present-day Pennatulacea, which are primitive colonial cnidarians, broadly comparable with the modern sea-pens (Glaessner and Wade, 1966; Glaessner, 1979, 1984). Some of the fronds possess basal discs, which may represent holdfasts or floats; these when detached may appear at certain of the fossil localities at which the frondose forms were not found (see below).

The complex frondose colonies, such as *Bradgatia linfordensis*, are regarded as having been composed of clusters of fronds radiating from a central attachment. The varied style of preservation of these specimens means that they are regarded as several forms of preservation or growth stages of the same organism described by Boynton and Ford (1995). These organisms may either have been sessile bush-like organisms as shown diagrammatically by Jenkins (1985; Jenkins and Gehling, 1978), or were floating colonies that settled on to the sea floor in quiet conditions (Boynton and Ford, 1995). They do not seem to have been taken into account by Seilacher (1992) in his discussion of his proposed taxonomic category, the *Vendobionta*.

Both the simple and complex frondose fossils have been assigned to the extinct phylum 'Petalonamae', Class Rangeomorpha (Pflug, 1972; Boynton and Ford, 1995), Family Charniidae. Frondose organisms comparable to some of those seen in Charnwood Forest have been recorded in several localities in Newfoundland, Russia, China and Namibia, all in Neoproterozoic strata.

A possible interpretation of certain of the disc-like fossils to which no species name has been given is that they may be detached holdfasts from *Charniodiscus concentricus*.

The supposed medusoid fossils, such as *Cyclomedusa cliffi*, *Cyclomedusa* cf. *davidi* and possibly *Ivesheadia lobata*, *Shepshedia palmata*, *Blackbrookia oaksi*, have been placed as Phylum Cnidaria, ?Class Cyclozoa (Fedonkin, 1983), Family Cyclomedusidae (Runnegar, 1992; Runnegar and Fedonkin, 1992). Comparable modern examples of these cnidarians are the sea anemones, corals and jellyfish. Narbonne (1998) suggests that the Ediacaran fossils may well have some affinity with the first two, but doubts whether any could be ascribed to a 'jellyfish' type of organism.

So little detail is visible of the possible stems and branches of 'Problematica' that it is not possible to assign them to any biological group. Similarly, the apparently segmented form *Pseudovendia charnwoodensis* is only very tentatively suggested to be a primitive arthropod.

The Charnwood fossil assemblages are broadly comparable to the late Precambrian Ediacaran fauna found worldwide although there are some differences; for example, complex frondose fossils such as *Bradgatia linfordensis* and *Bradgatia* aff. *linfordensis* do not appear to be represented elsewhere (Boynton, 1999). It should be noted that Norris (1989) and Runnegar (1995) doubted the assignation of the Ediacara fauna to the Cnidaria though neither had any sound alternative proposal. Based on an alleged photosynthetic symbiosis, Retallack (1994) suggested that the Ediacara fossils might be large lichens. However, Seilacher (1992) has argued a case for the Ediacaran fossils belonging to a novel group of organisms based on a pneumatic quilt-like body structure and obtaining their nourishment by absorption through the integument. He proposed that this category could be a new kingdom or a new phylum, the

Vendobionta. Neither the lichen nor the Vendobionta interpretations are supported herein.

Conclusions

The fossils of Charnwood Forest are rare examples of a diverse late Precambrian fauna that was preserved within deep-water, turbidite-dominated environments, and they consequently represent a unique insight into the early history of life on Earth. Fossil discoveries have been made at six levels in the Charnian Supergroup, encompassing some 3500 m vertical thickness of strata. The stratigraphically youngest horizons comprise four fossiliferous beds, near the top of the Maplewell Group in the Bradgate Formation. The two most important are at the North Quarry and Memorial Crags localities, and these show the most highly differentiated and diverse faunas yet found in Charnwood Forest. The oldest known fossils are those in the Ives Head Formation, near the base of the exposed Charnian sequence.

Six types of fossil and trace fossil have been found at localitiesin the Charnwood Forest, of which three proved amenable to taxonomic classification. Primitive colonial fossils, interpreted as sea-pens and placed in the extinct phylum 'Petalonamae', are represented by simple and complex frondose colonies exemplified by ***Charnia masoni*** and ***Bradgatia linfordensis*** respectively, with ***Charnia grandis*** considerably larger than *C. **masoni***. Some disc-like fossils possessing a complex internal structure, or having frond-like attachments, are medusoid (jelly-fish-like) organisms placed in the phylum Cnidaria; they include forms such as ***Cyclomedusa*** cf. ***davidi*** and ***Cyclomedusa cliffi*** and maybe some of the oldest fossils, from Ives Head, such as ***Shepshedia palmata***. In addition, possible worm trails, problematic branch or stem-like fossils and an arthropod-like fossil ***Pseudovendia charnwoodensis*** have been found in the rocks of the Charnwood Forest.

These fossils have commonly been equated with the Ediacaran faunas of the late Precambrian found worldwide, and while there are many obvious similarities there also appear to be some differences. It is noteworthy that the age of the Charnian Supergroup has not yet been precisely constrained (see introduction to Chapter 2), but on the basis of present knowledge it is possible that its fossils may be somewhat older than the Ediacaran faunas found elsewhere.

ASHES HOLLOW QUARRY (SO 434 930)

J. C. W. Cope

Introduction

This site is located within the outcrop of the Longmyndian Supergroup (Figure 5.1), to the west of the Church Stretton Fault. It is a long-abandoned quarry on the steep valley-side on the north of Ashes Hollow (Figure 5.9), one of a series of river valleys that cuts directly across the strike of the Longmyndian Supergroup. Ashes Hollow is named after the eponymous cottage, towards its south-eastern end, which is now abandoned.

Precambrian strata of the Burway Formation exposed in this quarry are of great importance as preservers of various trace fossils. Some of these were first interpreted as of organic origin by Salter (1856), but subsequently most authors (e.g. Greig *et al.*, 1968) have treated them as inorganic impressions. More recent investigations by Pauley (1986) were largely inconclusive, although this author does provide good descriptions and figures of the types of structure that occur. Among other considerations, Pauley (1990b) showed that the strata at Ashes Hollow Quarry were marine in origin and that therefore the so-called 'rain imprints', first described by Salter (1856) and described and figured in detail by Greig *et al.* (1968), formed in a depth of water that precluded subaerial exposure. Some other process is thus required to explain these small closely spaced imprints, and an organic origin seems at least possible. One of the most convincing arguments for the organic affinities of at least some of these impressions is that similar marks have been found in several other parts of the world in rocks of identical age, but never in rocks younger than early Cambrian (T.P. Crimes, pers. comm.). A full description of these impressions is under preparation by Crimes and Pauley.

Some of the Longmyndian impressions are similar to those found in latest Neoproterozoic strata of the White Sea area of northern Russia (see Palij *et al.*, 1979) or the Nama Group of

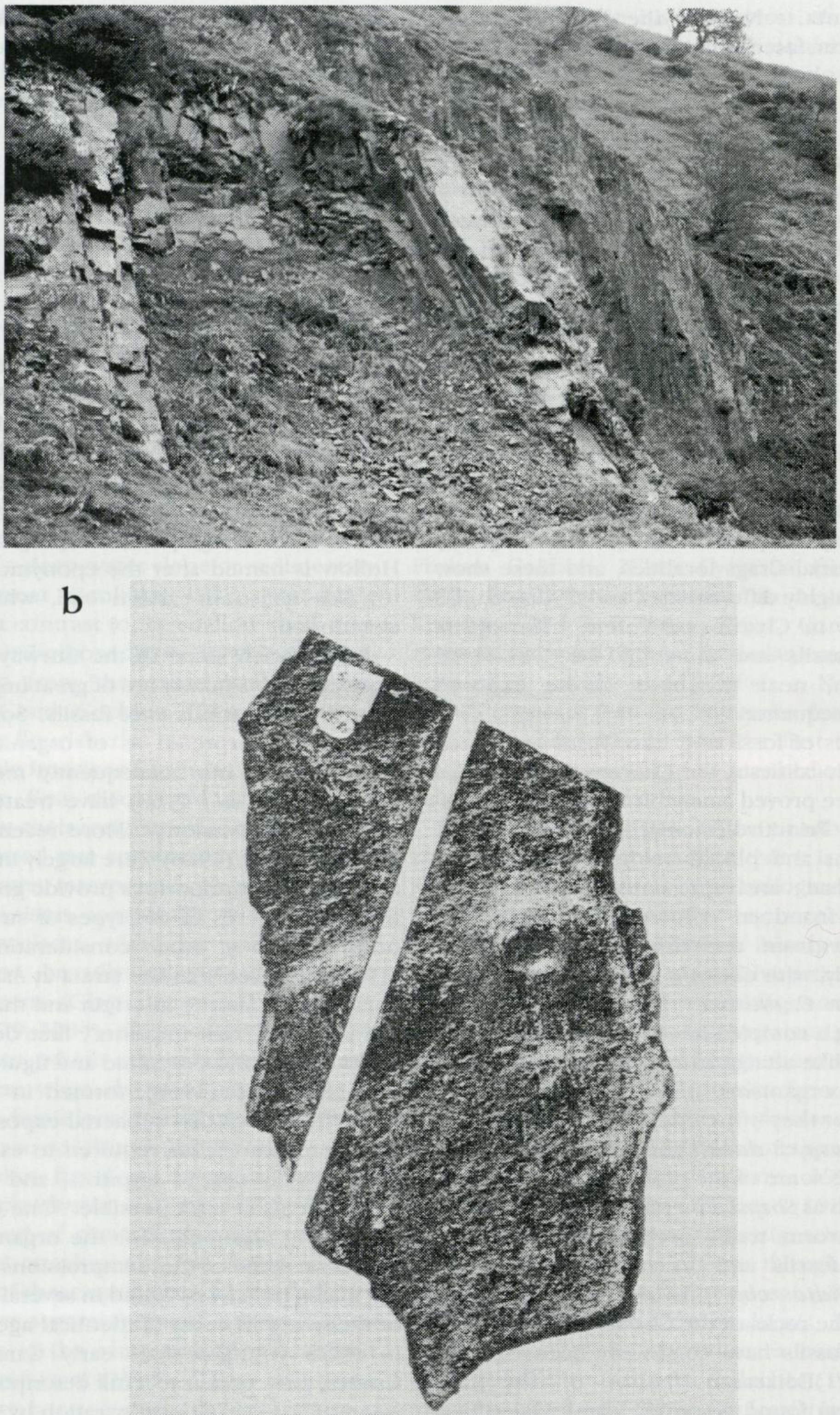

Figure 8.9 The fossiliferous locality at Ashes Hollow. (a) View of Ashes Hollow Quarry looking from the north-west. Note the near vertical dip of the beds, and the well-defined joint planes. The sandstone bed has been quarried in the foreground, leaving siltstones exposed at either side of the pit (Photo: J.C.W. Cope). (b) Specimen from Ashes Hollow, featuring probable organic unidentifiable 'medusoid' impressions (Plate 5A of Greig *et al.*, 1968).

Namibia (Crimes and Germs, 1982) or the sequence in the Boston Basin, USA (B.H. Bland, pers. comm.). Bland (1984) figured and described examples of the problematic organism *Arumberia* from lower horizons in the Longmyndian than those exposed in Ashes Hollow Quarry. In fact this quarry at Ashes Hollow is only one of many such localities within the outcrop of the Longmyndian Supergroup that has yielded impressions that are probably of organic origin. In addition to the Burway Formation, the overlying Synalds Formation has also yielded many such impressions at various horizons. The principal works on these rocks, with references to the impressions, are those by Salter (1856, 1857); Cobbold (1900); James (1956); Greig *et al.* (1968); Bland (1984) and Pauley (1986, 1990b.)

Description and interpretation

Ashes Hollow Quarry was clearly worked for the well-bedded sandstone units that are interbedded with shaley mudstones in the west wall of the main quarry. The Burway Formation comprises a succession of mudstone, siltstone and sandstone beds that are well exposed in Ashes Hollow and described more fully by D. Wilson in Chapter 5 of this volume. The Ashes Hollow quarry (Figure 8.9a) has exploited some of the few thicker and therefore workable sandstone beds in this succession, those in the quarry being of fine to medium grade, showing both planar and cross-lamination. To the west of the principal quarry face, a thicker mudstone unit intervenes before two further sandstone horizons crop out. Altogether about 35 m of rock is exposed from the eastern to western extremities, the dip being locally steepened to near-vertical in the quarry.

The probable organic structures may be seen in various mudstone horizons within the quarry. They include features described by Greig *et al.* (1968) as pit and mound structures (Figure 8.9b) and interpreted as air-heave structures caused by escaping bubbles of gas. Bland (1984) has suggested that they were possibly related to medusoids such as *Cyclomedusa*. However, it is noted that in some cases the laminae for some distance beneath the structure are disturbed, for example Greig *et al.* (1968, p. 70) recorded a case of 7 mm penetration, suggesting that the circular structures are unlikely to be of medusoid origin. Their affinity remains uncertain, but while they have been noted from other Neoproterozoic rocks (e.g. Plummer, 1980) they do not seem to have been recorded from younger strata. Pauley's (1990b) interpretation of these rocks as having been formed in a prodelta makes it unlikely that these are gas-escape structures, although it does not rule out soft-sediment deformation as a cause.

Other structures are small and circular (although the cleavage has sometimes elongated these to ellipses) and are present either as positive hyporeliefs or as positive epireliefs (i.e. the rings may be positive facing downwards or upwards). Greig *et al.* (1968, Plate 5) recorded the hyporeliefs and figured some examples. These structures are up to 10 mm in diameter and often closely crowded together on a bedding-plane. Once more they appear at first sight to be inorganic, but again their restriction to the Neoproterozoic suggests that they are of biogenic origin. The larger of these circular impressions resemble some of the forms recorded from the Nama Group of Namibia and referred by Crimes and Germs (1982) to the genus *Bergaueria*. The same genus was also figured from the White Sea area of Russia by Palij *et al.* (1979) together with another circular genus, *Beltanelloides* that is smaller and very like some of the smaller circular Long Mynd impressions. Runnegar and Fedonkin (1992, fig. 7.5.10.B) figured *Beltanelloides soichevae* from the White Sea area and this species has affinities with some of the Longmyndian impressions. The smallest impressions, generally less than three millimetres in diameter, often with a depressed centre, can be identified with *Intrites punctatus* Fedonkin, the holotype of which was refigured by Fedonkin and Runnegar (1992, Fig. 7.6.4.B).

Conclusions

A variety of enigmatic impressions occur within the Burway Formation and Synalds Formation of the Longmyndian rocks. The earliest interpretation of these impressions as organic by Salter (1856, 1857) seems to some extent to have been finally confirmed. But despite the likely organic origin of many of these impressions, which is emphasized by their apparent stratigraphical restriction to the late Neoproterozoic and early Cambrian, we are far from understanding their true nature.

COED COCHION (SN 3335 1465)

J. C. W. Cope

Introduction

The site takes its name from the former house shown on the 6 inches to 1 mile Ordnance Survey map at SN 3332 1467; no trace of the house now remains and Coed Cochion does not appear on the 1:10 000 Ordnance Survey map. Its location is shown on the map of the Llangynog site, featured in Chapter 5 of this volume (Figure 5.22). The site was originally an insignificant, overgrown quarry exposing some three metres of siltstones. Following the discovery of Tremadoc rocks in the area to the north (Cope *et al.*, 1978), a revision of the local geology commenced. It became clear that the rhyolites making up the high ground of Castell Cogan to the south of Llangynog were unlikely to be of basal Arenig age as originally suggested by the Geological Survey (Strahan *et al.*, 1909). They lay stratigraphically beneath the Tremadoc rocks, and as few igneous rocks are known from the Anglo-Welsh Cambrian successions a Precambrian age seemed more likely. The quarry at Coed Cochion was then investigated as it lay nearer the Tremadoc outcrop than the rhyolites of Castell Cogan in a situation which, it was hoped, would enable those rhyolites to be dated more firmly. Initially, it was anticipated that this well-bedded sequence of rocks would prove to be Cambrian in age; however, following some excavation and prolonged collecting, one horizon yielded an Ediacaran fauna (Cope, 1977). It was only subsequently that Cambrian rocks and fossils were found in the vicinity (Cope, 1980; Cope and Rushton, 1992; Cope and McIlroy, 1998) and the surrounding area named as the Llangynog Inlier (Cope, 1982).

Description

Since 1979, and with help from the then Nature Conservancy Council, the Coed Cochion quarry has been enlarged and deepened. The slope immediately to its east was cleared of vegetation and soil at the same time, but has never yielded fossil material. The fossil-bearing horizons seem to be largely restricted to lower levels in the main quarry and a considerable apron of scree that has been allowed to build up now protects these.

A large amount of fossil material was collected from the excavated rock and this has been deposited in the National Museum of Wales, under the accession number NMW 79. 16G. It largely awaits description, although some has been figured by Cope (1977, 1983, 1989) and Cope and Bevins (1993).

Cope and Bevins (1993) have investigated the geology of the area in some detail, and this work has been favoured by the cutting of a new set of roadways through woodlands occupying the Precambrian area of the Llangynog Inlier. The result of this was that many of the long-lost localities of Cantrill and Thomas (1906) once again became available. In addition, new exposures were available that enabled Cope and Bevins (1993) to establish the succession and structure of the area. This work showed that the rhyolites of Castell Cogan, to the south, were the oldest rocks and have been referred to the Castell Cogan Member of the Coomb Volcanic Formation (see the Llangynog site report, Chapter 5). To the north, but everywhere in faulted contact, the rhyolites were succeeded by a dominantly volcaniclastic sedimentary succession that also included basalts, and with further rhyolitic lavas that showed affinity with the Castell Cogan lavas beneath. These rocks, named the Coed Cochion Member (Cope and Bevins, 1993), include the horizons that have yielded the Ediacaran fauna. The map of Figure 5.22 shows the member to crop out on both sides of the steep valley that runs southwards from the Wern Inn, Llangynog. The faunal impressions discussed below have been found at several horizons, but occur most commonly at the Coed Cochion quarry site; even here they are rare and prolonged collecting at the correct horizons is needed.

The sedimentary strata hosting the fossils dip everywhere at approximately 50° northwards; they are very finely laminated, in some cases with several laminae to the millimetre, but coarser layers of silt or sand grade make up thicker laminae which sometimes display internal fining upwards grading. This coarser material is most frequently quartz, usually angular, emphasizing the immaturity of the sediment. Occasional silt- and sand-grade laminae consist virtually entirely of broken feldspar laths, clearly winnowed from a nearby ash fall. Other minerals included chlorite (responsible for the pervasive greenish hue of the freshly exposed rock surfaces), sporadic celadonite aggregates and rarer white mica. The

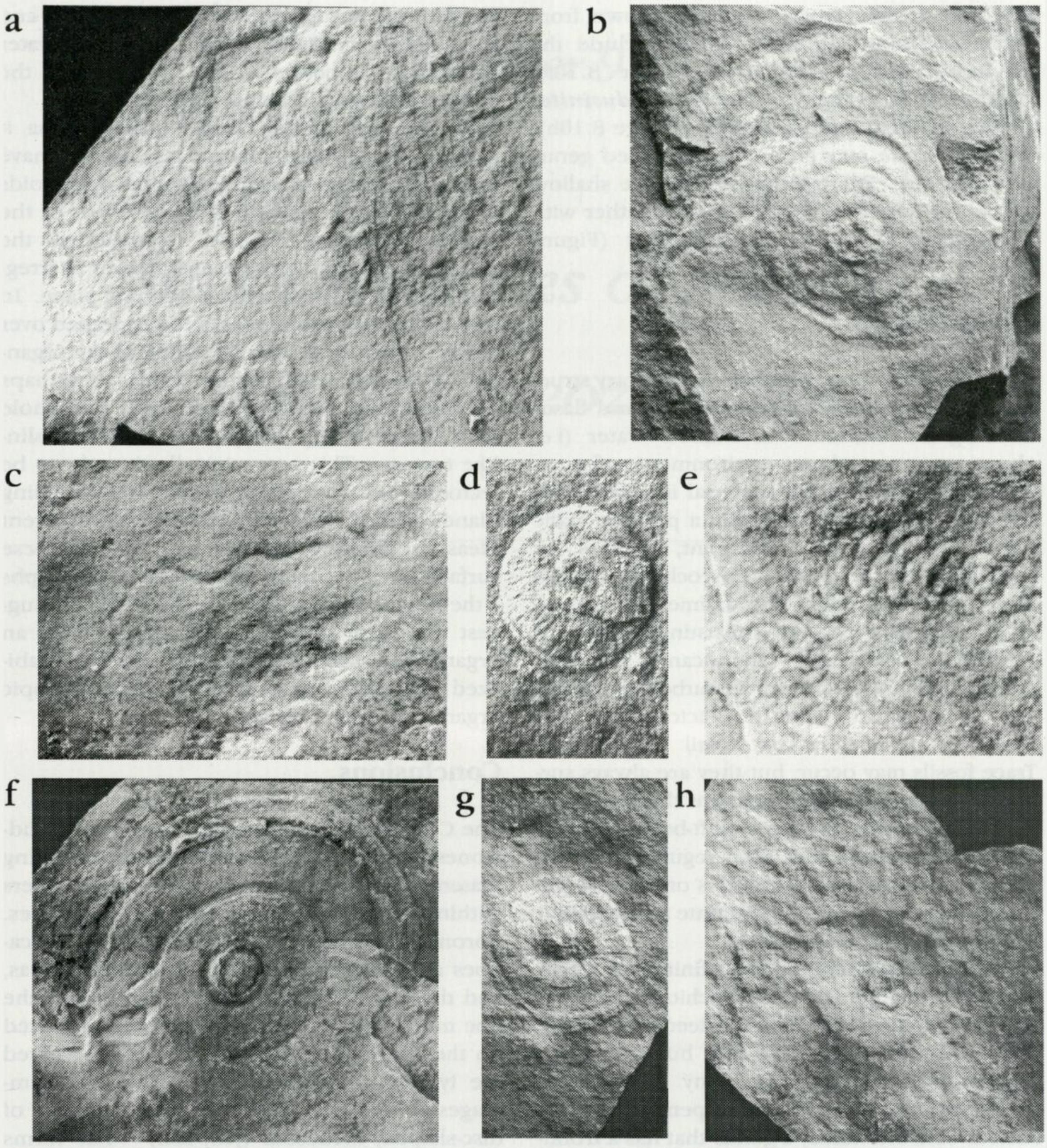

Figure 8.10 Fossils from Coed Cochion. (a) Shallow branching burrows × 2. (b) *Cyclomedusa* sp. × 1.5. (c) *Cochlichnus* sp. × 1.5. (d) *Medusinites* sp. × 1.5. (e) *Palaeopaschichnus* sp. a meandering feeding trail or spiral alga × 2. (f) *Ediacara* sp. × 1. (g) *Medusinites* sp. × 1.5. (h) *Hiemalora* sp. a medusoid with ?tentacular impressions × 1.5. (Photos: J.C.W. Cope.)

strata show sedimentary structures in places, including climbing ripple lamination and flaser bedding, and these are undisturbed by bioturbation. Mud laminae are common and generally very thin; they appear to be invariably stained black by manganese dioxide, as are the closely spaced joint sets that are at approximately right angles to each other and the bedding planes. The rock inevitably splits along the mud laminae, and upon these the fossils are preserved as hyporeliefs (i.e. the 'positive' impression is to be found facing downwards on the upper of the surfaces along which the rock parts).

The fossils that are found at the Coed

Cochion site are typical of those known from other Ediacaran localities. They include the medusoid genera *Ediacaria* (Figure 8.10f), *Cyclomedusa* (Figure 8.10b), *Medusinites* (Figure 8.10d,g) and *Hiemalora* (Figure 8.10h), although there may be one undescribed genus of medusoid. The trace fossils include shallow branching burrows (Figure 8.10a) together with *Cochlichnus* and *Palaeopaschichnus* (Figure 8.10 c,e)

Interpretation

In the Coed Cochion Member sedimentary structures such as ripple cross-lamination and flaser bedding are indicative of shallow water (i.e. above storm wave-base) environments of accumulation. The chloritic material in some beds was undoubtedly derived from a primary mafic mineral in the original sediment, whereas the graded layers may represent pyroclastic ash falls directly into the water. The sedimentary material is thus regarded as consisting largely of reworked volcanic ash. Significantly, the sedimentary laminae are never disturbed; i.e. there was no bioturbation, and this factor is one that seems to unite Ediacaran fossil assemblages. Trace fossils may occur, but they are always surface traces and do not penetrate the sediment; this may explain why these soft-bodied organisms are preserved with such regularity (Cope, 1985). By early Cambrian times organisms had evolved that were able to penetrate the sediment and bioturbation is the norm.

Opinion is divided on the affinities of fossils such as those found at Coed Cochion. It may be that the disc-shaped ones are indeed medusoids, related to modern-day jelly-fish, but an alternative hypothesis interprets many of these as anchorage discs or floats of pennatulaceans, such as *Charniodiscus*, a genus that has a frond-like body attached to a basal annulated disc (e.g. Figure 8.8). However, the Coed Cochion fauna represents a very shallow-water assemblage, that has hitherto yielded no *Charnia*-like fossils, and thus differs markedly from the deeper-water assemblages reported in this volume from the various Charnwood Forest GCR sites.

In the case of the Coed Cochion fauna it seems to be the frequent mud laminae that have cast impressions of the Ediacaran medusoids and trace fossils so well, although most of the laminae are devoid of fossils. In some cases the mud is present as a blanketing film over an irregular surface, such as a rippled bedding plane. In one case, a medusoid impression is draped over a ripple-crest suggesting stranding of the organism in exceptionally shallow water, as perhaps by a receding tide. In other cases the whole mud surface is apparently covered by a muslin-like texture. This was originally thought to be tectonic, but as it only affects a few bedding planes, this is believed unlikely. More recent ideas, supported by the fact that fossils on these surfaces always appear blurred on photographs – the photographs seem to be out of focus – suggest that such surfaces were covered with an organic film, such as a bacterial mat, that stabilized the surface and grew over macroscopic organisms on that surface.

Conclusions

The Coed Cochion site displays laminated mudstones, siltstones and sandstones representing material that accumulated in shallow waters within a sea that surrounded volcanic edifices. Aprons of sediment built up around the volcanoes as erosion reworked the ashes and lavas, and the marine life of the area was cast by the fine mud laminae that periodically accumulated on the sea floor. The fossils that are preserved are typical of Ediacaran shallow-water assemblages worldwide. Here they mainly consist of disc-shaped, medusoid (jelly-fish) – like forms together with other trace fossils representing shallow-burrowing organisms.