

Ediacaran Fossils from the Precambrian (Charnian Supergroup) of Charnwood Forest, Leicestershire, England

H. E. Boynton and T. D. Ford

Abstract: The Ediacaran fauna of Charnwood Forest is reviewed and several new forms are formally named and described, including a complex colonial form *Bradgatia linfordensis* and three new medusoid genera and species, *Ivesia lobata*, *Shepshedia palmata* and *Blackbrookia oaksii*. A new medusoid species *Cyclomedusa cliffi* is described. The frondose fossil *Charnia grandis* is recorded from Charnwood Forest for the first time. Three trails are also noted.

Introduction

Nearly 200 species comprise the Ediacaran/Vendian fauna, an assemblage of impressions of soft-bodied organisms now known from at least 25 localities on five continents (Runnegar, 1992). The phylogenetic position and evolutionary significance of this assemblage is still controversial, but understanding of the stratigraphical and geographical distribution is becoming better defined. The assemblage largely, if not entirely, predates the first appearance of small shelly fossils of early Cambrian (Tommotian) age. Extinction of most Ediacaran forms appears to have taken place before the latter appeared (Fedonkin, 1978). The Ediacaran fauna has generally been assigned to the Vendian substage of the late Proterozoic (Sokolov, 1973), though other broadly equivalent and variously spelt substages have been proposed, e.g. Ediacaran (Termier and Termier, 1960; Jenkins, 1981), Ediacarian (Cloud and Glaessner, 1982; Glaessner, 1984), and Sinian (Grabau, 1922). Though all authors agree that the strata concerned are latest Precambrian, a formal stratigraphical nomenclature based on type localities is still being evaluated (Harland, 1989; Cowie and Brasier, 1989; Cowie, 1992).

Most Ediacaran fossils are preserved either as impressions on the upper surfaces of fine-grained sediments, as in Charnwood Forest, or as casts on the underside of overlying coarser-grained sediments, as at Ediacara.

Charnwood Forest, Leicestershire

Fossils were first discovered, though not recognized as such, in the Precambrian rocks of Charnwood Forest well over a century ago. Ramsay (1858) briefly noted ring-like markings on slates in the quarry north of Hanging Rocks near Woodhouse Eaves, and the quarry became known as the "Ring Pit". Harrison (1877), quoting Professor Ramsay, noted that the rings might or might not be of organic origin, possibly made by seaweeds swinging round in the tides. However, Hill and Bonney (1877-1880) dismissed these "curious concretionary markings" as inorganic. In a photograph by J. Burton taken on June 2nd 1881, entitled "Ring Pit Quarry looking north, Pocketgate, Woodhouse Eaves, Leicestershire" and now in Leicester Museum, the rocks were described as "Cambrian slates split along

bedding planes on which are found numerous concentric rings ranging from 4 to 12 inches (10-30cm.) in diameter". These rings had apparently first been seen on one of the upper beds as early as 1840.

Other possible fossils were found in Charnwood Forest by Professor Lapworth, Mr J. Rhodes and Dr F. W. Bennett (Watts, 1947) who picked up pieces of banded slate traversed by what they thought were worm burrows in Deer Park Spinney in Bradgate Park, in beds now regarded as part of the Brand Group. The specimens (all but one are now in the British Geological Survey collections at Keyworth, specimen nos. 104548 and 01802/1-6; the other is in Leicestershire Museum, specimen no. 13/1904) were cylindrical tubular markings filled with coarser material, occasionally showing some parallelism of the infill to the wall of the tube. Another alleged worm tube was recorded by Friedman (1950) but it is a knobbly pyritic structure of probable inorganic origin (specimen no. 84592 in the British Geological Survey collection). Poorly preserved, they have all been hitherto regarded as pseudofossils, though the recent discovery of trace fossils in the Swithland Formation by Dr B. Bland (pers. comm.) may re-open the matter.

Records of the Charnian fauna known today date from 1957 when a schoolboy, Roger Mason, was climbing with friends in the Charnwood Golf Course North Quarry (the Ring Pit). He discovered a frond-like impression on one of the bedding planes; this was subsequently described and named *Charnic masoni* by Ford (1958). Together with *Charniodiscus concentricus* and several discoid fossils, this has been further discussed by Ford (1963, 1968, 1980), Boynton (1978), Boynton and Ford (1979) and by Sutherland *et al.* (1987). Re-interpretations of the detailed structure and biological nature of the Charnian fossils and their equivalents in other parts of the world have also been published by Glaessner (1959, 1966, 1971, 1979, 1984), by Glaessner and Wade (1966), by Jenkins and Gehling (1978) and by Runnegar and Fedonkin (1992).

As a result of intensive searches some 80 specimens have now been recorded by the authors in Charnwood Forest. Closer examination of the bedding surfaces has also revealed faint traces of structures not previously noted. Recent finds include some taxa and localities not previously recorded.

Charnian Supergroup: Stratigraphy and Age

Watts outlined a stratigraphical subdivision of the Charnian rocks in 1910 but a full description was not published until his posthumous book in 1947. Moseley (1979) remapped Charnwood Forest and has revised and formalized Watts' sequence (in Moseley & Ford, 1985) as in Table 1.

Previous records of Charnian fossils have mostly been from the Hallgate Member of the Bradgate Formation, formerly the Woodhouse Beds of Watts' 1947 classification. Ford (1968) recognized that the fossil occurrences at the Charnwood Golf Course Quarry, the Outwoods and the Memorial Crags were in the Woodhouse Beds (now Hallgate Member) at varying bed thicknesses above the Slate Agglomerate (now Sliding Stone Slump Breccia); this variation may be due to local changes in thickness of the basal part of the Hallgate Member. Moseley (1979), however, regarded the fossil occurrences as being at three separate horizons in the Hallgate Member. Other fossil occurrences are in the Old John Member of the Beacon Hill Formation in Bradgate Park, in the Lubcloud Greywacke Member of the Ives Head Formation, and in Cliffe Hill Quarry at Markfield, where owing to discontinuity of exposure and faulting the horizon is uncertain but is probably within the Hallgate Member. Thus, the majority of the known fossils occur in the Hallgate Member. Three occurrences of "worm" trails have also been found in this Member. As yet unpublished, burrows of *Teichichnus* type have recently been found in the Swithland Formation (B. Bland, pers. comm.). Despite several searches, no recognizable acritarchs have been found (C. Peat, pers. comm.).

The field relationships of the Charnian rocks strongly favour, but do not prove, a Precambrian age. In the Nuneaton inlier in Warwickshire, Cambrian beds unconformably overlie rocks closely similar to the

Charnian, and both the Nuneaton and Charnwood Precambrian sequences appear to terminate in a phase of dioritic (markfieldite) intrusion. Radiometric dating indicates a late Precambrian age for some of the Charnian igneous rocks but still leaves considerable uncertainty about the date of sedimentation. Meneisy and Miller (1963) obtained a range of K-Ar dates for the Charnian volcanic (porphyroid) rocks of Bardon Hill, yielding a preferred age of 684 ± 29 Ma; these extrusive igneous rocks were thought to be broadly contemporaneous with the Maplewell Group. The younger dates they obtained may be due to overprinting by later events, but the determination of 684 ± 29 Ma seems to be too high, perhaps due to inherited argon. Cribb (1975, revised with a new constant by Pankhurst, 1982) obtained a "young" Rb-Sr date of 547 ± 57 Ma for the southern group of diorites, including the intrusion at Markfield. Thorpe (1979, 1982) argued a case for the Charnian being part of a southern British calc-alkaline igneous province about 600 ± 50 Ma. Recently Tucker and Pharaoh (1991) have obtained a U-Pb date from zircons in the Nuneaton diorite (markfieldite) at 603 ± 2 Ma and Brasier (1992) has taken this to indicate the age of the whole Charnian Supergroup. However, no radiometric date has yet been obtained for any of the Charnian sediments and the dates obtained from associated igneous rocks still leave open doubts as to their relationship to the sediments. Overseas occurrences of Charnian fossils lie in rocks generally dated at around 550-570 Ma: such a date is reasonable for the Charnian fossils but, again, most overseas records are also in rocks where direct dating is not possible. In the present state of knowledge it is perhaps best to regard the Charnian fossils as in the 550-600 Ma age range.

As discussed by Ford (1980) these dates place the Charnian and its fossils in the Vendian division of the Late Precambrian as understood in Russia (Sokolov,

CHARNIAN SUPERGROUP		
Group	Formation	Member
BRAND (198-356m)	Swithland* Brand Hills	Stable Pit Quartz Arenite Hanging Rocks Conglomerate
MAPLEWELL (1702-1608)	Bradgate*	Hallgate* Sliding Stone Slump Breccia
	Beacon Hill	Old John* Sandhills Lodge Beacon fine-grained tuffs(*?) Benscliffe
BLACKBROOK (1435-718m)	Blackbrook Reservoir Ives Head*	South Quarry Slump Breccia Lubcloud Greywackes* Morley Lane Tuffs
The first thickness figure is from the southwest limb of the Charnwood anticline and the second from the northeast limb. Fossiliferous formations or members are shown by asterisks. After Moseley and Ford (1985).		

Table 1.

1972, 1973), which has been correlated with the Ediacaran of South Australia (Termier and Termier, 1960; Cowie and Brasier, 1989; Cowie, 1992). Similarly, correlation with some part of the Sinian System of China (Grabau, 1922) is very probable.

Sedimentary Environment

The Charnian sediments comprise a succession of coarse vitric tuffs, lithic tuffaceous pelites and slump breccias in the Blackbrook and Maplewell groups. These are followed by more mature sediments in the Brand Group, including quartz arenites, with localized conglomerates and thick pelites (Swithland Formation) in the upper part. Extrusive volcanic activity was largely confined to the Maplewell Group, though thick lavas and tuffs also occur beneath the lowest exposed beds of the Blackbrook Group in the Morley Quarry borehole (Pharaoh and Evans, 1987).

Sedimentation commenced in the Blackbrook Group with periodic volcanicity yielding silt-sized pyroclastic debris within a thick pelitic succession. Whereas most of the Blackbrook Group indicates quiet sedimentation, there are scattered slumped and contorted beds in a few localities. Deposition of pyroclastic silts and pelites continued into the Maplewell Group with episodes of short-lived explosive volcanic activity. Instability is represented by slump and pull-apart breccias of the Benscliffe, Sand Hills Lodge, and Sliding Stone members. The slump breccias indicate gravity slides of a mixture of coarse agglomerate with uprooted slabs of pelite, whilst the pull-apart breccias consist of clasts of pelite and tuffaceous pelite in matrices of arenite, greywacke or tuff.

The Brand Group shows a marked change to more mature sediments with sheets of quartz arenite containing conglomerate lenses passing up into thick pelites with scattered thin greywackes. The incoming of the Brand Group arenites suggests a hiatus with a considerable period of erosion but no clear contacts are exposed. Rounded pebbles of porphyroid in some of the conglomerate lenses demonstrate that some erosion of the Maplewell Group may have occurred, but no angular unconformity has been detected and so far no exotic pebbles have been found within the Brand Group.

The Charnian sediments appear to have been deposited in a subsiding basin with a volcanic arc lying somewhere to the west as shown by the rather coarser pyroclastic material of Bardon Hill and Whitwick in the northwest part of the Charnwood anticline (Moseley, 1979; Moseley and Ford, 1989). The orientation of current bedding and slump structures indicates that most of the basin infill was derived from the west but there was also some epiclastic detritus derived from a landmass to the southwest. The environment of the main (Hallgate Member) fossil horizon was one of pyroclastic detritus of variable but chiefly fine grained character. Both fine lamination and graded bedding have been noted. Shallow water-depth indicators such as mud-cracks and ripple-marks are lacking but at least some of the detritus probably fell from the atmosphere directly into the sea where it settled either as laminae

of varying grain size or in agglomeratic beds which slumped due to seismic shocks.

No clear sedimentary water-depth indicators have been found. The community of benthic organisms with hold-fasts, planktonic medusoids and occasional trails could occur at any depth, though it seems likely that depths were not great adjacent to active volcanoes, perhaps little more than wave-base. Indeed, it seems unlikely that planktonic organisms could sink to great depths and still be preserved on bedding surfaces.

Palaeontology

The Charnian fossils fall into the following groups: (1) simple frondose colonies; (2) complex frondose colonies; (3) discs, with or without concentric rings; (4) circular to ovoid forms with various patterns of lobes; (5) possible worm burrows.

Some of the faintest impressions are difficult to see except in optimum lighting conditions; these are strongly oblique sunlight, normally only available at certain times of day, at certain seasons of the year, and varying between localities. Owing to the resistant nature of the outcrops and the slaty cleavage, collection of fossil-bearing slabs is rarely possible, and therefore most specimens remain in their field localities, where, regrettably, some vandalism has already taken place.

Preservation. Erosional removal of the overlying beds is an essential feature to reveal the fossils, and it has therefore been difficult to study the relationships between the fossiliferous beds and their cover. Only at one locality has it been possible to make thin sections through the fossiliferous bed and its cover. This showed little difference in lithology, no more than a slight increase in ash content of the overlying bed. Macroscopically at the Old John locality the immediate cover showed a hint of increased water movement and sorting. No equivalent of the distinct ash fall tuff beds in Newfoundland has been seen. The fossiliferous horizons thus represent brief preservational events in a continuum of volcanoclastic sedimentation.

The fossils are preserved as casts or external moulds on the upper surfaces of beds of indurated and cleaved fine-grained tuffaceous sediment. Weathering has enhanced the relief on some bedding planes, particularly if they are not too strongly cleaved. The relative resistance of the organisms' bodies to decay after burial was proposed as a reason for different preservation by Anderson (1978). External moulds could be formed where the bodies were compacted into the mud on which they came to rest. The strength of the relief in some specimens suggests that the bodies had sufficient strength in the body tissues to project upwards into overlying sediments during lithification, but no preserved upper surface of an organism within an overlying bed has yet been found, precluding a full comparison with the fossils at Ediacara, which are preserved in the undersides of overlying beds (Wade, 1968, 1969).

The Charnian sediments are on the borderline between high grade diagenesis and low grade metamorphism, and cleavage is present in most of the

fine-grained rocks. Evans (1963, 1968, 1979) and Moseley (1979) have shown that although cleavage and fold axes are roughly parallel they were separate events, with cleavage imposed after the main folding event. The fossils occur on bedding planes where weathering has etched out morphological detail. Most discs are ovoid, but occasionally others are circular on the same bedding plane. The elongation of the ovoid discs is not always in the same ratio and not obviously related to cleavage. Three discs on the same bedding plane in The Outwoods have parallel elongation, but the ratios are 1.03, 1.37 and 1.6. The orientation is near to but not quite parallel to the cleavage; thus it seems unlikely that the elongation could be a cleavage effect and the orientation is more likely to have been due to current direction at the time of settlement. Thus the elongation of the ovoid discs is here more likely to be an original feature in contrast to the probable elongation by cleavage noted in Norwegian medusoids by Farmer *et al.* (1992). No distortion of the frondose fossils by cleavage has been detected.

Fossil horizons. Fossils have been found at six localities. Whilst four, and possibly five, of these are in the same member, they cannot be proved to be at exactly the same horizon.

1. Old John, Bradgate Park — Hallgate and Old John members
2. Memorial Crag, Bradgate Park — Hallgate Member
3. The Outwoods, Nanpantan — Hallgate Member
4. Charnwood Golf Club (North) Quarry — Hallgate Member
5. Cliffe Hill Quarry, Markfield — Hallgate Member?
6. Ives Head — Lubcloud Greywacke Member, Blackbrook Group

The Fossils. 1. *Simple frondose colonies.* The best known of these are *Charnia masoni* Ford and *Charniodiscus concentricus* Ford. *C. masoni* consists of a frond composed of a series of lobes obliquely divergent from a sinuous median line suggesting that a supporting structure lay out of the plane of the impression. Each lobe is constricted at close intervals to give a segmented appearance. The distal end has lobes of decreasing size. In the Charnwood specimens of *C. masoni* the proximal end appears to have broken off from some form of attachment, but in both *C. concentricus* and some specimens from Ediacara the proximal end of the rachis merges with the centre of a disc which may have acted as a holdfast. In *C. concentricus* the lobes are less well-defined, closer together and arise at right angles to the rachis, with distal upward curvature.

In the original description, Ford (1958) suggested that the frondose organisms could be algal, but subsequently Glaessner (1959, 1966, 1984), Glaessner and Wade (1966), Jenkins and Gehling (1978) and Jenkins (1985) have argued that the organisms have greater affinity with cnidarians such as pennatulids. Others, such as Pflug (1966, 1970, 1973) and Seilacher (1984, 1992), have proposed that the frondose organisms are a totally distinct, and extinct, type of organism which requires a separate classification in a Phylum Vendobionta. Pflug's descriptions include diagnoses where it is

difficult to separate factual observation from imaginary features. Seilacher suggested that the Vendobionta had a quilted air mattress body structure a few millimetres thick and that they were sessile obtaining their nourishment by absorption through the integument. We regard this interpretation as inapplicable both to the simple and the complex frondose colonies described herein which show evidence of being erect on the sea-floor with a three-dimensional structure. As Seilacher (1984) has suggested, no direct evidence of cnidarian polyps has been found. However, we agree with Glaessner (1966) who postulated that the segments and the outer ends of the lobes might have been occupied by polyps, as seen in modern pennatulids (sea-pens). In both *Charnia* and *Charniodiscus* fronds the outer terminations of the lobes are poorly defined, so that no seatings or attachments for polyps are visible. Some of the medusoids have very faint traces of what may have been tentacles outside the discs.

These two frondose organisms are thought to have been benthic, attached to the sea floor by discoid holdfasts. Modern pennatulids have a bulbous organ inflated with water at the base of the rachis providing attachment in soft sediments and this may well have been the case with *Charnia*. The preservation of the fossils is through the fronds falling sideways on to the sediment surface; obverse or reverse impressions of different characters would result, some showing the rachis, others not.

Most *Charnia* specimens in Charnwood Forest are about 200 mm long but a single incomplete impression high on the Memorial Crag is about 600 mm long (Fig. 1), and when complete was possibly as much as a metre long (Brasier, *in* Cowie and Brasier, 1989). Comparable large fronds have been found in Newfoundland, Russia and Australia. Originally named *Rangaea grandis* by Glaessner and Wade (1966), this large species was assigned to *Glaessnerina* by Germs (1973) though he said that *Charnia* and *Glaessnerina* might well be the same genus. Glaessner (1979, 1984) retained the generic name *Glaessnerina*, but this large form was referred to *Charnia grandis* by Runnegar (1992). The Memorial Crag specimen is here assigned to *C. grandis*. A cast is in Leicestershire Museums Geology collection, accession no. G31/1994 (Fig. 1).

Other frondose organisms found elsewhere broadly comparable with *Charnia* and *Charniodiscus* include *Charniodiscus arboreus* and *Phyllozoon hanseni* from the Bunyeroo Gorge, South Australia (Jenkins and Gehling, 1978), *Charniodiscus oppositus* Jenkins & Gehling (1978) from Ediacara, South Australia, *Charnia grandis* (Glaessner and Wade, 1966), *Pteridinium simplex* Gürich (1930) and *Rangaea schneiderhöhni* Gürich (1930) from Namibia, *Pteridinium cf. simplex* Gürich from North Carolina, U.S.A. (Gibson *et al.* 1984), and *Rangaea longa* Glaessner and Wade (1966) from Ediacara. Several types of fronds, including spindle-shaped forms, lobate and bush-like forms, all unnamed so far, have been found in the Conception Group of southeast Newfoundland and only limited descriptions are available (Misra, 1969; Anderson, 1972, 1978; Anderson and Misra, 1968).

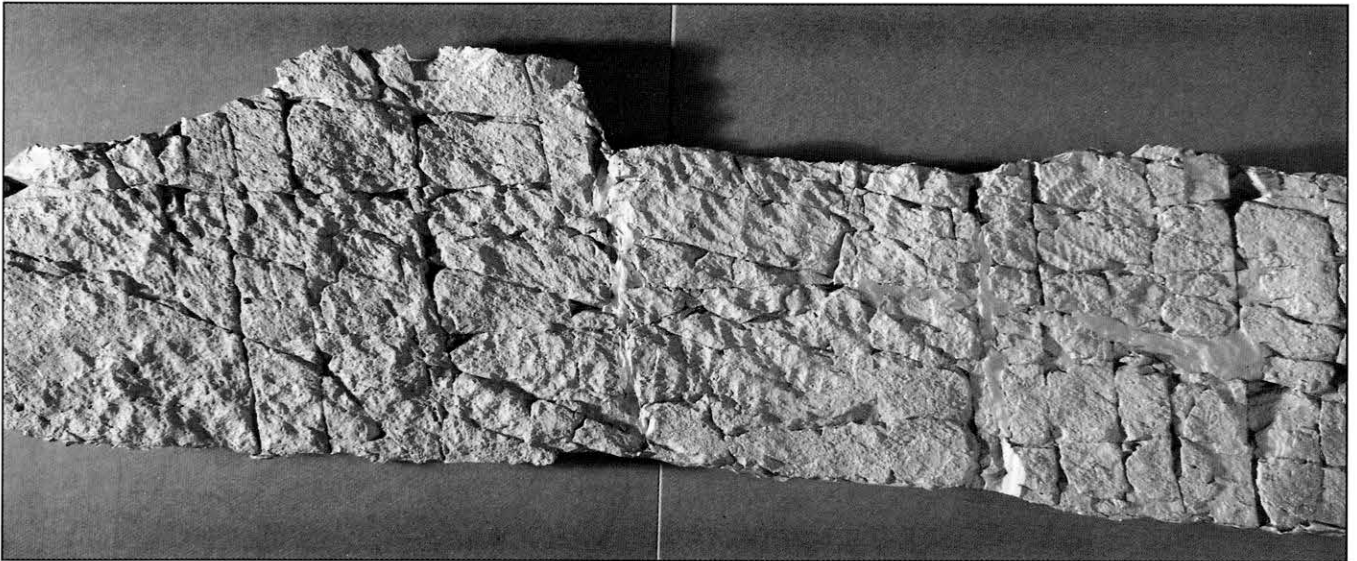


Fig. 1. *Charnia grandis* (Glaessner and Wade): cast of incomplete specimen about 600 mm long.

Charniodiscus cf. *arboreus* has been recorded with a variety of other metazoans in the Wernecke Mountains of the Yukon by Narbonne and Hofmann (1987). A wide variety of fronds, medusoids and trails has been found in the Mackenzie Mountains of northwest Canada (Narbonne and Aitken, 1990). *Charnia masoni* and *Pteridinium nenoxa* have been recorded with a variety of probable medusoids in north Yakutia, Russia, by Fedonkin (1990). Membranous, carbonized compressions in the Dengying Formation of the Sinian System of the Eastern Yangtze Gorge in China were originally described as a new species of *Charnia*, but were re-assigned to *Paracharnia dengyingensis* by Sun (1986a) on account of their much wider axial stems and shorter polyp leaves. The presence of a *Charnia* fauna in several parts of China, Siberia and northern Iran has been noted by Brasier (in Cowie and Brasier, 1989). Distinctions between these various frondose organisms have been made on the basis of details of the lobes, the presence and size of a stem and on the size of the colony. Several of the above species have been assigned and re-assigned to other genera at different times, and those given above are those currently in use.

The discovery in Charnwood Forest of a single miniature *Charnia*-type frond only 17 mm long with a very small disc holdfast (Fig. 2) suggests that at least some of the frondose organisms may have had a budding mode of reproduction; similar small feather-like fronds have been found on the margins of some of the complex frondose colonies of *Bradgatia* noted below, supporting the view that budding may have occurred from such colonies (Figs 4, 6, 8, 10).

The small impression *Pseudovendia charnwoodensis* Boynton and Ford (1979) was referred to as a primitive arthropod, but it may well be a fragment of a frond.

2. *Complex frondose colonies.* Ten highly complex but faint impressions have been found at the Memorial Crags locality and at first glance they resemble ball-like masses of sea-weed. They represent organisms which may have been up to 40cm in diameter and they can be broadly described as radiating bundles of *Charnia*-

like fronds. The impressions suggest that the complex colonies may either have been sessile bush-like organisms, as shown diagrammatically by Jenkins (1984, 1985), or have represented floating colonies which later settled on the sea-floor in relatively quiet conditions. The radiating fronds appear to spring from one or more central protuberances which may represent either anchoring mechanisms or floats buoying up the cluster of fronds. The tissues may have been fairly rigid, strengthened by chitin or collagen, though no direct evidence of either of these has been found. Nor has evidence been found of crushing or wrinkling on

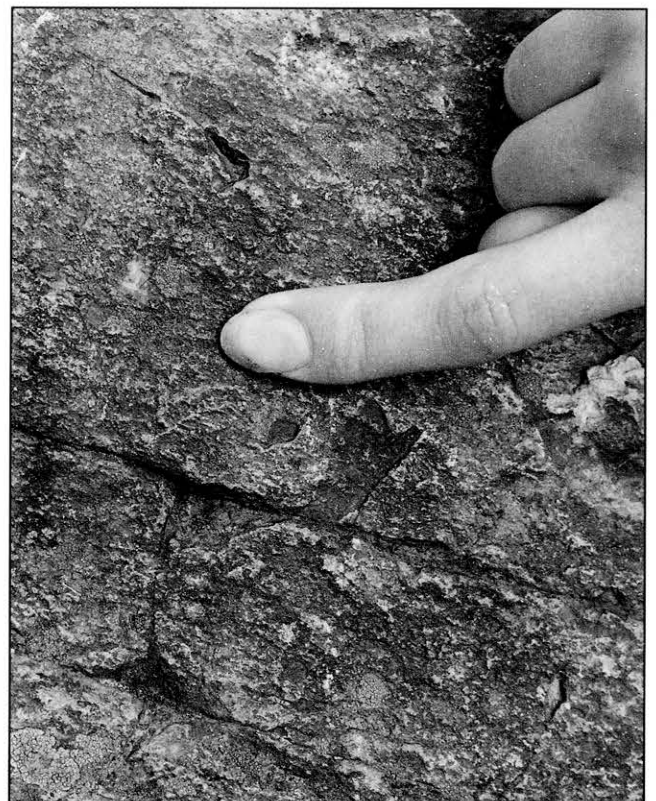


Fig. 2. Small *Charnia* frond, about 17 mm long.

settlement. These complex colonies are herein considered to be a single new monospecific genus with variations in the form of the impressions caused by the angle of rest on the sediments, the mode of preservation and perhaps by decay effects. They are herein named *Bradgatia linfordensis*. *Bradgatia* can be visualized as a colonial organism consisting of a large number of fronds emanating from an ill-defined central area (Figs 3-11).

Some of the trailing fronds resemble miniature *Charnia* (Figs 4, 6, 8, 10) thus suggesting that the organism could have been a colony of small *Charnia*-like fronds growing from a centre. This raises the question as to the relationship between the complex colonies and the solitary large frondose organisms. It is possible to speculate that they were alternating generations, but without further evidence the problem remains unsolved and the forms are treated as separate taxa.

3. *Discs and disc-like impressions*. By far the most common fossils in the Precambrian rocks of Charnwood Forest are discs. They are generally ovoid in shape, range up to 162 mm in length and have been found at five localities. Only a few circular discs have been found. Hitherto all have been referred to *Cyclomedusa davidi* Sprigg in its broader definition by Glaessner (1979) which incorporates forms with and without fine radial striations preserved.

Both ovoid and round forms may or may not have inner concentric rings of varying strength. Some are completely devoid of such features whilst others have numerous closely packed rings, which may be sharp ridges or more gentle convex ridges in cross-section. The centres of the discs may or may not have evidence of a distinct boss or the base of a stem-like projection which is now flattened. Whether these represent attachment points of fronds or the central organs of medusoids will be discussed below. Accordingly, the interpretation of the discs is either as benthic frond hold-fasts attached to or embedded in the sea-floor or as the central organs of planktonic drifting jellyfish. Whether they are Hydrozoa or Scyphozoa cannot be determined at present, and nothing to support a morphological evolution from simple Hydrozoa such as *Cyclomedusa* to complex Scyphozoa such as *Mawsonites* proposed by Sun (1986b) has been found.

Discoid (medusoid?) impressions are common at most of the same localities as the frondose organisms and are known from other late Precambrian sequences which have not yielded fronds as yet, e.g. South Wales (Cope, 1977). A large medusoid fauna has recently been described from Finnmark by Farmer *et al.* (1992). The fossils show that there was a substantial variety of both frondose and discoid organisms round the world in late Precambrian times. At present no morphological types can clearly be shown to pre-date others so that no



Fig. 3. *Bradgatia linfordensis* holotype. About 410 mm wide.

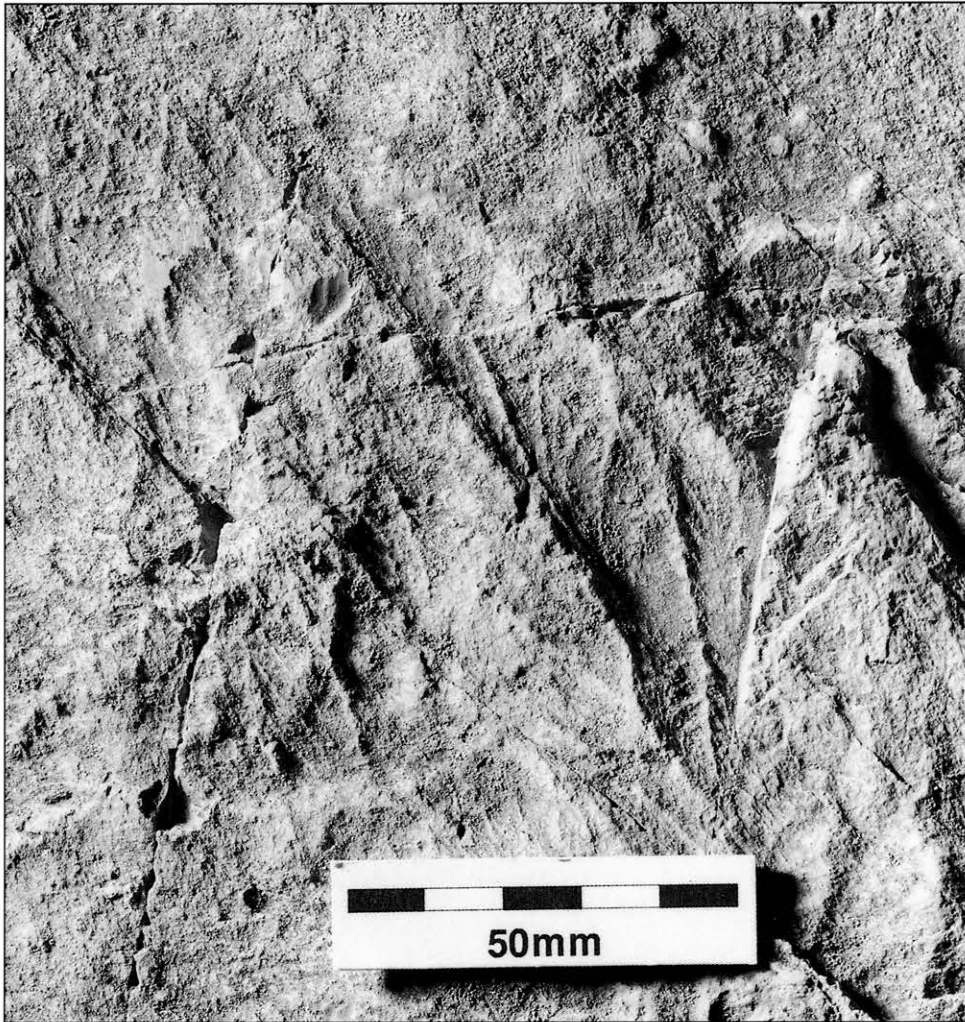


Fig. 4. Enlargement of upper right part of *Bradgatia linfordensis* showing the *Charnia*-like character of the small frondose branches.

phylogenies are known. The evolutionary lineage proposed by Jenkins (1984, 1985) is as yet unsupported by a sequential stratigraphical distribution of progressively more evolved forms.

The different types of disc-like fossil found in Charnwood Forest are:

- a) An ovoid disc with a single raised rim but with no boss or concentric rings; only occasional small irregularities occur within the disc. Six specimens have been found, the largest in Cliffe Hill Quarry, Markfield. It is ovoid measuring 151×65 mm. Another specimen from the same locality shows two overlapping ovoid discs. These were noted but not named by Boynton (1978, pl. 22, fig. 4). They are not named here though they show some similarities to *Beltanella gilesi* Sprigg and to *Planomedusinites grandis* Sokolov.
- b) Five large ovoid discs were found (three subsequently lost in quarrying) in Cliffe Hill Quarry. They consist of an outer, slightly wavy, convex, irregular rim separated by a smooth gentle depression from a raised central convex boss. These were listed as *Cyclomedusa* cf. *dauidi* Sprigg by Boynton (1978, pl. 21, figs. 3, 4) and are broadly comparable with *Tirasiana disciformis* Palij (Fedonkin, 1978, pl. 3). They are assigned to a new species *Cyclomedusa cliffi*.
- c) Circular to ovoid discs with slightly irregular rims

and faint lobes in the central area. Figured but not named by Boynton (1978), these discs occur on Ives Head in beds of the Lubcloud Greywacke Member, some 2000 metres stratigraphically below the fossiliferous Hallgate Member of the Maplewell Group. They are poorly preserved in rather coarse volcanoclastic sediments. The locality has yielded two specimens with an ill-defined cluster of deformed, possibly coiled, lobes in the centre, *Ivesia lobata* gen. et sp. nov. (Figs 12, 13), another showing two (or possibly three) discs adjoining, herein named *Blackbrookia oaksi* (Fig. 17), and a third with a palmate disposition of markings and a faint suggestion of a stem, herein named *Shepshedia palmata* (Fig. 16).

- d) Ovoid discs showing many concentric rings. Best known from the Hallgate Member of the Bradgate Formation, these occur in The Outwoods. The largest specimen is still *in situ* (cast in University of Leicester Geology Dept. accession nos. 115421/0 and 115422/0). It is 220×160 mm and has at least 12 concentric rings which are sharp ridges in cross-section. A small irregular oval boss (with an axis 2 mm long) occurs at the centre of one of these specimens and there are very faint traces of what may have been tentacles on the largest specimen, some apparently extending beyond the margin of the disc. Referred to *Cyclomedusa* cf. *dauidi* by Boynton (1978) and herein, the many concentric rings indicate

some similarity to *Kullingia concentrica* Føyn and Glaessner, though the rings are not as regularly spaced. *Kullingia* sp. of Narbonne and Aitken (1990) in northwest Canada and *Liaonanella multicyclia* Xing and Lui (in Hong *et al.* 1989) in China are other comparable forms. The multi-ringed form from The Outwoods also resembles *Madigania annulata* Sprigg which has been incorporated within *Cyclomedusa* by Glaessner (1979). These assignments have also been discussed by Narbonne and Hofmann (1987). Comparison may also be made to *Kullingia delicata* Narbonne *et al.* (1991), though its multitude of delicate rings distinguishes it from the Charnwood specimens. It has been suggested that these strongly ringed discs bear some resemblance to the umbrella structures of chondrophore floats (Føyn and Glaessner, 1979).

e) Other discs which do not fit into the above categories include some with variably developed central bosses and one specimen which has four concentric rings within a well-defined rim. These four rings are broad and gently arched in cross-section. Other discs have been figured by Ford (1963), Boynton (1978) and Jenkins and Gehling (1978), and comparable forms have been figured by numerous authors. A discussion of the comparisons between the various discs appears in Narbonne and Hofmann (1987). Some differ so little from the disc-like holdfasts of fronds such as

Charniodiscus concentricus that it may be that most, if not all, are detached holdfast impressions. It seems unwise to assign these to new species and no formal names are proposed. A solitary circular mark on a very weathered dip slope of the Beacon fine-grained tuffs of Beacon Hill shows too little detail to be sure whether it is of organic origin or not.

4. *Trace fossils.* Three isolated occurrences of trails have been found, two in the Charnwood Golf Course Quarry and one on the Memorial Crags in Bradgate Park. One is a faint, shallow, curving groove 2 mm wide and 300 mm long and resembles *Planolites* or possibly *Gordia*. Another is in positive relief, about 6-7 mm wide and 100 mm long, looking rather like a faecal cast (Fig. 18). The third, on the Memorial Crags, is a straight wide flattened groove, possibly of *Planolites* type (Fig. 19), about 25 mm long and 3 mm wide. Some caution must be exercised in accepting these as evidence of former crawling organisms.

5. *Problematica.* Problematic fossils also occur at Ives Head, in Bradgate Park and in Charnwood Golf Club Quarry. They seem to be impressions of incomplete lengths of a stem or rachis with one or two branches each terminating in a rounded swelling which droops outwards. Examples up to 370 mm long have been found. With no other detail preserved it is impossible to assign these to any biological group at present.



Fig. 5. *Bradgatia linfordensis* Form A. 310 mm wide.

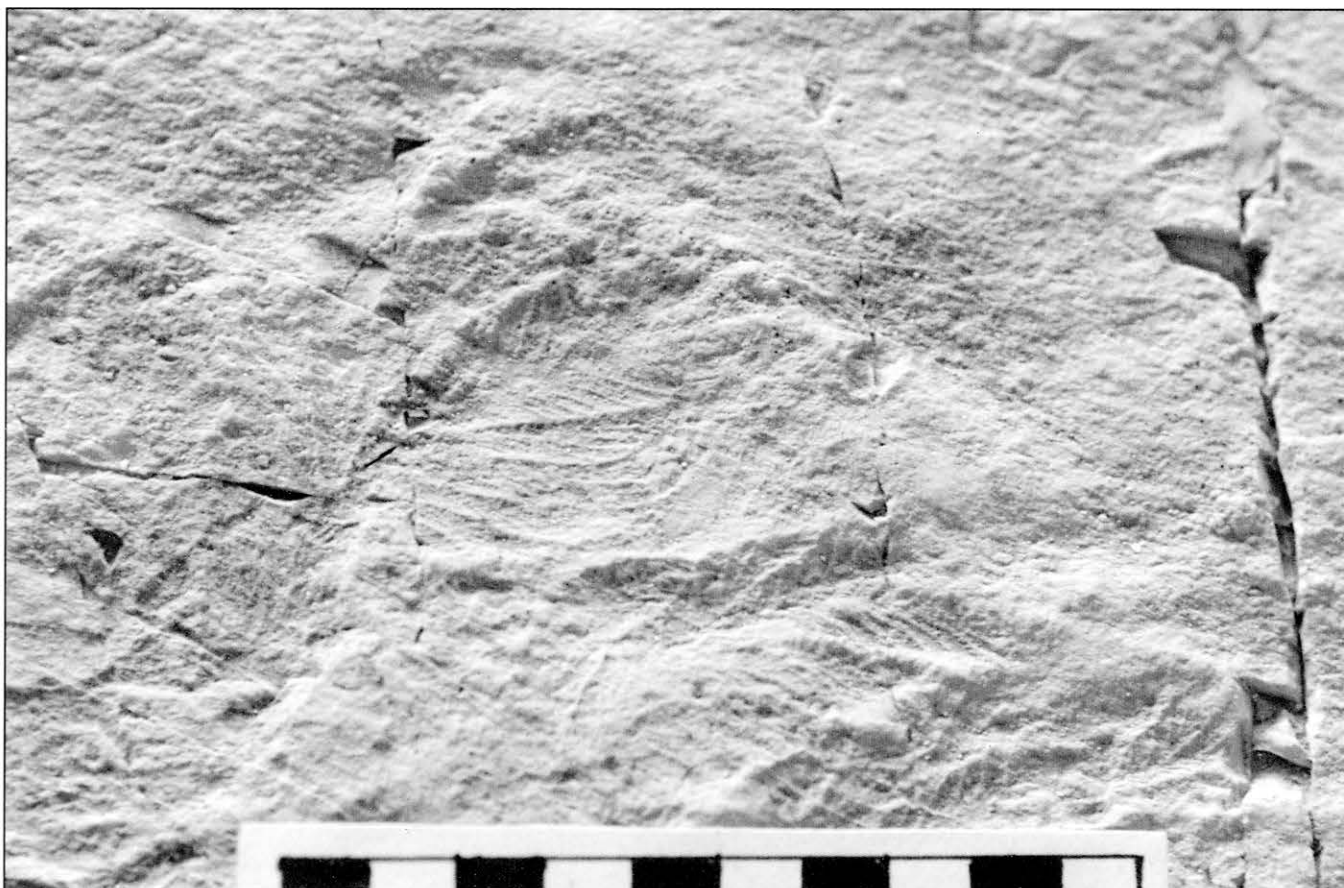


Fig. 6. Enlargement of part of Form A showing small *Charnia*-type branches about 50 mm long.



Fig. 7. *Bradgatia linfordensis* — cast of Form B, 416 mm long.

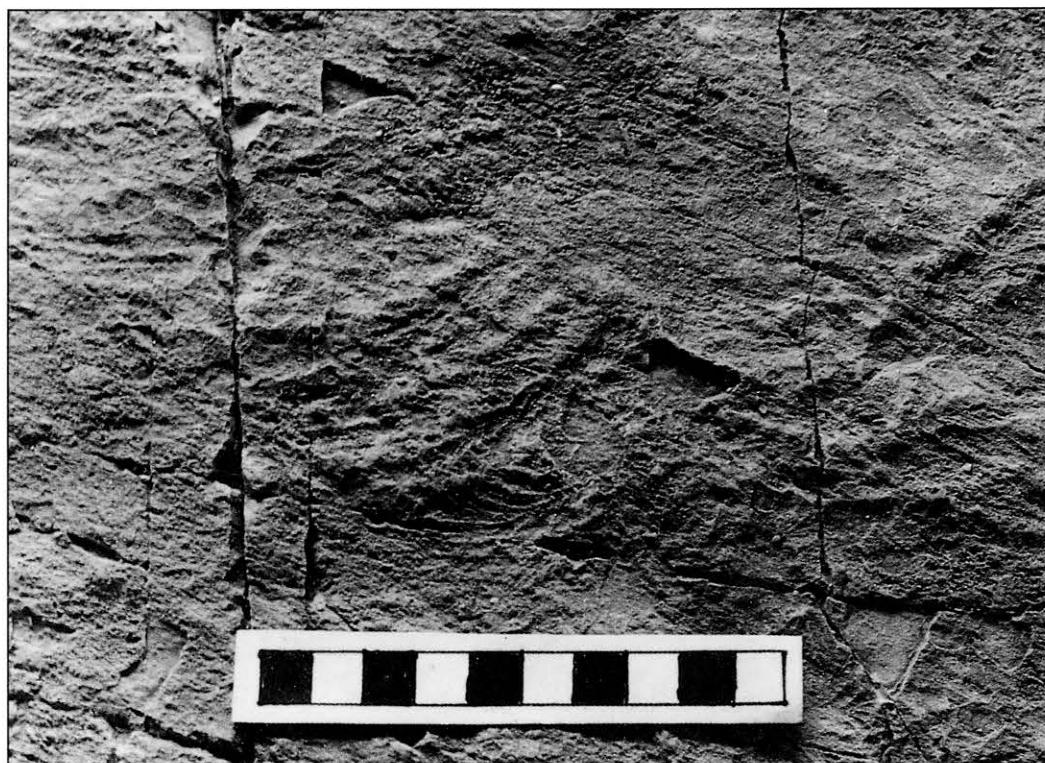


Fig. 8. Enlargement of part of Form B showing small *Chamia*-like branches about 50 mm long.

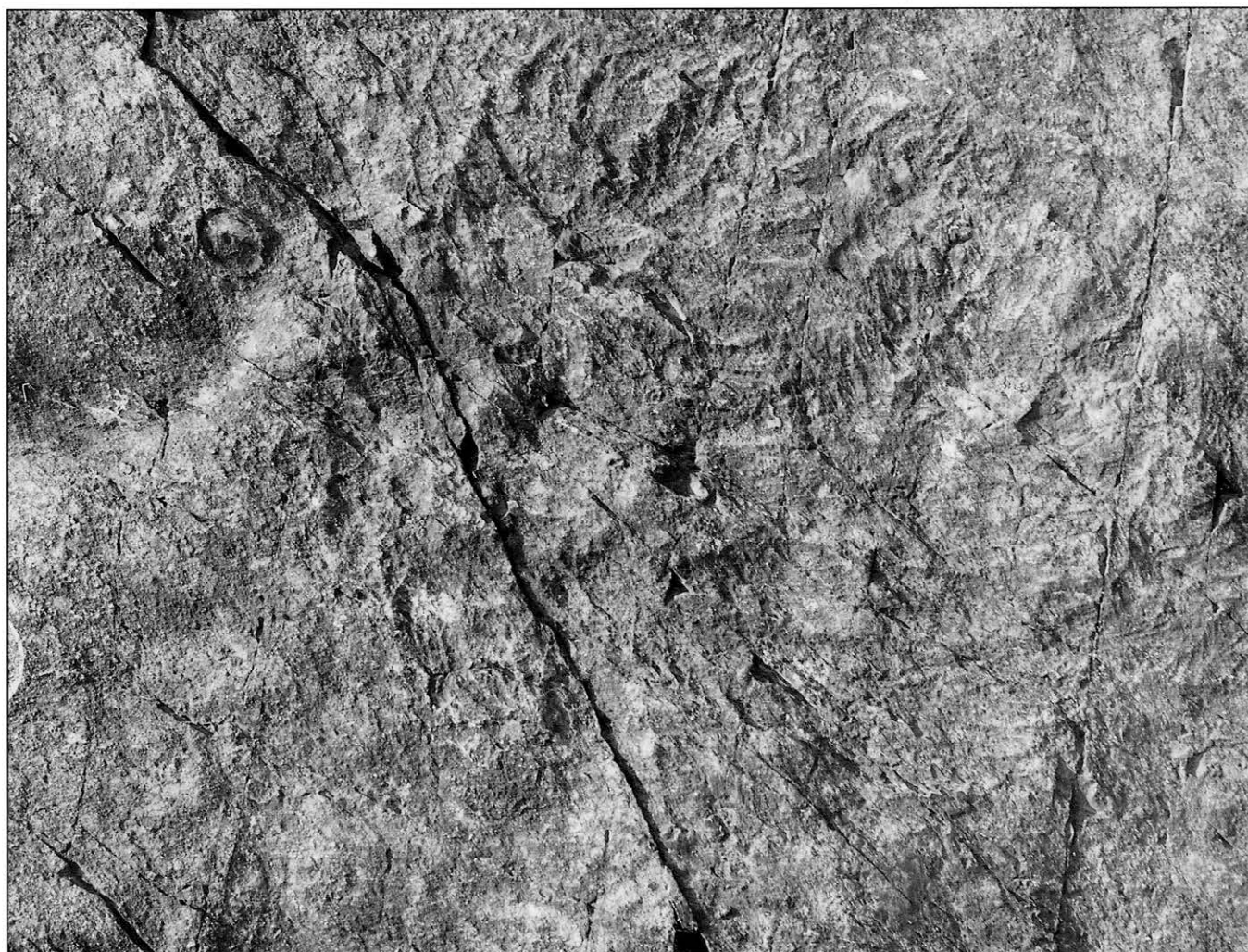


Fig. 9. *Bradgatia linfordensis* Form C. 200 mm wide.

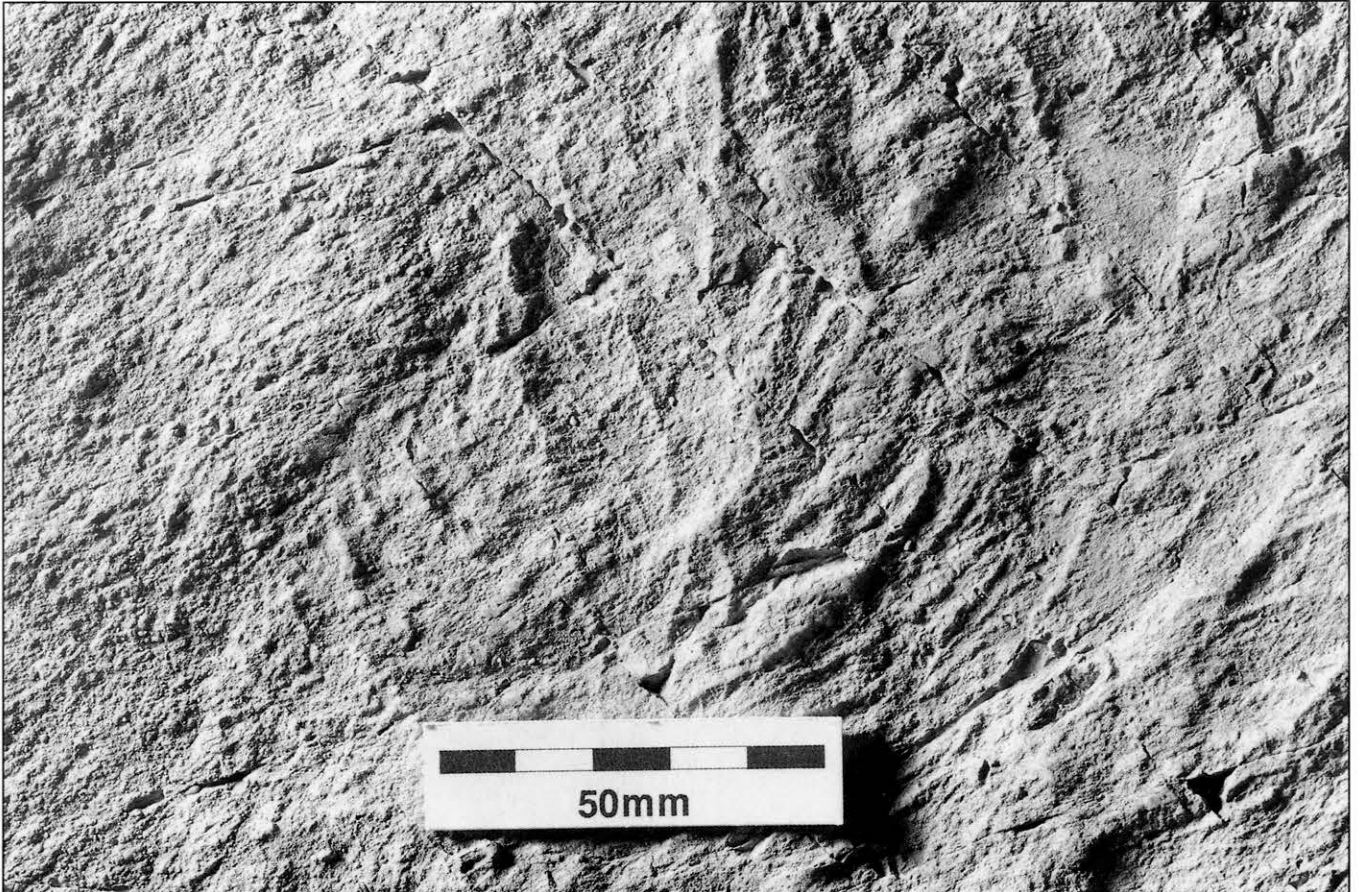


Fig. 10. Enlargement of part of Form C showing small *Charnia*-like branches about 50 mm long.

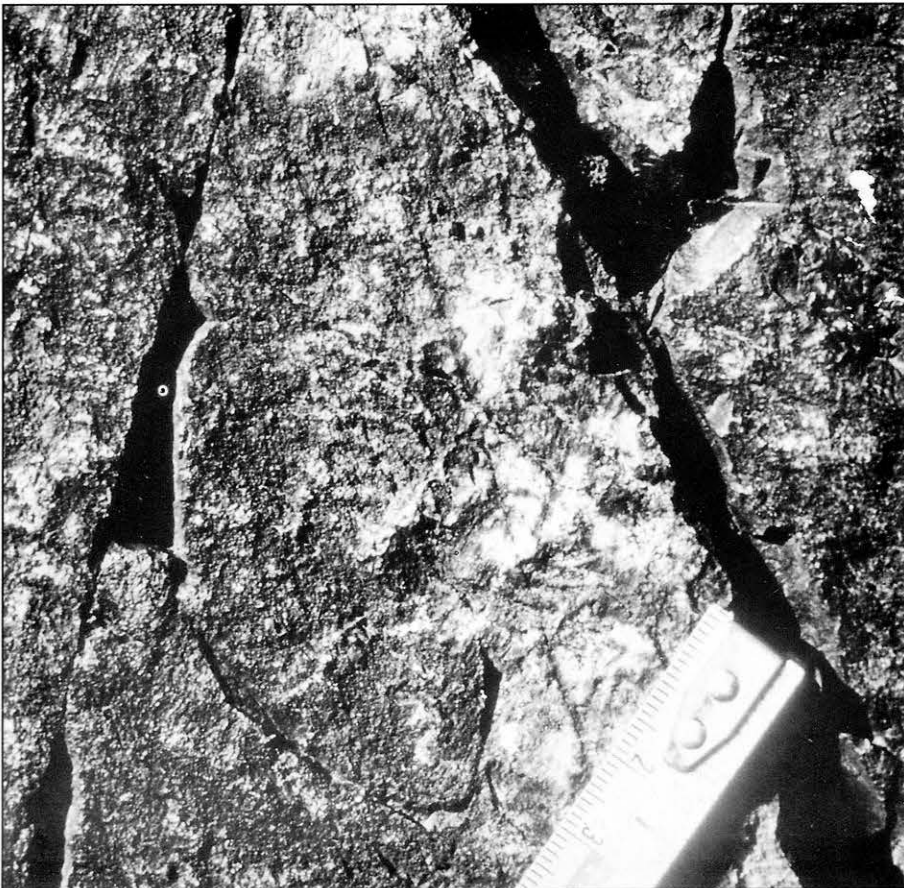


Fig. 11. *Bradgatia linfordensis* Form D. 50 mm wide.



Fig. 12. *Ivesia lobata* — holotype. 150 mm wide.

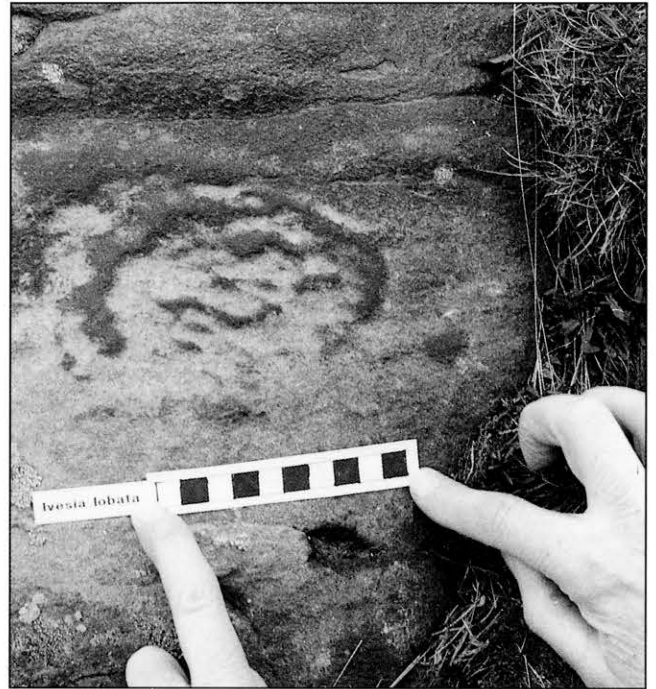


Fig. 13. *Ivesia lobata* — topotype. 150 mm wide.

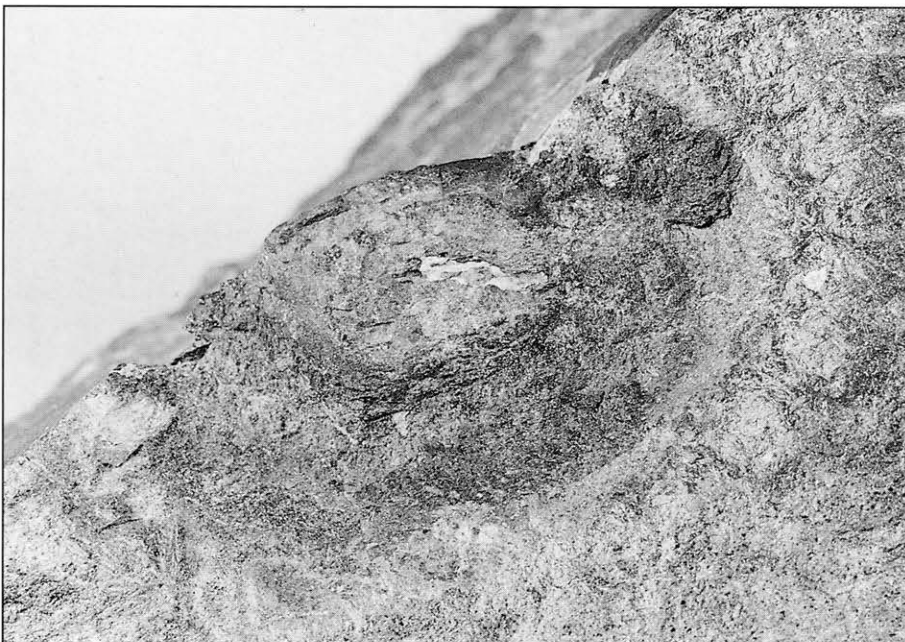


Fig. 14. *Cyclomedusa cliffi* — holotype. 150 mm diameter.

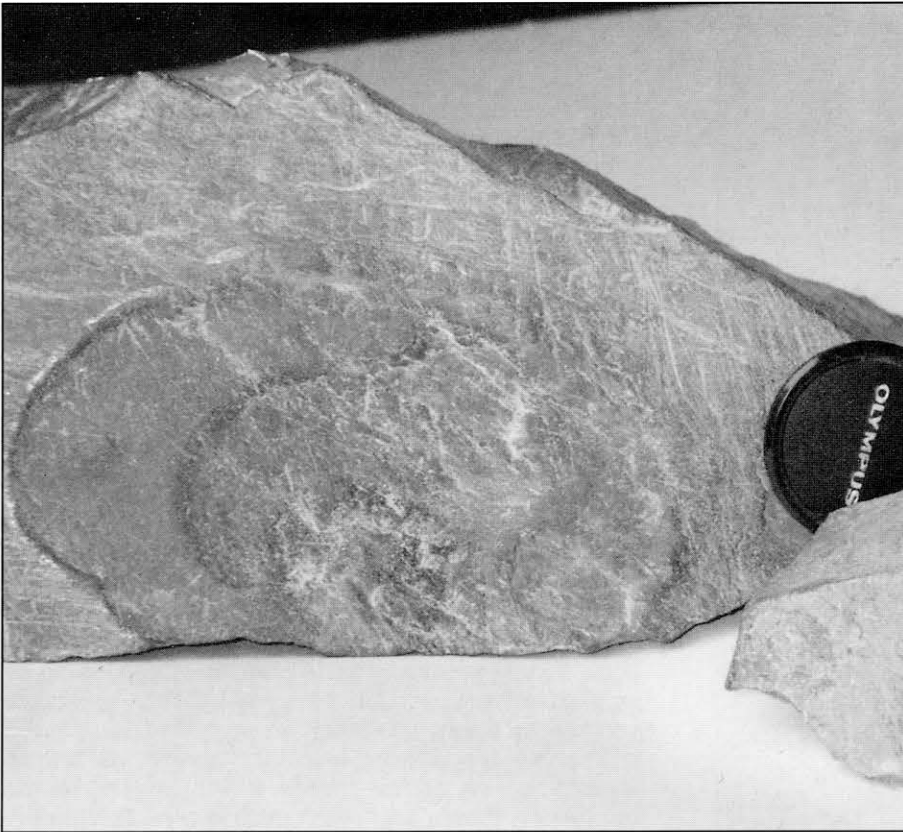


Fig. 15. *Cyclomedusa cliffi* — topotype. 160 mm diameter.



Fig. 16. *Shepshedia palmata* — holotype. 120 mm wide.



Fig. 17. *Blackbrookia oaksii* — holotype. Each subquadrangular impression is 160 mm in diameter.

Systematic Palaeontology

Four new monospecific genera are described below: *Bradgatia linfordensis*, *Ivesia lobata*, *Shepshedia palmata* and *Blackbrookia oaksii*; one new species *Cyclomedusa cliffi* is also proposed. Type specimens are mostly still *in situ* in the field. Plaster replicas have been deposited in either or both of the University of Leicester Geology Department collections or in Leicestershire Museums geology collections.

Phylum Petalonamae Pflug, 1972
 (Problematical Coelenterata (Glaessner, 1979))
 Class Rangeomorpha Pflug 1972
 Family Charniidae Glaessner 1979

Genus *Bradgatia* nov.

Diagnosis: A colonial, soft-bodied but moderately rigid organism consisting of a complex cluster of *Charnia*-like fronds diverging from a central ring or boss-like structure. The stems have a plaited appearance and may bifurcate several times (Figs 3, 4).

Bradgatia linfordensis sp. nov.

Diagnosis: as for genus.

Etymology: after Bradgate Park and the nearby village of Newtown Linford, Leicestershire.

Horizon: Hallgate Member, Bradgate Formation, Maplewell Group, Charnian Supergroup.

Type locality: Memorial Crag, Bradgate Park, Leicestershire, England (SK 524 111); near the base of the bedding plane on the south face.

Holotype: still *in situ*. Plastotype replicas in the Geology Dept. University of Leicester, accession no. 115413/0, and in Leicestershire Museums Geology Collections Accession No. G26/1994.

Description: The holotype is an ovoid colony of fronds measuring 410 × 300 mm (Fig. 3). The fronds appear to arise from a centre composed of three small raised protuberances each 10 mm in diameter; two rings appear to mark further protuberances which have been damaged. The outer margin of the colony is a finely indented rim composed of the small distal ends of fronds. The number of these is indeterminate owing to poor preservation but there must be at least one hundred present. The rest of the colony is a complex cluster of fronds radiating from the central area by stems which may bifurcate; they decrease in thickness towards the margin of the colony. From these stems arise a series of fronds which occasionally show faint, segmented or lobate structures as in *Charnia*, each about 50 mm long. The fronds show little evidence of wrinkling or overlap so were probably stiffened by some substance such as collagen. The stems show a knotted, plaited or knobby appearance particularly towards the central area. The tips of the fronds at the bottom of the impression show a slight curvature to the left, possibly due to current action. Several other specimens have been found on the same bedding plane, and faint traces also occur in Charnwood Golf Course Quarry and at other localities in Charnwood Forest. Each is treated as a separate form.



Fig. 18. Trail; Charnwood Golf Course Quarry. About 6-7 mm wide and 100 mm long.

Form A (Figs 5, 6) is still *in situ* (cast in University of Leicester Geology Dept. accession nos. 115414/0 & 115415/0; another cast in Leicestershire Museums Geology collection accession no. G27/1994); 310 × 260 mm with an elliptical raised boss 52 × 26 mm in the centre; the boss shows no detail but may represent a central float or anchoring mechanism which filled with sediment when the colony settled. Arising from the boss are stems up to 10 mm wide which bifurcate and thin to 1 mm nearer the margin. One stem has an irregularly knotted appearance. The margin of the colony is finely indented, consisting of the distal ends of fronds, best seen on the left-hand side. An ovoid disc is present within the left-hand side of the colony and faintly preserved within it are at least three *Charnia*-like fronds about 50 mm long (Fig. 6) radiating from a central point, again suggesting a possible budding mechanism of reproduction.

Form B (Figs 7, 8; cast in University of Leicester Geology Dept. accession nos. 115416/0 & 115417/0; and in Leicestershire Museums Geology collection accession no. G28/1994) lies towards the top of the Memorial Crags bedding plane. It is the largest of the known colonies at 416 × 234 mm. It is less ovoid owing to its mode of preservation. It has no clear central area, but the fronds do appear to radiate from the upper centre of the colony. To the left of the centre the fronds are less clearly defined making the stems relatively stronger and giving the pectinate appearance. Two fronds below the centre are about 50 mm long and show the *Charnia* type of segmentation. One of these is reminiscent of the lobate form described from Mistaken

Point by Misra (1969, pl. 8b). The right-hand part of the colony is better preserved but split by an open joint. Some of the stems again show an irregularly knotted appearance. The indented margin of frond tips is well displayed.

Form C (Figs 9, 10) is still *in situ* in the lower centre of the Memorial Crags bedding plane (cast in Leicestershire Museums Geology collection accession no. G29/1994). An ovoid colony 200 × 180 mm without any distinct centre of radiation of fronds (Boynton, 1978; Brasier *in* Cowie and Brasier, 1989). Some of the fronds at the upper right give an impression of a water-lily. This part is again comparable with one of Misra's forms (Misra, 1969, pls 2a, 4d, 8b), noted by him as lobate-dendrite (see also Anderson, 1978, fig. 7; Anderson and Conway Morris, 1982, pl. 1, no. 3). Some fronds show faint segmentation, whilst distal portions of the fronds are small and feathery giving an indented margin to the colony. At the right-hand margin are two small *Charnia*-like fronds, each about 50 mm long (Fig. 10); they extend beyond the margin and may again represent budding juveniles.

Form D is much smaller than the other colonies (Fig. 11). It lies in the right centre of the Memorial Crags bedding plane (cast in Leicestershire Museums Geology collection accession no. G30/1994). Preservation is poor, and is made worse by slickensiding. It measures only 50 mm in diameter and appears to have two central disc-like depressions. Five curved lobes arise on the left, separated by prominent ridges, and are without segmentation. The lobes on the right are more pointed like the distal ends of *Charnia*. A small *Charnia* frond appears to be separating from the colony at the bottom left.

Two rather more faint impressions, not designated here as forms, lie to the left of Form C. One is an ovoid colony 170 × 130 mm. *Charnia*-like fronds are visible at the top left, some apparently showing bifurcation. There is no central area but an approximate focus of radiation near the top suggests that only half the colony may be present in the impression. A comparison may be made with one of the Newfoundland forms (Misra, 1969, pl. 4d). Another impression lies even further to the left of Form C, and appears at first to be a specimen of *Charniodiscus concentricus* but is much more complex; it consists of an ovoid disc with a central raised area bordered by two concentric ridges. Arising from these appear to be two faint branches. A less well-defined stem emanates from the bottom of the disc with very poorly defined lobes.

Discussion: As *Bradgatia linfordensis* is a previously undescribed type of fossil impression, and as its detail is faintly preserved, it is difficult to make comparisons with other organisms, living or fossil. The nearest possible comparatives are the impressions reported from the late Precambrian Conception Group of Mistaken Point, Newfoundland by Anderson and Misra (1968), Misra (1969) and Anderson (1978). These are unnamed and no detailed descriptions have yet been published so that meaningful comparisons cannot be made. However, Jenkins (1985, fig. 6) provided a sketch of *Bradgatia linfordensis* and noted similarities to *Ranga*



Fig. 19. Possible trail about 25 mm long on the Memorial Crags.

schneiderhohni. He suggested that the latter had several fronds arising *Charnia*-fashion from a single holdfast (Jenkins, 1985, fig. 5). We visualize *Bradgatia* as probably nektonic rather than sessile, so the similarity may be more in the style of preservation than in the original biology. Form C may represent a colony preserved at maturity in the act of reproductive budding. Within the top left is a small ovoid disc which may or may not be related to the frondose colony. At the bottom right of the holotype is a small *Charnia* frond about 15 mm long, which may represent a juvenile either of an isolate frond or newly budded off the colony.

As described above, the fossil impressions give a hint of a budding mode of reproduction, which may of course alternate with a sexual mode. The frondose organisms *Charnia* and *Charniodiscus* may be mature buds from colonies, but without further evidence they are best left as distinct taxa.

Following Glaessner (1984) and Runnegar and Fedonkin (1992), *Bradgatia linfordensis* is regarded as a member of the Phylum Petalonamae (Pflug, 1972) at this stage, though future research may require re-assignment.

Phylum Cnidaria

?Class Cyclozoa Fedonkin 1983

Family Cyclomedusidae Gureev 1987

Genus *Ivesia* nov.

Diagnosis: a circular disc of medusoid type with the central area marked by prominent, irregular lobate structures, perhaps with radial arrangement (Figs 12, 13).

Ivesia lobata sp. nov.

Diagnosis: as for genus.

Etymology: after Ives Head and the lobate structures.

Horizon: Lub Cloud Greywacke Member, Ives Head Formation, Blackbrook Group, Charnian Supergroup.

Type locality: holotype *in situ* on Ives Head, Shepshed, Charnwood Forest, Leicestershire (SK 477 170). Casts in Leicester University Geology Dept. Collections accession no. 115577, and in Leicestershire Museums Geology Collections accession no. G32/1994.

Description: the holotype is a circular disc 150 mm in diameter with a slightly wavy margin, which is preserved as a slightly irregular convex ridge (Fig. 12). The upper margin is less well-defined and appears to expand into a lobate protuberance. In the centre of the disc is a series of irregular lobes with a coiled, possibly weakly radiate, arrangement; one of the lobes extends to the left margin. Very faint markings around the disc may tentatively be interpreted as traces of fronds or tentacles arising from the central lobes.

Discussion: this fossil was described but not figured by Boynton (1978). After opinions from various expert visitors, it is herein considered to be a new form of medusoid. Preservation in rather coarse-grained sediment obscures all fine detail. A broad but tentative comparison may be made with the dubiofossil *Protoniobia* (Sprigg, 1949; see also Wade, 1972). A cast of another specimen at the same locality is in Leicestershire Museums Geology collection (accession

no. G33/1994) (Fig. 13). These fossils are at a much lower stratigraphical horizon than most of the other Charnian fossils.

Although medusoids were referred to problematical Coelenterata by Glaessner (1979, 1984), *Ivesia lobata* and the other fossils described below are here placed within the Phylum Cnidaria.

Genus *Cyclomedusa* Sprigg 1947

Cyclomedusa cliffi sp. nov.

Diagnosis: ovoid medusoid impression characterized by a raised oval central boss and an irregularly crenulated margin (Fig. 14).

Etymology: after Cliffe Hill quarry, Markfield, Leicestershire.

Horizon: Hallgate Member, Bradgate Formation, Maplewell Group, Charnian.

Locality: Cliffe Hill Quarry, Markfield, Leicestershire.

Holotype: Leicestershire Museums accession no. G730.1993.

Description: a poorly preserved incomplete ovoid disc 150 × 120 mm (the latter estimated from the broken block) with a slightly undulating margin. Within this is a flat area 20 mm in diameter surrounding a slightly depressed area 20 mm wide. In the centre is a raised convex boss estimated at 30 × 22 mm.

Discussion: this species differs from other cyclomedusids in its greater ovality, strong ovoid boss and irregular margin. It resembles the form *Tirasiana disciformis* Palij, named in an abstract by Palij (1976) and more formally described by Bekker (1985).

Another specimen in a private collection measures 160 × 100 mm; it has a slightly raised and more crenulate margin, and two concentric flat areas separated by raised rings; each flat area is about 30 to 40 mm wide (Fig. 15). In the centre is a slightly raised boss 50 × 30 mm.

Class and Family Uncertain.

Genus *Shepshedia* nov.

Diagnosis: an ovoid impression with a palmate arrangement of three broad branches arising from a short stem (Fig. 16).

Shepshedia palmata sp. nov.

Diagnosis: as for genus.

Etymology: from the nearby town of Shepshed, Leicestershire, and the palmate style of the impression.

Horizon: Lub Cloud Greywacke Member, Ives Head Formation, Blackbrook Group, Charnian.

Type locality: holotype *in situ* on Ives Head, Shepshed, Charnwood Forest, Leicestershire (SK 477 170) (Fig. 16). Casts in Leicester University Geology Dept. Collections accession no. 115573, and in Leicestershire Museums Geology Collection accession no. G34/1994.

Description: the palmate impression measures 120 × 80 mm and consists of three main branches which dichotomise towards the margin yielding 11 terminations about 1 mm wide. There is a gap at the margin which suggests the former presence of a stem.

Discussion: the poor preservation in rather coarse-grained sediment precludes further description of this

organism, which was originally described as a dubiofossil (Boynton, 1978). However, five other similar impressions have been found on the same bedding plane and no sedimentologist visiting the site has offered an inorganic explanation for them. *Shepshedia palmata* has some superficial similarity to the unnamed bush-like form noted in Newfoundland by Anderson and Conway Morris (1982, pl. 1, fig. 4). A cast of another specimen is in Leicestershire Museums Geology collections accession no. G35/1994.

Genus *Blackbrookia* nov.

Diagnosis: approximately square impressions of general medusoid character, possibly occurring as a pair, each with a raised rim (Fig. 17).

Blackbrookia oaksi sp. nov.

Diagnosis: as for genus.

Etymology: From the adjacent valley of the Blackbrook stream and reservoir, and the parish church of Oaks-in-Charnwood therein.

Horizon: Lub Cloud Greywacke Member, Ives Head Formation, Blackbrook Group, Charnian.

Type locality: holotype *in situ* on Ives Head, Shepshed, Charnwood Forest, Leicestershire (SK 477 170) (Fig. 17). Casts in Leicester University Geology Dept. Collections accession no. 115576, and in Leicestershire Museums Geology collection accessions no. G36/1994.

Description: the single impression consists of two subquadrangular impressions lying side by side with traces of a third alongside; each of the two measures 160 mm in diameter. The margin of the impression is an irregularly raised ridge up to 5 mm wide. Within this are very irregular lobate ridges comparable with those in *Ivesia lobata*.

Discussion: whether the two squares are part of the same organism is not clear in the coarse-grained sediment, but faint markings suggest that they may be linked, and there are traces of a stem and branches projecting to the left. The single impression was figured by Boynton (1978, pl. 22, fig. 2) as a dubiofossil but it is now regarded as a new genus probably of medusoid nature.

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Helen E. Boynton
7 The Fairway
Oadby
Leicester LE2 2HH

Trevor D. Ford
Geology Dept
University of Leicester
Leicester LE1 7RH