Precambrian fossil discoveries and new fossil localities in Charnwood Forest, Leicestershire

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Abstract: New localities with Precambrian fossils have been found in Charnwood Forest. New specimens include *Hadrynichorde* aff. *catalinensis*, which is a species potentially new to Britain. Also revealed are juvenile forms of organisms not recorded previously, and fossil forms that have no clear associations with currently recognised species.

Precambrian rocks have only limited exposures in Britain, as they are mostly buried beneath thousands of metres of younger strata. Even more limited are the sedimentary strata – tuffaceous and volcaniclastic rocks, which in Leicestershire are the result of locally extensive volcanic activity (Moseley and Ford, 1989; Carney, 2010).

Great swathes of Precambrian sedimentary rocks are exposed in Newfoundland, Canada, and in the Ediacara Hills of Australia, as well as in Russia, Eastern Europe and Africa, and these outcrops have yielded thousands of fossils belonging to the Ediacaran biota. In Britain, exposures of sedimentary Precambrian rocks relate to outcrops and quarries in Charnwood Forest, Leicestershire, with other exposures in Shropshire and in Southern Wales (Cope, 2000). With such restricted areas of exposed rock, the number of specimens discovered has been small.

Following the casting with silicone rubber of a Leicestershire quarry face famed for the holotypes of *Charnia masoni* and *Charniodiscus concentricus* (Ford, 1958), several hundred new specimens have come to light in a community termed the 'Mercian Assemblage' (Wilby *et al.,* 2011); this includes species previously unrecognised outside of Canada, and also new species that are unique to Britain.

Two new fossil localities can be added to the six already known in Charnwood Forest. A review of the known Bradgate Park fossil location has also yielded many new specimens. These include a plethora of juvenile forms, and proposed species that are previously unrecognised in Britain. Additionally, several unusual specimens, not akin to previously recorded forms, may be regarded as new elements of the Ediacaran biota.

History of fossil discoveries

The story of how the then-schoolboy Roger Mason discovered the holotype of *Charnia masoni* is well known (Ford, 1958). In 1957 he and two friends came across the fossil specimens while climbing in a quarry near Woodhouse Eaves. Bringing the specimens to the attention of Trevor Ford, at the University of Leicester, the specimens (*Charnia masoni* and *Charniodiscus concentricus*) were formally described up as the first unequivocal, macroscopic, Precambrian fossils to have been discovered (Ford, 1958).

In truth, the fossils had been discovered a year previously by a schoolgirl, Tina Negus (née Batty). But, without contacts within geology circles, she was only able to bring the specimen to the attention of her school teachers, where her find fell on deaf ears (Ford, 2011). The quarry location had several mentions in old texts. In 1848, J. Plant and J Harley had discovered ring-like impressions on the bedding surfaces, and the find was relayed to the geologist Prof. A. C. Ramsay (Howe *et al*., 2012). He interpreted the rings as being tethered seaweeds, blown about by currents to scribe circular scratch marks on the seabed (rather like the genus *Kullingia* (Kulling, 1964; Jensen *et al.*, 2002)). Prior to this, the ring marks had been well known to the quarry men, who colloquially referred to the site as the 'Ring Quarry'. It was later presumed that the marks were inorganic in origin (see *Mercian Geologist*, 2008, 4-5).

Discoveries in the 1970s by Trevor Ford, Bob King, and later Helen Boynton, revealed five new fossil sites. New species were described, namely *Bradgatia linfordensis*, *Ivesheadia lobata*, *Shepshedia palmata* and *Blackbrookia oaksi* (Boynton & Ford, 1995).

Fossiliferous bedding planes from all six localities have been cast in plaster by the British Geological Survey (Edwards and Williams, 2011), and the casts are now housed at the B.G.S. stores at Keyworth, Nottingham. From the casting in the large quarry from which the *Charnia* specimen was originally found, hundreds of new specimens have been discovered and several new species are currently being described (Wilby *et al.*, 2011).

Geological setting

The outcrops of Precambrian rocks in rural Leicestershire represent the core of a Charnwood Anticline, where the Blackbrook Group is succeeded by the Maplewell Group (Moseley and Ford, 1985). The Blackbrook Group includes the rocks of the Ives Head Formation, which is famed for the occurrence of a bedding plane where fossil species *Ivesheadia lobata, Blackbrookia oaksi* and *Shepshedia palmata* were discovered (Boynton and Ford, 1995). These fossils may represent *Charnia* like organisms in a state of decay prior to lithification, and as such these 'ivesheadiomorphs' have been interpreted as taphomorphs (Liu *et al.*, 2010). Within the Maplewell Group, the Beacon Hill

Formation has few fossil forms associated with it, but microbial matting and sparse discs occur in Bradgate Park. The overlying Bradgate Formation is the source of most of Charnwood's Precambrian fossils, including the iconic *Charnia masoni* (Ford, 1958).

The rocks of the Charnian Supergroup are mainly of volcanoclastic origin, consisting of grains derived from primary volcanic eruptions; material derived from the erosion of pre-existing volcanic deposits seems relatively rare (Carney, 2010). The reason that such delicate fossils exist, is that the finer grained ashy material periodically settled out onto the sea floor, engulfing living organisms and allowing them to be preserved. A possible explanation of why the Bradgate Formation contains the most fossil horizons is that the Maplewell Group represents a period of maximal volcanic activity, and subsequent volcanic ash fall out (Carney, 2010).

The new fossil locations

Within Bradgate Park, already famous for its fossil bed containing *Charnia* and *Bradgatia* genera (Boynton and Ford, 1995), a new fossil locality has been recognised on a bedding plane of about 20 m^2, which is extensively covered by lichen that obscures much of the finer structures. This bedding plane lies 4-5m stratigraphically below that on which lie the first Charnian fossils to have been recorded (Boynton & Ford, 1995); it is of a similar composition to the original site and lies within the Sliding Stone Slump Breccia beds (Bradgate Formation), but not in beds as coarse as the fossil-bearing bedding plane in the Beacon Hill Formation.

Two large ovate discs are exposed, together with an unusual form, reminiscent of a species of *Charniodiscus* (this specimen is faint, and warrants further investigation following cleaning of the rock surface). One of the discs is a large ovoid, 100x75 mm, in negative epirelief; it consists of two concentric rings with a faint halo of an outer ring just visible, nearly doubling its overall size; no attached frond is visible. The second disc is ovoid, measures 120x100 mm and is in negative epirelief; it has seven distinct concentric bands around a central ovoid depression that is 45x35 mm, but there is no frondose element or stem attached. A rock fracture bisects the fossil, which is thus stepped by 10 mm (Fig. 1).

The two fossil forms have attributes relating to *Aspidella* aff. *terranovica* (Billings, 1872). However, forms with such concentric rings have also been seen at the Quarry at Woodhouse Eaves (Wilby *et al*., 2011), where they occur as holdfasts of *Primocandelabrum* species (Hofmann *et al.*, 2008). No frondose structures are visible at the new locality, so the association with *Primocandelabrum* cannot be confirmed.

A second locality occurs on the south-western limb of the Charnwood anticline, within an area known locally as the Altar Stones. Two coarse beds are interleaved with finer grained beds. Within the latter a discoid fossil with possible attached frondose element has been found. On the same bedding plane, two more discoid forms have been recognised. The initial specimen is a prominent, roughly circular disc, 36x34 mm, enclosing three faint concentric rings (Fig. 2). From a break in its outer margin a presumed, faint, undulating stem

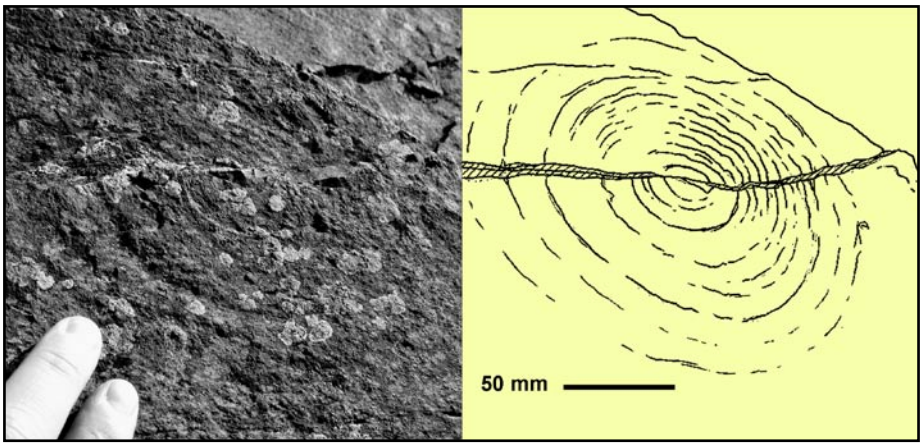


Figure 1. *Large, concentric-ringed holdfast disc, with surface features partially obscured by lichens on the bedding plane.*

Figure 2. *Discoid holdfast with possible conjoined, sinuous stem and mop-headed structure.*

Charnia grandis – one specimen
Bradgatia linfordensis – 15 specimens
Aspidella aff. *terranovica* – >150 specimens
Cf. *Primocandelabrum* – 3 specimens *
Hiemalora sp. – 2 specimens *
Cf. *Hadrynichorde* – 4 specimens *
Juvenile colony forms – 35 specimens *
Filament forms *
Problematica, inc. possible worm traces

Table 1*. Fossils recorded in the new investigations in Bradgate Park; asterisks denote newly recorded species and forms.*

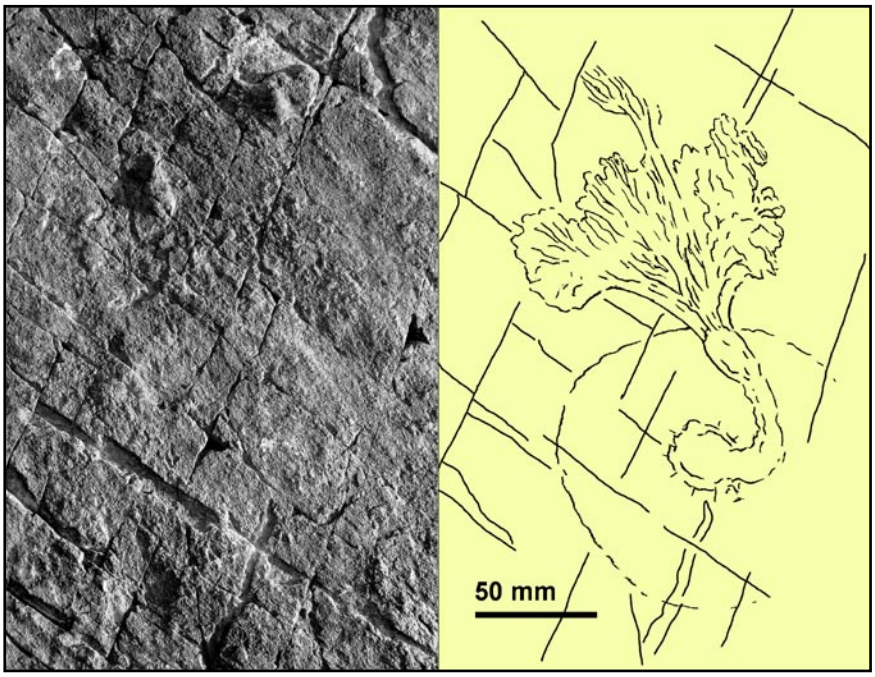


Figure 3*. Fossil comparable with* Primocandelabrum*, with large circular holdfast, curved stem and cauliflower-like frond complex.*

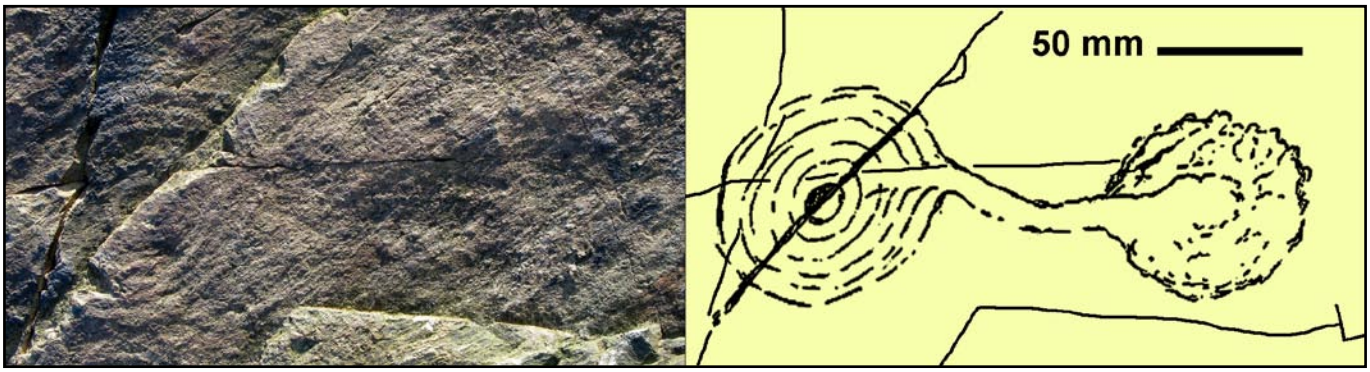


Figure 4*. Presumed* Primocandelabrum *multi-ringed discoid form with a break in its outer ring and an emerging stem with globose frond attached.*

extends for 57 mm to terminate in a bulbous 'mop-headed' structure that is 55x35 mm. The total length of the specimen is 147 mm. Two further three-ringed circular discs have diameters of 34 and 31 mm. The fossil horizons correlate with the Sliding Stone Slump Breccia, at the base of the Bradgate Formation, and are at the same stratigraphical level as the original fossil locality in Bradgate Park.

The Bradgate Park fossil plane

Bradgate Park is a large enclosed area of parkland that contains the classic fossil locality (Boynton and Ford, 1995), which is a bedding plane at the top of 25 or more distinct silty laminae. This offers an insight to a Precambrian sea floor of about 563 million years ago (Wilby *et al*., 2011). The surface shows little signs of current-activity, indicating that the sea floor was well below the storm wave base, probably beneath water that was over 50 m deep (Carney, 2010).

The site had previously yielded more than 50 fossil forms, including the holotype and paratypes of *Bradgatia linfordensis* (Boynton and Ford, 1995). Fossils previously described consist largely of discoid forms (*Aspidella* aff. *terranovica*), *Bradgatia* specimens, a large *Charnia grandis* (Boynton and Ford, 1995; Ford, 1999) and a small juvenile specimen of a *Charnia* frond only 17mm long. The new investigation of the classic Bradgate Park fossil plane has revealed more than 200 fossil forms, including species not recognised previously (Table 1).

Forms comparable with *Primocandelabrum*

A genus previously thought to be endemic to Newfoundland, *Primocandelabrum* (Hofmann *et al*., 2008), has recently been discovered at the Quarry at Woodhouse Eaves (Wilby *et al*., 2011). Two *Primocandelabrum* forms also exist on the Bradgate Park fossil plane; they are visible only at dawn, with oblique natural lighting. A possible third specimen is a juvenile (see below).

One specimen has a circular disc (holdfast) 142 mm in diameter, with an off-centred attached stem 70 mm long, terminating in a slightly bulbous swelling before the emergence of a cauliflower-like frond complex 150 mm wide and 170 mm high (Fig. 3).

The second specimen has an ovoid disc 90x80 mm, with seven concentric rings broken where a stem 80 mm long emerges and terminates in a globose structure, roughly circular and 65 mm in diameter (Fig. 4). Among the *Primocandelabrum* related species from

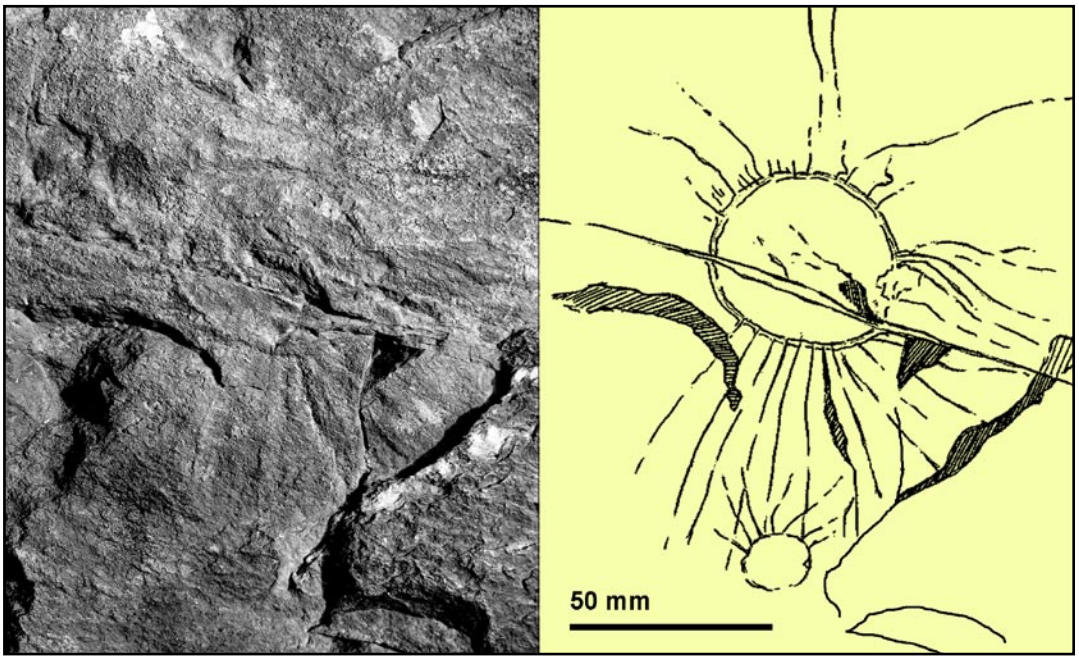


Figure 5. *Two specimens of different sizes of* Hiemalora *aff.* stellaris*, with their raised-rimmed holdfasts and stellate, radiating, anchoring filaments.*

Figure 6. *A fine filamentous item, possibly* Hadrynichorde *aff.* catalinensis*.*

Leicestershire, a globose-headed, 'dumb-bell' taxon (Wilby *et al*., 2011) may possibly relate, albeit the frond of the Bradgate Park specimen is rather faint.

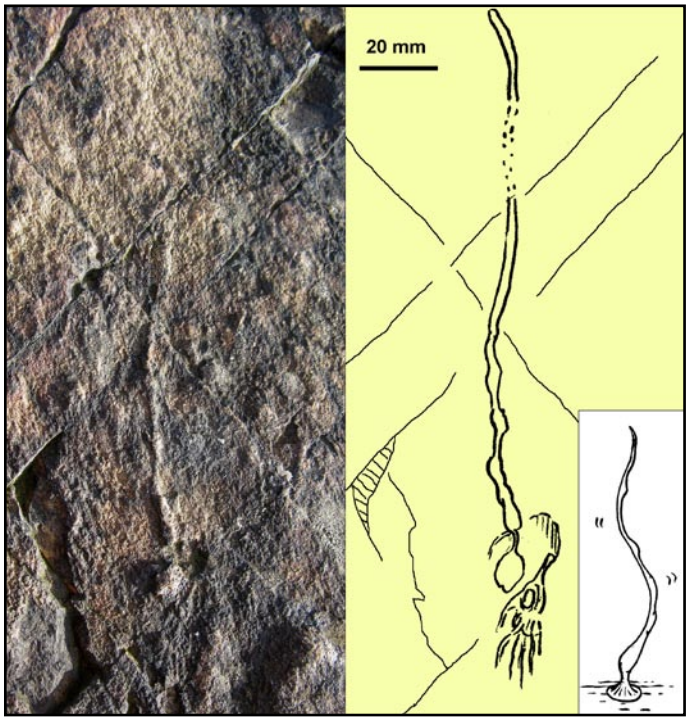
Hiemalora specimens

Two distinct *Hiemalora* aff. *stellaris* (Fedonkin, 1982) specimens have been discovered at the Bradgate Park fossil plane. This also is a species that is frequently found in Newfoundland, but which has recently been described from the Quarry at Woodhouse Eaves (Wilby *et al*., 2011). It was once thought to be a medusoid form, but it may refer to an anchored holdfast of *Primocandelabrum hiemaloranum* of Newfoundland (Hofmann *et al*., 2008).

The Bradgate Park fossils consist of two forms in close proximity (Fig. 5). The holdfasts are discoid structures, with a well-defined raised rim, from which numerous anchoring filaments arise and radiate. The larger specimen has a disc 50x38 mm, with filamentous anchoring arms up to 50 mm long. Beside the larger specimen, a smaller one consists of a circular disc 16 mm across, with anchoring filaments to 20 mm long.

Specimens comparable with *Hadrynichorde*

With the advantage of natural oblique lighting, several long filamentous structures are visible with a morphology that mirrors specimens of *Hadrynichorde catalinensis* (Hofmann *et al*., 2008) from Newfoundland. The species has been interpreted variously as fine worm traces comparable with *Planolites*, or whip-like algal forms, and also possibly related to the *Laminaria*-like kelp fossil *Hadryniscala avalonica*, also from Newfoundland (Hofmann *et al*., 2008). The *Hadrynichorde* genus is typified by a raised ovoid disc attached to a long, fine, filament structure 1 mm in relief, 1.0–2.5 mm wide and up to 730 mm long. The filament is typically tapered, with graceful curves along its length, with small bulbous swellings, so that it resembles knotted string.



The largest of the newly discovered Bradgate Park forms is 430 mm long, with a small ovoid, basal holdfast 16x10 mm. Its relief is about 1 mm, and it tapers from 2 mm wide to 1 mm at its tip. A smaller specimen, 150 mm long, has small thickenings along its length, again in the style of knotted string (Fig. 6). These fossils appear to be *Hadrynichorde* aff. *catalinensis*, which would be a genus and species new to Britain and Europe.

It is proposed that *Hadrynichorde* species may represent an extinct forerunner of extant species described as sea-whips, which are colonial forms of deep-water environments. Modern colonies (eg. extant species *Funiculina quadrangularis* of British waters) are found in close association with sea-pens (*Pennatula* sp.). It is notable that *Charnia* was for many years

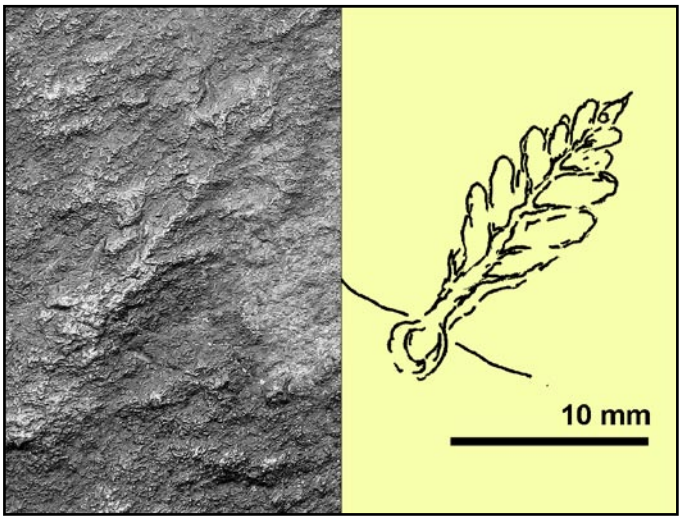


***Figure 7**. Fossil comparable with* Charniodiscus*, with disc holdfast, conjoined stem, and branches from central rachis.*

presumed to be a sea-pen, until cleary demonstrated not to be related (Antcliffe and Brasier, 2007). That sea-whips and sea-pens co-exist in today's deep oceans seems to mirror a Precambrian deep-water environment where *Charnia* and *Hadrynichorde* coexisted.

Juvenile fossil forms

Juvenile fossil forms of Precambrian age are exemplified by the Drook Formation of Newfoundland, which has revealed a bedding plane on which juvenile specimens occur amidst specimens of *Ivesheadia lobata* (Liu *et al*., 2012, 2013). The so-called Ivesheadiomorphs are interpreted as being taphomorphs derived from decayed frondose organisms such as *Charnia*, and as such have been called 'effaced' specimens (Liu *et al*., 2010). The association between juvenile specimens, with no fully developed adult specimens, and dead, rotting, specimens is ecologically significant. It suggests the fossil plane shows re-colonisation of the seabed after a mass mortality event (Liu *et al*., 2012).

The Bradgate Park fossil plane has multiple large 'adult' forms of *Bradgatia linfordensis* and *Charnia grandis* present, and yet about 35 specimens of small, juvenile fossils have been found. The range of lengths of the juveniles is 11–38 mm, with one *Charniodiscus* specimen of 78 mm. That specimens of juvenile size should co-exist with adult-sized forms suggests a vibrant environment, where reproduction is occurring and both young and old organisms exist side by side. It is not indicative of re-colonisation of an area of seabed following a mass mortality event.

The only previous reference to juvenile forms at Bradgate Park was to a *Charnia* specimen of 17 mm length (Boynton and Ford, 1995). With a small disc, pronounced stem, and a frond with a central rachis and paired branching forms, it seems more reminiscent of *Charniodiscus*, but this is open to interpretation.

The interpretation of juvenile fossil forms is difficult, as the specimens, by their very nature, are small, and some of the fine details required for identification are lacking. Fossils from the Drook Formation fall into several categories, akin to genera *Charnia*, *Charniodiscus*, the Newfoundland genus *Trepassia* (Narbonne *et al*., 2009), and indeterminate forms (Liu *et al*., 2012). The juvenile forms on the Bradgate Park bedding plane fall into six groups (Table 2).

Forms comparable with *Charnia masoni*

Two specimens from the Bradgate Park fossil plane have primary, secondary and, on one of the specimens, possible tertiary branches visible. In spite of their small size (15 mm) the apices are clearly visible, but the basal ends of the forms are missing, so full estimation of overall length is not possible.

Forms comparable with *Charniodiscus*

There are several juvenile forms with morphology akin to the genus *Charniodiscus*. They typically feature a small round disc, with a short stem attached to a lanceolate, tapered frond, with a prominent rachis. From the rachis arise paired, angled branches (Fig. 7). Some of the forms have markedly tapered fronds, terminating almost in a spike, like the species *C. spinosus* (Hofmann *et al*., 2008). This analogy is open to interpretation, but the species is not known from British assemblages. Also present on the bedding plane is a *Charniodiscus* type of intermediate size, 78 mm long (Fig. 8).

Cf. *Charnia masoni*
Cf. *Charniodiscus*
Charniomorph forms
Multi-filamentous forms
Primocandelabrum forms
Disc and stem forms

***Table 2**. Juvenile forms of fossils that have been recognised at Bradgate Park.*

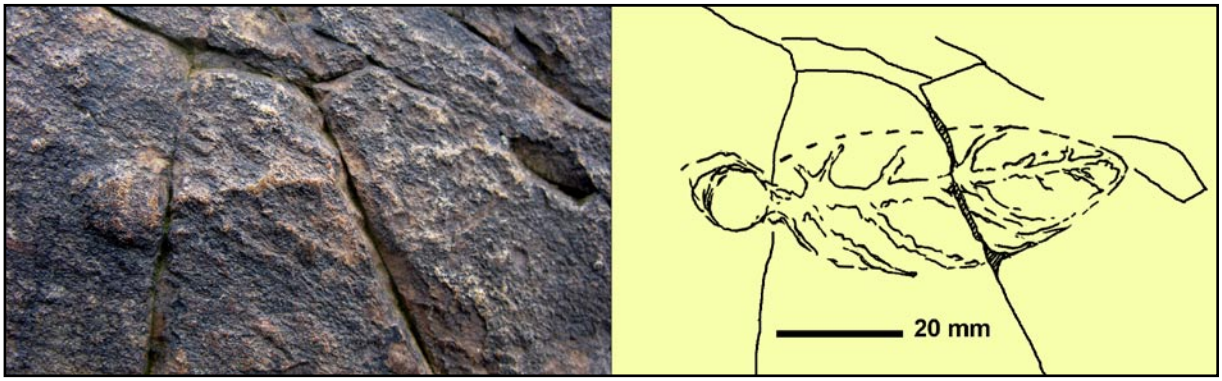


***Figure 8**.* Charniodiscus *form.*

Charniomorph forms

Several forms have distinct *Charnia* like morphologies, but the specimens lack the fine details of first and second order branching to assign a species. Specimens of discs, with attached stems and lanceolate fronds are reminiscent of *Charniodiscus*, but are also too weathered to reveal finer detailing. A small disc holdfast, with long stem, lanceolate frond and possible crenulations along its edge, may have *Charniodiscus* affinities (Fig. 9). An unusual specimen has a small, faint disc, no stem, and a long rachis with many paired branches that emerge nearly perpendicular to the rachis (Fig. 10). A narrow, lanceolate form, it does not seem to resemble the current known genera of fossils from the Mercian Assemblage at Charnwood Forest.

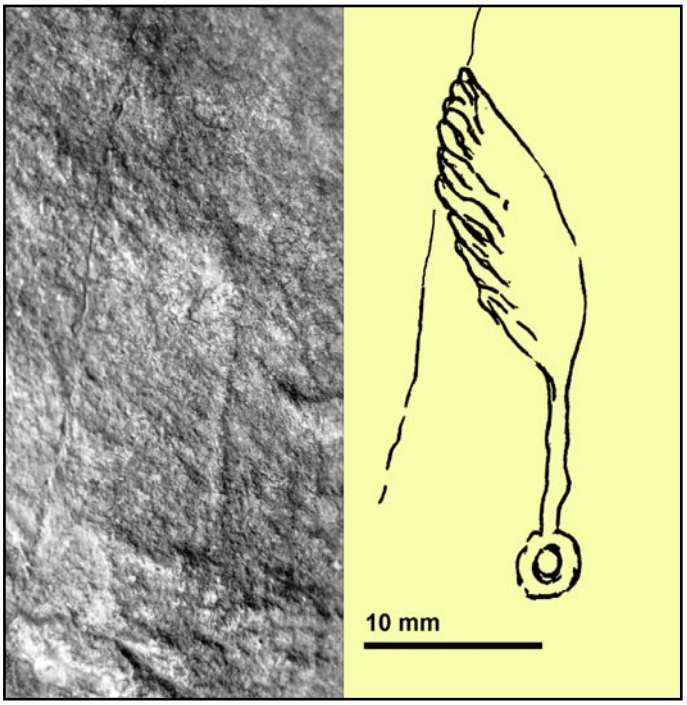


Figure 9. *Charniomorph, with concentric disc holdfast, conjoined long stem and frond.*

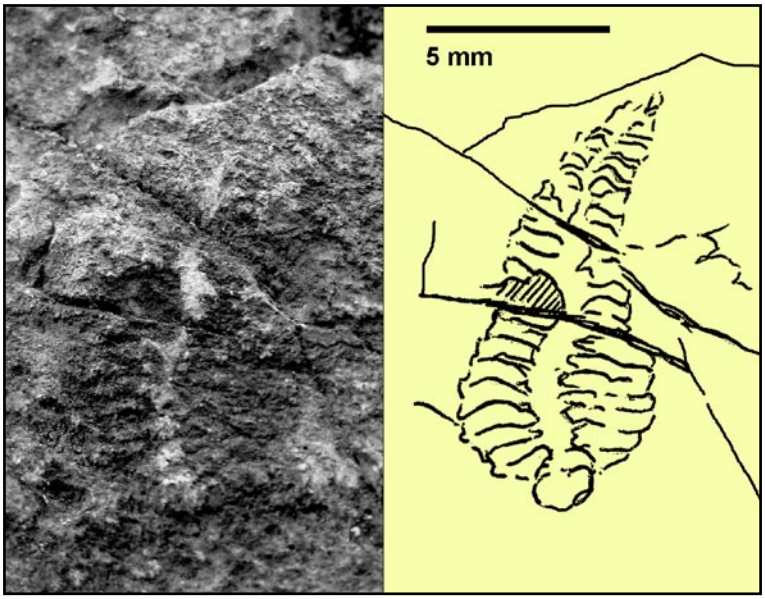


Figure 10. *Charniomorph with a faint disc, no stem, long rachis, and near-perpendicular branches.*

Multi-filamentous forms

Two of the new specimens have morphologies quite unlike other fossil species of the Mercian Assemblage. One specimen had previously been interpreted as the 'type-D' variant of *Bradgatia linfordensis* (Boynton and Ford, 1995), but this may be incorrect. The specimen is slightly broken, but no distortion is present. It does not show the *Charnia*-like elements (Boynton and Ford, 1995), but possesses at least seven separate filament structures, each tapering to a blunt point (Fig. 11). The filaments arise from a central source, now obscured as a result of vandalism, and one filament appears to be angled, near its tip, at 45° degrees, such that it overlaps the adjacent strand above. An estimate of overall length is 50 mm. A second multi-filamentous fossil (Fig. 12) has a small, faint disc structure attached to an off-centred rachis, from which emanate filamentous strands, each about 25 mm long, which are separated but extending parallel with each other. Total length of the partial form exposed is 42 mm. The morphology of these forms poses many questions; they may be juvenile forms of known genera, or potential new species.

Specimen comparable with *Primocandelabrum*

A single specimen on the fossil bedding plane has a morphology reminiscent of the many specimens of *Primocandelabrum* sp. as described elsewhere in Charnwood Forest (Wilby *et al*., 2011). It is 60 mm long with a discoid holdfast and an attached, tapered stem (Fig. 13). The stem terminates in a calyx-like form, from which emerges a rounded cluster of branches.

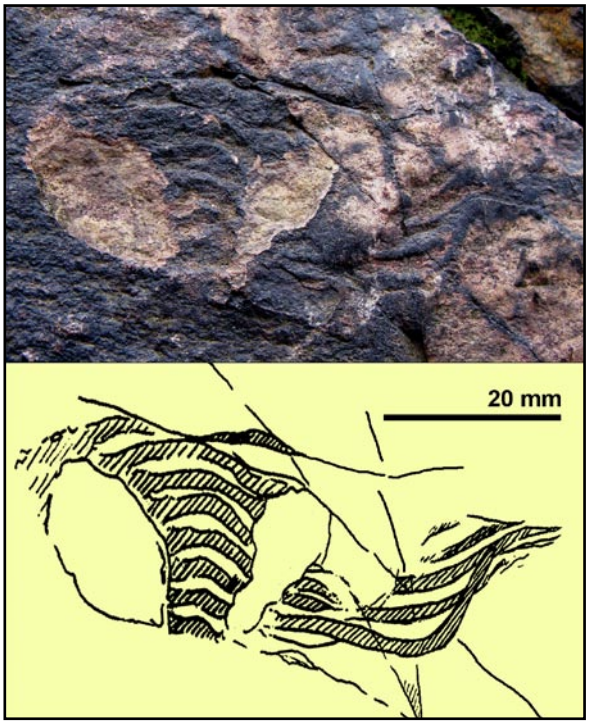


Figure 11. *Multi-filamentous form with an indeterminate base and seven sinuous filaments.*

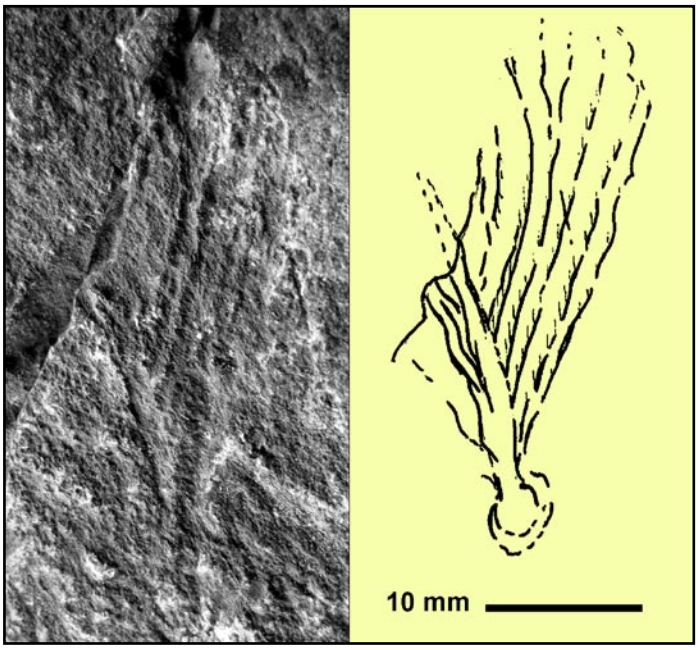


***Figure 12**. Multi-filamentous form with a faint disc and with parallel branches emanating from its rachis.*

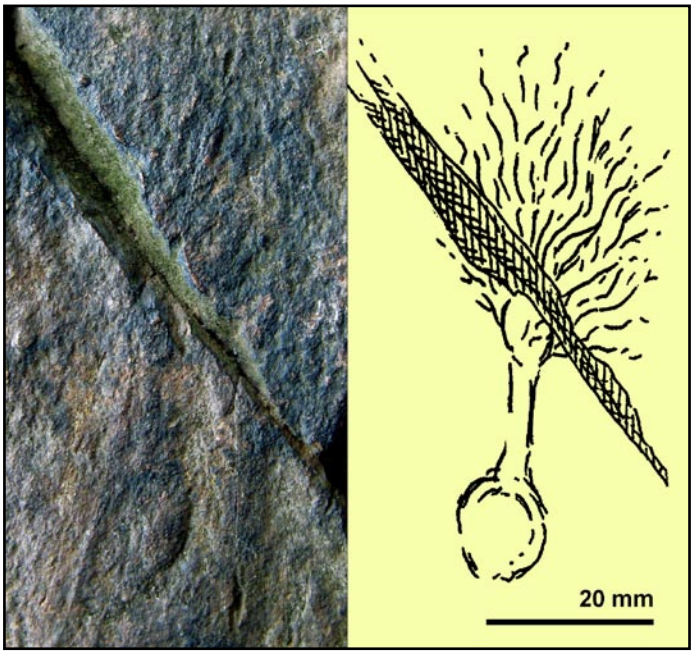


***Figure 13**. Fossil comparable with* Primocandelabrum*, with a comparatively large disc holdfast, stout stem, and cluster of branches.*

Disc and stem forms

Many specimens exist of small disc-like holdfasts, 3–5 mm in diameter, with conjoined stems from their centres, but with no definable frond structure attached. Whether the delicate frond features were destroyed in the fossilisation process, or were ripped away by sea current activity is unknown. These specimens are difficult to classify taxonomically, but seem to add to the many, larger specimens of *Aspidella* aff. *terranovica* on the fossil plane and disc holdfast fossils of unknown affinity.

Problematica

There are specimens on the bedding plane that show no affinity to known genera of Precambrian fossils from Charnwood. Interpretation of these forms is difficult, as they are often isolated examples. Of note is the fossil interpreted as a worm trail like *Planolites* (Boynton and Ford, 1995).

The Mercian Assemblage environment

Although the areas of Precambrian rocks in Charnwood Forest are small compared with extensive fossil planes in Newfoundland, they do show promise for future fossil discoveries. Investigations in 2012 have revealed two new fossil localities, one in Bradgate Park, an area already famed for Precambrian fossils, and another at the Altar Stones, in rocks of similar stratigraphical age. The new discoveries, from the two new localities, are largely discoid fossil forms, between 32 and 120 mm in diameter.

The well-known Bradgate Park fossil plane has revealed many new fossils, and the number of known fossil species has greatly increased, with the inclusion of the genera *Primocandelabrum*, *Hiemalora* and probably *Hadrynichorde*. The probable *Hadrynichorde* specimens may represent a species that is new to Britain and Europe. Of particular note are the large numbers of juvenile Precambrian organisms that have been found, many with affinities with the known fossil genera from Leicestershire, but others that may represent new species.

The juxtaposition of juvenile forms with similar larger organisms indicates a vibrant life assemblage on the Precambrian sea floor in what is now rural Leicestershire (Fig. 14). The biota of Newfoundland represents a deep-water environment, not dissimilar to that of the Leicestershire biota. Being so similar, these two environments share many species, which presumably occupied the same niches. *Charnia*, *Charniodiscus*, *Bradgatia*, *Aspidella* and the possible effaced taphomorphs *Ivesheadia* and *Blackbrookia* are all known to be common to both the Avalonian Assemblage in Newfoundland and the Mercian Assemblage in Leicestershire.

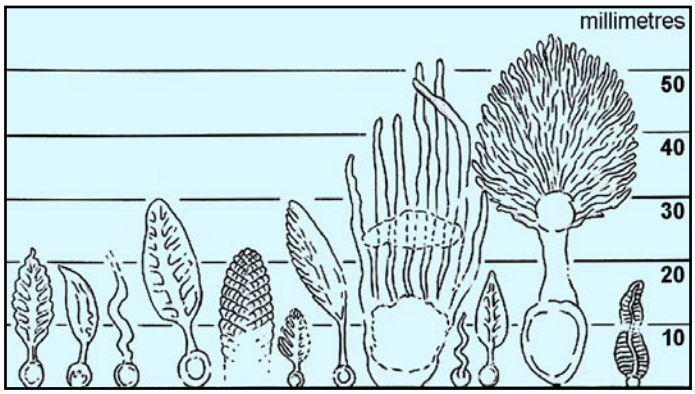


***Figure 14**. Some of the juvenile fossils that occur on the bedding plane in Bradgate Park.*

New casting techniques of classic Charnwood Forest sites have revealed that presumed Avalonian endemic genera, such as *Hiemalora*, *Primocandelabrum* and *Thectardis*, are also found in the Mercian Assemblage, and the degree of endemism presumed for Newfoundland has been over-estimated (Wilby *et al*., 2011). The probable *Hadrynichorde* forms of Bradgate Park may represent another species no longer endemic to Newfoundland, but common to the Leicestershire biota.

Acknowledgements

The author would like to thank Alex Liu, Helen Boynton, Arthur King and Trevor Ford for their discussions and opinions.

Site access

Classic localities of Precambrian fossils have been victims of mindless vandalism and also attempts at fossil extraction. Details of site locations are therefore now withheld, but legitimate researchers can gain information by contacting Dr. Mike Howe (at mhowe@bgs.ac.uk or at British Geological Survey, Keyworth, Nottingham NG12 5GG, UK).

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