

## Reviewing the Ediacaran fossils of the Long Mynd, Shropshire

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LIU, A.G. (2011). Reviewing the Ediacaran fossils of the Long Mynd, Shropshire. *Proceedings of the Shropshire Geological Society*, **16**, 31–43. The Precambrian fossils of the Long Mynd, Shropshire, are becoming increasingly important to studies of palaeoecology and evolution immediately prior to the ‘Cambrian Explosion’ of animal life. Longmyndian fossils are discussed within the broader context of global Ediacaran palaeontology, and their biological affinities are explored. Stratigraphic ranges for the taxa of the Longmyndian Supergroup are then provided, to assist in correlating the region with other global fossil localities.

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### INTRODUCTION

The Ediacaran Period 635–542 Ma, ratified as recently as 2004, is the youngest period of the Proterozoic Eon (Knoll *et al.*, 2004; Van Kranendonk *et al.*, 2008). Ediacaran fossil assemblages document the transition from microbe-dominated Proterozoic environments, to the metazoan-dominated ecosystems of the Phanerozoic (*cf.* Clapham *et al.*, 2003). Fossils of the macroscopic Ediacara biota (soft-bodied organisms which can reach over one metre in length), do not closely resemble any modern taxa, and are found in a variety of depositional environments at over 35 locations worldwide (for a summary, see Fedonkin *et al.*, 2007a). While many of these Ediacaran fossils cannot currently be assigned to modern taxonomic groups, study of the Ediacara biota is nevertheless of great importance for increasing our understanding of metazoan evolution.

The appearance and proliferation of macroscopic organisms on Earth during the Ediacaran to Cambrian transition facilitated dramatic shifts in marine ecological organisation, taphonomic processes, behavioural capabilities, and environmental conditions (e.g. Seilacher and Pflüger, 1994; Bottjer *et al.*, 2000; Brasier *et al.*, 2011; Butterfield, 2011). Ediacaran biological diversification also correlates temporally with several physical and chemical changes in the Late Neoproterozoic oceans. These include large perturbations in chemical cycles (e.g. Halverson *et al.*, 2005; Canfield *et al.*, 2007), extensive glaciations (Hoffman *et al.*, 1998), and supercontinental break-up (e.g. Scotese, 2009). Determining the chronology of and relationships

between these events will enable us to better appreciate the palaeobiological processes occurring in the Late Neoproterozoic biosphere.

The shallow-water assemblage of Ediacaran fossils from the Long Mynd of Shropshire, U.K. (Figure 1), includes the first biological structures to be described from rocks of Precambrian age (Salter, 1856; see historical review in Callow *et al.*, 2011). Although these fossils have been known for many decades, they have recently become increasingly important, since the Longmyndian successions have been recognised to record some of the oldest macrofossil-bearing shallow-water siliciclastic environments in the world. Herein, the context and importance of the Long Mynd fossil assemblage is discussed. Preliminary stratigraphic ranges are presented for the taxa of the Longmyndian Supergroup, and the assemblage is compared to those of other Ediacaran localities worldwide.

### A BACKGROUND TO EDIACARAN RESEARCH

Early scientists considered the Precambrian to be ‘Azoic’ (a term defined by Murchison, 1845, to describe crystalline rocks beneath his basal Silurian zone), and therefore devoid of life. This supposition was based upon the apparent absence of shells, bones, or fossil impressions in rocks of that age. From a mid-1800s viewpoint, animals first appeared and diversified in what is now the Cambrian Period (e.g. Buckland, 1841). The lack of animal fossils in older rocks seemingly represented a true absence of organisms. Despite this, and contrary to the general conceptions of his peers, Charles Darwin had recognised by 1859 that the history of life on Earth must have stretched

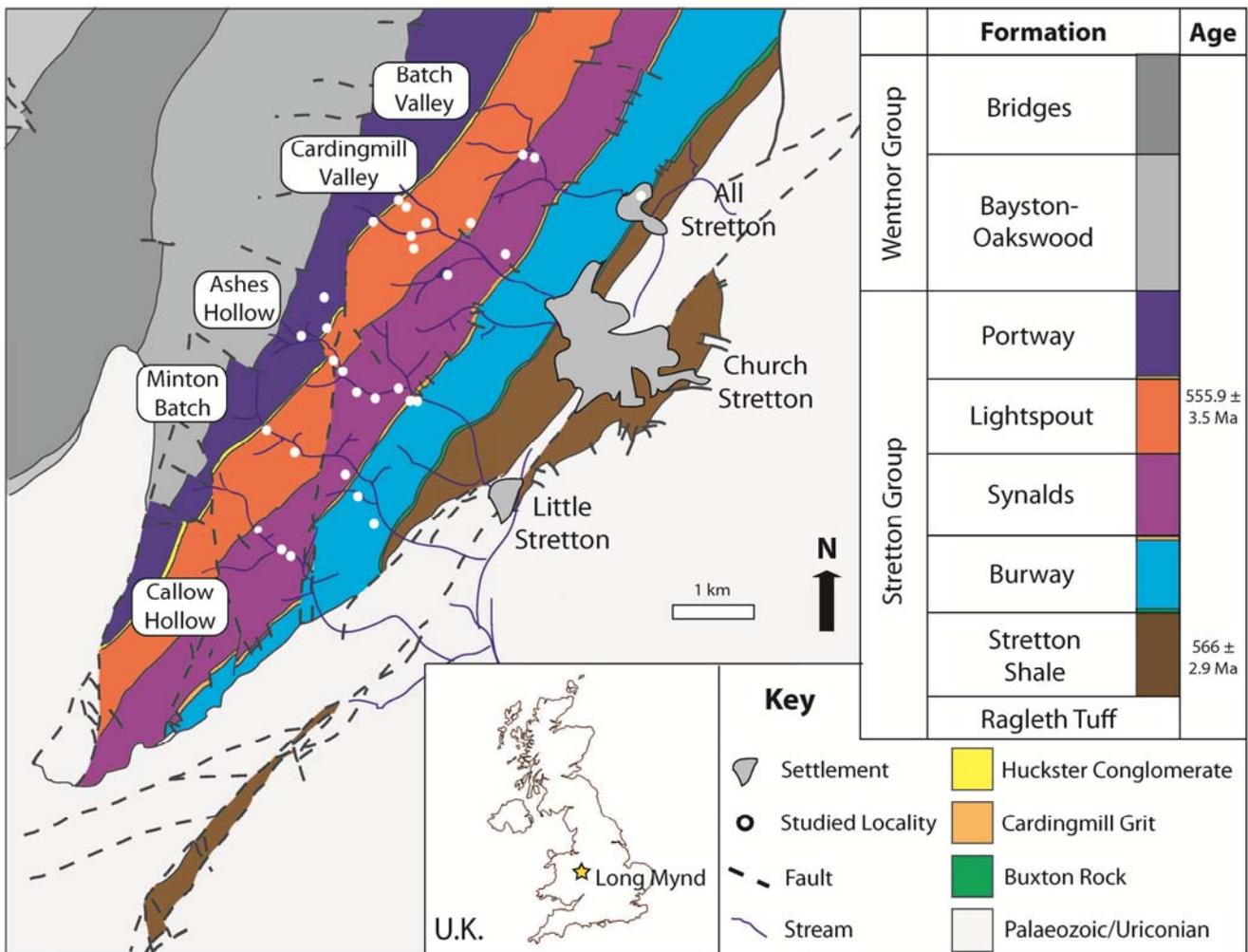


Figure 1. A map, and generalised stratigraphic column (not to scale), showing the geology of the Long Mynd, Shropshire, U.K. The map is redrawn from BGS Map sheet E166 (Church Stretton). Field sites examined during this study are identified by white dots. See the stratigraphic column for a key to the geological units. Dates are from Compston *et al.* (2002). Labels refer to the major settlements and valleys on the eastern flanks of the Long Mynd.

back prior to the Cambrian (Darwin, 1859, pg. 307):

*“if my theory be true, it is indisputable that before the lowest Silurian [now Cambrian] stratum was deposited, long periods elapsed, as long as, or probably far longer than, the whole interval from the Silurian age to the present day; and that during these vast, yet quite unknown, periods of time, the world swarmed with living creatures.”*

The discrepancy between Darwin’s expectations, based on evolutionary theory, and the sparse fossil record, presented a paradox now commonly referred to as Darwin’s Dilemma (see the historical review in Brasier, 2009). Solving this dilemma has only been possible through subsequent

palaeontological discoveries, with the Ediacara biota forming an integral part of this narrative.

The first fossils to be described from definitively Precambrian rocks came from the Long Mynd of Shropshire even as Darwin was writing *The Origin of Species*; *Arenicola* (sic) *didyma* in 1856 (originally described as trace fossils; Salter, 1856, 1857). Regrettably, the true importance of these finds was not immediately recognised, despite their mention by Darwin in *The Origin* (Darwin, 1859; see review in Callow *et al.*, 2011), and the presence of pre-Cambrian fossils thus remained largely unreported. Large ‘rings’ preserved in a slate quarry in rural Leicestershire, England, were noted in 1866 (Ansted, 1866) and again in 1877 (Hill and Bonney, 1877), while the discoidal impression *Aspidella terranovica* from Newfoundland,



1977), and the north-eastern USA (Landing, 2004).

During the Ediacaran Period, these regions lay off the micro-continent of Avalonia, a terrane that was likely located on the edge of the Cadomian arc subduction zone, in the vicinity of the Florida, Amazonia and West Africa cratons (Li *et al.*, 2008). The Avalon assemblage is dominated by a group of frondose fossils called rangeomorphs (Narbonne, 2004), which resemble fern fronds in their gross morphology.

Avalonian rangeomorph fossils exhibit considerable morphological diversity, but are only known from the deep-water depositional environments of Newfoundland and Leicestershire (e.g. Wood *et al.*, 2003; Wilby *et al.*, 2011). In contrast, the shallow-water depositional environments of the Long Mynd do not exhibit any frondose taxa, despite being of a similar age. The Long Mynd is therefore of great palaeobiological importance, since it can potentially reveal whether the lack of rangeomorphs in shallow-water settings is governed by taphonomic, environmental, or evolutionary factors.

## THE LONG MYND SUCCESSIONS

The Longmyndian Supergroup, outcropping on the eastern flanks of the Long Mynd, Shropshire, is dated at ~567–555 Ma (Figure 1; Compston *et al.*, 2002). It records a shallowing-upwards shallow-marine to fluvial (deltaic and alluvial) siliciclastic succession (e.g. McIlroy *et al.*, 2005).

Although outcrops are plentiful, they are rarely stratigraphically continuous for more than a few metres, and are often affected by strong deformational cleavage. Younger Neoproterozoic shallow marine sections in Australia and the White Sea region contain diverse assemblages of Ediacaran fossils. However, shallow marine successions of Avalonia exhibit a comparably depauperate assemblage, mostly comprising discoidal impressions.

The rocks and fossils of the Long Mynd have been discussed by several luminaries of early British geology (e.g. Salter, 1856; Callaway, 1879; Lapworth, 1888; Blake, 1890; Watts, 1925), who mainly puzzled over their antiquity, and their place in British stratigraphy. In more recent times, the focus has shifted to characterising the depositional

environments preserved in the succession, and determining the original organisms the fossils represent (e.g. Pauley *et al.*, 1991; McIlroy *et al.*, 2005).

The small circular impressions so abundant on many Longmyndian bedding planes were initially interpreted as ‘worm burrows’ (*Arenicola didyma*; Salter 1856; later renamed *Arenicolites didymus* and *A. sparsus*, Salter 1857). These were joined within the assemblage by Annelid tubes, ‘numerous hollows’ discussed as gas bubbles or rain imprints, thread-like lines discussed as mineral structures, and the possible trilobite *Palaeopyge ramsayi* (Salter, 1856, 1857). Several of these interpretations have since been revised. The possible trilobite has been discarded completely (see Ramsey, 1859; Callow *et al.*, 2011; personal observation of *Palaeopyge* suggests that it is a fractured mineralised crust on the rock surface), whilst the paired nature of Salter’s *Arenicolites* burrows has also come under intense scrutiny (Greig *et al.*, 1968; McIlroy *et al.*, 2005; though more recently the apparent coupling of some of Salter’s “*A. didymus*” specimens has been supported; Callow *et al.*, 2011).

Regardless of their paired nature, it is widely recognised that the structures described by Salter as *A. didymus* are not burrows (e.g. McIlroy *et al.*, 2005; Callow *et al.*, 2011), and therefore their original Linnaean nomenclature cannot be applied. However, given the present lack of suitable terminology for these structures of uncertain biological affinity, they are here referred to as Salter’s “*A. didymus*” (see Callow *et al.*, 2011, figures 3a, c, e). A complete revision of this impression and its biogenicity in the near future would be of value. The fine threads Salter described have been recognised as similar to the probable microbially induced sedimentary structure ‘Arumberia’ (e.g. McIlroy *et al.*, 2005).

The biogenicity of various other discoidal bumps and pits on numerous Longmyndian bedding planes has been debated for many years (e.g. Salter, 1856, 1857; Toghil and Chell, 1984; Pauley, 1991; McIlroy *et al.*, 2005; Callow *et al.*, 2011). Current opinion generally follows the reasoning of McIlroy *et al.* (2005) in viewing the majority of these impressions (though not all), as biogenic features, and assigning them to the globally-distributed taxa *Beltanelliformis brunsa*, *B. minutae*, *Intrites punctatus*, and *Medusinites* aff.

*asteroides* (McIlroy *et al.*, 2005; Figures 3A–B, 3E).

Detailed reviews of all of these fossils have recently been presented by McIlroy *et al.* (2005) and Callow *et al.* (2011), and readers are therefore referred to those publications for more thorough taxonomic treatments for these taxa. This author concurs with those studies in viewing the linear structure ‘Arumberia’ (also found in late Neoproterozoic shallow water environments from Australia, Newfoundland, India, the Russian Urals, and China; Glaessner and Walter, 1975; Liu, 1981; McIlroy & Walter 1997; De, 2006; Fedonkin *et al.*, 2007a, p. 172), as a probable organo-sedimentary structure, formed by the action of fluids flowing over a cohesive, microbially-bound sediment (*cf.* McIlroy & Walter 1997; McIlroy *et al.*, 2005). A diverse microscopic biota including bacterial spheroids and filaments is also present in the successions, preserved in a variety of taphonomic modes (Peat, 1984; Callow and Brasier, 2009).

### THE BIOGENICITY OF LONGMYNDIAN PITS

Consideration of at least some Longmyndian discoidal impressions as raindrop imprints remains a valid suggestion (*cf.* Toghill, 2006). Salter himself entertained a raindrop hypothesis (Salter, 1856), becoming convinced of their presence by 1857. The common alternative abiogenic hypothesis to explain discoidal impressions on siliciclastic bedding planes is that of gas bubbles, released in soft sediment by either the degassing of fresh sediment (Kindle, 1916), decay of organic matter (Spicer, 1904), or microbial activity.

Whilst this author recognises that some Longmyndian specimens from the Synalds Formation may represent fossilised raindrop impressions (e.g. Toghill, 2006, figs 38–39; *contra* Callow *et al.*, 2011), it can be demonstrated that the majority do not. Both rain imprints (e.g. Lyell, 1851; Hladil and Beroušek, 1993) and gas bubble escape structures (e.g. Frey *et al.*, 2009), exhibit a suite of specific morphological characteristics (though see Moussa, 1974). It can be demonstrated that many Long Mynd specimen morphologies do not fit either the raindrop or gas escape criteria. The often sub-aqueous depositional environment (e.g. within the Burway Formation; Pauley Unpublished PhD Thesis, 1986), the consistently

small size of many impressions, the presence of straight boundaries between impressions, and a lack of crater rims (e.g. Figure 3A; summarised in McIlroy *et al.*, 2005), all suggest that many Longmyndian examples are unlikely to be fossilised rain imprints. Furthermore, the absence of sedimentary deformation beneath these same discoidal impressions (Callow *et al.*, 2011), and substantial morphological disparity throughout the assemblage, would argue against a gas escape explanation.

A biogenic interpretation for Longmyndian discoidal features is therefore preferred, and the challenge is now to determine exactly what sort of organisms are being preserved. Callow *et al.* (2011) consider Salter’s “*A. didymus*” as most likely to represent structures related to microbial activity (*cf.* MISS; Noffke *et al.*, 2001), while algal or microbial vesicle affinities have been explored for *Beltanelliformis* (summarised in McIlroy *et al.*, 2005). *Intrites* has been compared to protistan organisms, while *Medusinites aff. asteroides* has variously been discussed as a trace fossil (McIlroy *et al.*, 2005) and a polyp (Narbonne and Aitken, 1990). With so few distinguishing morphological characteristics, elucidating the precise biological affinities of small discoidal impressions will continue to be difficult until we gain a better understanding of both modern biology, and the original depositional environments of these assemblages.

### STRATIGRAPHIC RANGES

Although previous Long Mynd palaeontological studies have documented the fossils found in each geological formation, or from individual hills or valleys (e.g. Salter, 1856; McIlroy *et al.*, 2005), accompanying locality information has rarely been provided in the published literature. It has therefore been difficult to quantify accurate stratigraphic ranges for individual taxa (see the unpublished PhD. thesis of Pauley, 1986, for the only previous information regarding this).

Extensive fieldwork by the author in the Longmyndian Supergroup, documenting fossils in each of the major valleys on the eastern flanks of the hills (see Figure 1 for localities), has produced a stratigraphic range chart for the Long Mynd biota (Figure 4). Correlation of individual field sites is here based upon the Church Stretton geological

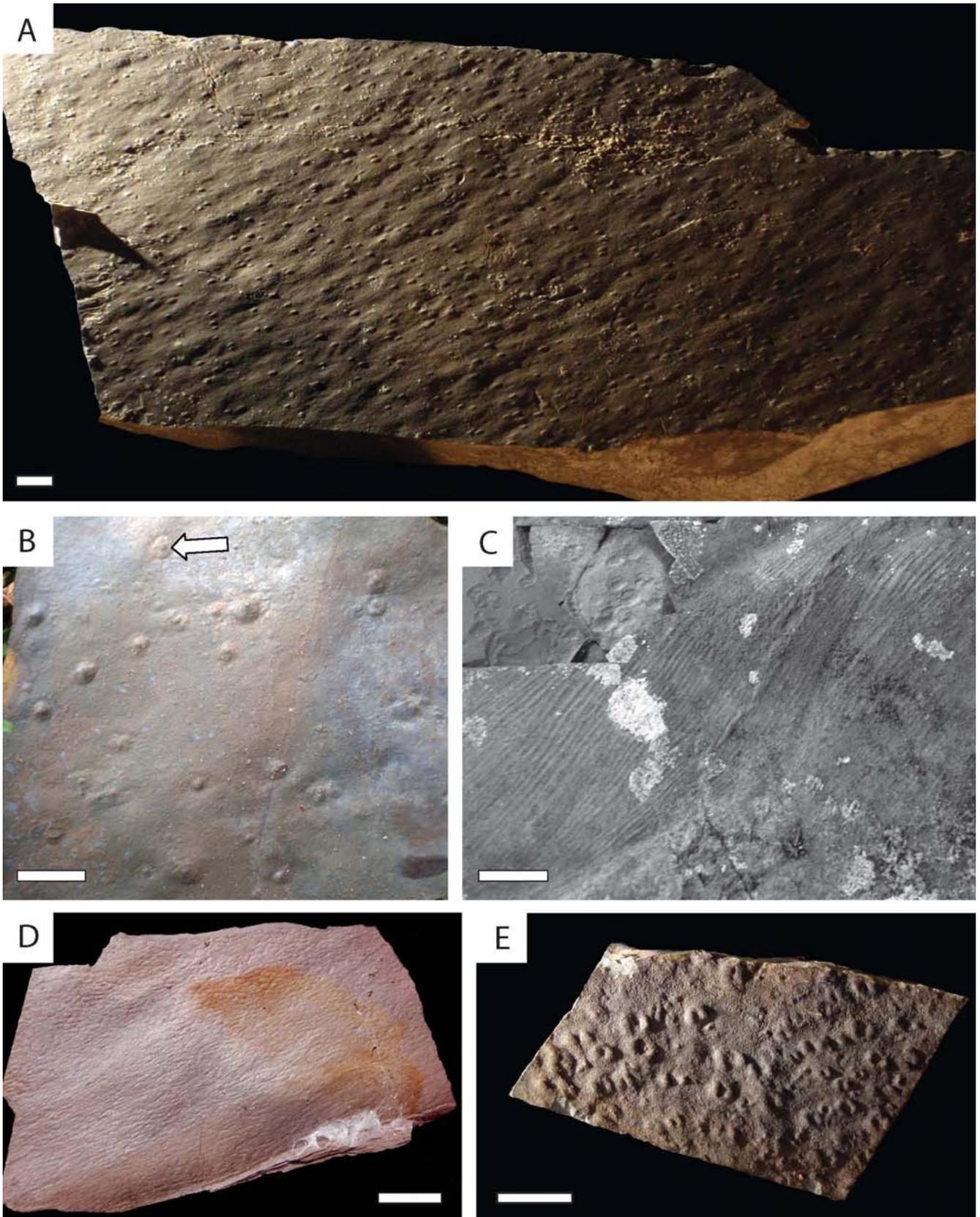


Figure 3. Ediacaran fossils of the Long Mynd, Shropshire, U.K. **A:** *Beltanelliformis brunsae* (larger lumps) and *Beltanelliformis minutae* (small, sharp bumps), viewed under low-angle light. Lightspout Formation, Cardingmill Valley. **B:** *Medusinites* aff. *asteroides* preserved on the base of a siltstone, with characteristic central dimple (arrowed). Upper Burway Formation, Ashes Hollow. **C:** The linear feature ‘Arumberia’, Synalds Formation, Cardingmill Valley. **D:** Microbial mat texture, Synalds Formation, Batch Valley. **E:** *Intrites punctatus*, upper Burway Formation, Ashes Hollow. Scale bars = 10 mm, except C = 50 mm. Specimens A–B, D–E, are housed within the Palaeontological Collections, Department of Earth Sciences, University of Oxford. The specimen in C remains in the field.

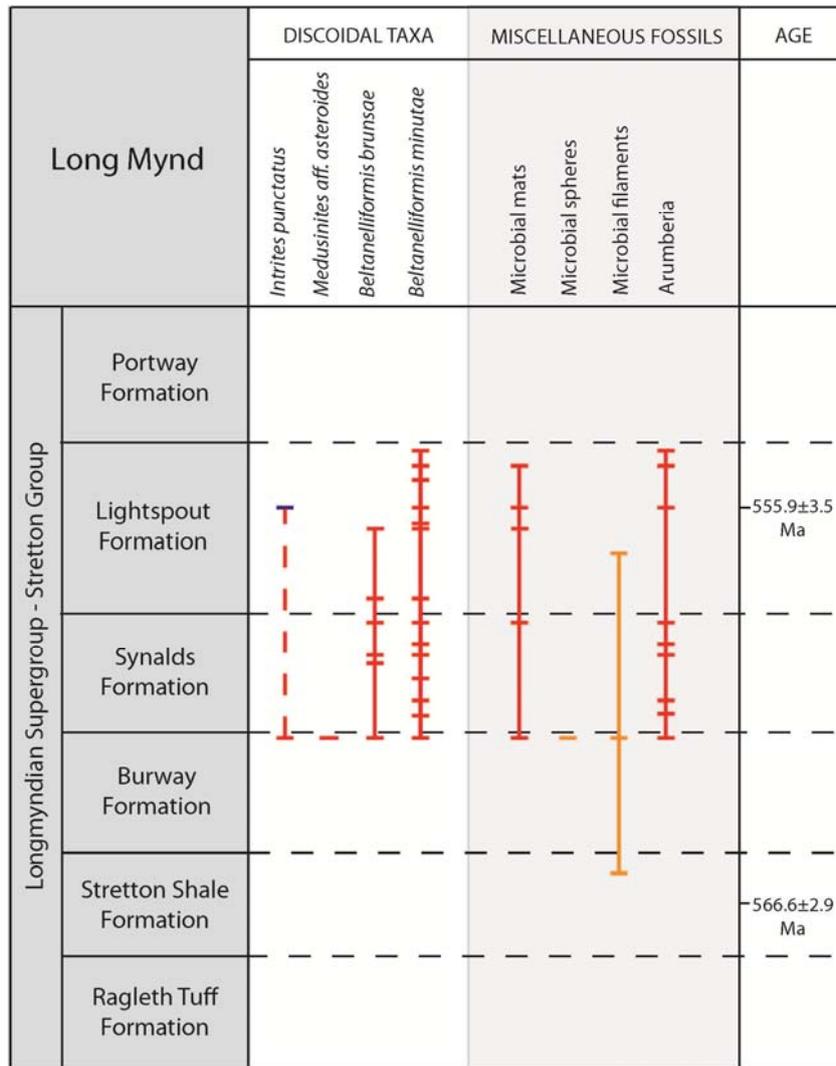


Figure 4. Biostratigraphic ranges of Ediacaran taxa from the Long Mynd, Shropshire, U.K. Red horizontal bars indicate primary observations made by the author. Orange bars are data from Peat (1984), and Callow and Brasier (2009). The blue bar represents a specimen that is considered doubtful. Radiometric dates are taken from Compston *et al.*, 2002. For specific locality information, please see Liu Unpublished D.Phil. Thesis, 2011. The full stratigraphic range of “A. didymus” in the Longmyndian Supergroup is currently unknown.

map published by the British Geological Survey (sheet E166). Due to the incompleteness of the Longmyndian exposure, and extensive cleavage deformation of these units, it has not been possible to accurately determine the stratigraphic position of each site, or the throw on the numerous small faults that cut through the area but are not marked on the published map. Nevertheless, it is considered that the stratigraphic positions of the bedding planes presented herein are sufficient for the purposes of recognising broad biostratigraphic patterns.

The shallow-marine to fluvial environments of the Long Mynd do not possess a particularly diverse biota (compared to broadly contemporaneous deep-water settings such as the Charnian Supergroup of Leicestershire, or the

Conception Group of Newfoundland; *cf.* Wilby *et al.*, 2011; Liu *et al.*, *In Press*). Indeed, in terms of shared biotic components, only microbial mats are found within all of these Avalonian localities.

*Beltanelliformis minutae* is the most common Long Mynd taxon, but the stratigraphic ranges of both microbial mats, and the linear structure ‘Arumberia’, correlate with that of *B. minutae* (Figure 4). The similar stratigraphic ranges of *Beltanelliformis* and ‘Arumberia’ in the Long Mynd, and their common appearance together on bedding planes (though both are also found individually), confirm the observations of previous workers (Salter 1857; Bland 1984), and may suggest a potential relationship between these two impressions. However, there are no clear spatial relationships between them on individual bedding

planes. The discoidal taxa *Medusinites* aff. *asteroides* and *Intrites* are found to be fairly rare within the Long Mynd successions, occurring only on a limited number of bedding planes, and possibly only in the upper Burway Formation (Figure 4). However, where they do occur, they do so in abundance. Finally, the apparent rarity of microbial filaments within the studied Longmyndian beds is most likely to be due to under-sampling at present.

The majority of fossil occurrences are confined to the transitional Burway, Synalds and Lightspout Formations, which document a shift from very shallow nearshore (deltaic?) deposits through to alluvial and fluvial sedimentation (McIlroy *et al.*, 2005). Above this, the terrestrial sandstones of the Portway Formation are unfossiliferous. My own studies did not extend down into the Stretton Shales, but the discovery of filamentous microfossils (Peat, 1984), combined with an inferred turbiditic marine depositional environment (McIlroy *et al.*, 2005; a broadly comparable depositional regime to that found in Newfoundland and Charnwood), makes the unit an interesting prospect for future palaeontological exploration. Unfortunately, the palaeontological potential of the Stretton Shales may be dampened somewhat by its position directly beneath the town of Church Stretton, and the effects of severe weathering upon the few remaining outcrops.

### WHAT CAN WE LEARN FROM THE LONG MYND?

The Long Mynd biota is very different to that of Charnwood Forest, Leicestershire, or the Conception Group of Newfoundland, in being composed primarily of small discoidal taxa, and microbial structures. This is despite all three regions sharing similar ages (Compston *et al.*, 2002; Van Kranendonk *et al.*, 2008; Wilby *et al.*, 2011).

The three discoidal taxa commonly found in the Conception and St John's Groups of Newfoundland (*Aspidella*, *Hiemalora*, *Triforillonia*), have not yet been found on the Long Mynd, making biostratigraphic correlation with those units difficult. As yet unreported discoveries in the shallow-marine to alluvial red-beds of the Signal Hill Group of Newfoundland, suggest a similar biota does exist in shallow water settings there (Matthews Unpublished Masters Thesis,

2011). This implies that the original depositional environment may be the primary factor in explaining the very different biota observed in the Long Mynd.

As for specific controls, salinity, water depth, temperature, sedimentation rate, and nutrient supply could all be significant variables, and palaeo-latitude remains an intriguing factor in this debate (*cf.* Brasier, 1995). All discoidal fossils in both regions seem to disappear once coarse-grained fluvial channel deposits begin to dominate (for example in the Portway Formation of the Long Mynd, and the upper Ferryland Head Formation in Newfoundland), again suggesting that the organisms represented by the fossils were restricted to specific aqueous environments.

Production of similar range charts for the shallow-water Newfoundland successions will be very revealing. Further constraining the sedimentological contexts of these units, and their stratigraphic ages, would also be beneficial in order to put these finds into a broader Ediacaran context. A doctoral project at Oxford is currently investigating this problem (see also Matthews Unpublished Master's Thesis 2011). Correlation with the Radnor and Llangynog Inliers of the western U.K. (see Carney, 2000) could likewise be informative. Llangynog in particular contains a fossil assemblage dominated by discoidal forms (Cope and Bevins, 1993), though those Welsh specimens constitute different taxa to those found on the Long Mynd.

The substantially higher taxonomic diversity exhibited in Newfoundland (compared to the U.K.) is possibly a function of a larger area of accessible outcrop, with more bedding planes available for study, combined with a historical sampling bias due to the greater number of researchers working on the Newfoundland successions. Further study is necessary to confirm this, since the possibility that the depleted palaeobiological diversity observed in the U.K. is real would be of great significance.

The areas in most need of future palaeobiological study within in the Long Mynd are the younger, coarse-grained fluvial deposits on the western flanks of the hills (which have never previously yielded reports of fossils), and the levels beneath the Burway Formation that sample deeper water depositional environments. This latter option would take us into facies where we could potentially see evidence for frondose rangeomorph

macro-organisms, but the units suffer from three significant problems. Firstly, the rocks beneath the Burway Formation outcrop very sparsely, with the town of Church Stretton directly above the most lithologically interesting formations. Secondly, where they do outcrop, cleavage induced by tectonic activity obscures most bedding plane faces, making fossil observations difficult. And finally, the Church Stretton Fault bounds the lower end of the succession, preventing access to units of greater antiquity.

Despite this, the discovery of microbial filaments and spheroids throughout the Longmyndian succession (Peat, 1984; Callow and Brasier, 2009), suggests that from a microfossil perspective, the Long Mynd may yet have many secrets to yield. Combined with discoveries being made as the shallow water deposits of Newfoundland are explored, there remains considerable potential for this, most historical of Ediacaran fossil localities, to provide further insights into the early stages of macroscopic evolution.

### CONCLUDING REMARKS

The Ediacaran sedimentary successions of Shropshire are of considerable importance to studies of life during the Ediacaran Period, both from a historical perspective, and in terms of what they can tell us about shallow water Avalonian depositional environments and ecosystems.

Extensive research into the palaeobiology, geochronology and sedimentology of the Long Mynd is now required to determine how its biota relates to that seen in other regions of a similar age and palaeogeographic position.

While macrofossil stratigraphic ranges show some promise for regional correlation across Avalonia, more fieldwork and taxonomic study is required to determine whether true biostratigraphy can be usefully applied to the Ediacaran Period as a whole. It is anticipated that this first attempt at documenting the stratigraphic ranges of the Long Mynd Ediacara biota will contribute to an increased understanding of macroscopic biology and evolution prior to the Cambrian Explosion.

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