

Dating the Cambrian Purley Shale Formation, Midland Microcraton, England

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Abstract – Zircons from a bentonite near the base of the Purley Shale Formation in the Nuneaton area, Warwickshire, yield a $^{206}\text{Pb}/^{238}\text{U}$ age of 517.22 ± 0.31 Ma. Based on the fauna of small shelly fossils and the brachiopod *Micromitra phillipsii* in the underlying Home Farm Member of the Hartshill Sandstone Formation, trilobite fragments that are questionably referred to *Callavia* from the basal Purley Shale Formation, and the presence of trilobites diagnostic of the *sabulosa* Biozone 66 m above the base of the Purley Shale Formation, the bentonite likely dates an horizon within Cambrian Stage 3, at about the level of the *Fallotaspis* or basal *Callavia* Biozone. This is consistent with bentonite ages from other localities in southern Britain, which constrain the age of the lower and uppermost parts of Cambrian Stage 3. The new date provides additional chronological control on the earliest occurrence of trilobites in the Midland Microcraton, a date for the marine transgression at the base of the Purley Shale Formation, and is the first radiometric age from the Cambrian succession of Warwickshire.

Keywords: Cambrian, radiometric age, trilobites, Avalonia, stratigraphy, geochronology.

1. Introduction

The rock successions of southern Britain have proved important for calibrating a global Cambrian chronology (Rushton *et al.* 2011, fig. 1). The age of the lowermost Cambrian rocks in England and Wales are undetermined, but in Pembrokeshire, a thin bentonite from the Caerfai Bay Shales Formation, some 11 m above the top of the St Non's Sandstone Formation at Caerfai Bay, yielded an age of 519 ± 1 Ma (Landing *et al.* 1998; see Fig. 1), and has been cited in support of a minimum age of 521 Ma for the base of Cambrian Series 2 (see Peng & Babcock, 2008; Harvey *et al.* 2011). In Shropshire, Cambrian rocks have yielded dates that constrain the age of the Cambrian Series 2 – Series 3 boundary (Harvey *et al.* 2011). A bentonite just below the top of the Green Callavia Sandstone yields an age of 514.45 ± 0.36 Ma (Harvey *et al.* 2011), which provides a maximum age for the boundary between Cambrian stages 3 and 4 (see Fig. 1), as provisionally recognised by Rushton *et al.* (2011, p. 3). A bentonite from within the basal Upper Comley Sandstone yields a U–Pb date of 509.10 ± 0.22 Ma that provides a minimum age limit on the base of Series 3, and of Cambrian Stage 5 (Harvey *et al.* 2011; Fig. 1). This date provides constraint for the interpolated age of 510 Ma

for the Series 2 – Series 3 boundary given by Peng & Babcock (2008).

Here we report a newly analyzed bentonite layer from the lower part of the Purley Shale Formation in Warwickshire, England, which provides the first radiometric age for the Cambrian sedimentary succession of the Charnwood Block within the Midland Microcraton (see Rushton *et al.* 2011). The new age provides additional chronological control on the Cambrian succession of England and Wales, and provides new stratigraphic ties with the evolving global Cambrian chronology (Peng & Babcock, 2008).

2. Geological and stratigraphical setting

The Charnwood Block is an integral component of the Avalon Composite Terrane (*sensu* Woodcock, 2011, p. 20), which was already assembled by early Cambrian times, and records part of the Cambrian succession of Avalonia. The Cambrian of the Charnwood Block is exposed in inliers in the Charnwood Forest area of Leicestershire, in the Nuneaton Inlier on the eastern edge of the Coventry Coalfield and in the small Dosthill Inlier on its western boundary fault, the latter two areas being in Warwickshire. Rushton (1974, pp. 105–13) gave a general summary of the stratigraphy in these inliers, with references to earlier work. More recent accounts that also refer to many borehole records are given in Bridge *et al.* (1998), Powell, Glover & Waters,

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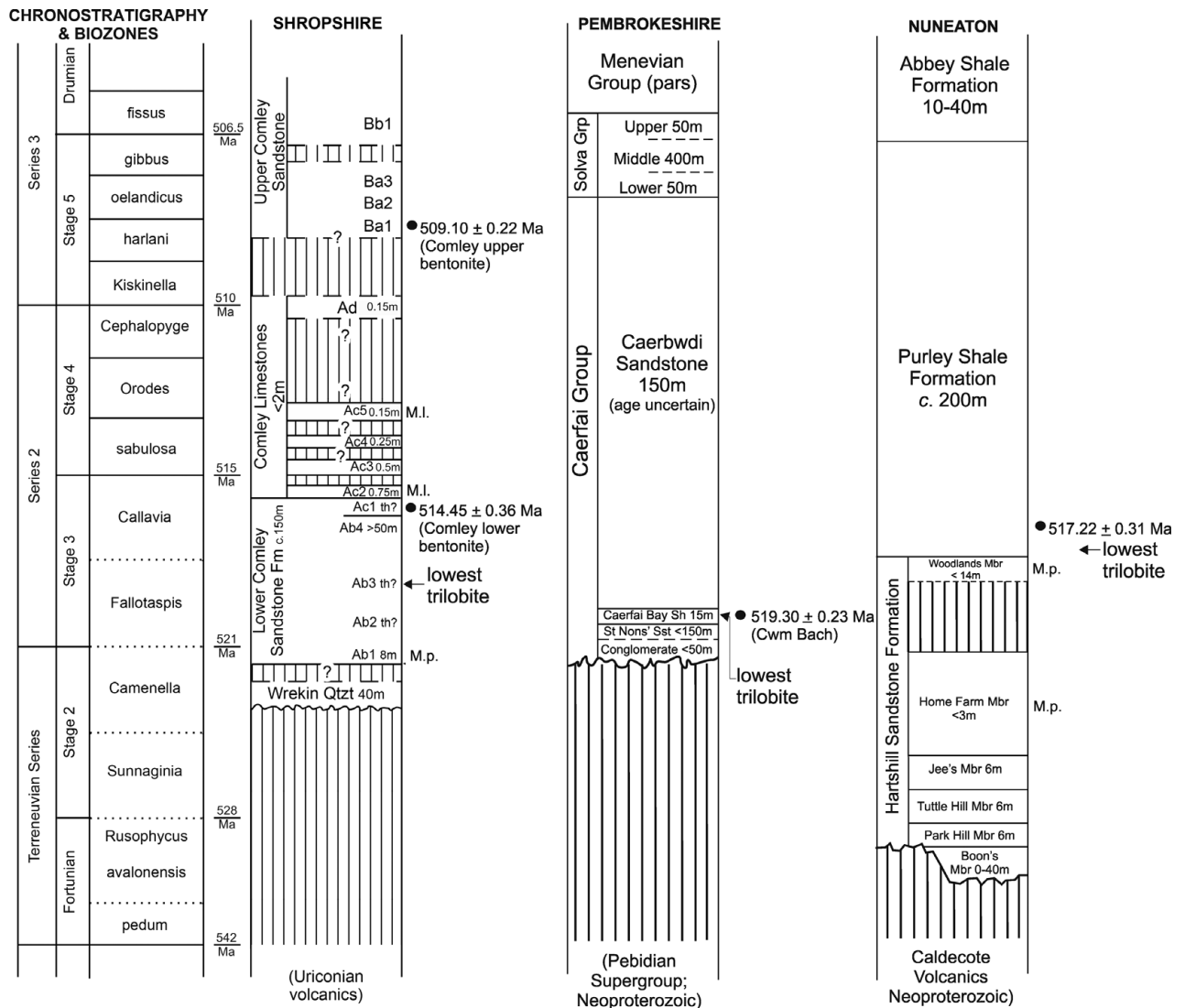


Figure 1. Stratigraphy of the Cambrian, Terreneuvian, Series 2 and Series 3 lithological succession for the Nuneaton area of Warwickshire and contemporaneous lithostratigraphic successions in Shropshire and Pembrokeshire, South Wales. Also shown are intervals from which radiometric dates have successfully been determined. Abbreviations: M.p. – *Micromitra phillipsii*; M.I. – *Micromitra labradorica*; 'th' – thickness. The alphanumeric nomenclature for the Shropshire column is after Cobbold (1921). In the column for Shropshire, 'Comley upper bentonite' and 'Comley lower bentonite' are defined in Harvey *et al.* (2011). In the column for Pembrokeshire, the age of the Caerfai Bay Shales at 'Cwm Bach' is the bentonite locality reported by Harvey *et al.* (2011), which gives a comparable, but slightly more refined age to that of the bentonite at Caerfai Bay, which yielded an age of 519 ± 1 Ma to Landing *et al.* (1998).

(2000) and Rushton *et al.* (2011). Within the Charnwood Block, the Cambrian rocks of Nuneaton represent a relatively complete stratigraphical succession. The arenaceous lower divisions of the Hartshill Sandstone Formation (Fig. 1) are known from extensive quarry exposures and have been thoroughly studied (Brasier, 1989 and references therein), and the whole succession of the Stockingford Shale Group has (aside from some parts of the Purley Shale Formation) been studied from excavations and borehole cores (Taylor & Rushton, 1971).

The six members of the Hartshill Sandstone Formation (Fig. 1) were described by Bridge *et al.* (1998, pp. 21–30). Brasier (1989, p. 87) showed that they were deposited in a variety of near-shore to offshore marine facies and recorded the presence of several

trace fossils of Cambrian type. In the absence of body fossils, correlation of the lower four members, all of them arenaceous, is not very certain. The Home Farm Member is a condensed succession of thin fossiliferous calcareous and phosphatic units, bounded above and below by non-sequences. Brasier (1984, 1986, 1989) described the diverse fauna of small shelly fossils and discussed their correlation with the Bonavista Group (Terreneuvian) of SE Newfoundland, especially with the Cuslett Formation, and the overlying Fosters Point Formation (Landing & Benus, 1988); he suggested correlation of the Home Farm Member with part of the Tommotian and the lowest part of the Atdabanian stages of the Siberian Platform. The uppermost division of the Hartshill Sandstone Formation, the Woodlands Member (Fig. 1), overlies a hard-ground and an inferred



Figure 2. (Colour online) (a) Geographical position of the bentonite horizon in the NW corner of Woodlands Quarry. (b) The thin bentonite horizon (arrowed) in the basal Purley Shale Formation above the sill, Alan Cook (right) and Adrian Rushton for scale.

non-sequence at the top of the Home Farm Member, and appears locally to pass up rapidly into the succeeding Purley Shale Formation (Brasier, 1989, p. 90).

The Stockingford Shale Group was deposited on a stable but gently subsiding marine shelf, mainly below wave-base. It is divided into seven mudstone formations with thin sandstone beds at some levels, the Purley Shale Formation being the lowermost unit. Deposition appears to have been fairly continuous, apart from an important non-sequence proved in the upper part of Cambrian Series 3 between the Abbey Shale and Mancetter Shale formations, and the possibility of a hiatus in the mid-part of the Purley Shale Formation (see Rushton *et al.* 2011, p. 33, for further discussion). Agnostoids, eodiscid and polymerid trilobites and bradoriid arthropods occur almost throughout the succession and enable correlation with the successions in SE Newfoundland and the biozonal succession in Scandinavia.

3. Sampled locality and horizon

Woodlands Quarry, 200 m NNW of Hartshill Green (5 km NW of Nuneaton), exposes the top of the Hartshill Sandstone Formation, including the upper part of the Jee's Member, the Home Farm Member and the Woodlands Member, succeeded conformably by the basal part of the Purley Shale Formation, the basal

contact of which is displaced by a minor cross-fault and complicated by a lamprophyre sill that is intruded into the lowest part of the Purley Shale Formation succession (Eastwood *et al.* 1923, p. 33). Quarrying has long ceased and the locality is now a Site of Special Scientific Interest or 'SSSI' (Rushton *et al.* 1999, p. 81) and is the stratotype for the Home Farm Member.

In the 1970s, after the quarry had been landscaped, a white clay bed about 2 cm thick was temporarily exposed near the base of the Purley Shale Formation in the SW face of the quarry; Adrian Rushton collected a small sample that, following analysis by C. R. Hallsworth at the British Geological Survey, was shown to be of volcanic origin. The west side of the quarry has since largely been levelled off and become overgrown. No bentonite can now be seen there, but in 2011 the present authors succeeded in sampling what is assumed to be the same bentonite bed at the northern end of the quarry (Fig. 2).

The new exposure of bentonite is situated in the NW corner of the Quarry at UK National Grid Reference SP 32417 94805, and at 113.5 to 114.5 m above Ordnance Datum (Lat. $52^{\circ} 33' 0.558''$ N, Long. $1^{\circ} 31' 24.0564''$ W; Fig. 2). The bentonite is estimated to be 7 m stratigraphically above the base of the Purley Shale Formation, but at this locality a sill about 7 m thick, extending from a level about half a metre above the base of the formation to about 6.25 m below

the level of the bentonite, makes the topographical separation from the base of the Purley Shale Formation to the bentonite bed about 14 m.

4. U–Pb (zircon) geochronology: absolute age of the Purley Shale Formation bentonite

All analyses were carried out at the NERC Isotope Geosciences Laboratory (NIGL). Prior to ID-TIMS (Isotope Dilution Thermal Ionisation Mass Spectrometry) analyses, zircons were subject to a modified version of the chemical abrasion technique (Mattinson, 2005). For details of sample pre-treatment, dissolution, anion exchange chemistry, mass spectrometry and data reduction at NIGL see Harvey *et al.* (2011) and references therein. Errors for U–Pb dates are reported in the following format: X(Y)[Z], where X is the internal or analytical uncertainty in the absence of all systematic error (tracer calibration and decay constants), Y includes the tracer calibration error (using an estimate of the 2 standard deviation of 0.05 % for the Pb/U ratio in the tracer), and Z includes the additional ^{238}U decay constant errors of Jaffey *et al.* (1971). These systematic errors are added, in quadrature, to the weighted mean internal error. All analytical uncertainties are calculated at the 95 % confidence interval.

Nine optically clear zircon crystals extracted for chronology had a prismatic habit and pointed crystal terminations typical of magmatic zircon and were analyzed for U–Pb geochronology (Table 1). Grains z6 and z8 yielded $^{206}\text{Pb}/^{238}\text{U}$ ages of 1293.3 and 620.7 Ma that are interpreted as xenocrystic. Concordant grains z5 and z7 yielded $^{206}\text{Pb}/^{238}\text{U}$ ages of 518.4 Ma that are slightly older than the eruption age (Fig. 3) suggesting a prolonged pre-eruptive magmatic history. The ages of five zircon grains (z1–4 and z12) are equivalent within error and yielded a $^{206}\text{Pb}/^{238}\text{U}$ age of $517.22 \pm 0.31(0.40)[0.66]$ Ma (MSWD = 0.67; probability of fit = 0.61). This is taken as the preferred eruption age of this tuff and the emplacement age at this stratigraphic level (Fig. 1).

5. Biostratigraphy and correlation

Faunas are recorded below the bentonite horizon, principally from the Home Farm Member of the Hartshill Sandstone Formation (Fig. 1). The oldest identifiable fossils that overlie the bentonite are from Locality 1 of Rushton (1966, p. 4), which is estimated to lie about 60 m above the bentonite layer.

5.a. Home Farm Member

Brasier (1984, p. 230) recognised six faunal assemblages from the Home Farm Member, in ascending order numbers I–VI, and listed their constituent taxa. Assemblage V, with around 30 taxa, is particularly rich and diverse; it has species in common with faunas from Scandinavia and Siberia, in particular with faunas

Table 1. U–Th–Pb data for zircons analysed by ID-TIMS

Sample	Th/U	$^{206}\text{Pb}^*$ $\times 10^{-13}$	mol % $^{206}\text{Pb}^*$	Pb^*/Pb_c	Pb_c (pg)	Radiogenic isotope ratios						Isotopic ages					
						$^{208}\text{Pb}/^{206}\text{Pb}$	$^{207}\text{Pb}/^{206}\text{Pb}$	% err	$^{207}\text{Pb}/^{235}\text{U}$	% err	$^{206}\text{Pb}/^{238}\text{U}$	% err	corr.	$^{207}\text{Pb}/^{206}\text{Pb}$	% err	$^{207}\text{Pb}/^{235}\text{U}$	$^{206}\text{Pb}/^{238}\text{U}$
(a)	(b)	(c)	(c)	(c)	(c)	(e)	(e)	(f)	(e)	(f)	(e)	(f)	(f)	(g)	(f)	(g)	(g)
z1	0.73	0.363	98.8%	26.0	0.37	0.228	0.05779	0.24	0.66556	0.33	0.08353	0.14	0.728	521.4	5.3	518.0	517.24
z2	0.69	0.389	98.8%	25.8	0.40	0.215	0.05770	0.25	0.66430	0.34	0.08350	0.17	0.735	517.9	5.4	517.2	517.08
z3	0.63	0.399	98.9%	29.1	0.36	0.196	0.05766	0.24	0.66420	0.32	0.08355	0.14	0.719	516.5	5.4	517.2	517.34
z4	0.61	0.725	98.8%	25.7	0.73	0.192	0.05795	0.23	0.66771	0.30	0.08357	0.12	0.746	527.5	5.0	519.3	517.46
z5	0.76	1.315	99.2%	39.9	0.88	0.236	0.05780	0.17	0.66719	0.25	0.08372	0.11	0.813	521.7	3.7	519.0	518.39
z6	0.79	0.643	98.6%	22.6	0.73	0.188	0.05742	0.31	1.7588	0.43	0.2221	0.22	0.719	507.7	6.9	1030.4	1293.28
z7	0.72	0.582	99.4%	49.3	0.31	0.227	0.05792	0.29	0.66856	0.35	0.08372	0.15	0.584	526.4	6.3	519.8	518.35
z8	0.69	0.764	99.3%	44.7	0.45	0.213	0.06060	0.15	0.84439	0.23	0.10106	0.11	0.850	624.7	3.2	621.6	620.69
z12	0.63	0.362	97.4%	11.9	0.79	0.198	0.05778	0.75	0.66469	0.84	0.08343	0.17	0.592	521.1	16.5	517.5	516.67

(a) z1, z2 etc. are labels for fractions composed of single zircon grains or fragments; all fractions annealed and chemically abraded after Mattinson (2005).

(b) Model Th/U ratio calculated from radiogenic $^{208}\text{Pb}/^{206}\text{Pb}$ ratio and $^{207}\text{Pb}/^{235}\text{U}$ age.

(c) Pb^* and Pb_c represent radiogenic and common Pb, respectively; mol % $^{206}\text{Pb}^*$ with respect to radiogenic, blank and initial common Pb.

(d) Measured ratio corrected for spike and fractionation only.

(e) Corrected for fractionation, spike, and common Pb; up to 1 pg of common Pb was assumed to be procedural blank: $^{206}\text{Pb}/^{204}\text{Pb} = 18.50 \pm 0.50\%$; $^{207}\text{Pb}/^{204}\text{Pb} = 15.8 \pm 0.5\%$;

$^{208}\text{Pb}/^{204}\text{Pb} = 38.02 \pm 0.75\%$ (all uncertainties 1-sigma). Excess over blank was assigned to initial common Pb.

(f) Errors are 2-sigma, propagated using the algorithms of Schmitz & Schoene (2007).

(g) Calculations are based on the decay constants of Jaffey *et al.* (1971). $^{206}\text{Pb}/^{238}\text{U}$ and $^{207}\text{Pb}/^{235}\text{U}$ ages corrected for initial disequilibrium in $^{230}\text{Th}/^{238}\text{U}$ using Th/U [magma] = 4. Data in **bold** were used in the age calculation.

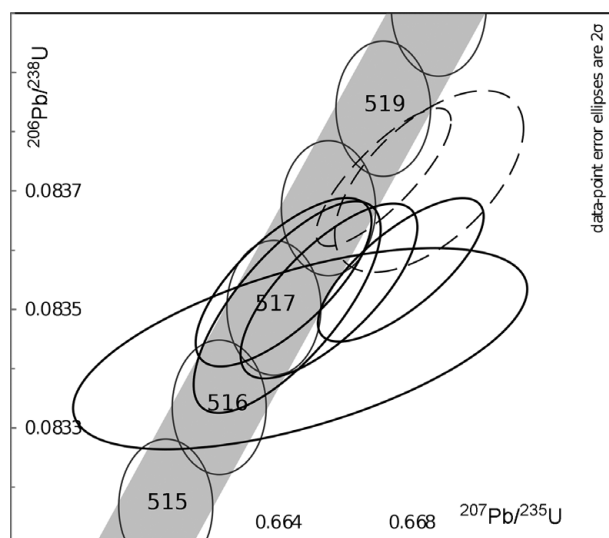


Figure 3. Conventional concordia plot for zircons from the Purley Shale Formation for single zircon grains analysed by the ID-TIMS method. The dashed ellipses show grains z5 and z7 that were not used in the age calculation.

near the Tommotian–Atdabanian boundary, and with eastern Canada, such as those of the *Camenella baltica* Biozone of the successions in Cape Breton Island and Newfoundland (Landing, 1991, 1995, 1996). Brasier's (1984) Assemblage VI extends up to the basal bed of the Woodlands Member; it is much less diverse, but includes some persistent, mainly tubular, fossils such as *Coleoloides*, *Hyolithellus* and *Torellella* that range up from lower assemblages.

5.b. Woodlands Member

Brasier's (1984) Assemblage VII is a sparse fauna with *Coleoloides typicalis* and *Torellella* sp., collected from thin calcareous lenses at the top of the Woodlands Member (Fig. 1).

5.c. Purley Shale Formation

In 1912 the Geological Survey collected fragments of trilobites from calcareous nodules 0.3 m above the base of the Purley Shale Formation at Camp Hill Grange Quarry, 1.4 km SE of Woodlands Quarry, which was formerly a good section (Pringle, 1913; Eastwood *et al.* 1923, p. 33) but was subsequently filled in. The trilobite fragments were identified as *Callavia?* by Smith & White (1963, p. 401) and are the earliest record of trilobites from the Charnwood Block. Rushton (1966, p. 37) collected a cephalic fragment from the same locality and horizon and identified it with doubt also as *Callavia?*, and additionally recorded trilobite fragments from the same horizon at Woodlands Quarry. The whereabouts of the material recorded by Illing (1913, p. 452) from a horizon 12 m above the base of the Purley Shale Formation at Stoneleigh Quarry '200 yards (c. 184 m) S of Worthington Farm' (at SP 3200 9557) has not been

ascertained. Brasier *et al.* (1978), who investigated a larger range of localities (including the working quarries to the SE of Hartshill), added greatly to the fauna by studying acid-insoluble residues from the calcareous deposits. Brasier's (1984) Assemblage VIII, from calcareous nodules 1.5 m above the base of the Purley Shale Formation, contains *Callavia?*, *Coleoloides typicalis*, sponge spicules, conodonts?, *Platysolenites antiquissimus* and *Teichichnus* burrows (Brasier, 1989).

All of the above workers have noted the appearance of trilobite fragments just above the base of the Purley Shale Formation, but they are not identifiable to species level and are only doubtfully compared to *Callavia* (Fig. 4). It is suspected that the appearance of trilobite fragments is linked to the rapid change to more open marine facies from the Woodlands Member to the Purley Shale Formation, which Brasier (1989, p. 87) plausibly envisaged as partly lateral equivalents. In the Cambrian correlation report (Rushton *et al.* 2011, p. 6) the first appearance of trilobites was adopted as a criterion for the recognition of the base of Series 2 of the Cambrian, but it was recognized also that the lowest trilobite biozones might overlap with the *Camenella baltica* Biozone at the top of the first Cambrian Series, the Terreneuvian.

6. Biostratigraphic significance of *Micromitra*

The fauna from the Home Farm Member of the Hartshill Sandstone Formation contains the brachiopod *Micromitra phillipsii*, characterized by a small, ventral posteriorly projecting knob, a long straight hinge line and rounded postero-lateral angles (see Cobbold, 1919; and Brasier, 1984, 1986). Holl (1865) originally described *M. phillipsii* from the Hollybush Sandstone of the Malvern area and the lectotype was re-figured by Cocks (2008, pl. 1, fig. 15). Matley (1902) recorded *M. phillipsii* from the underlying Malvern Quartzite as well as the Hollybush Sandstone, whose age, based on acritarchs, was discussed by T. L. Potter (in Rushton *et al.* 2011, p. 31); a recent review of this material has confirmed Matley's identification. In the Nuneaton area, *M. phillipsii* occurs in the Home Farm Member and also the Hartshill Sandstone Formation at the base of the Home Farm Member, ranging up to Bed 10ii of Brasier (1989, fig. 5.6). Elsewhere in England *M. phillipsii* is recorded in the lower Cambrian *Obolella groomii* grits of Shropshire (Cobbold, 1921; at the Ab1 horizon of Cobbold, see Fig. 1). Although Hinz (1987) recorded '*M. phillipsi*' from the somewhat younger Comley Limestones (see Fig. 1), those specimens are not considered to represent *M. phillipsii* as they appear to lack the characteristic knob.

In England, *M. phillipsii* appears to be characteristic of the *Camenella* Biozone and is not known to range up to the level of the oldest trilobites. Landing (1991, 1995) recorded *M. phillipsii* from the lower Cambrian Avalonian successions in Cape Breton, Newfoundland, the Cuslett Formation and the Fosters Point Formation

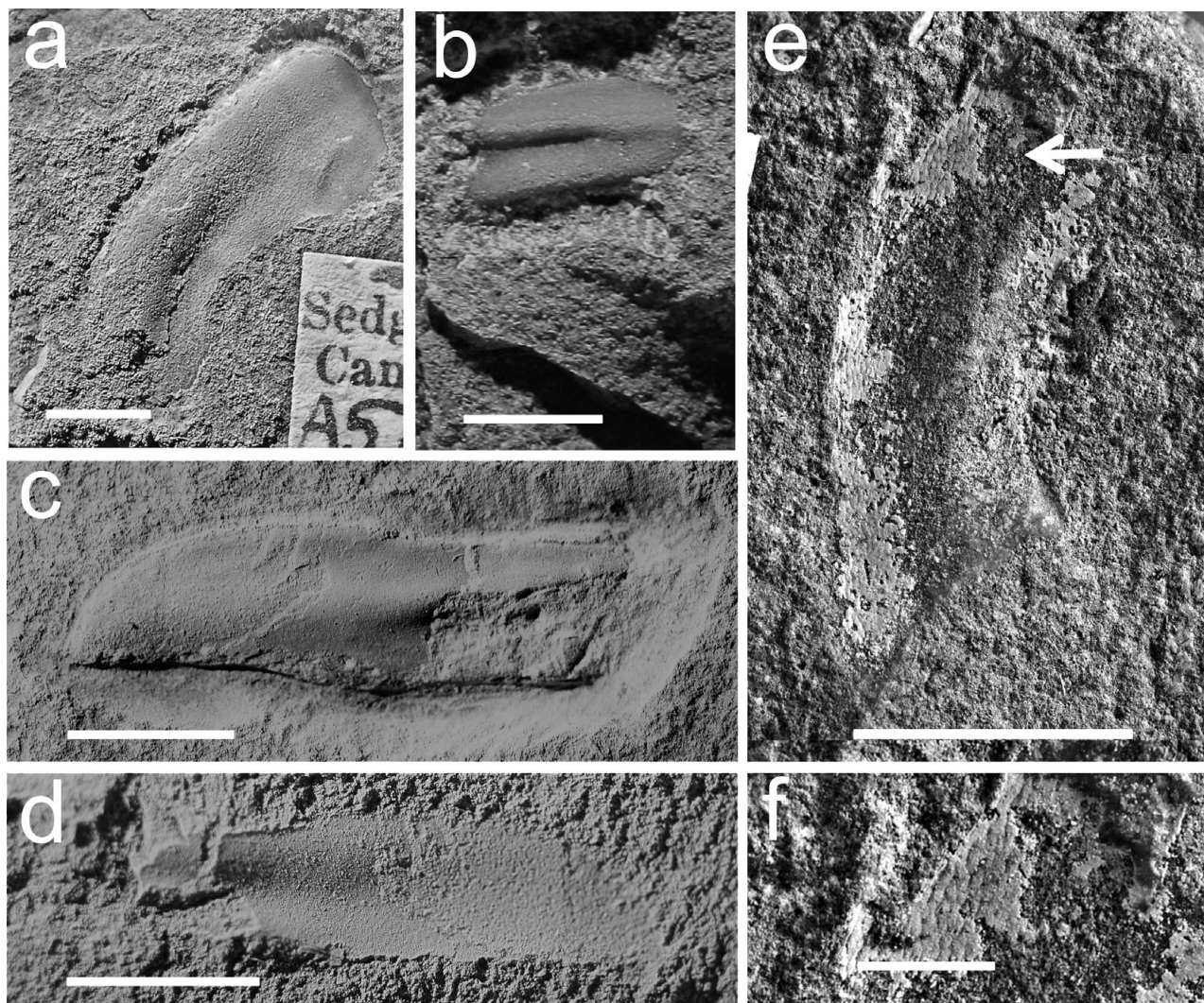


Figure 4. Trilobites. (a, e, f) Cephalic fragment from Camp Hill Grange Quarry; (a) internal mould, SM A.57266a; (e) the counterpart (SM A.57266b) of the same shows sculpture that resembles that at the edge of the cephalic shield of *Callavia callavei* from the Comley Limestones (arrowed); (f) part of the same, enlarged. (b) Pleural fragment from Woodlands Quarry, within c. 30 cm of the base of the Purley Shale Formation, SM A.57267a. (c, d) Part and counterpart of a pleural segment assigned doubtfully to *Callavia*. GSM 102127 and GSM 102128; locality as for (a). Scale bars: (a, b) 3 mm; (c–e) 5 mm; (f) 1.5 mm.

(Bonavista Group), and the Brigus Formation. The Cuslett and Fosters Point formations form part of the *Camanella baltica* Biozone; Brasier, Anderson & Corfield (1992) showed the FAD of *M. phillipsii* in Avalonia within the lower part of the Cuslett Formation. Brasier (1984) correlated the Home Farm Member in Nuneaton with the Cuslett Formation of Newfoundland, with faunas typical of the *Camanella baltica* Biozone, whilst Brasier, Hewitt & Brasier (1978) correlated the top of the Home Farm Member and the overlying Woodlands Member with the Tommotian Stage of Siberia. However, the Brigus Formation overlies the Fosters Point Formation and lies within the *Callavia broeggeri* Biozone and this indicates that *M. phillipsii* may range higher in Newfoundland than in England.

The species *Micromitra labradorica* (Billings), which is distinguished from *M. phillipsii* in lacking the characteristic knob on the ventral valve and having a high arched beak, is younger, and appears more characteristic of the *Callavia* Biozone (Cobbold, 1921;

Brasier, 1989; Hinz, 1987), at which level it occurs in the Cambrian succession of Shropshire (see Fig. 1). It has, however, not been recovered from the Cambrian succession of Warwickshire.

7. Stratigraphic significance of the bentonite

Trilobite fragments from levels near the base of the Purley Shale Formation (Figs 1, 4) appear to correlate to a level low in Stage 3 of the Cambrian, corresponding to some part of the Atdabanian of the Siberian successions, but their biozonal level remains doubtful. A fauna some 66 m above the base of the Purley Shale Formation with *Serrodiscus bellimarginatus* and *Strenuella sabulosa* is correlated with the *sabulosa* Biozone, which is treated as the base of Stage 4 of the Cambrian by Rushton *et al.* (2011). There is no closer biostratigraphical control on the upper biozonal limit for the bentonite. Therefore, based on palaeontological information from the local succession, the bentonite

is not older than the latest parts of the *Camenella* Biozone (Fig. 1), but could be somewhat younger, especially if, as seems likely, there is a significant time gap represented by the non-sequence between the Home Farm Member and the Woodlands Member; the bentonite is not younger than the *sabulosa* Biozone. However, it is likely that the bentonite age is nearer the earlier part of Series 2, within the *Fallotaspis* or *Callavia* trilobite Biozone, rather than nearer the top of that interval (Fig. 1) as this is supported by radiometric ages from Shropshire and Pembrokeshire for strata near the top and base of Stage 3 respectively (Fig. 1; see also Harvey *et al.* 2011).

The age of 517.22 ± 0.31 Ma for the lower part of the Purley Shale Formation suggests that the deepening of marine lithofacies in Warwickshire post-dates the commencement of the global eustatic sea level rise interpreted for the Browns Pond dysoxic interval of the Laurentian succession (Landing, 2012). In the approximately equivalent Cambrian interval in Shropshire, the Lower Comley Sandstone succession is marine from the level of the late *Camenella* Biozone through to the *Callavia* Biozone, its earliest trilobite being referable possibly to *Fallotaspis* or *Kjerulfia* (see Bergström, 1973). The equivalent stratigraphic interval in South Wales is represented by the unfossiliferous Caerbwdy Sandstone Formation, which is interpreted to be the product of deltaic deposition (Loughlin & Hillier, 2011). The bentonite horizon at Woodlands Quarry therefore appears to date a local marine transgression in the Nuneaton area.

8. Conclusions

Zircons from a bentonite near the base of the Purley Shale Formation in the Nuneaton area, Warwickshire, provide a $^{206}\text{Pb}/^{238}\text{U}$ age of 517.22 ± 0.31 Ma, the first radiometric age for the Cambrian succession of the Midland Microcraton and important for constraining the chronology of the earliest occurrence of trilobites in this region of Avalonia. The first occurrence of trilobites in the Purley Shale Formation is somewhat later than the trilobite fragments recovered from the Caerfai Bay Shales Formation of Pembrokeshire (see Siveter & Williams, 1995; Harvey *et al.* 2011) and this is consistent with the appearance of trilobites in the Warwickshire succession being associated with a local marine transgression and a more open marine shelf setting. The new bentonite date provides an additional chronological control on the interval assignable to the *Eofallotaspis* and *Callavia* biozones of Cambrian Stage 3.

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