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THE CONTRIBUTION OF PALAEONTOLOGICAL DATA TO AN UNDERSTANDING OF THE EARLY PALAEOZOIC FRAMEWORK OF EASTERN ENGLAND

S.G. MOLYNEUX[1]

(3 figures)

ABSTRACT. – Palaeontological data can provide various lines of evidence to further understanding of the early Palaeozoic framework of eastern England. Biostratigraphical dating and correlation underpin interpretations of stratigraphy, while other palaeontological data may aid interpretation of depositional environments and thermal histories. Each of these lines of enquiry can contribute to the delineation of cratonic and basinal areas.
Seventeen boreholes have proved Lower Palaeozoic sequences in the putative concealed Acadian fold belt of eastern England. Sequences proved beneath Upper Palaeozoic or younger successions include strata of Tremadoc, Llanvirn, Caradoc, Llandovery, Wenlock, Ludlow, Přídolí and Emsian age. In contrast, most Lower Palaeozoic sequences proved at subcrop on the eastern part of the postulated Midlands Microcraton are Tremadoc or older; later Ordovician strata are not known from the eastern part of the microcraton, and Silurian strata are only encountered in its more central and southern parts. These distributions are consistent with the idea of a fold belt lying to the east of the microcraton. Facies variations eastwards from the microcraton to the concealed fold belt are in general poorly documented. However, those in the late Llandovery and Wenlock Series (Silurian) mirror the gross variations in facies that occur westwards from the microcraton into the Welsh Basin, and generally concur with models that position the boundary between the microcraton and the concealed fold belt along a line from the vicinity of Charnwood to the Thames Estuary.

1. INTRODUCTION.

Various models have been proposed for the Precambrian and early Palaeozoic framework of southern Britain (Turner 1949, Dunning 1977, Wills 1978, Watson & Dunning 1979, Evans 1979, Ziegler 1982, Pharaoh *et al.* 1987). Most interpretations envisage that much of southern and central England is underlain by a concealed cratonic region, variously known as the Midlands Microcraton or the London Platform, which is flanked to the west by the Welsh Basin and to the east by a concealed fold belt beneath eastern England. Deformation of the latter is probably Acadian (Pharaoh *et al.* 1987, p. 366) and is therefore likely to be of early Devonian age (Soper *et al.* 1987). The main points of disagreement between the various models concern the extent of the microcraton and the concealed eastern fold belt, and the location of their mutual boundary. Pharaoh *et al.* (1987) adduced isotopic, geochemical, low grade metamorphic, structural and geophysical evidence to delimit the eastern margin of the microcraton, and their conclusions form the basis of the framework depicted in Fig. 1.

Palaeontological data have so far made little contribution to this discussion, but are potentially able to provide independent tests of other lines of evidence. Biostratigraphical dating and correlation is of primary importance in stratigraphical analysis. By revealing differences in patterns of sedimentation, biostratigraphical data may permit discrimination between cratonic and basinal areas; periods of eustatic regression, for example, are more likely to result in stratigraphic gaps at interior cratonic rather than basinal sites (Fortey 1984). In addition, biostratigraphy can provide information on the timing of volcanic and deformation episodes, while other palaeontological data may aid the interpretation of sedimentary environments, facies and thermal histories. When applied to southern Britain, investigations along these lines may help to delimit the

1. British Geological Survey, Keyworth, Nottingham NG12 5GG, U.K.

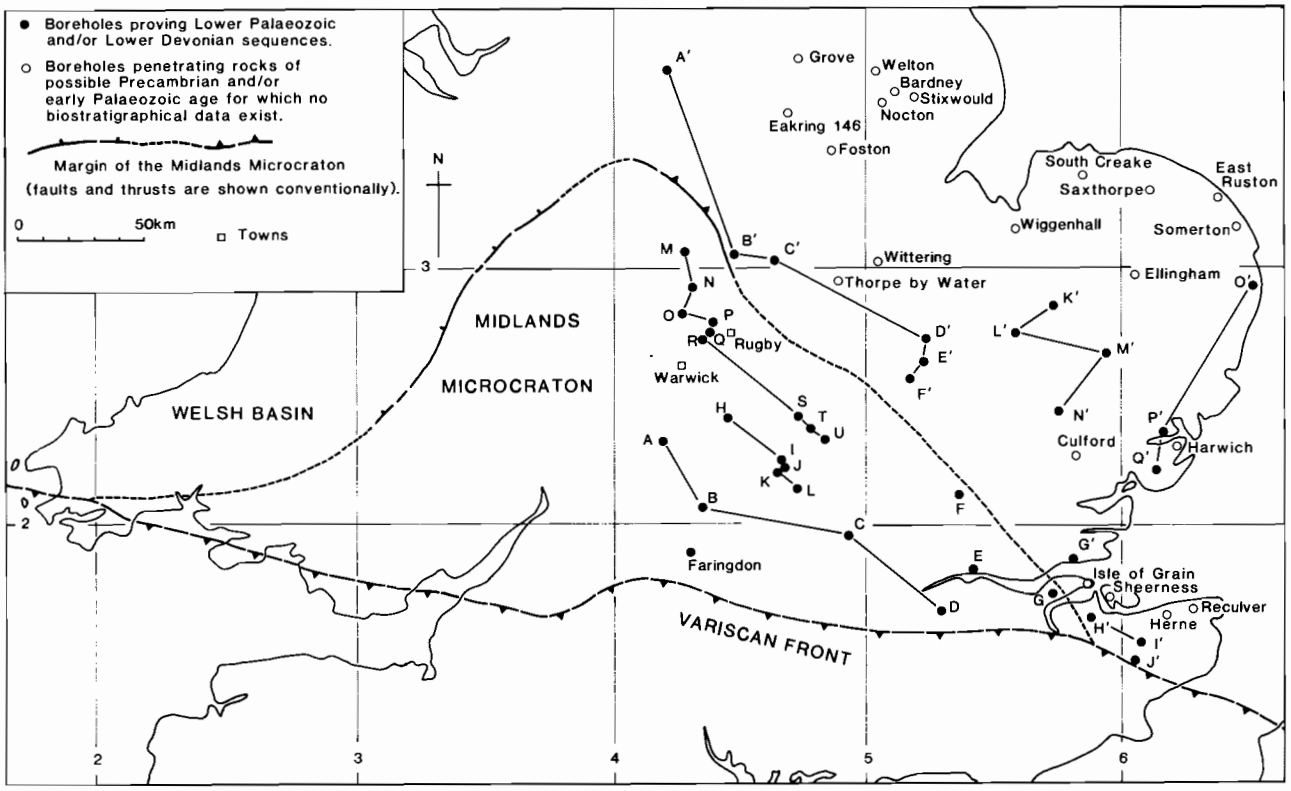

Figure 1. Location of boreholes cited in the text.

A-U: boreholes on the Midlands Microcraton. A Batsford; B Apley Barn; C Little Missenden; D Streatham Common; E Beckton; F Ware; G Cliffe Marshes; H Withycombe Farm; I Twyford (nos 1-4); J Calvert (east and west); K Marsh Gibbon; L Westcott (nos 1 and 2); M Shuttington Fields; N Merevale (nos 1-3); O Meriden; P Combe Abbey; Q Brandon; R Ryton No. 1; S Lillingstone Lovell; T Deanshanger; U Tattenhoe.

A'-Q': boreholes in the concealed Acadian fold belt. A' Eyam; B' Merry Lees Drifts; C' Crown Hills; D' Huntingdon; E' Great Paxton; F' Wyboston; G' Canvey Island; H' Bobbing; I' Chilham; J' Brabourne; K' Lakenheath; L' Soham; M' Stowlangtoft; N' Clare; O' Lowestoft; P' Stutton; Q' Weeley.

The identification letter of each borehole allows cross-reference to Figs 2 and 3. About 30 boreholes in an area of approximately 600 sq. km between Warwick and Rugby on the Midlands Microoraton have also encountered Tremadoc rocks beneath Carboniferous strata (Old *et al.* 1987, p.4).

contact between the Midlands Microcraton and the concealed fold belt, and establish the timing of deformation in the latter.

The initial requirement of any palaeontological analysis is to determine what data are available. Information from numerous publications, some dating from the late nineteenth century, have been collated and supplemented with new data for this review.

2. REVIEW OF PALAEONTOLOGICAL DATA.

Cored boreholes that have yielded palaeontological data from the eastern part of the Midlands Microcraton and from the concealed Acadian fold belt are described below. The location of the boreholes is depicted in Fig. 1, and the ages of early Palaeozoic (pre-Acadian) rocks proved in each borehole are summarised in Figs 2 and 3.

2.1. THE MIDLANDS MICROCRATON.

2.1.1. **Apley Barn** [National Grid Reference SP 3438 1066] (Fig. 2 column B): Lower Devonian strata, comprising grey green, reddish brown and purple, mottled, silty mudstones and sandstones, were encountered beneath Upper Devonian strata at a depth of 1343.66m, and were penetrated for 162.56m to terminal depth (TD) at 1506.22m (Poole 1969). Spores occur in a number of samples collected between 1356.26m and 1503.58m (Richardson & Rasul 1978). Certain aspects of the assemblage, notably the abundance of *Apiculiretusispora* and *Dibolisporites,* the morphology of *Apiculiretusispora,* and the presence of *Emphanisporites erraticus* (Eisenack) are characteristic of the lower and middle Emsian. On negative evidence, namely the absence of *Calyptosporites, Ancyrospora* and *Hystricosporites,* the assemblage is unlikely to be as young as late

Emsian. From this, Richardson & Rasul (1978) conclude that an early or middle Emsian age is most probable for the early Devonian strata. Reworked Ordovician and Silurian acritarchs are also present (Richardson & Rasul 1978).

2.1.2. **Batsford (Lower Lemington)** [SP 216 346] (Fig. 2 column A): Grey shales, sandstones and limestones underlie Coal Measures (Upper Carboniferous) strata at a depth of 465.73m, and were drilled to terminal depth at 518.31m (Williams & Whittaker 1974). Dips are variable, between 10° and 49°. The common occurrence of the brachiopod *Eocoelia sulcata* (Prouty) indicates a late Telychian (upper Llandovery) age. Examples of the graptolite *Monograptus* cf. *priodon* (Bronn) are also indicative of the late Llandovery, while acritarchs, including *Domasia elongata* Downie, are consistent with this age. A detailed log of the Silurian strata in this borehole is provided by Williams & Whittaker (1974, pp. 96-97).

2.1.3. **Beckton** [TQ 428 817] (Fig. 2 column E): Devonian (Old Red Sandstone) sedimentary rocks underlie Gault (early Cretaceous) strata at a depth of 297.18m, and were penetrated to terminal depth at 310.9m (Barrow & Wills 1913, Smart and others 1964). The Devonian strata comprise grey, green and

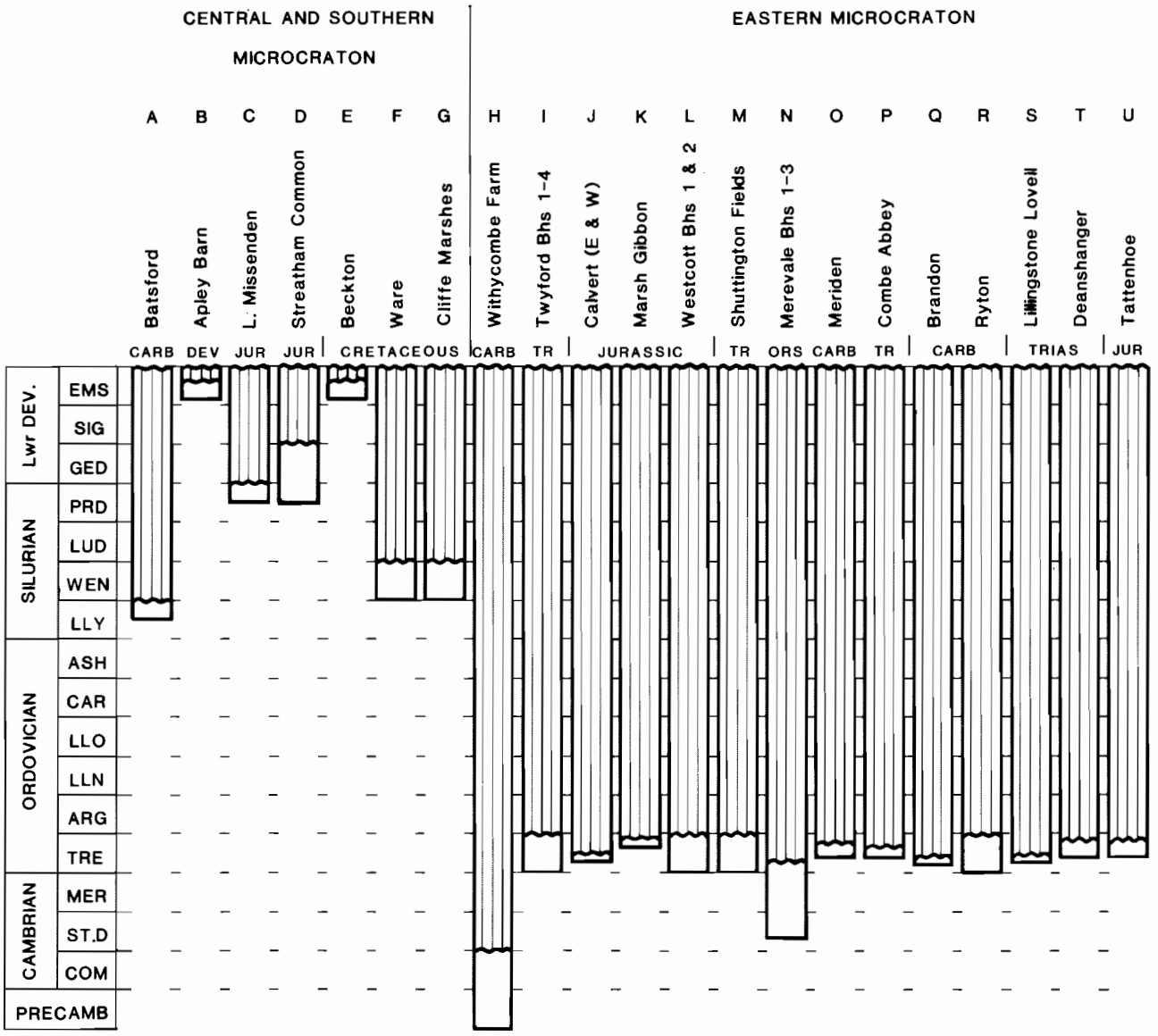

Figure 2. Summary of ages of basement beds proved in boreholes on the Midlands Microcraton. The boreholes are discussed alphabetically in section 2.1. Vertical lines in each borehole section indicate that strata are absent. The age of beds at the base of each borehole is indicated by the open box, the height of the box being determined by the ages proved. Abbreviations: CRET: Cretaceaous; JUR: Jurassic; TR: Triassic; CARB: Carboniferous; DEV: Devonian; ORS: Old Red Sandstone; Lwr DEV: Lower Devonian; EMS: Emsian; SIG: Praguian; GED: Lochkovian; PRD: Přídolí; LUD: Ludlow; WEN: Wenlock; LLY: Llandovery; ASH: Ashgill; CAR: Caradoc; LLO: Llandeilo; LLN: Llanvirn; ARG: Arenig; TRE: Tremadoc; MER: Merioneth; ST.D: St David's; COM: Caerfai; PRECAMB: Precambrian.

purplish brown sandstones, siltstones, marls and impure limestones, with a dip of about 45°. Spores obtained by Mortimer & Chaloner (1972) from a sandstone at 308.15m include *Retusotriletes greggsii* McGregor, cf. *Granulatisporites rousei* var. *major* Schultz, *Anapiculatisporites petilus* Richardson, *Dibolisporites* sp. cf. *gibberosus* (Naumova) *var. major* (Kedo) Richardson, *Bullatisporites bullatus* Allen, *Emphanisporites rotatus* McGregor, *Lophotriletes takatinicus* Chibrikova and *Perotrilites* spp. Mortimer & Chaloner (1972) interpret this assemblage as being of Emsian age.

2.1.4. **Brandon** [SP 3948 7562] (Fig. 2 column Q): Greenish grey shales, dipping at about 45°, were encountered beneath Coal Measures (Upper Carboniferous) strata at a depth of 151.9m, and were drilled for 2.9m. The graptolites ?*Clonograptus tenellus* (Linnarsson) and *Dictyonema flabelliforme* cf. *anglicum* Bulman indicate an early Tremadoc age, equivalent to the Transition Beds of the Shineton Shales (Bulman & Rushton 1973).

2.1.5. **Calvert (East)** [SP 690 245 approx.] (Fig. 2 column J): Greenish grey shaly mudstones, red-stained at the top and steeply dipping (40° to vertical), were encountered beneath Liassic (Lower Jurassic) strata at a depth of 135.2m and were drilled to 426.1m, penetrating an estimated true thickness of strata of 146m. The graptolites *Clonograptus tenellus callavei* (Elles & Wood) and *C. tenellus tenellus* (Linnarsson) indicate the *C. tenellus* Biozone (Bulman & Rushton 1973).

2.1.6. **Calvert (West)** [SP 687 245 approx.]: Records are imperfect, but greenish grey Tremadoc shales were encountered between depths of 139.1m and 197.8m. They yielded the brachiopod *Lingulella nicholsoni*? (Callaway) and a fragment of *Clonograptus,* and are presumed to represent the *C. tenellus* Biozone (Bulman & Rushton 1973).

2.1.7. **Cliffe Marshes** [TQ 705 750] (Fig.2 column G). Lower Greensand (early Cretaceous) strata overlie Silurian beds at a depth of 316.08m (Whitaker 1908, Dines *et al.* 1954). The total depth reached by the borehole is not recorded in the literature, but B.G.S. records indicate T.D. at 323.7m. Fossils from this depth, which include the brachiopods *Atrypa reticularis* (Linnaeus), *Leangella segmentum* (Lindström) and crinoid columnals, indicate a Wenlock age (Stubblefield in Bullard *et al.* 1940, p.89, Dines *et al.* 1954). Bassett (1974, p.773) notes that the faunas and lithologies are similar to those of the Wenlock Shale in the Welsh Borderland.

2.1.8. **Combe Abbey** No. 1 [SP 398 789 approx.] (Fig. 2 column P): Gently dipping red-stained and grey shales were encountered beneath Triassic rocks at 69.8m and were drilled to 99.7m. They yielded a mixed shelly and graptolitic fauna, including the trilobites *Euloma* sp., *Shumardia* sp. and *Acanthopleurella* sp., and the graptolites *Dictyonema flabelliforme* aff. *flabelliforme* (Eichwald) and *D. f. patulum* Bulman & Rushton. The trilobites were formerly thought to indicate the *Shumardia pusilla* Biozone (Stubblefield in Bulman 1928, p.29), but Bulman & Rushton (1973) note that they seem to be specifically distinct from the trilobites of that biozone and may represent a different horizon. They conclude that the Tremadoc strata proved in the Combe Abbey Borehole are above the *Clonograptus tenellus* Biozone, and believe them to be comparable with the Tremadoc of the Deanshanger Borehole (q.v.) which yielded the same subspecies of *Dictyonema.*

2.1.9. **Deanshanger** [SP 7652 3880] (Fig. 2 column T): Greyish green sandy siltstones and grey mudstones, dipping at 30°, were encountered beneath Triassic strata at a depth of 191.52m, and were drilled to 259.1m, penetrating a stratigraphical thickness of 57.9m. A mixed shelly and graptolitic fauna, including the trilobites *Anacheirurus plutonis* Bulman & Rushton, *Asaphellus homfrayi* (Salter), *Shumardia pusilla* (Sars), *Orometopus* cf. *elatifrons* (Angelin) and *O. aridos* Bulman & Rushton, and the graptolites *Dictyonema flabelliforme* (Eichwald) s.l., *D. f.* cf. *anglicum* Bulman, *D. f.* aff. *belgicum* Bulman, *D. f.* cf. *bryograptoides* Bulman and *D. f. patulum* Bulman & Rushton, was recorded. Bulman & Rushton (1973) noted a discrepancy in the evidence of age provided by the trilobites and graptolites. The former are suggestive of the *Shumardia pusilla* Biozone of the upper Tremadoc, whereas the latter are typical of the lower Tremadoc. To resolve this difficulty, Bulman & Rushton (1973) postulated an age equivalent to the Brachiopod Beds of the Shineton Shales, which overlie the *Clonograptus tenellus* Biozone but underlie the *S. pusilla* Biozone. However, acritarchs collected between 201.11m and 255.42m are reported to resemble assemblages from the lower part of the *S. pusilla* Biozone in the Shineton Shales, but differ markedly from assemblages from the Brachiopod Beds and the higher part of the *S. pusilla* Biozone (Rasul in Bulman & Rushton 1973, p.8).

2.1.10. **Lillingstone Lovell** [SP 7197 4197] (Fig. 2 column S): Greenish grey shales, dipping at about 20°, were encountered beneath Triassic rocks at 270.22m and were drilled to 299.39m, penetrating a stratigraphical thickness of about 24m. The graptolites *Adelograptus* cf. *hunnebergensis* (Moberg), *Anisograptus* cf. *norvegicus* Bulman, *Clonograptus tenellus tenellus* (Linnarsson) and *C. t. callavei* (Elles & Wood) are indicative of the *C. tenellus* Biozone (Bulman & Rushton 1973).

2.1.11. **Little Missenden** [SU 9009 9818] (Fig. 2 column C): Middle Jurassic sedimentary rocks overlie dark grey Palaeozoic shales and grey, sandy and shelly limestones at a depth of 366.52m. The latter were penetrated to 385.27m, with dips of between 5° and 10° (Strahan 1916). Straw (1933) concluded that either a late Downtonian or post-Downtonian age was possible for the Palaeozoic strata, based on a fauna which included invertebrate fossils and fish remains. Siveter (1989) argued for correlation with the late Prídolí on evidence obtained from ostracodes, particularly the occurrence of *Nodibeyrichia pustulosa* (*gedanensis*) (Hall) and *Kloedinia wilckensiana* (Jones).

2.1.12. **Marsh Gibbon No. 1** [SP 6481 2374] (Fig. 2 column K): Greyish green, fine-grained sandstones were encountered beneath Liassic (Lower Jurassic) rocks at a depth of 121.46m. The sandstones are underlain in the borehole by dark grey siltstones and mudstones to a depth of 174.35m. The hyolithid *"Hyolithes" belswardinensis* Bulman and the trilobite *Shumardia pusilla* (Sars) are indicative of the *S. pusilla* Biozone (Bulman & Rushton 1973).

2.1.13. **Merevale Boreholes** (Fig. 2 column N): Each of the Merevale Boreholes (Nos 1, 1A, 2 and 3) proved Cambrian sequences that can be correlated lithostratigraphically and biostratigraphically with formations mapped in the nearby Nuneaton inlier. A detailed account of the succession proved in each borehole is provided by Taylor & Rushton (1971).

Merevale No. 1: This borehole encountered the Monks Park Shales unconformably beneath Upper Old Red Sandstone at a depth of 32.00m. The Monks Park Shales, proved to a depth of 115.01m, are underlain by the Moor Wood Flags and Shales to 130.28m and the Outwoods Shales to terminal depth at 217.63m. The sequence is Upper Cambrian, with the following trilobite biozones proved in ascending order: the *Agnostus pisiformis, Olenus* and *Parabolina spinulosa* Biozones in the Outwoods Shales, and the *P. spinulosa, Leptoplastus* and *Peltura* Biozones in the Monks Park Shales.

Merevale No. 1A: The borehole proved Monks Park Shales unconformably beneath Upper Old Red Sandstone at 29.92m. They are seen to terminal depth at 54.86m.

Merevale No. 2: The borehole proved Merevale Shales unconformably beneath Upper Old Red Sandstone at a depth of 213.66m. The Merevale Shales are present to a depth of 219.48m, and are underlain by Monks Park Shales to terminal depth at 258.01m. The Merevale Shales have yielded *Dictyonema flabelliforme* cf. *sociale* (Salter) and *Tomaculum problematicum* Groom, and are of Tremadoc age.

Merevale No. 3: This borehole was drilled on the Cambrian outcrop of the Nuneaton inlier, and proved Outwoods Shales to 157.96m, underlain by Mancetter Grits and Shales to 216.18m, disconformably underlain by Abbey Shales to terminal depth at 249.63m. The Abbey Shales are dated as Middle Cambrian at outcrop, but yielded few diagnostic trilobites in the borehole. Faunas from the Mancetter Grits and Shales indicate the latest Middle Cambrian *Lejopyge laevigata* Biozone. The Upper Cambrian *A. pisiformis* and *Olenus* Biozones are represented in the Outwoods Shales.

2.1.14. **Meriden** [SP 2682 8186] (Fig. 2 column O): Dark grey shales with gentle dips (about 5°) were encountered beneath Coal Measures (Upper Carboniferous) strata at 994.3m, and were drilled to 1028.7m. They have yielded the brachiopods *Lingulella nicholsoni* (Callaway) and *Eurytreta ["Acrotreta"] sabrinae* (Callaway), the bradoriid crustacean cf. *Beyrichona triceps* (Matthew) and the graptolite *Dictyonema flabelliforme* aff. *sociale* (Salter). *D. f. sociale* is generally characteristic of Lower Tremadoc strata, but Bulman & Rushton (1973) note that the specimens from Meriden Borehole have short *bithecae* and postulate that they indicate an horizon which is possibly above the *C. tenellus* Biozone. The bradoriid cf. *Beyrichona triceps* resembles specimens from Upper Tremadoc strata in the Tortworth inlier near Bristol.

2.1.15. **Ryton No. 1** [SP 3632 7399] (Fig. 2 column R): Greenish grey shales, dipping at about 35°, were encountered at 904.2m beneath Coal Measures (Upper Carboniferous) strata, and were drilled to 908.6m. They have yielded the brachiopods *Lingulella* cf. *nicholsoni* (Callaway) and *Eurytreta sabrinae* (Callaway) and the graptolite *Dictyonema flabelliforme* (Eichwald) *s.l.* Bulman & Rushton (1973) suggest an indefinite horizon within the Tremadoc.

2.1.16. **Shuttington Fields** [SK 2642 0610] (Fig. 2 column M): Horizontal grey shales referred to the Tremadoc were encountered beneath Triassic strata at a depth of 269.7m, and were drilled to 297.5m (Bulman & Rushton 1973). They have yielded *Eurytreta sabrinae* (Eichwald) and *Tomaculum problematicum* Groom.

2.1.17. **Streatham Common** [TQ 2956 7103] (Fig. 2 column D): Pale greenish grey and mottled reddish purple sandstones and mudstones, with dips of between 20° and 30°, underlie Jurassic strata at a depth of 341.38m and were seen to 383.44m (Whitaker 1889). Boring continued to 387.4m, but the final 4m of core was not recovered. Fragments of fish from core at 373.38m were identified by Toombs (in Ball *et al.* 1961, p.217) as *Traquaraspis symondsi* (Lankester), *Tesseraspis tessellata* Wills and *?Corvaspis*. This fauna is reported to indicate a late

Downtonian or early Dittonian age (i.e. late Přídolí or earliest Devonian).

2.1.18. **Tattenhoe** [SP 8289 3437] (Fig. 2 column U): Grey and red-stained siltstones, sandstones and shale were encountered beneath Liassic (Lower Jurassic) rocks at a depth of 149m and were drilled to 210.43m. Dips are steep, between 70° and vertical. The Tremadoc strata are folded and faulted, and a high proportion of beds are inverted. Bulman & Rushton (1973) estimate that the total stratigraphical thickness of beds penetrated is only a few metres. Graptolites recorded include *D. flabelliforme* (Eichwald) *s.l.*, *D. f.* aff. *flabelliforme* and *D. f. patulum* Bulman & Rushton. Bulman & Rushton (1973) suggest an horizon above the *C. tenellus* Biozone, perhaps equivalent to the strata in the Deanshanger Borehole, which yielded the same subspecies of *D. flabelliforme.*

2.1.19. **Twyford Boreholes Nos 1-4** (Fig. 2 column I). Beds in each borehole are referred to the Tremadoc, though there is little biostratigraphical evidence of age.

No. 1 [SP 6802 2569]: Pale green weathered mudstones, passing down into greyish green siltier beds, were encountered beneath Triassic (Rhaetian?) strata at a depth of 138.86m. The postulated Tremadoc strata were drilled to 156.67m. Dips are steep (60° to vertical) and there is evidence of slickensiding. A specimen of *Lingulella?* was recorded (Bulman & Rushton 1973).

No. 2 [SP 6760 2650]: Pale green and grey muddy siltstones, dipping at 60°, were encountered beneath Triassic strata at a depth of 139.75m, and were bored to 153.9m.

No. 3 [SP 6859 2659]: Pale green and greyish green siltstones and mudstones, dipping at 40° to 50°, were encountered beneath Liassic (Lower Jurassic) rocks at a depth of 134.24m, and were drilled to 143.26m. An acrotretid brachiopod was recorded (Bulman & Rushton 1973).

No. 4 [SP 6697 2561]: Pale green and dark mudstone and siltstone, with thin limestones, were encountered beneath Liassic (Lower Jurassic) rocks at a depth of 140.84m, and were drilled to 150.57m. Steep dips (50° to vertical) were recorded.

2.1.20. **Ware** [TL 3531 1398] (Fig. 2 column F). Shales and mudstones interbedded with thin limestones are seen below Gault (Cretaceous) strata at a depth of 242.77m, and have yielded brachiopods and trilobites indicative of a Wenlock age (Whitaker & Jukes-Browne 1894, pp. 506,507), including "*Leptaena transversalis, Orthis elegantula, Pentamerus galeatus, P. linguifer?, Strophomena rhomboidalis*" and "*Phacops caudatus*". The thickness of the Wenlock in the borehole is 10.67m to terminal depth at 253.44m, but because of the dip of 40° recorded by Whitaker & Jukes-Browne (1894, p.502), the true thickness of strata is estimated to be approximately 7m. Bassett (1974, p.773) notes that the faunas and lithologies resemble those of the Wenlock Shale in the Welsh Borderland.

2.1.21. **Westcott Boreholes Nos 1 and 2** [SP 7103 1653] (Fig. 2 column L): Westcott Borehole No. 2 encountered beds referred to the Tremadoc beneath Liassic (Lower Jurassic) strata at a depth of 163.7m. The Tremadoc beds, which comprise greenish grey and red-stained silty mudstones dipping at about 45°, were drilled to a depth of 173.7m. The No. 1 Borehole is comparable. An acrotretid brachiopod was recorded from borehole No. 1, and *Lingulella* cf. *lepis* Salter and *Tomaculum?* from borehole No. 2 (Bulman & Rushton 1973).

2.1.22. **Withycombe Farm** [SP 4319 4017] (Fig. 2 column H): The Withycombe Formation underlies Coal Measures (Upper Carboniferous) strata at a depth of 841.12m, and rests unconformably on weathered andesitic igneous rocks at a depth of 1035.1m. The formation comprises grey, green and purplish mudstones with impure silty limestones in the upper part of the section, becoming sandier below 1024.66m, and has a dip of between 6° and 10°. Although the Withycombe Formation was formerly thought to be of Silurian age (Poole 1978, p.20), a recent review of the palaeontological evidence has reassessed its age as Cambrian (Rushton & Molyneux 1990). The macrofauna from the formation includes *Platysolenites antiquissimus* Eichwald and representatives of *Aldanella* and *Watsonella,* all of which are indicative of early Cambrian age. Acritarch assemblages comprise mostly sphaeromorphs, but also present are examples of *Granomarginata squamacea* Volkova, a species which is consistent with an early Cambrian age.

2.2. THE CONCEALED ACADIAN FOLD BELT.

2.2.1. **Bobbing** [TQ 874 652] (Fig. 3 column H'). Great Oolite (Middle Jurassic) strata rest unconformably on steeply dipping grey micaceous siltstones and sandstones at a depth of 363m. The latter are seen to terminal depth (TD) at 381 m, but the estimated true thickness of the beds is only 6m. A macrofauna of bryozoans, brachiopods, bivalves, orthocone nautiloids, trilobites, crinoids, and rare graptolites occurs throughout this thickness, and is considered to be of late Ordovician age. Acritarchs and Chitinozoa from a composite sample, collected between 363m and 381m, include *Multiplicisphaeridium bifurcatum* Staplin, Jansonius & Pocock, *M. irregulare* Staplin, Jansonius & Pocock,

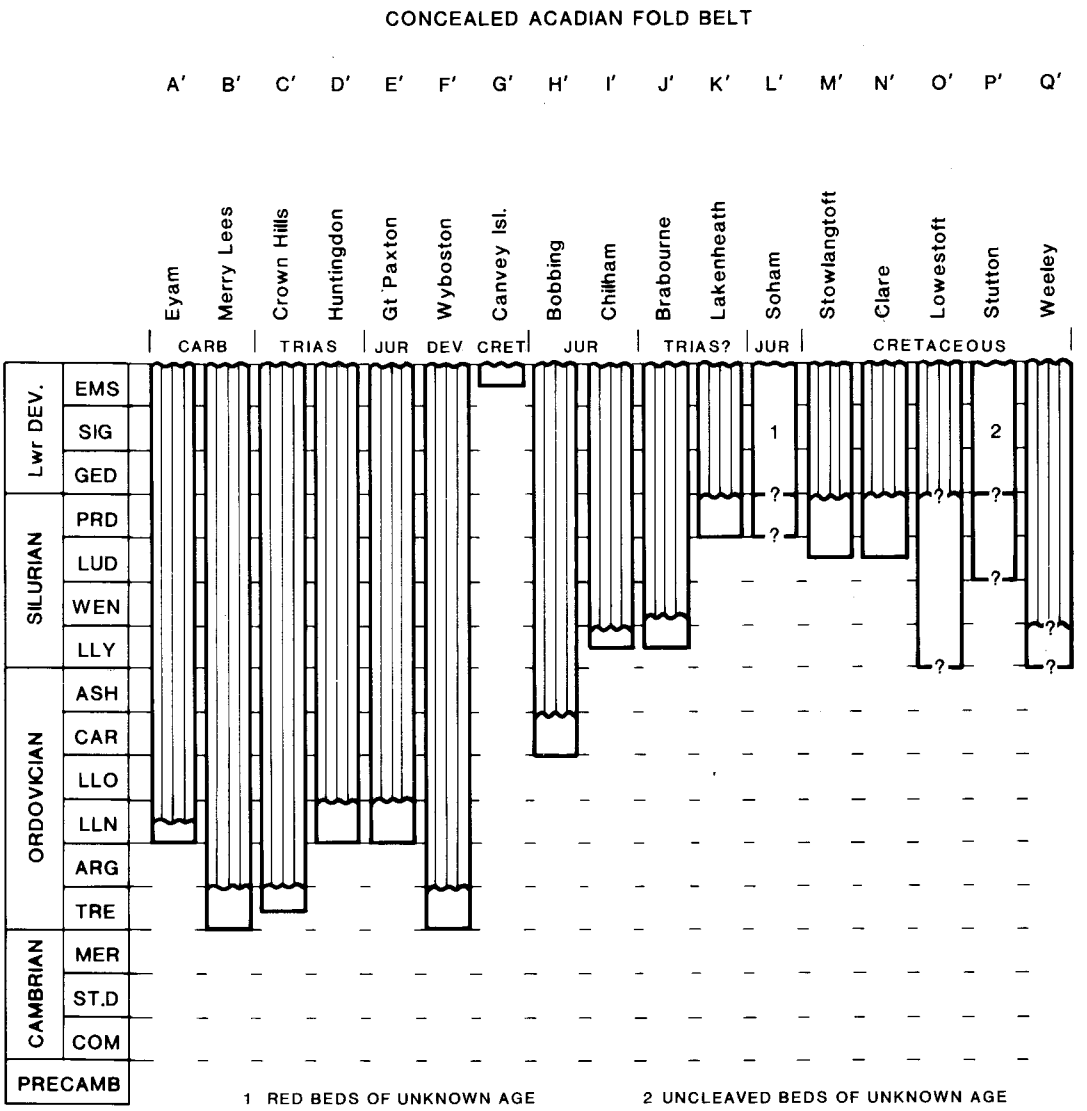

Figure 3. Summary of ages of basement beds proved in boreholes in the Acadian fold belt of eastern England. The boreholes are discussed alphabetically in section 2.2. See Fig. 2 for explanation and abbreviations.

Conochitina lepida Jenkins and *Spinachitina [Ancyrochitina] bulmani* (Jansonius) Männil, and are reported to indicate a Caradoc age (Lister and others 1969).

2.2.2. **Brabourne** [TR 077 423] (Fig. 3 column J'). Between depths of 585.52m and 610.82m, beneath rocks of possible Triassic age, the borehole proved slightly cleaved silty shales and mudstones, stained dull red and purple in the upper part and becoming dark sooty grey or nearly black below (Lamplugh & Kitchin 1911, Smart *et al.* 1966, pp. 16-17). Dips of 20°-30° are recorded, giving a true thickness of 21m to 24m. Shelly fragments, including probable brachiopods and trilobites, occur at 588.26m and between 601.37m and 602.89m, but are not diagnostic of age. Unpublished British Geological Survey (B.G.S.) records of acritarchs and chitinozoa include the acritarch *Domasia elongata* Downie from 606.25m, indicating a late Llandovery or early Wenlock age.

2.2.3. **Canvey Island** [TQ 8215 8330] (Fig.3 column G'). Rocks of Old Red Sandstone facies were encountered below Gault (Cretaceous) strata at a depth of 401.57m, and were proved for 130.91m to terminal depth at 532.48m (Smart *et al.* 1964). They comprise greyish and reddish brown sandstones with subordinate conglomerates and brown, grey and green mudstones and siltstones, dipping eastwards at 15°-28°. There is no record of any cleavage. Stubblefield (in Smart *et al.* 1964) identified ostracodes from red mudstones at 414.68m-414.76m as *Leperditia* sp., and concluded that the beds were not older than the Downton (i.e. Přídolí) Series. Between depths of 406.70m and 511.94m, Croft (in Smart *et al.* 1964) reported plant remains as cf. *Cooksonia,* cf. *Nematothallus* and cf. *Zosterophyllum,* suggesting that the flora was not younger than Middle Devonian and was possibly older. Mortimer (1967) recorded sixteen spore taxa, including "*Phyllothecotriletes* cf. *golatensis* Staplin, *Retusotriletes simplex* Naumova,

Granulatisporites cf. *newportensis* Chaloner & Streel and *Stenozonotriletes clarus* Ishchenko" from 497.76m and *Ancyrospora* cf. *reuta* Allen from 464.82m. Mortimer & Chaloner (1972, table 2) list *Calamospora atava* (Naumova) McGregor, *Retusotriletes translaticius* Chibrikova, *Hystricosporites* sp. A and *Emphanisporites rotatus* McGregor, but their depths are not specified. Chaloner & Richardson (in House *et al.* 1977) consider the palynological evidence to indicate a late Emsian age.

2.2.4. **Chilham** [TR 088 545] (Fig. 3 column I'). At a depth of 336.80m, Lower Jurassic sedimentary rocks unconformably overlie Lower Palaeozoic shales, stained red and purple in their upper 6.10m. There is a discrepancy in the literature concerning the depth that the borehole reached (see Smart and others 1966, p.16), but the Lower Palaeozoic shales are reported to have been penetrated for 55.47m. This places total depth at 392.27m. Because of the 80° dip, the true stratigraphic thickness of beds penetrated may be no more than 9.63m. Pyritised graptolites, identified by Elles (in Lamplugh *et al.* 1923), include *Monograptus crispus* Lapworth, *M. discus* Törnquist, *M. exiguus* (Nicholson), *M. marri* Perner, *M. nodifer* Törnquist, *M. nudus* Lapworth, *M. priodon* (Bronn) and *Rastrites equidistans* Lapworth, and indicate the *M. crispus* Biozone (Telychian Stage, late Llandovery).

2.2.5. **Clare** [TL 7834 4536] (Fig. 3 column N'). Lower Palaeozoic rocks underlie Gault (early Cretaceous) strata at a depth of 232.28m, and were seen to terminal depth at 264.74m. They comprise grey mudstones, siltstones and thin sandstones in rhythmically bedded units, richly fossiliferous in parts and apparently steeply dipping (Millward 1980); Pharaoh *et al.* (1987, p.366) suggest that the rocks are cleaved. Unpublished B.G.S. records of the acritarch *Leoniella carminae* Cramer, from 236.20m, and abundant spore floras with *Retusotriletes* cf. *warringtoni* Richardson & Lister, from 236.20m and 247.14m, suggest a late Silurian (Ludlow or Přídolí) age. Bassett *et al.* (1982, fig.1) report that ostracodes indicate a possible Přídolí age.

2.2.6. **Crown Hills** [SK 624 037] (Fig. 3 column C'). Bulman & Rushton (1973) report that grey iron-stained silty and micaceous mudstones underlie Triassic rocks at a depth of 255.1m and were drilled to 304.9m. Their dip of about 20° gives a true thickness of about 47m. Tremadoc shelly fossils, recorded between depths of 256.6m and 300.2m, include *Eurytreta sabrinae* (Callaway), *"Hyolithes"* aff. *magnificus* Bulman, *Asaphellus homfrayi* (Salter) and *Micragnostus calvus* (Lake), indicating an horizon above the *Clonograptus tenellus* Biozone (Bulman & Rushton 1973). Pharaoh *et al.* (1987) note that the mudstones have a weak spaced cleavage.

2.2.7. **Eyam** [SK 2096 7603] (Fig. 3 column A'). Cleaved grey mudstones and silty mudstones with patchy purple staining are present beneath Dinantian rocks, between depths of 1803.25m and 1851.05m. The thickness of the Lower Palaeozoic rocks in the borehole is 47.80m, but given a dip of 45°-60°, their true thickness may be less than 34m (Dunham 1973). A shelly fauna of brachiopods (*Lingulella*), orthocone nautiloids and trilobites (*Macrogrammus*?, *Merlinia* and *Platycalymene*?), provides inconclusive evidence for an Arenig or Llanvirn age (Rushton in Dunham 1973). Palynological assemblages have been obtained at several depths between 1821.15m and 1849.50m. The most productive sample, from 1834.17m, yielded abundant though poorly preserved acritarchs and chitinozoa, including *Arbusculidium filamentosum?* (Vavrdová) Vavrdová, *Dicrodiacrodium fulcratum*? Burmann, *Peteinosphaeridium* cf. *velatum* Kjellström and ?*Siphonochitina formosa* Jenkins, which are reported to indicate a probable early Llanvirn age (Downie in Dunham 1973).

2.2.8. **Great Paxton** [TL 2088 6389] (Fig. 3 column E'). Uncleaved grey shales, mudstones, siltstones and thin sandstones, dipping steeply at 60°-70° to the southeast, underlie Lower Jurassic beds at a depth of 135.64m and are present down to 201.17m. Because of the steep dip, a true stratigraphical thickness of only about 27m was penetrated. An abundant fauna of brachiopods, molluscs, trilobites, ostracodes and graptolites, described by Stubblefield (1967), Skevington (1973), Rushton & Hughes (1981) and Jenkins (1983), occurs throughout. According to Skevington (1973), the graptolites comprise a late Llanvirn fauna, with *Didymograptus acutus* Ekström, *D. artus* Elles & Wood, *D. murchisoni* (Beck), *D. murchisoni* cf. *geminus* (Hisinger), *D. murchisoni speciosus* Ekström and *Glyptograptus* cf. *euglyphus* (Lapworth). However, Jenkins (1983) referred most of the pendent didymograptids to a new species, *Didymograptus pluto*, and reassessed the age of the fauna as early Llanvirn. Fortey & Owens (1987, p.255) later referred the holotype of *D. pluto* to the early Llanvirn species *D. (D.) spinulosus* Perner.

Rushton & Hughes (1981) described twelve trilobite species from the borehole, of which seven were new. Of the remaining five, *Ampyx* cf. *linleyensis* Whittard, *Microparia* cf. *shelvensis* Whittard (referred to *M. plasi* Marek by Fortey & Owens 1987, p.167) and *Porterfieldia* cf. *convergens* (Whittard) are closely comparable with species from the lower Llanvirn of the Shelve Inlier in the Welsh Borderland. *Platycalymene tasgarensis tasgarensis* Shirley is restricted to the lower Llanvirn at Shelve, and *Pricyclopyge binodosa binodosa* (Salter) ranges from the Arenig to the lower Llanvirn there. The ranges of these trilobites suggest an early Llanvirn age, but Rushton & Hughes (1981)

pointed out that upper Llanvirn faunas are generically restricted, and that a late Llanvirn age could not be discounted as no direct comparisons could be made. Acritarchs and chitinozoa are abundant, but no details have been published (Rushton & Hughes 1981, p. 624).

Rushton & Hughes (1981) refer the Llanvirn trilobites from Great Paxton to the Raphiophorid Community. This occupies an ecological niche between the nearshore *Neseuretus* Community and the atheloptic assemblage of blind and nearly blind trilobite taxa which, by inference, lived in relatively deep water, below the photic zone. The Raphiophorid Community is inferred to have occupied a broad range of shelf environments, though the abundance of three genera, *Ampyx, Porterfieldia* and *Trinucleus,* led Rushton & Hughes (1981) to postulate that the Great Paxton fauna originated near the deeper, outer limit of the communities' range.

2.2.9. **Huntingdon** [TL 2369 7143] (Fig. 3 column D'). Slightly cleaved dark grey siltstones and mudstones, with red and green partings, are present beneath Triassic beds, between depths of 172.59m and 235.29m. Uncommon trilobites and graptolites, including *Ectillaenus* sp., *Pricyclopyge* sp., *Didymograptus* cf. *artus* Elles & Wood, *D.* cf. *"bifidus"* and *Glyptograptus dentatus* (Brongniart), indicate a Llanvirn age (Strachan in Williams *et al.,* 1972).

2.2.10. **Lakenheath** [TL 748 830] (Fig. 3 column K'). Butler (1981) reported a late Silurian or early Devonian fauna, including brachiopods, the bivalve *Nuculites antiquus*? (J. de C. Sowerby) and the ostracodes cf. *Frostiella groenvalliana* Martinsson and *Londinia,* from basement beds in this borehole. Bassett *et al.* (1982, fig. 1) suggest a possible Přídolí age on the evidence of the ostracodes (see also Siveter 1989, fig. 164). Pharaoh *et al.* (1987, p. 366) note that the Lower Palaeozoic beds in this borehole are cleaved.

2.2.11. **Lowestoft** [TM 538 926] (Fig. 3 column O'). Pale micaceous mudstones underlie Lower Greensand strata at a depth of 495.91m, and are seen to terminal depth at 558.39m. They have yielded inarticulate brachiopods (Strahan 1913a, Stubblefield in Bullard *et al.* 1940, p.88), including *Lingula* and *Orbiculoidea.* Spores, acritarchs and chitinozoa in a sample from 548.64m are reported to include *Retusotriletes* cf. *warringtoni* Richardson & Lister, *Synorisporites verrucatus* Richardson & Lister, *Cymatiosphaera pavimenta* (Deflandre) Deflandre and *Visbysphaera dilatispinosa* (Downie) Lister (unpublished B.G.S. data), indicating a Silurian age.

2.2.12. **Merry Lees Drifts** [SK 460 068] (Fig. 3 column B'). Bulman & Rushton (1973) report that grey and stained shales are faulted against Coal Measures (Upper Carboniferous) strata below Triassic rocks, at a depth of 64.70m. They record the occurrence of a shelly fauna that suggests a Tremadoc age, with *Lingulella* cf. *nicholsoni* (Callaway), *Linnarssonia*? cf. *belti* (Davidson) and hyolithids.

2.2.13. **Soham** [TL 5928 7448] (Fig. 3 column L'). Holmes (in Worssam & Taylor 1969) records Lower Lias (Lower Jurassic) strata unconformably overlying red beds of uncertain age at a depth of 133.05m. The latter comprise red, green and reddish brown sandstones and conglomerates, seen to 162.76m. The red beds are unconformable on cleaved and fractured red and green mudstones, which become greyer below 187.45m and sandier below 223.72m. Dips in the cleaved red and green mudstones increase from about 45° above 235m to 90° below that depth. The borehole reached a depth of 242.14m.

The lower, cleaved beds have yielded a fauna of bivalves and ostracodes (Stubblefield in Mortimer & Chaloner 1972, Butler 1981). Butler (1981) considered the fauna to be of mixed aspect, the ostracodes *Londinia* and *Macrypsilon* being typical of the late Silurian whereas other elements, such as the tentaculitoidean *Dicricoconus* and the bivalves *Palaeosolen, Parallelodon* aff. *hamiltoniae* (Hall & Whitfield) and *Prothyris,* are typical of the Devonian. Bassett *et al.* (1982, fig. 1) have suggested a possible Přídolí age on ostracode evidence. Mortimer & Chaloner (1972) recorded spores from depths of 189.59m, 190.80m and 192.15m but these are mostly long-ranging taxa, including representatives of *Leiotriletes, Punctatisporites, Retusotriletes, Verrucosisporites, Convolutispora, Perotrilites* and cf. *Lycospora.* Chitinozoa are present in the assemblages from 189.59m and 190.80m, and acritarchs, plant material and a scolecodont in that from 190.80m.

2.2.14. **Stowlangtoft** [TL 9475 6882] (Fig. 3 column M'). Details of this borehole, drilled in 1983, remain unpublished. Lower Palaeozoic rocks are overlain by Gault (early Cretaceous) strata at a depth of 225.00m, and are seen to terminal depth at 295.60m. Their dips vary from 20° to nearly vertical. They comprise reddish and greenish grey silty sandstones and mudstones at the top of the section, with grey banded siltstones and mudstones below. Shelly faunas are present at several horizons, and spores, acritarchs and chitinozoa occur throughout the interval below 239.14m. Dr. J.B. Richardson (pers. comm.) reports that the samples between 239.14m and 295.60m contain numerous miospores

representing only a few species, and that their age is probably late Ludlow or possibly Přídolí. Dr Richardson has identified *Ambitisporites dilutus* (Hoffmeister) Richardson & Lister, spores resembling *Apiculiretusispora* sp. C of Richardson & Lister (1969), an undescribed species of *Apiculiretusispora, Archaeozonotriletes chulus* (Cramer) Richardson & Lister, ?*A.* cf. *divellomedium* Chibrikova and a dyad cf. *A. dubius* Richardson & Lister. Acritarchs present include *Leoniella carminae* Cramer, which is consistent with a late Silurian age.

2.2.15. **Stutton** [TM 1499 3345] (Fig. 3 column P'). Rocks that underlie Gault strata at a depth of 302.97m are considered to be Lower Palaeozoic. They comprise grey, thinly bedded calcareous sandstones and mudstones with a dip of about 45° but no cleavage or jointing to 308.00m, underlain by hard cleaved mudstones, nearly vertical, to terminal depth at 464.97m (Strahan 1913b, Whitaker 1906). The presence of an orthocone nautiloid and eurypterid fragments has led to suggestions of a late Silurian (Ludlow or Přídolí) age for the lower, cleaved interval (Stubblefield in Bullard *et al.* 1940, p.87). There are unpublished B.G.S. records of a restricted spore and acritarch assemblage of probable Silurian age from 425.50m, with *Ambitisporites dilutus* (Hoffmeister) Richardson & Lister.

2.2.16. **Weeley** [TM 1473 2183] (Fig. 3 column Q'). Lower Palaeozoic rocks underlie Gault strata at a depth of 333.60m, and are seen to terminal depth at 365.76m (Strahan 1913b, Bullard *et al.* 1940). No macrofauna has been recorded but unpublished B.G.S. records of chitinozoa from 336.19 m are reported to indicate a Llandovery age, though the fauna needs to be reassessed.

2.2.17. **Wyboston** [TL 1759 5723] (Fig. 3 column F'). Steeply dipping, indurated, dark grey silty mudstones, seen beneath Upper Devonian sedimentary rocks at a depth of 224.33m, yielded *Eurytreta* cf. *sabrinae* (Callaway), *Lingulella* cf. *nicholsoni* (Callaway) and a possible asaphoid fragment, and have been assigned a Tremadoc age (Stubblefield 1967, Bulman & Rushton 1973). They were cored for 11.28m to 235.61m.

3. UNDATED BOREHOLE SEQUENCES IN THE CONCEALED ACADIAN FOLD BELT.

The seventeen boreholes listed in section 2.2 represent only about half of the boreholes that are believed to have penetrated Lower Palaeozoic rocks in the concealed fold belt. A group of boreholes to the northeast of the Midlands Microcraton (Fig. 1), namely Bardney No. 1, Stixwould No. 1, Nocton No. 1 and Eakring (Duke's Wood) No. 146, proved quartzites, sandstones and shales of presumed Cambrian age, and Foston No. 1 penetrated phyllitic rocks that have been compared with the Precambrian of Charnwood (Kent 1967). There are no satisfactory biostratigraphical data to substantiate any of these suggested ages, though Eakring 146 yielded fragments of small phosphatic fossils including an *Acrotreta*-like brachiopod of possible Cambrian age (Stubblefield in Edwards 1967, p.9). Grove No. 3 and Welton No. 1, in the same area, are depicted by Pharaoh *et al.* (1987) as entering pelitic rocks of possible Precambrian or Lower Palaeozoic age, but biostratigraphical evidence is again lacking. The same general comment applies to basement sequences proved in boreholes at Thorpe by Water, Wittering, Wiggenhall and South Creake. With the exception of Wiggenhall, each of these boreholes was depicted by Wills (1978) as penetrating Precambrian rocks, but the cleaved sandstones and siltstones proved in Thorpe by Water are reported to be bioturbated and to have yielded a horny brachiopod and a possible graptolite fragment (unpublished B.G.S. records); the graptolite fragment suggests a possible Ordovician or early Silurian age.

A suite of boreholes around the coasts of East Anglia and Kent, namely Saxthorpe, East Ruston, Somerton, Harwich, Isle of Grain, Sheerness, Herne and Reculver, are thought to have penetrated Silurian rocks (Cocks *et al.* 1971, Wills 1978), but this has yet to be confirmed. Ellingham may have reached Lower Palaeozoic rocks beneath Devonian strata (Wills 1978). The Culford Borehole proved unfossiliferous beds which have been regarded as possibly Ordovician (Wills 1978) or Silurian (Cocks *et al.* 1971). However, the inferred presence of Cambrian strata in the Fobbing Borehole [TQ 7151 8422] (Wills 1978) can now be discounted (Stubblefield 1980).

4. COMPARISON OF AGES FROM LOWER PALAEOZOIC SEQUENCES ON THE MIDLANDS MICROCRATON AND IN THE CONCEALED FOLD BELT.

In this and the following section, the palaeontological data reviewed in sections 2.1 and 2.2 are compared in order to ascertain whether there is any support for the position of the microcraton - fold belt boundary as shown in Fig. 1.

One of the most striking aspects of a transect from west to east across the putative edge of the microcraton (Figs 2 and 3) is that many boreholes on the eastern part of the Midlands Microcraton (Fig. 1) have proved only Tremadoc or older rocks beneath an Upper Palaeozoic or Mesozoic cover (Fig. 2 columns H-U). Younger Ordovician rocks are missing from the microcraton, and evidence for Silurian beds is

restricted to the central and southern parts of the microcraton, in the Batsford (section 2.1.2), Cliffe Marshes (2.1.7), Little Missenden (2.1.11) and Ware (2.1.20) boreholes. In contrast, Lower Palaeozoic sequences in the concealed fold belt include rocks of Tremadoc, Llanvirn, Caradoc, Llandovery, Wenlock and Ludlow or Přídolí age. There is a discernible pattern in the distribution of strata in the fold belt, with early and middle Ordovician beds proved in a group of boreholes adjacent to the putative northerly apex and north-eastern margin of the microcraton (Fig. 3 columns A'-F'), and beds of latest Silurian age proved at more distal sites (relative to the microcraton), in boreholes in East Anglia (Fig. 3 columns K'-N'). A third group of boreholes, near the south-eastern margin of the microcraton (Fig. 3 columns H'-J'), has proved rocks of variable Ordovician and Silurian ages and facies.

The general pattern of Lower Palaeozoic biostratigraphical ages across the postulated eastern margin of the microcraton is consistent with the model of Pharaoh *et al.* (1987), since it suggests that rocks of post-Tremadoc age were either not deposited on the eastern part of the microcraton, or were subsequently eroded from it. This in turn suggests a certain amount of uplift along the putative margin of the microcraton, relative to the fold belt to the east. Such uplift may have occurred on the Thringstone Fault, which is believed to represent the edge of the microcraton (Pharaoh *et al.* 1987, Lee *et al.* 1990).

Lower Devonian strata have a more uniform distribution across the south-eastern edge of the microcraton. In addition to their record from the Canvey Island Borehole (section 2.2.3), Lower Devonian rocks are known from boreholes on the southern part of the Midlands Microcraton, namely Beckton Gasworks No. 4 (section 2.1.3), Streatham Common (2.1.17), Apley Barn (2.1.1) and possibly the Faringdon borehole (Falcon & Kent 1969, Mortimer 1967, Mortimer & Chaloner 1972).

5. FACIES VARIATIONS AND DEFINITION OF THE EASTERN EDGE OF THE MIDLANDS MICROCRATON.

Lack of data, resulting from the isolated, scattered glimpses of Lower Palaeozoic strata that boreholes necessarily provide, as well as lack of analysis of available cores, limits the comments that can be made regarding the subsurface distribution of facies. Tremadoc strata on the microcraton have generally similar lithologies and faunas to those in the concealed fold belt (Bulman & Rushton 1973), and consist predominantly of mudstones with mixed shelly and graptolitic faunas, though the latter tend to be more prevalent on the microcraton.

Younger Ordovician rocks are known only from the Bobbing (section 2.2.1), Eyam (2.2.7), Great Paxton (2.2.8) and Huntingdon (2.2.9) boreholes, each of which has proved a fully marine sequence in the concealed fold belt. The succession in Great Paxton is considered to have been deposited in a shelf environment, and similar depositional environments may have obtained for the successions in the other three.

The greatest potential differences across the putative eastern margin of the microcraton occur in the late Llandovery and Wenlock sequences. Late Llandovery strata in the Batsford Borehole (section 2.1.2) are referred by Ziegler *et al.* (1968) to the relatively nearshore *Eocoelia* Community, whereas late Llandovery strata proved in the Chilham Borehole (section 2.2.4) are graptolitic. Although graptolitic and basinal facies are not necessarily synonymous, the pattern of late Llandovery facies distribution eastwards from the microcraton may mirror that seen along its western edge, where shelly facies are coeval with the graptolitic facies of the Welsh Basin. The Cliffe Marshes and Ware boreholes (sections 2.1.7, 2.1.20) provide evidence for the occurrence of Wenlock shelly facies resembling those of the Welsh Borderland. By analogy with its western margin, these localities ought to be on the microcraton.

Differences in Přídolí strata are not so apparent. Fossiliferous, ostracode-bearing strata are known from the Little Missenden Borehole (section 2.1.11) on the microcraton, and from the Clare (2.2.5), Lakenheath (2.2.10) and Soham (2.2.13) boreholes in the concealed fold belt. Contrasts between the two areas are difficult to gauge from published accounts, though the restriction of carbonates to the Little Missenden sequence may be significant. However, the Little Missenden sequence may not be exactly coeval with those in the concealed fold belt (Siveter 1989, fig. 164). Emsian rocks of Old Red Sandstone facies are reported across the putative margin of the microcraton, at Canvey Island (section 2.2.3) in the fold belt and at Apley Barn (2.1.1) and probably also Beckton (2.1.3) on the microcraton. The Devonian sequence in the Streatham Common Borehole (2.1.17) is older (late Přídolí or early Lochkovian) but is also reported to be of "typical Old Red Sandstone facies" (Ball *et al.* 1961, p. 217).

6. BIOSTRATIGRAPHICAL DATING OF DEFORMATION IN THE CONCEALED FOLD BELT.

Evidence from the Clare (section 2.2.5), Lakenheath (2.2.10) and Soham (2.2.13) boreholes indicates that cleavage formation post-dates Přídolí times. Regarding a younger age limit for cleavage development, the lack of any reported cleavage from

the Emsian beds of the Canvey Island Borehole may be significant. The presence of uncleaved strata above cleaved rocks of possible Přídolí age in the Soham and Stutton (2.2.15) boreholes may provide critical evidence if they can be dated successfully. So far, this has not proved possible.

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