

Raphidioptera (Insecta: Neuropterida) from the Lower Cretaceous Purbeck Limestone Group, Dorset, UK

James E. Jepson^{a,*}, Robert A. Coram^b, Edmund A. Jarzembowski^c

^aSchool of Earth, Atmospheric and Environmental Sciences, University of Manchester, Williamson Building, Oxford Road, Manchester M13 9PL, UK

^b6 Battlemead, Swanage, Dorset BH19 1PH, UK

^cMaidstone Museum and Bently Art Gallery, St. Faith's St., Maidstone, Kent ME14 1LH, UK

ARTICLE INFO

Article history:

Received 27 February 2008

Accepted in revised form

22 September 2008

Available online 8 October 2008

Keywords:

Raphidioptera

Mesoraphidiidae

Mesozoic

Britain

Purbeck Limestone Group

New species

ABSTRACT

Four new species of snakefly (Raphidioptera: Mesoraphidiidae): *Mesoraphidia durlstonensis* sp. nov., *Mesoraphidia purbeckensis* sp. nov., *Mesoraphidia websteri* sp. nov. and *Mesoraphidia mitchelli* sp. nov., are described from the Lower Cretaceous Purbeck Limestone Group, southern England. This increases the number of described snakeflies from the Mesozoic deposits of Britain from two to five species, when the doubtful family Priscaenigmatidae is excluded.

© 2008 Elsevier Ltd. All rights reserved.

1. Introduction

The order Raphidioptera has approximately 210 extant species in two families: Raphidiidae and Inocelliidae (Aspöck, 2002; Grimaldi and Engel, 2005; Engel et al., 2006). Raphidioptera is the least diverse order of the holometabolous insects, and is grouped within the superorder Neuropterida along with Neuroptera and Megaloptera (Aspöck, 2002). The distinctive features of the order include an elongated prothorax, a long female ovipositor, and typical venation (Engel, 2002). Four autapomorphies have been suggested for the order, but only one of which can be applied to fossil wings: the forewing subcosta running into the anterior margin (Aspöck and Aspöck, 2004). The habitat preference of extant snakeflies is arboreal, in areas of cool weather with at least some periods of near freezing temperatures. This restricts them to cold temperate regions and excludes them from areas with hotter climates (Grimaldi and Engel, 2005). Mesozoic raphidiopterans, however, have been discovered in much warmer conditions such as inferred tropical climates (Engel, 2002). In Britain today snakeflies are rare, with four species in four genera in the family Raphidiidae; these are restricted to arboreal environments (Plant, 1997).

The Mesozoic raphidiopterans comprise three valid extinct families: Baissopteridae, Mesoraphidiidae and Alloraphidiidae, and one doubtful extinct family, Priscaenigmatidae (see Aspöck and Aspöck, 2004 for discussion). The Mesozoic raphidiopterans are very diverse at species level, supporting the idea that extant Raphidioptera are relict (Engel, 2002; Grimaldi and Engel, 2005).

Snakeflies from the Mesozoic of Britain are rare. Jarzembowski (1984) recorded a specimen from the Weald Clay (Lower Cretaceous, Hauterivian) of Surrey. Whalley (1985, 1988) described two raphidiopterans from the Lower Jurassic of Dorset: *Metaraphidia confusa* (Mesoraphidiidae) and *Priscaenigma obtusa* (Priscaenigmatidae). Priscaenigmatidae, however, has subsequently been excluded from the order (Aspöck and Aspöck, 2004). Clifford et al. (1994) figured a snakefly (*Mesoraphidia* sp.) from the Purbeck Limestone Group of Dorset. This specimen, described herein along with the other Purbeck specimens, brings the total number of described species from the Mesozoic of Britain to five, all in the family Mesoraphidiidae.

2. Geological setting

The Purbeck Limestone Group of southern England is a predominantly lagoonal succession currently considered to be basal Cretaceous (Berriasian) in age, although the precise position of the Jurassic/Cretaceous boundary is still in dispute, and may in fact lie within the Purbeck (Allen and Wimbledon, 1991; Ensom, 2002). The

* Corresponding author.

E-mail address: james.jepson@postgrad.manchester.ac.uk (J.E. Jepson).

Group is divided into a lower Lulworth Formation and upper Durlston Formation; both of these have yielded fossils of Raphidioptera.

The type section of the Purbeck Limestone Group, and the source of all currently recognised Purbeck raphidiopteran material, is Durlston Bay, near Swanage, Dorset (National Grid Reference SZ 035 780). Fossil insects from this site were first studied and named in the mid 19th Century, principally by Prof. J. O. Westwood (1854). It remains highly productive and has provided the holotypes of approximately 200 insect species to date.

3. Systematic palaeontology

The studied material is deposited in the following collections: Booth Museum of Natural History, Brighton (BMB) and Maidstone Museum and Bently Art Gallery, Kent (MNEMG).

The material was studied using an Olympus SZH stereomicroscope with a camera lucida attachment for producing drawings. Some drawings are composite, merging the part and counterpart to establish a more complete venation; this was achieved using a light box. 10% ethanol was used to view vein detail. Photographs were taken using a Nikon D1X digital SLR camera mounted on a rostrum stand.

Wing vein abbreviations are as follows: C, costa; Sc, subcosta; R, radius; Rs, radial sector; Rs1, first branch of Rs; Rs2, second branch of Rs, M, media; MA, media anterior; MP, media posterior; MP1, first branch of MP; MP2, second branch of MP; Cu, cubitus; CuA, cubitus anterior; CuP, cubitus posterior; A, analis; r, radial cell; dc, discal cell; mc, medial cell; ac, anal cell; p, pterostigma.

Order: Raphidioptera Navás, 1918

Family: Mesoraphidiidae Martynov, 1925

Genus *Mesoraphidia* Martynov, 1925

Type species. *Mesoraphidia grandis* Martynov, 1925 from Karatau, Kazakhstan (Upper Jurassic).

Diagnosis. Wings short to long (5–18 mm long) and elongate. Narrow costal area. Costal veinlets not exceeding 10. Sc terminating at costal margin near mid-point of wing. Pterostigma long. R runs parallel to costal margin and curves with it towards apex. Rs separates from R approximately one third of length of wing from base; it is then connected to R by two crossveins forming the three radial cells. Elongated dc. Two or three medial cells posterior to MP in forewing. Anal area similar to other raphidiopterans; elliptical ac.

Included species. In addition to the type species, 21 species from the Jurassic and Cretaceous of Europe, Asia and the USA (Engel, 2002; Engel et al., 2006), and four species described below.

Mesoraphidia durlstonensis sp. nov.

Figs. 1–3

1994 *Mesoraphidia* sp. Clifford et al.: p.143, fig. 1

Derivation of name. The species' name refers to Durlston Bay.

Holotype. Forewing: BMB 018371 and 0183737 [DB175/RAPH 1] (part and counterpart). Clements (1993) Bed DB175, *Corbula* beds, Durlston Formation, Purbeck Limestone Group; Durlston Bay, Swanage, Dorset; Upper Berriasian; collected by R.A. Coram.

Paratype. MNEMG 2007.45 [DB175/RAPH 2] (part and counterpart). Fore- and overlapping hindwing. Horizon and locality as for holotype; collected by R. A. Coram.

Paratype. Hindwing: MNEMG 2007.46 [DB175/RAPH 4] (part and counterpart). Horizon and locality as for holotype; collected by R. A. Coram.

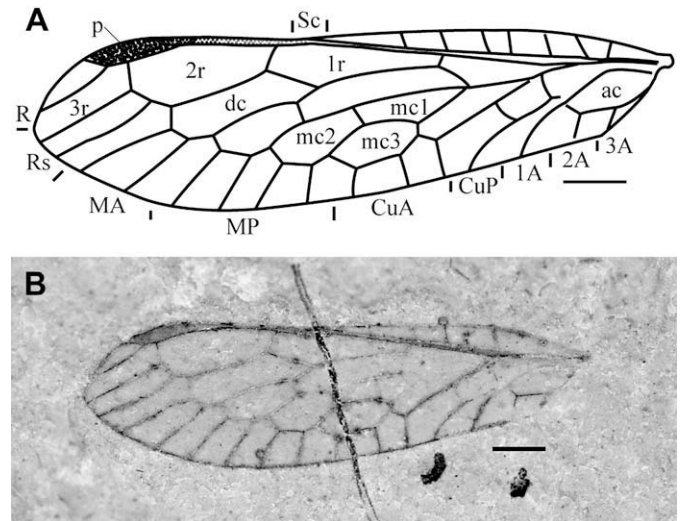


Fig. 1. A, B, *Mesoraphidia durlstonensis* sp. nov., holotype forewing BMB 0183737; Durlston Bay, Upper Berriasian. A, venation drawing. B, photograph. Scale bar represents 1 mm.

Diagnosis. Larger than other Purbeck *Mesoraphidia*. dc narrower than that of *M. purbeckensis* sp. nov. Costal area shorter and narrower than in *M. websteri* sp. nov. CuA has fewer forks than *M. gobiensis* Ponomarenko, 1988. Differs from all other *Mesoraphidia* in the following combination of characters: many costal veinlets; long pterostigma, almost half length of wing; Rs2 exhibiting a kink in vein; three radial cells, 2r wide and 3r long; Rs and MA two branched, both branches simple; lack of a distinct fork for MA; MP two branched, both branches forking once.

Description. Holotype forewing (Fig. 1): narrow and elongate; 10.6 mm long and 2.9 mm wide. C complete; costal area preserved with seven crossveins. Sc terminates approximately 6 mm from wing base (just past mid-point of wing) on anterior wing margin. R complete and long, terminating near wing apex; one crossvein present between R and C, 9.0 mm from wing base. Pterostigma present; over 3 mm long; beginning of pterostigma difficult to determine as pigment fades towards wing base. Three radial cells present: 1r: 2.6 mm long and 0.5 mm wide; 2r: 2.4 mm long and 0.7 mm wide and 3r: 1.7 mm long and 0.4 mm wide. Rs arises from R approximately 3.5 mm from wing base. Rs two branched; Rs1 and Rs2 simple, Rs2 exhibits a kink in vein; both Rs1 and Rs2 arise in distal part of wing near apex. dc formed by a crossvein between Rs and MA, 2.4 mm long and 0.5 mm wide (at widest point). MA arises 1.7 mm from R where M forks into MA and MP; it then runs into Rs 0.6 mm from the split with M. MA coalesced with Rs for 1.9 mm. MA two branched with both branches simple. One crossvein present between MA and MP. MP deeply forked with each branch forked near posterior wing margin. Three cells present between MP and CuA: mc1: 1.8 mm long, 0.4 mm wide; mc2: 1.4 mm long, 0.8 mm wide and mc3: 1.3 mm long, 0.6 mm wide. CuA coalesced with M for 0.6 mm. CuA forks near posterior wing margin; distal branch forked, basal branch simple. Two crossveins present between CuA and CuP; CuP simple. Anal area is preserved with 1A, 2A and 3A present. ac oval shaped, 1.4 mm long, 0.6 mm wide.

Paratype MNEMG 2007.46: hindwing lacking basal portion (Fig. 3). Length as preserved 8.0 mm; estimated total length 10.5 mm. Width 2.7 mm. C incomplete; costal area with three crossveins present but incomplete. Sc terminates approximately 4.4 mm from wing apex (before mid-point of wing) on anterior wing margin. R long, terminating near wing apex; one crossvein present between R and C, 1.0 mm from wing apex. Pterostigma

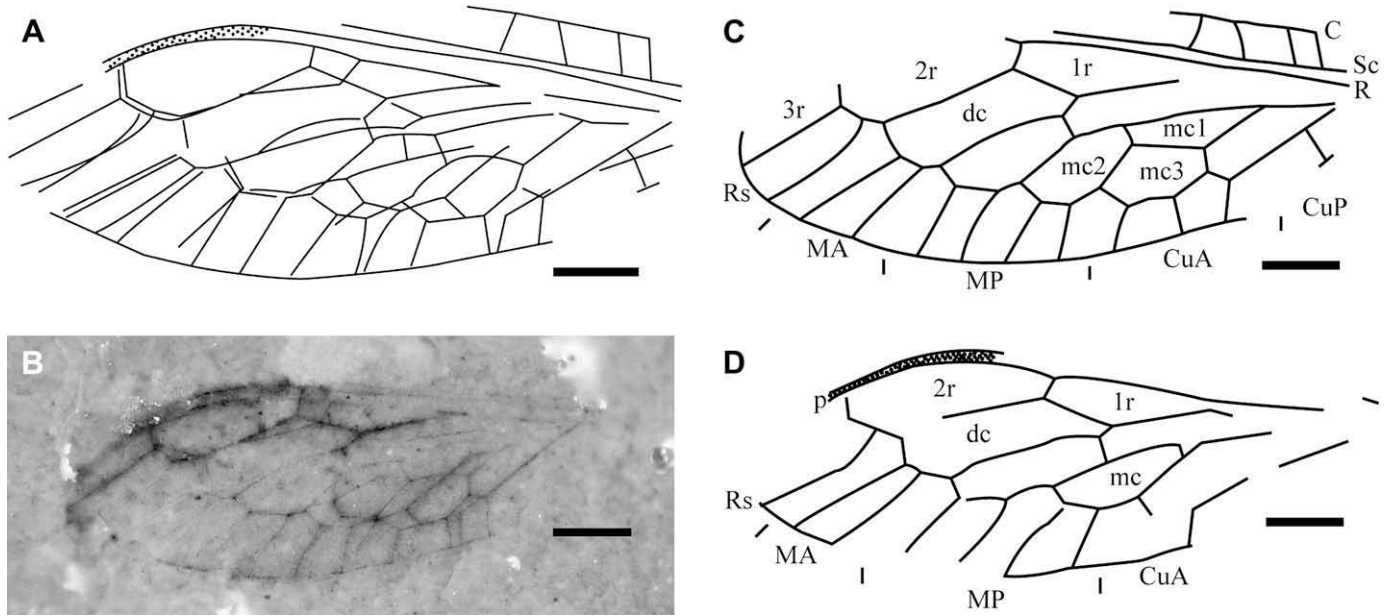


Fig. 2. A, B, C, D, *Mesoraphidia durlstonensis* sp. nov. paratype MNEMG 2007.45; Durlston Bay, Upper Berriasian. A, venation drawing of overlapping fore- and hindwing. B, photograph under 10% ethanol. C, venation drawing of forewing. D, venation drawing of hindwing. Scale bar represents 1 mm.

(or pterostigma and dark membrane) long, from base of wing (as preserved) to r-c crossvein. Three radial cells present: 1r: 2.4 mm long and 0.5 mm wide, cut by crossvein; 2r: 2.3 mm long and 0.6 mm wide and 3r: 1.2 mm long and 0.3 mm wide. Rs arises 5.7 mm from wing apex; Rs two branched; Rs1 and Rs2 simple, Rs2 has a kink in vein; both Rs1 and Rs2 arise in distal part of wing near apex. MA origin not preserved, MA and Rs coalesced for 1.1 mm before separating. dc: 2.7 mm long and 0.6 mm wide (at widest point). MA two branched, both branches simple. Two crossveins present between MA and MP. MP origin 7.5 mm from wing apex; MP deeply forked with MP1 and MP2 branched. One cell present

between MP and CuA; mc: 1.7 mm long, 0.5 mm wide. CuA forks near posterior wing margin. Two crossveins present between MP and CuA. One crossvein present between CuA and CuP; CuP forked. One crossvein present between CuP and 1A. Anal area poorly preserved; 1A present, but incomplete.

Remarks. Three specimens have been assigned to this species comprising two forewings and two hindwings. The paratype MNEMG 2007.45 shows slight differences in wing shape and vein proportions from the holotype. However, it has been assigned to *M. durlstonensis* sp. nov. on the basis of its similar size, overall venation pattern and comparable variation observed within extant species of snakeflies (e.g. species described in Aspöck et al., 1983; Rausch and Aspöck, 1993; pers. obs. JEJ). The overlapping fore- and hindwing of MNEMG 2007.45 indicates that the paratype MNEMG 2007.46 is of the same species due to similarities in venation and size. This is the only species from the Purbeck that has a pigmented pterostigma, but this may simply be fortuitous preservation. *M. durlstonensis* sp. nov. is the largest species of snakefly from the Purbeck, being almost twice the size of the other Purbeck raphidiopterans described herein.

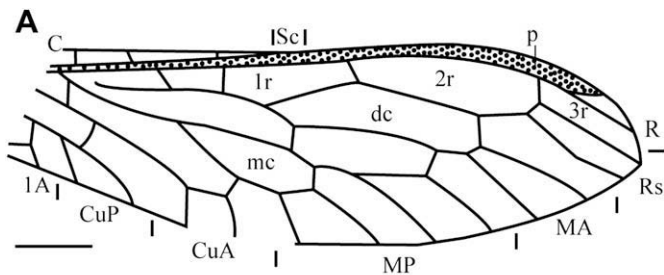


Fig. 3. A, B, *Mesoraphidia durlstonensis* sp. nov., paratype hindwing MNEMG 2007.46; Durlston Bay, Upper Berriasian. A, composite venation drawing from part and counterpart. B, photograph. Scale bar represents 1 mm.

Mesoraphidia purbeckensis sp. nov.

Fig. 4

Derivation of name. After the Isle of Purbeck, Dorset.

Holotype. Forewing: MNEMG 2007.47 [DB175/RAPH 6]. Clements' Bed DB175, *Corbula* beds, Durlston Formation, Purbeck Limestone Group; Durlston Bay, Swanage, Dorset; Upper Berriasian; collected by R. A. Coram.

Diagnosis. Forewing small compared to most species of *Mesoraphidia*. Few costal veinlets. Differs from *M. durlstonensis* sp. nov. in possessing narrower mc3, CuA forking more proximally, and most distal r-c crossvein being closer to termination of R. dc wider than in *M. durlstonensis* sp. nov., *M. websteri* sp. nov. and *M. mitchelli* sp. nov. 1A, 2A and 3A long compared to other Purbeck *Mesoraphidia*. Differences from other *Mesoraphidia* species as for *M. durlstonensis* sp. nov.

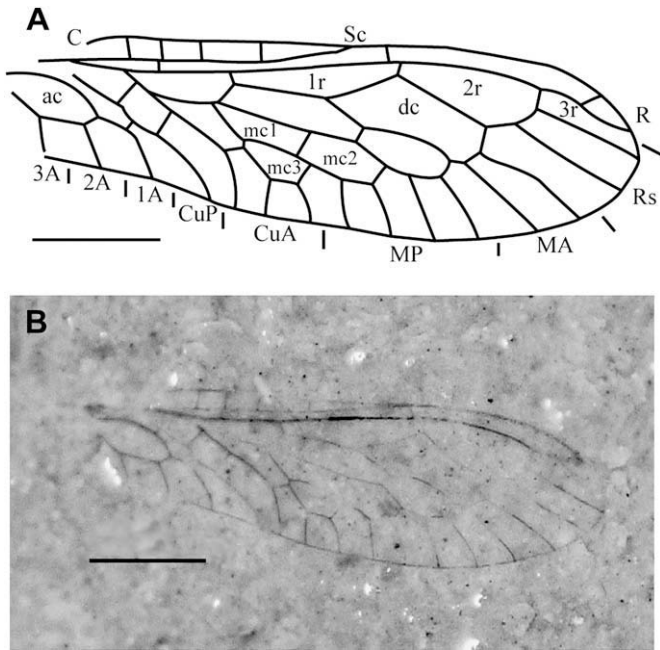


Fig. 4. A, B, *Mesoraphidia purbeckensis* sp. nov., holotype forewing MNEMG 2007.47; Durlston Bay, Upper Berriasian. A, composite venation drawing from part and counterpart. B, under 10% ethanol. Scale bar represents 1 mm.

Description. Forewing: 4.9 mm preserved length, 5.1 mm estimated total length. Width 1.4 mm. C incomplete; costal area with four crossveins present but incomplete. Sc terminates approximately 2.3 mm from wing apex (just past mid-point of wing) on the anterior wing margin. R complete and long, terminating near wing apex; one crossvein present between R and Sc, 3.8 mm from wing apex; two crossveins present between R and C, 0.4 mm and 1.9 mm from wing apex. Pterostigma not preserved. Three radial cells present: 1r: 1.2 mm long, 0.3 mm wide; 2r: 1.0 mm long, 0.4 mm wide and 3r: 0.7 mm long, 0.2 mm wide. Rs arises approximately 3.1 mm from wing apex. Rs two branched; Rs1 and Rs2 simple; both Rs1 and Rs2 arise in distal part of wing near apex. dc: 1.2 mm long and 0.4 mm wide (at widest point). MA arises 0.7 mm from origin of M + CuA. MA coalesced with Rs for 0.7 mm. MA two branched with both branches simple. MP coalesced with CuA for short distance (~0.2 mm). MP and CuA arise 3.9 mm from wing apex. MP deeply forked with both branches forked. Three cells present between MP and CuA: mc1: 0.7 mm long, 0.2 mm wide; mc2: 0.6 mm long, 0.3 mm wide and mc3: 0.3 mm long, 0.2 mm wide. CuA forks near posterior wing margin; first branch forks again, second branch is simple. Two crossveins present between CuA and CuP; CuP simple. One crossvein present between CuP and 1A. 1A, 2A, 3A preserved, all simple; only part of ac present, 0.3 mm wide.

Remarks. *M. purbeckensis* sp. nov. has the smallest wing length of the Purbeck *Mesoraphidia* and the second smallest wing length within *Mesoraphidia*. It is more typical of the size of Purbeck snakeflies, with the exception of *M. durlstonensis* sp. nov. The pterostigma is not present; this is most likely an artefact of preservation where the pigmentation has not been preserved.

Mesoraphidia websteri sp. nov.

Fig. 5

Derivation of name. After Mr Andrew Webster, collector of Purbeck insects.

Holotype. Hindwing: MNEMG 2007.48 [DB175/RAPH 8]. Clements' Bed DB175, *Corbula* beds, Durlston Formation, Purbeck

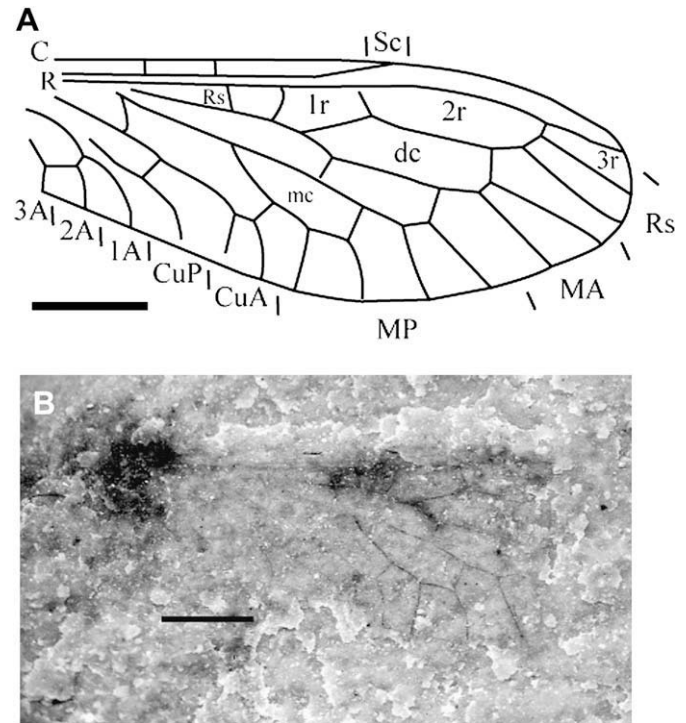


Fig. 5. A, B, *Mesoraphidia websteri* sp. nov., holotype hindwing MNEMG 2007.48; Durlston Bay, Upper Berriasian. A, composite venation drawing from part and counterpart. B, photograph. Scale bar represents 1 mm.

Limestone Group; Durlston Bay, Swanage, Dorset; Upper Berriasian; collected by R. A. Coram.

Diagnosis. Wing shorter than *M. durlstonensis* sp. nov. but longer than *M. purbeckensis* sp. nov. and *M. mitchelli* sp. nov. Costal area longer than other Purbeck *Mesoraphidia*. R terminates further before apex than *M. durlstonensis* sp. nov. Differences from other *Mesoraphidia* species as for *M. durlstonensis* sp. nov.

Description. Hindwing: incomplete, 5.2 mm preserved length, 5.7 mm estimated total length. Width 2.1 mm. C incomplete; costal area poorly preserved and incomplete with two crossveins present. Sc terminates 2.1 mm from wing apex at two-thirds of wing length. R long, terminating 0.4 mm from wing apex. Pterostigma not preserved. Three radial cells present: 1r: 1.1 mm long and 0.4 mm wide; 2r: 1.6 mm long and 0.4 mm wide and 3r: 0.6 mm long and 0.3 mm wide. Rs and MA arise at different points, Rs 3.4 mm from wing apex, MA 4.3 mm from wing apex. Rs and MA coalesced for 0.6 mm before forking. Rs two branched; Rs1 and Rs2 simple; both Rs1 and Rs2 arise in distal part of wing near apex. dc 1.6 mm long and 0.5 mm wide (at widest point). MA two branched, both branches simple. MP origin not preserved; MP deeply forked with MP1 and MP2 two branched. One cell present between MP and CuA: mc: 1.3 mm long, 0.4 mm wide. CuA forks near the posterior wing margin. Two crossveins present between MP and CuA. One crossvein present between CuA and CuP; CuP simple. Anal area poorly preserved; 1A, 2A and 3A present but incomplete.

Remarks. *M. websteri* sp. nov. has been tentatively assigned to a new species as its small size and venation exclude it from *M. durlstonensis* sp. nov. and its larger size excludes it from *M. purbeckensis* sp. nov. The apparent lack of a pterostigma, as with *M. purbeckensis* sp. nov., is probably an artefact of preservation.

Mesoraphidia mitchelli sp. nov.

Fig. 6

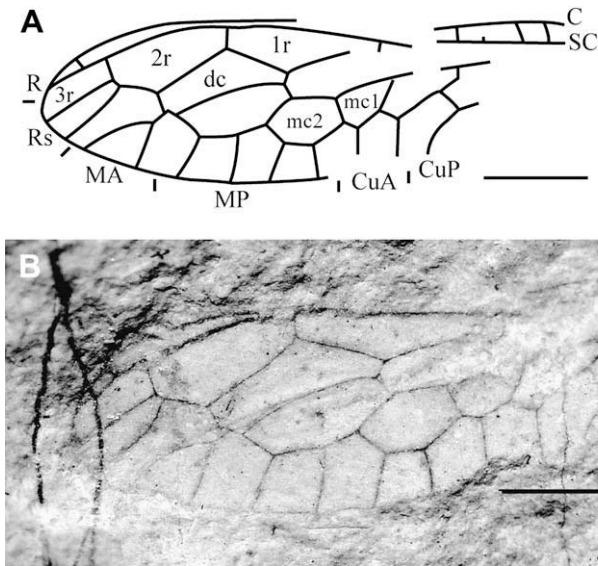


Fig. 6. A, B, *Mesoraphidia mitchelli* sp. nov., holotype MNEMG 2007.49; Durlston Bay, Lower Berriasian. A, venation drawing. B, photograph under 10% ethanol. Scale bar represents 1 mm.

Derivation of name. After Mr A. A. Mitchell, collector of the holotype.

Holotype. MNEMG 2007.49 [USCDB/TM 924]. Soft Cockle beds (probably Clements' Bed DB66), Lulworth Formation, Purbeck Limestone Group; Durlston Bay, Swanage, Dorset, UK; Lower Berriasian; collected by A. A. Mitchell.

Diagnosis. Differs from all other species of *Mesoraphidia* in the possession of two medial cells: mc1 and mc2; and in the fusion of MP2 and CuA for a short distance near the posterior wing margin. A distinct fork of MA also distinguishes it from all congeners with the exception of *M. gaoi* Ren et al., 1995 and *M. parvula* Martynov, 1925.

Description. 5.0 mm preserved length, 5.4 mm estimated total length. Width 1.5 mm. C incomplete; costal area with four crossveins present but incomplete. Sc termination not seen. R incompletely preserved, long, terminating near wing apex; one crossvein present between R and C, 0.4 mm from wing apex. Pterostigma not preserved. Three radial cells present: 1r: 1.4 mm long and 0.4 mm wide; 2r: 1.1 mm long and 0.5 mm wide and 3r: 0.7 mm long and 0.3 mm wide. Rs arises approximately 3.2 mm from wing apex. Rs two branched; Rs1 and Rs2 simple; both Rs1 and Rs2 arise in distal part of wing near apex. dc 1.2 mm long and 0.4 mm wide (at widest point). MA origin not preserved. MA coalesced with Rs for 0.8 mm. MA with distinct fork closer to wing margin than fork of RS; both branches simple. MP deeply forked with both branches forked near posterior wing margin. Two cells present between MP and CuA: mc1: 0.4 mm long, 0.2 mm wide and mc2: 0.7 mm long, 0.4 mm wide. CuA forked, fused for a short distance with MP2. Part of CuP preserved. Anal area not preserved.

Remarks. *M. mitchelli* sp. nov. differs significantly from all the other Purbeck *Mesoraphidia*. The two cells of mc is the most significant difference; this could be due to either one less cell in the forewing or one extra in the hindwing. However, it is difficult to ascertain whether *M. mitchelli* sp. nov. is a fore- or hindwing because the base of MA has not been preserved nor CuP and the anal veins. The distinct fork of MA is also different from the other Purbeck *Mesoraphidia*. The apparent lack of a pterostigma is most probably an artefact of preservation, because pigment is rarely preserved in this bed. *M. mitchelli* sp. nov. is the oldest snakefly from the Purbeck.

4. Discussion

Prior to this research, there have been only five fossil snakefly specimens recorded in Britain from two families: Mesoraphidiidae and Priscaenigmatidae (Jarzembowski, 1984; Whalley, 1985, 1988; Clifford et al., 1994). The position of Priscaenigmatidae in Raphidioptera, however, has been questioned (see Aspöck and Aspöck, 2004 for discussion); therefore, if it is removed from the order, fossil snakeflies in Britain would only be represented by the family Mesoraphidiidae.

The most notable features shared by the Purbeck fauna are a more 'simplified' venation: veins Rs and MA are two branched with both branches forking close to the posterior wing margin and MP with a deep fork with both branches forking once near the posterior wing margin. *M. purbeckensis* sp. nov., *M. websteri* sp. nov. and *M. mitchelli* sp. nov. are very small, with estimated wing sizes ranging from 5.1–5.7 mm; they are a little larger than the smallest known snakefly, *Nanoraphidia*, from the Lower Cretaceous of Burma with a wing length of 4.5 mm (Engel, 2002). This small size separates them from the majority of other *Mesoraphidia* species (exceptions being *M. parvula* (5.5 mm) and *M. gaoi* (5 mm) (Martynov, 1925; Ren et al., 1995)) which are almost double or more the size of these snakeflies. *M. durlstonensis* sp. nov., however, is of a more average size for the genus. There are significant differences between the snakefly found in the older Upper Soft Cockle beds and the snakeflies from the younger *Corbula* beds. These differences are the distinct fork of MA and the two medial cells and the posterior fusion of CuA and MP.

The Purbeck climate is interpreted as having been seasonally semi-arid (Allen, 1998), providing further evidence that Mesozoic raphidiopterans were less climatically restricted than they are today. There is evidence that the climate became rather more humid midway through Purbeck times: for example, evaporites become much less frequent and there is a sustained increase in the clay mineral kaolinite (Deconinck, 1987), indicative of more intense weathering of the massifs supplying sediment to the depositional basin. The preserved material suggests that there may have been a raphidiopteran faunal change associated with this climate change, but more specimens are required to confirm this.

Extant raphidiopterans are predators of small arthropods both as larvae and adults and live exclusively on trees, the larvae very often developing under bark (Grimaldi and Engel, 2005). Purbeck raphidiopteran fossils are found alongside those of other tree-associated taxa (such as cupedoid beetles) and occasional remains of conifer foliage, all suggestive of a forested hinterland and a raphidiopteran habitat similar to that of today.

Acknowledgements

We wish to thank John Nudds, Karl Bates, Peter Falkingham (The University of Manchester) for useful discussions, and Dmitri Logunov and Philip Rispin (The Manchester Museum) for access to extant specimens of Raphidioptera. Also, thanks to two anonymous reviewers for their comments and suggestions.

References

- Allen, P., Wimbledon, W.A., 1991. Correlation of NW European Purbeck-Wealden (nonmarine Lower Cretaceous) as seen from the English type-areas. *Cretaceous Research* 12, 511–526.
- Allen, P., 1998. Purbeck-Wealden (early Cretaceous) climates. *Proceedings of the Geologists' Association* 109, 197–236.
- Aspöck, U., 2002. The phylogeny of the Neuropterida (Insecta: Holometabola). *Zoologica Scripta* 31, 51–55.
- Aspöck, U., Aspöck, H., 2004. Two significant new snakeflies from Baltic amber, with discussion on autapomorphies of the order and its included taxa (Raphidioptera). *Systematic Entomology* 29, 11–19.

- Aspöck, H., Aspöck, U., Rausch, H., 1983. *Mauroraphidia maghrebina* n. gen. n. sp. – eine neue Raphidiiden-Spezies aus dem Atlas (Neuropteroidea: Raphidioptera). *Zeitschrift der Arbeitsgemeinschaft Österreichischer Entomologen* 35, 27–32 (In German).
- Clements, R.G., 1993. Type-section of the Purbeck Limestone Group, Durlston Bay, Swanage, Dorset. *Proceedings of the Dorset Natural History and Archaeological Society* 114 (for 1992), 181–206.
- Clifford, E., Coram, R., Jarzembowski, E.A., Ross, A.J., 1994. A supplement to the insect fauna from the Purbeck Group of Dorset. *Proceedings of the Dorset Natural History and Archaeological Society* 115 (for 1993), 143–146.
- Deconinck, J.F., 1987. Minéraux argileux des faciès Purbeckiens: Jura suisse et français, Dorset (Angleterre) et Boulonnais (France). *Annales Société Géologique du Nord* 106, 285–297.
- Engel, M.S., 2002. The smallest snakefly (Raphidioptera: Mesoraphidiidae): a new species in Cretaceous amber from Myanmar, with a catalog of fossil snakeflies. *American Museum Novitates* 3363, 1–22.
- Engel, M.S., Lim, J.-D., Baek, K.-S., 2006. Fossil snakeflies from the Early Cretaceous of southern Korea (Raphidioptera: Mesoraphidiidae). *Neues Jahrbuch für Geologie und Paläontologie* 2006, 246–256.
- Ensom, P.C., 2002. The Purbeck Limestone Group of Dorset, southern England: a guide to lithostratigraphic terms. *Special Papers in Palaeontology* 68, 7–12.
- Grimaldi, D.A., Engel, M.S., 2005. *Evolution of the Insects*. Cambridge University Press, New York, p. 755.
- Jarzembowski, E.A., 1984. Early Cretaceous insects from southern England. *Modern Geology* 9, 71–93.
- Martynov, A.V., 1925. To the knowledge of fossil insects from Jurassic beds in Turkestan. 1. Raphidioptera. 6 seryia. *Izvestiya Rossiiskoi akademii Nauk* 19, 235–246.
- Plant, C.W., 1997. A key to the adults of British lacewings and their allies (Neuroptera, Megaloptera, Raphidioptera and Mecoptera). *Field Studies* 9, 179–269.
- Rausch, H., Aspöck, H., 1993. *Phaeostigma holzingeri* n. sp. – eine neue Kamelhalsfliege aus Ipiros (Griechenland) (Neuropteroidea: Raphidioptera: Raphidiidae). *Zeitschrift der Arbeitsgemeinschaft Österreichischer Entomologen* 45, 19–26 (In German, with English summary).
- Ren, D., Lu, L., Guo, Z., Ji, S., 1995. Fauna and Stratigraphy of the Jurassic–Cretaceous in Beijing and Adjacent Areas. Seismic Publishing House, Beijing (In Chinese, with English summary).
- Westwood, J.O., 1854. Contribution to fossil entomology. *Quarterly Journal of the Geological Society of London* 10, 378–396, pls 14–18.
- Whalley, P.E.S., 1985. The systematics and palaeogeography of the Lower Jurassic insects of Dorset, England. *Bulletin of the British Museum (Natural History) Geology* 39, 107–189.
- Whalley, P.E.S., 1988. Mesozoic Neuroptera and Raphidioptera (Insecta) in Britain. *Bulletin of the British Museum (Natural History) Geology* 44, 45–63.