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## An interesting new genus of Berothinae (Neuroptera: Berothidae) from the early Eocene Green River Formation, Colorado

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### Abstract

*Xenoberothen angustialata* **gen. et sp. nov.** (Neuroptera: Berothidae) is described from the early Eocene of the Parachute Creek Member of the Green River Formation (U.S.A., Colorado). It is assigned to Berothinae as an oldest known member of the subfamily based on the presence of scale-like setae on the foreleg coxae. Distal crossveins of the fourth (outer) gradate series which are located very close to the wing margin in *Xenoberothen* **gen. nov.** is a character state previously unknown in Berothinae.

**Key words:** Berothidae, Berothinae, Green River Formation, Eocene

### Introduction

The Berothidae is a small family comprising slightly more than 120 extant species, when Rhachiberothinae is included (Oswald 2015). They occur mainly in warm-temperate to tropical regions (Aspöck & Randolph 2014: Fig. 55). Fossil berothids are numerous (55 named species in 35 genera, including *Mesithone* Panfilov, 1980 according to Jepson 2015), known from the Middle Jurassic to the late Eocene (see list of Makarkin *et al.* 2011 with additions by Jepson *et al.* 2012; Azar & Nel 2013; Khramov 2015; Makarkin 2015; Makarkin & Ohl 2015, Yuan *et al.* 2016 and exclusions from the family in Wedmann *et al.* 2013; Makarkin 2016).

Only five species of Berothidae have been described from the Cenozoic, all from Eocene ambers: the early Eocene *Microberothen maccolloughi* Archibald & Makarkin, 2004 from Hat Creek amber, British Columbia, Canada, and *Oisea celinea* Nel *et al.*, 2005 from Oise amber, France; and the late Eocene *Whalferia wiszniowskii* Makarkin & Kupryjanowicz, 2010 and *Elektroberothen groehni* Makarkin & Ohl, 2015 from Baltic amber, and *Whalferia venatrix* (Whalley, 1983) from English amber.

Here, an interesting new genus and species of Berothidae is described from the early Eocene Green River Formation in Colorado, U.S.A., the first record of the family from Cenozoic sedimentary (lacustrine) deposits.

### Material and methods

The specimen examined here was found in the upper-most layers of the Parachute Creek Member of the Green River Formation (D. Kohls, pers. comm.). This formation is considered to span from 53.5 to 48.5 Ma based on <sup>40</sup>Ar/<sup>39</sup>Ar dating (Smith *et al.* 2003, 2008). The Parachute Creek Member accumulated during ca. 2.8 million years of the Ypresian, from 51.3 to 48.5 Ma, and therefore this specimen is about 48.5 million years old, i.e., late Ypresian according to the scale of Cohen *et al.* (2013).

The photographs were taken by David Zelagin using a Canon 5D Mark II camera and a Canon 65 MP-E macro lens. Helicon Focus v 5.3 was used to stack the images. The line drawing was prepared by the author using Adobe Photoshop CS3.

Venational terminology in general follows Kukalová-Peck & Lawrence (2004) as interpreted by Yang *et al.* (2012, 2014). Terminology of details of venation (e.g., spaces, veinlets, traces) follows Oswald (1993). Crossveins

are designated after the longitudinal veins with which they connect and are numbered in sequence from the wing base, e.g., 2r-m, a crossvein connecting R/RP and M/MA in the second series; 4im, a crossvein between MA and MP in the fourth series.

Abbreviations: AA1–AA3, first to third anterior anal vein; CuA, anterior cubitus; CuP, posterior cubitus; MA and MP, anterior and posterior branches of media; RA, anterior radius; RP, posterior sector; RP1, proximal-most branch of RP; RP2, branch of RP distad RP1; ScP, subcosta posterior.

Institutional abbreviations: UCM, Museum of Natural History of the University of Colorado, Boulder, U.S.A.

## Systematic paleontology

### Order Neuroptera Linnaeus, 1758

### Family Berothidae Handlirsch, 1906

### Subfamily Berothinae Handlirsch, 1906

### Genus *Xenoberotha* gen. nov.

#### Type and only species. *Xenoberotha angustialata* sp. nov.

**Diagnosis.** May be easily distinguished from other genera of the family by a combination of the following character states: [1] scale-like, short, densely spaced setae on procoxae; [2] forewing very narrow (length/width ratio 4.1); [3] forewing CuA pectinate; [4] outer gradate series of crossveins close, nearly parallel to hind margin.

**Remarks.** This combination of character states does not occur in any other genus of the family. Condition [4] is characteristic of only this genus in the subfamily.

**Etymology.** From the Greek *xenos* [ξένος], strange, unusual, and *Berotha*, a genus-group name. Gender feminine.

### *Xenoberotha angustialata* sp. nov.

Figs 1, 2

**Holotype.** UCM 80385a,b (part, counterpart), collected on 11 August 2009 by David Kohls, and deposited in UCM. An incomplete female specimen with the left forewing relatively well preserved, and the right hind wing fragmentarily preserved.

**Type locality and horizon.** UCM locality 2009063 ('Claudia's Place'), situated between East Fork and Middle Fork of Parachute Creek; Garfield County, Colorado, U.S.A. Parachute Creek Member of the Green River Formation; early Eocene (late Ypresian).

**Etymology.** From the Latin *angustus*, narrow, and *alatus*, winged, referring to the narrow forewings of the species.

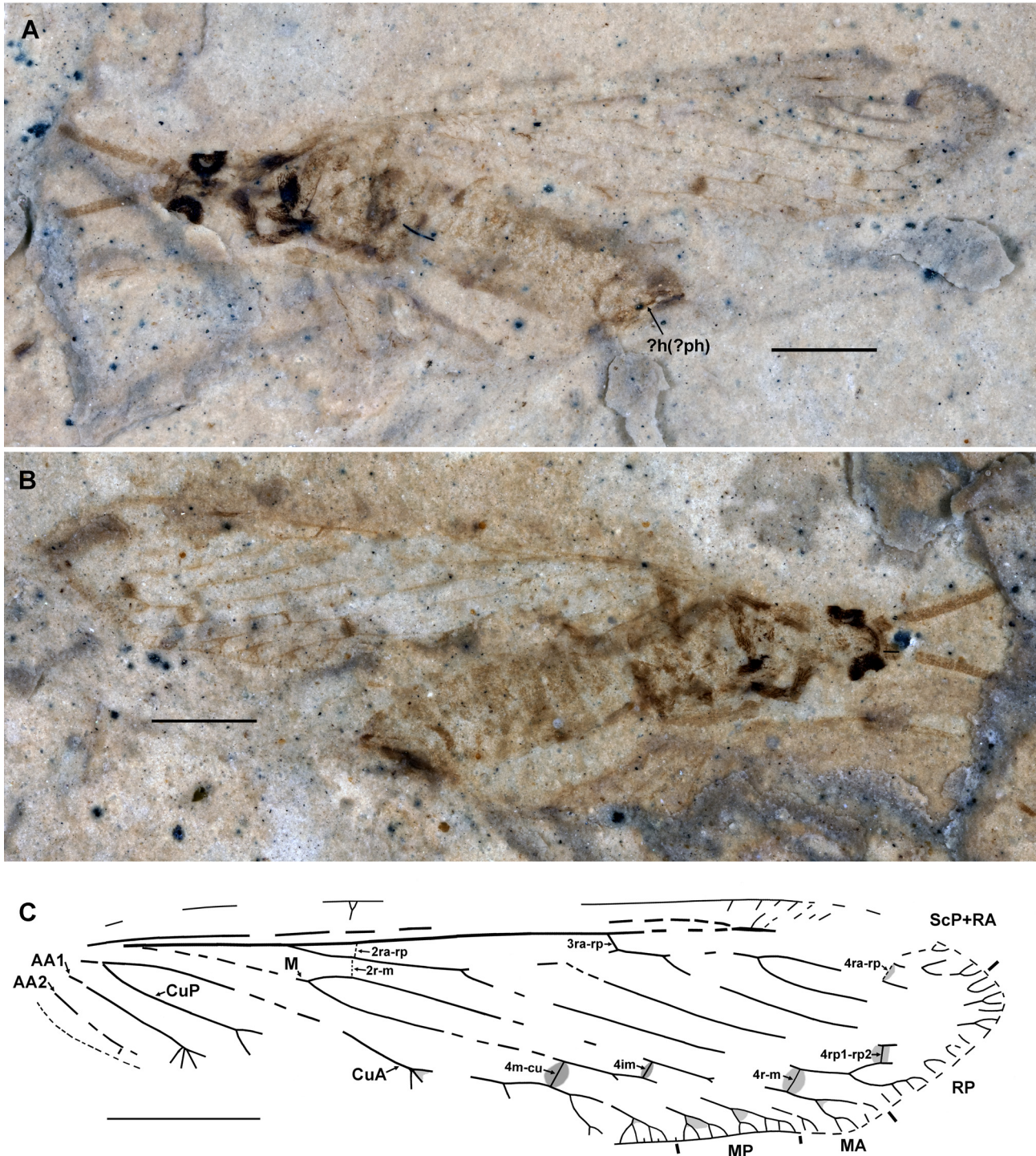
**Description.** Female. Head poorly preserved except for well-preserved eyes. Antennae filiform, rather stout; scapus very short, transverse (length shorter than diameter); pedicellus not visible (or does not differ from basal flagellomeres); proximal flagellomeres transverse, covered with fine short setae.

Thorax very poorly preserved; details not visible. Abdomen apically with poorly preserved, long antero-ventrally directed processes (probably hypocaudae of gonocoxite 9 or pseudohypocaudae of tergite 9).

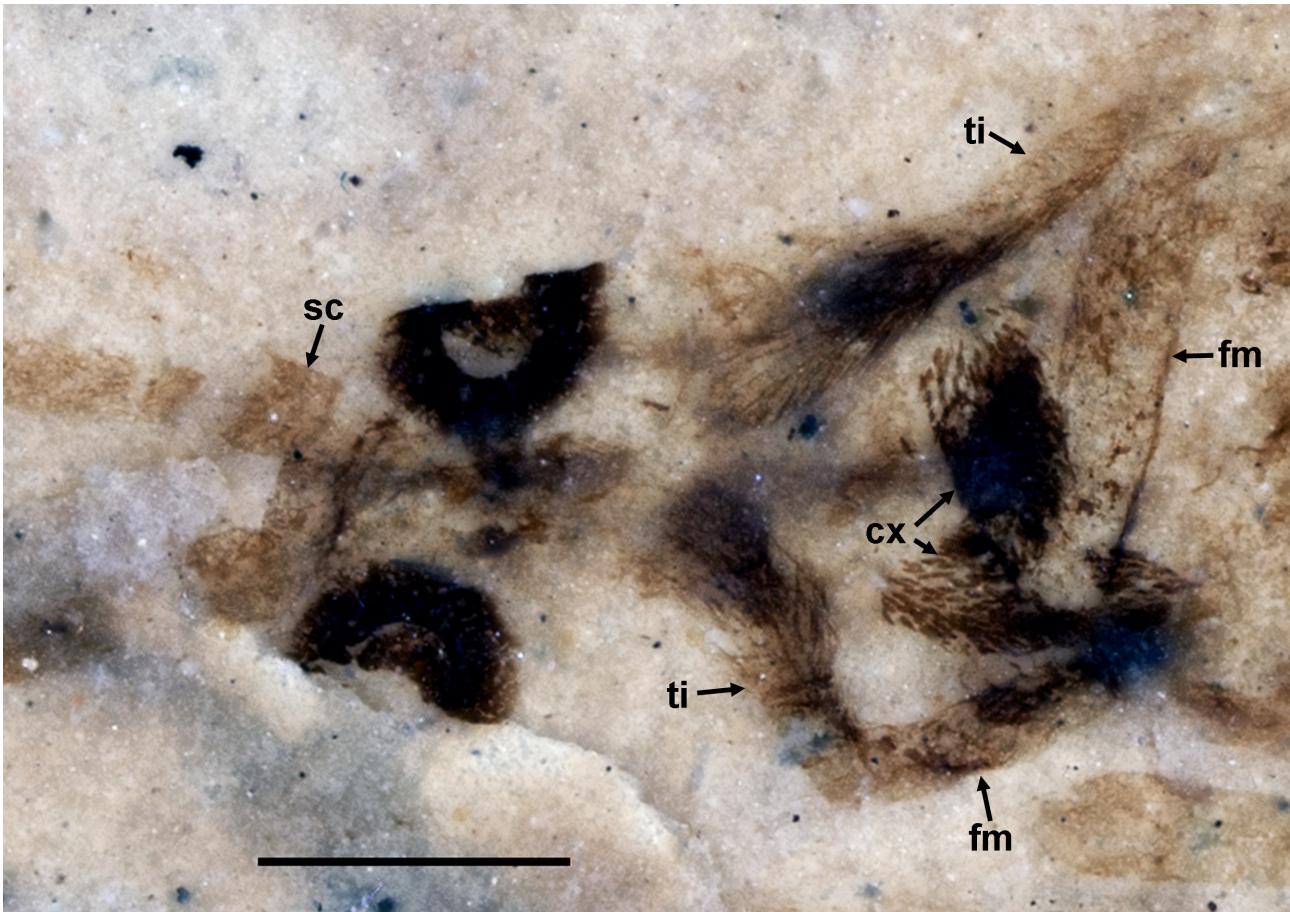
Foreleg: coxae relatively short, stout, densely covered with short, dilated setae resembling scales (Fig. 2); femora moderately stout, with few preserved, rather short setae; tibiae nearly as long as femur, densely covered with fine long setae, mainly in distal part. Mid-, hind legs poorly preserved.

Forewing very narrow, with hind margin distally excised; ca. 6.35 mm long, 1.55 mm wide. Costal space narrow; subcostal veinlets not preserved except one, once forked. ScP, RA probably distally fused; ScP+RA long, entering margin slightly proximad wing apex; some distal veinlets of ScP+RA with terminal fork. Three crossveins detected in RA space: 2ra-rp poorly preserved, located far proximad origin of RP1; 3ra-rp stout, dark, located between origins of RP2, RP3; 4ra-rp poorly preserved, located far distad presumable fusion of ScP, RA. RP

originated far from wing base, with four branches. RP1 originating far distad origin RP; forked at outer gradate series, both branches shallowly forked; RP2 to RP4 distally with only shallow branching. 2r-m poorly preserved, connecting RP, MA rather far for fork of M. M appears not fused basally with R; forked slightly distad origin of RP; intramedial space rather broad basally. MA, MP similarly branched distally: both relatively deeply forked at gradate series, then all four branches shallowly forked one to four times. Cu dividing into CuA, CuP near wing base. Anterior trace of CuA distally shallowly forked, pectinate with four rather long branches, one short shallowly forked branch; two proximal-most branches originate from one point. CuP deeply forked, somewhat proximad fork



**FIGURE 1.** *Xenoberotha angustialata* gen. et sp. nov., holotype UCM 80385. A, the specimen as preserved (part). B, same (counterpart); both wetted with ethanol. C, the venation of the left forewing (converted to standard view, with apex to the right). Grey shadings show the color pattern. h, hypocausta; ph, pseudohypocausta. Scale bars = 1 mm.



**FIGURE 2.** *Xenoberotha angustialata* **gen. et sp. nov.**, holotype UCM 80385. Head and forelegs, ventral view (wetted with ethanol). cx, coxa; fm, femur; sc, scapus; ti, tibia. Scale bar = 0.5 mm.

of M; distal part not preserved. AA1 with three proximal-most branches originating from one point; distal part not preserved. AA2 probably pectinate, but poorly preserved (only one branch preserved). AA3 not detected. Outer (fourth) gradate series of crossveins nearly parallel to hind margin; four crossveins detected connecting RP2 to CuA. Trichosors fragmentarily preserved along hind margin. Color pattern: five crossveins of gradate series broadly margined with brown (i.e., 4ra-rp, 4rp1-rp2, 4r-m, 4im, 4m-cu); some distal forks of CuA, MA and MP inside pale brown.

Basal portion of right hind wing fragmentarily, poorly preserved, venation hard to interpret.

## Discussion

Superficially, the new genus is most similar to the Australian berothine genus *Stenobiella* Tillyard, 1916, and the African rhachiberothine genus *Hoelzeliella* Aspöck & Aspöck, 1997. All species of these genera have similarly narrow wings (see Kimmins 1930; Aspöck & Aspöck 1984: Figs 27, 46–54; Aspöck & Aspöck 1997: Fig. 36; Winterton 2010: Fig. 2). However, *Xenoberotha* **gen. nov.** possesses a short scapus and pectinate CuA, whereas in *Stenobiella* the scapus is long and CuA is few branched. In *Hoelzeliella*, the forelegs are raptorial and RA and ScP are distally widely separated, whereas in *Xenoberotha* **gen. nov.** the forelegs are not raptorial and RA and ScP are distally fused (or closely approach).

It is possible to determine the subfamily affinity of the new genus despite the few characters available in the specimen. Its most remarkable feature is the presence of densely spaced scale-like setae on the procoxae. In the Neuroptera, such modified dilated setae resembling scales of Lepidoptera are found only in the berothid subfamily Berothinae. These may occur on the thorax of both sexes, and on the coxae (very rarely on other leg segments), abdomen (very rarely) and veins of both fore- and hind wings of females (Aspöck & Aspöck 1996; Aspöck &

Nemeschkal 1998). The coxal scales are known in some species of three extant genera: on the procoxae in *Podallea* Navás, 1936 (Africa, Madagascar and Arabian Peninsula) and *Lekrugeria* Navás, 1929 (Africa and southern Asia), and on the mid- and metacoxae in *Stenobiella* (Aspöck & Aspöck 1981, 1984, 1986, 1996). However, these scales are relatively long and do not cover the entire surface of the procoxa, at least in *Podallea* (see Tjeder 1959: Fig. 301). In *Xenoberotha* **gen. nov.**, all of the visible surface of the procoxae is covered by small scales.

Thus, the berothine affinity of *Xenoberotha* **gen. nov.** may be regarded as confident based on the presence of these scales. The pectinate CuA is also characteristic of most genera of the Berothinae. In this case, the long, antero-ventrally directed processes seen at the apex of the abdomen are most probably the hypocaustae of gonocoxite 9.

Hitherto, only one fossil species of this subfamily was known, i.e., *Elektroberotha groehni* from late Eocene Baltic amber (Makarkin & Ohl 2015). Therefore, *Xenoberotha angustialata* **sp. nov.** is the oldest known member of the Berothinae.

The only character state of *Xenoberotha* **gen. nov.** previously unknown in Berothinae is the position of distal crossveins of the fourth (outer) gradate series, which is very close to the wing margin. In other berothines these crossveins are located far from the margin, even in the narrow-winged *Stenobiella*. By this character state, *Xenoberotha* **gen. nov.** is most similar to some species of Mesozoic genera of various systematic positions, e.g., *Rhachbermissa phenax* Engel & Engel, 2008 (Paraberothinae) and *Jersiberotha myanmarensis* Engel & Grimaldi 2008 (Berothidae *incertae sedis*) from latest Albian Burmese amber.

In general, *Xenoberotha* **gen. nov.** possesses many plesiomorphic conditions at the family and subfamily levels, e.g., the scapus is short; 2r-m connects RP and MA; CuP is deeply forked; and two crossveins are present proximad the fusion of ScP and RA in the forewing (see details in Makarkin & Ohl 2015), consistent with its relative antiquity.

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