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Source: American Museum Novitates, 2014(3812) : 1-36

Published By: American Museum of Natural History

URL: https://doi.org/10.1206/3812.1

AMERICAN MUSEUM NOVITATES

Number 3812, 36 pp. August 29, 2014

Morphology of the males of seven species of Ortheziidae (Hemiptera: Coccoidea)

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ABSTRACT

Because adult male Coccoidea rarely live more than three or four days, they are seldom collected and their morphology has been little studied. Therefore, the systematics of the Coccoidea is dependent on the morphology of the paedomorphic adult female. A good example is the family Ortheziidae, in which the males of only four extant and three fossil taxa are known among more than 200 species. The present work provides descriptions of the male morphology of seven further species: *Graminorthezia graminis* (Tinsley), *Insignorthezia insignis* (Browne), *Newsteadia americana* Morrison, *Orthezia annae* Cockerell, *O. newcomeri* Morrison, and *Praelongorthezia praelonga* (Douglas), as well as another belonging to an undetermined genus. The males of three additional genera are added to the previous literature on male Ortheziidae, providing significantly better sampling of male morphological variation within this family. Variation among genera confirms the latest classification of Kozár, in which *Graminorthezia, Insignorthezia,* and *Praelongorthezia* are separated from *Orthezia*. The use of confocal microscopy for the study of uncleared slide preparations is discussed as it allowed better visibility of macrostructures, although minute structures such as pores could not be thoroughly observed. An identification key to the species of known male Ortheziidae is included.

INTRODUCTION

The Ortheziidae or ensign scale insects are a relatively small family within the scale insects (Hemiptera: Coccoidea) with 206 species (Miller et al., 2013) that are found pri-

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 ISSN 0003-0082

marily in leaf litter, although some species occur on the upper parts of their host plants and are then often destructive pests in greenhouses. The family has an almost worldwide distribution but is, perhaps, most abundant in the Neotropical region. Kozár (2004) revised the Ortheziidae, and introduced several new genera and tribes. Like all families within the Coccoidea, ortheziid species are diagnosed on the basis of female morphology (Morrison, 1925; Morrison, 1952; Kozár and Konczné Benedicty, 2000; Kozár and Miller, 2000; Konczné Benedicty and Kozár, 2001; Miller and Kozár, 2002; Kozár, 2004; Vea and Grimaldi, 2012) and Kozár's new classification was also based on the adult female. In general, only the adult females (and sometimes late-instar nymphs) are currently identifiable because the original descriptions were based solely on the former, along with their associated nymphs. However, our understanding of the morphology of adult male scale insects is gradually improving, with the recognition that phylogenetic analyses based on male morphology have given us a much improved understanding of scale insect phylogeny (Hodgson and Hardy, 2013) compared with the structure of the larviform adult females. Additionally, specimens of fossil adult males of many scale insect families are now known and are commonly preserved in amber around the world (almost always without their adult female counterpart). These have provided an excellent fossil record of the Coccoidea for the past 130 million years, but accurate interpretation of these fossils requires a much better understanding of the morphology of Recent ones. By reason of the rarity of adult males and the difficulty in associating them with their respective females, the adult males of only two named species of Recent Ortheziidae (*Orthezia urticae* (Linneaus) and *Newsteadia floccosa* (De Geer)) have been described in detail (Koteja, 1986), although two further unidentified species assigned to the genus *Orthezia* have also been described (Koteja, 1986; Hodgson and Foldi, 2006). In addition, three fossil taxa, each assigned to a monotypic genus, have been described based solely on macropterous males: two preserved in Eocene Baltic amber, namely *Palaeonewsteadia huaniae* Koteja (Koteja, 1987a) and *Protorthezia aurea* Koteja (Koteja, 1987b), and one in Early Cretaceous Lebanese amber, *Cretorthezia hammanaica* Koteja and Azar (Koteja and Azar, 2008). Thus, male morphological variation in the Ortheziidae is hardly known.

This study describes the adult male morphology of seven ortheziid species in five genera based on the classification of Kozár (2004): *Graminorthezia graminis* (Tinsley), *Insignorthezia insignis* (Browne), *Newsteadia americana* Morrison, *Praelongorthezia praelonga* (Douglas), *Orthezia annae* Cockerell, *O. ?graminicola* Morrison (described as an undetermined genus here), and *O. newcomeri* Morrison. Their morphology is then compared with previous descriptions of both extant and fossil male Ortheziidae. Finally, the potential of confocal laser scanning microscopy (CLSM) is discussed as a tool for observing slide-mounted specimens that have been incompletely cleared. CLSM was found to be a promising nondestructive alternative to slide remounting, for the study of cuticular details of these poorly prepared specimens. This method resulted in a 3-D reconstruction of the surface of the specimen without the need to remount, thus preventing damage to the specimen.

Materials and Methods

This study used already slide-mounted material from the Natural History Museum, London (BNHM), and the Coccoidea collection of the United States National Museum of Natural History, housed at the U.S. Department of Agriculture, Beltsville, Maryland (USNM).

Species identification of these specimens was assumed to be accurate as each was collected with adult females in the same series (i.e., from the same host plant), except for *O. ?graminicola,* which was associated with a female with different collection data. Details for each of these specimens are provided under each species account below, where the number of studied specimens is indicated as (for instance) 1/2 ad male, where "1" refers to the number of slides and "2" the total number of adult males. These mounted specimens were in two states, either: (1) completely cleared preparations, where all structures were easily observable using standard compound light microscopy (these were usually more recent preparations); or (2) older preparations, where the clearing step was skipped or incompletely done, so that many cuticular structures were obscured by internal organs, preventing optimal examination of the specimens under transmitted light. The latter were observed using a Zeiss LSM 710 Confocal Laser Scanning Microscope (CLSM) (Objective: EC Plan-Neofluar 10X/0.30 M27, Laser HeNe633 at 5%), at the American Museum of Natural History (AMNH). The stain used for these specimens is unknown, although the pink-colored cuticle is probably acid fuschin, as commonly used in scale insect slide-mounting preparations.

Drawings were made using a Wild M20 compound microscope using a drawing tube or from images obtained with the CLSM. Each drawing represents the entire body, excluding the complete wings; the dorsal surface is on the left side and the ventral surface is on the right side, following the convention for scale insect descriptions. Details of structures are variously enlarged around the body. Terminology follows Hodgson and Foldi (2006), except for wing venation, where Koteja's terminology was used (see Koteja, 2008). Abbreviations in the descriptions were as follows (after Hodgson and Foldi, 2006): *fs* for fleshy setae (thick and blunt setae lacking a sclerotized socket), *hs* for hair setae (hairlike setae, with a flagellate apex and a shallow setal socket), *lp* for loculate pores (large pores with an arrangement of 3 to 6 inner loculi), *smp* for simple minute pores (simple ring pores, each 1–3 μm across, found throughout the body), and *mcp* for minute convex pores (each pore 3 or 4 μm wide, restricted to the head).

Identification Key to the Recent Species of the Ortheziidae Based on Adult Males

1. Hamulohalteres absent; setae on legs long and hairlike.....2
– Hamulohalteres present; setae on legs short and spinose along ventral margin.....3
2. Trochanter and femur not fused; with 3 alar setae on forewing ....*Newsteadia americana* Morrison
– Trochanter and femur fused; with 1 alar seta on forewing.....*Newsteadia floccosa* (De Geer)
3. Compound eyes each with obviously more than 100 ommatidia; fleshy setae on body pointed apically 4
– Compound eyes each with obviously less than 100 ommatidia; body fleshy setae thick and round.....*Graminorthezia graminis* (Tinsley)

4. Median ridge on sternite IX present.....5
– Median ridge on sternite IX absent.....8
5. Antennae almost twice body length; with long fleshy setae, each twice length of other abdominal setae, present on dorsal abdominal segments..*Insignorthezia insignis* (Browne)
– Antennae not longer than 1.5 X body length; fleshy setae on abdominal segments about same length as hairlike setae.....6
6. Loculate pores absent on dorsal part of epicranium; tubular duct plate on tergite VII divided into lateral groups of ducts; loculate pores on abdominal segments, each usually with 3 loculi only occasionally with 4 loculi.....*Praelongorthezia praelonga* (Douglas)
– Loculate pores present on dorsal part of epicranium; tubular duct plate on tergite VII not divided into lateral groups of ducts, each plate complete; loculate pores each with at least 4 loculi 7
7. Body length less than 2 mm; loculate pores on abdominal sternites absent ....*Orthezia* sp. (in Koteja, 1986)
– Body length more than 2 mm, multilocular pores on abdominal sternites present ....*Orthezia* sp. (in Hodgson and Foldi, 2006)
8. Each tubular duct plate on tergite VII with fewer than 10 tubular ducts; capitate setae present on antennal segments .... ?*Orthezia graminicola* Morrison (but see comments in description)
– Significantly more than 10 tubular ducts on tergite VII; capitate setae absent on antennal segments.....9
9. With less than 50 tubular ducts on tergite VII; body less than 2 mm long; setae on appendages with a mixture of short and significantly longer setae..... .....*Orthezia annae* (Cockerell)
– With significantly more than 50 tubular ducts on tergite VII; body more than 2 mm long; longer setae on appendages absent.....10
10. Dorso-midcranial ridge reaching postoccipital suture; tubular ducts on anterior margin of tergite VII surrounded by two types of peripherical setae, one type almost twice as long as others and broadening at midlength; with dermal structures throughout the body except for appendages; hamulohalteres with 3 hamuli.....*Orthezia newcomeri* Morrison
– Dorso-midcranial ridge not reaching postoccipital suture; tubular ducts on anterior margin of tergite surrounded by only one type of seta; dermal structures throughout the body absent; hamulohalteres with 2 hamuli.....*Orthezia urticae* (L.)

DESCRIPTIONS OF ADULT MALES

Hemiptera Linnaeus, 1758

Sternorrhyncha Amyot and Audinet-Serville, 1843

Coccoidea Fallén, 1814

Ortheziidae Amyot and Audinet-Serville, 1843

Ortheziidae Amyot and Audinet-Serville, 1843: 619. Type genus: *Orthezia* Bosc d'Antic, 1784.

Family Description, based on adult male morphology: *Mounted material*: Body slender, legs long and frail, antennae usually longer than body, antennae nine-segmented with curved

fleshy setae and an apical bristle; head with two well-developed compound eyes; head and thorax separated by a distinct constricted neck; prothorax with median prosternal ridge (except *Newsteadia*); basisternum with a median ridge; forewings with polygonal wing discs (see Koteja, 1986); subcostal ridge + cubital ridge + anterior flexing patch present (except *Newsteadia* for anterior flexing patch); hamulohalteres present (except for *Newsteadia*); tarsus one-segmented; abdominal spiracles present; tergite VII with a group of tubular ducts; tergite VIII with a group of differentiated pores, each with one central loculus (except *Newsteadia*); penial sheath triangular, blunt.

Head: More or less round (sometimes wider than long). Dorsally, midcranial ridge well developed; dorsomedial part of epicranium sclerotized, without reticulations, becoming more sclerotized posteriorly, ending in a transverse postoccipital ridge. Laterally, genae absent, ocular sclerite without setae or pores, with two well-developed compound eyes, number of ommatidia variable across genera, ocelli present laterally, preocular ridge short, postocular ridge usually short ventrally and longer dorsally, sometimes extending to scape (*Praelongorthezia*). Ventrally, midcranial ridge well developed, extending from near posterior margin of ventromedial part of epicranium dorsally almost to posterior margin of dorsomedial surface of epicranium; ventromedial surface of epicranium sclerotized but not reticulated, with ventral head setae, *lp* and *mcp*. Posterior margin of epicranium invaginated to form a shallow, transverse apophysis; ventral plate present posterior to epicranium; mouth opening medially, usually without setae on ventral plate and around mouth. **Antenna:** Nine-segmented, long and filiform; all segments narrow. Scape each with short setae. Pedicel each with few *fs* and *hs* + a campaniform sensillum dorsally, somewhat removed from distal margin. Segments III–IX all long and filiform, becoming narrower toward apex, with numerous curved *fs* of usually one type (except in Genus undetermined). Segment IX elongate; almost always without capitate setae but with *fs* + 1 strong terminal bristle, and sometimes short antennal bristles laterally near apex. Head separated from thorax by a neck constriction.

Thorax: *Prothorax:* mostly membranous; cervical sclerites complex, anteriorly articulating with postocular ridge. Ventrally, sternum with a strongly sclerotized median ridge; transverse ridge and prosternal apophyses absent. Antemesospiracular setae fused with posterior propleural setae. *Mesothorax:* dorsally, mesoprephragma broad but shallow; prescutum oval and quite large; sclerotized but without nodulations; prescutal ridge almost absent, represented by a small sclerotization anterolaterally to prescutum; margin of prescutum posteriorly delineated by a short pair of convergent, unsclerotized, prescutal sutures that do not meet medially; prescutum without prescutal setae or pores. Scutum sclerotized throughout, without nodulations; scutal setae present. Scutellum subpentagonal, rounded anteriorly, bounded anteriorly by scutoscutellar sutures; without setae but sometimes with *lp*; posterior margin of scutellum represented by a ridge (posterior notal wing process), extending laterally along posterior margin of scutum to postalare. Mesopostnotum broad but short, with a rather small membranous area anteriorly; much of mesopostnotum deeply embedded beneath metathorax as a mesopostphragma. Laterally, prealare quite long and narrow, terminating near mesepisternum; tegula sclerotized, with tegular setae. Mesepisternum nodulated near lateropleurite; subepisternal ridge long and well developed. Mesopleural apophyses well developed, each generally with a small area of reticulation. Postalare without reticulations or setae. Postmesospiracular setae absent. Ventrally, basisternum well developed, with strong median and precoxal ridges; with *hs* basisternal setae distributed more or less throughout; furca large, narrow waisted, arms rather broad and very divergent, extending almost

to marginal ridge anteriorly. *Metathorax:* dorsally, metapostnotum narrow but distinct across segment medially; metatergal setae and pores present. Dorsospiracular setae: *hs* and *lp* present. Laterally, dorsal part of metapleural ridge well developed, articulating with base of hamulohaltere. Metepisternum unsclerotized and without postmetaspiracular setae or pores; precoxal ridge weak, extending anteriormedially from posterior end of each metapleural ridge toward posterior spiracle. Antemetaspiracular setae and pores absent. Metepimeron with a sclerotized ridge running posteriorly; without setae. Ventrally, metasternum large and sclerotized, broader anteriorly than posteriorly, with a large subrectangular pit centrally, with strongly sclerotized lateral margins; pit opening into well-developed metafurca. **Wings:** Forewing hyaline, without microtrichia but with polygonal discs on surface (Koteja, 1986); subcostal ridge usually extending along anterior margin to about ¾ wing length, cubital ridge originating at one-fifth from wing base; when other veins present, anterior flexing patch and radial sector apparent (Koteja, 1986), although radial sector difficult to see on mounted material; alar fold present but very narrow when hamulohaltere present. Hamulohalteres long and narrow when present (absent in *Newsteadia*), with apical hamuli on anterior margin at distal end of sclerotized ridge. **Legs:** Mesothoracic shortest, others subequal in length. Long setae on coxa and trochanter not differentiated. Fleshy setae (*fs*) not differentiated from *hs*. Each trochanter with campaniform sensillae, more or less in a straight line; separation of trochanter and femur distinct (except *Newsteadia floccosa*), almost at right angles to leg margin, probably without an articulation. Tibia with setae, becoming spurlike on distal half to two-thirds, particularly on ventral side. Tarsus one-segmented, with spurlike setae; tarsal spurs not differentiated; tarsal campaniform sensilla present and convex; tarsal digitules very short and spinose, usually not differentiated. Claws fairly long and narrow, much longer than width of tarsus; claw digitules spinose or setose, shorter than claw; a small claw denticle almost always present.

Abdomen: *Segments I–VII:* tergites lightly sclerotized; sternites also lightly sclerotized but with distinct, sclerotized, intersegmental ridges. Presence of loculate pores and their distribution varies across genera. Tubular ducts present in a band across tergite VII (or on two separate plates in *Praelongorthezia*), inner surface of each duct with shallow spiral ridges. Abdominal spiracles present on anterodorsal part of pleurites I–VIII at least but more or less easily detectable. *Segment VIII:* tergite unsclerotized; sternite lightly sclerotized but with a strongly sclerotized crescentic ridge along anterior and lateral margins, fusing with sclerotization of penial sheath posteriorly; tergite with *hs* dorsal abdominal setae, plus locular pores (absent in *Newsteadia*), structurally different from *lp* on other abdominal segments (slightly smaller with an external ring divided in many small compartments, and without an inner large loculus; see Discussion) and many *smp*; pleural *hs* present.; sternite with ventral abdominal setae but no pores; sometimes with a median ridge. **Genital segment:** Segment IX represented by area immediately around anus on dorsal surface, represented by a sclerotized area in anal region; *hs* present on tergite IX; anus large with a lightly sclerotized area along anterior margin; sternite IX represented by a large sclerotized sternal plate (except for *Newsteadia*), presence of a median ridge and/or setae variable across genera. Penial sheath broad, triangular, and blunt; ventrally and laterally with a group of short, apically rounded setae on each side of anterior end of penial sheath; posteriorly, minute setae absent on either surface near apex. Aedeagus parallel sided anteriorly but becoming pointed

posteriorly in dorsal view (apex broader in *Newsteadia*), extending to near apex of penial sheath. Penial sheath with a small group of sensilla near apex.

Comments: The wing venation for this family description includes the presence of only subcostal ridge, cubital ridges, and anterior flexing patch (the latter absent in *Newsteadia*). Koteja (1986) described the wings of *Orthezia urticae* and identified an anterior flexing patch (= "medial sector" in Koteja, 1986) and a radial sector (see current terminology in Koteja, 2008). Wing venation in Coccoidea, especially for the flexing patches and radial sector are challenging to observe on slide-mounted specimen, principally due to clearing with KOH (Koteja, 2008) and are best observed on fresh or dry unmounted material (Simon, 2013). The radial sector could not be identified on studied mounted material, but may be present.

Graminorthezia Kozár

Graminorthezia Kozár, 2004: 272. Type species*: Orthezia graminis* Tinsley, 1898.

Comments: Because *Graminorthezia* currently comprises 11 described species (Miller et al., 2013) based on female morphology, the description of the adult male of *G. graminis* acts for now as the generic diagnosis. The genus is classified in the tribe Ortheziini (Kozár, 2004), along with *Insignorthezia*, *Orthezia,* and *Praelongorthezia*, and was defined based on adult female morphology and distinguished from these other genera by "bands or rows of wax plates within the ovisac band," "head of dorsum without sclerotized cephalic plates," and "no more than 7 abdominal spiracles" (Kozár, 2004: 271). The genus is distributed mainly in the Nearctic, with some species in the Neotropical regions.

Graminorthezia graminis (Tinsley)

Figures 1, 2, 3A

Orthezia graminis Tinsley, 1898: 13–14.

Material Examined: USA, New Mexico, Dona Ana, on "grass," 26. ix. 1897, Townsend coll. (USNM): 1/2 ad male (in good condition but uncleared; description of specimens also based on confocal microscope images (fig. 1) and thus some pores and setae not observable and mentioned as such).

Description (as for family description unless otherwise stated): *Mounted material:* Body length 1.9 mm. Antenna nearly 1.17× body length (as opposed to 1.3 to 2.0 in other genera), most segments approximately subequal in length, with numerous *fs* randomly distributed. Body *hs* when visible, broad with a blunt apex; *lp*, *smp,* and *mcp* usually not visible but described when otherwise.

Head: Broad, wider than long (280 μm wide, 225 μm long). Dorsally, midcranial ridge with dorsal arm narrow and fading posteriorly, setae and pores not visible. Laterally, compound eyes about 100 μm long, each with about 60 ommatidia. Ocellus 25–30 μm wide. Ventrally, ventral setae and pores not visible. Ventral plate rectangular. Antenna. Total length 2.28 mm (ratio of

body length to antennal length 1:1.17). Scape almost square shaped: 78–92 μm long, 73–82 μm wide, each probably with 4 or 5 short setae. Pedicel: length 73–82 μm, width 52–60 μm; each with at least 3 or 4 *fs*. Segments III–IX: with proximal segments about 40–50 μm wide, apical segment 22–25 μm wide; *fs* short, those on segment III 25–30 μm long, those on apical segment about 20 μm long; lengths of segments (μm): III 250–265; IV 300–340; V 282–350; VI 317–339; VII 281–323 and VIII 258–267; approximate number of setae per segment: III–VIII with about 30–45 *fs*. Segment IX elongate: length 270–275 μm; with about 30 *fs* + 1 strong terminal bristle, about 22 μm long + 2 short antennal bristles laterally near apex; coeloconic sensilla not detected.

Thorax: *Prothorax*: dorsally, pronotal setae: 2 *hs* anterior propleural setae anteriorly on shoulder; no other setae observed. Ventrally, cervical sclerites complex, anteriorly articulating with postocular ridge; prosternal setae not detected but probably present. Anteprosternal setae probably absent. *Mesothorax:* dorsally, prescutum 90 μm long, 135 μm wide; sclerotized but without nodulations; mesoprephragma not observable but probably shallow; prescutal ridge almost absent, represented by a small sclerotization anterolaterally to prescutum; margin of prescutum posteriorly delineated by a short pair of convergent, unsclerotized; prescutal setae or pores not detected; distance between prescutum and scutellum medially 80 μm; scutal setae with 4 or 5 *hs* medially posterior to prescutum; *hs* near lateral margins not observed. Scutellum rounded anteriorly, 169 μm wide, 125 μm long; without setae but with 2 or 3 *lp*. Laterally, prealare quite long and narrow, terminating near mesepisternum; tegula with 3 tegular setae. Mesothoracic spiracle with peritreme almost round, width 40 μm. Ventrally, basisternum 400 μm wide, 182 μm long, 8–10 *hs* basisternal setae furca not observable. Postmesospiracular setae not detected. *Metathorax:* dorsally, metatergal setae and pores not observed. Dorsospiracular setae: at least 2 *hs* + 3 *lp* present. Ventrally, metasternal setae and pores not observable. Metathoracic spiracle with peritreme almost round, width 35 μm. **Wings:** Forewing 1940–2040 μm long, about 705–765 μm wide (ratio of length to width 1:0.37; ratio of body length to wing length 1:1); hamulohalteres, each about 212–247 μm long, 35–40 μm wide, with 2 apical hamuli placed on anterior margin at distal end of sclerotized ridge; each hamulus about 50 μm long. **Legs:** Coxae: I 138–144; II 129–147; III 142–147 μm long; coxa III with at least 3 setae. Trochanter + femur: I 400–518; II 408–450; III 490 μm long; trochanter III with 3 or 4 setae; each trochanter with 3 campaniform sensilla, more or less in a straight line on each surface; femur III with about 45 setae. Tibiae: I 695; II 560–630; III 670–675 μm; tibia III with about 70 setae; spurs on ventral surface of distal end each 14–27 μm long. Tarsi: I 225; II 230–240; III 225–235 μm long (ratio of lengths of tibia III to tarsus III 1:0.34); tarsus III with about 35 setae, mainly spurlike; tarsal digitules very short and spinose. Claws much longer than width of tarsus (each tarsus about 25 μm wide), claw III 50 μm long; each with a minute denticle; claw digitules spinose, shorter than claw.

Abdomen: *Segments I–VII:* Loculate pores detectable only on dorsopleurites, loculate pores on tergites and sternites not observable. Tubular ducts present in a band across tergite VII, each duct 6–10 μm wide, 15 μm deep. Dorsal abdominal setae and pores (totals): segments I–V 4 *hs*; VI 4 *hs*; VII about 20 *hs* and between 24 and 35 tubular ducts, in a band with about 3 rows of ducts. Pleural setae: dorso- and ventropleural setae combined on each side: I–VII 3 or 4 *hs* + at least 5 *lp*. Ventral abdominal setae and pores not observable.

Abdominal spiracles present on anterodorsal part of pleurites II–VI and possibly present on pleurite VII; each peritreme about 13 μm wide. *Segment VIII:* tergite with 1 pair *hs* dorsal abdominal setae plus about 60 small locular pores and many *smp*; sternite with setae detected but number uncertain; pores not detected, with 2 or 3 *hs* pleural setae. Abdominal spiracles not detected but probably present. **Genital segment:** With 2 or 3 *hs* dorsally; anus 40 μm wide, with a lightly sclerotized area along anterior margin; ventrally, segment IX with a median ridge; with at least 3 or 4 setae on each side. Penial sheath broad, width similar to posterior margin of abdominal segment VIII, length without segment IX 260 μm, with segment IX 365 μm; greatest width 170 μm; ventrally and laterally with a group of about 15 short, apically rounded setae on each side of anterior end of penial sheath. Aedeagus parallel sided anteriorly but becoming pointed posteriorly in dorsal view, extending to near apex of penial sheath; length about 225 μm.

Comments: Most of the structures were observable on these two uncleared specimens apart from some pores and setae on the thorax and the abdominal sternites. Some setae could be identified by their basal sockets, which are visible with confocal images. However, loculate pores (*lp*) were mostly not identifiable, and so mentioned as "not observable/detected" in the description; minute simple pores could not be detected with confocal images. Despite these missing details, it is clear that *Graminorthezia* is distinguishable from *Orthezia* based on male morphology. The distinctive characters are the general shape of the setae covering the body and appendages, which were distinctly blunt apically (fig. 2A); the shorter appendages than on the other species studied, and the larger and fewer ommatidia (i.e., about 60) in each compound eye.

Insignorthezia Kozár

Insignorthezia Kozár, 2004: 295. Type species: *Orthezia insignis* Browne, 1887.

Comments: Because *Insignorthezia* comprises 10 described species (Kozár, 2004), the description of the adult male of *I. insignis* acts for now as the generic diagnosis. Adult female *Insignorthezia* are distinguished from *Graminorthezia*, *Praelongorthezia* and *Orthezia* by the "absence of bands or rows of wax plates within the ovisac band" (Kozár, 2004: 271).

Insignorthezia insignis (Browne)

Figures 3B, 4

Orthezia insignis Browne, 1887: 169–172.

Material Examined: CEYLON (SRI LANKA), Paredeniya, xi. 1940, E.E. Green coll., 1/5 ad male, deposited at BNHM.

Description (as for family description unless otherwise stated): *Mounted material:* Moderately large, total body length 1.66–1.76 mm. Antennae exceptionally long, nearly 2 times total body length, most segments approximately subequal in length (vs. <1.3 times body length for all other species). Body with few setae; *lp* of triangular shape, each 7–8 μm wide, with mostly

3 loculi, occasionally 4, present on both dorsal surface.

Head: Width 285 μm and length 300 μm. Dorsally, with (on each side) about 5 *hs* of rather variable length (20–50 μm), all flagellate, plus 2 *lp* and 1 or 2 *mcp*. Laterally, compound eye about 155 μm long, with about 160 ommatidia. Ocellus 30–40 μm wide. Ventrally, ventral arm extending to midlength of head, fusing with preoral ridge and bifurcated posteriorly; ventral head setae: with (on each side) 8–12 *hs* plus 1–4 *lp* + 3 or 4 *mcp*. **Antenna:** Length 3.23 mm (ratio of total body length to antennal length 1:1.9). Scape: 94–117 μm long, 63–80 μm wide, each with 6 or 7 short *hs* + 2 or 3 minute pores ventrally and 4 *hs* dorsally. Pedicel: 65–85 μm long, 49–57 μm wide; each with 3 *fs*, 5 or 6 *hs*, 3 minute pores ventrally. Segments III–IX with proximal segments about 36–43 μm wide, while apical segment only 15–24 μm wide: *fs* short, those on segment III 28–38 μm long, those on apical segment 25–30 μm long; lengths of segments (μm): III 369–405; IV 433–479; V 423–509; VI 381–520; VII 400–494 and VIII 400–600; approximate number of setae per segment: III–VIII; about 45–70 *fs* +10–15 *hs*; no bristlelike setae detected. Segment IX elongate: 346–412 μm long; with about 80 *fs* + 1 strong terminal bristle, about 35 μm long + 1 antennal bristle laterally near apex.

Thorax: *Prothorax:* dorsally, pronotum not observable. Posttergites each a small, lightly sclerotized, oval area situated mediolaterally. Pronotal setae: median pronotal setae: 1 *hs* plus 2 or 3 *lp* + 2 or 3 *smp*; propleural setae not detected; also with a group of posterior propleural setae and pores just anterior to each prealare, extending ventrally and joining antemesospiracular setae: 1 *hs*, 5–6 *lp* + 3–5 *smp*. Ventrally, Prosternum with 1 *hs* prosternal setae + 1 *lp* on each side. *Mesothorax:* Dorsally, prescutum, 97 μm long, 134 μm wide; ridges as for family. Distance between prescutum and scutellum medially 97–117 μm; with about 2 *hs* scutal setae: + 15 minute pores medially posterior to prescutum. Scutellum anterior margin rounded and posterior margin straight, 170–181 μm wide, 109–112 μm long, with 2 *lp* + 3 *smp* but no setae. Laterally, tegula with 2 or 3 setae. Mesothoracic spiracle: peritreme almost round, width about 30 μm. Ventrally, basisternum 390 μm wide, 180 μm long; with about 10 *hs* basisternal setae. *Metathorax:* Dorsally, metapostnotum with 2 metatergal setae. Dorsospiracular setae: 1 *hs* plus 2 *lp*. Laterally, metathoracic spiracle peritreme almost round, width 35 μm. Ventrally, sclerotized area with 3–5 *hs* + 1 *lp* + some *smp* on each side; occasionally with 1 *hs* anterior metasternal seta and 0 or 1 *hs* posterior metasternal setae. **Wings:** Forewing length and width unknown because wings damaged, hamulohalteres with 2 hamuli. **Legs:** Coxae: I: 126–160; II: 129–148; III: 136–146 μm long; coxa III with about 4 setae. Trochanter + femur: I: 603–686; II: 527–597; III: 603–673 μm long; trochanter III with about 5 setae; each trochanter with 4 campaniform on each side; femur III with about 40 setae + 10 *smp*. Tibiae: I: 882–804; II: 776–805; III: 801–918 μm; tibia III with a total of about 115 setae + 5 *smp*; spurs on ventral surface of distal end of tibia similar to those anteriorly; each distal spur 26–30 μm long. Tarsi: I 187–200; II 184–212; III 194–212 μm long (ratio of length of tibia III to length of tarsus III 1: 0.44); tarsus III with about 30 setae, mainly spurlike; tarsal digitules very short and setose. Claws fairly long and thin, much longer than width of tarsus (each tarsus about 25 μm wide), held at a distinct angle to tarsus, each with a small denticle; length: III 60 μm; claw digitules both short and setose.

Abdomen: *Segments I–VII:* Tubular ducts present in as a band across tergite VII, each duct 8 μm wide, 20 μm deep, with a slightly spirally ridged inner surface. Dorsal abdominal setae and pores (totals): segments I–V: 4 extremely long *hs* (80–100 μm); VI: 4 extremely long *hs* + some *lp*, group fusing with pleurites; VII: about 20 *hs* and 20–25 tubular ducts. Pleural setae: dorso- and

ventropleural setae combined on each side: I–VII: 3 or 4 *hs* + 12–20 *lp* + 15–25 *smp*, most setae about 50–60 µm long. Ventral abdominal setae fleshy and shorter than dorsal abdominal setae, each 35–40 µm long (totals): I 8 *fs*; II 8 or 9 setae; III–VI 10–12 *fs*; VII 6–8 *fs*; *lp* absent on all sternites. Abdominal spiracle at least present from segment III to VII each peritreme about 10 µm wide. *Segment VIII:* tergite with 1 or 2 pairs of *hs* dorsal abdominal setae, plus about 40 small locular pores and many *smp*; sternite with about 10 ventral abdominal setae but no pores; margin rounded, with 2–4 *hs* pleural setae, 3 or 4 *lp* + 2–4 *smp*. **Genital segment:** Anus large (32 µm wide); with 1 or 2 *hs* on tergite IX; sternite IX without a median ridge, with 3 or 4 setae. Penial sheath as broad as posterior margin of abdominal segment VIII, length without segment IX 190 µm, with segment IX 243 µm; greatest width 140 µm; ventrally and laterally with a group of 20 *hs* on each side of anterior end of penial sheath. Aedeagus about 170–190 µm.

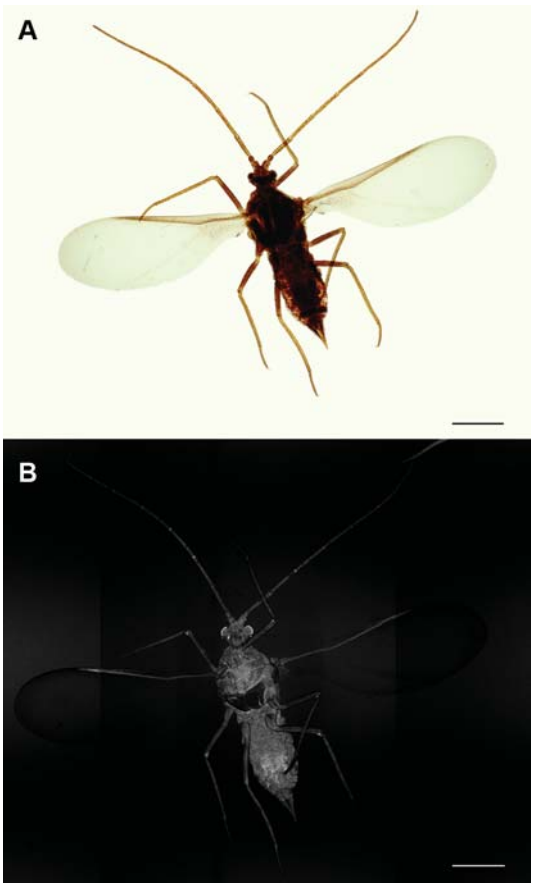

FIGURE 1. Dorsal surface of *Graminorthezia graminis* (Tinsley). **A.** Compound light microscope. **B.** Confocal microscope. Scale bar: 500 µm.

Comments: The adult male of *I. insignis* is unique in having extremely long appendages, particularly the antennae, almost twice as long as the body length, as compared to other genera; a pair of very long setae are present on each tergite, loculate pores of 3 or 4 loculi are on the pleurites and overlapping on tergites but absent on sternites, and sternite VIII does not have a median ridge (similar to *Orthezia*, but in constrast to *Graminorthezia* and *Praelongorthezia*).

Newsteadia Green

Newsteadia Green 1902: 284–285. Type species: *Coccus floccosus* De Geer, 1778.

Generic Diagnosis, based on adult male morphology: Head with dorsal midcranial ridge strong but fading posteriorly; ventral midcranial ridge strong and bifurcating posteriorly, compound eyes each with 30–50 ommatidia (vs. >60 and usually >100 in other genera); prosternum with a triangular sclerotized area (vs. prosternal medial ridge in other genera), with well-sclerotized margins; scutellum without setae or pores but with *smp*; scutum with median area short, without *hs* near lateral margins; metathorax with metatergal setae and pores present, but without *smp*; wing shape rounded, with reduced venation compared to other Ortheziidae (subcostal and cubital ridges only present); alar lobe or fold absent; hamulohalteres absent (vs.

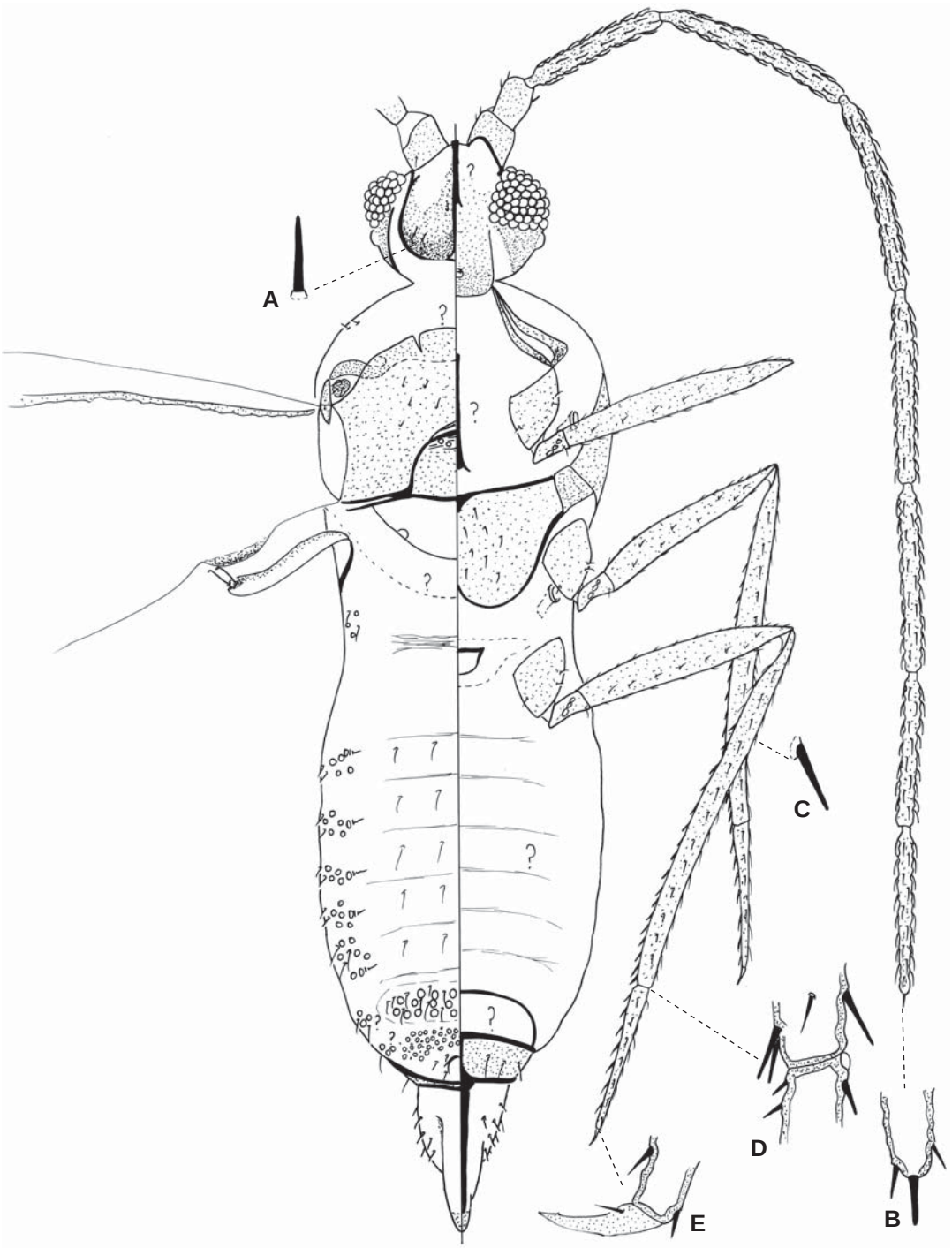

FIGURE 2. *Graminorthezia graminis* (Tinsley). Adult male. **A.** Thick and blunt setae on head and body. **B.** Antennal apical seta. **C.** Leg seta. **D.** Tibiotarsal connection. **E.** Claw.

present in *Orthezia*, *Praelongorthezia*, *Insignorthezia,* and *Graminorthezia*); legs with long *hs*; abdominal tergite VIII without locular pores (vs. present other known genera); sternite VIII without pores or setae; apex of aedeagus widening at tip (vs. pointed in other known genera); sternite IX undiscernible from penial sheath (see Discussion), body completely lacking of *lp* (vs. present in all other known genera).

Newsteadia americana Morrison

Figure 5

Newsteadia americana Morrison, 1925: 147–150.

Material Examined: United States: Indiana, Parke Co., 2 miles E of Clinton, 1-2.vii.2006, Jim Nardi coll., deposited at USNM. 1/1 ad male in fair condition, but prothorax rather foreshortened and covered by prescutum.

Diagnosis: *Newsteadia americana* differs from *N. floccosa* in lacking lateral branches of dorsal midcranial ridge (vs. present), ridge fading before reaching postoccipital ridge (vs. bifurcating posteriorly); trochanter and femur unfused (fused on *N. floccosa*), number of tubular ducts smaller than on *N. floccosa*.

Description: *Mounted material:* Total body length 1.63 mm. Antennae nearly 1.3 times total body length; body with few setae, *lp* absent, but *smp*, each 2–3 μm wide, present sparsely throughout body.

Head: Width 260 μm and length 225–250 μm. Dorsally, midcranial ridge and dorsomedial part of epicranium as for genus; with (on each side) 2 or 3 flagellate *hs*, each about 55 μm long, plus 1 or 2 *mcp* near midcranial ridge. Laterally, compound eyes each about 95 μm long with about 45–50 ommatidia; ocelli 25 μm wide; preocular ridge as for genus. Ventrally, midcranial ridge extending from posterior margin of ventromedial part of epicranium anteriorly and fusing with dorsal arm; ventral arm strong and bifurcated posteriorly; ventromedial part of epicranium with 7–10 long *hs* ventral midcranial ridge setae (each about 50 μm long) + 4–8 *mcp* on either side of ventral midcranial ridge. Other structures as for genus. **Antenna:** Total length 2.08 mm (ratio of total body length to antennal length 1:1.28). Scape: 124 μm long, 57–60 μm wide, each with 10–12 long *hs* distally (each about 40 μm long) plus a spinose seta near base dorsally, without pores. Pedicel: length 82–84 μm, width 50 μm; each with 5 or 6 *hs*, 3 coeloconic sensilla ventrally + a campaniform sensilla dorsally, somewhat removed from distal margin. Segments III–X all filiform, becoming slightly narrower toward apex, proximal segments about 26 μm wide, apical segment about 20 μm wide: *fs* quite long, each about 43 μm long on basal segments but shorter on apical segment (some only 30 μm long); *hs* short, mostly 15–18 μm long; lengths of segments (μm): III 340–365; IV 335–360; V 320–335; VI 281–290; VII 240; VIII 185–188, and IX 185–195; approximate number of setae per segment: III–VIII each with about 16–18 *fs* + 2–6 *hs*. Segment IX elongate, with about 17 *fs*, 2 *hs* medially + 1 strong terminal bristle, about 30 μm long, and 1 antennal bristle laterally near apex, 45–50 μm long; coeloconic sensilla not detected.

Thorax: *Prothorax:* structures hard to see as partially covered by prescutum. Dorsally, no setae or small convex pores detected. Laterally, proepisternum + cervical sclerites complex, but structure unclear: anteriorly probably articulating with postocular ridge; structure probably similar to that on *N. floccosa* (see Koteja, 1986); pleural apophysis quite large. With 1 *hs* antemesospiracular seta on

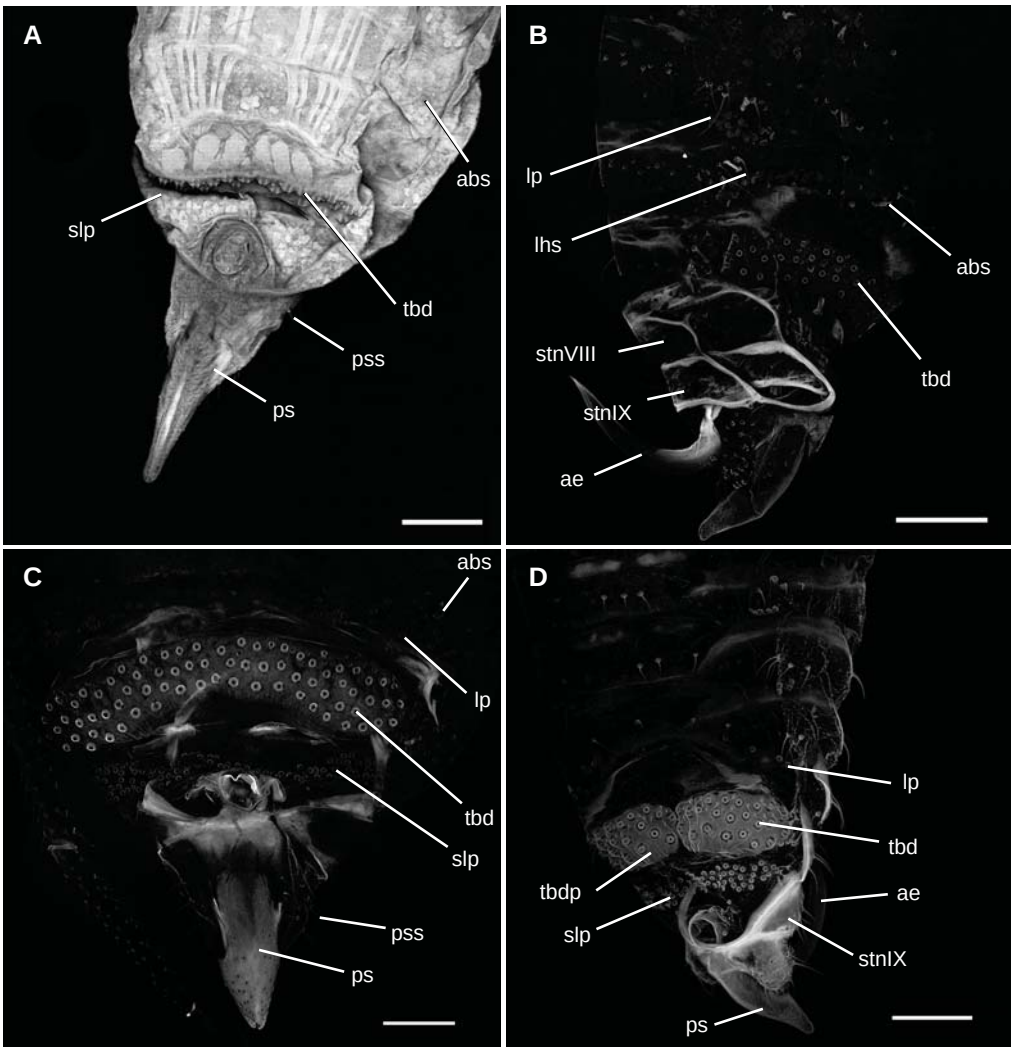

FIGURE 3. Confocal microscope images of the last abdominal and genital segments in the males of four genera in the Ortheziidae, from specimens mounted in Canada balsam. **A.** Dorsal surface of *Graminorthezia graminis* (Tinsley), uncleared specimen. **B**. Lateral side of *Insignorthezia insignis* (Browne), cleared specimen. **C.** Dorsal surface of *Orthezia newcomeri* Morrison, cleared specimen. **D.** Dorsal surface of *Praelongorthezia praelonga* (Douglas), cleared specimen. Abbreviations: **abs,** abdominal spiracle; **ae,** aedeagus; **lhs,** long hair seta; **lp,** loculate pore; **ps,** penial sheath; **pss,** penial sheath seta; **slp,** small locular pores; **stnVIII,** sternite VIII; **stnIX,** sternite IX; **tbd,** tubular duct; **tbdp,** tubular duct plate. Scale: 100 μm.

each side. Ventrally, prosternum and prosternal apophyses as for genus; number of prosternal setae uncertain but with 1 *hs* anteprosternal seta. Dorsally, prescutum, length uncertain but 207 μm wide; prescutal ridge almost absent, represented by a small sclerotization at anterior end; posteriorly, margin of prescutum delineated by a thin suture; prescutum without prescutal setae or pores. Prealare quite long, perhaps rather broad and well sclerotized, terminating near mesepisternum. Scutum with median area short, about 20 μm long; with 2 or 3 pairs of *hs* scutal setae + 0–2 minute pores on each side medially posterior to prescutum; without *hs* near lateral margins. Scutellum 145 μm wide, 128 μm long; bounded anteriorly by heavily sclerotized scutoscutellar suture; without setae

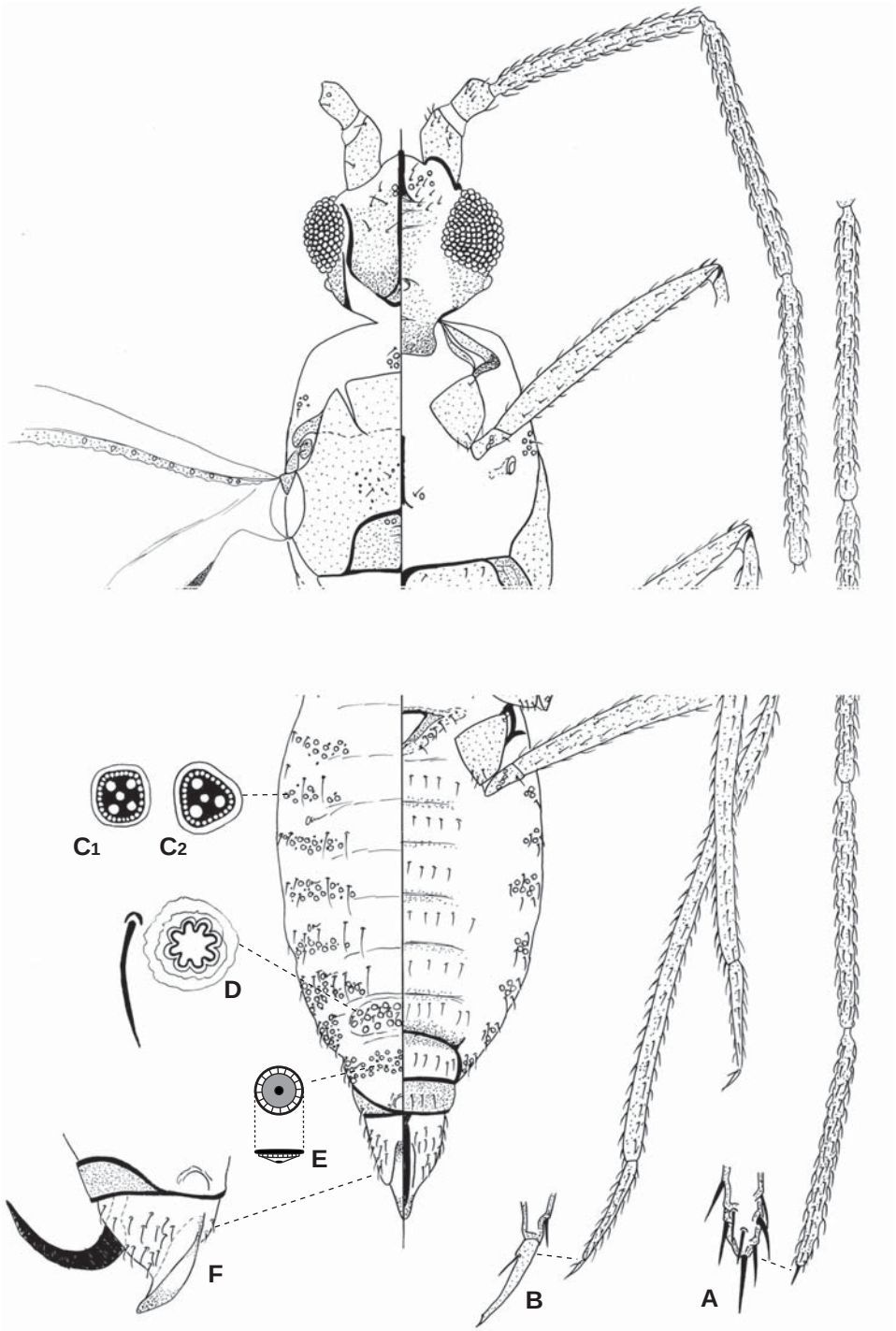

FIGURE 4. *Insignorthezia insignis* (Browne). Adult male. **A.** Antennal apical seta. **B.** Claw. **C1.** Abdominal pore with four loculi. **C2.** Abdominal loculate pore with three loculi. **D.** Tubular duct with peripheral seta. **E.** Small locular pore. **F.** Penial sheath.

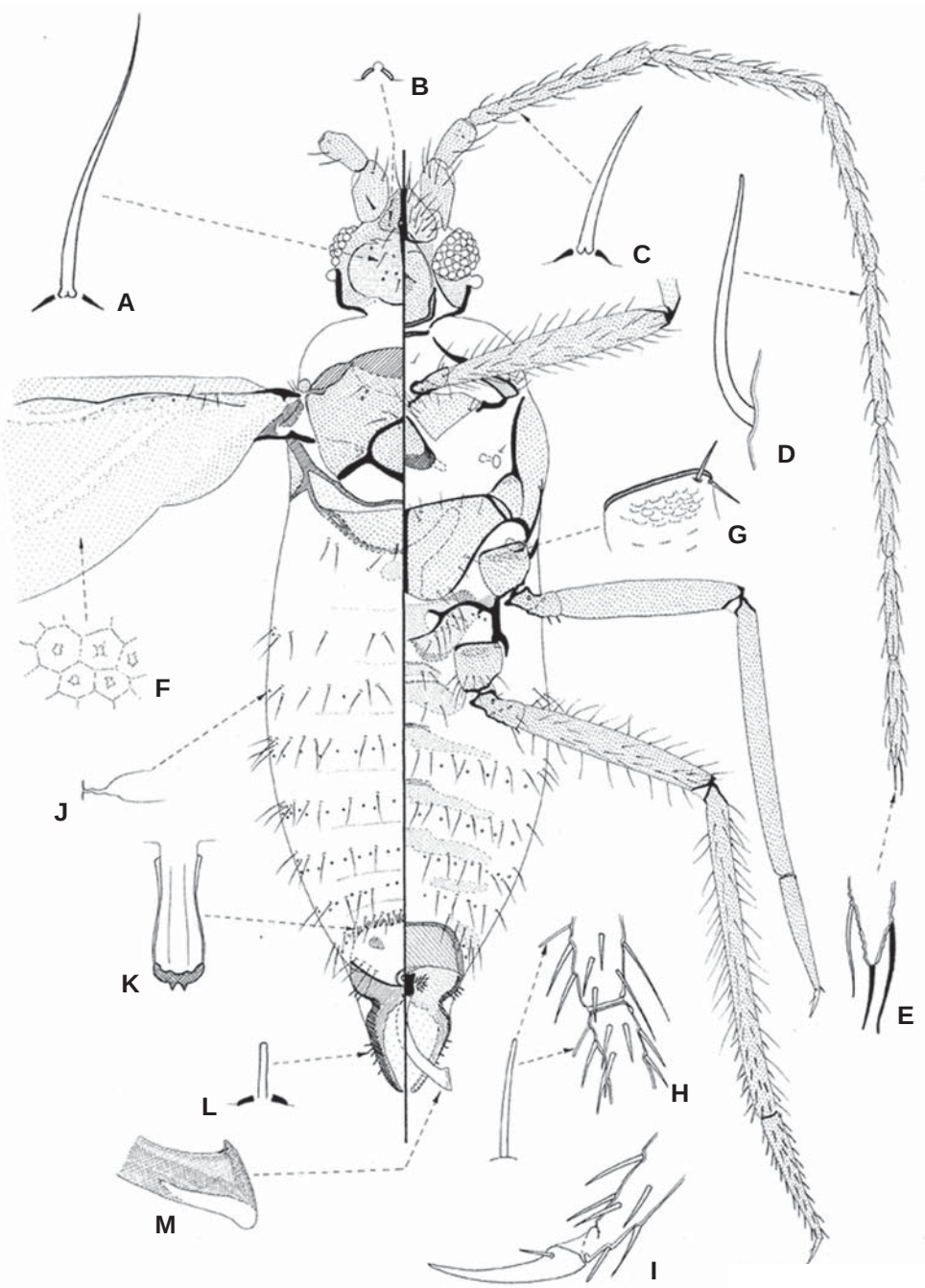

FIGURE 5. *Newsteadia americana* Morrison. Adult male. **A.** Minute convex pore (*mcp*). **B.** Head setae. **C1.** Antennal hair setae (*hs*), **C2.** Antennal fleshy setae (*fs*). **D.** Antennal apical and subapical bristles. **E.** Polygonal discs on wing surface. **F.** Coxa with platelike microridges with microspines. **G.** Tibiotarsal connection. **H.** Claw. **I.** Abdominal spiracle. **J.** Tubular ducts. **K.** Blunt penial sheath setae. **L.** Apex of aedeagus **M.** Aedeagus apex (drawing by Chris Hodgson).

but with 0 or 1 pair *smp*; posterior margin of scutellum marked by a thick ridge, which extends posterolaterally as posterior notal wing process to postalare. Laterally, tegula with 2 tegular setae but probably no *smp.* Mesepisternum not reticulated near lateropleurite; subepisternal ridge long and well developed. Mesopleural apophysis unclear. Mesothoracic spiracle: peritreme almost round, width 35 μm. Ventrally, basisternum, 375 μm wide, 170 μm long; with 9 or 10 *hs* basisternal setae + 0 or 1 *smp* on each side; furca large, narrow waisted, arms rather broad and very divergent, extending almost to marginal ridge anteriorly. *Metathorax:* Dorsally, metatergal setae: 4 present medially and 2 more laterally on each side, but without *smp*; metapostnotum present medially, small. Laterally, dorsospiracular setae absent and without *smp*. Dorsal part of metapleural ridge well developed but without hamulohalteres or suspensorial sclerites. Posterior part of metapleural ridge well developed; without "reticulations" along dorsal margin; metepisternum mildly sclerotized, without postmetaspiracular setae but with a few *smp*. Metepimeron represented by a sclerotized ridge running posteriorly, without setae. Metathoracic spiracle: peritreme almost round, width about 30 μm. Ventrally, metaprecoxal ridge strong, extending ventrally and appearing to fuse with a ridge along posterior margin of metasternum. Metasternum large and sclerotized, broader anteriorly than posteriorly, with a large subrectangular pit centrally, with strongly sclerotized lateral margins that fuse with metaprecoxal ridges; pit opens into a pair of metafurca; sclerotized area with a line of 6 long *hs* posterior metasternal setae on each side; apparently without anterior metasternal setae or pores. **Wings:** Forewing shape as for genus, 2.0 mm long, about 875 μm wide (ratio of length to width 1:0.44; ratio of total body length to wing length 1:1.23), each forewing with 3 alar setae plus a line of about 8–13 circular sensoria. Other structures as for genus. **Legs:** Mesothoracic legs shortest, others subequal in length. Fleshy setae few, short, with a blunt apex, easily separable from hairlike setae, without *smp*. Coxae: I 127; II 117–120; III 114–120 μm long; coxa III with about 13 *hs*; anterior surface of each coxa with platelike microridges with microspines. Trochanter + femur: I 485–493; II 405–408; III 450–460 μm long; trochanter III with 2 long setae (one about 25 and other about 65 μm long) + 1 *fs* (about 12 μm long); each trochanter with 3 oval sensoria on each side, arranged in a line, plus another more proximally; with a segmental line between trochanter and femur, almost at right angles to margin but probably with no articulation; femur III with about 45 long *hs*. Tibiae: I 545–555; II 525–530; III 600–605 μm; tibia III with many long *hs* (longest about 75 μm), these becoming spurlike on distal half to one-third, particular on ventral surface (each spur 20–25 μm long) plus 4 or 5 *fs*, each about 20 μm long. Tarsi: I 205–220; II 215; III 225–240 μm long (ratio of length of tibia III to tarsus III 1:0.39); tarsus III with many setae, mainly spurlike, but with 3 or 4 *fs*; claws length (III) 48–56 μm, with a hint of a small denticle.

Abdomen: *Segments I–VII:* tergites as for genus. Tubular pores: 13 present in a narrow band across tergite VII, each about 16–18 μm long, 7 μm widest, with a more heavily sclerotized inner end. Dorsal setae and pores (totals): segments I and II: 8–10 *hs* + 0–2 *smp*; III–VI: 8–12 *hs* + 12–16 *smp*; VII: about 36 *hs*, 13 tubular ducts + 0 *smp*; dorsal setae each about 33–35 μm long. Laterally, pleural setae: dorso- and ventropleural setae combined on each side: I–VII 3–6 *hs* + 2–5 *smp*; some setae rather long, up about 55 μm. Abdominal spiracles as for genus, each peritreme extremely small (perhaps 3 μm wide), opening into a narrow inner ductule about 13 μm long, before expanding into a wider trachea. Ventrally, sternites as for genus. Ventral setae similar

to dorsal abdominal setae but longer, each about 50 μm long; (totals) I and II: 4 setae + 0 *smp*; III and IV: 16 setae + 10–12 *smp*; V and VI: 8–10 setae + 12–14 *smp*; VII: 4 setae on each side + 2 *smp*. *Segment VIII*: with 3 or 4 long *hs* dorsal abdominal setae (each 50–60 μm long). **Genital segment:** Anus about 32 μm wide. Penial sheath 330 μm long with segment VIII and 200 μm without; greatest width 215 μm; with a group of 8 or 9 short, rather blunt *fs* on either side of basal rod, each about 10 μm long; plus a further group of 3 or 4 *fs* on each margin anteriorly, each about 13 μm long; also a line of 6 or 7 *fs* along each posterior margin, each about 7 μm long; each side of penial sheath apex with a group of about 10 sensoria. Aedeagus about 200 μm long; articulating anteriorly with a short, quite heavily sclerotized basal rod about 40 μm long.

Orthezia Bosc d'Antic

Orthezia Bosc d'Antic, 1784: 173. Type species: *Orthezia characias* Bosc d'Antic (= *Orthezia urticae* Linnaeus), by monotypy.

Generic Diagnosis, based on adult male morphology: Head broad, wider than long, with setae and pores present on both sides; compound eyes with between 100 and 150 ommatidia. Antennal apical segment with a terminal bristle and no subapical bristle. Scutal setae and pores present, anteprosternal sete absent; scutellum with loculate pores and *smp*, tegula with setae and *smp.* Wings with subcostal ridge often only extending to less than ¾ wing length; cubital ridge starting from 1/8 wing base; hamulohalteres with 2 or 3 hamuli. Legs with *hs* mostly on femur and *fs* on tibia and tarsus; claws with denticles and setose digitules. Abdominal tergite VII with a single plate bearing numerous tubular ducts, surrounded by fleshy setae of variable length. Sternite IX without a median ridge but with a few setae.

Comments: Described adult males of *Orthezia* now include *O. urticae* (Koteja, 1986), *O. annae* (herein) and *O. newcomeri* (herein).

Orthezia annae Cockerell

Figures 6, 7

Orthezia annae Cockerell, 1893: 403–404.

Material Examined: U.S.A., New Mexico, on "*Atriplex*," 11. i. 1897, Townsend coll., deposited at USMN: 1/2 ad males (in good condition but uncleared, description of specimens based on confocal microscope images and thus some pores and setae not observable and mentioned as such).

Diagnosis: *Orthezia annae* differs from other *Orthezia* spp. in having additional longer antennal setae, some on legs, similar to those on antennal setae, and fewer tubular ducts than on other *Orthezia* spp.

Description (as for family description unless otherwise stated): *Mounted material:* Body large, total body length 1.5–1.65 mm. Antennae 1.3 times total body length, most segments subequal in length; *fs* present on antennae.

Head: Width 300 μm, length 250 μm. Dorsally, dorsomedial part of epicranium, with at least 4 or 5 *hs*; *lp* and *smp* not observable. Laterally, compound eye about 115 μm long, with about 100 ommatidia; ocelli 23–30 μm wide. Ventrally, ventromedial part of epicranium, with ventral head

setae, number undefinable. **Antenna:** Total length 2.06 mm (ratio of total body length to antennal length 1:1.3). Scape: 70–88 μm long, 75–79 μm wide, each with at least 5 short hairlike setae ventrally and 1 *hs* dorsally. Pedicel: length 68–70 μm, width 57–61 μm; each with 2 *fs*, 6 or 7 *hs*. Segments III–IX with proximal segments about 40 μm wide, while apical segment only 22–26 μm wide: *fs* long, those on segment III 60–65 μm long, those on apical segment 45–50 μm long; lengths of segments (μm): III 248–257; IV 312–465; V 260–350; VI 291–352; VII 223–329 and VIII 179–256; approximate number of setae per segment: III–VIII with about 35–50 *fs*. Segment IX shortest: length 179–233 μm; with about 15 *fs* + 1 strong terminal bristle, about 45–50 μm long and 2 short antennal bristles laterally near apex.

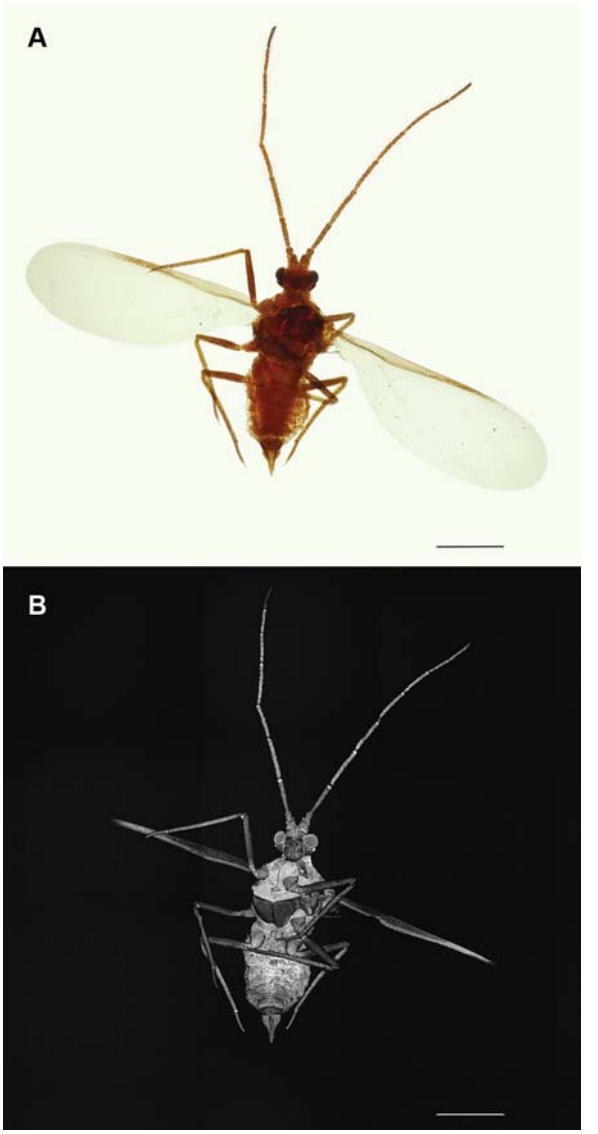

FIGURE 6. Ventral surface of *Orthezia annae* Cockerell. **A.** Light compound microscope. **B.** Confocal microscope. Scale bar: 500 μm.

Thorax. *Prothorax:* dorsally, pronotal ridge and posttergites not observable. Pronotal setae and pores not observable. Ventrally, prosternum with a sclerotized median ridge with at least 1 prosternal seta on each side. Anteprosternal setae and pores not observable. Antemesospiracular setae and posterior propleural setae not observed. *Mesothorax:* dorsally, prescutum 95 μm long, 170 μm wide, prescutal setae or pores. Distance between prescutum and scutellum medially 50 μm; scutal setae with at least 3 *hs* medially posterior to prescutum. Scutellum 170 μm wide, 120 μm long; margins and sutures as in genus. Laterally, tegula with 3 setae. Mesopleural apophyses well developed. Mesothoracic spiracle most probably present but not observable. Ventrally, basisternum, 310 μm wide, 210 μm long; with 10–12 *hs*, distributed more or less throughout; furca not observable. Postmesospiracular setae not observable. *Metathorax:* Dorsally, metatergal setae and dorsospiracular setae not observable. Laterally, dorsal part of metapleural ridge well developed, articulating with hamulohaltere. Metepimeron with a sclerotized ridge running posteriorly, without setae. Metathoracic spiracle most probably present, but peritreme not observable. Ventrally, metasternum large and sclerotized, broader anteriorly than posteriorly, with a large subrectangular pit centrally, with strongly

sclerotized lateral margins; setae and pores not observable. **Wings:** Forewing 1.9–2.0 µm long, about 638–796 µm wide (ratio of length to width 1:0.37; ratio of total body length to wing length 1:1.23), base of wing especially narrow, with subcostal ridge extending to less than ¾ of wing length; cubital ridge starting 1/8 of wing base; without alar setae; circular sensoria along posterior margin of subcostal ridge detected, but number unclear; sensoria extending to ¾ of wing length to where subcotal ridge disappears. Hamulohaltere 225 µm long, 30 µm wide; with 2 apical hamuli each 55 µm long. **Legs:** Leg setae 13–20 µm long but with additional, significantly longer, *fs* ventrally on femur and tarsus, and on both sides of tibia (30–40 µm long). Coxae: I 124–147; II 120–152; III 131–140 µm long; coxa III with at least 4 setae. Trochanter + femur: I 473–506; II 374–411; III 608–704 µm long; trochanter III with about 3 *hs*; each trochanter with 3 campaniform sensilla arranged in a line on each side; femur III with about 35 short setae + 4–6 long setae ventrally; also 7 or 8 longer *fs* on ventral side of femur among shorter setae. e I 585–649; II 527–562; III 608–704 µm; tibia III with a total of about 100 setae including long setae on both sides of tibia; each distal spur 23–25 µm long. Tarsi: I 164–193; II 142–180; III 148–214 µm long (ratio of length of tibia III to length of tarsus III 1:0.26); tarsus III with about 23–30 spurlike setae and 2 or 3 long setae ventrally; tarsal digitules very short and setose. Claws fairly long and thin, much longer than width of tarsus (each tarsus about 15 µm long), held at a distinct angle to tarsus, each with 1 small denticle; length: III 40 µm; claw digitules both short and setose.

Abdomen: *Segments I–VII:* Setae and *lp* detected on pleurites (number unknown) but not observable on sternites and tergites. Tubular ducts present in a band of about 20 ducts across tergite VII, each duct 10 µm wide, 20 µm deep. Abdominal spiracles present on anterodorsal part of at least pleurites II–VII. *Segment VIII:* tergite with 1 or 2 pairs of *hs* dorsal abdominal setae, small locular pores numerous, but exact number unknown; sternite with at least 6 setae (probably more but not observable) but no pores; margin rounded, with 2–4 *hs* pleural setae. With a pair of abdominal spiracles similar to those on more anterior abdominal segments. **Genital segment:** Anus large (40 µm wide). Penial sheath as broad as posterior margin of abdominal segment VIII, short, triangular, and blunt; length without segment IX 220 µm, with segment IX 281 µm; greatest width 140 µm; ventrally and laterally with a group of about 15 long *hs* (each 45 µm long) on each side of anterior end of penial sheath.

Comments: Despite the lack of resolution for some setae and pore distribution, *O. annae* is particular for the presence of longer setae on the legs (fig. 7), among the setae present in other Ortheziidae species.

Orthezia newcomeri Morrison

Figures 3C, 8

Orthezia newcomeri Morrison, 1952: 37.

Material Examined: USA, California, Sacramento, on *Rubus* sp., 16. v. 1963, R.E. Wilkey coll., deposited at the USNM: 1/1 ad male (in good condition).

Diagnosis: Very large body, more than 2.5 mm; large number of loculate pores on dorsal and ventral abdominal segments.

FIGURE 7. *Orthezia annae* Cockerell. Adult male. **A.** Antennal apical segment. **B.** Tibiotarsal connection. **C.** Claw. Because the specimens were uncleared, this figure illustrates only those structures visible both under the light microscope and in the confocal images.

Description (as for family description unless otherwise stated): *Mounted material:* Very large, total body length 2.6 mm. Antennae exceptionally long, nearly 1.7 times total body length, most segments approximately subequal in length. *lp* each 11–7 μm wide, with 4–6

loculi, present on both dorsal and ventral surfaces; *smp* each about 3–4 μm wide: sparsely present throughout body.

Head: Width 435 μm, length 400 μm. Dorsally, ventral arm strong, not bifurcated posteriorly; dorsal arm thinner and fading posteriorly, but with 2 short branches medially. Dorsomedial part of epicranium with (on each side) 2 or 3 *hs* of rather variable length (40–60 μm), all flagellate, plus 1 or 2 *lp* and 2 or 3 *mcp*. Laterally, compound eye about 160–175 μm long, with about 120 ommatidia; ocelli 30 μm wide. Ventral head setae with (on each side) 12 or 13 *hs*, 4–6 *lp* + 6–10 *mcp*; ventral plate with 2 long *hs* and 2 *lp* on each side. **Antenna:** Length 4.5 mm (ratio of total body length to antennal length 1:1.73). Scape: 150 μm long, 120 μm wide, each with 7 or 8 short *hs* + 1 or 2 minute pores ventrally and 4–6 *hs* dorsally. Pedicel: length 110–120 μm, width 70 μm; each with 4 or 5 *fs*, 0 or 1 *hs*, 2 or 3 minute pores ventrally. Segments III–IX: those proximally about 50 μm wide, apical segment only 25 μm wide: *fs* between 25–40 μm on all segments, becoming shorter toward apical segment. Lengths of segments (μm): III 633–638; IV 719–727; V 667–684; VI 646–656; VII 601–626 and VIII 474–481; approximate number of setae per segment: III–VIII with about 70–90 *fs* + 2–9 *hs*. Segment IX elongate: length 472–480 μm; with about 70 *fs* + 1 strong terminal bristle, about 25 μm long.

Thorax: *Prothorax:* dorsally, posttergites not identified. Pronotal setae: dorsally, 1 or 2 *hs* anterior propleural setae + 3 or 4 *lp* + about 15 minute pores anteriorly on shoulder; also with a group of posterior propleural setae and pores just anterior to each prealare, extending ventrally and joining antemesospiracular setae: 1 or 2 *hs*, 15 *lp* + about 20 *smp*. Ventrally, prosternum with a distinct sclerotized median ridge, with 4 *hs* prosternal setae + 4 *lp* + 5 *smp* on each side. Anteprosternal setae absent. Antemesospiracular setae fused with posterior propleural setae. *Mesothorax:* dorsally, prescutum quite large, probably rather convex, 230 μm long, 130 μm wide; distance between prescutum and scutellum medially 130 μm; scutal setae: with about 4 *hs* + 1 *lp* + 15 minute pores medially posterior to prescutum and with 1 hs near each lateral margin. Scutellum, 165 μm wide, 135 μm long; without setae but with 4 *lp* + 4 *smp*; postnotal apophyses well developed. Laterally, tegula with 2 tegular setae + 5 *smp*. Mesothoracic spiracle: peritreme almost round, width about 50 μm. Ventrally, basisternum 525 μm wide, 265 μm long; with 7 short *hs* basisternal setae, distributed more or less throughout. *Metathorax:* Dorsally, metatergal setae in a diffuse band of 4 *hs* + 6 *lp* + 3 *smp*. Dorsospiracular setae: 3 *hs* + 2 *lp* + 9 *smp*. Laterally, dorsal part of metapleural ridge well developed. Ventrally, metasternum sclerotized with 3 *hs* + 5 *lp* + 10 *smp* on each side; with 1 *hs* anterior metasternal setae and 1 or 2 *hs* posterior metasternal setae. Metathoracic spiracle: peritreme almost round, width 50 μm. **Wings:** Forewing 3.0 mm long, about 1.2 mm wide (ratio of length to width 1:0.39; ratio of total body length to wing length 1:1.15; with subcostal ridge extending to less than ¾ of wing length, cubital ridge starting 1/8 of wing base; with 4–6 alar setae and a line of at least 30–34 circular sensoria along posterior margin of subcostal ridge, extending almost to wing tip; hamulohalteres about 315 μm long, 38 μm wide, each with 3 apical hamuli, each 90–95 μm long. **Legs:** Coxae: I 205–215; II 220–240; III 225–230 μm long; coxa III with about 5 setae + 3 *smp*. Trochanter + femur: I 865; II 750–755; III 825–845 μm long; trochanter III with about 5 setae; femur III with about 65–70 setae (ventral ones becoming spurlike close to tibia) + 25 *smp*. Tibiae: I 1162–1183; II 1021–1059; III 1173–1176 μm; tibia III with a total of about 100 setae, becoming spurlike on distal half to two-thirds, particular on

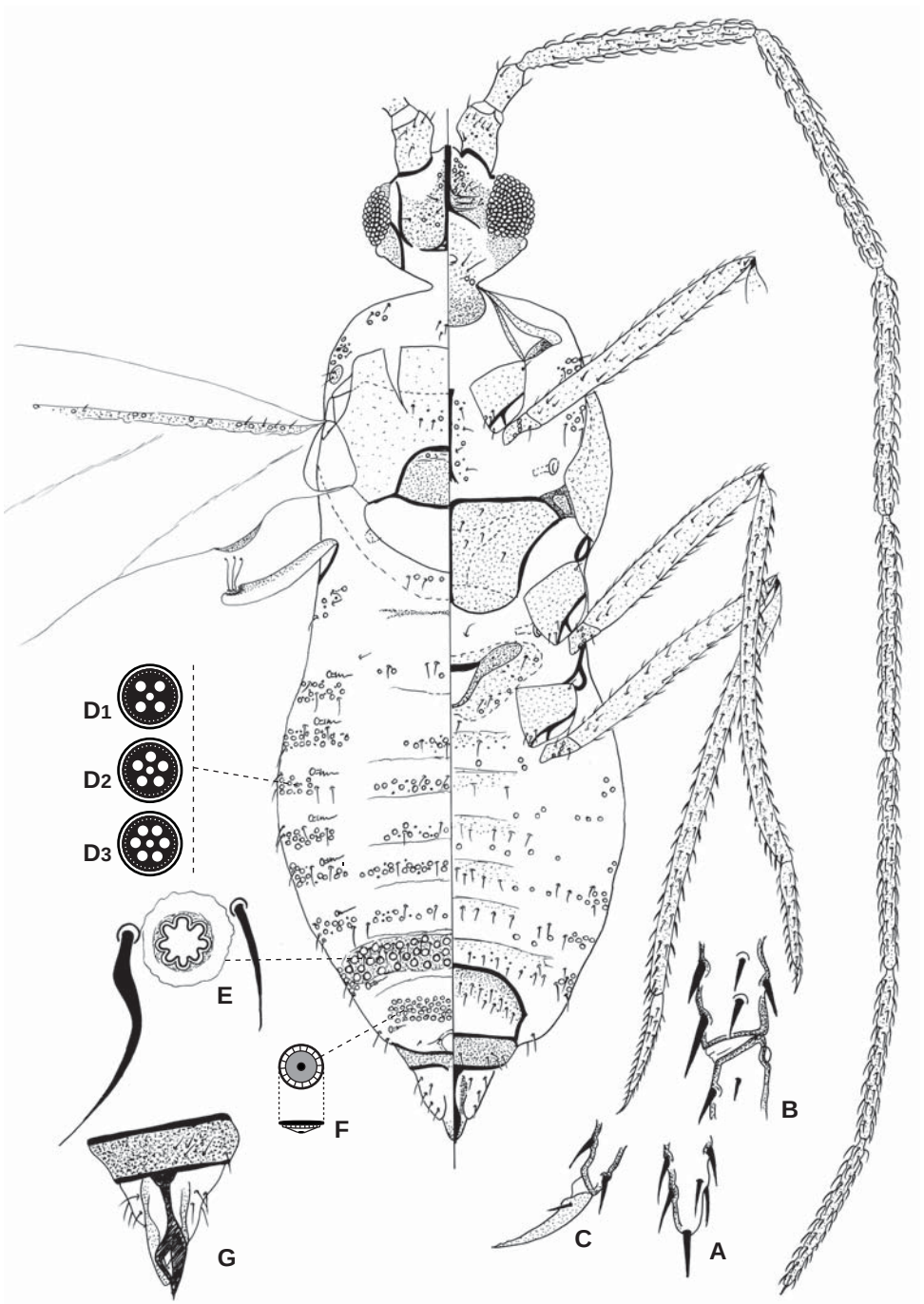

FIGURE 8. *Orthezia newcomeri* Morrison. Adult male. **A.** Antennal apical seta. **B.** Tibiotarsal connection. **C.** Claw. **D1.** Loculate pore with four loculi. **D2.** Loculate pore with five loculi. **D3.** Loculate pore with six loculi. **E.** Tubular ducts with two types of peripheral setae. **F.** Small locular pores. **G.** Penial sheath.

ventral side + 13 *smp*; each distal spur about 40 μm long. Tarsi: I 290; II 287–300; III 282–294 μm long (ratio of length of tibia III to length of tarsus III 1:0.25); tarsus III with about 40 setae.

Claws fairly long and thin, much longer than width of tarsus (each tarsus about 30 μm long), length: III 75 μm; claw digitules both short and setose.

Abdomen: *Segments I–VII: lp* present on both tergites and sternites, most abundant on sternites II–VI; also fairly numerous on all pleurites. Tubular ducts on a single sclerotized plate across tergite VII, each duct 15 μm wide, surrounded anteriorly by fleshy and flagellate setae of two sizes of about 10–15 and 50–65 μm long. Dorsal abdominal setae and pores (totals): segments I–V: 2–4 *hs* + 20–30 *lp* +10 *smp*; VI 3 *hs* + 22 *lp* somewhat fusing with the pleural *lp* + about 15 *smp*; VII about 70 *fs* distributed on anterior margin of tubular duct plate, 77 tubular ducts and many *smp*. Pleural setae: dorso- and ventropleural setae combined on each side: I–VII 4 or 5 *hs* + 18–25 *lp* + 15 *smp*; some setae rather long. Ventral abdominal setae mostly rather like *fs*, each 34–38 μm long (totals): I 2 setae; II 2 setae, 6 *lp* + 8 *smp*; III–VI about 12 setae, 15–18 *lp* + 15 *smp*; VII 21–25 setae, 5 *hs*, 0 *lp* + 0 *smp*. Abdominal spiracles on pleurites I–VIII, each peritreme about 10 μm wide. *Segment VIII:* tergite with 1 pair of *hs* dorsal abdominal setae, about 110 small locular pores (different from *lp* on rest of abdomen) and many *smp*; sternite with 25 ventral abdominal setae but no pores; margin rounded, with 3 *hs* pleural setae, 0 *lp* + 6 *smp*. **Genital segment:** Anus large (63 μm wide), with a lightly sclerotized area along anterior margin; with 2 *hs* on tergite IX; sternite IX with 10 setae. Penial sheath narrower than posterior margin of abdominal segment VIII, length without segment IX 233 μm, with segment IX 300 μm; greatest width 322 μm; ventrally and laterally with a group of 10 or 11 *hs* on each side of anterior end of penial sheath; posteriorly, nearer apex, without minute setae on either surface. Aedeagus of peculiar shape (uncertain if due to preparation), parallel sided anteriorly but enlarged at midlength tapering to a pointed tip which extends beyond apex of penial sheath; about 257 μm long.

Comments: The specimen studied here is particularly large, generally more sclerotized and with a larger number of loculate pores compared to other Ortheziidae. Additionally, the body is covered with small sclerotized dermal structures, different from any small pores. Finally, the aedeagus shape differs from other genera, tapering at midlength and becoming pointed apically. However, this might be an artifact of slide-mount preparation.

Praelongorthezia Kozár

Praelongorthezia Kozár, 2004: 381. Type species: *Orthezia praelonga* Douglas, 1891.

Comments: Because *Praelongorthezia* currently comprises 23 described species based on female morphology, the description of the adult male of *P. praelonga* acts for now as the generic diagnosis. The genus is classified in the tribe Ortheziini (Kozár, 2004) with *Insignorthezia*, *Graminorthezia,* and *Orthezia. Praelongorthezia* was defined based on adult female morphology and distinguished from these other genera by "bands or rows of wax plates within ovisac" and "head of dorsum with sclerotized cephalic plates" (Kozár, 2004: 271). *Praelongorthezia* has a Neartic and Neotropical distribution.

Praelongorthezia praelonga (Douglas)

Figures 3D, 9, 10

Orthezia praelonga Douglas, 1891: 246–247.

Material Examined: COLOMBIA, Cerritos, Risarabla, on "Citrus leaves," xii. 1997, F. Posada coll. (BNHM, BM1999-7): 2/4 ad males (in good condition).

Description (as for family description unless otherwise stated): *Mounted material:* Total body length 1.85–2.34 mm. Antennae, nearly 1.6 times total body length, except for last two segments. *Lp* each 7–8 μm wide, with mainly 3 loculi, sometimes 4 loculi, present on abdominal pleurites (absent on sternites and tergites), prothorax, and scutellum.

Head: Width and length 310 μm . Dorsally, midcranial ridge with one short branch medially, epicranium with (on each side) 4 *hs* all flagellate, but *lp* and *mcp* absent, preoral ridge dorsally long, extending posteriorly or fusing with postoccipital suture, with a short extension medially near each scape; postocular ridge strong dorsally, commencing from dorsal margin of each compound eye and extending posteroventrally along margin of neck. Laterally, compound eye about 140–200 μm long, with about 130 ommatidia; ocelli 30–40 μm wide. Ventrally, midcranial ridge strong and bifurcated posteriorly, ventral head present, with (on each side) 8–12 *hs*, 1–3 *lp* + 4–7 *mcp*. **Antenna:** Total length 3.31 mm (ratio of total body length to antennal length 1:1.6). Scape: 90–125 μm long, 75–90 μm wide, each with 3–7 short *hs* + 1–3 minute pores ventrally and 1 *hs* dorsally. Pedicel: length 70–83 μm, width 50–62 μm; with 2 *fs*, 1–4 *hs*, 1 or 2 minute pore ventrally + 1 (or rarely 2) campaniform sensillum. Segments III–IX with proximal segment 30–45 μm wide, apical segment 18–23 μm wide, with *fs* 35–40 μm long; lengths of segments (μm): III 371–458; IV 374–492; V 441–546; VI 462–567; VII 416–472 and VIII 345–377; approximate number of setae per segment: III–VIII with about 40–60 *fs* + 4–8 *hs*. Segment IX: length 250–444 μm; with about 60 *fs* + 1 strong terminal bristle, about 40 μm long; coeloconic sensilla not detected.

Thorax: *Prothorax:* Pronotal setae, with dorsally 1 *hs* anterior propleural setae anteriorly on shoulder; also with a group of posterior propleural setae and pores just anterior to each prealare, extending ventrally and joining antemesospiracular setae: 1 *hs* + 7–10 *lp*; median pronotal setae: 2 or 3 *fs* and about 5 *lp*. Ventrally, with 2–3 *hs* prosternal setae + 2 *lp* + 2 *smp* on each side. *Mesothorax:* dorsally, prescutum 130 μm long, 165 μm wide. Distance between prescutum and scutellum medially 110 μm; scutal setae: with about 2–4 hs medially posterior to prescutum. Scutellum 165 μm wide, 130 μm long; without setae but 4–6 *lp* + 4–8 *smp*. Laterally, tegula with 2 tegular setae. Mesothoracic spiracle: peritreme almost round, width about 35 μm. Ventrally, basisternum 400 μm wide, 220 μm long, with 6–10 *hs* basisternal setae. ***Metathorax*:** dorsally, metapostnotum with 2 metatergal setae. Dorsospiracular setae absent. Laterally, Metathoracic spiracle: peritreme almost round, width 30 μm. Ventrally, metasternum occasionally with 1 *hs* anterior metasternal seta and 2 hs posterior metasternal setae + 4 *lp* + 6 *smp*. **Wings:** Forewing 2.23 mm long, about 805 μm wide (ratio of length to width 1:0.36; ratio of total body length to wing length 1:1.1), with a line of at least 45–50 circular sensoria; hamulohaltere about 220 μm long, 25 μm wide; each with 2 apical hamuli, each 50 μm long. **Legs:** Coxae: I 140–160; II 140–171; III 140–171 μm long; coxa III with about 8 setae + 5 *smp*. Trochanter + femur: I 556–697; II 500–608; III 603–722 μm long; trochanter III with about 4 setae; femur III with about 55 setae + 17 *smp*. Tibiae: I 820–971; II 719–951; III 910–1088 μm; tibia III with a total of about 120 setae + 10 *smp*; each distal spur 26–30 μm long. Tarsi: I 200–256; II 219–268; III 200–279 μm long (ratio of length of tibia III to length of tarsus III 1:0.24); tarsus III with about 32 setae. Claws much longer than width of tarsus

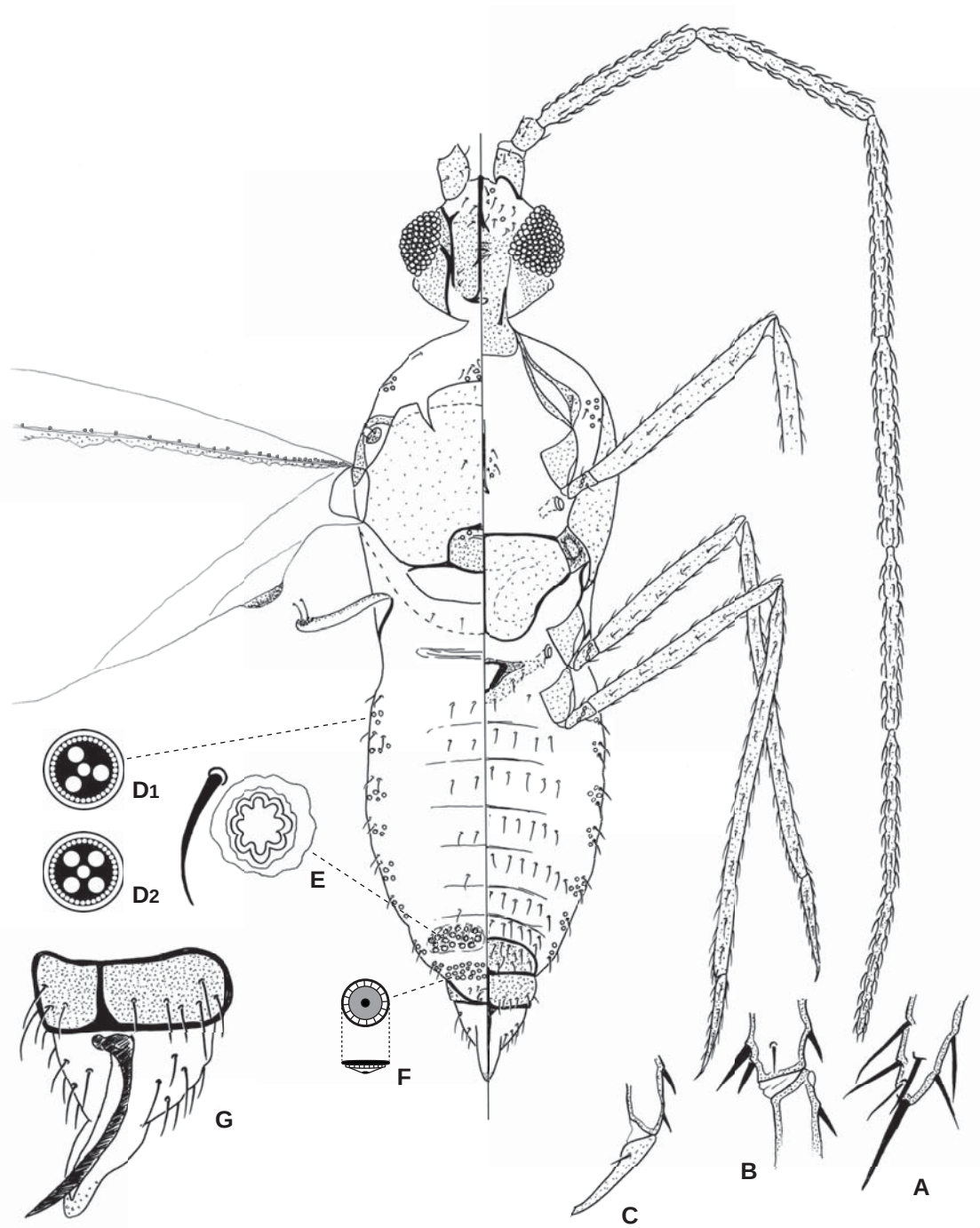

FIGURE 9. *Praelongorthezia praelonga* (Douglas). Adult male. **A.** Antennal apical seta. **B.** Tibiotarsal connection. **C.** Claw. **D1.** Loculate pore with three loculi. **D2.** Loculate pore with four loculi. **E.** Tubular ducts with two types of peripheral setae, **F.** Small locular pores. **G.** Penial sheath.

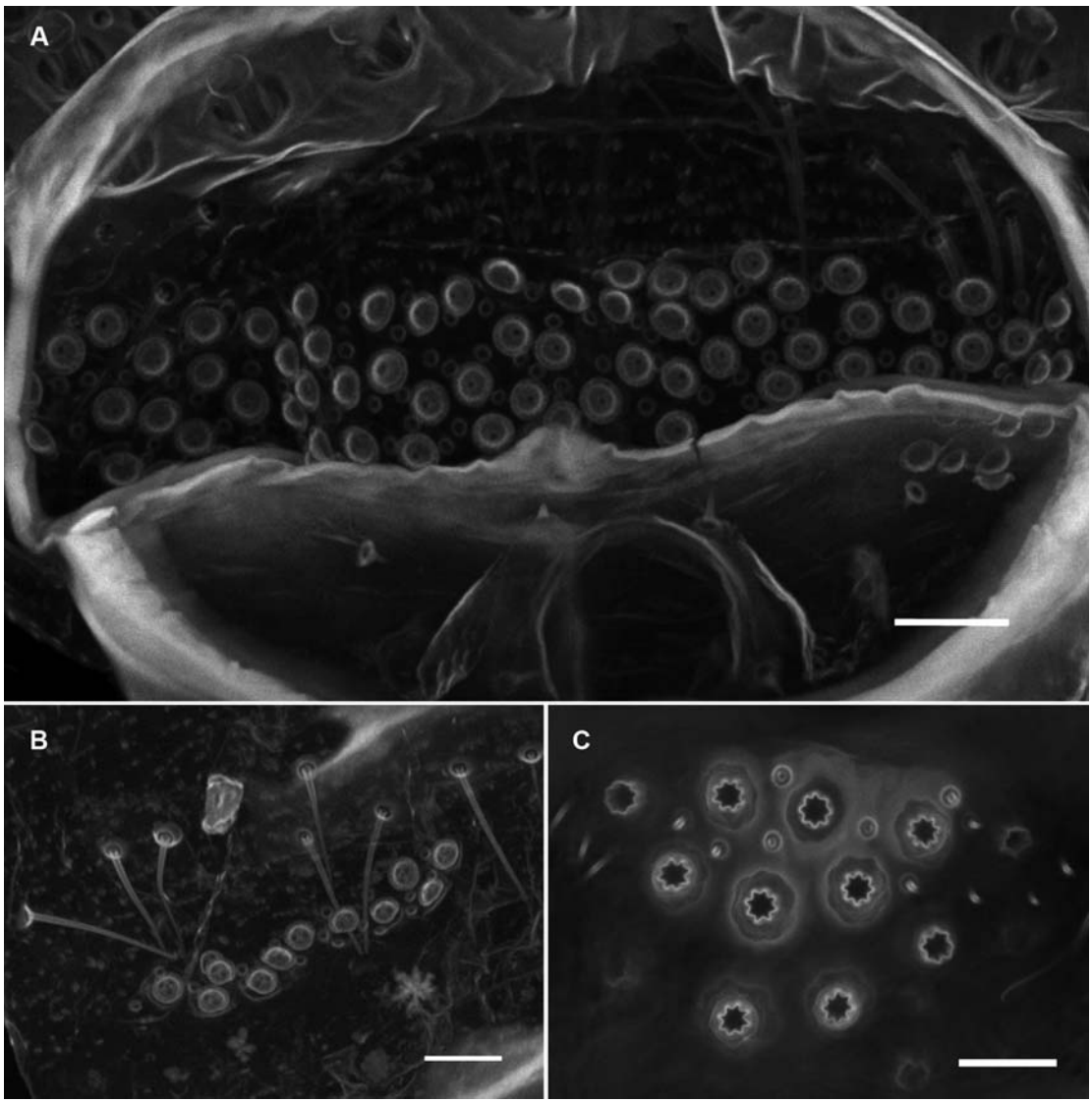

FIGURE 10. Details of cuticular structures on the abdomen of *Praelongorthezia praelonga* (Douglas) from CLSM. **A.** Small locular pores on tergite VIII. **B.** Loculate pores on pleurite. **C.** Tubular pores on tergite VII. Scale bar: 20 μm.

(each tarsus about 15 μm long), held at a distinct angle to tarsus, each with a small denticle; length III 60 μm; claw digitules both short and setose.

Abdomen: *Segments I–VII:* tubular ducts present in 2 lateral sclerotized plates (each about 140 μm long and 80 μm wide) on tergite VII, each duct 7 μm wide; ducts surrounded anteriorly by long flagellate setae (20 μm long). Dorsal abdominal setae and pores (totals): segments I–V 4 *hs*; VI 2 *hs*, *lp* absent dorsally; VII two sclerotized plates with about 20 *hs* and 40–45 tubular ducts on each plate, *hs* concentrated on anterior part of plates. Pleural setae: dorso- and ventropleural setae com-

bined on each side: I–VII 4–6 *hs* + 6–10 *lp* + 15 *smp*. Ventral abdominal setae mostly rather like fleshy setae, each 36–43 μm long (totals): I 5–7 setae + 1 *smp*; II: 6–9 setae + 1 *hs*; III–VI: 10–14 setae, 1 *hs*; VII: 16–19 setae, *lp* absent ventrally. Abdominal spiracles present on pleurites I–VII, each peritreme about 10 μm wide. *Segment VIII:* tergite with 2 pairs of *hs* dorsal abdominal setae, about 70 small locular pores and many *smp*; sternite with 15–20 ventral abdominal setae but no pores; margin rounded, with 4 *hs* pleural setae. **Genital segment:** Anus 45 μm wide, with 6 short *hs* on tergite IX; sternite IX with a strong median ridge, with 6–10 setae + 1 or 2 *smp* on each side. Penial sheath: length without segment IX 200 μm, with segment IX 265 μm; greatest width 135 μm; ventrally and laterally with a group of 9–15 *hs* on each side of anterior end of penial sheath; without minute setae posteriorly on either surface near apex. Aedeagus length about 203 μm.

Comments: This description is very similar to those of *Orthezia* sp. from Koteja (1986) and Hodgson and Foldi (2006). However, *Praelongorthezia praelonga* is here considered to have tergite VII divided into two sclerotized plates, each with a separate group of tubular ducts (fig. 3D).

Genus undetermined

Figure 11

Material Examined: U.S.A., Georgia, Spalding county, greenhouse, on *Sarracenia minor*, 15. vii. 1976, H.H. Tippins coll.: 1/1 ad male (in good condition), deposited at the USNM. (Labeled as *Orthezia ?graminicola*).

Description (as for family unless otherwise stated): *Mounted material:* Large, total body length 1.4 mm. Antennae nearly 1.3 times total body length, most segments approximately subequal in length. *Lp* each 9–12 μm wide, with 4–6 loculi; *smp* each about 1–2 μm wide, sparsely present throughout body. Abdomen with *lp* present only on pleurites; abdominal tergite VII with few tubular ducts.

Head: Shape as for family, wider than long, 285 μm wide, 264 μm long. Dorsally, dorsomedial part of epicranium with (on each side) 5 or 6 *hs* of rather variable length (20–30 μm), all flagellate, 3–6 *mcp*, *lp* absent. Laterally, compound eyes about 115 μm long, with about 110 ommatidia; ocelli 26–27 μm wide. Ventrally, ventromedial part of epicranium with (on each side) 6–9 *hs*, 2 or 3 *lp* + 1 or 2 *mcp*. **Antenna:** Total length 1.88 mm (ratio of total body length to antennal length 1:1.3). Scape: 80–84 μm long, 75–82 μm wide, each with 3 short *hs* + 1 or 2 minute pores ventrally and 1 *hs* + 1 minute pore dorsally. Pedicel: 64–68 μm long, 55–57 μm wide; each with 1 *fs*, 4 *hs*, 2 minute pores ventrally + 1 campaniform sensillum dorsally. Segments III–IX all shorter than other genera, those proximally about 37 μm wide, while apical segment only 18–24 μm wide: *fs* short, those on segment III 22–31 μm long, those on apical segment 27–35 μm long; lengths of segments (μm): III 263–279; IV 292–304; V 263–268; VI 243–271; VII 210–267 and VIII 176–199; approximate number of setae per segment: III–VIII with about 20–30 *fs* + 5–10 long capitate setae (about 50 μm); no bristlelike setae detected. Segment IX elongate, length 256 μm, with about 40 *fs* + 1 strong terminal but short bristle, about 15 μm long + 3 subapical capitate setae laterally near apex. **Thorax:** *Prothorax:* dorsally, posttergites each a small, lightly sclerotized, oval area situated mediolaterally. Pronotal setae: dorsally, 1 or 2 *hs* anterior propleural setae + 1 *lp* on shoulder; also with a group of posterior propleural

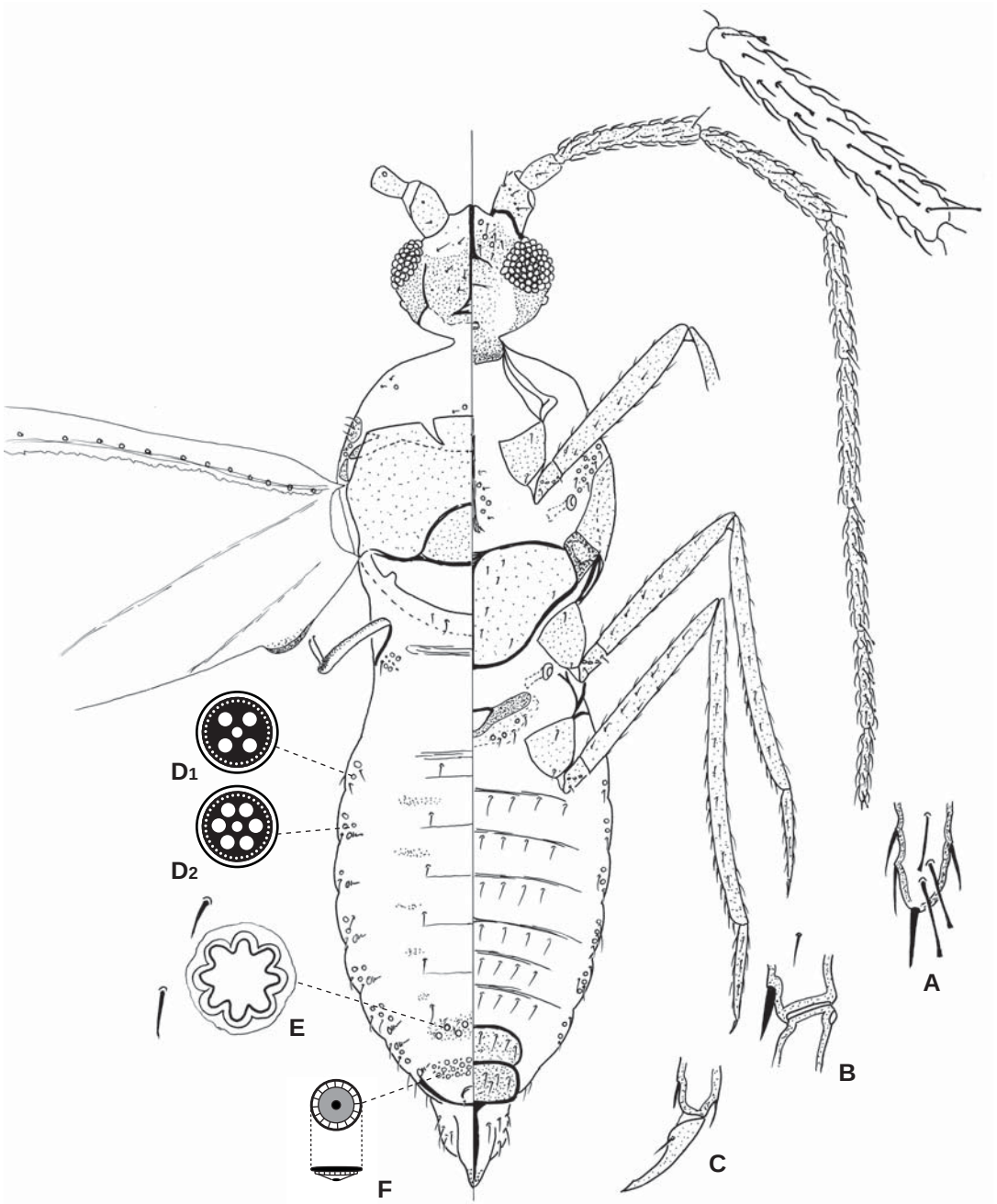

FIGURE 11. Genus undetermined. Adult male. **A.** Antennal apical seta. **B.** Tibiotarsal connection. **C.** Claw. **D1.** Loculate pore with four loculi. **D2.** Loculate pore with six loculi. **E.** Tubular duct with pheripheral setae. **F.** Small locular pore.

setae and pores just anterior to each prealare, extending ventrally and joining antemesospiracular setae: 1 *hs*, 5 *lp* + 10 *smp*. Ventrally, prosternum with 2–4 *hs* prosternal setae + 3 *lp* + 2 *smp* on each side. Anteprosternal setae absent. *Mesothorax:* dorsally, prescutum 120 μm long, 170

μm wide, without prescutal setae or pores. Distance between prescutum and scutellum medially 68 μm; scutal setae: with about 4 *hs* + 9 minute pores medially posterior to prescutum and with 1 *hs* near each lateral margin. Scutellum 152 μm wide, 105 μm long, without setae and *lp* but with 3 *smp.* Laterally, tegula with 3 *hs* tegular setae + 2 *smp*. Mesothoracic spiracle: peritreme almost round, width about 30 μm. Ventrally, basisternum, 434 μm wide, 195 μm long, with 10–12 *hs* basisternal setae distributed more or less throughout. *Metathorax:* dorsally, metatergal setae in a diffuse band of 1 or 2 *hs*. Dorsospiracular setae: 1 *hs* + 4 *lp* + 5 *smp*. Laterally, metathoracic spiracle: peritreme almost round, width 30 μm. Ventrally, metasternum with 2 *hs* + 3–5 *smp* on each side; occasionally with 2 *hs* anterior metasternal seta and 2 *hs* posterior metasternal setae + 4 *smp*. **Wings:** Forewings 1.6 mm long, about 550 μm wide (ratio of length to width 1:0.33; ratio of total body length to wing length 1:1.17), with subcostal ridge extending to less than ¾ of wing length, cubital ridge starting 1/8 of wing base; without alar setae but with a line of at least 27–31 circular sensoria along posterior margin of subcostal ridge, latter extending to 2/3 of total wing length. Hamulohalteres each about 212–247 μm long, 35–40 μm wide, with 2 apical hamuli, each 40–50 μm long. **Legs:** *fs* not separable from *hs*. Coxae: I 130–136; II 143–147; III 140-148 μm long; coxa III with about 7 setae + 5 *smp*. Trochanter + femur: I 450–457; II 406–416; III 457–459 μm long; trochanter III with about 3–5 setae; each trochanter with 3 campaniform sensilla arranged in a line on each side; femur III with about 55 *hs* + 11 *smp*. Tibiae: I 565–567; II 504–512; III 633 μm; tibia III with a total of about 70 *hs*, these becoming spurlike on distal 1/2 to 2/3 on ventral side + 7 *smp*; each distal spur 25–30 μm long. Tarsi: I 182; II 174–182; III 185–189 μm long (ratio of length of tibia III to length of tarsus III 1:0.3); tarsus III with about 25 *hs*, mainly spurlike. Claws fairly long and thin, much longer than width of tarsus (each tarsus about 20 μm wide); length: III 48 μm; claw digitules both short and spinose.

Abdomen: *Segments I–VII*: *Lp* entirely absent from tergites and sternites, a few present on all pleurites. Tubular ducts present across tergite VII, each duct 10 μm wide, 15 μm deep. Dorsal abdominal setae and pores (totals): segments I–V 2 *hs*; VI 2 *hs* + 2 *smp*; VII about 20 *hs* and 8 tubular ducts. Pleural setae: dorso- and ventropleural setae combined on each side: I–VII 2 *hs* + 2–4 *lp* + 2–5 *smp*; some setae rather long, up to 40 μm. Ventral abdominal setae mostly rather like *fs*, each 36–43 μm long (totals): I 5 *fs*; II 9 or 10 *fs*; III–VI 10 *fs*, 3 or 4 *smp*; VII about 15 *fs* + 4 *smp*. Abdominal spiracles present on anterodorsal part of pleurites I–VII, each peritreme about 10 μm wide. *Segment VIII:* tergite without *hs*; about 35 small locular pores (different from typical *lp*) and many *smp*; sternite with 10 ventral abdominal *hs* but pores absent; margin rounded, with 2 *hs* pleural setae, 0 *lp* + 0–2 *smp*. With a pair of abdominal spiracles similar to those on more anterior abdominal segments. **Genital segment:** Anus large (35 μm wide), sclerotized area along anterior margin with 1 or 2 *hs*. Penial sheath as broad as posterior margin of abdominal segment VIII, length without segment IX 154 μm, with segment IX 209 μm; greatest width 100 μm; ventrally and laterally with a group of 5 *hs* on each side of anterior end of penial sheath; without minute setae posteriorly, on either surface near apex. Aedeagus about 160 μm.

Comments: This single specimen was assigned to *Orthezia ?graminicola* based on an adult female with different collection information. This specimen, however, displays several unusual features not found in *Orthezia* species, namely: (1) very few tubular ducts on tergite VII, with very short setae (2) locular pores completely absent on both tergites and sternites, which also

have very few setae; (3) legs with notably few setae, and (4) antennae with long capitate setae, a character not previously observed in Ortheziidae.

DISCUSSION

Comparisons of Extant Genera

The above descriptions of the adult males of seven ortheziid species add significantly to the four detailed descriptions previously published (Koteja, 1986; Hodgson and Foldi, 2006). According to the latest revision of the family (Kozár, 2004), based on adult female morphology only, these 11 species belong to five genera: *Graminorthezia, Insignorthezia, Newsteadia, Orthezia,* and *Praelongorthezia*. From the above descriptions and those previously published, the following comments can be made:

(1) The study of male morphology supports the separation of species previously in *Orthezia* (Kozár, 2004) into the genera *Graminorthezia, Insignorthezia* and *Praelongorthezia*. This separation was made based on Morrison (1952) who recognized four informal groupings in *Orthezia*, which Kozár (2004) changed to the generic rank and classified into the tribe Ortheziini. This tribe was later found monophyletic based on female morphological characters (Vea and Grimaldi, 2012), but the relationships among the four genera are unresolved. Here, *Orthezia* and *Insignorthezia* are distinguished from *Praelongorthezia* and *Graminorthezia* by the absence of the median ridge on sternite IX. Knowledge of the male morphology of these four genera added to female morphology could help resolve their relationships.

(2) The large differences previously reported between *Newsteadia* and other genera, such as the absence of hamulohalteres, reduced number of ommatidia, long setae on the legs and the absence of small locular pores on tergite VIII, were also found in *Newsteadia americana*. Along with the morphology of adult females, this study confirms (until more adult males of *Newsteadia* are found) that *Newsteadia* is a distinct lineage within the Ortheziidae. Because *Newsteadia* currently comprises 58 species (Miller et al., 2013), descriptions of more adult males might help clarify the variation within the genus and possibly reveal characters dividing it into further groups, although the adult female morphology is relatively uniform (Kozár and Konczné Benedicty, 2000; Konczné Benedicty and Kozár, 2001; Miller and Kozár, 2002).

(3) The specimen labelled *Orthezia ?graminicola* (described here as "Genus undetermined") is peculiar in showing some important differences from other species of *Orthezia,* but also other genera in the family: "*Orthezia ?graminicola*" (a) lacks loculate pores (*lp*) on all sternites and tergites and has very few pores on the pleurites, (b) has fewer than 10 tubular ducts on tergite VII (significantly fewer than on all other males other than *Newsteadia*), (c) has antennal segments III to IX with modified setae resembling capitate setae (fig. 11), and (d) has significantly fewer setae on the legs than the other ortheziid species. It clearly differs therefore from all known male Ortheziidae. The only other slide associated with this specimen at the USNM with identical collection information is a male prepupa. A slide containing an adult female and labelled "*Orthezia graminicola*" with the same handwriting is also present in the USNM collection. All specimens just mentioned were collected in two

counties in the state of Georgia, USA. Additionally, the female specimen was collected on a date prior to that of the males, assuming that the subsequent identification of the male specimens was probably based only on the identical collection state. There is, therefore, real doubt as to whether these two lots of material are conspecific.

(4) Specimens described as "*Orthezia* sp." by Koteja (1986) and Hodgson and Foldi (2006) are also unlikely to belong to this genus. Both descriptions are based on specimens collected from Mexico and Colombia respectively. The specimens here described as *P. praelonga* were also collected in Colombia, but the present description differs from both Koteja's *Orthezia* sp. and Hodgson and Foldi's *Orthezia* sp. in that the tubular ducts on tergite VII are split into two sclerotized plates (a single transverse plate in the other descriptions) and loculate pores were not detected on the dorsal part of the epicranium (present in other descriptions). However, the significance of these differences is uncertain and, given the high overall similarity, it is likely that they are all *Praelongorthezia* species.

Fossils

The Ortheziidae has traditionally been considered as one of the oldest families of scale insects. Adult female ortheziids have been described from deposits as recent as Dominican amber (ca. 20 My), back to the early Cretaceous, the oldest being from Lebanese amber (see review in Vea and Grimaldi, 2012). To date, adult males have been described from only Lebanese and Baltic ambers. However, a newly discovered piece of Burmese amber, which includes embedded adult males, is under study (Vea and Grimaldi, in prep.)

The oldest adult male assigned to the Ortheziidae, *Cretorthezia hammanaica* (Koteja and Azar, 2008), was described from Early Cretaceous Lebanese amber and bears 10 antennal segments (only nine segments for Recent species), the apical antennal bristle is absent (present on all Recent species) but *C. hammanaica* has two longer flagellate setae on the antennal apex (Recent species bear a differentiated apical bristle), and the genital segment is particularly long compared with the other described Ortheziidae (fossil and Recent). Even though Koteja and Azar (2008) placed *Cretorthezia* in the Ortheziidae, they expressed doubts as to its relationships with other genera of the family. They also discussed only those characters unique to the genus ("small body size, markedly reduced wing venation, entirely reduced halters, long antennae bristles … conspicuous conical, acute penial sheath, about four times as long as wide at base" (Koteja and Azar, 2008: 137). Two other genera, *Palaeonewsteadia* (Koteja, 1987a) and *Protorthezia* (Koteja, 1987b), were described based on adult male inclusions, but from more recent Eocene-aged Baltic amber. *Palaeonewsteadia* was considered by Koteja to be a separate genus but closely related to the Recent *Newsteadia,* based on: (1) the small body size of *Newsteadia floccosa*, (2) the few large ommatidia in each compound eye, (3) the mesosternum with long setae, (4) the fused trochanter and femur, (5) the long setae on the legs, and (6) the narrow base of the hind wing. However, Koteja drew attention to several significant differences between the fossil and Recent genera, such as: (1) the presence of hamulohalteres in *Palaeonewsteadia* (absent in Recent *Newsteadia*) and (2) an anal fold on the forewing of the fossil (associated to the hamulohalteres). Differences in the genital segments were also noted by Koteja (1987a) who therefore assigned the fossil to a separate genus *Palaeonewsteadia*. Despite the assumption that those two genera are closely related, Hodgson and Hardy (2013) retrieved *Palae-*

onewsteadia as sister group to all Recent Ortheziidae. Further analyses involving the male Ortheziidae described here is necessary to reassess their relationships. A female specimen from Baltic amber was also described and assigned at that time to *Newsteadia* (Koteja and Żak-Ogaza, 1988). Although there is no possible way to associate specimens of different gender found in the same type of amber (except probably for syninclusions), one can say that the knowledge of the morphological variation of female *Newsteadia* is much better understood than that of the males, and so assignment to genera can be more easily made based on fossil female specimens.

Character Interpretation

The pores on tergite VIII (fig. 10A), described here as small locular pores, are different from the loculate pores on the rest of the abdomen. Hodgson and Foldi (2006) described them as "loculate pores" and Koteja (1986) as "multilocular pores"; both articles treated the pores on tergite VIII as identical to the one on the rest of the abdomen (fig. 10B). However, in CLSM images of this study (fig. 10A, B), these pores are smaller in diameter than the loculate pores and, although they seem to possess an external ring structure and are divided into numerous small compartments, there is no central loculus. These larger central loculi are present in all the loculate pores on the rest of the abdomen. On tergite VIII, these locular pores are present in relative abundance across all Ortheziidae bar *Newsteadia*, whereas typical loculate pores are present only marginally on this tergite (usually few, accompanied by flagellate setae).

Characteristic tubular ducts are always present in the Ortheziidae on tergite VII and are often located on a lightly more sclerotized plate (fig. 10C). These tubular ducts secrete wax filaments, hypothesized to help balance during flight (Gullan and Kosztarab, 1997). In the above specimens of *Praelongorthezia*, the sclerotized band is divided medially in two. Setae of variable lengths are often present around the tubular ducts, although their distribution differs between species. The structure of the tubular duct itself seems to be fairly constant across the family, but their frequency and distribution vary between species and genera. For instance, in *N. americana*, there is only a single row, with few ducts. The type of setae on the tubular duct plate also varies among species. In some cases, these setae are of one type, thin and very short, as in Genus undetermined (fig. 11E). In one particular case, however, two types can be found, with one very long and fleshy seta that appears slightly swollen near its middle and then tapers to its apex, and one shorter setae of regular shape, as seen in *Orthezia newcomeri* (fig 8E). Study of more species should clarify whether this character is taxonomically informative.

Hodgson and Foldi (2006) discussed the interpretation of the genital segment in comparison with aphids and concluded that the penial sheath, aedeagus, and basal rod were all derived from segment IX, with the penial sheath evolving from a paramerelike structure, somewhat similar to that in aphids. Koteja (1986) considered that sternite IX, which is complete in the genus *Orthezia,* is missing in *Newsteadia.* Koteja further hypothesized a transitional phase between the presence of a sternite IX (*Orthezia*) and the reduction of sternite IX in *Newsteadia* (by unsclerotization of the posterior margin): the presence of a sternite IX with a median ridge (*Praelongorthezia, Graminorthezia*), but with the median ridge remaining and becoming the basal rod. Following the same logic based on Ortheziidae, Hodgson hypothesizes a fusion of sternite IX to the penial sheath as seen in many other neococcoid families (Hodgson, personal

commun.). Although there is no direct evidence for this hypothesis, one could look at the relationships between the taxa involved in those three different structures. According to the latest phylogenetic assessment of the family (Vea and Grimaldi, 2012), a knowledge of the male morphological variation of the genital segments of *Arctorthezia* and other members related to *Newsteadia* would allow us to test this hypothesis and the origin of the basal rod (median ridge of sternite IX, according to Koteja [1986], present in *Graminorthezia* and *Praelongorthezia).* In general, given current knowledge, this would imply that the fusion of sternite IX with the penial sheath has occurred more than once in Coccoidea.

Because of their small size and the minute size of most of their important morphological characters, the study of scale insects is based on observation of material prepared for light compound microscopy. As such, specimens are meticulously prepared by clearing, staining, and fixing, before being mounted in Canada balsam. This reveals good detail of cuticular microstructures (ca. 100 μm and smaller in size) that are important for the taxonomy of this group. There is a very long tradition of using adult females for species-level descriptive work, based on their abundance, ease in finding them, and thus identification. Major collections of slide-mounted coccoids are comprised of perhaps ≥90%–95% females. Among the rare slide-mounted adult males, the oldest ones are often uncleared and without cuticular transparency. Therefore, they cannot be properly observed using a standard compound microscopy with transmitted light, despite their importance and rarity. Confocal scanning laser microscope (CSLM) is a promising alternative to the scanning electron microscope (SEM), as the former obtains highly resolved 3-D images of cuticular structures (Klaus et al., 2003; Böhm et al., 2011). Additionally, this method provides informative scans of opaque, slide-mounted material. In the present study, CSLM images were obtained of two slide mounts for rare Ortheziidae males, *Graminorthezia graminis* and *Orthezia annae*. These showed important structures in 3-D, revealing characters that were entirely obscured under full-spectrum transmitted light (figs. 1 and 6). For instance, in *Graminorthezia graminis*, the median ridge on sternite IX could be observed using CLSM, but was invisible using light microscopy. However, the visibility of cuticular microstructures was limited with CLSM and many minute pores and setae could not be observed, although some abdominal pores and setae could be made faintly visible by scrolling back and forth between image layers. Finally, CLSM scans of properly cleared specimens provided very clear images (fig. 10) and allowed us to observe the structural differences between loculate and small locular pores on the abdomen (fig. 10A, B).

CONCLUSION

The present study augments our knowledge of male morphology in the Ortheziidae by providing detailed descriptions of seven more species, representing five genera. To date, 11 morpho groups have had their males described in this family. Very few mounted specimens of adult males are available in collections. Additionally, when accessible, older slide mounts are usually uncleared, which makes any cuticular observation challenging. Given the rarity of collected males in this family and thus the high value of mounted specimens in collections, we assessed the use of CLSM as a nondestructive method to increase observability of structures for such cases (see *G. graminis* and *O. annae*). Despite some improvement with this technique

(figs. 1, 6), some cuticular characters, principally pores, could not be observed. Because of the difficulty of collecting adult males in natural habitats, the Ortheziidae presents a particular challenge as, except for a few species, most taxa are found in the leaf litter. Although species identification is based solely on adult female morphology, unidentified adult males in this family should be morphologically described in detail, even without immediate species female association. Such work will allow better understanding of morphological variation within the family, for phylogenetic purposes. Additionally, obtaining DNA barcodes for newly collected specimens should enable subsequent associations with their female counterparts.

ACKNOWLEDGMENTS

I would like to thank Chris Hodgson for providing the drawing and description of *Newsteadia americana*, and for all discussions regarding adult male morphology of scale insects in general and of the Ortheziidae in particular. I am also grateful to Dug Miller and Jon Martin for assisting with material loans from the scale insect collections of USNM (housed at USDA-Beltsville, MD) and the BNHM, London respectively; David Grimaldi and R. Toby Schuh for their valuable comments at different stages of this manuscript; James Thostenson for assistance with the CSLM images at the Microscopy and Imaging Facility of the AMNH. This project was funded by the Richard Gilder Graduate School and a National Science Foundation Doctoral Dissertation Improvement Grant # 1209870.

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