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***Gadigaleyrodes froggatti*, a new genus and species of whitefly (Hemiptera: Aleyrodidae) from Australia**

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Abstract

A new monotypic genus of whiteflies (Aleyrodidae), *Gadigaleyrodes* **gen.n.**, is described and illustrated for *G. froggatti* **sp.n.** from New South Wales, Australia. Specimens were collected by W. W. Froggatt in 1899 on *Syncarpia glomulifera*, and subsequently by P. S. Gillespie on an unknown climbing plant. The genus has unusual morphological features with traits common to both Aleurodicinae and Aleyrodinae. The subfamily placement is discussed, and a key provided to discriminate this taxon from similar whitefly genera in Australia.

Key words: Aleurodicinae, Aleyrodinae, Australia, California Academy of Sciences, Froggatt, Sydney Botanical Gardens, taxonomy, key

Introduction

This paper describes and documents a previously undescribed species found in New South Wales, Australia. It was first collected in 1899 by Walter Wilson Froggatt in the Royal Botanic Gardens in Sydney, Australia. Froggatt spent much of his entomological life as chief entomologist for New South Wales Department of Agriculture (now ASCU) (McDonald, 1981). His taxonomic work was mainly on Coccoidea describing only two species of whiteflies (Martin, 1999). Froggatt exchanged insect samples with various entomologists around the world subsequently donating the sample of the new species described below to the California Academy of Sciences Collection (CASC). The first author of this paper recognized in 2008 that this sample possibly represented an undescribed genus and species and in the same year the second author collected a single post-emergence pupal case of the same species in New South Wales.

Dumbleton (1956) considered the Australian Aleyrodidae fauna overlooked recognizing only 29 described species. In contrast, Martin (1999) treated 104 described species from Australia and mentioned 66 undescribed taxa. Gillespie (2006) described a number of unusual whitefly taxa from Australia which do not clearly conform to current subfamily classifications. The new taxon described here exhibits certain morphological characteristics that are unlike that of any other genus of whiteflies, and the host plant has not previously been known to support any whitefly species.

Material and methods

Puparia were slide mounted using a method modified from Dooley *et al.* (2010). They were soaked in 5% KOH for 24–48 hours, placed in water to remove the potassium hydroxide, then transferred into Essig's aphid fluid for clearing (20 parts of lactic acid, 4 parts of glacial acetic acid, 2 parts of phenol, and 1 part of water). Two drops of double stain (lignin pink, acid fuchsin, lactic acid, and phenol) were added to Essig's aphid fluid for 10–15 minutes

to stain the specimens. Puparia were transferred to 70% ethanol for 15 minutes and then into 90% ethanol for 10 minutes. Specimens were transferred to clove oil for 15 minutes prior to slide mounting in Canada balsam. Microscopy was performed using Nikon SMZ 1500 wide field stereo and Nikon Eclipse 80i compound microscopes. Images and measurements were taken using a Nikon DS-Fi1 Digital Image camera. Measurements in microns were taken using Nikon DS-L2 software (version 301.1001.0295.070216).

Measurements in microns were taken from the holotype and 10 paratypes with means indicated in brackets []. The length of the pupal case is determined to be the longest distance from the anterior margin of the pupal case to the most posterior margin between the caudal setae. The width of the pupal case is determined to be the widest diameter from the puparial margin (adjacent to the transverse suture). The length of the vasiform orifice is the longitudinal diameter of the opening and the width is the transverse diameter at its widest point both bordering the ring enclosing the vasiform orifice. The distance from the vasiform orifice to the caudal margin is the distance from the posterior border of the orifice to the posterior margin equidistant from the position of the caudal setal bases. The length of the setae is the distance from the center of the setal pinaculum to the acute apex. The description is based on the puparial morphology as no adults are known. The morphological terms used here follow that of Dooley *et al.* (2010). Users of the key to genera below are referred to Martin (1999) for morphological details of whitefly genera in Australia

Abbreviations (adapted from Gill 2012). Puparium morphology: A1–A8 (abdominal segments 1 through 8), C1 (cephalon), T1 (prothorax = thoracic segment 1), T2 (mesothorax = thoracic segment 2), and T3 (metathorax = thoracic segment 3). Chaetotaxy. AMS (cephalothoracic marginal setae), C1SMdS = dorsal anterior cephalic submedian seta, C2SMdS = dorsal posterior cephalic submedian seta (immediately anterior to rostrum), T1SMdS = dorsal prothoracic submedian setae, T2SMdS = dorsal mesothoracic submedian setae, T3SMdS = dorsal metathoracic submedian setae, PSMdS(n) where n = dorsal submedian abdominal seta on A1 thru A8, PSMdS(8) = posterior dorsal submedian A-8 seta either anterior to or posterior of the vasiform orifice, PMS = posterior marginal seta, PSMS = posterior submarginal seta, PVSMDs = ventral submedian A-8 seta, and CS = caudal setae.

Depositories. BMNH (The Natural History Museum), London, England. CASC (California Academy of Sciences Collection), San Francisco, California, USA. CDFA (California State Collection of Arthropods - California Department of Food and Agriculture), Sacramento, California, USA. PPQC (Plant Protection and Quarantine Collection - United States Department of Agriculture-APHIS-Plant Protection and Quarantine), South San Francisco, California, USA. USNM (United States Natural History Museum - National Coccoidea Collection), Beltsville, Maryland, USA.

Key to puparia of whitefly genera in Australia similar to *Gadigaleyrodes*

1. Abdominal intersegmental sutures (Figs 3, 7) well defined and spanning 3/4 or more of the width of puparium. 2
 - Abdominal intersegmental sutures absent or less well defined and spanning less than three quarters of puparium width most other Australian Aleyrodidae
2. Intersegmental sutures approaching but not reaching the lateral margin.
 - *Aleuroduplidens*; *Chitonaleyrodes*; *Cryptolingula*; *Pseudozaphanera*
- Intersegmental sutures reaching the lateral margin (Fig. 7) 3
3. More than 18 pairs of robust marginal setae (Figs 3, 7–9); 2 pairs of cephalic submedian setae present (Fig. 10); lingula included within vasiform orifice (Fig. 13); leg segments not sclerotized. ***Gadigaleyrodes* gen n.**
 - Less than 10 pairs of minute marginal setae; cephalic submedian setae absent; lingula included within or extending beyond vasiform orifice; leg segments sclerotized or not 4
4. Legs with two sclerotized segments, lingula extending beyond vasiform orifice margin *Pseudosynaleurodicus*
 - Legs with two unsclerotized segments: lingula included within vasiform orifice *Gagudjuia*

Gadigaleyrodes gen. n.

Type species: *Gadigaleyrodes froggatti* sp. n.

Puparium. Oval shaped measuring 1279–1610 [1371] long by 939–1219 [1010] wide with the holotype 1588 long by 1194 wide. Cephalic margin straight narrowing to an obtuse angle medially; caudal margin becoming slightly concave between the pair of marginal caudal setae (Figs 1, 3, 7)). Margin smooth with slightly roughened and

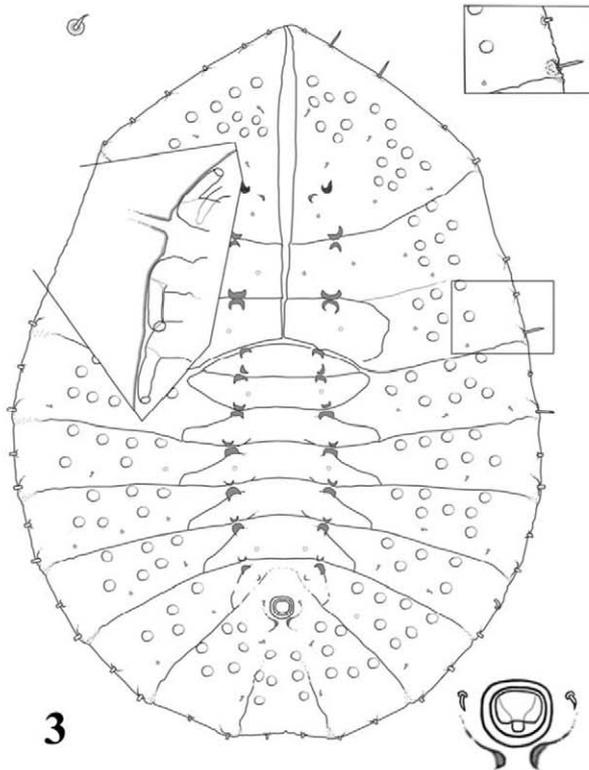
expanded marginal areas at posterior margin of each segment immediately mesad of intersegmental sutures, particularly noticeable in abdominal segments (Figs 3, 9). *Dorsum*. Longitudinal and transverse sutures on dorsum terminate at margin; pro-mesothoracic suture terminates at margin anteriorly to a position opposite rostrum; meso-metathoracic suture terminates at subdorsum. Abdominal rhachis present with lateral arms extending submedially, coalescing with pronounced intersegmental sutures on III–VIII, each rhachis reaching margin (Figs 1, 3–6). Submedian tubercles on dorsum present from cephalothorax extending in a series to abdominal segment VIII (Figs 5, 6). Median width of abdominal segment VII much narrower than preceding segments. Vasiform orifice cordate (Figs 14, 15), operculum (Fig. 15) covering most of orifice and situated 5–6 times the width of the orifice from posterior margin. Lingula (Fig. 13) included within vasiform orifice with head rounded and partially exposed beyond operculum. *Chaetotaxy*. Cephalothoracic and abdominal setae present on submedian, subdorsal, submarginal and pupal case margin. Two pairs of dorsal submedian cephalic setae and one pair each on T1, T2, and T3 present (Fig. 5). Meso-metathoracic legs with one ventral seta each on basal segment of leg (Fig. 17). Abdominal submedian setae on abdominal A1, A3, A5, and A7 absent. Pairs of dorsal submedian abdominal setae present on A2, A4, A6, and A8 (P(n) SmdS where n = 2, 4, 6, 8). Two pairs of P(8)SmdS present with one pair directly anterior and one directly posterior to the vasiform orifice. Also one ventral pair, PVSMdS, of submedian setae (Fig. 14) present lateral to midpoint of vasiform orifice. Margin with more than 20 pairs of evenly distributed setae; submargin with one dorsal abdominal seta paired between each lateral arm of rhachis from A1 to A8; subdorsum with two abdominal setae between each lateral arm of rhachis from A1 to A7 (one inside and one outside of the ventral fold). (Figs 3, 6). *Venter*. Legs two segmented, suture between leg segments visible only under high magnification; leg segments angular with their outer lateral angle oriented downward and slightly toward the median, each terminating in adhesive pad (Figs 3, 16, 18); antennae short, overlapping prothoracic leg segment but not extending beyond leg margin (Figs 16, 18). Distinctive ventral margin-concentric fold present slightly distal to legs and at some distance from margin. In vivo, the external margin and the concentric and radiating folds are waxy (Fig. 2).

Etymology. The genus is named in honor of the Gadigal tribe, the indigenous inhabitants of the Sydney basin, the area from which the original specimens were collected.

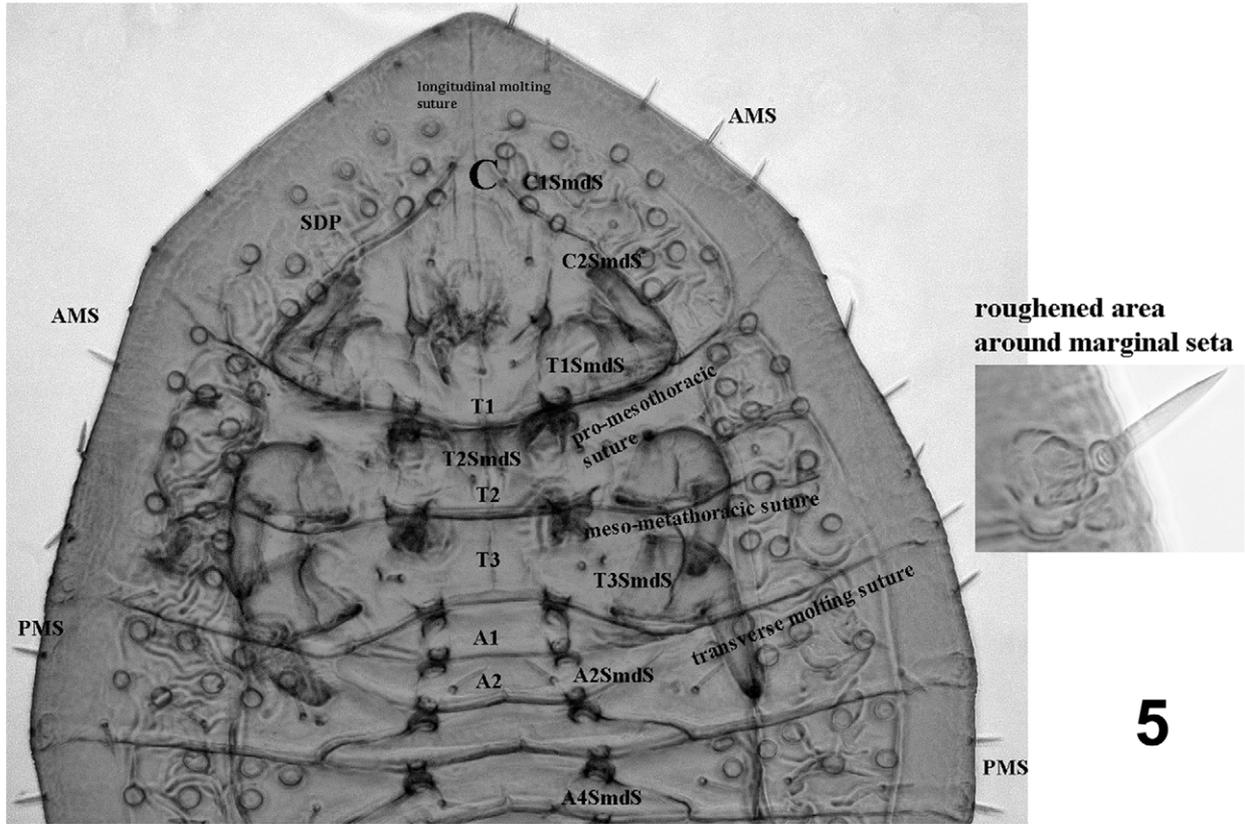
Comments. This genus is erected to contain a single unusual new species. It is remarkable for the well-defined segmental sutures including the rhachis, subdorsal papillae, submedian tubercles, two segmented legs, ventral fold, and the setation on the dorsum, venter, margin of the pupal case, subdorsum, and submedian. The unusual ventral fold appears to enclose and protect the legs. The variation in length, diameter, and structure of the dorsal and ventral setae and papillae into different sizes may be the result of effects of host substrates. This species appears to be quite uncommon, and was not found in a repeated search at both collection sites.

Gadigaleyrodes froggatti sp. n.

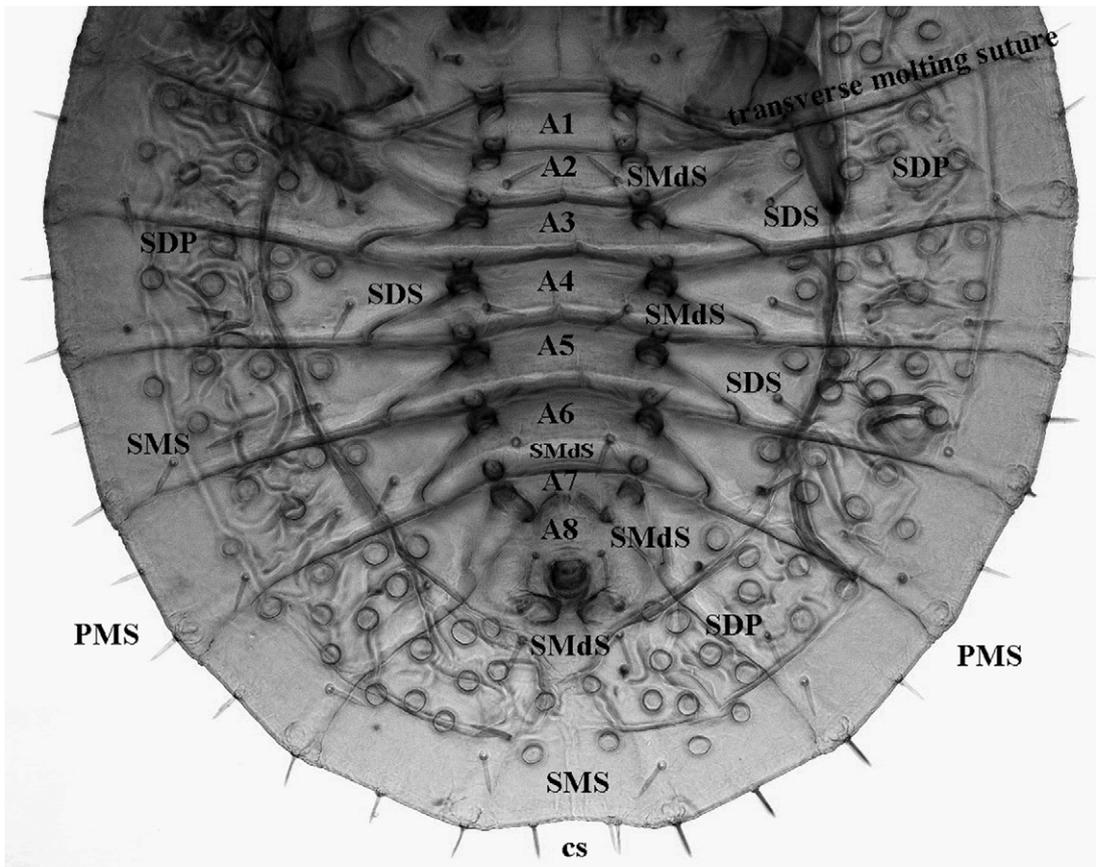
Puparium habitus. Thin veneer of clear wax present on dorsum but unapparent in life. Marginal wax not obvious, but whitish wax present ventrally (Fig. 2); puparium found on upper side of leaf; puparium oval shaped, pale brown with two pigmented areas medially, one from mesothoracic to metathoracic segments, and one on abdominal segments V and VI (Fig. 1). *Slide mounted puparium*. Puparium 1279–1610 [1371] long by 939–1219 [1010] wide with the holotype 1588 long by 1194 wide. Cephalic margin narrows, caudal margin slightly concave (Figs 1–4) between paired caudal setae (CS). Margin apparently smooth except for roughened or corrugated area mesad of junction of lateral margin and segmental suture, at base of associated marginal seta (Figs 3, 9). Under high magnification, margin shallowly and inconsistently crenulate. Tracheal and caudal clefts undifferentiated ventrally and dorsally. *Dorsum*. (Figs 1, 5) longitudinal molting suture terminates at the anterior margin of the pupal case. The transverse molting suture terminates at corrugated area mesad of or adjacent to last thoracic marginal seta. Pro-mesothoracic suture terminates at corrugated area mesad of marginal seta, arching anterior to opposite the rostrum (Fig. 5); meso-metathoracic suture terminates just beyond second pair of legs; transverse suture terminates at corrugated area mesad of associated marginal seta, or margin slightly arching upwards (Figs 3, 5, 9). Rhachis present with lateral arms coalescing with intersegmental sutures and these reaching margin. Subdorsum punctuated by wide band of rimmed, subcircular flat papillae (Figs 3, 5, 6, 8) from cephalon to below vasiform orifice. Cephalothoracic papillae numbering from 19–31 [26] on each side with the holotype numbering 24 and 28;



FIGURES 1–4. *Gadigaleyrodes froggatti* sp. n. puparium: 1, habitus dorsal; 2, habitus ventral; 3, illustration venter = cutaway, inset margin detail, vasiform orifice, dorsal seta; 4, habitus dorsal. Illustrations and images by Dr. Peter Gillespie.

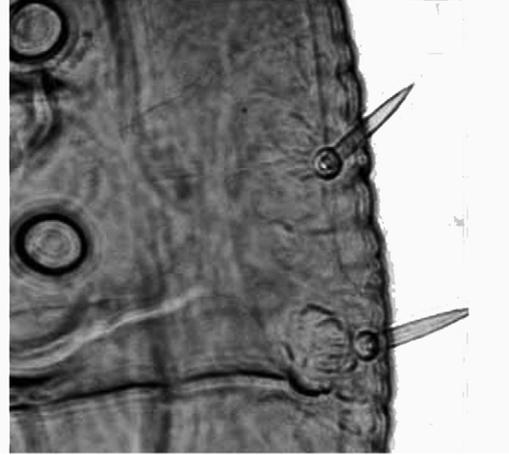
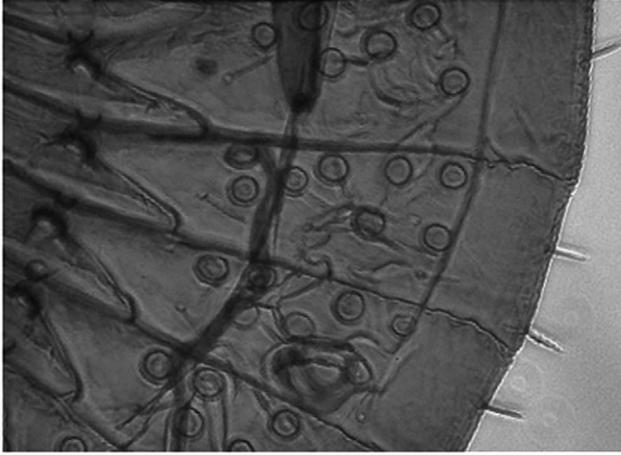


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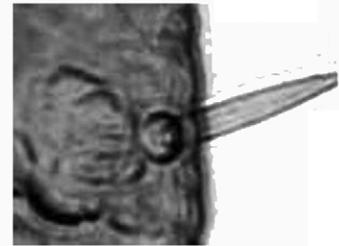
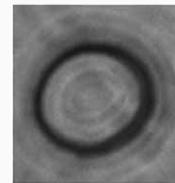
FIGURES 5–6. *Gadigaleyrodes froggatti* sp. n. Dorsum of slide mounted puparium (holotype): 5, cephalothorax; 6, abdomen (images by John Dooley).



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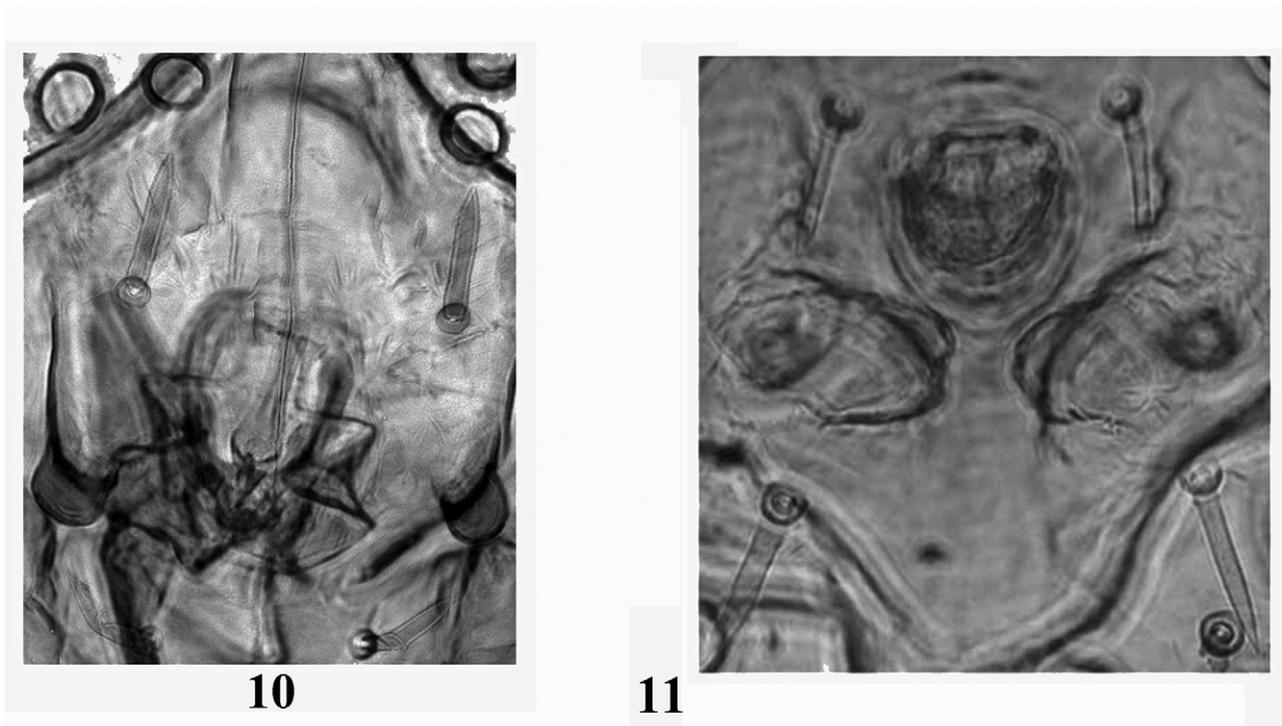


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FIGURES 7–9. *Gadigaleyrodes froggatti* sp. n. slide mounted puparium (holotype): 7, dorsal slide mount; 8, rachis, papillae, subdorsal fold, and marginal setae; 9, cuticle margin showing enlargement of roughened area surrounding marginal seta (images by John Dooley).



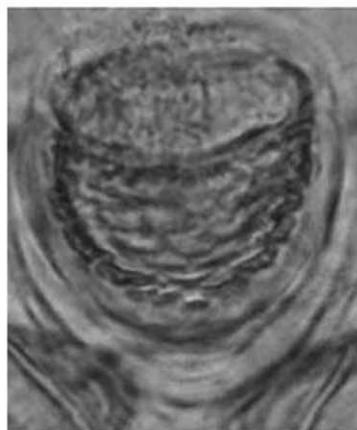
FIGURES 10–11. *Gadigaleyrodes froggatti* sp. n. Rostrum and vasiform orifice areas 10, rostrum with anterior and posterior dorsal submedian setae; 11, vasiform orifice with anterior and posterior dorsal submedian setae (images by John Dooley).

abdominal papillae numbering from 26–44 [33] on each side of the abdomen with the holotype numbering 41 and 44 papillae. Diameter of papillae, taken from 12 samples each of the subdorsal, cephalothoracic and abdominal papillae, from holotype and 3 paratypes: cephalothoracic papillae range from 26–36 [29] wide and the abdominal papillae from 26–40 [32] wide; holotype cephalothoracic papillae range from 26–34 wide and the abdominal papillae measuring 26–40 wide. Submedian tubercles present on cephalothorax and the 8 abdominal segments (Figs 5–6). Cephalon with pair of submedian tubercles posterior to C2SmdS setae; pair of tubercles along promesothoracic suture of T1; T2 through A7 segments with an anterior and posterior pair of submedian tubercles; A8 with pair of tubercles posterior and lateral to the vasiform orifice. *Vasiform orifice*. cordate 38–50 [43] long by 32–47 with holotype 47 long by 32 wide; with transverse scallops along the lateral margin to base of orifice (Figs 3, 7, 9, 10); operculum cordate 27–37 long [31] by 31–41 wide [36] with the holotype 32 long by 37 wide, covering most of orifice. Lingula included with vasiform orifice; Lingula head small, rounded, partially exposed beyond operculum. *Chaetotaxy* (Fig. 3, 5, 6). Lateral margin of pupal case with evenly distributed, stout lanceolate setae (Figs 5, 6, 9) ranging in numbers 9–13 [10] setae (AMS) on each side from C1 to T3 with the holotype having 21 on both sides; Two pairs of cephalic submedian setae present: C1SmdS 27–40 [34] long broken off of holotype and C2SmdS (located anterior to the mouth parts) 25–54 [43] long with the holotype 54 and 50 long. Three pairs of thoracic submedian setae present: T1SmdS 30–46 [36] long with holotype pair 40 and 46 long; T2SmdS is 36–51 [41] long with holotype 51; and T3SmdS 35–46 [41] with the holotype 35 long. Cephalothoracic subdorsal and submarginal setae number 3–10 [6] on each side with holotype numbering 4 setae on one side and 6 on the other side. Posterior (abdominal) marginal setae (PMS) 7–12 [10] setae on each side from A1 to A8 excluding caudal setae (CS) with holotype having 12 pairs of setae. Abdominal submedian setae on abdominal A1, A3, A5, and A7 absent. Pairs of submedian abdominal setae present A2, A4, A6, and A8 (P(n)SmdS where n = 2,4,6,8): P2SmdS 30–51 [42] with holotype 51 long, P4SmdS 36–48 [42] with holotype 47 and 48, P6SmdS 32–45 [39] with holotype 45, P8SmdS(a) 23–39 [34] anterolateral to the vasiform orifice with holotype each 39 long, and P8SmdS(b) 31–47 [38] posterolateral to the vasiform orifice with holotype each 47 long. CS (caudal setae) 27 to 43 [36] with holotype 41 and 42 long (Fig 6). A pair of ventral submedian setae on A8 (P8VSMdS) lateral to midpoint of vasiform orifice 50–126 long (Fig. 12) [84] with the holotype 75 and 126 long. *Venter* (Figs 3, 8, 12–14). Cuticle smooth except apical submargin which has a narrow band with a finely stippled pattern. A broad sub medial margin-concentric ventral fold is present, more prominent laterally and interrupted below vasiform orifice, at

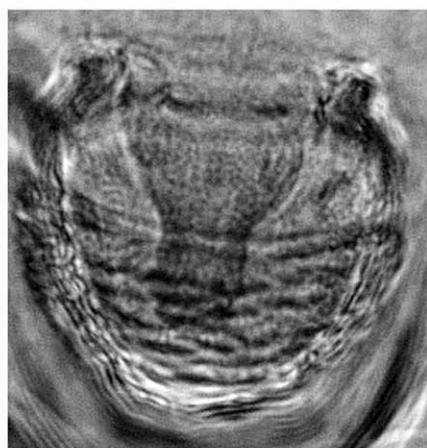
mesothoracic and longitudinal molting suture; ventral fold patterned internally. Legs bi-segmented with apical adhesive pad (Figs 16–18); basal segment of meso- and metathoracic legs each armed with 1 bristle-like seta with length 1/3 the width of basal segment (Fig. 17). Antenna parallel to and subequal to length of second segment of prothoracic leg overlapping first segment.



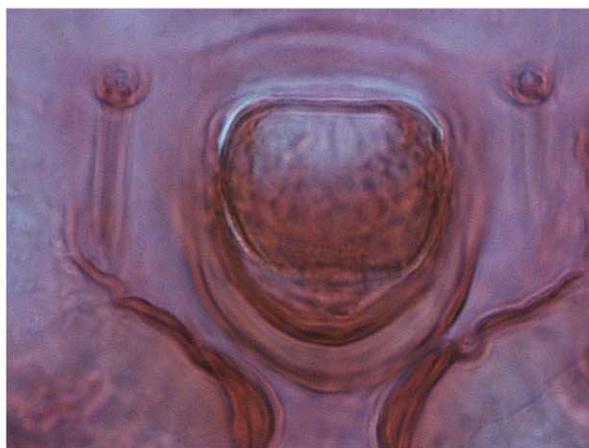
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FIGURES 12–15, *Gadigaleyrodes froggatti* sp. n. Vasiform orifice with lingula and operculum. 12, vasiform orifice with ventral lateral setae; 13, lingula; 14, venter of vasiform orifice; 15, operculum covering vasiform orifice (images by John Dooley).

Etymology. This species is named in honor of the original collector, William Wallace Froggatt.

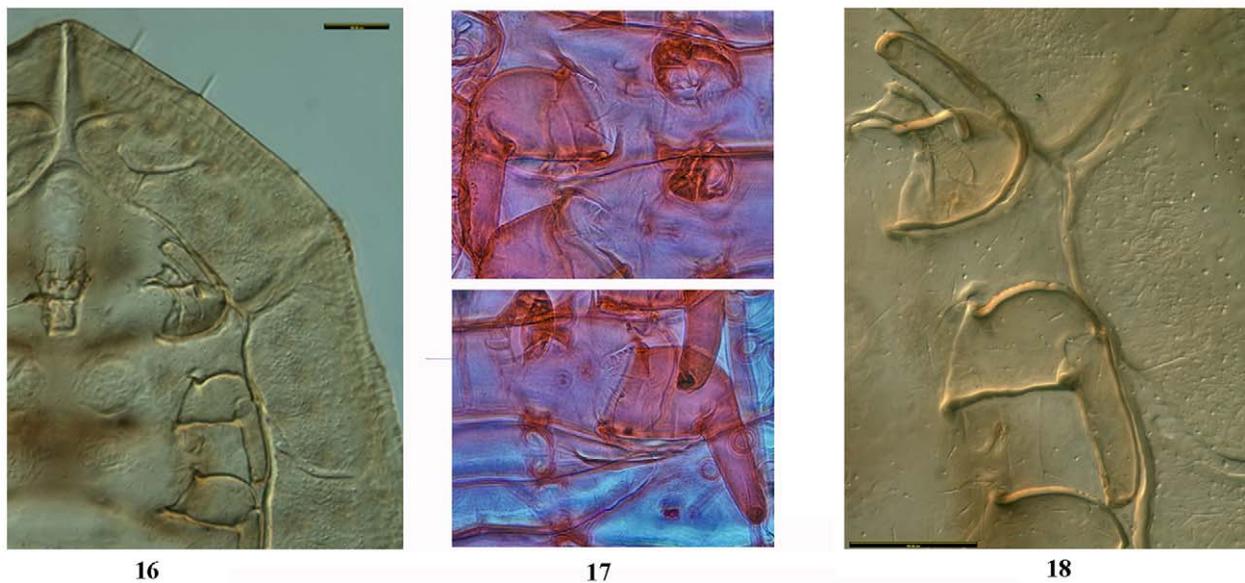
Hosts. *Syncarpia glomulifera* (Myrtaceae); also an unknown rainforest climber.

Material examined: Australia, New South Wales: Holotype puparium slide, “*Aleurodes* sp.”/ “*Syncarpia laurifol*”/ “Bot Gard. Sydney”/ “21.12.[18]99” (apwca091012638002—CASC).

Paratypes: 20 puparia on 14 slides same data as holotype, 4 puparia on 3 slides (ASCU), 2 puparia on 1 slide (BMNH), 7 puparia on 5 slides (CASC), 1 puparium slide (CDFA), 4 puparia on 2 slides (PPQC), 1 puparium slide (USNM); 1 puparium slide, Unknown host (climber), Jerusalem Falls, Barrington Tops National Park, NSW, 32.245618° S 151.724361° E, elev 347m, 23 Jan 2008, P.S. Gillespie (ASCT00167723—ASCU)

Comments. Despite the slightly damaged label, the handwriting is clearly that of Froggatt (P. Gillespie pers. obs.) and the “Bot Gard. Sydney” he refers to is clearly (the now) Royal Botanic Gardens, in Sydney central district on the shore between the current Sydney harbor bridge and Opera house. Many other specimens similarly labeled are in the collections of ASCU and Froggatt’s interest in these gardens (Froggatt, 1932) showed he liked to collect

there. The name of the host, “*Syncarpia laurifol*”, is presumably a misspelling of *Syncarpia laurifolia*, a junior synonym of *Syncarpia glomulifera*.



FIGURES 16–18. *Gadigaleyrodes froggatti* sp. n. Leg structures: 16, plate by Dr. Peter Gillespie; 17, showing leg setae on basal end of meso and metathoracic legs (images by John Dooley); 18, plate by Dr. Peter Gillespie.

Discussion

Whiteflies comprise a monophyletic family of over 1400 species with three extant subfamilies including the Aleurodicinae and Aleyrodinae (both occurring in Australia), and the Udamoselinae known only from two species in the New World (Martin, 2007), and one fossil subfamily, Bernaeinae (Grimaldi & Engel, 2005). Only adults are known from the latter two subfamilies, whereas species in the former two subfamilies are described primarily from puparial characters. The larger size of adults in the Aleurodicinae, and the greater number of wing veins in their larger forewings, serves to provide one useful character for discriminating the latter two subfamilies (Martin, 2007). Unfortunately, no adults of this new taxon are known, nor is molecular data currently available that might provide further clues to refine its placement. Historically, this is an important find, showing that new species can be described from over one hundred year old specimens that have been deposited in a collection, and highlights the value of vouchering material

Puparial character relationships

Legs of puparia in the two sub-families differ as follows:

Aleurodicinae—legs 2-segmented with apical segment directed downward and ending in a claw, or a collar with an apical seta, terminal tarsal appendages absent.

Aleyrodinae—legs 1- or 2-segmented, with apical segment directed to midline, terminal tarsal appendages present in form of adhesive pads.

Gadigaleyrodes and *Gagudjuia* Martin (Martin, 1999) share with Aleurodicinae the presence of 2-segmented legs that are directed downward. However, these two genera are tentatively placed within the Aleyrodinae, and they share the exaggerated segmentation where most intersegmental sutures terminate at the margin.

Acknowledgments

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