Mite parasitism of moths: Examples of paleosymbiosis in Dominican amber

G. O. Poinar Jr[a], A. E. Treat[b] and R. V. Southcott[c]

[a]*Department of Entomological Sciences, University of California, Berkeley (California 94720, USA),* [b]*Jerusalem Road, P.O. Box 393, Tyringham (Massachusetts 01264, USA), and* [c]*2 Taylors Road, Mitcham, South Australia 5062 (Australia)*

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Summary. Two adult moths (families Gracillariidae and Tineidae) in Dominican amber each contained a pair of larval parasitic mites attached to their bodies. The larval mites were identified as belonging to the family Erythraeidae and represent the first fossil evidence of moths parasitized by mites. Phylogenic and evolutionary implications of this find are discussed in light of similar extant associations.

Key words. Moth; Gracillariidae; Tineidae; fossil; mite; Erythraeidae.

Cases of paleosymbiosis (examples of symbiosis preserved in the fossil record) are uncommon. Examples of mite parasitism of insects in the fossil record are very rare, and up to the present have been restricted to examples of water mites attached to an adult caddisfly (Trichoptera)[1], and an adult midge (Chironomidae)[2] in Baltic amber, mites attached to an adult midge (Chironomidae) in Dominican amber[3] and a mite attached to an adult *Dasyhelea* (Ceratopogonidae) from the Miocene Barstow formation of the Mojave Desert[4]. The present paper presents the first fossil evidence of moths parasitized by mites.

Two separate pieces of amber from the Dominican Republic were observed to contain adult moths with parasitic mites attached to their abdomens. Specimen No. S-1-23 contained a tineid moth with two mites lodged under its left femur III (moth identified by John de Benedictus). Specimen No. S-1-24 contained a gracillariid moth with two mites attached to the dorsal side of the abdomen (moth identified by Jerry Powell). Both specimens came from amber mines located in the Cordillera Septentrional between Santiago and Puerto Plata in the northern portion of the Dominican Republic. These mines are in the Altamira facies of the El Mamey Formation (Upper Eocene), which is shale-sandstone interspersed with a conglomerate of well-rounded pebbles[5]. Differences in the magnitudes of absorption peaks in nuclear magnetic resonance spectra of the exo-methylene group of amber from different mines in the Dominican Republic were used to calibrate the ages of the various mines[6] using the 20–23 million year age of the Palo Alto mine as a standard[7]. The age of the mines in that region of the country varied from 25–40 million years.

The amber containing the fossils had all of the visual characteristics of natural Dominican amber and a series of chemical and physical tests[8] performed on the pieces verified that they were authentic. The specimens are maintained in the Poinar collection of Dominican amber at the University of California at Berkeley.

The mites on both moths (tineid and gracillariid) were well fed larvae of the family Erythraeidae. All four mites were moderate-sized brown larvae (the normal life color of larval erythraeid mites is bright red), with idiosoma lengths 260–350 µm; leg III of one mite on the tineid moth had an estimated length of 630 µm. Identification was based on the characteristics of the body (idiosoma) and the long thin legs and tarsi. The latter characters rule out other Parasitengona, including the Trombidioidea and the erythraeoid family Smarididae, whose larvae have chunkier tarsi[9, 10].

Generic identification within the Erythraeidae is not possible, as it would be necessary to observe the presently obscured details of the prodorsal scutum and eyes, as well as the fine detail of the pedotarsal claws, etc.

All of the erythraeid larvae were engorged (figs 1–5). This was especially noticeable on the two specimens attached to the gracillariid moth since they were more exposed than the others.

This study presents the first fossil evidence of parasitic mites on Lepidoptera. The geological history of erythraeoid mites was previously limited to a single individual in Canadian amber, originally noted by Ewing but later described as *Proterythraeus southcotti* Vercammen-Grandjean[11, 12]. This is an unfed specimen which has no physical contact with any other insect, thus a parasitic mode of life cannot be established. Nevertheless its similarity to modern larval Erythraeidae is so great that a parasitic mode of life for the larval *Proterythraeus* cannot be doubted.

Like other Parasitengona, erythraeids are typically parasitic in their larval stage only[13]. Their bright red, orange, or yellow larvae are often found singly or in small numbers attached at sometimes indiscriminate sites on terrestrial and aerial insects and other arthropods, where they slowly become engorged with hemolymph, seemingly with little injury to the host. When fully fed, the six-legged larvae leave the host and pass the rest of their active lives as predators. In the specimens here reported the position of the mites does not permit a generic or even a subfamilial determination. Eyes, dorsal scuta, and gnathosomal details are obscure in the gracillariid parasites, although the mouthparts of one appear to be in contact with the host's integument. On the tineid parasites these parts are totally hidden from view, and while some setae are visible on the legs and idiosoma they are not adequate for comparison with those of *Protery-*

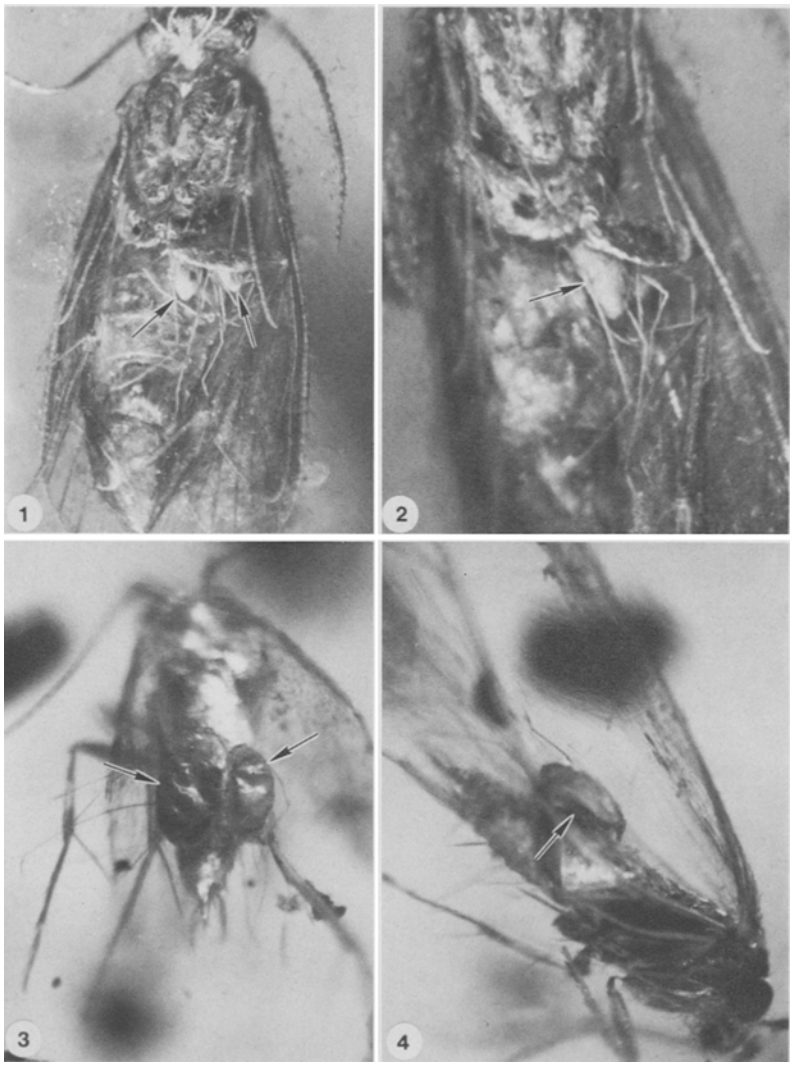

Figure 1. Ventral view of a tineid moth in Dominican amber showing the dorsum of two erythraeid mites (arrows) lodged under the left femur III.

Figure 2. Ventral-lateral view of a tineid moth in Dominican amber showing the lateral view of one (arrow) of the two erythraeid mites lodged under the left femur III.

Figure 3. Dorsal view of a gracillariid moth in Dominican amber with two engorged erythraeid mites (arrows) attached to the abdomen.

Figure 4. Lateral view of a gracillariid moth in Dominican amber with one (arrow) of the two erythraeid mites attached to the abdominal tergites.

Figure 5. Two partially engorged fossil parasitic erythraeid mites in relation to their gracillariid host. (R.V.S.)

thraeus southcotti. Tarsal claws cannot be resolved at accessible magnifications.

The earliest known fossil mite, the Devonian *Protacarus crani* Hirst, is possibly related to modern Actinedida, but was almost surely not parasitic. While acarine parasitism on insects may have evolved during the Paleozoic Era, evidence for it has not yet appeared in the fossil record. At what stage parasitism developed as a mode of life in the larvae of the Trombidiformes (Actinedida of some authors) is not known, in view of the rarity of fossils. Most mites of this group are predatory in both their larval and post-larval instars; a few are phytophagous. It may be surmised that parasitism is a late-developed mode of life for the larvae.

Both families of Lepidoptera have been reported as hosts to extant erythraeids. Treat[13] lists a single case of a possible *Callidosoma* sp. on a gracillariid and *C. treati* on three species of the tineid genus *Acrolophus*.
Thomas H. Davies has stated[14] that his extensive collecting in New Zealand has yielded erythraeid larvae more commonly on micro- than on macrolepidoptera. In the genus *Leptus*, whose larvae often appear on moths, it has been difficult or impossible to make specific determinations, partly because of the lack of correlations between larval and heteromorphic postlarval stages but mainly because of incompleteness of our knowledge of this genus (and other Erythraeidae). The amber enclosing the gracillariid also contains many insect fragments, suggesting that it may have come from a bird's nest.

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