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Caterpillars and cases of Tineidae (Clothes Moths, Lepidoptera) from Baltic amber (Eocene)

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Abstract

A first analysis of caterpillars of Tineidae and their cases preserved in Eocene Baltic Amber is presented, and an ecological interpretation based on comparisons with extant Tineidae is given. Several informative syninclusions (e.g., mammal hairs, Psocoptera) of two of the cases suggest that the caterpillars of some Tineidae in the Baltic Amber forest occupied comparable ecological niches as their synanthropic extant relatives, which live on keratin in dry habitats. Thus, the amber fossils appear to represent the oldest direct fossil evidence of keratinophagy in Lepidoptera.

Key words: Baltic amber, Ditrysia, Glossata, keratinophagy, Lepidoptera, Tineidae

Zusammenfassung

Eine erste Studie über Raupen der Tineidae und ihre Larvensäcke aus dem Eozän des Baltischen Bernsteins sowie deren ökologische Interpretation in Bezug auf rezente Formen wurde durchgeführt. Besonders einige aussagekräftige Syninklusen (Säugerhaare, Psocoptera) von zwei Tineiden-Larvensäcken deuten an, dass zumindest die Raupen einiger Taxa des Baltischen Bernsteinwaldes vergleichbare ökologische Nischen besetzten wie ihre rezenten synanthropen Verwandten, die in trockenen Habitaten von Keratin leben. Dies scheint der älteste direkte fossile Hinweis auf Keratinophagie bei Lepidoptera zu sein.

Schlüsselwörter: Baltischer Bernstein, Ditrysia, Glossata, Kerationophagie, Lepidoptera, Tineidae

1. Introduction

Caterpillars, the larvae of Lepidoptera, are highly significant ecologically, and thus represent valuable proxy indicators that can be used in the reconstruction of ancient biotopes, including that of the Eocene Baltic Amber forest. Several caterpillars preserved in Baltic Amber have been described and illustrated in the paleontological literature; very few, however, have been studied in detail with regard to precise systematic affinities and ecology (?Plutellidae, ?Oecophoridae, see MacKay 1969; Psychidae, see Sobczyk & Kobbert 2009).

Members in the Tineidae are commonly known as "moths" (a colloquial name also used for representatives of many other moth families) or, more specifically, "clothes or wool moths". Especially interesting are the subfamilies Tineinae and Meessiinae because these animals produce portable cases from the basic material silk and various particles (Davis & Robinson 1999). The genus *Infurcitinea* (Meessiinae) forms long tubes on lichens (Davis & Robinson 1999; Sterling & Parsons 2012). Apart from the widely known occurrence of a number of synanthropic case-bearing clothes moths of *Tineola bisselliella* and the *Tinea pellionella* species complex (Global Database of Tineidae; Robinson 1979) in anthropogenic biotopes, Tineidae caterpillars thrive in many natural biotopes where they reside on a wide variety of different substrates, including lichens, fungi, algae, ferns, dry fruits, dead plant litter, detritus, keratinous material like hairs, fur, skin and feathers, which may be parts of insect nests or vertebrate burrows, or occur in animal corpses and weathered carnivore faeces (Robinson 1979; Scoble 1995; Parenti 2000; Sterling & Parsons 2012). Those taxa that live on keratin (mammal hairs, feathers; e.g., in birds nests or other dry habitats) were especially well pre-adaptated to switch into anthropogenic niches.

Adults of Tineidae are among the more abundant

lepidopteran groups preserved in Baltic Amber (ca. 20% of Lepidopterean inclusions) (Skalski 1976). Tineidae belong to the Glossata (i.e. they possess a proboscis as imagos) and represent the most primitive Ditrysia, which are defined by the synapomorphy of a connecting tube between the copulatory opening and ovipore in adult females. The origin of the Ditrysia has been hypothesized to lie in the Early Cretaceous (Grimaldi & Engel 2005). In contrast to the imagos of Tineidae, cases and caterpillars of these animals are relatively rare among the Lepidopterean inclusions in Baltic Amber. A caterpillar affiliated to the Tineidae was mentioned but not illustrated by Menge (1856). Other studies on Baltic amber

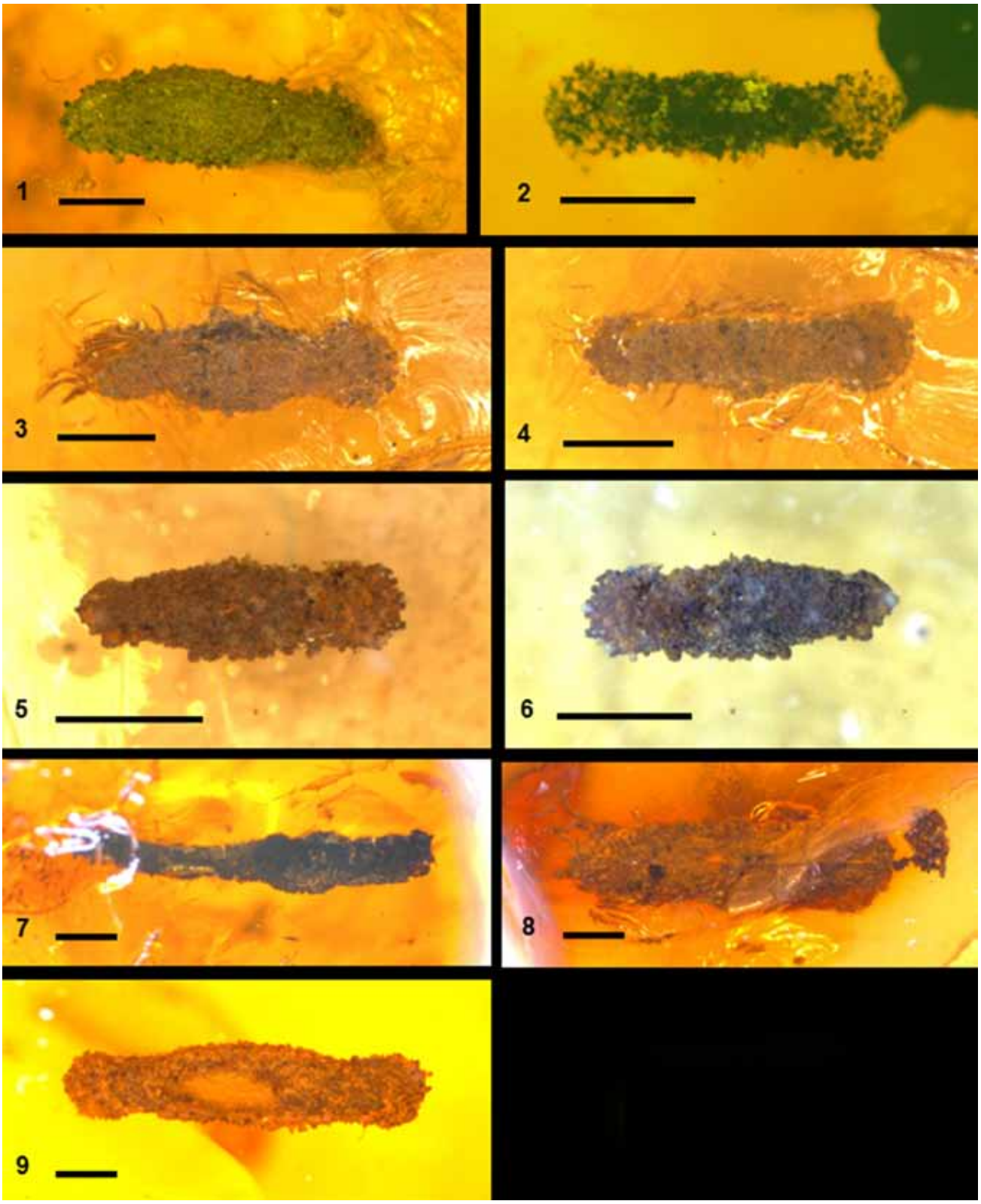

Plate 1: Tineidae cases. **(1)** no 4959; **(2)** no 4993; **(3, 4)** no 5047; **(5, 6)** no 5111; **(7)** no 5280; **(8)** no 5761; **(9)** no 5394; scale bars = 1 mm

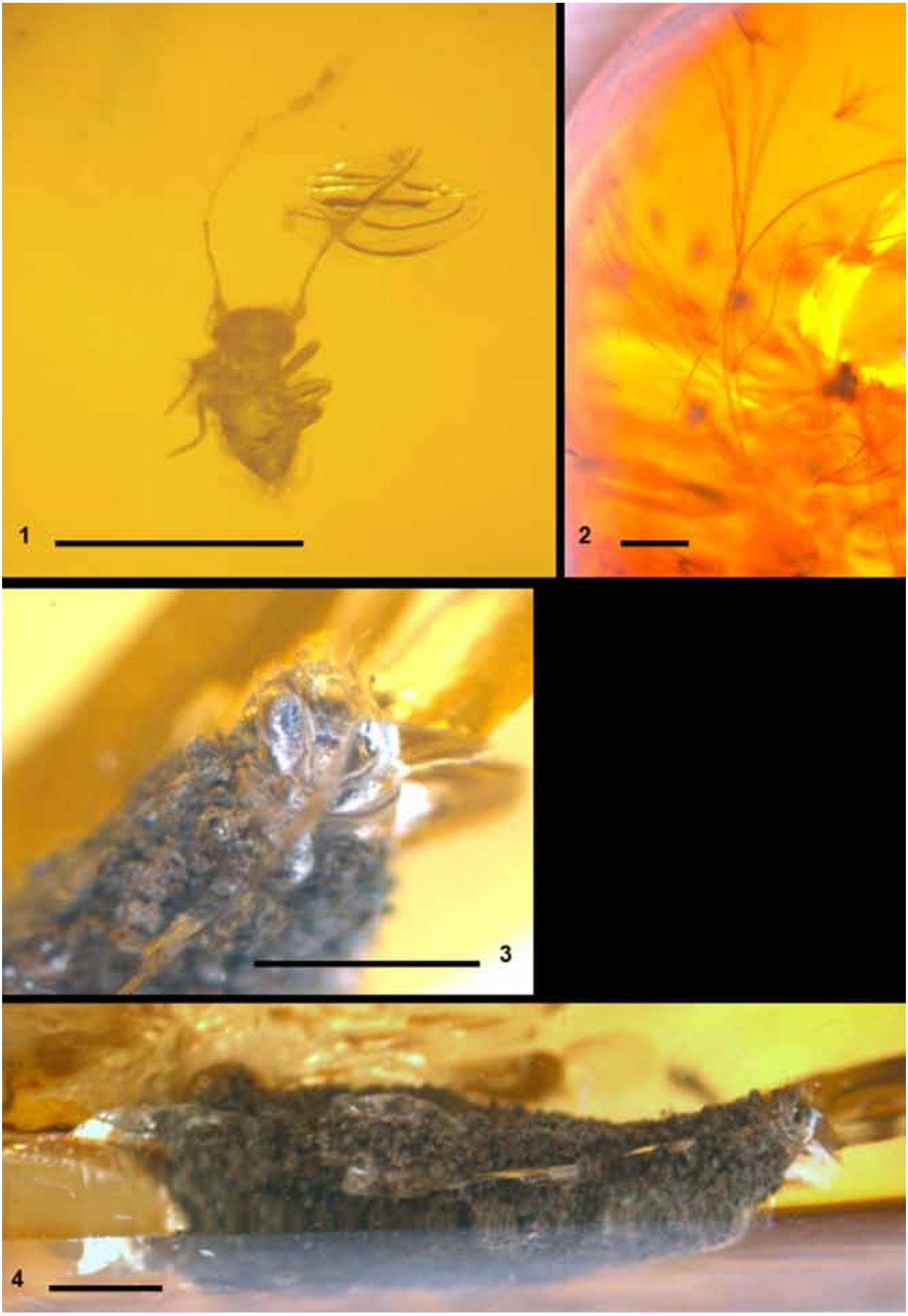

Plate 2: (1) Psocoptera sp.; **(2)** Mammal hairs; **(3, 4)** Tineidae case containing caterpillar no 5506; scale bars = 1 mm

that focus on three-dimensional preservation (Kobbert 2005), Psychidae (Sobczyk & Kobbert 2009), or exceptional inclusions (Weitschat 2009) include illustrations of Tineidae cases; a case containing a caterpillar is illustrated in Weitschat (2009).

This paper describes nine new cases of Tineidae, two of which contain caterpillars.

2. Material and Methods

The amber pieces were purchased from trusted dealers of Baltic amber. Inclusions were photographed with a stereomicroscope (Zeiss Stemi 2000-C) and digital camera system (Leica DFC 320, software LAS 4.1); other photographs were obtained from M. Veta together with the inclusion. The amber specimens are conserved by treatment with an acryl varnish and are kept in the author's private collection (accession numbers given in the Figure captions and in Tab. 1) at constant temperature in plastic clip bags within metal boxes to protect them from oxygen and light exposure.

3. Results

3.1 Systematic description

See Tab. 1

3.2 Description of the cases

The cases are generally dumbbell-shaped, tubular or spindle-shaped, symmetrical along the longitudinal axis with two equal ends, and most of the specimens are thickened in the middle portion. They are built from particles that are consistently uniform size and material, probably predominantly faecal pellets. Specimens vary from 2.2 to 6.6 mm long. Especially in the dumbbell-shaped specimens the openings are formed as lateral flap openings.

3.3 Description of the case-bearing caterpillar

Of the two specimens of Tineidae-type cases containing caterpillars, only the caterpillar in specimen 5731 (Pl. 3, Figs 1, 2) is preserved well enough to allow recognition of a number of characteristic features, including *Size:* Length of the caterpillar at max. 5.5 mm, prothorax 0.8 mm wide; *Legs:* Strongly bent, three pairs completely present; tarsi and claws bent inwards, claws miniscule, but tarsi well developed, pointed and long; a few setae occur on distal parts of tibias; *Head:* Epicranial notch flat; head hypognathous; stemmata not visible or absent; frons large; four setae on left head capsule visible, but more might be present; *Prothorax:* With a lateral group of three setae on T1 segment, and additional three setae visible in the dorsal region.

4. Discussion

Cases of Tineidae are relatively rare as fossils in Eocene Baltic Amber; they represent only 2% of the total lepidopteran remains in the Baltic Amber collection available for this study, and only 0.24% referring to all inclusions, despite the fact that the collection has a strong focus on lepidopteran remains. From Bitterfeld amber, which is mostly regarded as secondarily derived from Baltic amber (e.g., Swedo & Sontag 2013), another six Tineidae cases have been identified, but these are not included in this study as they fall within the range of variation of the specimens described here and lack informative syninclusions. Most lepidopteran cases from Baltic

Table 1: Overview of the Tineidae caterpillars and cases from Baltic amber

Spec. number	Figure	Size [mm]	Characteristics	Caterpillar	Syninclusions
4959	Pl. 1, Fig. 1	3.5	dumbbell-shaped	-	Psocidae, Nematocera, trichomes
4993	Pl. 1, Fig. 2	2.5	dumbbell-shaped	-	Mycetophilidae (2), detritus
5047	Pl. 1, Figs 3, 4	3	dumbbell-shaped	-	trichomes
5111	Pl. 1, Figs 5, 6	2.2	dumbbell-shaped	-	none
5280	Pl. 1, Fig. 7	6.5	+/- tubular	-	mammal hairs, *Machilidae*, Formicidae, Evaniidae, Opiliones, Ceratopogonidae, Sciaridae, Ceratopogonidae, Araneae, Collembola, leaflet, trichomes
5761	Pl. 1, Fig. 8	6	dumbbell-shaped	- (hatched)	none
5394	Pl. 1, Fig. 9	5.3	dumbbell-shaped, silk layer inside	- (hatched)	Mycetophilidae, Sciaridae, trichome, detritus
5506	Pl. 2, Fig. 3, 4	6.6	spindle-shaped	+	Sciaridae (5)
5731	Pl. 3, Fig. 1, 2	6.2	dumbbell-shaped	+	Sciaridae, trichomes

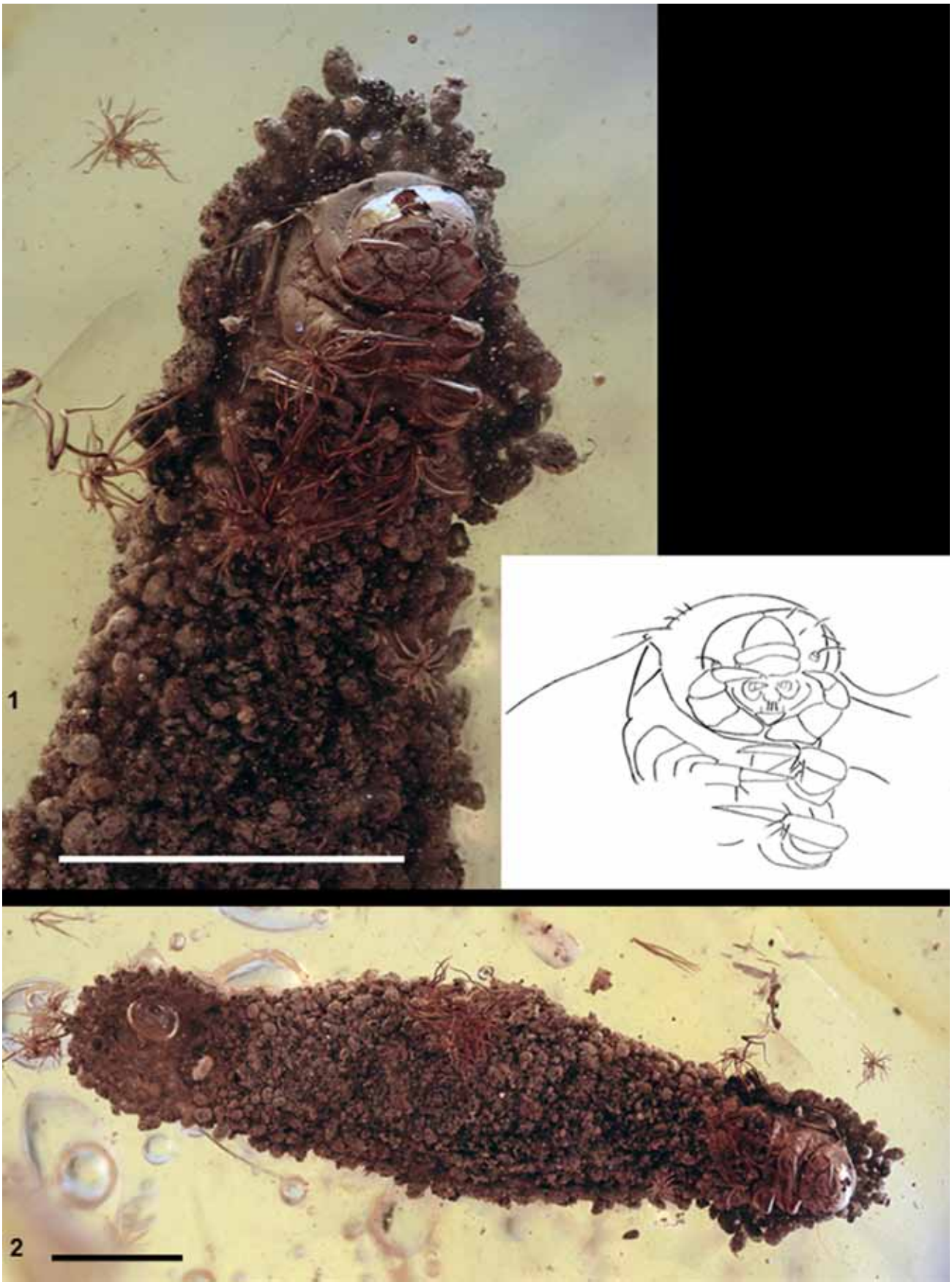

Plate 3: (1, 2) Tineidae case containing caterpillar no 5731; scale bars = 1 mm

Amber can be attributed to the family Psychidae with confidence; cases produced by these animals usually are conical in shape, have two unequal ends, and are built from diverse materials (Sobczyk & Kobbert 2009). Conversely, cases of Tineidae are far more common in Miocene Domenican amber (own observations; Grimaldi & Engels 2005).

The case-bearing caterpillar in specimen 5731 can be attributed to the superfamily Tineoidea based on the presence of the larval character "three prothoracic L-group setae" (Pl. 3, Fig. 1, drawing) (Robinson 1988). The setae extending from the head capsule were not used to further classify the fossil because not all head capsule setae are visible in the fossil. Nevertheless, the spatial arrangement of the setae that are well-preserved and visible concurs with the setal maps of Tineidae (Hinton 1956; Kristensen & Skalski 1999).

The cases of extant Tineidae are often dumbbell-shaped. However, these cases have rarely been illustrated in the literature (e.g., in Parenti 2000; Grimaldi & Engels 2005; Sterling & Parsons 2012; Lepiforum). The structure of the fossil cases (i.e. dumbbell-shaped and composed of small particles) and presence of two flap openings correspond to features seen in extant Tineidae cases; other diagnostic characters that could be used for a more precise classification within Tineidae are not available. However, information can also be obtained from the syninclusions preserved together with the cases detailed in this paper. One of the cases is associated with mammal hairs, which represent a typical keratin source for keratinophagous Tineidae. Mammal hairs (Pl. 2, Fig. 2) were identified by the following characteristics, which exclude a plant or fungal origin: they are tubular, unbranched, do not taper, range in diameter of some 10 µm, lack coaly substance, are seemingly covered with cuticular scales, show numerous occurrences in bundles, are very long in relation to their diameter. From the collection used here, there are only three inclusions of mammal hairs, one of them with an associated putative Tineidae imago (not shown).

Equally informative with regard to deciphering the habitats of the moths is the booklouse (Psocoptera; Psocidae) that is preserved together with one of the cases (Pl. 2, Fig. 1) because Psocidae are generally rare in Baltic Amber and extant relatives live on spores, fungal hyphae, lichens, algae, other decaying organic material, often on or below bark, in leaf litter or nests of other insects or birds (e.g., Grimaldi & Engels 2005). This concurs with the interpretation of the occurrence of mammal hairs as syninclusions of Tineidae cases. Bristletails such as *Machilis* (Machilidae, Archaeognatha), which also have been found as syninclusion in one of the amber pieces, occur on wet or dry stones, along coasts or mountainsides, but they are also found in bark crevices and moss. They dwell on plant debris, algae and lichens (Palissa 2011). Occurrences in bark and mosses are in good agreement with habitats of extant keratinophagous Tineidae. The ensign wasp (Evaniidae) syninclusion gives indirect evidence of the presence of cockroaches (Blattaria), which have also been dsecribed from Baltic amber, and whose oothecae are used for parasitic oviposition (Grimaldi & Engel 2005). Because of the high mobility of Evaniidae, no conclusion is drawn from this syninclusion. All other syninclusions are more or less abundant in Baltic amber, and hence not readily informative as syninclusions.

Cases of the synanthropic case-bearing clothes moths of the *Tinea pellionella* species complex and of *Tineola bisselliella* are directly comparable to the dumbbell-shaped fossil cases (Robinson 1979; Lepiforum). However, the cases of these animals consist of hairs, while the fossils are composed of faecal pellets. The closest extant relatives might be other Tineinae (e.g. *Monopis* sp., *Trichophaga* sp.; Parenti 2000) or Meessiinae (Davis & Robinson 1999; Global Database of Tineidae) (Eudarcia? sp. figuring in Sobczyk & Kobbert, 2009). *Eudarcia* sp. (Meessiinae), which also has a dumpbell-shaped case, precisely as *Tinea pellionella*, differs from the fossils with regard to the material used for the cases. Cases of *Eudarcia* sp. are composed of particles of various size (Lepiforum), while the fossil cases consist of particles that are uniform in size.

The fossil cases described in this paper are too poor in characters to allow a precise systematic affiliation at the genus level. However, the presence of mammal hairs as syninclusions in one of the specimens may suggest that the fossils belong to the keratinophagous ancestors in Tineinae, although an ancestor in the Meessiinae or some extinct subfamily of Tineidae also cannot be excluded.

5. Summary

Larval cases of Tineidae from Baltic amber, in part still containing caterpillars, are identified and described. A syninclusion of mammal hairs with one of the larval cases suggests that at least some of the Tineidae preserved in Baltic amber lived on keratin, thus providing the oldest phylogenetic evidence of keratinophagous Tineidae. Closest extant relatives most likely belong to the subfamily Tineinae.

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