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Short communication

A Burmese amber tick wrapped in spider silk

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ABSTRACT

A unique inclusion from Cretaceous (ca. 100 Ma) Burmese amber from Myanmar is described comprising a fossil hard tick (Parasitiformes: Ixodida: Ixodidae) wrapped in spider silk. Fossil ticks are very rare. Those from Burmese amber are the oldest examples of Ixodida recorded so far, and this is also the first time that this specific interaction between ticks and spiders has been documented in the fossil record. Spiders occasionally prey on ticks in modern ecosystems. However, those families which have been recorded catching ticks today lack a convincing Mesozoic fossil record and it is difficult to identify the producer of the fossil silk with any certainty. It is also possible that the tick was not part of the spider's usual prey spectrum, but accidentally entered the web and was subjected to immobilization wrapping as an initial precautionary attack.

1. Introduction

Fossilised examples of silk produced by spiders (Arachnida: Araneae) are rare discoveries. Several amber sources have yielded either strands of sticky silk complete with glue droplets (e.g. Zschokke, 2003, 2004), or even fragments of webs and wrapped prey items offering data about the likely feeding ecology of the web-builder. For example, Weitschat and Wichard (1998) figured an ant in Eocene (ca. 45–49 Ma) Baltic amber wrapped in the silk of an unknown spider. The same figure was reproduced by Wunderlich (2004), who also provided further photographs of arthropods trapped (or wrapped) in spider silk in both Baltic and the younger (Miocene: ca. 16 Ma) Dominican amber. These included myriapods, pseudoscorpions and several insect groups: namely silverfish, ants, cicadas, aphids, caddisflies, moths, wasps, beetles and flies. An overview of spider silk records in amber can be found in Boucot and Poinar (2010), while Ross and Sheridan (2013) figured a fairy fly and gall midge stuck to threads of spider silk in Dominican amber; an image also used for the cover of Penney and Ross (2016).

The oldest records of spider silk and/or webs come from Cretaceous ambers. Zschokke (2003, 2004) documented silk strands with glue droplets from both the ca. 100 Ma Burmese amber of Myanmar and the ca. 130 Ma Lebanese amber. Peñalver et al. (2006) described a web fragment from the ca. 110 Ma Spanish San Just amber containing a mite and a fly. This remains the oldest example of a fossil web with putative prey items. Brasier et al. (2009) also reported spider web fragments (without prey) from the ca. 140 Ma Sussex amber of southern England. Here, we document a unique example of a fossil tick in Burmese amber apparently wrapped in spider silk (Figs. 1–2). This find is remarkable since ticks themselves are extremely rare in amber; the oldest records also coming from Burmese amber (Grimaldi et al., 2002; Poinar and Brown, 2003; Poinar and Buckley, 2008; Peñalver et al., 2018; Chitimia-Dobler et al., 2017, 2018). While spiders are known to capture ticks occasionally in modern ecosystems (see 4.), this is the first time that a tick enshrouded in silk has been reported in the fossil record.

2. Material and methods

The specimen originated from the private collection of Mr Patrick Müller, Käshofen (Nr. BUB1527) and has now been deposited in

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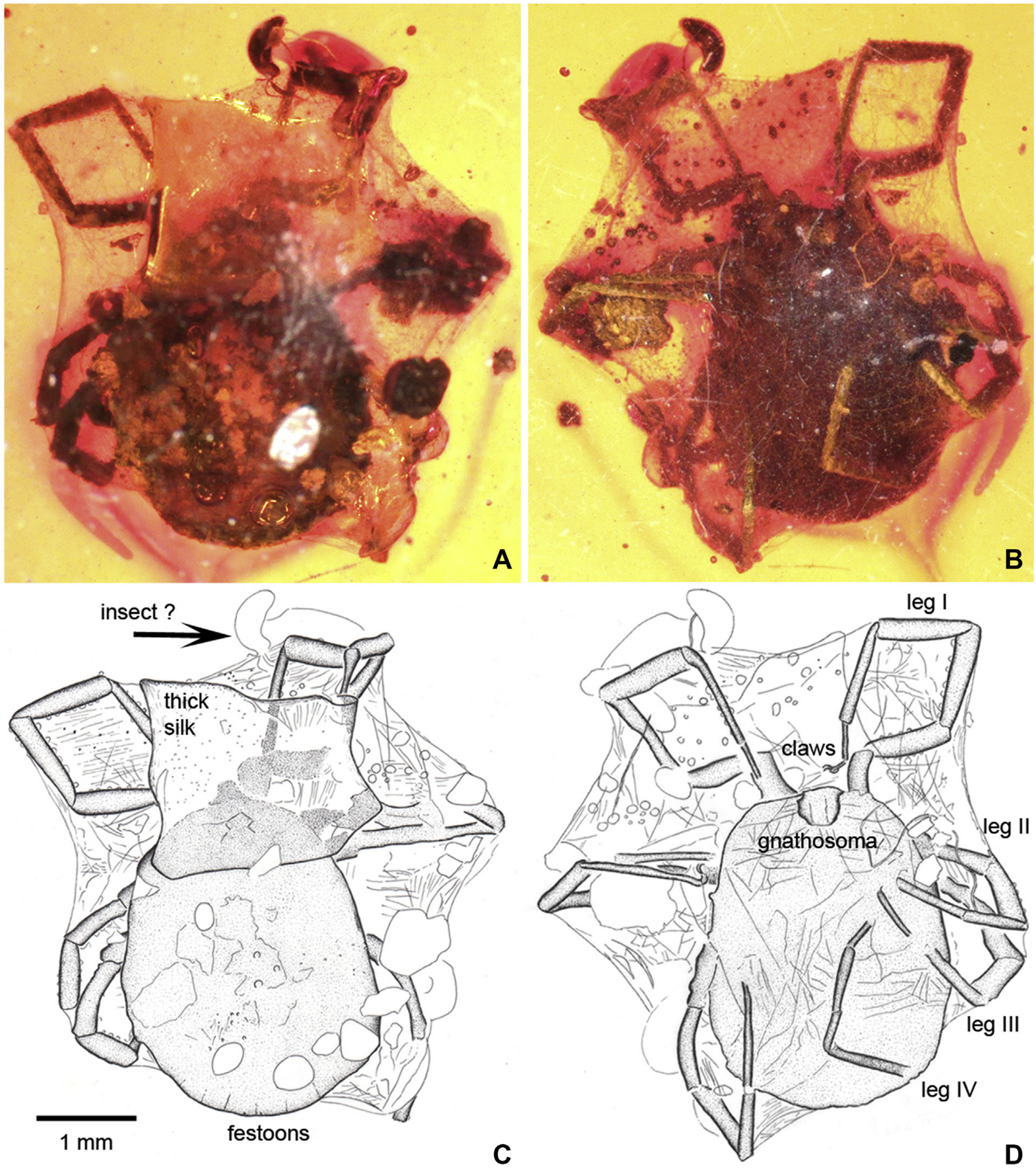

Fig. 1. MB.A. 4266, a hard tick (Ixodida: Ixodidae), possibly *Compluriscutula vetulum* Poinar and Buckley, 2008, wrapped in spider silk from the Cretaceous (ca. 100 Ma) Burmese amber of Myanmar. A. Dorsal view. B. Ventral view. C–D. Interpretative *camera lucida* drawings.

the fossil arthropod collection of the Museum für Naturkunde Berlin under the repository number MB.A. 4266. It consists of a flattened, pear-shaped piece of amber with dimensions of approximately 14 × 11 mm. Details of the wider geological setting of Burmese amber can be found in Grimaldi et al. (2002) and Ross et al. (2010), and it has subsequently been dated to Late Cretaceous (earliest Cenomanian) with a radiometric minimum age for the amber-bearing beds of 98.79 ± 0.62 Ma (Shi et al., 2012). The amber itself shows evidence of having been reworked, see e.g. comments in Wang et al. (2016), and thus could be slightly older than the radiometric date. However, Smith and Ross (2018) used the presence of bivalve borings to argue that some bivalve penetration must have occurred within weeks of production of the original resin. In this scenario the age of the amber and the age of the amber-bearing beds were not very different, leading Smith and Ross (2018) to favour an early Cenomanian age for the inclusions. Further details about the locality, the history of discovery and an overview of the arachnids found so far can be found in Selden and Ren (2017). For a map of the locality see e.g. (Dunlop et al. (2015: fig. 1)).

For photography a Keyence VHX-6000 Digital Microscope with a tiltable stand and a combination of incident and transmitted light for focus stacking was used (with magnification from 100× to 1000×). We partly used polarized light for more details and stack images were combined using the software Helicon Focus 6.7.1. Drawings were prepared with a *camera lucida* attachment on a Leica M205C stereomicroscope, again using a combination of incident and transmitted light.

3. Results

The inclusion (Fig. 1) consists of a moderately large tick (Parasitiformes: Ixodida) with an oval body: length 2480 μm, slightly wider posteriorly with a maximum width of 1890 μm and numerous marginal festoons on the posterior margin of the idiosoma (Fig 1A, C). Ventrally the gnathosoma can be resolved, albeit bent backwards and largely pointing downwards, while the legs are folded under the body and relatively slender. Legs I and IV can be seen in their entirety and are both ca. 3350 μm long. Where visible, the legs end in a pad-like pulvillus and a pair of claws which are slender, simple and slightly curved. From the number of legs and the scutum on the anterior part of the body it appears to be a nymph or a female. The fourth article of the palps is subapical and has elongate terminal setae. Setae were also detected on the legs and palps, but details are equivocal.

3.1. Identity of the tick

A clear oval area on the dorsum of tarsus I (Fig. 2A: arrow) represents Haller's organ. This structure confirms that the inclusion is a tick. Haller's organ is unique for ticks and the rare holothyrid mites (e.g. Mans et al., 2016) and the presence of marginal festoons in the new fossil (see above) excludes it from being a holothyrid, and further excludes several groups of ticks. Of the five major tick clades *sensu* Mans et al. (2016) – Nuttalliellidae, Argasinae, Ornithodorinae, Prostriata and Metastriata – only metastriates have festoons. The recently described extinct family from Burmese amber, Deinocrotonidae, also lacks festoons (Peñalver et al., 2018). Generally, the amber is quite dark and the new tick inclusion is partially concealed. Thus taxonomically relevant details such as the presence or absence of eyes, the condition of the spiracles and the morphology of the anal and genital region, are difficult to resolve. Despite these limitations, the general shape is consistent with a metastriate hard tick. The metastriate genera *Amblyomma* C.L. Koch, 1844 and *Haemaphysalis* C.L. Koch, 1844 have already been recorded from Burmese amber (Klompen in Grimaldi et al., 2002; Chitimia-Dobler et al., 2017, 2018). Other known ticks from Burmese amber have been assigned to extinct genera, possibly related to *Amblyomma*. Of these, *Cornupalpatum burmanicum* Poinar and Brown, 2003 is a smaller fossil (known only from the larva), with a more rounded body and more robust legs. The habitus of the present specimen, including the proportions of the legs and pedipalps, is perhaps closer to another species: *Compluriscutula vetulum* Poinar and Buckley, 2008. However, an unequivocal identification in this condition of preservation is difficult.

3.2. Evidence for silk wrapping

The tick is enmeshed in a mass of pale fibres (Fig. 2A–B), and it is important to distinguish from the outset whether the inclusion is wrapped in (spider) silk, or simply represents a dead specimen surrounded by decay structures such as fungal hyphae. Fungi – as well as fungivory by animals and parasitism on animals by fungi – have been documented from several Cretaceous ambers (Sung et al., 2008; Schmidt et al., 2010). Fungal decay processes have been observed quite frequently in fossil spiders from the younger Baltic amber (e.g. Wunderlich, 2004: photos 475–494), and may take the form of threads spanning the space between the legs. However, fungal decay in amber spiders usually involves mycelial hyphae spreading out from the body, often with a local concentration at the place where the fungi first emerged. For comparison, in modern ticks undergoing post-mortem decay hyphae may also initially appear from orifices, like the spiracle and anus (Fig. 3A–B), and then spread out from here. The Burmese amber tick does not show localised masses of putative hyphae, and the threads instead appear to wrap and envelop the specimen (Fig. 1) rather than grow out from it. Furthermore, the narrow angles by which the filaments branch from each other (Fig. 2B) are more typical for silk strands from a spider web, but would be unusual for hyphae in fungal mycelia, while the filaments themselves appear to be composed of several individual fibres (Alexander Schmidt, pers. comm. 2017). For these reasons we are confident that this is a tick wrapped in spider silk, and not an artefact of decay processes.

The tick is thus preserved in an approximately rectangular shroud of silk. Several small and larger pieces of detritus are also included and obscure the morphology in places. For example, there is an association with a small, unidentified object which may be an insect (Fig. 1C). The silk spans the gaps between the body and the appendages and individual silk threads can often be resolved throughout the specimen (Fig. 2). A particularly thick, subquadrate patch of silk (Fig. 1C) covers the anterior part of the dorsal idiosoma and parts of the first pair of legs. Droplets of sticky glue (as per Zschokke, 2004) cannot be resolved on any of the silk threads (Fig 2B–D); see also 4.

4. Discussion

We can only speculate about the spider responsible. Several families have been reported preying on both hard and soft ticks in extant ecosystems; for reviews see Samish and Rehacek (1999) and Samish and Alekseev (2001), and references therein. Dysderidae, Nesticidae, Theridiidae, Amaurobiidae, Lycosidae, Ctenidae and Salticidae have all been recorded as tick predators, and Bernardi et al. (2010) has since added observations of tick predation by Pholcidae. Of these, only salticids (jumping spiders) completely refrain from prey wrapping; see Barrantes and Eberhard (2007) for an overview. Something like a lycosid (wolf spiders) seems an unlikely source. When members of this group use wrapping behaviour they generally attach the prey to the substrate, and in any case these spiders are geologically much too young. A putative Cretaceous wolf spider (Kim and Nam, 2008) is almost certainly a misidentification. In fact, most of the spider families listed above are not known either from Burmese amber (Wunderlich, 2008, 2015, 2017; Selden and Ren, 2017) or from other Mesozoic deposits in general. Only cobweb spiders (Theridiidae) have possible Cretaceous records comprising a Burmese amber species, *Cretotheridion inopinatum* Wunderlich, 2015, which was tentatively placed in this family by Wunderlich (2015), and a questionable further record from the slightly younger Canadian amber (McAlpine and Martin, 1969). Note that Wunderlich (2008) placed a fossil from Cretaceous Jordanian amber in a, previously established, extinct family (Protheridiidae) which may be ecologically close to theridiids. We cannot exclude the possibility that a spider from an extinct group was responsible.

The web-building family Dictynidae was tentatively reported from Burmese amber (Wunderlich, 2008), although the genus *Burmadictyna* Wunderlich, 2008 was subsequently transferred from Dictynidae to the new extinct family Burmadictynidae by Wunderlich (2017, p. 220), thus Dictynidae are no longer recorded from Burmese amber. In any case, modern dictynids have not been reported using prey-wrapping behaviour (e.g. Jackson, 1977). Generally, web-building spiders are more prone to use wrapping

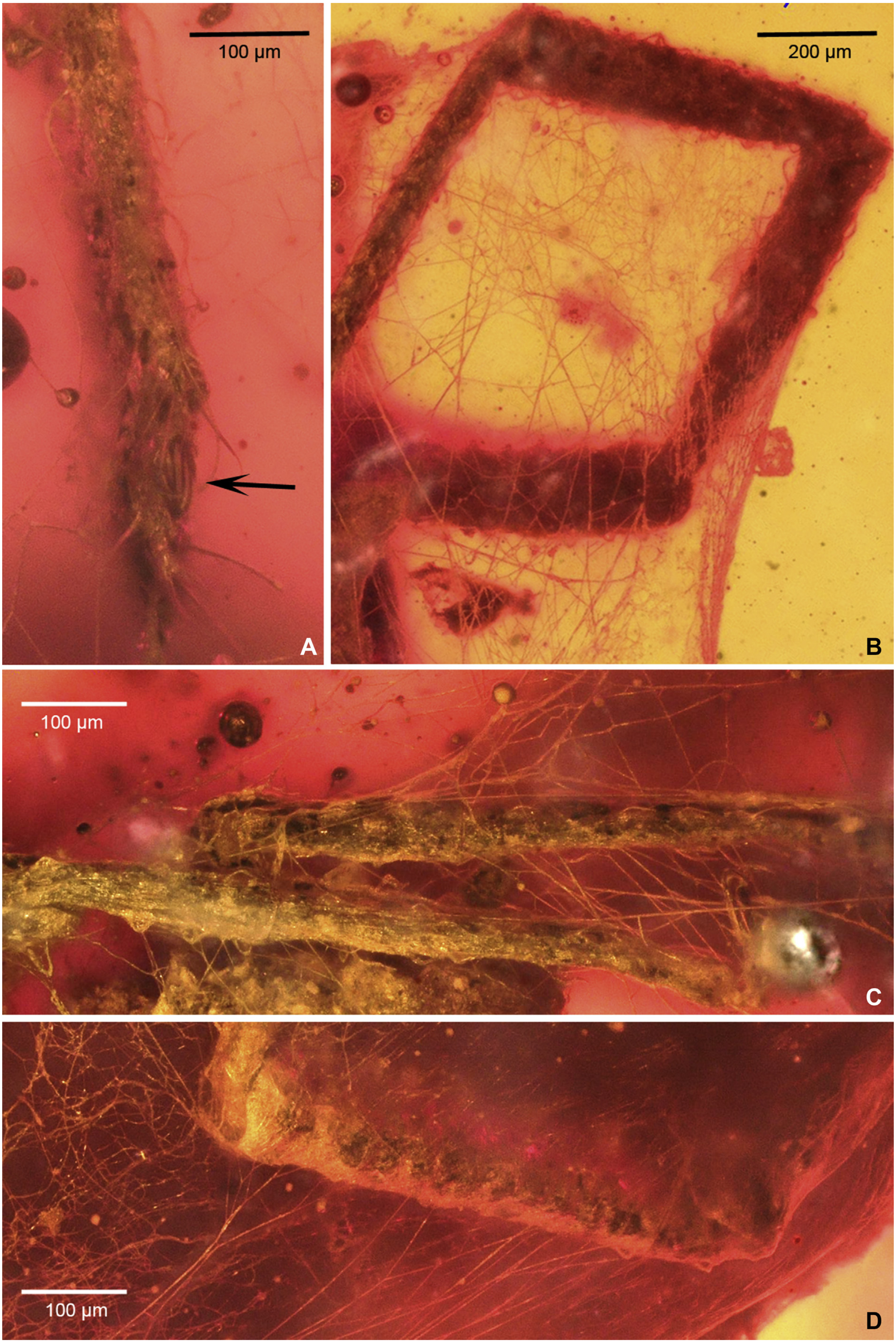

Fig. 2. Details of the specimen shown in Fig. 1. A. Right leg I showing Haller's organ (arrowed). B. Left leg I and associated silk threads. C. Right legs II–III and associated threads. D. Left leg IV and associated threads. Note the narrow angles by which the filaments often branch from each other and the absence of sticky glue droplets.

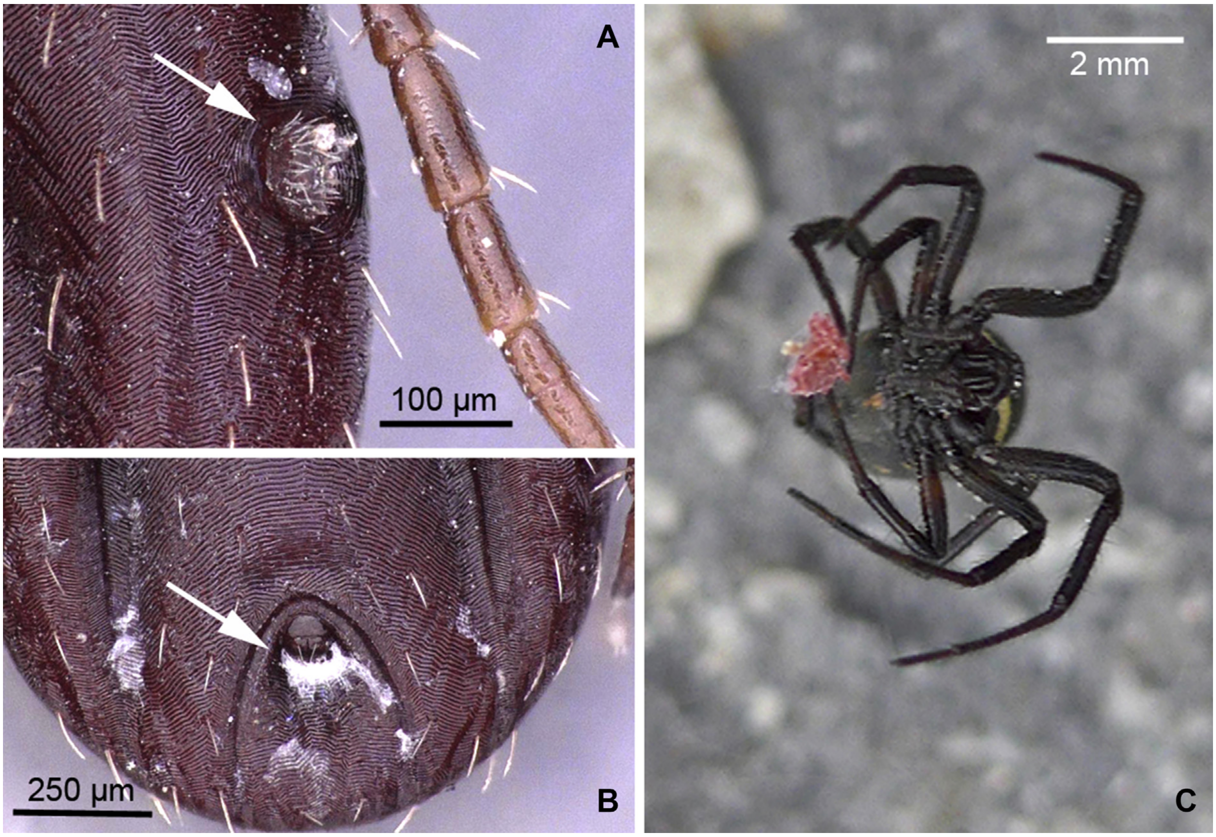

Fig. 3. Modern comparisons. A–B. Extant tick during the initial phases of decay in which fungal hyphae (arrowed) emerge from the spiracle and around the anus; photos by LCD. C. The cobweb spider *Steatoda bipunctata* (Theridiidae) wrapping what appears to be a red spider mite; photo by PAS taken on 11.VII.2017 at Vasalemma, Harju, Estonia.

behaviour than free-living species (Nentwig and Heimer, 1987). Intuitively, we suspect that the tick discovered here may have been wrapped by an ecribellate (araneoid) or cribellate orb-weaver. Araneoidea is substantial clade of web-builders which includes Araneidae (orb-weavers), Linyphiidae (money spiders) and Theridiidae (Fig. 3C). Araneids and linyphiids construct webs adapted to catch prey out of the air which either flies into, or jumps into, the web. A tick on the substrate is less likely to have been caught by such a spider, but could (theoretically) fall into a web from overhanging vegetation. Araneoids use viscous silk, but the absence of obvious glue droplets in this inclusion (Fig 2B–C) is unhelpful here as these spiders do not generally use viscous silk for wrapping (S. Zschokke, pers. comm. 2017). In detail, in araneoids silk for prey wrapping originates from the minor ampullate glands (e.g. La Mattina et al., 2008) while the viscous silk for prey capture comes from the flagelliform glands. An exception to this is Theridiidae which have been reported throwing sticky silk and glue droplets onto prey items (Nentwig and Heimer, 1987; Japyassú and Caires, 2008). This could be evidence that our inclusion was not wrapped by a theridiid.

We should note that cribellate orb-weaving spiders (deinopoids) are quite well represented in the Cretaceous, including several species specifically from Burmese amber (Wunderlich, 2015, 2017). They may have been more abundant at that time than araneoids. Prey wrapping has been documented in, for example, living taxa in the family Uloboridae (Lubin et al., 1978; Lubin, 1986), but further evidence for the spider involved in the present fossil is lacking.

4.1. Immobilization wrapping?

Irrespective of the spider responsible, we must entertain the possibility that the tick was not part of the predator's usual prey spectrum, but became ensnared in the web accidentally and was wrapped as a precaution. Some spiders, especially among orb-weavers and the uloborids deliberately use silk for their initial attack, and in the case of uloborids these spiders no longer have venom glands and rely entirely on wrapping to subdue their prey (Lubin, 1986). This attack process has been termed immobilization wrapping (Robinson et al., 1969) and effectively renders the prey harmless before the spider bites it, and tests whether it is palatable. How the wrapped tick came to be trapped in amber remains a mystery. Perhaps a web on a tree stem was engulfed by resin? Alternatively if the spider chose not to eat the tick, and if the spider lived on a tree above a resin ooze, it could have dropped the discarded tick onto the resin where it became engulfed.

5. Concluding remarks

In summary, fossil ticks are very rare and Burmese amber remains the oldest source of palaeontological data discovered to date; although molecular data (e.g. Mans et al., 2012, 2016) predicts the occurrence of ticks considerably earlier, perhaps as far back as in the Carboniferous. Ticks may not be a typical part of most spiders' diets, but modern spiders do occasionally catch and eat them. Our new inclusion is a unique in the fossil record and reveals that at least some spiders occasionally caught ticks during the mid-

Cretaceous. However, we do not know which family of spider was responsible, nor if the spider would have consumed or discarded this unusual prey item.

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