



## An acrocarpous moss in Cretaceous amber from Myanmar



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### ABSTRACT

Recent studies have indicated considerable changes in the lineage composition of mosses during the Cretaceous terrestrial revolution. However, Cretaceous moss fossils are generally rare. Here we describe a sterile gametophyte fragment of an acrocarpous moss preserved in mid-Cretaceous amber from Myanmar. The fossil at hand is assigned to the extant Dicranales based on its narrowly lanceolate, awned leaves with a single costa, quadrate-rectangular, bulging leaf cells forming a serrate leaf margin, and oblong-ovate leaf bases with hyaline, rectangular cells. The protruding cells of the awns point to the possibility that they previously carried gemmae, as is seen in numerous extant representatives of the Calymperaceae genera *Calymperes* and *Syrhropodon*. The fossil differs from both genera by its indistinctly separated hyaline basal leaf cells, and is placed in the form genus *Calymperites* as *C. burmensis* sp. nov.

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### 1. Introduction

With some 9000–13,000 extant species, mosses represent the most speciose lineage of bryophytes (Renzaglia et al., 2007; Magill, 2010). This lineage originated in the Paleozoic (Clarke et al., 2011; Fiz-Palacios et al., 2011; Magallon et al., 2013), but the reconstruction of its evolutionary history is hampered by its sparse fossil record and the incomplete preservation of most fossils (Krassilov and Schuster, 1984; Oostendorp, 1987; Taylor et al., 2009; Kenrick et al., 2012). The earliest fossils which have been assigned to mosses date back to the Carboniferous, but their taxonomic status is ambiguous (Renault and Zeiller, 1885; Lignier, 1914; Thomas, 1972; Hübers and Kerp, 2012). The classification of Permian, Triassic or Jurassic mosses is likewise difficult because many taxonomically relevant characters are not preserved. Moreover, the available morphological character states do not fully overlap with those of extant genera or families (Heinrichs et al., 2014c). Accordingly, these fossils are usually assigned to form genera or genera with unclear taxonomic relationships (Neuburg, 1960;

Krassilov and Schuster, 1984; Ignatov, 1992; Ignatov and Shcherbakov, 2011a). The situation takes a turn for the better in the Cretaceous. Here, a few excellently preserved fossils were assigned to extant families (*Eopolytrichum antiquum* Konopka, Herend., G.L. Merr. & P. Crane, Polytrichaceae; Konopka et al., 1997) or genera (*Campylopodium allonense* Konopka, Herend. & P. Crane, Dicranaceae; Konopka et al., 1998). However, documented evidence of Cretaceous moss fossils is scarce. Cretaceous moss fossils are urgently needed to scrutinize the hypothesis of major changes in the lineage composition of mosses during the late Mesozoic, which were recently postulated based on molecular data (Shaw et al., 2003; Newton et al., 2007; Fiz-Palacios et al., 2011).

In the present paper we describe an inclusion of an acrocarpous moss in a piece of Cretaceous amber from Myanmar, and discuss its relationships to extant and extinct taxa.

### 2. Materials and methods

The amber piece was found at the famous amber locality near the village of Tanai which is located on the Ledo Road about 105 km north of Myitkyina in Kachin State, Myanmar (see Figure 1 in Grimaldi et al., 2002), and it has been transferred to the amber collection of the American Museum of Natural History in New York (collection number AMNH Bu ASJH-2). Syninclusions of the

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unidentified bryophyte are two dipterans, a mite, a branched plant hair and detritus fragments.

Both biostratigraphic data obtained from the amber-bearing sediment and the amber inclusions indicate a mid-Cretaceous age of the amber (Grimaldi et al., 2002; Cognato and Grimaldi, 2009). Based on marine microfossils and ammonites from this amber locality, Cruickshank and Ko (2003) suggest a late Albian age of the amber-bearing sediment, hence the inclusions have an age of approximately 100 Ma, with a minimum age of 98 Ma (earliest Cenomanian) that is based on recent U–Pb dating of zircons (Shi et al., 2012).

The amber piece was originally intended to be integrated into a necklace and represents the counterpart of BU ASJH-1, which contains an inclusion of the extinct liverwort *Gackstroemia cretacea* Heinrichs, Schäf.-Verw., Feldberg, & A.R. Schmidt (Heinrichs et al., 2014b). After an initial inspection of the inclusion, the piece of amber was embedded in a high-grade epoxy resin [EPO-TEK 301-2, Epoxy Technology Inc., mixing ratio 100 (resin) : 37 (hardener)] in a procedure that is based on the protocols described by Nascimbene and Silverstein (2000). After curing, the sample was trimmed and polished on opposite sides using a series of wet silicon carbide abrasive papers (firm Struers, Germany) with decreasing grit sizes [grit from FEPA P 600–4000 (25.8 μm to 5 μm particle size)] to minimize light scattering for the investigation.

The preparation was studied under a Carl Zeiss Stemi 2000 dissection microscope and a Carl Zeiss AxioScope A1 compound microscope, each equipped with a Canon 60D digital camera. In some instances, incident and transmitted light were used simultaneously. The images of Figs. 1 and 2 are digitally stacked photomicrographic composites of up to 40 individual focal planes obtained using the software package HeliconFocus 5.0 for a better illustration of the three-dimensional inclusions.

### 3. Results

#### 3.1. Systematic palaeontology

Phylum: Bryophyta

Class: Bryopsida

Subclass: Dicranidae

Order: Dicranales (s.l.)

Family *incertae sedis* (but see Discussion)

Genus *Calymperites* Ignatov & Perkovsky, *Arctoa* 22 (2013): 90.

#### *Emended diagnosis.*

Gametophytes with spirally inserted leaves narrowing from an oblong-ovate base into a lanceolate upper region or leaves oblong-lingulate; upper lamina cells thick-walled, subquadrate to short-rectangular, small, bulging; basal cells thin-walled, rectangular; leaf margin subentire to serrate-dentate; costa single, ventrally convex, extending to leaf apex or short-excurrent.

Type species: *Calymperites ucrainicus* Ignatov & Perkovsky, *Arctoa* 22 (2013): 90.

*Calymperites burmensis* Heinrichs, Schäf.-Verw., Hedenäs, Ignatov & A.R. Schmidt, **sp. nov.**

Holotype: Amber inclusion AMNH Bu ASJH-2, Figs. 1 and 2

Repository: American Museum of Natural History (AMNH)

Type locality: Myanmar

Stratigraphic range and age: Upper Albian or lowermost Cenomanian, about 98–100 Ma.

#### *Diagnosis.*

Upright gametophytes with leaves narrowing from an oblong-ovate base consisting of mostly elongate, hyaline cells into a lanceolate upper region consisting of brownish cells; hyaline basal leaf cells not sharply separated from thick-walled upper leaf cells, leaf margin serrate-dentate, costa extending to leaf apex, sometimes forming an awn that possibly produces propagules.

#### *Description.*

Single sterile, unbranched gametophyte, ca. 4 mm long but lowermost portion not preserved; leaves crisped when dry, erect-spreading when moist, ca. (1.5–)1.8–2.5 mm × 0.34 mm, sheathing with an oblong-ovate base that abruptly to gradually tapers into a narrowly lanceolate upper region, apex usually awned, occasionally acute or narrowly truncate; margin flat or lower 20–40% weakly recurved, finely serrulate, near apex often with a few, triangularly protruding, large, somewhat hyaline cells; costa single, percurrent to excurrent, ventrally convex and obviously built of several cell layers; upper laminal cells subquadrate to short-rectangular, (6–)8–13(–15) × 6–10 μm, thick-walled, opaque, bulging, towards the margin apparently partially bistratose (much more opaque than other lamina cells); basal cells hyaline, (sub-quadrate to) rectangular, ca. 10–40 × 10–22 μm, thin-walled, filling the complete leaf base, gradually turning into thick-walled upper cells.

Derivation of name: Refers to the origin of the amber.

#### 3.2. Key to the species of *Calymperites*

1. Distal portion of leaves oblong-lingulate, costa extending to leaf apex.....*C. ucrainicus*
- 1\*. Distal portion of leaves lanceolate, costa often excurrent, forming an awn.....*C. burmensis*

### 4. Discussion

Amber, fossilized tree resin, is a prime preservation agent for soft-bodied biological structures such as fungi, algae, and bryophytes (Grimaldi, 1996). Fossiliferous amber is known from the Triassic onwards (Schmidt et al., 2006, 2012) but bryophyte inclusions have so far been recognized only in a few Cretaceous (Bell and York, 2007; Heinrichs et al., 2011) and Cenozoic deposits (e.g., Grolle and Meister, 2004; Heinrichs et al., 2014a). Several Cenozoic amber deposits are well-known for their rich inclusions of mosses. Eocene Baltic and Rovno amber, Oligocene Bitterfeld amber, and Miocene Dominican amber yield a considerable diversity of well preserved moss inclusions that allowed for detailed investigations not only of the gross morphology of the gametophytes but also of delicate structures such as the leaf cell pattern, and occasionally also of the sporophytes (e.g., Frahm and Newton, 2005; Frahm, 2010; Ignatov and Perkovsky, 2011). Cenozoic amber inclusions of mosses usually match the morphology of extant genera or species, and allow for numerous insights into the moss flora of the Paleogene and early Neogene. A large amount of other Cenozoic moss fossils is known from clays, silts or lignites (Miller, 1984; Frahm, 2000). All these fossils indicate that the Cenozoic moss flora largely resembled the extant one, at least at generic level.

This situation changes if we follow bryophyte lineages back in the Cretaceous. Krassilov and Schuster (1984: 1187) stated that “No forms related to extant genera seem to exist before the Eocene”. Since then, one exception has been published: Konopka et al. (1998) assigned a Late Cretaceous fossil of an acrocarpous moss to the extant genus *Campylopodium* (Müll. Hal.) Besch., a genus that is

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