

*CYNODONTIUM EOCENICUM*, A NEW MOSS FROM THE BALTIC AMBER  
*CYNODONTIUM EOCENICUM*, НОВЫЙ МОХ ИЗ БАЛТИЙСКОГО ЯНТАРЯ

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Abstract

A new species, tentatively recognized within the moss genus *Cynodontium*, is described from the Baltic Amber based on well preserved plant gametophyte. Its overall habit, presence of distinct teeth in the leaf apex and recurved leaf margins resemble most modern species of the genus, although the characteristics of scattered papillae and absence of diagnostic characters precludes its unequivocal identification with any extant species. Among the acrocarpous moss taxa previously described from the Baltic Amber, the papillose cells were known only in *Hypnodontopsis*, a markedly smaller moss, with entire and not strongly channelled leaves.

Резюме

Из Балтийского янтаря описан новый вид рода *Cynodontium*. Общий вид побега, длинные узкие желобчатые листья с отогнутым краем, а также зубчатость края листа в верхушке вполне соответствуют строению современных представителей данного рода. Вместе с тем, рассеянно расположенные папиллы и отсутствие возможности изучения других важных диагностических признаков, включая спорофит, не позволяют отнести образец к какому-либо ныне существующему виду. Среди родов верхоплодных мхов, описанных из Балтийского янтаря, папиллозные клетки были известны ранее только у *Hypnodontopsis*, который имеет значительно более мелкие размеры и цельнокрайные листья, которые также не имеют выраженной желобчатости.

KEYWORDS: Eocene, bryophytes, Dicranales, Rhabdoweisiaceae, amber inclusions

INTRODUCTION

Baltic amber is one of the richest sources of information about the biota in Europe in the Paleogene. It has derived from warm-temperate or subtropical conifers, although the genus or genera, which produced it, remain a subject of discussion (Wolfe *et al.*, 2016). Among amber inclusions, the most numerous and paleontologically revealing are insects, which collections count at thousands (Engel, 2001; Alekseev, 2013).

The coast near Königsberg/Kaliningrad (Sambia) was one of the main sources of Baltic amber. Especially rich is the Palmnicken quarry, where amber is embedded in Blue Earth layer, which age was recently re-evaluated by Aleksandrova & Zaporozhets (2008a, b) as the latest layer of the Eocene, the Priabon. Vegetation of that age was similar to warm-temperate one, occurring nowadays in East Asia (Alekseev & Alekseev, 2016), being composed of Pinaceae, Cupressaceae (incl. Taxodioideae), Fagaceae,

Juglandaceae and Lauraceae, with permanent occurrence of Podocarpaceae, Arecaceae, Magnoliaceae, Hamamelidaceae, and Cornaceae.

The first data on moss inclusions in Baltic amber were published by Goeppert & Berendt (1845). Later Caspary & Klebs (1907) described seven species. Recently Frahm (2010) published a comprehensive summary on amber mosses. He listed 33 genera besides those, which were not available for his personal studies. There is no doubt that this amount represents only a poor sampling, as the modern moss flora in the areas with the similar vegetation is much richer in bryophytes, *e.g.*, 1145 species have been reported from Japan (Higuchi, 2011). Certainly, further studies may result in discovering a much higher diversity, especially if scattered collections, like the following one presented in this paper, will be included. It certainly will open a great look on the bryophyte flora of the amber forest.

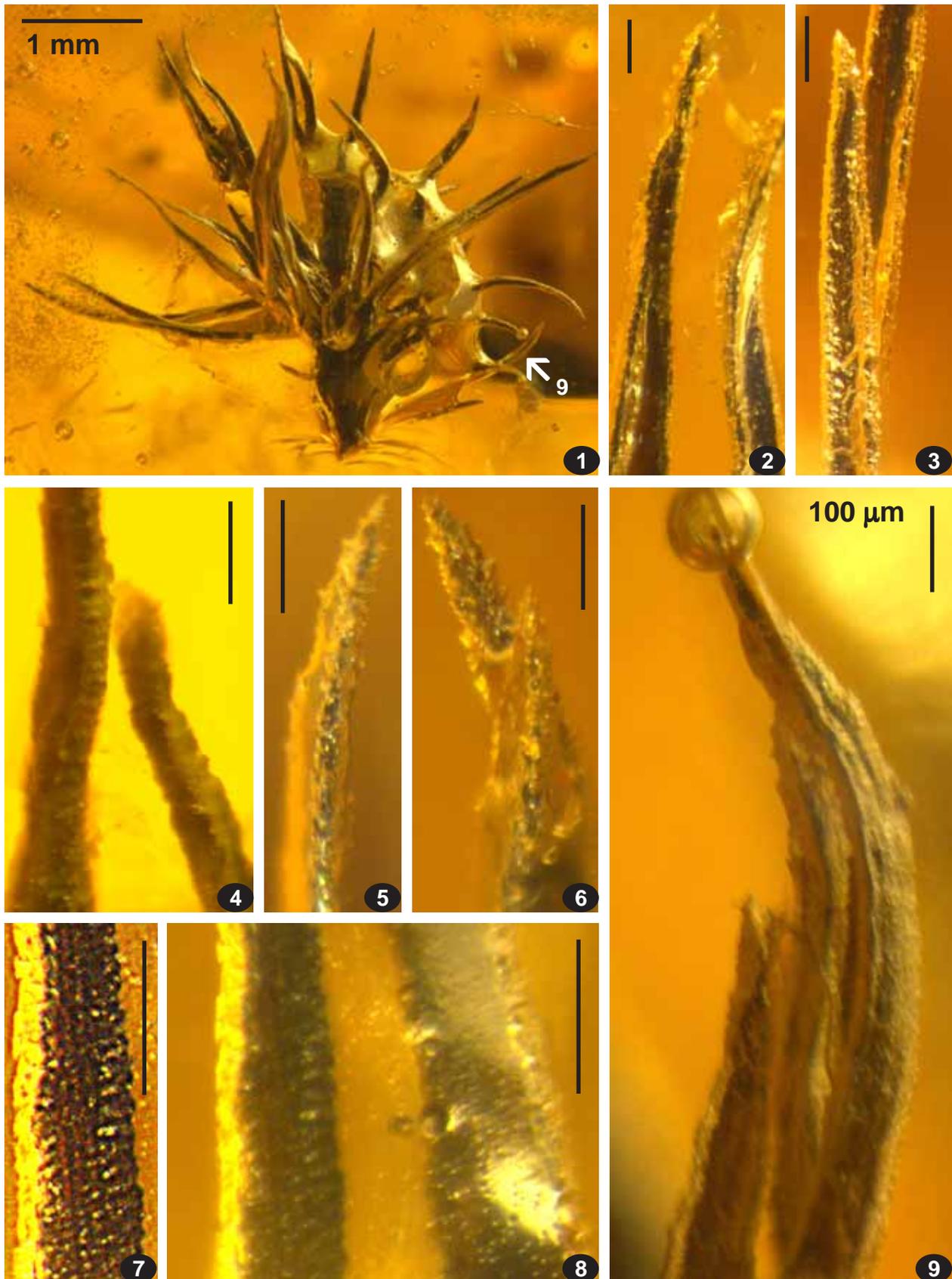
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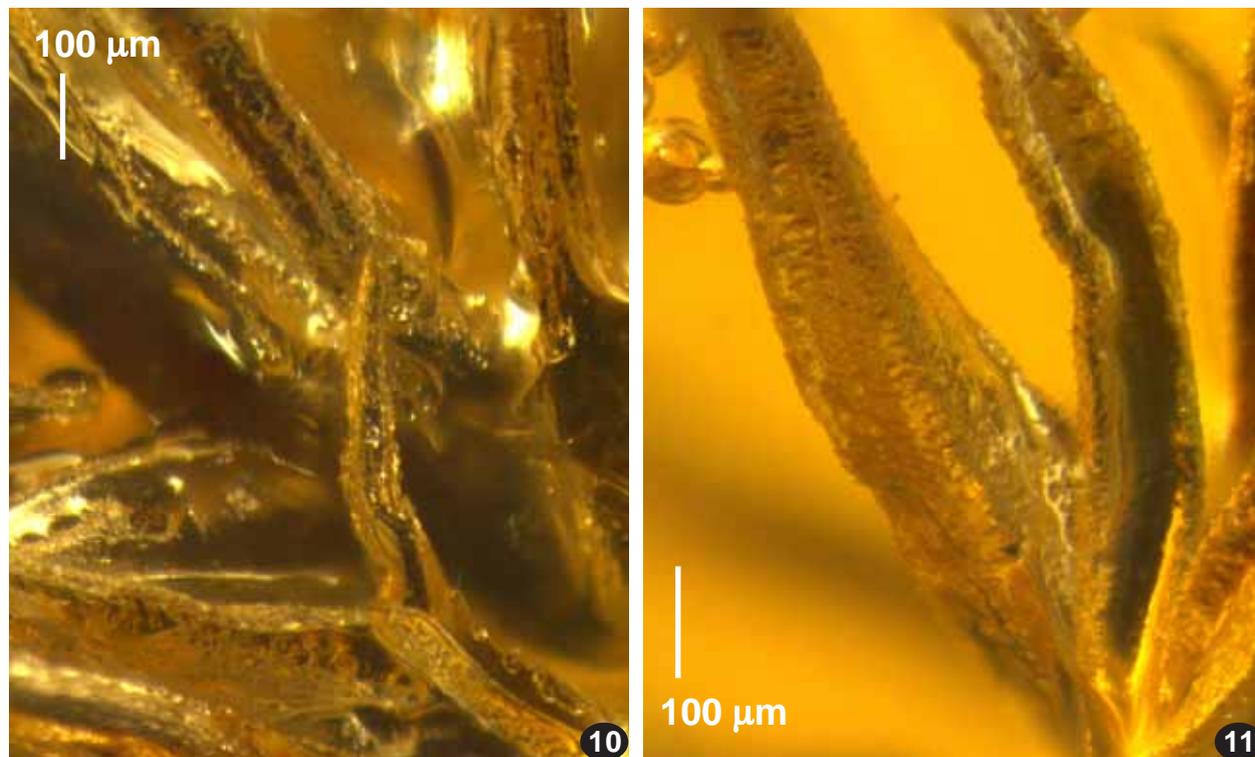
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Figs. 1–9. *Cynodontium eocenicum* sp. nov. (from BIN #1581/112): 1: holotype, total view; 2–6: distal parts of leaves, showing the papilloso-serrulate leaf margins; 7: left leaf from Fig. 8, strongly contrasted for clearer outlines of the middle lamina areolation; 8: two leaves in median part, allowing to estimate papillae density as one per cell; 9: smaller leaf from shoot base (its location indicated in Fig. 1), showing the slightly recurved leaf margin in middle part. Scales for 2–9: 100 µm.



Figs. 10–11. *Cynodontium eocenicum* sp. nov. (from BIN #1581/112): 10: young leaf among larger leaves in the central part of shoot; 11: distinctly channeled leaf in its middle part.

#### MATERIALS AND METHODS

The amber piece discussed in the present paper is a part of Paleobotanical collection of the Komarov Botanical Institute.

The fossil moss was studied and photographed using the stereomicroscope Leica M 165 and partly Olympus SZX16 with a 1.6× objective lens, equipped with the Infinity 4 digital camera. To better illustrate the three-dimensional inclusion, images were stacked from 5–15 optical sections using the software package HeliconFocus 4.50 (Kozub *et al.*, 2008).

#### OBSERVATIONS

**Material description:** The moss is embedded in a rather big amber piece, 3×3×1 cm, transparent from one side, close to the moss, without syninclusions. The stem is erect (Fig. 1), short, not seen among leaves, but, judging from the leaf arrangement, its length is about 1 mm. Leaves are crowded, 25 in number, rigid and spreading, straight to slightly incurved. Most leaves are from 2.3 to 2.8 mm long, from approximate measurements, as the position of their bases is not sufficiently visible. The leaves are smaller towards the shoot base, with the shortest one *ca* 1.0 mm long. Leaves are 150–200 µm wide at about half of their length while narrowest leaves in proximal part of shoot are narrower than 100 µm. Leaves are linear-lanceolate. Although their bases are not exposed, there is no evidence that they are distinctly sheathing. Leaves are gradually long acuminate, evenly tapered to the sharply acute apex. Clear views in their middle portions indi-

cate that they are shallowly keeled and deeply channelled (Figs. 10–11). The general aspect of leaves in their upper parts indicates that they are likely multistratose across their whole width (Fig. 4). Thus, the costa delimitation is unclear and it seemingly fills almost the whole volume of the upper part of leaf, although serrate margins near the leaf apex indicate that the costa is not percurrent but rather ends shortly below leaf apex. Three to six teeth are seen near leaf apex (Figs. 5–6). Margins are usually plane, although narrowly recurved in one relatively young and less rigid leaf (shown in Figs. 9 and 11). Cells are seen only in few places, allowing estimation of their shape as quadrate, sized about 10 µm (cf. Figs. 7–8; image in Fig. 7 represents maximally contrasted image from Fig. 8). Papillae occur on both sides of leaf, being small, rounded, low, likely one per cell, distinct along margins and folds but otherwise not clearly visible (*e.g.*, in Fig. 8). They look somewhat uneven in size (Figs. 2–3), although in more flat places (*e.g.*, in Fig. 8) they likely are more homogeneous.

**Comparison:** The above described moss matches the general characteristics of the subclass Dicranidae (haplolepidous mosses). Typical gametophytic characters of this group of mosses include the reduced size of stems, sparse branching, long and narrow leaves with a strong, single, percurrent to excurrent costa. The papillose leaf cells as seen in Fig. 8 are most commonly developed in representatives of the largest family Pottiaceae but occur also in Grimmiaceae, Amphidiaceae, Rhabdoweisiace-

ae, Aongstroemiaceae, Calymperaceae, Rhachithecaceae, Ditrichaceae and some of the basal clades, such as *Timmia* or *Luisierella*, to name a few. On the other hand, the serrate leaf margins visible in Figs. 5–6 rather suggest the affinity to Dicranaceae or Ditrichaceae. The combination of narrow, channelled leaves, serrate leaf margins and papillose or mamilllose cells is nevertheless not very common among haplolepidous mosses, and can be encountered e.g. in the genera *Cynodontium* or *Cnestrum* of Rhabdoweisiaceae, *Bryoerythrophyllum recurvirostrum* and *B. wallichii* agg., *Didymodon eroso-denticulatus* or *D. sinuosus* of Pottiaceae, *Dichodontium* (of ambiguous placement within Dicranidae), *Eccremidium* (Ditrichaceae) or *Chrysoblastella* (Chrysoblastellaceae)

The scattered papillae (or possibly mamillae with superficial papillae) are not typical of the above mentioned genera of Pottiaceae which have the habit of the amber inclusion and this also applies to the mentioned representatives of Ditrichaceae, in which we rather find mammillose bulging cells. In another representative of Pottiaceae, *Hydrogonium arcuatum*, a species with mostly long to subulate leaves and slightly serrulate apex, the papillae are mostly absent. On the other hand, most *Cynodontium* and *Cnestrum* species have markedly serrulate to strongly serrate leaf margin in the apical part of the leaf. It is probably possible to rule out the species of *Cnestrum* based on the relatively large size of the fossil plant, and also the species with somewhat broader and extremely serrate apices, such as *Cynodontium gracilescens* or *C. asperifolium*. The other extant species of *Cynodontium* are very similar in habit to the fossil plant, although the lamina cells are rather mamilllose than papillose, as the fossil inclusion suggests. Even in *Cynodontium bruntonii*, which might have rather highly papillose upper lamina cells, the mammilosity is mostly obvious. The exact character of the surface in the fossil moss can nevertheless only hardly be exactly ascertained.

Extant species of *Cynodontium* are more common in boreal biota, a few species are known from Mexico (Sharp et al., 1994) and India (Gangulee, 1971), which makes the fossil presence of *Cynodontium* in possible.

The fossil genus *Dicranites* Caspary & Klebs was described to accommodate *Dicranum*-like plants. However, the status of the genus is ambiguous, as at least a part of its syntypes belongs to *Hypnodontopsis* (Frahm, 2004). After the lectotypification it may be synonymized with the latter genus, which is commented below.

Extant species of Dicranaceae (in the older sense, i.e. including Leucobryaceae, Rhabdoweisiaceae etc.) are represented with two genera in Baltic Amber, *Campylopus* and *Campylopodia* (Frahm, 2010). Both of them have smooth lamina cells, and costa filling subulae almost throughout. Plant size and details of areolation are not described in amber material, but *Campylopodia* was referred to the extant species, *C. himalayana* (Broth) J.-P. Frahm, which according to Gangulee (1971) has laminal cells rectangular to elongate. The specimens of *Campy-*

*lopus* sp. are referred to the genus due to its sporophyte structure, while their gametophytes are not described in details. Usually, plants of this genus have relatively tall stems, unlike the situation in described specimen.

It is worth mentioning the Upper Cretaceous *Campylopodium allonense* Konopka, Herend. & P. Crane, with a perfectly preserved dicranoid peristome (Konopka et al., 1998). This fossil is at least twice as old as the age of Baltic Amber.

Among acrocarpous moss species of Baltic amber, papillose cells are a characteristic of the genus *Hypnodontopsis* (Rhachithecaceae). This is a very polymorphic and widespread genus of mosses, occurring both in the Baltic, as well as in Rovno amber in Ukraine (Ignatov & Perkovsky, 2011, 2013). The three extant species of the genus are known as rare plants in Mexico, Uganda, Myanmar and Japan. Frahm (2004, 2005, 2010) classified amber remains in five species of *Hypnodontopsis*. However, earlier Caspary & Klebs (1907) suggested that the numerous collections that they were able to see belonged to one highly polymorphic species. Ignatov & Perkovsky (2013) found that the variation in one collection from Rovno rather supports a broad understanding of species of *Hypnodontopsis*. Therefore, they accepted its identity with *H. mexicanus*, the only extant species reported from the Baltic amber. Its leaves have been described as being 1.0–1.2 mm long (Sharp et al., 1994). Amber plants are also small, with most leaves about 1.0 mm long, some being only 0.5 mm long, with few uppermost leaves occasionally reaching 2.0 mm. Thus, they are definitely smaller than the plant from collection discussed here. The leaves of *Hypnodontopsis* are slightly but rather evenly keeled along the whole length. The largest leaves are rather oblong, with parallel margins, more rapidly tapered shortly below leaf apex. Leaf apices are often blunt, except for the lower leaves, which are long acuminate. Rough lamina surface is often described as mamilllose, i.e., having one more or less shallow projection above cell lumen. It disagrees with the case of the extant *H. mexicanus*, which lamina cells have 2–3 small papillae above cell lumen. Both fossil and extant species of *Hypnodontopsis* have entire leaves, whereas they are serrulate shortly below leaf apex in the specimen described here. These differences are enough to exclude *Hypnodontopsis* from the possibly related genera of our new finding.

#### TAXONOMY

*Cynodontium eocenicum* Ignatov & Jan Kučera, sp. nov.

Holotype: Baltic amber. Late Eocene. Komarov Botanical Institute Paleobotanical collection 1581, specimen 112 (BIN #1581/112).

**Diagnosis:** Similar to recent representatives of the genus *Cynodontium* in the linear lanceolate, strongly channelled leaves with subpercurrent costa, serrate leaf apices, and papillose cells but differing in the character of the papillosity and seemingly not mamilllose cells.

**Description:** Stem, short, *ca* 1 mm long. Leaves crowded, spreading, straight to slightly incurved, 2.3–2.8 mm long, *ca.* 0.3 mm wide closer to base, 0.2 mm wide in middle part, linear-lanceolate, gradually long acuminate, evenly tapered to sharply acute apex, deeply channelled in the middle part; margins with few teeth near apex, entire below. Costa single, strong, subpercurrent. Cells quadrate, 10 µm, moderately thick-walled, unipapillose, papillae of both sides of leaf, entire, rounded.

**Etymology:** The specific epithet is derived after the geological period, the Eocene, 56–34 Ma ago, indicating the specimen age.

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#### LITERATURE CITED

- ALEKSANDROVA, G.N. & N.I. ZAPOROZHETS. 2008a. Palynological characteristics of Upper Cretaceous and Paleogene deposits on the west of the Sambian Peninsula (Kaliningrad region), Part 1. – *Stratigraphy and Geological Correlation* **16**: 295–316.
- ALEKSANDROVA, G.N. & N.I. ZAPOROZHETS. 2008b. Palynological characteristics of Upper Cretaceous and Paleogene deposits on the west of the Sambian Peninsula (Kaliningrad region), Part 2. – *Stratigraphy and Geological Correlation* **16**: 528–539.
- ALEKSEEV, V.I. 2013. The beetles (Insecta: Coleoptera) of Baltic amber: the checklist of described species and preliminary analysis of biodiversity. – *Zoology and Ecology* **23**(1): 5–12.
- ALEKSEEV, V.I. & P.I. ALEKSEEV. 2016. New approaches for reconstruction of the ecosystem of an Eocene Amber Forest. – *Biology Bulletin* **43**: 75–86.
- CASPARY, R. & R. KLEBS. 1907. Atlas von dreissig Tafeln zu der Abhandlung: Die Flora des Bernsteins und anderer fossiler Harze des ostpreussischen Tertiärs. – *Abhandlungen der Königlich Preussischen Geologischen Landesanstalt, Berlin*.
- ENGEL, M.S. 2001. A monograph of the Baltic amber bees and evolution of the Apoidea (Hymenoptera). – *Bulletin of the American Museum of Natural History* **259**: 1–192.
- FRAHM J.-P. 2004. A new contribution to the moss flora of Baltic and Saxon amber. – *Review of Palaeobotany and Palynology* **129**: 81–101.
- FRAHM J.-P. 2005. The genus *Hypnodontopsis* (Bryopsida, Rhachithecaceae) in Baltic and Saxon amber. – *Bryologist* **108**: 228–235.
- FRAHM, J.-P. 2010. Die Laubmoosflora des Baltischen Bernsteinwaldes. – *Jena, Weissdorn Verlag*. 101 pp.
- GANGULEE, H.C. 1971. Mosses of Eastern India and adjacent regions. Part 2. – Privately published, Calcutta: 177–566.
- GÖPPERT, H.R. 1853. Über die Bernsteinflora. – *Monatsberichte der Königlich Preussischen Akademie der Wissenschaft zu Berlin* [1853]: 450–477.
- GÖPPERT H.R. & G.C. BERENDT. 1845. Der Bernstein und die in ihm befindlichen Pflanzenreste der Vorwelt. – *Commission der Nicolaischen Buchhandlung, Berlin*.
- HIGUCHI, M. 2011. Endemic species of bryophytes in Japan. – *Bulletin of the National Science Museum. Series B, Botany* **37**(3): 117–126.
- IGNATOV, M.S. & E.E. PERKOVSKY. 2011. Mosses from Rovno amber (Ukraine). – *Arctoa* **20**: 1–18.
- IGNATOV, M.S. & E.E. PERKOVSKY. 2013. Mosses from Rovno amber (Ukraine). 2. – *Arctoa* **22**: 83–92.
- IGNATOV, M.S. & E.E. PERKOVSKY. 2016. Mosses from Rovno amber (Ukraine). 3. *Pottiodicranum*, a new moss genus from the Late Eocene. – *Arctoa* **25**: 229–235.
- KONOPKA, A. S., P. S. HERENDEEN & P. R. CRANE. 1998. Sporophytes and gametophytes of Dicranaceae from the Santonian (Late Cretaceous) of Georgia, USA. – *American Journal of Botany* **85**: 714–723.
- KOZUB, D., V. KHMELIK, Yu. SHAPOVAL, V. CHENTSOV, S. YATSENKO, B. LITOVCHENKO & V. STARYKH. 2008. Helicon Focus Software. – <http://www.heliconsoft.com>
- SHARP, A.J., H. CRUM & P.M. ECKEL (eds.). 1994. The Moss flora of Mexico. – *Memoirs of the New York Botanical Garden* **69**: 1–1113.
- SCHIMPER, W.P. 1869. Traité de paléontologie végétale. Vol. 1. – *J. B. Baillière et Fils, Paris*.
- WOLFE, A.P., R.C. MCKELLAR, R. TAPPERT, R.N.S. SODHI & K. MUEHLENBACHS. 2016. Bitterfeld amber is not Baltic amber: Three geochemical tests and further constraints on the botanical affinities of succinite. – *Review of Palaeobotany and Palynology* **225**: 21–32.