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Description of a new genus and two new species of Leiodidae (Coleoptera) from Baltic amber using phase contrast synchrotron X-ray microtomography

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Abstract

A new genus and two new amber fossil species of Leiodidae are described: *Catops perkovskyi* sp. n. (Cholevinae Cholevini) and *Tafforeus cainosternus* gen. n., sp. n. (Leiodinae Pseudoliodini); using virtual dissection by propagation phase contrast synchrotron X-ray microtomography, which allows for visualization of the genital structures in a non-invasive way. The external and internal morphology of the new species is compared to that of the extant related species. Putative evolutionary relationship between *Tafforeus* and the genus *Cainosternum* Notman, 1921, and their placement in the tribe Pseudoliodini are discussed.

Key words: paleoentomology, Cholevini, Pseudoliodini

Introduction

Only a small number of fossil species of Leiodidae have been described. Among approximately 4000 valid species, currently five fossil species are attributed to this family, four from amber deposits and one from limestone deposits: *Catops nathani* Perkovsky, 2001a (Cholevinae, Cholevini) and *Nemadus microtomographicus* Perreau & Tafforeau, 2011 (Cholevinae, Andemadini), from Baltic amber; *Prionochoeta gratschevi* Perkovsky, 2009 (Cholevinae, Cholevini), from Rovno amber (Ukraine); *Aglyptinus poinari* Perkovsky, 2000 (Leiodinae, Scotocryptini), from Dominican amber; and *Mesagyrtoides fulvus* Perkovsky, 1999b, from the upper Jurassic limestone of Shar Teg (Mongolia). *Nyujwa zherichini* Perkovsky, 1990, from the lower Cretaceous limestone of Buriatia (Russia), originally placed in the tribe Agyrtodini of the subfamily Camiarinae, has been subsequently transferred to Nitidulidae (Kirejtschuk 2008).

If the taxonomic position of each amber fossil species of Leiodidae is rather clear (they are all placed in genera previously described for extant species), the original placement of the more ancient fossil from limestone deposits (*Mesagyrtoides* Perkovsky, 1990; placed in the tribe Pseudoliodini of the subfamily Leiodinae) is disputable since the description explicitly mentions open procoxal cavities, which are generally closed in Pseudoliodini (Newton 1998).

Two other genera, *Mesecanus* Newton, 1981, from the Jurassic deposits of Novospassk, and *Ponomarenkia* Perkovsky, 2001b, from the Jurassic deposits of Transbaikalia, both currently assigned to Agyrtidae (Leschen & Beutel 2004), the presumed sister group of Leiodidae, have been attributed previously either to Leiodidae (Perkovsky 1999a) or Agyrtidae (Newton 1981, 1997; Perkovsky 2001b). The difficulty of finding an appropriate placement for these genera, which have several character states intermediate between the two families, suggests that the separation between the latter could have occurred during the Jurassic period.

The small number of fossil taxa in the literature is not merely due to a lack of interest in fossils among specialists of Leiodidae (a single author described four among the five extinct species). Indeed, the biotopes of Leiodidae do not predispose them to being trapped in fossil deposits, especially not in amber. Many extant species of Leiodidae live in the ground (e.g., decayed organic material, mold, nests or burrows of ground mammals, superficial underground environment, caves, etc.) like Cholevinae; some are mycetophagous like Agathidiini,

Leiodini and Pseudoliadini; a few are commensals like Platyspyllinae (with mammals) and Scotocryptini (with Hymenoptera: Apidae). There are two possible explanations, however, that could account for the presence of Leodidae in amber deposits. Those that fly may have been trapped accidentally along with Diptera, Hymenoptera or other flying Coleoptera, which are commonly found in amber. The known species, as well as those described in this paper, were most likely captured in this manner: they belong to genera that are winged and usually known to fly easily (*Nemadus* Thomson, 1867, *Catops* Paykull, 1798, *Prionochoeta* Horn, 1880). Species that are more specialized in ground biotopes may have been trapped directly in amber generated from the roots of trees (Martinez-Delclós *et al.* 2004).

In this paper we describe two new species found in Baltic amber: *Catops perkovskyi* sp. n., the second fossil species of *Catops* (Cholevinae, Cholevini), and *Tafforeus cainosternus* gen. n., sp. n. (Leiodinae, Pseudoliadini), using propagation phase-contrast X-ray synchrotron microtomography (PPC-SR μ CT).

When possible, we present preliminary hypotheses on the phylogenetic placement of the species and genus described in this paper.

Material and methods

The specimens studied in this paper come from the Baltic amber deposits of Jantarnij, near Kaliningrad in Russia.

The observations of external and internal structures were made via PPC-SR μ CT, a technique used to visualize the habitus of amber fossils (Tafforeau *et al.* 2006; Lak *et al.* 2008; Soriano *et al.* 2010) and which also allows a complete virtual dissection of the specimens and a visualization of the external and internal morphology (especially genital structures) with a resolution close to 1 μ m (Perreau & Tafforeau 2011). The scan of the samples was performed at the beamline BM5 of the European Synchrotron Radiation Facility (ESRF, Grenoble, France).

All the microtomographic data linked to these specimens (original slices and processed data) and used for the present analysis are publicly available on the ESRF online paleontological microtomographic database <<http://paleo.esrf.eu>>.

Visible light observations with a stereomicroscope (Leica M10) have also been performed.

Taxonomy

Catops perkovskyi sp. n.

Type material. Holotype: ♂, **RUSSIA:** amber deposit of Jantarnij, near Kaliningrad (collection of M. Perreau, Paris, n°MP002).

Description. Body length: 3.0 mm. Habitus as in Figs. 1–2. Head with fine punctation. Antenna long (one-third of body length) and slender, all antennomeres longer than wide except for disk-like eighth (Fig. 3). Maxillary palps with last palpomere as long as penultimate. Eyes well developed.

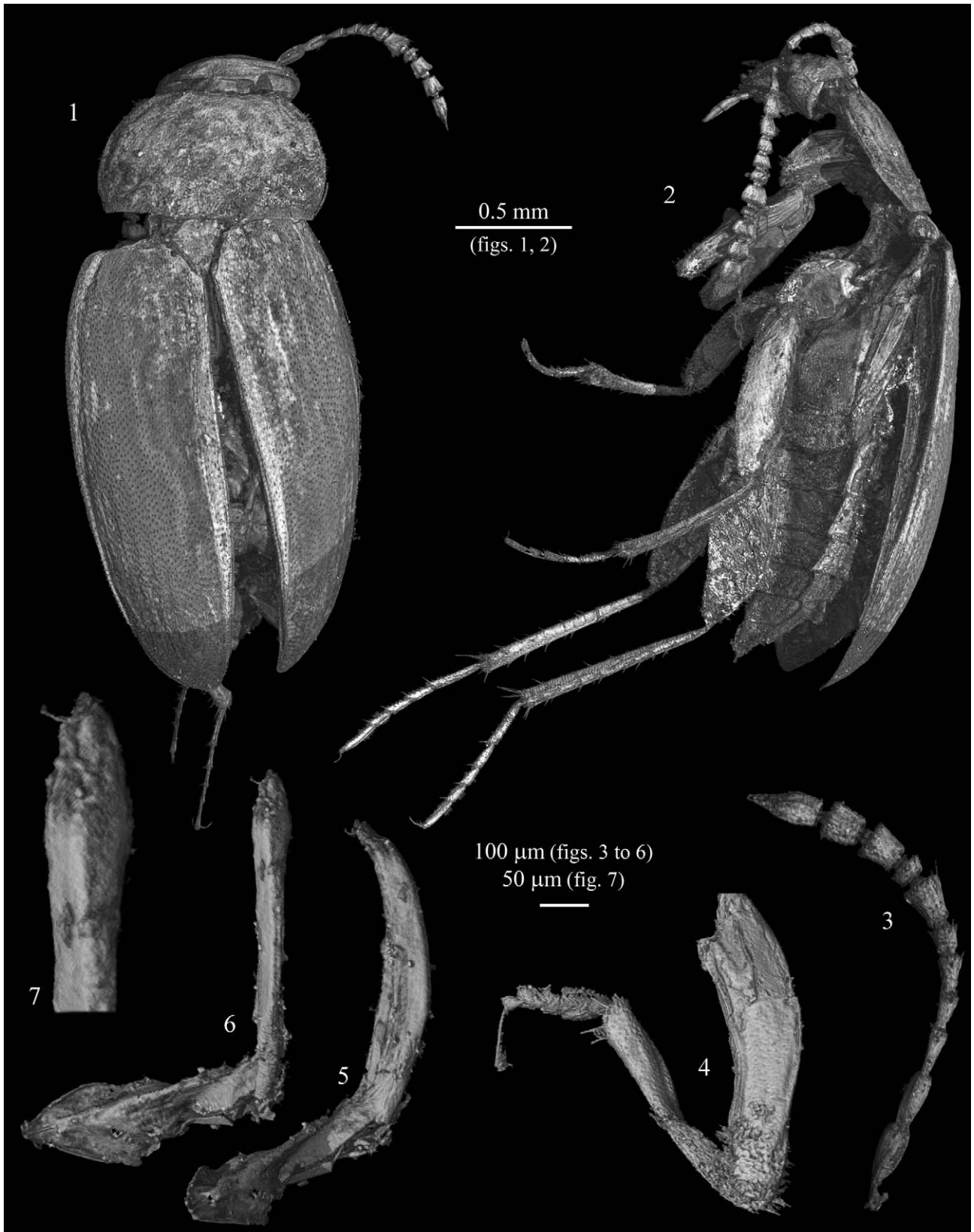
Pronotum 1.6 times wider than long, with lateral sides widely arcuate, not sinuate near basal angles. Anterior margin 1.4 times wider than straight basal margin. Basal angles distinct and obtuse. Punctation simple, randomly distributed, punctures small with distance between them much larger than their diameter.

Elytra 1.6 times longer than wide, with punctation similar to that of pronotum, randomly distributed, punctures small and widely spaced, with distance between them much larger than their diameter, as in extant species of *Catops*. Single longitudinal stria visible: parasutural stria. Tiny short setae that accompany punctures in extant species indistinct, probably due to lack of preservation or visualization.

Profemur without ventral tooth (Fig. 4). Protibia sinuate in middle of ventral side (Fig. 4). All tarsi 5 segmented. Protarsi dilated, 0.75 times as wide as apex of protibia. First two mesotarsomeres dilated. Metatarsi without any dilation.

Aedeagus very long and slender, regularly and strongly arcuate, nearly semi-circular in lateral view (Fig. 5), broken inside body at level of first third of its length by undetermined process (Fig. 6). Apex of median lobe roughly triangular. Tegmen (both basal lamella and parameres) has not been found.

Female unknown.



FIGURES 1–7. External and internal morphology of *Catops perkovskyi* sp. n. (holotype) by PPC-SR μ CT. 1, habitus dorsal view. 2, habitus lateral view. 3, antenna. 4, front leg. 5, aedeagus, lateral view. 6, aedeagus, dorsal view. 7, apex of aedeagus, dorsal view.

Distribution. The new species is known only by the holotype from Baltic amber, from the deposit of Jantarnij, near Kaliningrad.

Etymology. The species is dedicated to Evgeny Perkovsky, who was the first to study fossils in Leiodidae and described the first fossil species in this family.

Discussion. This species is placed in the genus *Catops* because of the absence of epistomal suture, the two first mesotarsomeres dilated, and the shape of the aedeagus: median lobe narrow and arcuate, and parameres thin. Moreover, the extremely long and arcuate median lobe of the aedeagus is characteristic of the “*Catops longulus*” species group. The elongated antennae with all antennomeres (except the eighth) longer than wide, and the absence of tubercles on the ventral side of profemora, are also consistent with a placement in this species group. *Catops perkovskyi* differs from *C. longulus* by a triangular apex of the aedeagus that is shorter (compared to the total length of the aedeagus), by the sinuate internal side of the protibia (straight in *C. longulus*) and by its smaller size. It is clear that the sinuate protibia is not an artifact due to bad preservation in amber, given that it is exactly symmetrical in the right and left protibiae.

***Tafforeus* gen. n.**

Type species. *Tafforeus cainosternus* sp. n.

Description. Body oval and convex (Figs. 8–9).

Head with fine, randomly dispersed punctures, without antennal grooves on ventral side. Epistomal suture present. Labrum rectangular, anterior edge not emarginate. Last maxillary palpomere approximately twice as long as penultimate, not expanded. Antennae 11-segmented, as long as one-third of body length, slender, with indistinct 5-segmented club, the eighth antennomere reduced but not discoid (Fig. 11).

Pronotum without basal or lateral rim, with tiny and very sparse punctation and distinct transversal microreticulation (the microreticulation is not visible in tomographic pictures, but can be clearly seen when the specimens are directly observed in visible light). Posterior angles widely rounded (Fig. 8). Prosternum short. Posterior edge of procoxal cavities closed, postcoxal process reaching prosternal process which is triangular (Fig. 10). Mesoventrite highly carinate, carina deeply notched (Fig. 15).

Elytra each with 10 distinct rows of punctures (including the parasutural stria), with traces of superficial transversal strigae, parasutural stria deep (Fig. 8). Abdomen with six visible ventrites.

Tarsal formula: 5-5-4 in male (Figs. 12–14), 5-4-4 in female. Protarsi and mesotarsi dilated in male (Figs. 12–13), not dilated in female. Metatarsi not dilated in both sexes (Fig. 14). All tibiae with large lateral spines denser in apical half.

Aedeagus long and slender. Parameres long and thin, as long as median lobe and held closely against it (Figs. 16–17).

Etymology. The genus is dedicated to Paul Tafforeau, the pioneer in the paleontological applications of synchrotron X-ray imaging. Gender masculine.

***Tafforeus cainosternus* sp. n.**

Type material. Holotype: ♂, **RUSSIA:** amber deposit of Jantarnij, near Kaliningrad (collection of M. Perreau, Paris, n°MP005). **Paratypes:** ♀, same data and same depository as holotype (not scanned by PPC-SRμCT); ♂, amber deposit of Jantarnij, near Kaliningrad n°56/2003 ex Friedrich Kernegger collection, will be deposited in Schmalhausen Institute of Zoology, Kiev (not scanned by PPC-SRμCT).

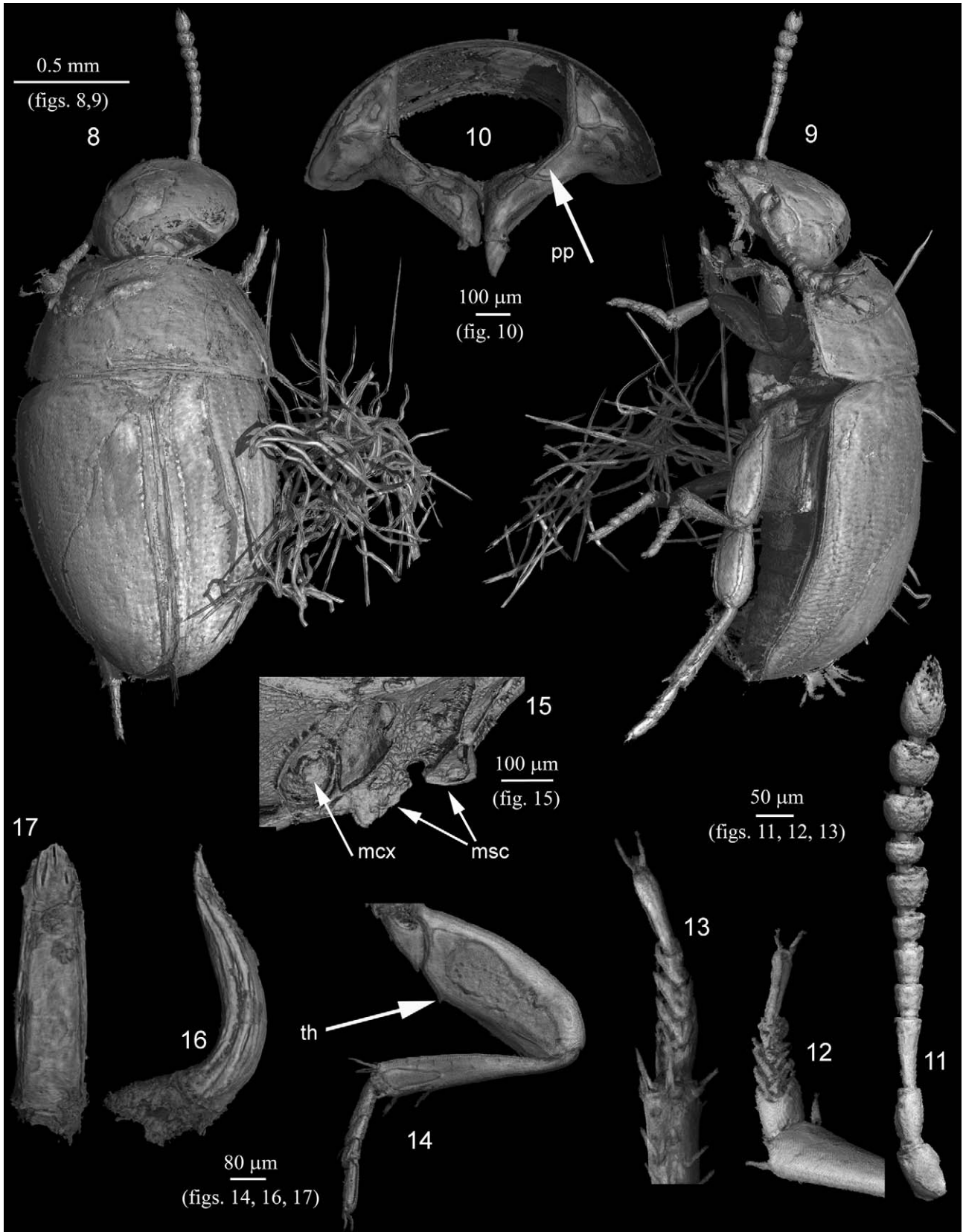
Description. Male (**Holotype**). Most of the characters are given in the description of the genus, in addition:

Body length 2.3 mm.

Pronotum 1.9 times wider than long, widest close to base. Elytra 1.1 times longer than wide, sides regularly arcuate.

Male protarsus 0.8 times as wide as apex of protibia (Fig. 12). Male mesotarsus 0.75 times as wide as apex of mesotibia (Fig. 13). Male metafemur with tiny tooth in middle of ventral side (Fig. 14).

Aedeagus as long as one-quarter of body length, slender, parameres as long as median lobe and contiguous to it (Figs. 16–17).



FIGURES 8–17. External and internal morphology of *Tafforeus cainosternus* sp. n. (holotype) by PPC-SR μ CT. 8, habitus dorsal view. 9, habitus lateral view. 10, prosternum and procoxal cavities from behind (pp = triangular prosternal process). 11, antenna. 12, protarsus, dorsal view. 13, mesotarsus, dorsal view. 14, posterior leg (th=ventral tooth). 15, mesoventral carina (msc) and mesocoxal cavity (mcx), lateral view. 16, aedeagus, lateral view. 17, aedeagus, dorsal view.

Female (paratype) with tarsal formula 5-4-4, without tarsal dilatation.

Distribution. The new species is known only from Baltic amber, from the deposit of Jantarnij, near Kaliningrad, Russia.

Etymology. The name of the new species refers to possible phylogenetic affinities with the genus *Cainosternum* Notman, 1921 (see discussion below).

Observation. The sample appears intermixed with stellate hairs of evergreen oaks (Figs. 8–9), commonly found in Baltic amber (A. Schmidt, personal communication).

Discussion. Concealed insertions of antennae occur only in two subfamilies of Leiodidae: Leiodinae and Catopocerinae (Newton 1998). *Tafforeus* has six visible abdominal ventrites, a prosternum that is shorter than procoxal cavities, and contiguous metacoxae, as Leiodinae, and not as Catopocerinae which have five visible abdominal ventrites, a prosternum that is longer than procoxal cavities, and metacoxal cavities separated by at least a third of their width (Newton 1998; Perreau & Růžička 2007). Therefore, *Tafforeus* takes its place naturally in Leiodinae.

Many morphological characters suggest a phylogenetic placement of *Tafforeus* in Pseudoliadini rather than in Leiodini or Agathidiini: the closed procoxal cavities and the triangular shape of the prosternal process (Fig. 10) (generally quadrangular in Leiodini (Newton 1998)); the straight apical margin of the labrum (deeply emarginate in Leiodini); the eighth antennomere not flattened (Fig. 11) (flattened in Leiodini); the transversal microreticulation of the pronotum and striolation of the elytra (rare in Leiodini); the absence of antennal grooves (present in Agathidiini). However, the combination of 5-5-4 male and 5-4-4 female tarsal formula occurs in Agathidiini, and not in Pseudoliadini (male tarsal formula 5-4-4), except in the monospecific genus *Cainosternum* Notman, 1921. This genus has been placed by some authors in Agathidiini for this reason (Wheeler 1986, 2005), but it is more likely to be placed in Pseudoliadini (Newton 1998) because of the absence of antennal grooves.

Tafforeus shares the same male and female tarsal formula and the absence of antennal grooves with *Cainosternum*. Moreover, *Tafforeus* has a deeply notched mesoventral carina (Fig. 15) as *Cainosternum* (Notman 1921; Wheeler 1986), which is not a frequent character state in Leiodidae: apart from *Cainosternum*, it has only been recorded in the genus *Perkovskius* Perreau & Růžička, 2007 of the subfamily Camiarinae. *Tafforeus* differs from *Cainosternum* in the number of longitudinal rows of punctures on elytra (10 on each in *Tafforeus*, ca. 20 in *Cainosternum*); the pronotum of normal size, approximately as wide as the elytra (small and 0.8 times as wide as the elytra in *Cainosternum*) and by the widely rounded apex of the aedeagus (abruptly narrowed before the apex in *Cainosternum*).

The unusual combination of characters shared by *Tafforeus* and *Cainosternum*: labrum not deeply emarginate; lack of antennal grooves, tarsal formula 5-5-4 in male and 5-4-4 in female; mesoventral carina deeply notched, suggests close phylogenetic relationship between these two genera. Compared to *Tafforeus* and the other genera of Pseudoliadini, Leiodini and Agathidiini, the large number of longitudinal rows of punctures on elytra (ca. 20 on each elytron, twice the common number) and the small size of the pronotum of *Cainosternum* are likely to be considered as derived characters. However the lack of comprehensive phylogenetic analysis for Leiodinae makes it difficult to interpret character states as plesiomorphies or apomorphies, and the above discussion of relationships among genera should be treated as preliminary hypothesis.

Conclusion

The morphology of the currently recorded fossil species of Cholevinae in Baltic amber is extremely similar to that of the extant species of the genera to which they belong: *Nemadus*, *Catops*, *Prionochoeta*, the genera which were first described in the extant fauna. The main differences between extinct and extant congeneric species are in the male and female genitalia, if those are known: *Catops perkovskyi*, *Nemadus microtomographicus* (Perreau & Tafforeau 2011) and *C. nathani* (unpublished data), which is usually the case for extant congeners. The specific characterisation of the extinct species with undescribed genitalia (*Prionochoeta gratschevi*) is unclear.

Despite the controversy surrounding the accuracy of dating Baltic amber, it is generally accepted that Baltic amber deposits date back to the Eocene, from 47 to 33 million years ago (Ritzkowski 1997; Perkovsky 2007). The small number of morphological modifications (except for the species level characters) between the extant and Eocene fossil species of Cholevinae suggests that the main extant genera and even extant species groups of Cholevinae were already established at that point in time.

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References

- Horn, G.H. (1880) Synopsis of the Silphidae of the United States with reference to the genera of other countries. *Transactions of the American Entomological Society*, 8, 219–322.
- Jeannel, R. (1936) Monographie des Catopidae. *Mémoires du Muséum d'Histoire naturelle*, 1, 1–433.
- Kirejtschuk, A.G. (2008) A current generic classification of sap beetles (Coleoptera, Nitidulidae). *Zoosystematica Rossica*, 17(1), 107–122.
- Lak, M., Néraudeau, D., Nel, A., Cloetens, P., Perrichot, V. & Tafforeau, P. (2008) Phase contrast X-ray synchrotron imaging: opening access to fossil inclusions in opaque amber. *Microscopy and Microanalysis*, 14, 251–259.
- Leschen, R. & Beutel, R.G. (2004) Ocellar atavism in Coleoptera: plesiomorphy or apomorphy? *Journal of Zoological Systematics and Evolutionary Research*, 42, 63–69.
- Martínez-Delclós, X., Briggs, D.E.G. & Peñalver, E. (2004) Taphonomy of insects in carbonates and amber. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 203, 19–64.
- Newton, A.F. (1981) New name for the extinct genus *Mesagyrtes* Ponomarenko (Coleoptera: Silphidae s.l.). *Psyche*, 88, 335–336.
- Newton, A.F. (1997) Review of Agyrtidae (Coleoptera), with a new genus and species from New Zealand. *Annales zoologici*, Warszawa, 47, 111–156.
- Newton, A.F. (1998) Phylogenetic problems, current classification and generic catalogue of world Leiodidae (including Cholevinae). In: Phylogeny and evolution of subterranean and endogean Cholevidae (=Leiodidae Cholevinae), Proceedings of XX International Congress of Entomology, Firenze, 1996. *Atti del Museo regionale di Scienze naturali*, Torino, 41–178.
- Notman, H. (1921) Some new genera and species of Coleoptera collected at Westfield, Chautauca Co., N. Y. *Journal of the New York entomological Society*, 83(3–4), 145–160.
- Paykull, G. (1798) *Fauna svecica. Insecta. Tomus I.* Joh. F. Edman, Upsaliae, 10 + 358 pp.
- Perkovsky, E.E. (1999a) Evolutionary development of the specific antennal structure in leiodid beetles and systematic position of Jurassic *Mesecanus communis* and *Polysitum elongatum* (Coleoptera: Staphylinoidea, Leiodidae). *Vestnik Zoologii*, 35, 75–79. [in Russian]
- Perkovsky, E.E. (1999b) New genus and species of late Jurassic Leiodinae (Coleoptera, Leiodidae) from Mongolia. *Vestnik Zoologii*, 34, 77–79. [in Russian]
- Perkovsky, E.E. (2000) The first find of Leiodid tribe Scotocryptini (Coleoptera: Leiodidae: Leiodinae) in fossil resin (Dominican amber). *Paleontologičeskij Žurnal*, 34, supplement 3, S331–S332.
- Perkovsky, E.E. (2001a) The first Eocene representative of Cholevini—*Catops nathani* sp. n. from the Baltic amber. *Vestnik Zoologii*, 35, 75–79. [in Russian]
- Perkovsky, E.E. (2001b) The systematic position of the lower Cretaceous beetle *Mesecanus parvus* (Coleoptera, Staphylinoidea) from Turga. *Vestnik Zoologii*, 35, 79–81. [in Russian]
- Perkovsky, E.E. (2007) A comparative analysis of the Baltic and Rovno amber arthropod faunas: representative samples. *African invertebrates*, 48, 229–245.
- Perkovsky, E.E. (2009) New species of *Prionochaeta* (Coleoptera, Leiodidae, Cholevinae) from Rovno amber. *Vestnik Zoologii*, 43(4), 373–377. [in Russian]
- Perreau, M. & Tafforeau, P. (2011) Virtual dissection using phase-contrast X-ray synchrotron microtomography: reducing the gap between fossils and extant species. *Systematic Entomology*, 36, 573–580.
- Perreau, M. & Růžička, J. (2007) Systematic position of *Perkovskius* Lafer 1989 (Coleoptera: Leiodidae), with description of a second species from Far East of Russia. *Annales de la Société Entomologique de France* (N. S.), 43(3), 257–264.
- Ponomarenko, A.G. (1990) Silphidae Latreille, 1807. In: Rasnitsyn, A.P. (Ed.), Late Mesozoic insects of eastern Transbaikalia. *Trudi Paleontologičeskogo instituta Akademii nauk SSSR*, 239, 51–53.

- Ritzkowski, S. (1997) K-Ar Altersbestimmungen der bernsteinführenden Sedimente des Samlandes (Paläogen, Bezirk Kaliningrad). In: Ganzelewski, M., Rehren, T.H. & Slotta, R. (Eds.), Proceedings of the Symposium Neue Erkenntnisse zum Bernstein. *Metalla* (Sonderheft), 66, 19–24.
- Soriano, C., Azar, D., Delclós, X., Hand, S., Nel, A., Néraudeau, D., Ortega, J., Pérez de la Fuente, R., Perrichot, V., Saupe, E., Solórzano-Kraemer, M. & Tafforeau, P. (2010) Synchrotron phase contrast X-ray imaging of amber inclusions. *Comptes Rendus Palevol*, 9, 361–368.
- Tafforeau, P., Boistel, R., Boller, E., Bravin, A., Brunet, M., Chaimanee, Y., Cloetens, P., Feist, M., Horszowska, J., Jaeger, J.J., Kay, R.F., Lazzari, V., Marivaux, L., Nel, A., Nemoz, C., Thibault, X., Vignaud, P. & Zabler, S. (2006) Applications of X-ray synchrotron microtomography for non-destructive 3D studies of paleontological specimens. *Applied Physics A, Materials Science & Processing*, 83, 195–202.
- Thomson, C.G. (1867) *Skandinaviens Coleoptera, synoptiskt bearbetade. Tom. IX*. Lundbergska Boktryckeriet, Lund, 404 pp.
- Wheeler, Q.D. (1986) Rediscovery and cladistics placement of the genus *Cainosternum* (Coleoptera: Leiodidae). *Annals of the Entomological Society of America*, 79, 377–383.
- Wheeler, Q.D. & Miller, K.B. (2005) Slime mold beetles of the genus *Agathidium* Panzer in North and Central America (Coleoptera: Leiodidae), part I. *Bulletin of the American Museum of Natural History*, 290, 5–95.