

ORIBATID MITE FOSSILS FROM QUATERNARY AND PRE-QUATERNARY SEDIMENTS IN SLOVENIAN CAVES I. TWO NEW GENERA AND TWO NEW SPECIES OF THE FAMILY OPPIIDAE FROM THE EARLY PLEISTOCENE

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Abstract. Two new genera of the oribatid mite family Oppiidae (Acari: Oribatida) are proposed based on fossils found in Early Pleistocene clastic sediments in caves of the Classical Slovenian Karst (Kras). *Rhinoppioides* MIKO gen. nov., with type species *R. quadrituberculatus* MIKO sp. nov., differs from the similar recent taxon *Oppiella* (*Rhinoppiella*) BALOGH, 1983 by the presence of a rudimentary pedotectum II, simple setiform sensillus without rami and the position of the rostral setae, as well as by the presence of ventral spiniform tubercles. *Praoppiella* MIKO et MOUREK gen. nov., with type species *P. oanae* MIKO et MOUREK sp. nov., differs from other genera of the family by the form of bothridia and two pairs of tubercles on the anterior border of the notogaster, both resembling those of suctobelbid species, and special development of the rostrum.

■ Fossil oribatid mites, Oppiidae, new genus, new species, *Rhinoppioides*, *Praoppiella*, Pleistocene sediments, Slovenian Classical Karst

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Introduction

Oribatid mites are among the oldest terrestrial arthropods, being known from fossils of Middle Devonian age (Norton et al., 1988), if not from earlier periods (Bernini et al., 2002). More taxa, already modern in aspect, are known from the early Jurassic and further taxa from the Cretaceous periods (for overview see Labandeira et al., 1997). The earliest records of species belonging to Oppioidea are from Baltic amber (Paleogene, Eocene, Priabonian – see Sellnick, 1931) and Dominican amber (Eocene, see Norton and Poinar, 1993). The Paleogene oppioid mites belonged to three recent families, namely Autognetidae, Oppiidae and Suctobelbidae. Based on the original figures, two of the oppiid mites from Baltic amber, namely *Oppia medium* (SELLNICK, 1931) and *Oppia angustum* (SELLNICK, 1931), are probably misplaced in *Oppia* and may belong to *Oppiella* sensu lato. If true, then the Baltic amber fossils represent the oldest known Oppiellinae. Two other Baltic amber fossils were attributed by Sellnick in the same paper to the recent species *Autogneta longilamellata* (MICHAEL, 1885) and *Suctobelbella subtrigona* (OUDEMANS, 1916), but their identification cannot be checked, as the specimens have

been lost. Further oppioid mites were described from Chiapas amber from the Miocene (Acquitani) – *Oppia setifer* (WOOLEY, 1971) and *Oppia mexicana* (WOOLEY, 1971), both described originally under *Damaeus* (see Woolley, 1971; Norton and Poinar, 1993). A further Miocene species, *Oppites melilii* PAMPALONI, 1902, is known from Sicilian amber (Serravallian; see Norton and Poinar, 1993). Krivolutskij et al. (1990) reported species of *Multioppia* from the Upper Pleistocene. Recent species of *Oppiella* were reported from Holocene peat-bogs and lake sediments (Krivoluckij et al., 1990, Solhøy and Solhøy, 2000, Erickson et al., 2003).

No Oppiidae were known from the Pliocene or Early Pleistocene, but new material has become available from these periods, collected from cave sediments in the Slovenian Classical Karst (Kras in Slovenian Language). The aim of this paper is to describe two new species of Oppiidae, based on fossils collected from Early Pleistocene sediments in the Račiška pečina cave. Unlike other Pleistocene or Holocene fossils of oppiid mites, each represents a new genus, unknown in the recent fauna (see Moldovan et al., 2011 for details). We also attempt to establish the relationships between the new taxa with recent species or genera

within the family. Representatives of three presumably new species belonging to the recent genera *Dissorhina* (Oppiidae) and *Miracarus* (Microzetidae), also collected from the cave sediments in the Slovenian Classical Kras, will be described and discussed in subsequent papers.

Material and methods

Specimens were collected by Oana Moldovan, Andrej Mihevc and Ioana Meleg from sediments in Račiška pečina Cave (N 45° 30' 12.5"; E 14° 9' 1.56"). The sample was collected from the upper half of a section that was deposited in the Early Pleistocene (about 1,8 My old; see Moldovan et al., 2011 for further details, map and stratigraphy). This section consists of subhorizontally laminated flowstone with interbedded red clays and silts. Lutitic interbeds between the flowstone layers resulted from successive flooding which deposited well-sorted fine-grained allochthonous sediments (Horáček et al., 2007; Zupan Hajna et al., 2008).

The sample was taken from the exposed face which had already been sampled for paleomagnetic and paleontological studies (Moldovan et al., 2011). Approximately 1 kg of sediment was removed and placed in sealed, labeled plastic bags. In the laboratory, the sample was immersed in 10% KOH for 30 min, and then washed successively through sieves of 250 µm, 125 µm and 40 µm. Sub-samples from each sieve dimension were placed in 90% alcohol, examined separately under an Olympus SZX2 stereomicroscope and the mites removed. Specimens were studied in open cavity-slide preparations under a compound light microscope equipped with a camera lucida, using lactic acid as a medium. A slightly modified version of the system proposed by Weigmann (2006) and Norton et Behan Pelletier (2009) was followed during this work. Given the poor state of the specimens and the limited number of individuals, SEM photography was not attempted; light microphotographs were taken during sorting of the material from the sediment.

The light micrographs were made using a compound microscope equipped with a Nomarski DIC and a digital CCD camera. The final micrographs were constructed from various numbers of optical layers using Helicon Focus[®], and edited and assembled into plates in Adobe Photoshop[®].

Description of new genera and new species

Rhinoppioides Miko gen. nov.

Text-figs 1-3, Pls 1-2

D i a g n o s i s : Long body, prodorsum with elongated rostral part, without costulae, with pair of simple interbothridial tubercles, postbothridial tubercles merged with bothridium. Sensillus simple, setiform, smooth or with only a few small barbs distally, without rami. Genital and anal setation, as well as leg setation, unknown.

T y p e s p e c i e s : *Rhinoppioides quadrituberculatus* MIKO sp. nov.

R e m a r k s : Similar to *Oppiella* (*Rhinoppia*) BALOGH, 1983 (see Miko, 2006 for details), from which it differs by the presence of rudimentary pedotectum II and position of

the rostral setae which are inserted on a broad rostrum relatively far from each other, at about the same mutual distance as the lamellar and interlamellar setae.

Presence of a rudimentary pedotectum II is unusual within Oppiidae, and among recent Oppioidea a similar structure could be found regularly only in Autognetidae. Nevertheless, the absence of a rostral incision, lamellar structures and also the development of the ventral part of the body suggests placement within Oppiidae, in the vicinity of *Oppiella* in the sense of Miko (2006). To resolve the systematic position definitely, at least the first pair of legs would be needed, which was impossible to observe on the available material. Placing into Oppiidae/Oppiellinae must therefore be seen as provisional.

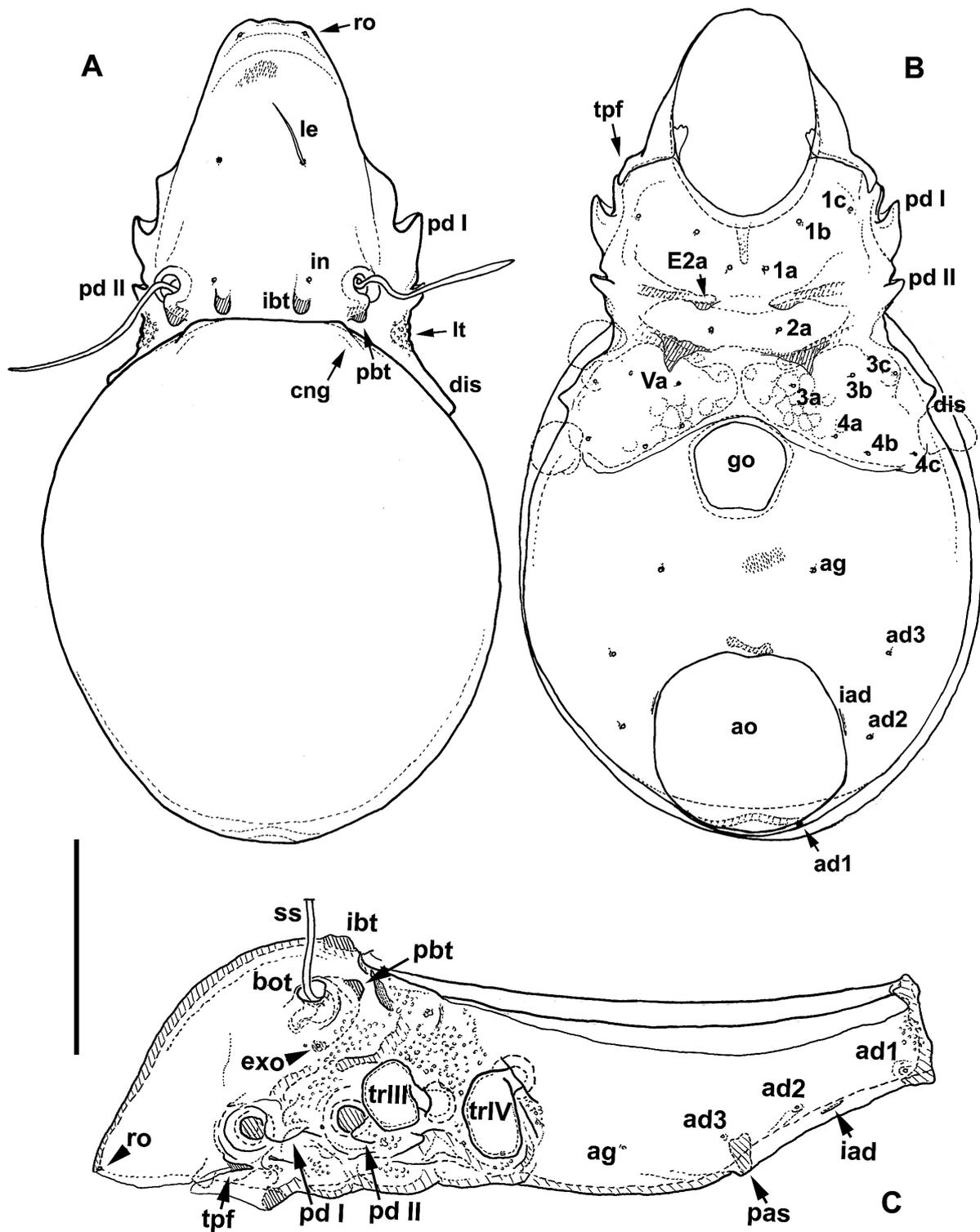
Rhinoppioides quadrituberculatus MIKO sp. nov.

D i a g n o s i s : *Rhinoppioides* with broad, vaguely tripartite rostrum, four similarly developed tubercles on posterior part of prodorsum (postbothridial and interbothridial pairs). Prodorsum without lamellar or costular structures; sensillus simple, long, unbranched, smooth or with few minute barbs. Pair of variably developed, spiniform tubercles *Va* present in ventrosejugal area.

M e a s u r e m e n t s : Body length of holotype 375 µm, maximum body width (notogaster) 218 µm, dorsal length of prodorsum 139 µm, width between the tips of pedotectum I 137 µm. Measurements of two other studied individuals (paratypes, see Pl. 1D, F): body length 340 and 355 µm, length of prodorsum 124 and 127 µm, maximum width of body 196 and 188 µm, width of prodorsum 126 and 135 µm. Sensillus length from 100 to 125 µm.

G e n e r a l c h a r a c t e r s : Available material with cuticle partly macerated (Pl. 1E, Pl. 2B); incomplete and damaged, not always enabling full assessment of characters. Body reddish-brown, in one case light brownish-yellow. Prodorsum finely punctate, finer punctation observable also on some areas ventrally (Text-figs 1A, B). Lateral parts of body around acetabula, in postbothridial and ventrosejugal area and in lateral parts of epimeres, with distinct fine granulation. Notogaster seemingly without particular microsculpture, smooth.

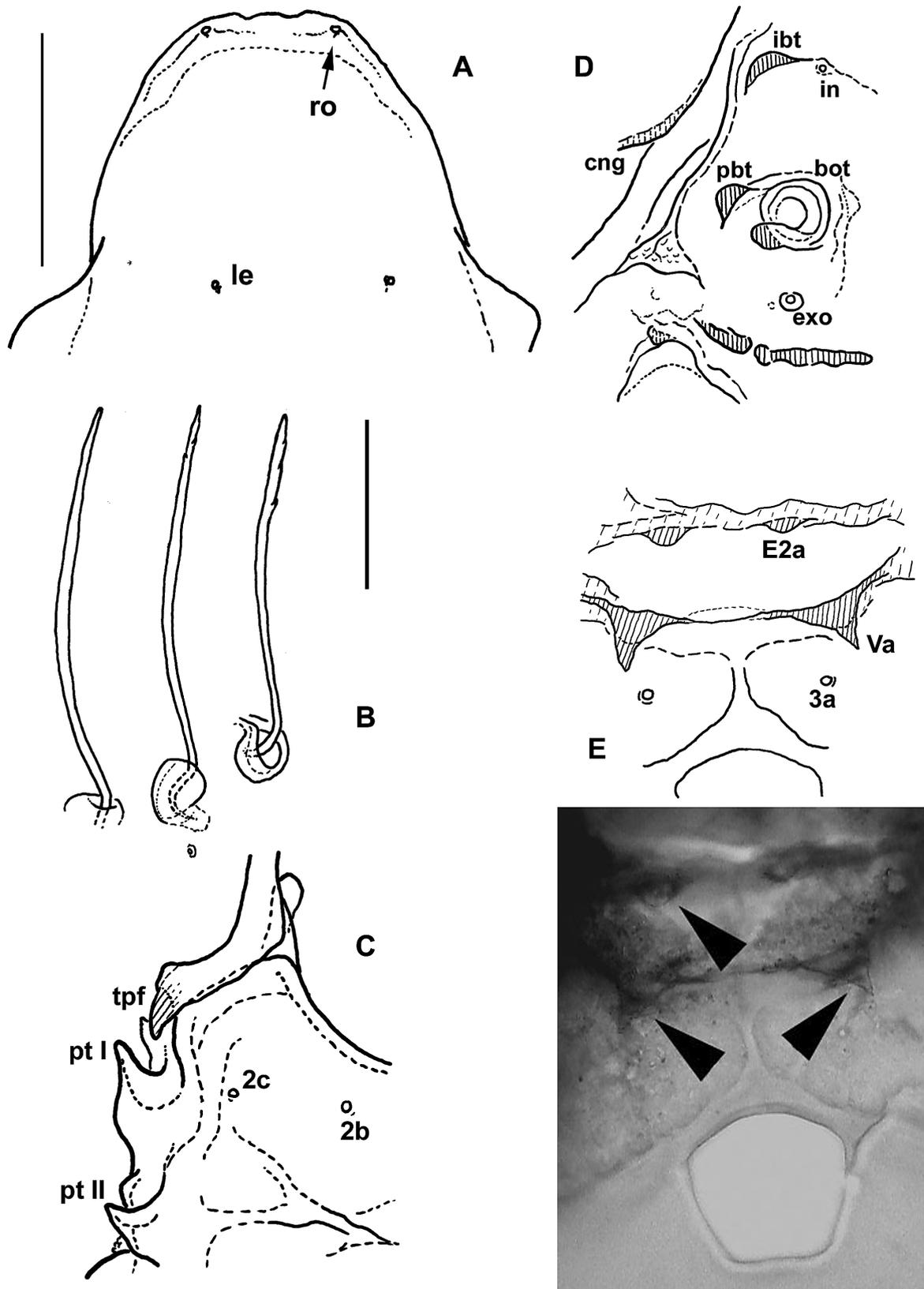
P r o d o r s u m : (Text-fig. 1A, Pl. 2A). Prodorsum of oppioid form: conical, with broad rostrum. Rostral tectum (Text-figs 2A, 1A, C) relatively short, vaguely divided into three blunt, rounded lobes, separated by very shallow incisions; lateral lobes as broad as or broader than central lobe, and projecting slightly more anteriorly. Pedotectum I well developed and quite strong; pedotectum II weakly developed, usually present in rudimentary, but observable form (Text-fig. 2C, Pl. 2D); in dorsal view appearing as pointed projection lateral to bothridia. Prodorsum without lamellae, costulae or analogous structures and without furrows, in lateral view (Text-fig. 1C) arched. Postbothridial tubercles merged with posterior part of bothridia (as in *Oppiella* sensu lato), creating a distinct postbothridial projection. Interbothridial tubercles simple but well developed, of a size and shape similar to postbothridial tubercles (Text-fig. 1A, Pls 2A, B). Lateral tecta (Text-fig. 1A: *lt*) in sejugal area well developed, granulated. Only one prodorsal (lamellar) seta preserved in one individual, relatively long (29 µm),



Text-fig. 1. *Rhinoppioides quadrituberculatus* MIKO gen. et sp. nov. A – dorsal view of holotype (prodorsal setae largely missing except right lamellar seta, notogastral setae missing and their insertions not discernable); B – ventral view of holotype (genital and anal valves missing, only insertions of ventral setae visible, gnathosoma missing); C – lateral view of paratype (notogaster missing). Bar indicates 100 μ m. For explanation of acronyms see page 31.

setiform, smooth. Insertions of rostral setae close to the anterior rostral margin, located on more sclerotized transversal band behind rostral tectum, sometimes even on indistinct tubercles. Insertions of rostral, lamellar and interlamellar setal pairs all situated at similar mutual distances, collectively outlining a long rectangle. Distance *ro-le* as long as *le-in* or slightly longer. Insertions of exobothridial

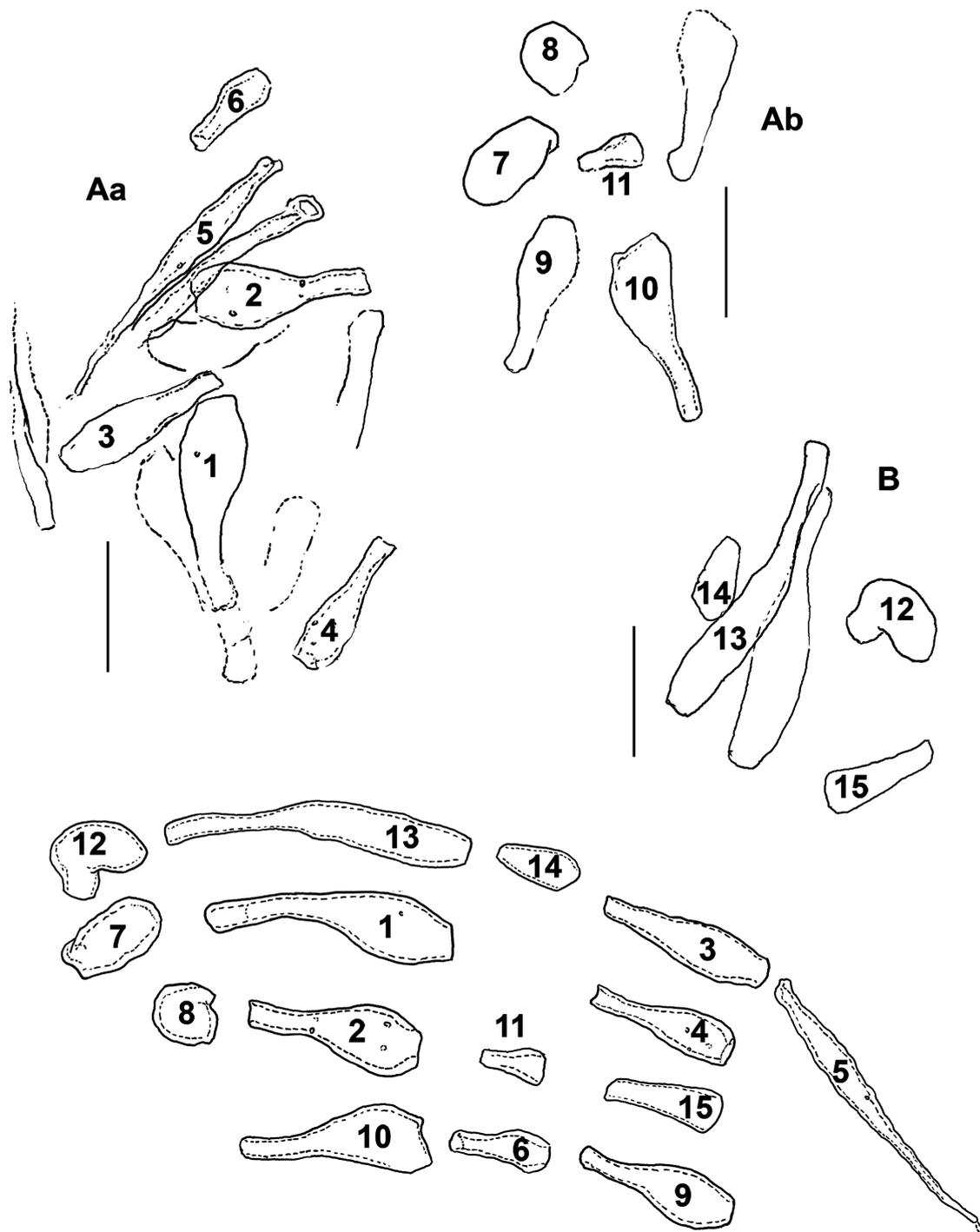
setae present laterally and more ventrally to bothridia, on usually distinct tubercle, with a small pore anterior to them. Sensillus of very characteristic form: long (100, 107 and 125 μ m), setiform or very slightly spatulate distally, narrowed but blunt at end, smooth, without cilia or branches but sometimes with two or three small, indistinct barbs or spines (Text-fig. 1C, Pl. 2A).



Text-fig. 2. *Rhinoppioides quadrituberculatus* MIKO gen. et sp. nov. A – rostrum; B – variation of sensillus; C – ventral view on lateral part of epimeral region; D – laterodorsal view on bothridial and sejugal area; E – ventral spines Va (drawing and micrograph of the part of ventral plate of paratype). Bars indicating 50 μ m. For explanation of acronyms see page 31.

Notogaster: (Text-fig. 1A, Pl. 1). Difficult to observe in detail on holotype, absent from one paratype (Pl. 1F), and highly damaged in the other one. Shape of notogaster broadly oval to ovoid, with short notogastral crista present

(Text-figs 1A, 2D, Pl. 2B), projecting slightly anterior as small, but visible humeral angle. Anterior margin of notogaster between humeral angles almost straight. Insertions of notogastral setae not distinguishable in available material.



Text-fig. 3. *Rhinoppioides quadrituberculatus* MIKO gen. et sp. nov. Above: assumed fragments of legs as seen in body cavity of holotype (Aa – in dorsal view, Ab – in ventral view) and paratype (B, only dorsal view available). Below: speculative reconstruction of legs, assumed segments leg IV in above rows (numbers 1, 3, 5, 7, 12, 13, 14), assumed segments of leg I below (numbers 6, 9, 10). Rest of the segments assumed to belong to legs II and III. Only trochanters III (nr. 8) and IV (nr. 7, 12) undoubtedly belonging to the new species. Bars indicating 50 µm, numbers indicate identity of segments.

Ventral characters: (Text-fig. 1B, Pls 2 E-F). Surface of ventral plate at least in some parts finely punctate, with muscle sigillae visible mostly on epimeres III and IV. Tectum of podocephalic fossa with distinct spiniform apophysis (Text-fig. 2C, 1B-C, Pl. 2C), sometimes less visible or slightly reduced. Sejugal epimeres with a pair of sharp, posteriad projecting, spiniform tubercles *Va*, adjacent to ventral surface and in some individuals less developed or

partly reduced (Text-figs 1B, 2E). A pair of smaller and less distinct, blunt tubercular structures also observed on epimeres 2, although it is not clear if they were really projecting above the surrounding surface or only created by local internal thickening of cuticle (E2a in Text-fig. 2E). Genital opening rather small, about two times shorter and narrower than anal opening; genital and anal plates missing in available material. Short and simple preanal sclerite pres-

ent, relatively tall (thick) when seen in lateral view (Text-fig. 1C). Posterior end of ventral plate in postanal area thickened (Text-fig. 1C), axial part in ventral or dorsal view slightly invaginated (Text-figs 1A, B). No ventral setae preserved, except perhaps single epimeral seta 1c in one of the paratypes – although hardly observable, appearing as relatively short and smooth (Text-fig. 1C, under pedotectum I); epimeral formula (I to IV) most probably as usually seen in Oppiidae (3-1-3-3), but lateral areas difficult to observe and setal insertions (eg. 3c, but possibly 4d) may be misinterpreted or overlooked (Text-fig. 1B, Pl. 2F). Single aggenital and three adanal setal pairs in usual positions. Discidium (Text-fig. 1B, Pl. 2E) normally developed, tooth-like or triangular, blunt.

L e g s : (Text-fig. 3). No complete legs were present in our material. Except for one of the paratypes, trochanters III and IV were preserved (Text-fig. 1C). However, two of the studied individuals (holotype, and one paratype which was later lost in the course of the study) contained parts of legs inside the body cavity. Forms and size of segments resembles those of oppioid mites, but it can only be speculated if the leg parts actually belonged to the studied individuals (Text-figs 3 Aa, Ab and B). In any case, most probably all types of segments were present, indicating that these legs were most probably not, or not significantly, longer than the measured body of *R. quadrituberculatus* n.sp. If the leg segments belong to the same individual, and their speculative identification as presented in Text-fig. 3 below is (at least partly) correct, then the length of the first pair of legs could be estimated as less than 295 µm (assuming that tarsus I should be shorter than tarsus IV), and the length of assumed leg IV could be around 375 µm.

M a t e r i a l e x a m i n e d : Holotype (Pls 1 A-C, sampling label “mite 007-2”) and three paratypes (Pl. 1D, sampling label “mite 007-1”; Pl. 1 E, sampling label “mite 007-7”; and Pl. 1 F, sampling label “mite 007-3”) were present in material from the same sample (R4) from red clay Pleistocene sediments, about 1.8 million years old, collected from a profile of elastic sediments from the cave Račiška pečina in the Classical Karst (Kras), Slovenia. One of the individuals (007-1) was unfortunately lost after examination. The holotype (mounted in Canada balsam) is deposited in the Acarological Collection of Senckenberg Museum Goerlitz, one mounted paratype is deposited in the Emil Racovita Institute of Speleology in Cluj-Napoca, Romania, and one paratype is in the collection of the National Museum in Prague.

D e r i v a t i o n o m i n i s : The name of genus reflects the similarity to *Rhinoppia*, a subgenus of *Oppiella*, characterized by an elongated rostrum and absence of lamellar costulae and well developed tubercles. The species name relates to the characteristic set of four similarly developed tubercles on the posterior part of the prodorsum.

R e m a r k s : This species was reported in Moldovan et al. (2011) as *Oppiella* (cf. *Rhinoppia*) sp. 1 in Text-fig. 3f and as *Oppiella* (*Rhinoppia*) sp. 2 in Pl. 1.

***Praoppiella* MIKO et MOUREK gen. nov.**

Text-fig. 4, Pl. 3

D i a g n o s i s : Oppiid mites with large cup-like bothridia with indistinct postbothridial tubercles not fused with bothridial rim, with rounded rostrum, short lamellar costulae and well developed interbothridial tubercles. Two pairs of tubercles, larger postbothridial (humeral) and smaller central, present on anterior margin of notogaster.

T y p e s p e c i e s : *Praoppiella oanae* MIKO et MOUREK sp. nov.

R e m a r k s : General body form and development of prodorsum (interbothridial tubercles, lamellar costulae, position of setae) indicate similarity to recent species of *Oppiella* sensu lato, e.g. *Oppiella* (*Moritzoppia*) SUBIAS et RODRIGUEZ, 1988. However, large cup-like bothridia and presence of two pairs of tubercles on anterior border of notogaster broadly resemble characters of the suctobelbid group of oribatids. Some important characters (ie. subcapitulum and chelicerae, legs, genital plates etc.) are unfortunately lost from the single available specimen. Some characters resemble species of the family Machuelliidae (eg. small body size, form of sensillus, epimeral setae 4a-c inserted in one row on posterior border of epimeres etc.), but notogastral and interbothridial tubercles are unknown in Machuelliidae. Therefore, including the genus in Oppiidae, in the vicinity of *Oppiella*, seems to us the most appropriate, though it should be seen as provisional.

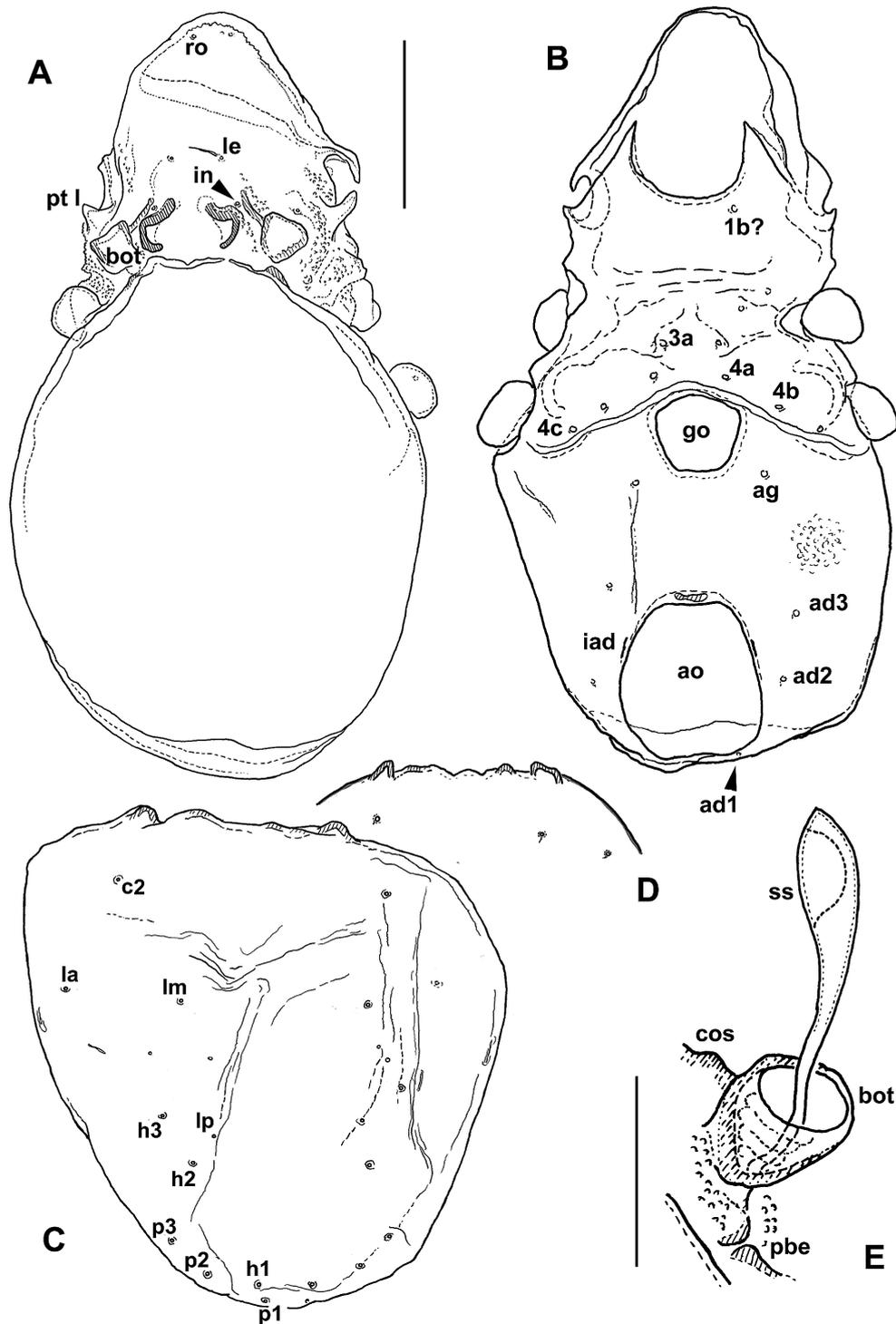
***Praoppiella oanae* MIKO et MOUREK sp. nov.**

D i a g n o s i s : *Praoppiella* with auricular interbothridial tubercles, relatively short, smooth and claviform sensillus and weakly developed axial notogastral tubercles. Rostrum rounded, pedotectum I well developed and postbothridial enantiophysis with both anterior and posterior tubercle present.

M e a s u r e m e n t s : Body of the single available individual (holotype) damaged and partly deformed, enabling only approximate measurements. Length of body 230 µm, length of prodorsum 80 µm. Maximum width of notogaster about 140 µm, maximum width of prodorsum (between tips of pedotecta I) 80 µm.

G e n e r a l c h a r a c t e r s : Body yellowish-reddish brown coloured. Surface densely covered by dirt and other artefacts, allowing neither detailed study of fine structures, nor observation and reliable identification of many setal insertions. Surface of lateral parts of prodorsum and podosoma with granulation, rugged or granulated surface also apparent on ventral plate.

P r o d o r s u m : (Text-fig. 4A, Pls 3A, E). Triangular, with slightly elongated rostral part. Rostral margin broadly rounded, with particular form (Pl. 3F): anterior border rounded, forming more transparent band; at inner edge of band, where cuticle appears thicker and coloured, with jagged, dentate cuticular pattern, integrated within the rostral cuticle. Short and relatively straight lamellar costulae running anteromedial, reaching slightly beyond insertions of interlamellar setae, followed by indistinct line almost reaching insertions of lamellar setae (Text-fig. 4A, Pl. 1A).



Text-fig. 4. *Praoppiella oanae* MIKO et MOUREK gen. et sp. nov. (holotype). A – dorsal view of the body (notogaster largely detached from body, rostral part of prodorsum partly invaginated); B – ventral view; C – dorsal view of detached part of notogaster; D – anterior margin of notogaster as drawn before detachment from the rest of the body; E – bothridium and sensillus. Bars indicating 50 µm (for A,B, C and D, above) and 25 µm (for E, below). For explanation of acronyms see page 31.

Interbothridial tubercles distinct, large, auricular. Bothridia relatively very large, cup-like, positioned near anterior edge of notogaster, without postbothridial lobe or attached tubercle. However, a pair of tubercles (postbothridial enantio-physe, Text-fig. 4E) present behind bothridia, loosely connected with bothridial base by thickened cuticle. Prodorsal setae lost from the studied individual, but a seta-like structure observed (Text-fig. 4 A) in location of right lamellar seta. Rostral setae inserted close to the jagged cuticular

structure of rostrum, lamellar and interlamellar setae inserted at normal positions as in other Oppiellinae. Sensillus (Text-fig. 4E, Pls 3D, E) relatively short, claviform (or club-shaped), about 37 µm long. Head about the same length or slightly shorter than the stalk, with lighter part observable in some views in transmitted light (Text-fig. 4E), indicating most probably spoon-like invagination of surface from medial side (perhaps artefact). Second sensillus missing. Pedotecta I present, relatively well developed.

Notogaster: (Text-figs 4 C-D, Pl. 3B). Rounded, broadly oval. External (postbothridial, humeral) pair of tubercles on anterior margin more strongly developed, broad, rounded, U-shaped or triangular, blunt, with short but observable crista running posteriad. Central pair of tubercles weakly developed, present as a short, rounded or semicircular ridge just on the border of notogaster (Pl. 3C). Notogastral setae not preserved, insertions not easily identifiable. Insertions of 10 pairs of notogastral setae assumed (Text-fig. 4 C), pair *c2* relatively far behind anterior margin of notogaster. Additional pores or insertion-like structures observed on notogaster, but unclear if should be assumed to be artefacts or real structures.

Ventral part: (Text-fig. 4B). Very difficult to observe in our individual. Discidium not prominent, broadly rounded. Genital and anal plates lost; size of apertures and mutual distance as usual in Oppiidae, anal aperture much larger than the genital one. Epimeral border 4 developed as quite distinct, broad transversal ridge, slightly bent forward anterior to genital opening. Insertions of epimeral setae hardly identifiable, only insertions of *4a*, *4b* and *4c* more clearly visible, these being inserted in one row anterior to the epimeral border IV. Insertions *3a* and perhaps also *1b* found as indicated in Text-fig. 4 B. Adanal and aggenital setae inserted in usual positions.

Legs: Lost from the single available specimen, only trochanters III and IV preserved but without setae (Pl. 3A, E), thus setal insertions impossible to identify.

Material examined: Single damaged individual (holotypus) found in clastic Pleistocene sediments of the Račiška cave in Classical Karst (Kras), Slovenia (sample R4, same as *R quadrituberculatus*). The holotype mounted in Canada balsam is preserved in the acarological collection of the Senckenberg Museum in Goerlitz, Germany.

Derivatio nominis: The genus name refers to the similar recent genus *Oppiella*. Prefix *Pra-* in genus name is an equivalent to "ancient" in several Slavic languages, the species name is dedicated to colleague and co-author Oana Moldovan from the Emil Racovita Institute of Speleology, Romania, who discovered the material and provided it for study.

Remarks: The rostrum of this species has a quite peculiar structure. The denticulate pattern on the margin of the rostral cuticle resembles the rostral teeth of recent *Suctobelbella* species. Presence of a much weaker, thin, transparent external band, forming a complete, rounded rostral tectum, may represent either an ancient or derived state of rostrum development. As the cuticle of this specimen is generally heavily damaged, the possibility that the structure is an artefact also cannot be excluded.

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Explanation of the plates

PLATE 1

Rhinoppioides quadrituberculatus MIKO gen. et sp. nov.

A – Holotype, dorsal view.

B – Holotype, ventral view.

C – Holotype, lateral view.

D-F – paratypes. Paratype under D was lost during the study, only original orientation micrograph of lower quality available. All bars – 50 µm.

PLATE 2

Rhinoppioides quadrituberculatus MIKO gen. et sp. nov. (paratypes).

A – Prodorsum in dorsal view.

B – Bothridial and sejugal area in laterodorsal view.

C – Tectum of podocephalic fossa.

D – Ventral view on lateral part of propodosoma.

E – Anogenital and part of epimeral area, insertions of adanal and aggenital setae indicated.

F – Detailed view on epimeres I-III-IV with insertions of epimeral setae indicated.

All bars – 50 µm, except in C (25 µm)

PLATE 3

Praoppiella oanae MIKO et MOUREK gen et sp. nov. (holotype).

A – Dorsal view, without notogaster.

B – Notogaster.

C – Detail of anterior border of notogaster

D – Sensillus and bothridium.

E – Lateral view on prodorsum and podosoma.

F – ventral view on rostrum.

Bars – 50 µm (A, B, E, F), 25 µm (D) and 10 µm (C).

Explanation of acronyms

ao – anal opening

bot – bothridium

cng – notogastral crista

cnt – centronotal tubercle

cos – lamellar costula

dis – discidium

E2a – epimeral tubercles (spines)

go – genital opening

ht – humeral tubercle

iad – adanal pore iad

ibt – interbothridial tubercle

lt – lateral tectum

pas – preanal sclerite

pbe – postbothridial enantiophyse

pbt – postbothridial tubercle

pd I, pd II – pedotectum I and II

ss – sensillus

tpf – tectum of podocephalic fossa

tr III, tr IV – trochanters III, IV

Va – ventrosejugal tubercles (spines)

Standard names of setae not explained. They refer in most of the cases to setal insertions.

