



<http://dx.doi.org/10.11646/zootaxa.3784.3.6>

<http://zoobank.org/urn:lsid:zoobank.org:pub:1F39FD34-968E-40A5-B66B-E3E78BD5B35E>

A new species of *Duvalius* from world's deepest cave (Coleoptera: Carabidae)

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Abstract

The new hypogean ground beetle, *Duvalius abyssimus* n. sp., from Krubera-Voronja, world's deepest cave (Arabika massif, Western Caucasus) is described and illustrated. Diagnostic morphological characters of the imago, male and female genitalia are provided. Its relations with other *Duvalius* Delarouzée species from the Western Caucasus geographic area are discussed. An updated overview of the biocoenosis of its peculiar habitat is made.

Key words: Trechini, Krubera-Voronja Cave, Western Caucasus, Abkhazia, Deep subsurface biosphere

Resumo

Uma nova espécie de carabídeo, *Duvalius abyssimus* n. sp., da gruta mais profunda do Mundo, Krubera-Voronja (maciço de Arábica, Cáucaso Ocidental) é descrita e ilustrada. A descrição fornece os caracteres diagnósticos do imago, genitália masculina e feminina. As suas relações com outras espécies de *Duvalius* Delarouzée do Cáucaso são discutidas e é aportada uma actualização da biocenose do seu peculiar habitat.

Introduction

Cave beetles have always been iconic inhabitants of the subterranean habitats, in fact, they were historically the first cave-adapted species described for science (Camacho 1992). The order Coleoptera represents an important fraction of cave biodiversity, particularly interesting because of the highly endemic patterns of distribution (Zagmajster *et al.* 2008).

The Caucasus region is a world hotspot for biodiversity (Myers *et al.* 2000) and its large extension of limestone has a particular biogeographic interest for cave-adapted species (Sendra & Reboleira 2012). The Western Caucasus harbours some endemic cave-dwelling ground beetles genera, e.g. *Jeannelius* Kurnakov, 1959, *Meganophthalmus* Kurnakov, 1959, *Caucasaphaenops* Belousov, 1999 or *Taniatrechus* Belousov & Dolzhanski, 1994 or *Caucasorites* Belousov & Zamotajlov, 1997 (Belousov 1999; Belousov & Koval 2009; Kryzhanovskij *et al.* 1995; Zamotajlov *et al.* 2010).

The genus *Duvalius* Delarouzée, 1859 has a wide distribution along the Mediterranean area, expanding through Asia (Belousov 1991; Casale & Laneyrie 1982; Casale 2011; Jeannel 1930; Zinetti *et al.* 2013). There are more than 220 species described, assigned to nine subgenera: *Biharotrechus* Bokor, 1922; *Duvalius* s.str.; *Euduvalius* Jeannel, 1928; *Hungarotrechus* Bokor, 1922; *Neoduvalius* Muller, 1913; *Paraduvalius* Knirsch, 1924; *Platyduvalius* Jeannel, 1928; *Trechopsis* Peyerimhoff, 1908 and *Typhloduvalius* Hurka & Pulpan, 1980 (Moravec *et al.* 2003; Anichtchenko 2013). Although it exhibits important differences in external morphology, the truly stronger diagnostic characters lies on the shape of the aedeagus (Jeannel 1930), but a systematic revision is needed to elucidate the taxonomic complexity of the genus (Faille *et al.* 2013).

The genus *Duvalius* is a successful colonizer of the subterranean habitat. Most species have a hypogean life-style, living mainly in caves or in the mesovoid shallow substratum (MSS) (Zinetti *et al.* 2013).

Duvalius is closely related to the genus *Trechus* Clairville, 1806, another well represented genus in the same geographic area, also with some species colonizing to the subterranean environment (Casale 2011; Reboleira *et al.* 2010). The characters used to distinguish these two large polyphyletic genera of Trechini, are weakly defined. The difference is based mostly in form and disposition of the copulatory piece of the aedeagus, the endophallus, and the pubescence of the protibias, being the last one not always valid (Mateu & Ortuño 2006).

Biospeleological research conducted in world's deepest cave, Krubera-Voronja, located in the Arabika Massif (Abkhazia), lead to the discovery of new species for science and interesting new perspectives regarding the vertical distribution of entomofauna related to depth (Sendra & Reboleira 2012). Among the material collected was a new species of *Duvalius* here described.

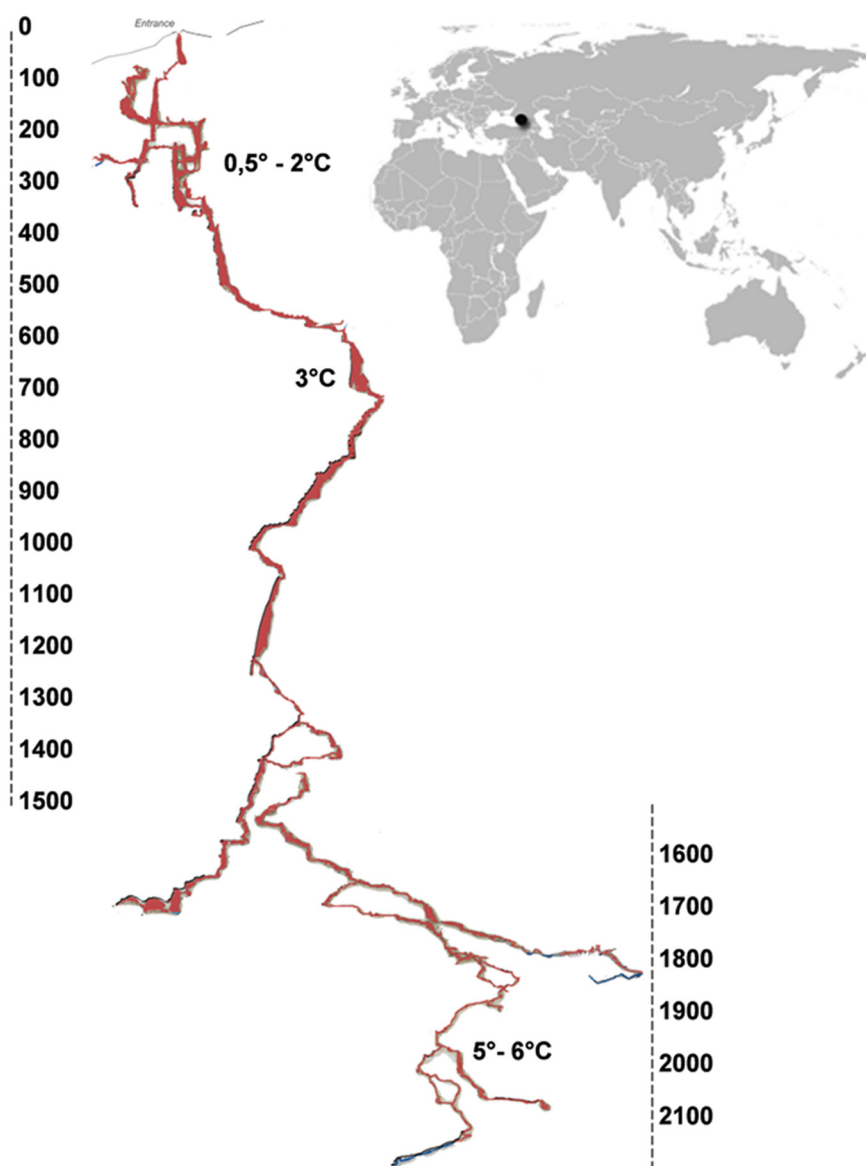


FIGURE 1. Location and map of Krubera-Voronja Cave with depth in meters (Cave map adapted from Ukrainian Speleological Association 2013, compiled by A. Klimchouck).

Material and methods

Field work was conducted in the Krubera-Voronja Cave (UTM: 43° 24' 35" N, 40° 21' 44" E), located at 2240 m.a.s.l. in the Ortobalagan valley, within the Arabika Massif, a large limestone massifs of Abkhazia in Western Caucasus (Fig. 1).

The cave was monitored from July to August of 2010 and in September of 2013, from the base of the first shaft, in total darkness at -60 m, to the deepest part of the cave, the last siphon at -2140 meters below the surface.

Sets of baited pitfall traps were used in the base of the first shafts and in each bivouac (-700 m, -1400 m and -1690 m) and active search was performed from the basis of the first pit until -2140 m deep, during the Ibero-Russian Cavex Team expedition.

The male genitalia was extracted from the abdomen, separating the tergal apodemal ring and separating the parameres from the associated membranes in the surface of the median lobe. The terminal abdominal segments of the female were placed in a saturated solution of KOH for 8 hours. Later Scheerpeltz's solution was used for washing and Chlorazol Black E® for the staining. A last washing was made in KOH and finally with Scheerpeltz's solution. After examination, genital preparations were included in dimethyl hydantoin formaldehyde (DMHF) on an acetate sheet and pinned below the specimens.

Detailed analysis was made using a microscope and stereomicroscope with a drawing tube. The measurements correspond to: body length, from mandible tip to elytral apex; head length, from apex of labrum to the mid region between the posterior area of tempora; head width, measured across the head and between the eyes; pronotum length, measured from anterior to basal margin along midline; pronotum width, between the widest region of the lateral margins; elytron length, basal margin near scutellum to apex of the longest elytron and elytra width, measured across the widest point of the two elytra.

Type material is deposited in the following entomological collections: Sofia Reboleira, Universidade de Aveiro, Portugal (SR/UA); and Vicente M. Ortuño, Universidad de Alcalá, Spain (VMO/UAH).

Results

Duvalius abyssimus Reboleira & Ortuño n. sp.

(Figs. 2–5)

Type series. Holotype: 1 ♂, Krubera-Voronja Cave (UTM: 43°24'35"N, 40°21'44"E), Caucasus (Abkhazia), 27.VII.2010, S. Reboleira & A. Sendra leg. (SR/UA).

Paratype: 1 ♀, same data as holotype, 09.VIII.2010 (VMO/UAH).

Diagnostic features (Figs. 2 and 4): Microphthalmous and micropterous trechine species. Body elongated, with long antenna and legs. Integument depigmented and testaceous, slightly shiny and with soft microreticulation. Cordiform pronotum, nearly as wide as long, with the anterior part largely protruding and posterior angles acute and sinuate toward the straight base. Ovate elytra with the shoulders not marked, seven striae visible, but only the first three punctuate. Male protarsi with the first tarsomeres enlarged. Median lobe of the aedeagus thin and long, with the apex of the apical blade slightly curved towards the dorsal part and the inner sac with a symmetric sclerotized piece, channel-shaped, of which a thin and fine structure is projected rearward.

Description: Large species, total body length: 6.60–6.77 mm.

Head: (Fig. 2) longer than wide (width/length \approx 0.64–0.65, excluding mandibles), neck well marked, temples convex and very long (four times the diameter of the eye), deep and complete frontal furrows bordering all the supraocular area and slightly reduced in the posterior part, eyes reduced and not convex with a few ommatidia, two supraocular setae (the anterior is placed slightly behind the level of the posterior edge of the eye and the posterior almost adjacent to the rear of the supraocular groove); clypeus with two setae on each side; labrum slightly notched and fringed with six setae near the anterior margin; mandibles long and very sharp; labial and maxillar pieces typical of the genus; labium lobulated and bisetulated at the base of labial tooth which is truncated (Fig. 3), articulated with the labium in the prebasilar area, bordered with six long setae (Fig. 3); antennae very long and full of setae, reaching the level of the 6th umbilical setae.

Pronotum (Fig. 2): cordiform, nearly as wide as long (width/length \approx 1.03), its greatest width in its anterior

third; lateral margin markedly sinuated; basal margin slightly notched with the posterior angles protruding backwards; lateral channel of moderately width and marked in all its length; basal grooves deep and not punctuated; convex disk with well marked median sulcus; two pronotal bilateral setae (the anterior situated in the first third part and the posterior slightly forward the rear angle).

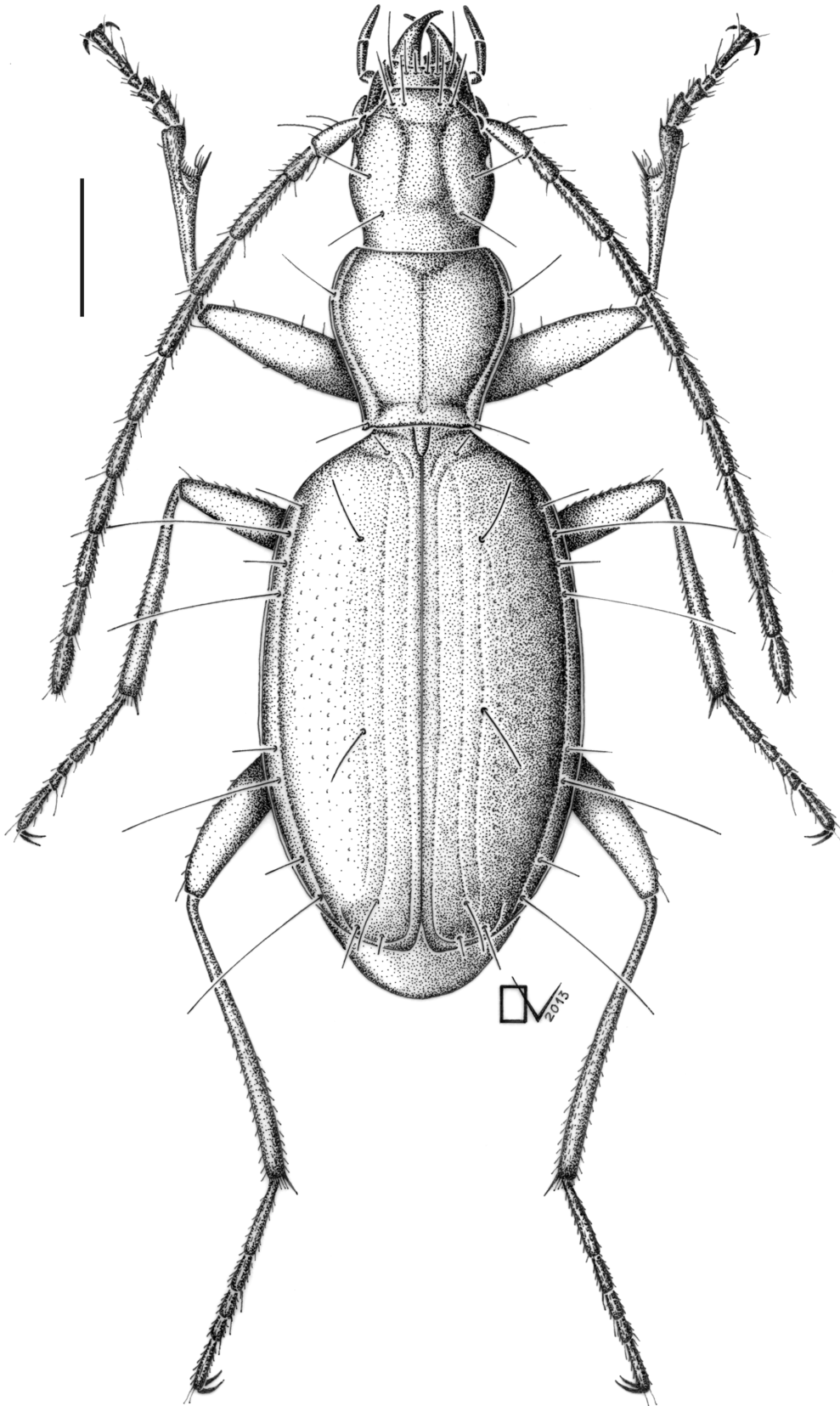


FIGURE 2. Habitus of *Duvalius abyssimus* n. sp. Scale bar: 1 mm.

Elytra (Fig. 2) oval and narrow (width/length ≈ 0.64 – 0.66), reaching maximum width slightly behind half; base of elytra oblique with effaced shoulders; striae 1st–3rd well marked by a punctured groove; striae 4th–7th only punctuate, becoming progressively weaker toward the outer striae; scutellar striole short and located at the base of the first interstria; apical striole short but well defined; internal interstriae very slightly convex, being the external ones flat; lateral channel width; discal setae inserted over the 3rd stria, the anterior located in the basal fifth and the posterior discal setae roughly central, next to 3/5; scutellar pore at the origin (anastomosis) of the 1st–2nd stria; apical triangle present, formed by the subapical seta (inserted at the end of the 2nd stria), first apical seta close to the elytral apex at the level of the second stria), second apical seta contiguous to the recurrent striole; umbilical series typical of the genus, with four equidistant setae in the humeral group and four setae in the apical group (two anterior and two posterior).

Legs (Fig. 2) very long; anterior tibia furrowed longitudinally in the outer margin of the dorsum; anterior first two tarsomeres of the male clearly widened and toothed on the inner margin.

Aedeagus (Fig. 4) large (1.38 mm), median lobe thin and elongated; basal bulb slightly dilated, arcuate in a regular curve and with a very small sagittal aileron; apical blade formed by a small sclerotized surface with blunt contour in dorsal view (Fig. 4c) and slightly raised towards the dorsal part (Figs. 4a, b); inner sack with a symmetrical sclerotized piece, channel-shaped, of which a piliform structure is projected rearward (Fig. 4a–c); parameres slender, subequal, each with three apical setae of different thickness (Fig. 4d–e).

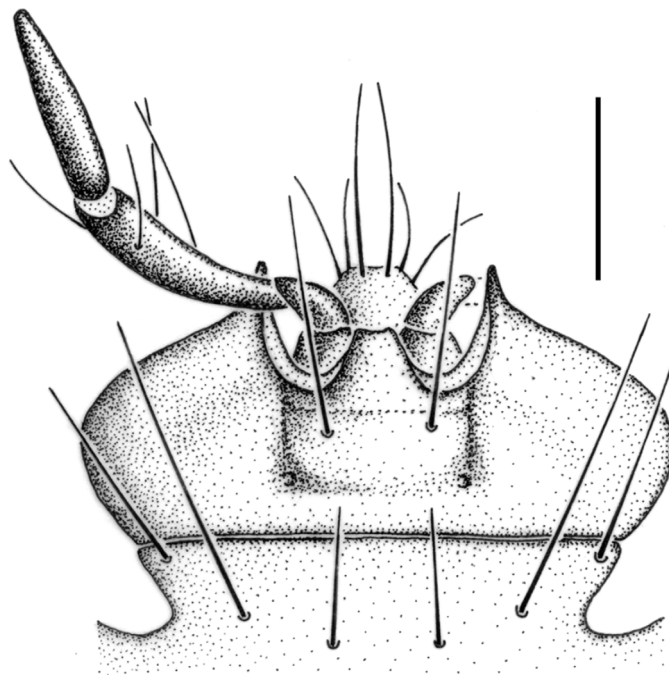


FIGURE 3. *Duvalius abyssimus* n. sp. labium and labial pieces. Scale bar: 0.25 mm.

Female genitalia (Fig. 5). External genitalia (Fig. 5a) formed by dimerous IX gonopods (gonocoxites and gonosubcoxites) and IX laterotergites; gonocoxites unguiform, wide, with 3 to 4 spiniform setae inserted in the dorsal surface and with a small ventral groove that harbours two small sensorial setae; gonosubcoxite trapezoidal, slightly longer than wide, with 3 or 4 large spiniform setae in the inner margin (near the corner) and two large setae on the ventral basal margin; laterotergite IX wing-shaped, slightly sclerotized and with more than 30 setae in the basal half. Internal genitalia (Fig. 5b) membranous and voluminous (length ≈ 1.07 mm; $\text{Ø} \approx 0.19$ – 0.28), the vagina is short and wide, and leads to a large copulatrix bursa, pleated longitudinally in bellows; the distal half of the complex (spermatheca) is poorly folded, hyaline, ending as a “cul-de-sac”.

Etymology. *abyssimus* from the Latin name for abyss, once it was discovered in Krubera-Voronja, world’s deepest cave since 2001 and as far, the only cave surpassing the depth of -2000 meters below the surface.

Affinities and biogeographical remarks. *Duvalius abyssimus* n. sp. is the third species of the genus in the Western Caucasus region. Two cave-dwelling species were previously known: *D. miroshnikovi* Belousov & Zamotajlov, 1995, from Bariban Cave, Sochi, Alek massif, in Russia and *D. sokolovi* Ljovuschkin, 1963, from the Arabika massif, Abkhazia (Belousov 1991, Belousov *et al.* 1995, Kryzhanovskij *et al.* 1995, Ljovuschkin 1963, 1972).

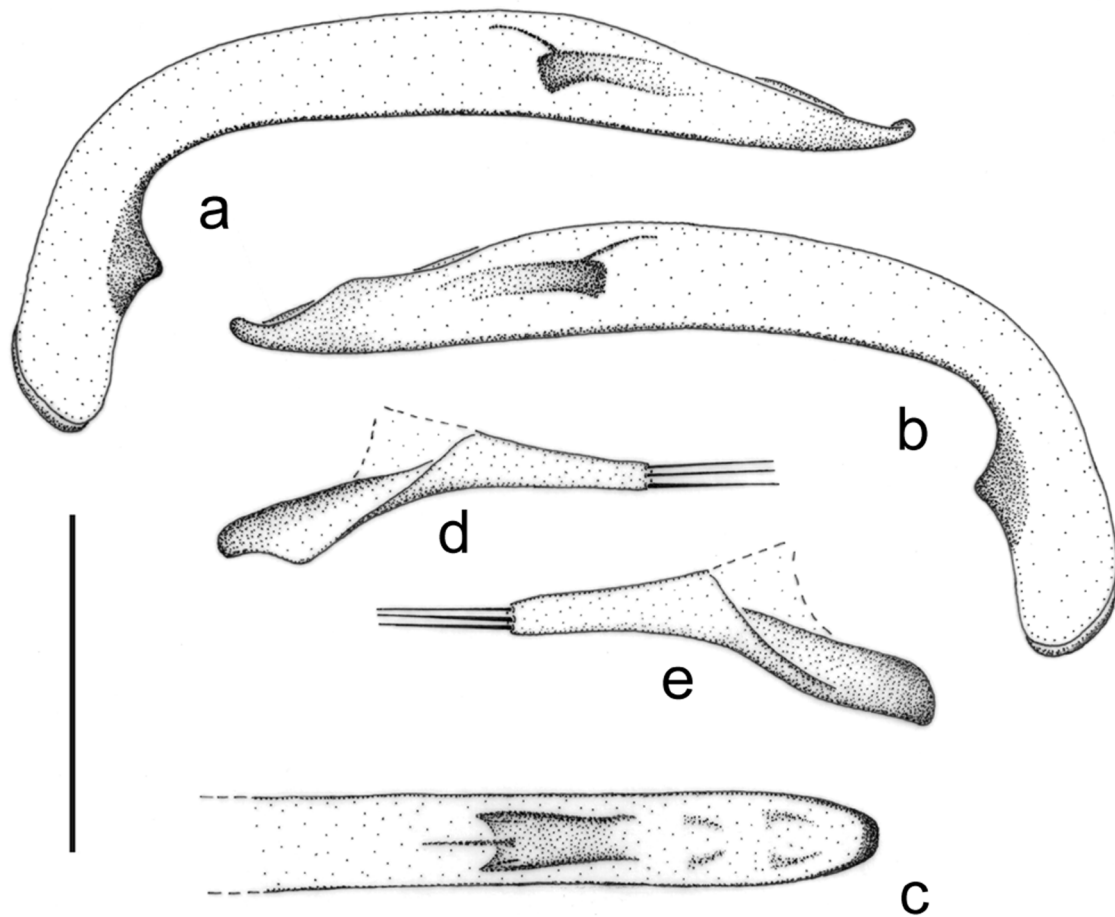


FIGURE 4. *Duvalius abyssimus* n. sp., aedeagus, a, b: Median lobe in lateral view; c: Median lobe in dorsal view; d and e: Left and right parameres in lateral view. Scale bar: 0.5 mm.

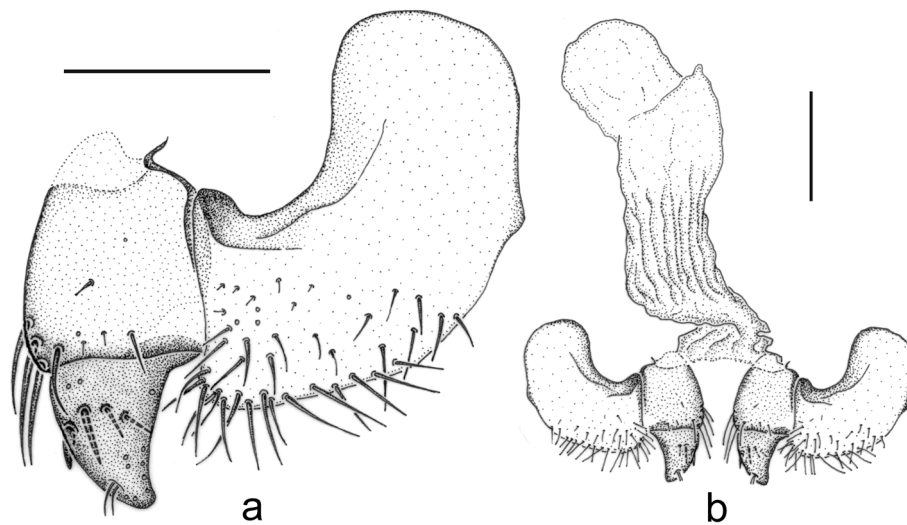


FIGURE 5. *Duvalius abyssimus* n. sp., female genitalia, a—external, b—external and internal. Scale bar: a 0.2 mm and b 0.3 mm.

Duvalius miroshnikovi from Alek massif, a small mountain ridge that is located approximately 40 km west of Arabika, seems to be the closest species to *D. abyssimus*. *D. miroshnikovi* is distinguished by the size and by the distinct shape of the aedeagus, especially the shape of the median lobe, and by the presence of 4 to 5 setae in the parameres, although the number of these setae is often variable in Trechini (Belousov *et al.* 1995).

Duvalius sokolovi was described based on a short diagnosis and a general habitus illustration of one single female from the Arabika massif. The type locality called as “Trechus Cave” is described as a small cave (\approx 6 meters) where the female holotype was found walking among limestone debris (commonly known as MSS). Without providing further information in the description, the type locality is impossible to be identified by local people or speleologists within the Arabika massif. It is also impossible to revise the type specimen of *D. sokolovi* because it was lost (Golovatch pers. comm.). Furthermore, the available description of *D. sokolovi* is short and does not include many diagnostic features. Even so, *D. sokolovi* can be distinguished from *D. abyssimus* **n. sp.** by its incomplete frontal furrows, the proportional head size related to pronotum and by the posterior border of the elytra, much more prominent (Ljovuschkin 1963).

Given the problems concerning the identity of *D. sokolovi*, this name could be eventually considered as *nomem dubium*.

Ecology and habitat. The specimens of *Duvalius abyssimus* **n. sp.** were collected in the Krubera-Voronja cave by active search in the upper part of the cave, at -60 meters depth, where temperature is about 3 °C and humidity is 100%. This cave harbours the world’s deepest terrestrial subterranean invertebrate community and it is inhabited by arthropods with different degrees of adaptation to subterranean life (Sendra & Reboleira 2012). The richest part of the cave is the basis of the first shaft, where *Duvalius abyssimus* **n. sp.** was found. It has a major input of nutrients from surface and consequently higher richness (Sendra & Reboleira 2012). The pseudoscorpion *Neobisium (Blothrus) birsteini* Lapschoff, 1940 (Neobisiidae), is the main predator widespread along the deepest branch of the cave, together with the opilion and spider of the genera *Nemaspela* Šilhavý, 1966 (Nemastomatidae) and *Troglohyphantes* Joseph, 1881 (Linyphiidae), only found in the upper parts of the cave. A major proportion of this biocoenosis is composed by decomposers: a millipede of the order Chordeumatida and a species of *Leucogeorgia* Verhoeff, 1930 (Julidae); the springtails *Plutomurus ortobalaganensis* Jordana & Baquero, 2012 (Tomoceridae), *Deuteraphorura kruberaensis* Jordana & Baquero, 2012 (Onychiuridae), *Schaefferia profundissima* Jordana & Baquero, 2012 (Hypogastruridae) and *Anurida stereoodorata* Jordana & Baquero, 2012 (Neanuridae) (Jordana *et al.* 2012) and the beetle *Catops cavicis* Giachino, 2011 (Leiodidae) (Giachino 2011).

Acknowledgements

We express our gratitude to our colleague Dr. Alberto Sendra, which conducted the biological sampling together with the first author. This work would have been impossible without the speleological support provided by the CAVEX - International Cave Exploration Team, especially by Dr. Sergio García-Dils, Pilar Orche Amaré, Javier Le Pera and Paco Martínez, who helped in the biological sampling. We are particularly indebted to Dr. Sergei Golovatch and Dr. Achille Casale for kindly providing information and bibliographical support, and to Dr. Henrik Enghoff for taxonomic support with millipedes. All specimens were collected under permission of Abkhazia government, included in the CAVEX Team Expedition Summer of 2010 and 2013.

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