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Notes on the discolouration in the high-mountain *Carabus auronitens escheri* PALLIARDI, 1825 (Coleoptera: Carabidae)

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Abstract

The dull and coloured forms of *Carabus auronitens* FABRICIUS, 1792 (Coleoptera: Carabidae) in the Carpathians (known as subspecies *C. auronitens escheri* PALLIARDI, 1825) are investigated. The two colour forms are sympatric but paratopic where they both occur. The dull form '*opacus*' lives under stones near melting snow patches in rocky, treeless habitats; the coloured form lives in wooded habitats. The phenomenon of discolouration is discussed. Scanning electron micrographs revealed that the '*opacus*' cuticle lacks structures responsible for colour generation. This can be linked to a more efficient thermal regulation in a habitat that is too extreme for the bright metallic form.

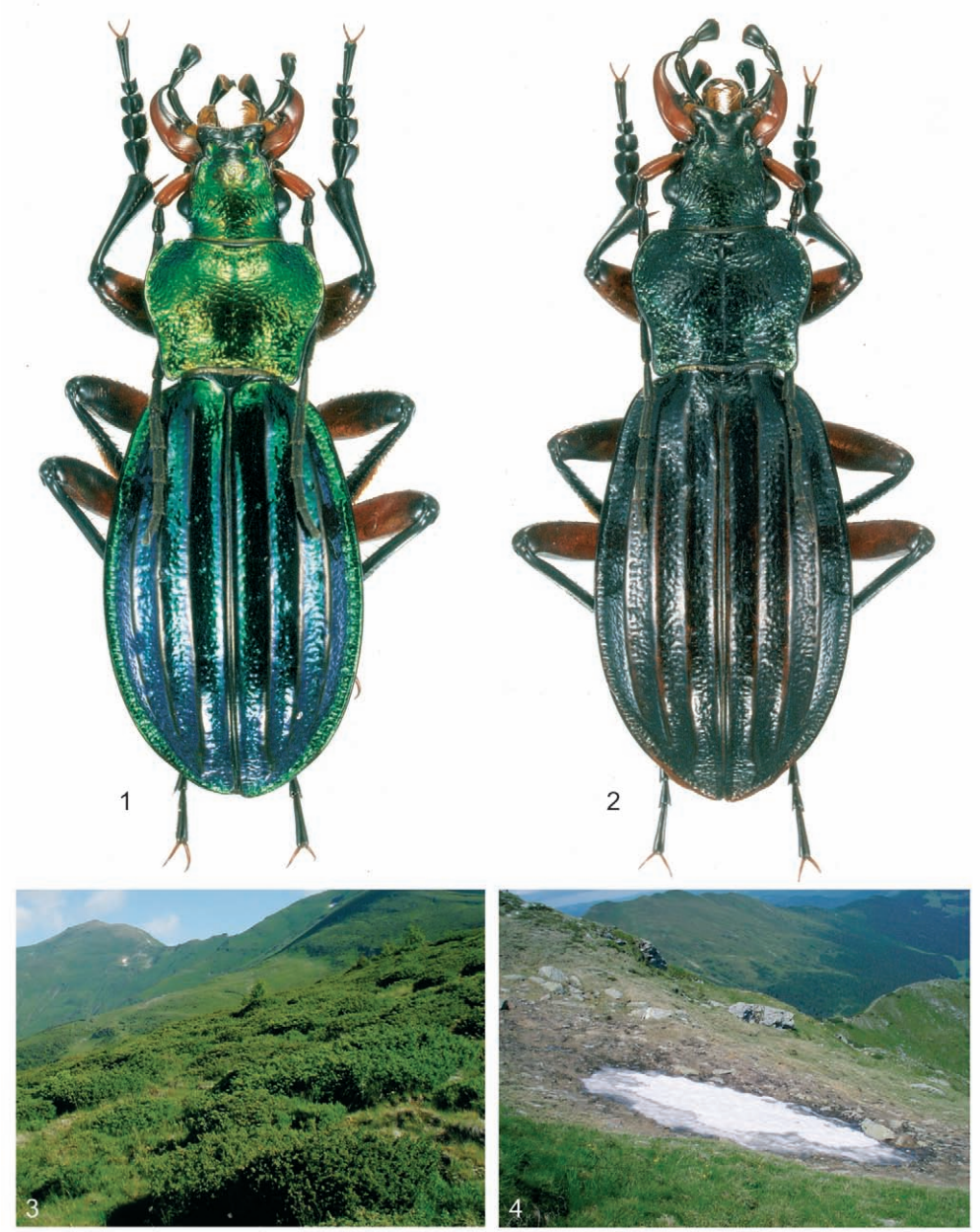
Key words: Coleoptera, Carabidae, *Carabus auronitens escheri*, discolouration, Munții Rodnei, high altitude, colour generating structures.

Introduction

Discolouration is a phenomenon observed in lycaenid butterflies (Lepidoptera: Lycaenidae), where closely related taxa (sister species or monophyletic groups) have wings with different colours arising out of the presence or absence of structural colours (BÁLINT & JOHNSON 1997). It has been proved experimentally that discolouration in these butterflies is a kind of speciation mechanism in high altitude regions, where the discoloured taxon has a better thermal regulation (BIRÓ et al. 2003).

We knew from museum specimens about the existence of a *Carabus auronitens* FABRICIUS, 1792 "colour form" which lacks the vivid metallic colour that typifies the species and has a curious dull brown appearance. This form lives in colder, more humid and therefore generally mountainous areas throughout Central and Western Europe. *Carabus auronitens escheri* PALLIARDI, 1825 is a Carpathian subspecies. This lustrous taxon (Fig. 1) lives throughout the Carpathian range, and a discoloured form, which is mostly dark brown, with only traces of metallic lustre around the elytral and pronotal margins (Fig. 2), is restricted to certain mountains with extensive areas at high altitude.

The distribution of the dull form appears to coincide with certain other beetles that are glacial relicts and inhabit the edges of melting snow patches in the alpine grasslands. Therefore it was hypothesized that this form lives exclusively in the alpine zones of certain mountain ranges within the distribution area. The relationship between the normally metallic coloured populations and the "dull", brown populations was unknown. There is no reliable information whether the two colour forms are really sympatric and synchronic, and if so, how they are distributed in their habitats. Similarly, there is no study to demonstrate whether the metallic colour of *C. auronitens* is really structural and if so, whether the dull colour form lacks the colour generating structures. The present paper aims to (1) provide new data on the biology of the two colour forms of *C. auronitens* and to (2) make a preliminary study of the microstructures of their elytra.



Figs. 1–2: Habitus photographs of 1) *Carabus auronitens* (*escheri*) *escheri*, and 2) *C. auronitens* (*escheri*) *opacus*.

Figs. 3–4: Habitats of 3) *Carabus auronitens* (*escheri*) *escheri* (path south of Vf. Roşu, 1840 m), and 4) *C. auronitens* (*escheri*) *opacus* (dolina at Vf. Roşu, 2020 m).

Material and methods

The taxonomic status of the discoloured form is unclear and this paper avoids arguing for or against any proposed system. In DEUVE (2004) they are listed as follows: *Carabus* (*Chrysocarabus*) *auronitens* (*escheri*) *escheri* PALLIARDI, 1825 (metallic) and *Carabus* (*Chrysocarabus*) *auronitens* (*escheri*) *opacus* HAURY, 1878 (dull brown). The name '*opacus*' is also available as a species-group name (BOUSQUET et al. 2003). In this paper, the two forms are called '*auronitens*' and '*opacus*' without taxonomic rank. Another discoloured form described from the Transylvanian Carpathians, *Carabus* (*Chrysocarabus*) *auronitens* (*escheri*) *funestus* CSIKI, 1905 could not be examined, because the original specimens are missing.

The exact habitats of the two "forms" of *Carabus auronitens* could not be ascertained from the labels on the rather old museum specimens that were available for study, so a field study was carried out in the Munţii Rodnei, Romania, the origin of most of the specimens of the dull coloured Carpathian *C. auronitens* '*opacus*'. The presence of both forms in this area was mentioned by CSIKI (1946, 1951) – where the regular, metallic form is named "*C. auronitens* var. *levipennis* SEIDLITZ" – with more exact locality data and capture times (May to July in case of the metallic form, June and July for the discoloured form). The discoloured form is only reported from two peaks: Vf. [=Vîrful, peak] Ineu and Vf. Roşu. HŮRKA (1975) also recorded this species from the 'intercalar' and 'alpine' zones, without distinguishing between the two colour forms. Our field work was focused around a route that connects the two known localities (Vf. Ineu and Vf. Roşu) and surveyed a wide range of habitats and elevations (1400–2200 m).

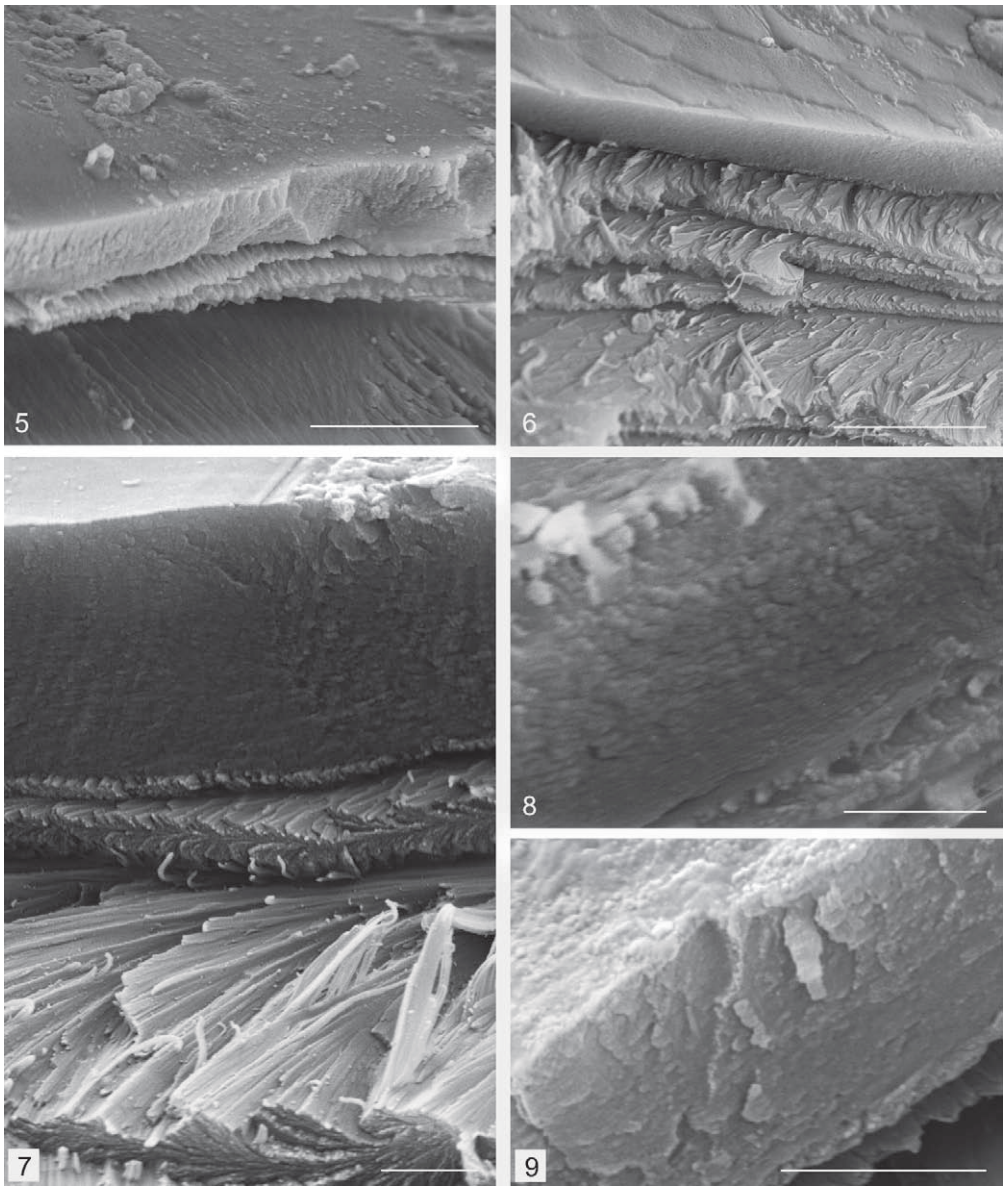
The elytra and the thoracic plates of both *auronitens* colour forms plus the species *Carabus* (*Chrysocarabus*) *rutilans* (*rutilans*) DEJEAN, 1826 were examined and their micro- and nanostructures compared. Investigations were mainly concentrated on thoracic plates, as this is where the most striking colour differences are observed. The plates were broken up, sputter-coated with gold-palladium and examined by a Hitachi S-2600 N Scanning Electron Microscope. All specimens examined are from the HNHM collection and their data are listed in the Appendix.

Results and discussions

Field observations: The species was found to be rather rare. Two specimens were caught only a few hundred meters away from each other: a bright metallic '*auronitens*' specimen in between *Pinus mugo* patches (Fig. 3), and an '*opacus*' specimen in an open, treeless habitat under a stone at a melting snow patch (Fig. 4). This observation perfectly matches the data of another such pair of specimens collected by L. Ádám in Munţii Făgăras in 1995 (see Appendix). Metallic '*auronitens*' specimens were never collected in open high altitude habitats, but they were repeatedly found in alpine river valleys with dense forest vegetation (e.g. Munţii Parîng and Retezat).

Dull '*opacus*' specimens were never encountered at lower altitudes or near forests, or during the high summer period in the alpine belt. They were found in open habitats above the *Pinus cembra* – *P. mugo* belt in alpine pastures where ravines or rocky swards were still partly covered by snow patches. The two forms hardly ever meet.

It can be concluded that '*opacus*' lives near melting snowfields (1900–2500 m) and its microhabitat is situated under stones close to or nearby snow. At this altitude, no woody plant occurs. The regular, metallic '*auronitens*' reaches as high as 1800 m, where the last patches of *Pinus mugo* can be found providing a natural hiding place for the beetle, which is conspicuous when running on the open ground. The two distinct forms are certainly sympatric but paratopic as they do not share the same microhabitat. Most probably the dull form is connected to habitats provided by melting snow.



Figs. 5–6: SEM images of cuticle breaks of 5) *Carabus auronitens* (*escheri*) *escheri*, and 6) *C. auronitens* (*escheri*) *opacus*. Scale bars = 20 µm.

Figs. 7–9: SEM images of the cuticle of 7) *Carabus rutilans* (*rutilans*), 8) *C. auronitens* (*escheri*) *escheri*, and 9) *C. auronitens* (*escheri*) *opacus*. Scale bars = 5 µm.

Scanning electron microscopy: The thoracic plates of '*auronitens*' and '*opacus*' differ in one important aspect. The chitinous area below the surface is granulate (Figs. 5, 8) in '*auronitens*'. The diameters of the granulae are around 300–500 nanometers and match the physical properties of other colour-producing photonic structures (BERTHIER 2003). A similar granulate structure was detected in the related *C. rutilans* (Fig. 7). Although the gleaming green colour is perhaps caused by striated layers under the thick outer cuticle, this granulate structure could modify its appearance; the basic colour producing mechanism is very similar in many beetle species (VIGNERON et al. 2006a, b).

The thoracic plates of '*opacus*' have no granulate structure (Figs. 6, 9). They appear to be mostly homogeneous, and they show finely lamellate structures along the fractures in contrast to that of the form '*auronitens*' and *C. rutilans*, where the fractures are also granulate. There is no structure in the thoracic plate which can produce colour. Because of this, the '*opacus*' elytra exhibit a chemically derived colour originating from brown melanin pigment. It is likely that this coloration helps '*opacus*' individuals to absorb more solar energy than '*auronitens*' individuals (BIRÓ et al. 2003).

We can only speculate how *C. auronitens* '*auronitens*' uses its structural colour and why *C. auronitens* '*opacus*' does not need it. One of the most plausible explanations is the above mentioned thermal regulation; '*opacus*' is adapted to a colder and more hostile climate, where a more efficient thermal regulation is necessary. Another explanation is that vivid colour is a hindrance in open high-altitude biota, where daytime activity can result in individuals being more easily spotted by predators.

Conclusions

Carabus auronitens '*auronitens*' and *C. auronitens* '*opacus*' live in the same region but in distinctive habitats. The former inhabits places where the ground is shaded by shrubs and trees and the latter occurs at higher altitudes in open alpine grasslands and ravines. The '*auronitens*' – '*opacus*' transition occurs around 1800–2000 m near the upper limit of the altitudinal range of *Pinus mugo* and other woody plants. Below this line the metallic coloured '*auronitens*' can be found, usually running on the ground or between grasses. Above this line the '*opacus*' form occurs mostly at or near melting snow patches and frequently under stones partly embedded in the snow. The similarity between the distribution of the discoloured form and the other beetle taxa that live exclusively at melting snow patches in the alpine zone is striking. Obviously, not all mountains in the Carpathian range have suitable habitats. But those where the '*opacus*' form is found are notable for a significant number of endemic alpine beetle taxa.

The metallic colour of '*auronitens*' is produced by a complex structure in the elytra and thoracic plates, which is composed of layers of granulae with 300–500 nm diameter. This structure is missing in '*opacus*'. Therefore, the elytra are brown, coloured purely by pigment. As '*opacus*' lives at open, high altitude habitats with extreme climate, this structural difference is most probably correlated with a better thermal regulation, in a similar way to that described for lycaenid butterflies.

Outside the Carpathians a few other dull coloured forms of *Carabus auronitens* are known: *Carabus auronitens* (*auronitens*) *subfestivus* OBERTHÜR, 1884 in NW France (Brittany) and *Carabus auronitens* (*montanus*) *montanus* GÉHIN, 1882 in SW France and the western Pyrenees. Another form of *Carabus auronitens* (*auronitens*) *auronitens*, not even accepted as a subspecies, var. *putzeysi* MORS, 1863 (occurring in Belgium), has discoloured elytra and a metallic pronotum. These forms may also live in habitats too extreme for the fully coloured forms.

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Appendix

LABEL DATA OF EXAMINED MATERIAL (all in HNHM, Budapest): all specimens grouped according to geographical regions; original label data presented [with equivalent translations of recent geographical names], numbers in brackets refer to number of specimens. Of the regularly coloured *auronitens* forms (altogether 486 Carpathian specimens examined) data of only those are listed that were captured in the vicinity of known '*opacus*' occurrences, which therefore give information about the habitat preferences.

Carabus auronitens '*opacus*'

R O M A N I A: Făgăraş Mts. – Cîrţişoara, Bîlea Lac, 2000 m, *Poion alpinae* havasi gyep [alpine grassland], kövek alól [from under stones], 25.VI.1995, leg. L. Ádám (1); Braşov/Kronstadt, Umgb. [surroundings of] Szeb. [unidentifiable], VII.1934, leg. S. Honner (1); Fogarasi h.[avasok], Bulea-tó [Lacul Bîlea], 7.VII.1912, leg. Schmidt (1). Rodna Mts. – jud. [=county] Bistriţa-Năsăud, Munţii Rodnei, dolina SW under peak of Vf. Roşu, 2020 m, under stone near melting snowpatch [293], 47°30'25"N, 24°54'37"E, 27.V.2007, leg. G. Makranczy (1); Radnai havasok, Ünőkő [Vf. Ineu], sub-alpine, 20.VI.1942, leg. Csiki (1); Pietrosz [Vf. Pietrosu], 21.VI.1913 (1); Borsa, Pietrosz [Vf. Pietrosu], 2000–2300 m, 30.VII.1941, leg. Z. Kaszab (1); Tr. [= Transylvania], Óradna [Rodna], Ünőkő [Vf. Ineu], leg. Bokor (2); Radnai hav.[asok], 3.VII.1941, leg. G. Majthényi (1); Radnai havasok, Ünőkő [Vf. Ineu], 17.VII.1903, leg. Csiki (2); Radnai havasok, Ünőkő [Vf. Ineu], 4.VII.1903, leg. Csiki (1); R. borberek [Valea Vînului], 13.VII.1903, leg. Csiki (1).

U K R A I N E: Zakarpatska oblast' – Hoverla, Drezsepole, 1875, leg. Pável (1).

S L O V A K I A: Vysoké Tatry – Tátra, leg. J. Frivaldszky (1).

Carabus auronitens '*auronitens*'

R O M A N I A: Cîrţişoara, Bîlea Lac, 1900 m, *Pinetum mugi* talajról [from ground], 25.VI.1995, leg. L. Ádám (1), jud. Bistriţa-Năsăud, Munţii Rodnei, path S of Vf. Roşu, 1840 m, on ground between *Pinus mugo* bushes, 47°29'43"N, 24°54'46"E, 27.V.2007, leg. G. Makranczy (1).

References

BÁLINT, Z. & JOHNSON, K. 1997: Reformation of the *Polyommatus* section with a taxonomic and biogeographic overview (Lepidoptera, Lycaenidae, Polyommatini). – Neue entomologische Nachrichten 40: 1–68.

BERTHIER, S. 2003: Iridescence, les couleurs physiques des insects. – Paris: Springer, 227 pp.

BIRÓ, L.P., BÁLINT, Z., KERTÉSZ, K., VÉRTESY, Z., MÁRK, G.I., HORVÁTH, Z.E., BALÁZS, J., MÉHN, D., KIRICSI, I., LOUSSE, V. & VIGNERON, J.P. 2003: Role of photonic-crystal-type structures in the thermal regulation of a Lycaenid butterfly sister species pair. – Physical Review E 67: 021901–021907.

BOUSQUET, Y., BŘEZINA, B., DAVIES, A., FARKAČ, J. & SMETANA, A. 2003: Tribe Carabini Latreille, 1802, pp. 118–206. – In: Löbl, I. & Smetana, A. (eds.): Catalogue of Palaearctic Coleoptera. Vol. 1: Archostemata-Myxophaga-Adephaga. – Stenstrup: Apollo Books, 819 pp.

CSIKI, E. 1946: Die Käferfauna des Karpaten-Beckens. I. Allgemeiner Teil und Caraboidea. – In: Tasnádi-Kubacska, A. (ed.): Naturwissenschaftliche Monographien IV, 798 pp.

CSIKI, E. 1951: Die Käferfauna des Radnaer Gebirges. – Acta Biologica Academiae Scientiarum Hungaricae 2 (1–3): 119–168. (in Russian)

DEUVE, T. 2004: Illustrated catalogue of the genus *Carabus* of the world (Coleoptera: Carabidae). – Sofia-Moscow: Pensoft, 461 pp.

HŮRKA, K. 1975: Zur montanen Fauna der Laufkäfer des Rodna-gebirges in den Ostkarpaten (Coleoptera, Carabidae). – Studii şi comunicări, Muzeul Brukenthal Ştiintele naturii 19: 197–206.

VIGNERON, J.P., RASART, M., VANDENBEM, C., LOUSEE, V., DEPARIS, O., BIRÓ, L.P., DEDOUAIRE, D., CORNET, A. & DEFRANCE, P. 2006a: Spectral filtering of visible light by the cuticle of metallic woodboring beetles and microfabrication of a matching bioinspired material. – Physical Review E 73: 041905-1-8.

VIGNERON, J.P., LOUSSE, V., COLOMER, J.-F. & VIGNERON, N. 2006b: Natural layer-by-layer photonic structure in the scales of *Hoplia coerulea*. – Proceedings of SPIE 6285: 628506-1-5.

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