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Contribution to the Knowledge of the Genus *Proceratium* Roger (Hymenoptera: Formicidae: Proceratiinae) in the New World

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Abstract

The genus *Proceratium* Roger comprises rare ants that are irregularly distributed in tropical and temperate regions of the world. Despite this global distribution, these ants are rarely collected, likely due to their cryptobiotic lifestyle. In the New World, the genus comprises 22 known species distributed from Southern Canada to the South of Brazil, and in some Caribbean islands. The taxonomy of the genus *Proceratium* is here updated for South America. We describe *P. amazonicum* **sp. nov**, from Rondônia state and provide distribution data for *P. brasiliense, P. convexipes,* and *P. silaceum*. We also present, for the first time, high-resolution images of the *P. colombicum* type and *P. ecuadoriense,* and provide a new record of *P. micrommatum* from Peru, and comment about its morphological variation and distribution. A key for the workers of the *P. micrommatum* clade is also provided. The species we describe belongs to *P. micrommatum* clade and represents the second species recorded from Brazil after 60 years, since only *P. brasiliense* was known previously in the country.

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Introduction

The genus *Proceratium* Roger, 1863 consists of rare ants that are distributed irregularly in the tropical and temperate areas of the world (Baroni Urbani & de Andrade, 2003). The genus consists of 85 valid extant and six fossil species (Bolton, 2019). The taxonomy of the genus was relatively well resolved on a global scale by Baroni Urbani and de Andrade (2003). Taxonomic studies are also available for the Afrotropical Region (Hita Garcia et al., 2014), Fiji (Hita Garcia et al., 2015), Samoa and Pacific Islands (Liu et al., 2015), and China (Staab et al., 2018). Despite this global distribution, these ants are only rarely collected, likely due to their cryptobiotic lifestyle in leaf litter or soil (Baroni Urbani & de Andrade, 2003).

The natural history of this genus is known from only few fragmentary reports (Brown 1974; 1979, Hita Garcia et al., 2014). Most *Proceratium* nest in rotten wood, in the ground, under stones, or in trees, and colonies appear to be rather small, usually with 10-50 workers (Brown, 1958; Brown, 1974; Baroni Urbani & de Andrade, 2003), although Fisher (2005) recorded more than 350 workers in a nest of *Proceratium avium* Brown, 1974. African *Proceratium* species were collected at lower elevations, in dry sand forest of the Gorongosa National Park in Mozambique. The species are not restricted to low elevation, individuals from *P. nilo* Hita et al. (2014) were collected at 1000 m in the Tanga region in Tanzania, as well as *P. sali* Hita Garcia et al. (2014) collected at an elevation between approximately 1150 to 1480 m. The specialized predation of *Proceratium* species on arthropod

eggs, especially spider eggs, was first suggested by Brown (1958), who succeeded in keeping a colony of *P. silaceum* Roger in the laboratory by feeding them almost exclusively with spider eggs. However, Masuko (2019) recently reported data on 107 *P. itoi* (Forel, 1918) colonies from the Manazuru forest, in Japan, 90 of which were complete or near complete colonies (workers, queens and larvae). Although a total of more than 1,700 arthropod eggs were collected from the ant nests, none of them were from spiders (Masuko, 2019).

Due to the rarity of specimens in collections, there is very little information about intra- and interspecific variation (Hita Garcia et al*.,* 2014). Surface sculpture is a commonly used character for species level identification (Hita Garcia et al*.,* 2014), although it appears to be relatively variable. However, the lack or presence of abundant, long, standing pilosity on top of a very dense mat of subdecumbent to decumbent hairs seems to be species-specific (Hita Garcia et al*.,* 2014).

In the New World, the genus comprises 22 known species distributed from southern Canada to the south of Brazil and in some Caribbean islands. To date, the most recent study in the Neotropical region is that of Sosa-Calvo and Longino (2008) and Escárraga et al. (2019) with keys adapted from Baroni Urbani and de Andrade (2003). Baroni Urbani and de Andrade (2003) also performed a species-level cladistic analysis in an attempt to infer the most probable relationships between the fossil and the extant *Proceratium* species. These analysis revealed eight species clades, within them, the *P. micrommatum* clade, with 15 Neotropical species.

In Brazil, the only species reported until now is *P. brasiliense* (Baroni Urbani & de Andrade, 2003; Feitosa, 2015), recorded in the states of Bahia, Minas Gerais, Rio de Janeiro, São Paulo, and Santa Catarina (antmaps.org: Janicki et al., 2016). Here we describe a new *Proceratium* species for Brazil, give taxonomic notes for *P. ecuadoriense* and *P. colombicum*, with their respective type specimens, as well as a new locality record of *P. micrommatum* (Roger, 1863), as well as an updated key to the workers of the *P. micrommatum* clade.

Material and methods

Abbreviations of depositories

CEPEC: Centro de Pesquisas do Cacau, Ilhéus, Bahia, Brazil.
IAvH: Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Villa de Leiva, Colombia.
INPA: Instituto Nacional de Pesquisas da Amazônia, Manaus, Amazonas, Brazil.
MCZ: Museum of Comparative Zoology, Cambridge, Massachusetts, U.S.A.

We follow the morphological nomenclature of Bolton (1994) and Baroni Urbani and de Andrade (2003). In order to describe pubescence and pilosity, we follow Wilson (1955) and use the terms "erect", "suberect", "subdecumbent", "decumbent" and "appressed". The terminology for the description of surface sculpturing is based on Harris (1979). Specimens were identified and measured using a Leica M250A stereomicroscope, with magnifications of 20x, 40x and 60x, under a white light. Digital images were made using the same equipment. All measurements are given in millimeters and the abbreviations used are:

HW: Head width. In full-face view, the maximum width of head.

HL: Head length. In full-face view, from the anterior edge of the clypeus to the medial posterior margin of the head.

EL: Eye length. In lateral view, maximum length of eye measured in oblique.

SL: Scape length. In frontal view, measured from apex of first antennal segment to base, excluding the basal condyle.

WL: Weber's length. In lateral view, the diagonal length of mesosoma in profile, from the midpoint of the anterior pronotal declivity to posterior margin of metapleuron.

PW: Pronotal width. In dorsal view, the maximum width of pronotum, measured from side to side.

PtH: Petiole height. In lateral view, the distance from lower edge of petiolar sternite to apex of petiolar tergite (node), taken as a vertical measurement perpendicular to the longitudinal axis of the petiole.

PtL: Petiole length. In lateral view, the maximum distance between anterior and posterior extremes of petiolar node, excluding anterior and posterior condyles.

PtW: Petiole width. In dorsal view, maximum width of petiole measured.

GL: Gaster length. In lateral view, the maximum length of gaster.

LT3: Abdominal tergum III length. In lateral view, maximum length of abdominal tergum III.

LS4: Abdominal sternum IV length. In lateral view, maximum length of abdominal sternum IV (following Ward, 1988).

LT4: Abdominal tergum IV length. In lateral view, maximum length of abdominal tergum IV (following Ward, 1988).

TL: Total length. The total outstretched length of the ant from the mandible apex to the gastral apex.

CI: Cephalic index. HW / HL x 100.

OI: Ocular index. EL / HW x 100.

SI: Scape index. SL / HL x 100.

DPeI: Dorsal petiole index. PtW / PtL x 100.

ASI: Abdominal segment index. LT4 / LT3 x 100.

IGR: Gastral reflexion index. LS4 / LT4

Results

Proceratium amazonicum Fernandes, Delabie & Fernández, new species (Fig 1A–B; 2A–F)

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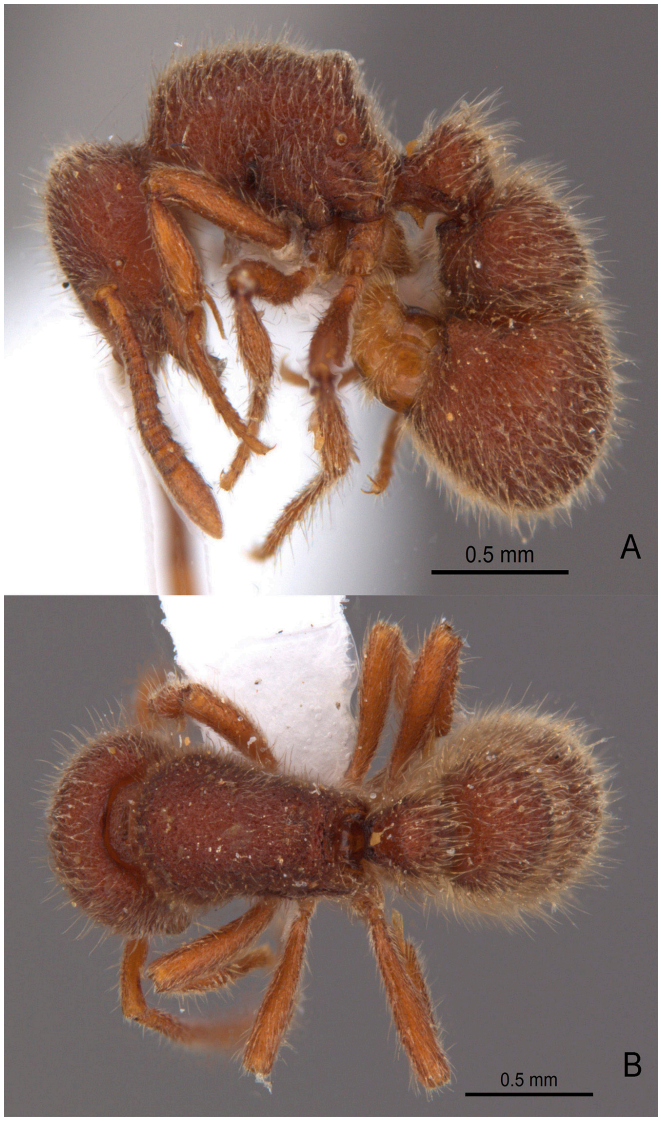

Fig 1A-B. *Proceratium amazonicum* sp. nov. Lateral view (A) and dorsal view (B).

Type material: Holotype worker. BRAZIL, Rondônia, Floresta Nacional do Jamari (Flona Jamari), 63°01′24″W 9°09′40″S, Serra da Onça, Novo Mundo, 10.i.2018, soil sample on the ground, D.C. Castro col., INPA (1 worker).

Etymology: "*amazonicum*" is a neologism indicating the provenance of this species from the Amazon (Rondônia state).

Diagnosis: Frontal triangle on head elevated; mandible with 4 denticles (including the apical tooth); propodeal tumulus narrow and high; long, erect or suberect hairs on petiole and dorsum of abdominal segment III; large species TL: > 3.00 mm; body densely foveolate.

Holotype measurements: SL: 0.52, HW: 0.70, HL: 0.79, EL: 0.03, WL: 0.86, PW: 0.48, PtL: 0.28, PtH: 0.26, PtW: 0.28, LT3: 0.35, LT4: 0.60, LS4: 0.18, GL: 0.97, TL: 3.39, CI: 88, OI: 4, SI: 65, IGR: 0.30, ASI: 171, DPeI: 100.

Worker description. (Figs 1A−B; 2A−F).

Head longer than broad; sides slightly narrower anteriorly than posteriorly. Vertex in full face view convex. Clypeus recognizable as small triangular or subtriangular tooth between antennal sockets. Frontal carinae close to each other, not covering antennal insertions. Lateral expansions of the frontal carinae relatively narrow, raised and diverging posteriorly. Frontal triangle elevated. Genal carinae strongly marked. Sulcus between genal carinae and gular area impressed. Eyes present, composed of 6−7 convex facets slightly below midline of head. Scapes thicker in distal half and far short of vertexal margin. First funicular joint 1/4 longer than broad. Mandible with 4 denticles including the apical tooth.

Mesosoma slightly elongate. Promesopleural and mesometapleural sutures weakly impressed. Propodeum with elevated tumosity (tumulus) on apex, before the declivity. Declivous face of propodeum flat, sides crenulate and concave close to propodeal lobes. Propodeal lobe semitransparent. Propodeal spiracle tumuliform. Petiole slightly longer than broad, with sides subparallel in anterior third and convex posteriorly in dorsal view. Anterior border of petiole straight. In lateral, view of the basal area of petiole slightly smaller than the apex. Ventral process of petiole triangular, semitransparent and sharply pointed. Abdominal segment III (G1 tergite) slightly shorter than 1/3 length of abdominal segment IV (G2 tergite), in lateral view. Abdominal segment III (G1 sternite) with ventral carina, close to anterior border. Abdominal segment IV (G2 sternite), ventrally with marked subround convex projection. Abdominal segment IV (sternite) slightly convex. Constriction between abdominal segments III and IV strongly impressed. Abdominal sternite III very short medially, carinate and protruding anteriorly on sides.

Mid tibiae without pectinate spur. Spurs of fore legs without basal spine. Fore basitarsi longer than mid and hind ones. Pretarsal claws simple. Arolia small.

Sculpture. Head, mesosoma, petiole and gaster densely foveolate. Legs foveolate.

Body covered by hairs of three main types: (1) short, dense, subdecumbent on whole body, very dense on dorsal face of propodeum tumulus, sparse and erect on funicular joints; (2) long, erect or suberect on petiole and on abdominal segment III (G1 sternite, lateral view); sparse on whole body, absent from tumulus of basal face of propodeum and on antennae. Appressed, short and sparse hairs present on head.

Colour ferrugineous-brown with slightly lighter antennae and legs.

Distribution. Brazil (Rondônia).

Observations. The single specimen of this new species was collected in soil at a depth of 10 cm in an area of 25x25 cm (TSBF trap, Anderson & Ingram, 1993). A soil sample was placed in a Winkler extractor (Bestelmeyer et al., 2000) for 48 hours. The material was obtained in the federal reserve of Floresta Nacional do Jamari (FLONA do Jamari) located on the grounds of the municipalities of Cujubim, Porto Velho, Ariquemes and Itapuã do Oeste, in the state of Rondônia, Brazil.

Additional examined material.

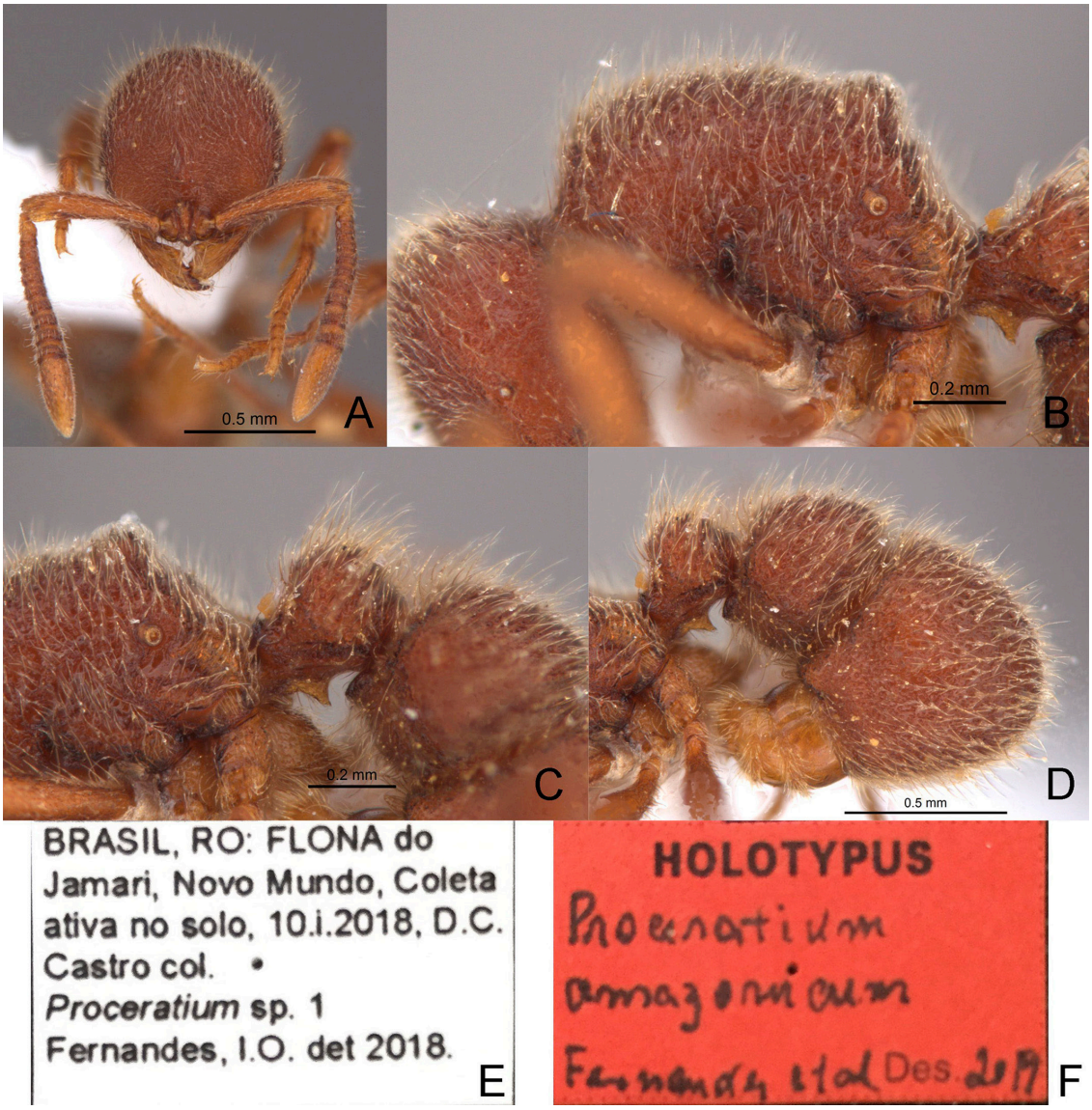

Fig 2A-F. *Proceratium amazonicum* sp. nov. Head in frontal view (A), mesosoma in lateral view (B), mesosoma and petiole in lateral view (C), petiole and gaster in lateral view (D), locality (E) and designation (F) label.

***Proceratium brasiliense* Borgmeier, 1959.**

BRAZIL: Bahia: Ilhéus, CEPEC, #4374, 1986, J. Delabie col. [id. M.L. de Andrade] (1 worker) (CPDC); Ilhéus, Praia do Norte, 02.vi.1994, 8:00 (mating flight), J.H.C. Delabie col. [id. M.L. de Andrade] (2 alate gynes) (CPDC); Ilhéus, Praia do Norte, 19.iii.1995, 7:00 (mating flight) (1 alate gyne) (CPDC); Ilhéus, Praia do Norte, 30.i.1996 (mating flight), I.C. do Nascimento col. (1 alate gyne) (CPDC); **São Paulo:** Cananeia, 23.x.2002 #5395, L.P.M. Macedo col. (1 worker) (CPDC).

***Proceratium convexiceps* Borgmeier, 1957**.

PANAMA: Colon. IBISCA, San Lorenzo Forest, FL-C2B28a, 17.x.2003, no colector, labelled "*Proceratium* sp.2" (1 alate gyne) (CPDC).

***Proceratium colombicum* de Andrade, 2003 (Fig 3A–D)**

Type material: Holotype worker from Colombia labelled: "Nariño, Orito, Territorio Kofan, 00° 30' N 77°13' W, 1000 m, 25.ix.1998, E. L. Gonzalez", in IAvH [examined].

***Proceratium ecuadoriense* de Andrade, 2003 (Fig 4A–D)**

Type material: Holotype worker from Ecuador labelled: "Ecuador: Prov. Pichincha, S. & J. Peck, 1975, Tinalandia, 16 km SES. Domingo de los Colorados, Jun, MCZ Holotype 35014".

***Proceratium micrommatum* (Roger, 1863) (Fig 5A–D; 6A-D).**

PANAMA: Colon**,** San Lorenzo Forest, 9^{0}17'N 79^{0}54'W, M-G-Z-06 Berleze, R1, 18.x.2003, N. Winchester & K. Jordan col. (1 worker) (CPDC); IBISCA, San Lorenzo Forest, FIT-R1-14/5, 27-28.x.2003, A. Tishechkin col., labelled "*Proceratium* sp.1" (3 alate gynes) (CPDC); IBISCA, San Lorenzo Forest, FIT-R2-11, 17-18.v.2004, A. Tishechkin col.,

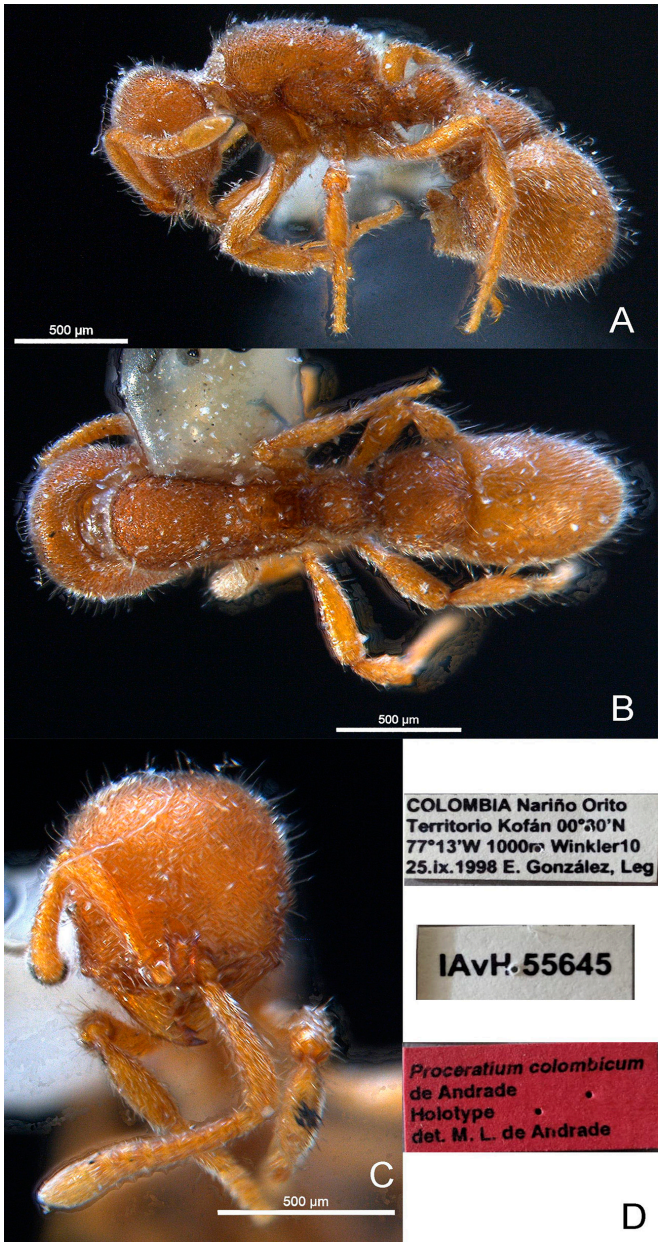

Fig 3A-D. *Proceratium colombicum.* Holotype. Lateral view (A), dorsal view (B), head in frontal view (C), label (D). Photos provided by María Camila Tocora and Gianpiero Fiorentino, IAvH 55645.

labelled "*Proceratium* sp.1" (5 alate gynes) (CPDC). **PERU:** Porto Maldonado, Madre de Dios, Estação Sachavacayoc, 12°51'09,6"S 69°22'00.3"W, 20.vii.2012, Neotropical Ant Course, Trilha do Condenado I, after bridge, extrator Winkler, I.O. Fernandes et al., col., (1 worker) (INPA); MD [Madre de Dios], Reserva Nacional Tambopata, Sachavacayoc, 12°51'21"S 69°21'43"W, 210m, 19-31.vii.2012, [R.M] Feitosa col., Neotropical Ant Course, UFV LABECOL n. 000044 (1 worker) (INPA).

P. micrommatum workers measurements (n. = 2). SL: 0.39-0.43, HW: 0.58-0.60, HL: 0.60-0.64, EL: 0.03, WL: 0.70-0.73, PW: 0.38-0.39, PtL: 0.23-0.25, PtH: 0.25-0.26, PtW: 0.23-0.24, LT3: 0.25-.30, LT4: 0.60-0.61, LS4: 0.15-0.16, GL: 0.88-0.91, TL: 2, CI: 93-96, OI: 5, SI: 65-67, IGR: 0.25-0.26, ASI: 203-240, DPeI: 96-100.

Fig 4A-D. *Proceratium ecuadoriense.* Holotype. Lateral view (A), dorsal view (B), head in frontal view (C), label (D). Photos provided by Stefan Cover, MCZ 35014.

***Proceratium silaceum* Roger, 1863**.

MEXICO: Veracruz**,** Est. Los Tuxtlas, 23.ix.1992. L. Quiroz col. (1 worker) (CPDC); **USA:** Florida, 5.5 miles N. Gainesville, 05.iii.1992, LR. Davis Jr. [id. M.L. de Andrade] (8 workers) (CPDC).

Key to workers of *Proceratium* species from *P. micrommatum* clade (modified from Baroni Urbani & de Andrade, 2003). The fossil species *P. dominicanum* and *P. poinari*, as well as *P. longiscapus* known on the gyne only, are excluded from this key.

1. Spur of the mid tibia not pectinate 2
- Spur of the mid tibia pectinate 11

2. Dorsal part of propodeum with a tumulus covered only with short hairs 3
- Dorsal part of propodeum without a tumulus, covered with long and short hairs 7

3. Gaster completely sculptured 4
- Sculpture present only in the midle or less on the gaster 6

4. Small species TL:< 2.90 ..... *P. colombicum* (Colombia: Nariño)
- Large species TL:> 3.20 5

5. Head, mesosoma and gaster reticulate-faveolate and granulate; tumulus on the propodeum broad and low .... *P. ecuadoriense* (Ecuador)

- Head mesosoma and gaster densely faveolate; tumulus on the propodeum narrow and high ..... ***P. amazonicum*** sp. nov. (Brazil: Rondônia)

6. Petiole 1/5 longer than broad. Postpetiole shorter than 1/2 of the gastral tergite I; postpetiole and gaster more convex ..... *P. catio* (Venezuela, Colombia and Ecuador)

- Petiole at most 1/8 longer than broad. Postpetiole slightly longer than 1/2 of the gastral tergite I; postpetiole and gaster less convex ..... *P. brasiliense* (Colombia and Brazil)

7. Mid basitarsi with hairs shorter than 1/2 of the basitarsal length ..... *P. taino* (Dominican Republic)

- Mid basitarsi with at least one hair about 1/2 of the mid basitarsal length 8

8. Area between the basal and declivous faces of the propodeum with a transverse carina angulate or denticulate laterally .. *P. mexicanum* (Southern USA to Guatemala)

- Area between the basal and declivous faces of the propodeum with at most very superficial traces of transverse carina 9

9. Mesosoma gently convex in profile. Postpetiole in dorsal view more convex and slightly angulate anterolaterally. Integumental sculpture impressed ..... *P. convexiceps* (Mexico to Ecuador)

- Mesosoma more elongate in profile. Postpetiole in dorsal view more rectangular and angulate anterolaterally. Body sculpture more superficial 10

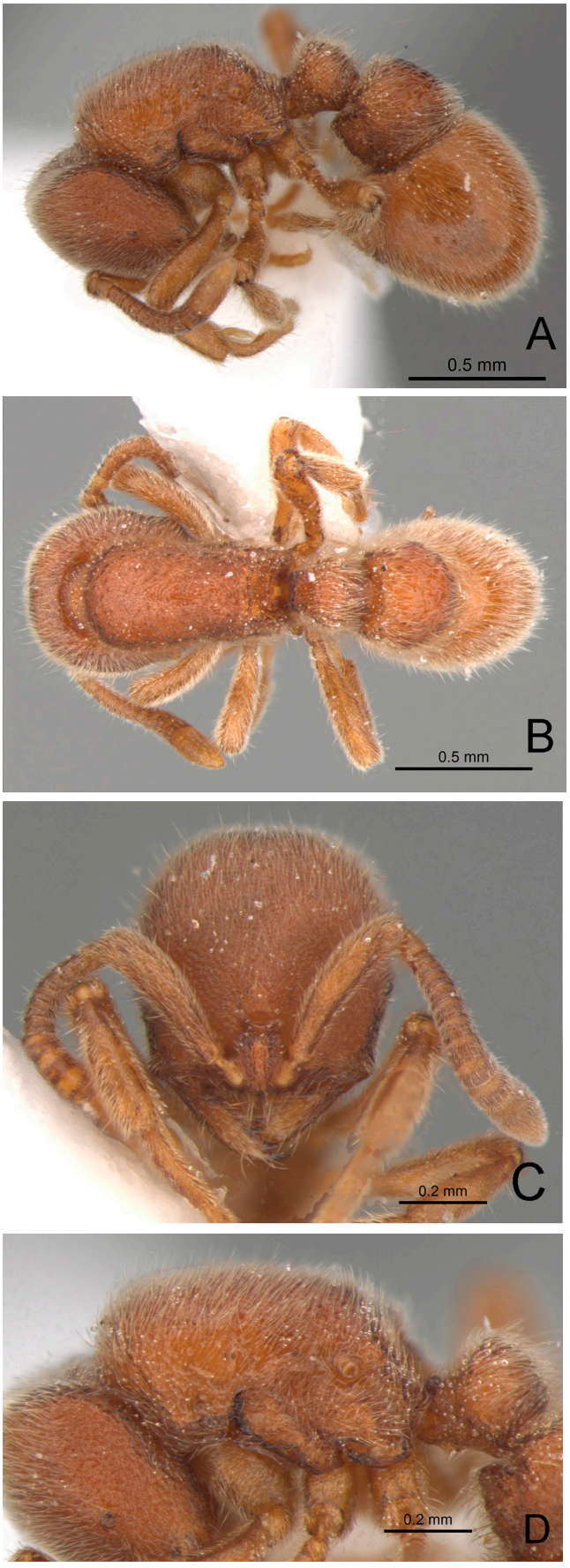

Fig 5A-D. *Proceratium micrommatum.* Lateral view (A), dorsal view (B), head in frontal view (C), mesosoma in lateral view (D). Specimen from Peru, Madre de Dios - Deposited in the INPA Collection.

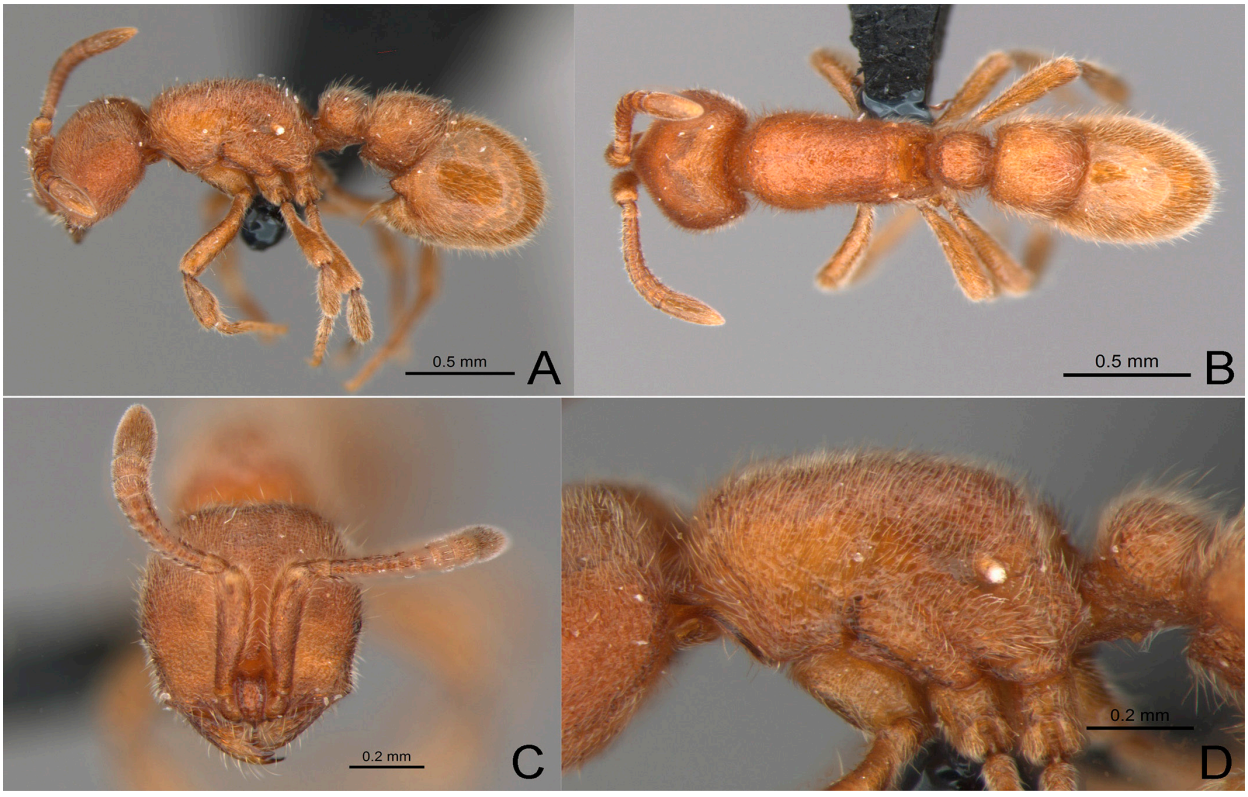

Fig 6A-D. *Proceratium micrommatum*. Lateral view (A), dorsal view (B), head in frontal view (C), mesosoma in lateral view (D). Specimen from Peru, Madre de Dios - Deposited in the INPA Collection (UFV LABECOL n. 000044).

10. TL: ≥3.80 mm. WL: ≥1.05 mm ..... *P. panamense* (Costa Rica to Venezuela)
- TL: <3.60 mm. WL: ≤0.95 mm ..... *P. micrommatum* (USA to Peru)

11. Clypeus surrounding the antennal sockets, subrectangular and protruding anteriorly. Propodeal dorsum with a median swelling ..... *P. transitionis* (Colombia)

- Clypeus not surrounding the antennal sockets, reduced medially and triangular. Propodeal dorsum without swelling ..... *P. lattkei* (Venezuela)

Discussion

Proceratium amazonicum belongs to the *P. micrommatum* clade as defined by Baroni Urbani and de Andrade (2003). In the same phylogeny, a small group inside of the *P. micrommatum* clade is formed by the species *P. brasiliense, P. catio*, *P. colombicum* and *P. ecuadoriense.* All these species have the propodeal tumulus covered with short hairs on the dorsum, as does *P. amazonicum* **sp. nov.** *Proceratium amazonicum* **sp. nov.** can be easily distinguished from any other species in *P. micrommatum* clade, by the combination of total length over 3.00 mm, with a tumulus on propodeum and has a completely sculptured gaster. *Proceratium catio* and *P. brasiliense* have sculpture limited to the middle of the gaster, while in *P. amazonicum* **sp. nov**. the gaster is completely sculptured. *Proceratium colombicum* is smaller (TL < 2.90 mm in *P. colombicum*, 3.39 mm in *P. amazonicum*). *Proceratium ecuadoriense* also has a completely sculptured gaster, but the propodeal tumuli are broad and low in *P. ecuadoriense*, while in *P. amazonicum* they are narrow and high.

Proceratium convexiceps occurs in Costa Rica and Panama and a single worker of Mexico (El Ocotito) was attributed to this species with the possibility that it belongs to a different one (Baroni Urbani & de Andrade, 2003). *Proceratium colombicum* is only known from its type locality, Nariño, in Colombia, and for the first time pictures with high resolution of the type species are presented here (Fig 3A-D). *Proceratium colombicum* appears as basal to *P. brasiliense* and *P. catio* (or sister to *P. ecuadoriense*) and differs from both, in the worker, by the following set of characters: head, mesosoma, petiole and postpetiole covered by dense granulation instead of granulate-rugulose foveolate, and first gastral tergite entirely densely granulate instead of densely granulate after the curvature only (Baroni Urbani & de Andrade, 2003). Like in *P. colombicum*, *P. ecuadoriense* is only known from its type locality in Ecuador, and for the first time pictures with high resolution of type specimens are presented (Fig 4A-D). *Proceratium ecuadoriense* appears as the basal species of a small clade containing three additional species: *P. brasiliense, P. catio* and *P. colombicum*, but differs from these three taxa by the following two characteristics in the worker: broader and lower propodeal tumulus and deeper integumental sculpture.

Proceratium micrommatum (Fig 5A-D; 6A-D) is recorded

for the first time in Peru. Aside from the original description, we compared the specimens with the type specimen photos available in antweb (FOCOL0932) (www.antweb.org). The specimen have a transverse carina on the declivous face of the propodeum and the anterior border of the petiole concave. The declivitous face of the propodeum presented some variations in the species (Fig 5A-D and 6A-D), which can be superficially marginate or marked, sometimes dentate (lateral margin of the declivity). Considering the *P. micrommatum* characteristics, the species can be easily confused with *P. mexicanum*, but the latter species has the propodeal carina strongly impressed. Baroni Urbani and de Andrade (2003) described *P. mexicanum* based on a misidentified *P. micrommatum*. The authors mentioned that if the interpretation of *P. mexicanum* was correct, a certain amount of geographic variability should characterize this species. The collection of additional material or a revisionary study might allow the separation of one or more species. In its current understanding, *P. micrommatum* has the widest distribution of all species of the genus in the New World and our record from Peru complements the distribution for South America given by Baroni Urbani and de Andrade (2003). The species was also recorded in Colombia (Sossa-Calvo & Longino, 2008, Achury & Suarez, 2017) and Ecuador (Salazar et al., 2015).

The *Proceratium silaceum,* a species belonging to the *P. silaceum* clade (Baroni Urbani & de Andrade, 2003), is recorded here from Veracruz, Los Tuxtlas, Mexico. Another two records of *P. silaceum* from Veracruz, one with images, is available on antweb (PSW7415-1 and MMP01642 CASENT0733458) confirming the species distribution.

The description of *Proceratium amazonicum* **sp. nov.** raises the genus to 23 valid species in the New World, and represents the second species recorded from Brazil after 60 years, as previously only *P. brasiliense* was known for the country.

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