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SCORPIONS FROM THE PARC NATIONAL DU TSINGY DE NAMOROKA, MADAGASCAR, WITH DESCRIPTION OF A NEW SPECIES OF *OPISTHACANTHUS* PETERS, 1861 (SCORPIONES: HORMURIDAE)

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Abstract: A new contribution to the scorpions of the Parc National du Tsingy de Namoroka is presented and a new species of *Opisthacanthus* is described. The rare buthid *Tityobuthus antsingy* Lourenço & Goodman, 2004, previously described from a cave in the reserve, is confirmed by the collection of a second specimen, also found inside a cave. This species seems however to be only a trogloxene element. Some comments are also added on the extraordinary diversity of the genus *Opisthacanthus* in Madagascar, with a total number of species now raised to 13. This attests for a very high level of endemicity in this group, as already suggested for several other genera of Malagasy scorpions.
Key words: Scorpiones, Hormuridae, *Opisthacanthus*, *Tityobuthus*, new species, diversity, endemism, Namoroka Reserve, Madagascar.

Escorpiones del Parc National du Tsingy de Namoroka, Madagascar, y descripción de una especie nueva de *Opisthacanthus* Peters, 1861 (Scorpiones: Hormuridae)
Resumen: Se presenta una nueva aportación sobre los escorpiones del Parque Nacional del Tsingy de Namoroka, y se describe una especie nueva de *Opisthacanthus*. El raro bútido *Tityobuthus antsingy* Lourenço & Goodman, 2004, descrito previamente de una cueva del parque, se ve confirmado por la recogida de un segundo ejemplar, encontrado igualmente en una cueva. Esta especies, sin embargo, parece ser sólo un elemento troglóxeno. Se incluyen también unos comentarios sobre la extraordinaria diversidad del género *Opisthacanthus* en Madagascar, donde el número total de especies se eleva ahora a 13. Esto indica un alto nivel de endemismo en el grupo, como ya se ha sugerido para otros géneros de escorpiones malgaches.
Palabras clave: Scorpiones, Hormuridae, *Opisthacanthus*, *Tityobuthus*, especie nueva, diversidad, endemismo, reserva de Namoroka, Madagascar.

Taxonomy / Taxonomía: *Opisthacanthus* (*Monodopisthacanthus*) *faillei* **sp. n.**

Introduction

The scorpion fauna of the Parc National du Tsingy de Namoroka (ex Réserve Naturelle Intégrale de Namoroka), located in the Northwestern portion of Madagascar was the subject of two previous notes by Lourenço and Goodman (2004) and Lourenço *et al*. (2006). In these publications, a new species of buthid scorpion was described, *Tityobuthus antsingy* Lourenço & Goodman, 2004 and a new subspecies of *Microcharmus*, *Microcharmus pauliani namoroka* Lourenço, Goodman and Fisher, 2006. Reference was also made to the genera *Opisthacanthus* Peters (Hormuridae) and *Grosphus* Simon (Buthidae), but based on juvenile material and consequently without a definitive identification (Lourenço & Goodman, 2004). During a recent new survey carried out in the Parc National du Tsingy de Namoroka by Research people from the Muséum national d'Histoire naturelle, Paris, two more specimens of scorpions were collected. The first precisely matched with *Tityobuthus antsingy*, confirming also the presence of this rare species in caves of the park. The species is however, considered only as a trogloxene element. The second, an adult male of *Opisthacanthus* led to the conclusion of one more new species for this genus in Madagascar and likely yet another endemic element to the region of Namoroka. This new species is described here. Some additional comments are also proposed about the remarkable diversity of this genus in Madagascar (Lourenço *et al*., 2018).

Methods

Illustrations and measurements were made with the aid of a Wild M5 stereo-microscope equipped with a drawing tube (camera lucida) and an ocular micrometer. Measurements follow Stahnke (1970) and are given in mm. Trichobothrial notations follow Vachon (1974) and morphological terminology mostly follows Hjelle (1990).

The present composition of the genus *Opisthacanthus* in Madagascar

The rather complex taxonomic history of the genus *Opisthacanthus* Peters and most historical aspects concerning Malagasy species of *Opisthacanthus* have already been presented in previous publications and will not be further discussed here (Lourenço, 2014a, 2014b; Lourenço & Goodman, 2006, 2008; Lourenço *et al*., 2016a, 2018).

The present study of a new sample of scorpions including one specimen of the genus *Opisthacanthus*, subgenus *Monodopisthacanthus* from Namoroka National Park, has resulted in the discovery of one new species. The new species was collected in a dense humid forest of the park and was in part previously related to *Opisthacanthus madagascariensis* Kraepelin, 1894 which is also known from the western portion of the island (Lourenço & Goodman, 2004). Nevertheless, *O. madagascariensis* is exclusively found in spiny forest thickets and grassland formations.

The check-list given below takes into account the most recent taxonomic modifications proposed for the genus (Lourenço, 2014a, 2014b; Lourenço & Goodman, 2006, 2008; Lourenço *et al*., 2016a, 2018).

Genus ***Opisthacanthus*** Peters, 1861

Subgenus ***Monodopisthacanthus*** Lourenço, 2001

Opisthacanthus ambanja Lourenço, 2014
Opisthacanthus andohahela Lourenço, 2014
Opisthacanthus antsiranana Lourenço, 2014
Opisthacanthus darainensis Lourenço & Goodman, 2006
Opisthacanthus faillei sp. n.
Opisthacanthus lavasoa Lourenço, Wilmé & Waeber, 2016
Opisthacanthus lucienneae Lourenço & Goodman, 2006
Opisthacanthus maculatus Lourenço & Goodman, 2006
Opisthacanthus madagascariensis Kraepelin, 1894
Opisthacanthus milloti Lourenço & Goodman, 2008
Opisthacanthus pauliani Lourenço & Goodman, 2008
Opisthacanthus piceus Lourenço & Goodman, 2006
Opisthacanthus titanus Lourenço, Wilmé & Waeber, 2018

The genus *Opisthacanthus* is currently distributed in Madagascar, sub-Saharan Africa, the Caribbean, Central and South America. The range of the genus in Africa is almost 7.5 million km², it is ca. 3.5 million km² in the New World, and less than 0.45 million km² in Madagascar (Lourenço *et al*., 2018). Despite its small size, Madagascar is home to 13 species, as many as in Africa.

Consequently, one question can be addressed: why is the diversity of the genus *Opisthacanthus* comparatively so high in Madagascar?

Taking into account its Gondwanan origin, the *Opisthacanthus* lineage can be considered rather old, back to the Cretaceous period (Lourenço *et al*., 2018). During evolutionary time this lineage was facing the evolution of several other scorpion groups which were likely competing with the ancestral *Opisthacanthus*. In Africa there are several other groups, including other Hormuridae (cf. *Cheloctonus* Pocock, 1892 and *Iomachus* Pocock, 1893), but particularly the more recent Scorpionidae represented by *Scorpio* Linnaeus, 1758 and *Opistophthalmus* C. L. Koch, 1837. In Tropical America, all these groups are absent, but another group represented by the Chactidae prevails and has currently the same distribution than *Opisthacanthus*, The Chactidae includes many genera with large species such as *Brotheas* C. L. Koch, 1837, *Broteochactas* Pocock, 1893, *Chactas* Gervais, 1844 and *Teuthraustes* Simon, 1878 which could have played an important role in the competition process and turnover of the South-American scorpions. In Madagascar however, these lineages probably never existed, therefore allowing the radiation of the genus. There is only another Hormuridae in Madagascar the genus *Palaeocheloctonus* Lourenço, 1996 (Lourenço & Wilmé, 2015a) represented by two species. Equally, the elements of the endemic family Heteroscorpionidae Kraepelin, 1905 represented by six species are rather rare and show patchy distributions (Lourenço & Goodman, 2009).

Taxonomic treatment

Family **Buthidae** C. L. Koch, 1837

Genus ***Tityobuthus*** Pocock, 1893

***Tityobuthus antsingy* Lourenço & Goodman, 2004**
Fig. 1-2.
Tityobuthus antsingy Lourenço & Goodman, 2004: Rev. Ibér. Aracnol., 9: 19.

ORIGINAL MATERIAL. 1 female holotype. Madagascar, ex-Province de Mahajanga, Réserve Naturelle Intégrale (RNI) de Namoroka (today Parc National du Tsingy de Namoroka), site Andriabe, 3.3 km SE Namoroka (village), 16° 24.666'S, 45° 18.911' E, 140 m, 23/IX/2003 (S. M. Goodman - 13803). Type deposited in the Field Museum of Natural History, Chicago, USA.

NEW MATERIAL. 1 female. Ex-Province de Mahajanga, Parc National du Tsingy de Namoroka, Grotte des chauves-souris (S16°24'30" E45°18'40"), in the dark zone of the cave, 124 m, 25/X/2016 (A. Faille). Material deposited in the Muséum national d'Histoire naturelle, Paris, France.

NEW DIAGNOSIS: Species moderate in size, in relation to the other species of the genus, with 27 to 29 mm in total length for females. General coloration pale yellow throughout the body and the appendages. Carapace pale yellow with an inverted triangular but diffused dark spot, between median and lateral eyes, and with some dark zones on the lateral margins; eyes surrounded by black pigment. Mesosoma pale yellow with three inconspicuous longitudinal strips; the median divided by a yellow band. Metasomal segments I to IV yellow; segment V and telson reddish. Legs yellow with diffused spots. Pedipalps yellow with diffused spots on the internal and external faces; Chelicerae yellow with dense variegated pigmentation over the entire surface. Carapace with a moderately pronounced concavity, forming a weak angle. Cheliceral dentition with basal teeth of movable fingers reduced and almost fused. Pectines with 19-19 and 20-20 teeth; fulcra present. Sternites smooth; sternite V without any bright zone on posterior edge. Dorsal furrow of metasomal segments strongly granulated, forming two extra carinae on segment IV. Telson less elongated than in the other species of the genus, with the exception of *Tityobuthus pallidus* Lourenço; aculeus moderately curved; subaculear tooth moderate and slightly spinoid with two basal granules. Cheliceral dentition typical of the family Buthidae (Vachon, 1963); basal teeth of movable fingers reduced and almost fused.Tibial spurs reduced. Pedipalp fixed and movable fingers with 8-9 almost linear rows of granules. Trichobothrial pattern type A-α (alpha) orthobothriotaxic (Vachon, 1974, 1975).

TAXONOMIC POSITION: From its general morphology, and especially by the diffused pigmentation, *Tityobuthus antsingy* appears to be more closely related to *T. guillaumeti* Lourenço, *T. judsoni* Lourenço, and *T. pallidus*. Some characters lead however this species to be distinguished from the other species of the genus. A quite unique pattern of pigmentation with the pedipalp femur and patella yellow and with only the internal and external faces dark. The presence of fulcra on the pectines. The dorsal furrow of metasomal segments strongly granulated and the furrow granulation of metasomal segment IV forming two 'extra dorsal carinae'. It also shows the presence of reduced tibial spurs.

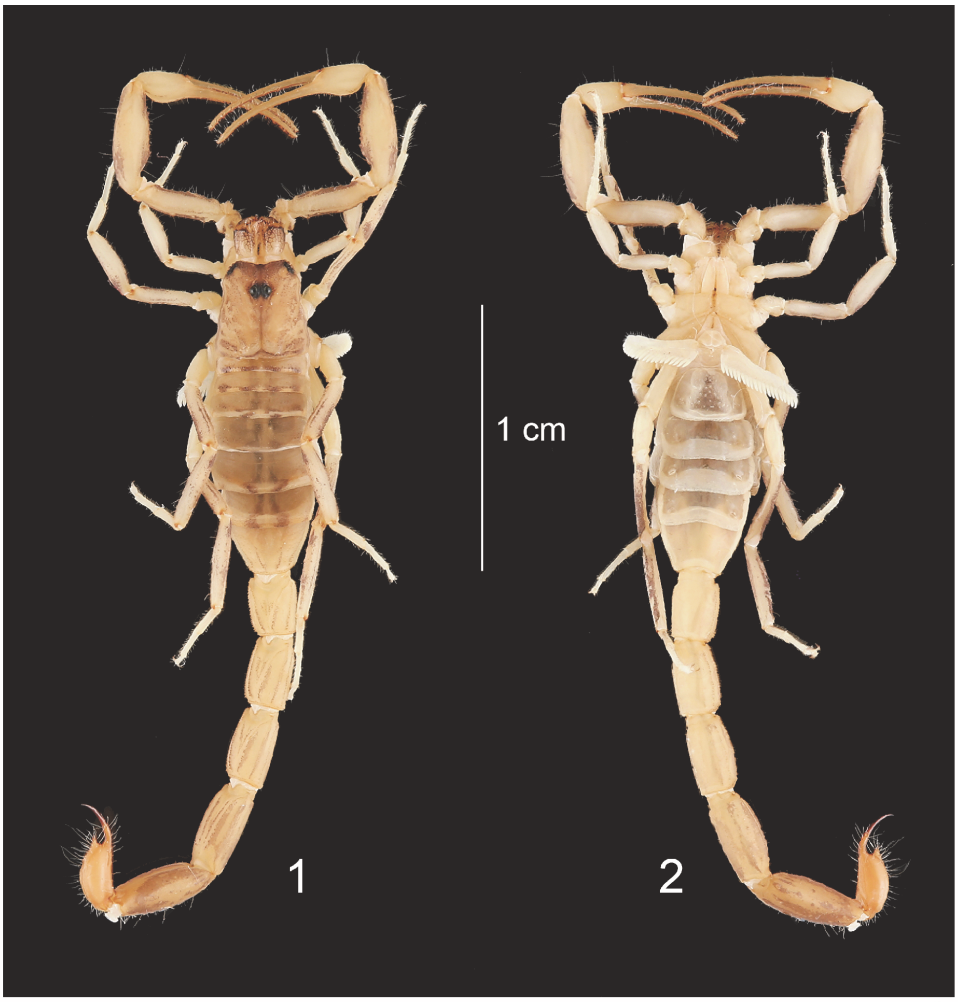




Fig. 1-2. *Tityobuthus antsingy*. Female topotype. Habitus, dorsal and ventral aspects. **Fig. 3-4.** *Opisthacanthus* (*Monodopisthacanthus*) *faillei* sp. n. Male holotype. Habitus, dorsal and ventral aspects.

Family **Hormuridae** Laurie, 1896

Genus ***Opisthacanthus*** Peters, 1861

Subgenus *Monodopisthacanthus* Lourenço, 2001

***Opisthacanthus* (*Monodopisthacanthus*) *faillei* sp. n.**
Fig. 3-4, 5-15.

TYPE MATERIAL: Madagascar, ex-Province of Mahajanga, Region of Boeny, District of Soalala. Parc National du Tsingy de Namoroka, (S16°24.602' E045°18.325') in wet zone (dense humid forest), trapped with UV light, 26/X/2016 (A. Faille).
Holotype deposited in the Muséum national d'Histoire naturelle, Paris

ETYMOLOGY: Patronym: The specific name honors Arnaud Faille (Stuttgart State Museum of Natural History) who collected the new species.

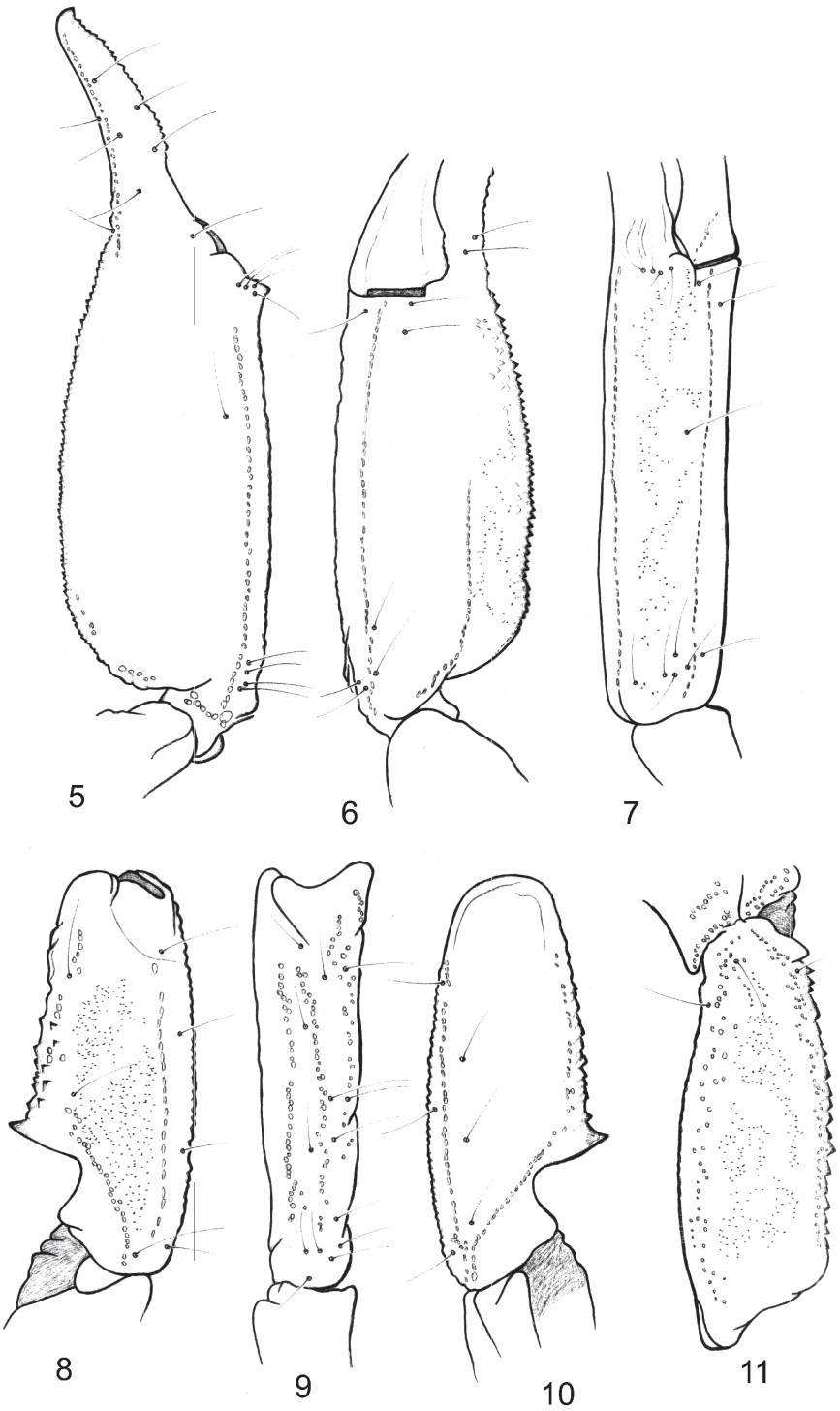


Fig. 5-11. *Opisthacanthus* (*Monodopisthacanthus*) *faillei* sp. n. Male holotype. Trichobothrial pattern. **5-7**. Chela, dorso-external, ventral and external aspects. **8-10**. Patella, dorsal, external and ventral aspects. **11**. Femur, dorsal aspect.

DIAGNOSIS: Scorpions of moderate size: male with 56.9 mm in total length. Coloration reddish to reddish-yellow, with blackish zones over pedipalp carinae and some infuscate variegated zones on chelicerae. Pectines with 7-8 teeth in male. Hemispermatophore very slender with an elongated distal lamina, weakly enlarged. Genital operculum in male formed by two semi-oval to round plates, with a minute incision in the base. Trichobothrial pattern of type C, orthobothriotaxy.

DESCRIPTION BASED ON HOLOTYPE

Coloration. Basically reddish to reddish-yellow with blackish zones over pedipalp carinae and some infuscate variegated zones on chelicerae. Carapace reddish; median and lateral eyes surrounded with black pigment. Tergites reddish-yellow. Metasomal segments dark reddish to reddish-brown; vesicle pale yellow; aculeus dark reddish. Chelicerae dark yellow; base of fingers reddish; the whole surface with diffuse variegated spots; fingers dark brown with reddish teeth. Pedipalps reddish to reddish-brown; most carinae blackish; chela fingers dark brown to blackish. Venter and sternites dark yellow; pectines and genital operculum yellow, much paler than sternites; sternum and coxapophysis with reddish tonalities; legs golden yellow.

Morphology. Carapace with punctuation and smooth zones; furrows moderately shallow. Anterior margin with a strong concavity reaching as far as the level of the 2nd lateral eye. Median ocular tubercle flattened and almost in the centre of

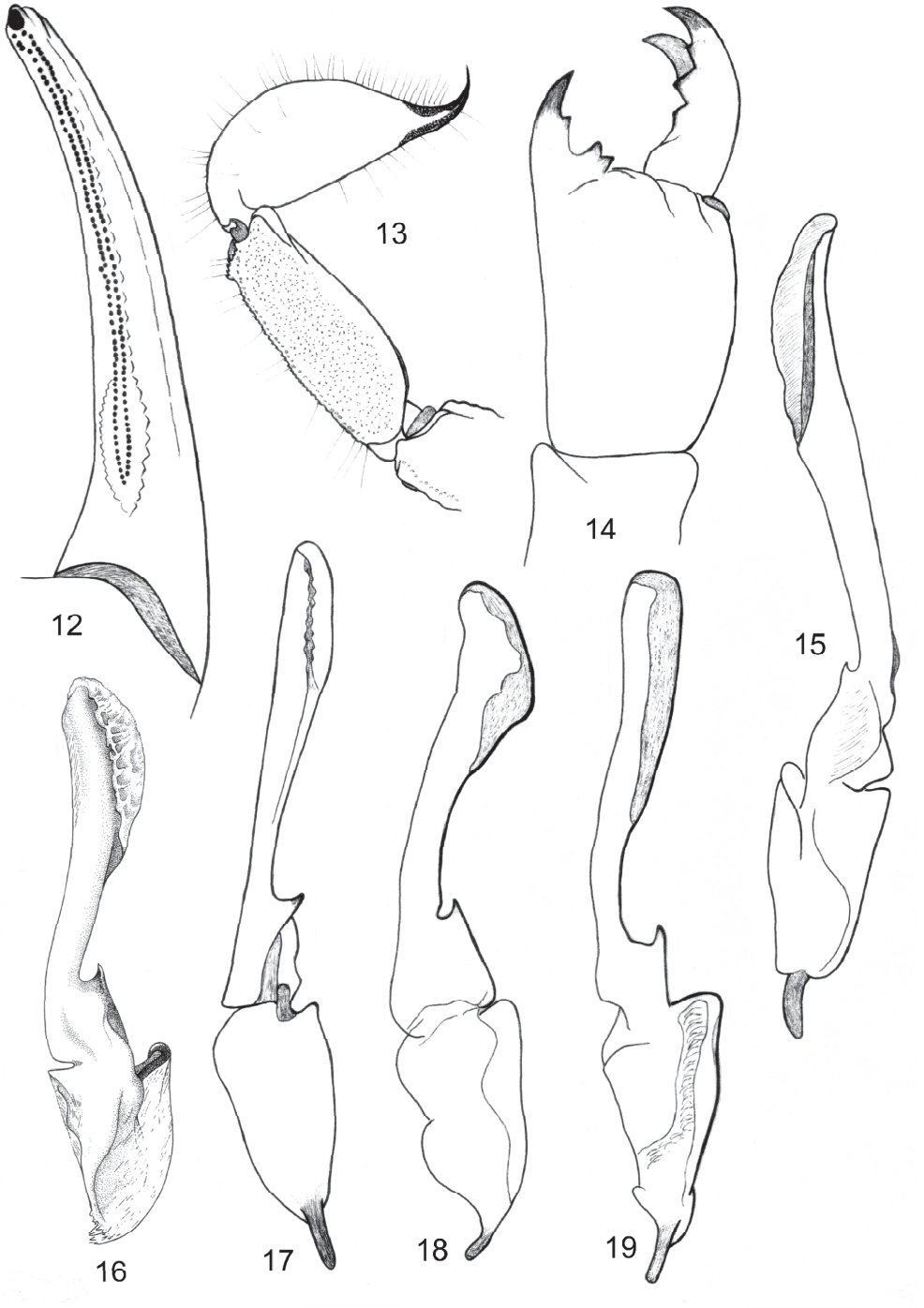


Fig. 12-15. *Opisthacanthus* (*Monodopisthacanthus*) *faillei* sp. n. Male holotype. **12**. Cutting edge of movable finger, showing the two series of granulations. **13**. Metasomal segment V and telson, lateral aspect. **14**. Chelicera, dorsal aspect. **15**. Left hemispermatophore, lateral aspect (right hemispermatophore not formed). **16-19**. Right hemiespermatophores of associated species. **16**. *O. madagascascariensis*. **17**. *O. lavasoa*. **18**. *O. antsiranana*. **19**. *O. ambanja*.

the carapace; median eyes moderate to small, separated by less than one ocular diameter; three pairs of large lateral eyes. Sternum pentagonal longer than wide. Genital operculum formed by two semi-oval to round plates in male, with a minute incision in the base. Tergites with a moderate to weak median carina, smooth and with punctuations; tergite VII intensely granulated. Pectinal tooth count 7-8 in male holotype. Sternites smooth and shiny; VII acarinate with few punctuations. Metasomal segments I to V longer than wide, with intense granulations in particular on segment V. All carinae moderately marked in segments I-IV; segment V rounded with some spinoid granules on the ventral surface. All segments with moderate chetotaxy. Telson with a pear-like shape; smooth and covered with strong chetotaxy. Pedipalps: femur with dorsal internal, dorsal external, ventral internal and ventral external carinae strong, tuberculate; dorsal face with thin granulation; ventral face with minute granulation; internal face moderately granulose. Patella with internal and external faces moderately granulated; dorsal and ventral faces weak to moderately granulated; dorsal internal, ventral internal, ventral external and external carinae strong; other carinae less well marked. Chela moderately to strongly granular excepted on ventral face; dorsal marginal, external secondary, ventrointernal and ventral median carina strong; other carinae less well marked. Chelicerae typical of Scorpionoidea (Vachon, 1963); teeth strongly sharp. Trichobothriotaxy type C; orthobothriotaxic (Vachon, 1974). Legs: tarsi with two lateral rows of spines, three internal and three external, surrounded by a few long setae. Spurs moderate to weak. Hemispermatophore very slender with an elongated and bilobated distal lamina, weakly enlarged.

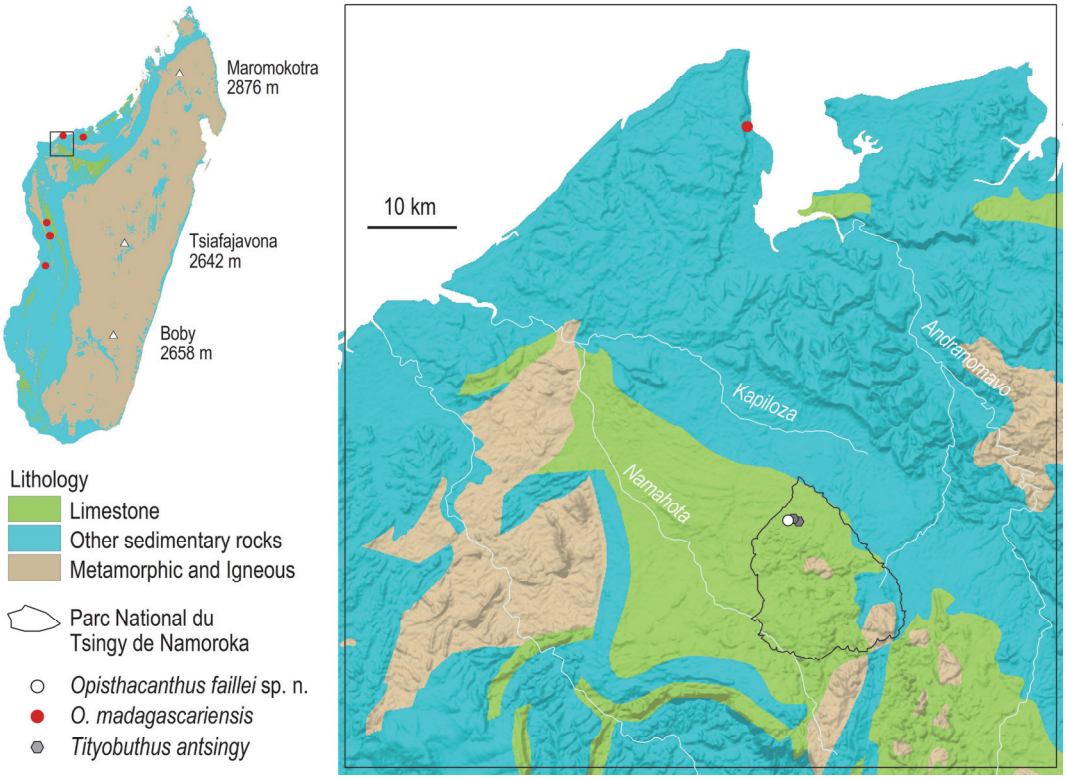


Fig. 20. Type locality of *Opisthacanthus faillei* sp. n. and distribution localities of *Tityobuthus antsingy* in the Parc National du Tsingy de Namoroka, The park lies in the Mahajanga sedimentary basin in the region farther away from the high mountains of Madagascar, at a distance of nearly 400 km from Tsiafajavona and more than 400 km from the highest summit Maromokatra (top left).

MORPHOMETRIC VALUES (IN MM) OF MALE HOLOTYPE. Total length (including telson) 56.9. Carapace: length 9.6; anterior width 6.2; posterior width 9.7. Mesosoma length 19.6. Metasomal segment I: length 3.5, width 2.5; II: length 3.9, width 2.2; III: length 4.0, width 2.0; IV: length 4.2, width 1.9; V: length 5.7, width 1.8, depth 2.1. Telson length 6.4. Vesicle: width 2.0, depth 2.4. Pedipalp: femur length 11.5, width 4.0; patella length 10.9, width 4.4; chela length 19.7, width 4.9, depth 3.3; movable finger length 8.1.

RELATIONSHIPS: The type locality of the new species is included within the geographical range of *Opisthacanthus madagascariensis*. However, by several characters of its morphology and in particular the shape of hemispermatophores, it seems closer to *O. lavasoa* described from Andohahela in the SE region of the island. It can be distinguished from these two species by a number of characters: (i) a paler coloration with golden yellow legs, (ii) smaller global size, (iii) distinct morphometric values, and (iv) sternum longer than wide, (v) tergite VII and metasomal segment V strongly granulated, (vi) hemispermatophore with a distinct morphology – quite slender compared to that of *O. madagascariensis* and with a bilobate distal lamina (see figures 15-19).

THE PN DU TSINGY DE NAMOROKA

The PN du Tsingy de Namoroka rests on Mesozoic limestone dating to the Jurassic and early Cretaceous (about 195-100 million years ago Ma) and is a complex karst region with an extensive network of caves and underground water sources (Besairie & Collignon, 1971). Portions of the limestone have been eroded into sharp pinnacles known as *tsingy* in Malagasy. We have suggested elsewhere (e.g., Lourenço *et al*., 2016b) that the limestones tsingy formations in Madagascar may have been able to harbour species relying on humid conditions during the drier periods of the paleoclimate oscillations. The Tsingy of Namoroka lies in the northwestern corner of the Melaky center of endemism (Wilmé *et al*., 2012, 2016; Lourenço *et al*., 2016b), i.e., in the region farther away from the high mountains of Madagascar, at a distance of nearly 400 km from the closest highest summit of Madagascar (Figure 20). The rivers of this region must have dried up quickly when the climate became colder and drier, given the poor orographic rainfall experienced by the watersheds of the Melaky center of endemism, more so in the region of Namoroka towards the Mozambique Channel. Thus, for many endemic species, reliefs such as the tsingy had to act as ecological refugia (sensu Mercier & Wilmé, 2013) during the dry periods of the Plio-Quaternary, including for *Opisthacanthus faillei* sp. n. collected in a humid forest in 2018 (figure 21-23). A total of four species and four genera are currently known from the Tsingy of Namoroka, namely *Grosphus* (aff.) *hirtus* Kraepelin 1901 and *Tityobuthus antsingy* Lourenço & Goodman 2004 in the family Buthidae, *Microcharmus pauliani namoroka* Lourenço, Goodman & Fisher 2006 in the family Microcharmidae and *Opisthacanthus faillei* sp. n. in the family Hormuridae.

Biogeographic considerations for the subgenus *Monodopisthacanthus*

Monodopisthacanthus is a lineage from the dry biomes of Madagascar, with one wide-ranged species and 12 narrow-ranged species occurring in dry and sub-humid forests.

Lourenço *et al*. (2016a, 2018) detailed the biogeography of the *Opisthacanthus Monodopisthacanthus* at the time of the description of *Opisthacanthus* (*Monodopisthacanthus*) *lavasoa*, and showed that *O. titanus* Lourenço, Waeber, Wil-



Fig. 21-23. Aspects of field ecology. **20**. Cave where *Tityobuthus antsingy* was collected. **21**. Entomological trap where *Opisthacanthus faillei* sp. n. was detected. **22**. *Opisthacanthus faillei* sp. n. alive in the field (photos by A. Faille).

mé, 2017 collected in a humid rainforest in Eastern Madagascar probably belongs to a relict population surviving on a mountain located in the rainshadow on the leeward side of the humid Betsimisaraka mountains, therefore experiencing a local climate with lower rainfall as compared to most humid forests found along the Eastern belt of the island (Lourenço & Wilmé, 2015b; Lourenço *et al*., 2016b, 2016c, 2017). *O. faillei* sp. n. is also exceptional when it comes to the environment where the holotype has been collected: a sub-humid forest in one of the driest biomes of the island.

Lourenço *et al*. (2016a) proposed that following the K–Pg mass extinction (66 Ma), during the early Paleogene, the ancestral *Monodopisthacanthus* was present in Madagascar and has survived the K–Pg. At the time, Madagascar was located at some 7 to 8 degrees to the south of its current position (Wells, 2007), and was isolated from both Africa and peninsular India; the South-Indian drift was affecting the eastern coast of Madagascar, therefore increased the rainfall, and Northern Madagascar entered the monsoon belt. At the end of the Paleocene (56.0 Ma), a major global increase in temperature occurred, the Paleocene–Eocene thermal maximum (PETM), which lasted some 200,000 years (Zachos *et al*., 2005). Only by the mid Oligocene, 29 Ma, has Madagascar completed its drift out of the arid belt and entered completely the trade wind regime (de Wit, 2003; Wells, 2007; Waeber *et al*., 2015; Lourenço *et al*., 2018 and references therein).

At the time of the PETM, the ancestral population in the subgenus *Monodopisthacanthus* would have been able to cope with some kind of dry conditions but would have been extirpated from the driest regions of the island, especially Southern Madagascar, which then was still in the arid belt. During the driest periods of the paleoclimate oscillations, some *Monodopisthacanthus* could have survived in refugia, typically in reliefs where water/humidity was maintained as in limestone formations (Mercier & Wilmé, 2013). Lourenço *et al*. (2016a) proposed that the ancestral *Monodopisthacanthus* populations adapted to the dry conditions during the Paleocene in eastern Madagascar but could have disappeared from the eastern belt of the island when Madagascar entered the trade wind regime with increased humidity along this portion of the island.

The Madagascar *Opisthacanthus* belong to a single group and the new species described here is adding to the evolutionary radiation for the members of this group. This pattern observed in the scorpions of Madagascar is not unusual in the global Malagasy faunal and floral context, i.e., high species diversity and endemism.

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