

Three new cavernicolous species and three new records of the millipede genus *Pacidesmus* from southern China (Diplopoda: Polydesmida: Polydesmidae)

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Abstract. Three new species of *Pacidesmus* are described from caves in southern China: *P. whitteni*, new species, from Guangxi Zhuang Autonomous Region, *P. trilobatus*, new species, and *P. uncatus*, new species, the latter two from Yunnan Province. The three new species differ from the most similar congeners mainly in certain details of gonopodal structure. Additional records of *P. bifidus*, *P. martensi* and *P. sinensis* are also presented. The genus is thus composed of a single high-montane forest-dwelling species in northern Thailand at present, as well as another 11 species, all presumed troglobionts from southern China.

Key words. *Pacidesmus*, new species, new record, cave, southern China, subterranean biology

INTRODUCTION

This article is dedicated to the cherished memory of our friend Tony Whitten.

Pacidesmus Golovatch, 1991 is a small Oriental millipede genus that has hitherto been known to encompass nine accepted species (Table 1). Among them, only the type species *P. shelleyi* Golovatch, 1991 is known from forest litter at 2,200 m a.s.l. on top of Mount Doi Inthanon in northern Thailand, whereas the remaining species seem to be troglobionts restricted to caves in southern China, especially Guangxi and Guizhou provinces (Golovatch et al., 2010; Golovatch & Geoffroy, 2014).

Within the family Polydesmidae, the genus is characterised by the seminal groove starting mesally, then recurving laterad at the base of a particularly prominent endomere branch to enter an accessory seminal chamber that opens on a hairy pulvillus, and the gonopodal telopodite being divided distally into endomere and exomere branches (Golovatch, 1991; Golovatch & Geoffroy, 2006).

This paper is devoted to the description of three new species and gives new records of three previously described species,

based on *Pacidesmus* material taken recently from caves in southern China.

MATERIAL AND METHODS

All specimens used in this study were collected by hand from caves in southern China, and were preserved in 95% ethanol. The type specimens and other material are deposited in the Zoological Collection of the South China Agricultural University, Guangzhou, China (SCAU). Geographical coordinates of the caves are not provided as is generally accepted in cave biodiversity studies for the conservation of sensitive habitats.

Observations, dissections and measurements were performed using a Leica S8 APO stereo microscope. Photographs were taken with a Canon EOS 40D camera, focus-stacked with Z-stack software, and edited using Adobe Photoshop CS5. Colouration as described in this study is based solely on alcohol material. Line drawings were prepared with an Olympus BX51 or ZEISS Axioskop40 microscope with an attached camera lucida. The terminology used here follows that of Golovatch et al. (2010), and the higher-level taxonomy is that of Enghoff et al. (2015).

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TAXONOMY

Class Diplopoda de Blainville in Gervais, 1844

Order Polydesmida Pocock, 1887

Family Polydesmidae Leach, 1815

Pacidesmus Golovatch, 1991

Type species. *Pacidesmus shelleyi* Golovatch, 1991.

All known species belonging to this genus are listed in Table 1.

***Pacidesmus whitteni*, new species**
(Figs. 1, 2)

Material examined. Holotype male (SCAU pGX1-1), China, Guangxi Zhuang Autonomous Region, Fengshan County, Jinya Town, Hangdong Village, I Dong Cave, coll. Mingyi Tian et al., 14 June 2014. Paratypes: 1 male, 2 females (SCAU pGX1-2), same data as holotype.

Diagnosis. Adult males of *P. whitteni* are distinct from other *Pacidesmus* species, based on the following combination of characters: (1) anterior margin of metaterga forming a distinct shoulder (Fig. 1A, C); (2) endomere long and slender, with a subapical process and a small tooth at midway;

(3) exomere stout, finger-shaped (Fig. 2). *Pacidesmus whitteni* seems to be particularly similar to *P. armatus* (from caves in Guangxi, China), but is distinguished by (1) the caudolateral corners of the paraterga being strongly triangular (Fig. 1A, C) vs. narrowly rounded to pointed in *P. armatus*; (2) the exomere being larger, finger-shaped (Fig. 2) vs. smaller and unciform in *P. armatus*.

Etymology. *Pacidesmus whitteni* is dedicated to the memory of Tony Whitten, the late passionate scientist and manager of biodiversity research and conservation in Asia.

Description. Based on type specimens. Length of both sexes ca. 23–29 mm, width of pro- and metazonae 1.5–1.6 and 2.5–2.8 mm, respectively. Colouration: in alcohol generally pallid (Fig. 1). Mouthparts and gonopodal telopodites light yellowish.

Body. Adults with 20 rings. Width: head < collum < ring 3–4 < 2 < 5–16, thereafter (rings 17–19) body gradually tapering caudad towards telson.

Head. Densely pilose, epicranial suture conspicuous (Fig. 1B). Antennae long, reaching past middle of ring 3 when extended posteriorly, slightly clavate (Fig. 1A, B).

Exoskeleton. Collum fan-shaped, with a faint lateral incision/denticle on each side (Fig. 1B). Paraterga evident (Fig. 1A–E), midbody metaterga ca. 1.6 times as wide as prozonae. Paraterga 2–4 clearly upturned dorsally above a faintly

Table 1. The known species of *Pacidesmus* with their distributions.

Species	Localities
<i>P. armatus</i> Golovatch, Geoffroy & Mauriès, 2010	Cave Xialan Dong, Cave Shui Dong and Cave Shenglong Dong, Huanjiang County, Guangxi Zhuang Autonomous Region, China (Golovatch et al., 2010).
<i>P. bedosae</i> Golovatch, Geoffroy & Mauriès, 2010	Cave Dongtu Dong, Cave Huoka Dong and Cave Ganxiao Dong, Huanjiang County, Guangxi Zhuang Autonomous Region, China (Golovatch et al., 2010).
<i>P. bifidus</i> Golovatch & Geoffroy, 2014	Cave Henglixin Dong, near Fengshan County, Guangxi Zhuang Autonomous Region, China (Golovatch & Geoffroy, 2014).
<i>P. martensi</i> Golovatch & Geoffroy, 2006	Cave Luoshui Dong and Cave Luosai Dong, Honglin Town, Qianxi County; Cave Hei Dong, Dafang County, Guizhou Province, China (Golovatch & Geoffroy, 2006; Golovatch et al., 2006).
<i>P. shelleyi</i> Golovatch, 1991	Doi Inthanon National Park, Chiang Mai Province, Thailand (Golovatch, 1991).
<i>P. sinensis</i> (Golovatch & Hoffman, 1989)	A cave in Guizhou Province and Cave Kaikou Dong, Zhenning County, Guizhou Province, China (Loksa, 1960; Golovatch & Hoffman, 1989; Chen & Meng, 1990).
<i>P. superdraco</i> Golovatch, Geoffroy & Mauriès, 2006	Cave Laitai Dong, Libo County, Guizhou Province, China (Golovatch et al., 2006).
<i>P. tiani</i> Golovatch, Geoffroy & Mauriès, 2010	Caves Ganglai Dong I and II, Huanjiang County, Guangxi Zhuang Autonomous Region, China (Golovatch et al., 2010).
<i>P. trifidus</i> Golovatch & Geoffroy, 2014	Cave Kulou Dong, Guilin City, Guangxi Zhuang Autonomous Region, China (Golovatch & Geoffroy, 2014).

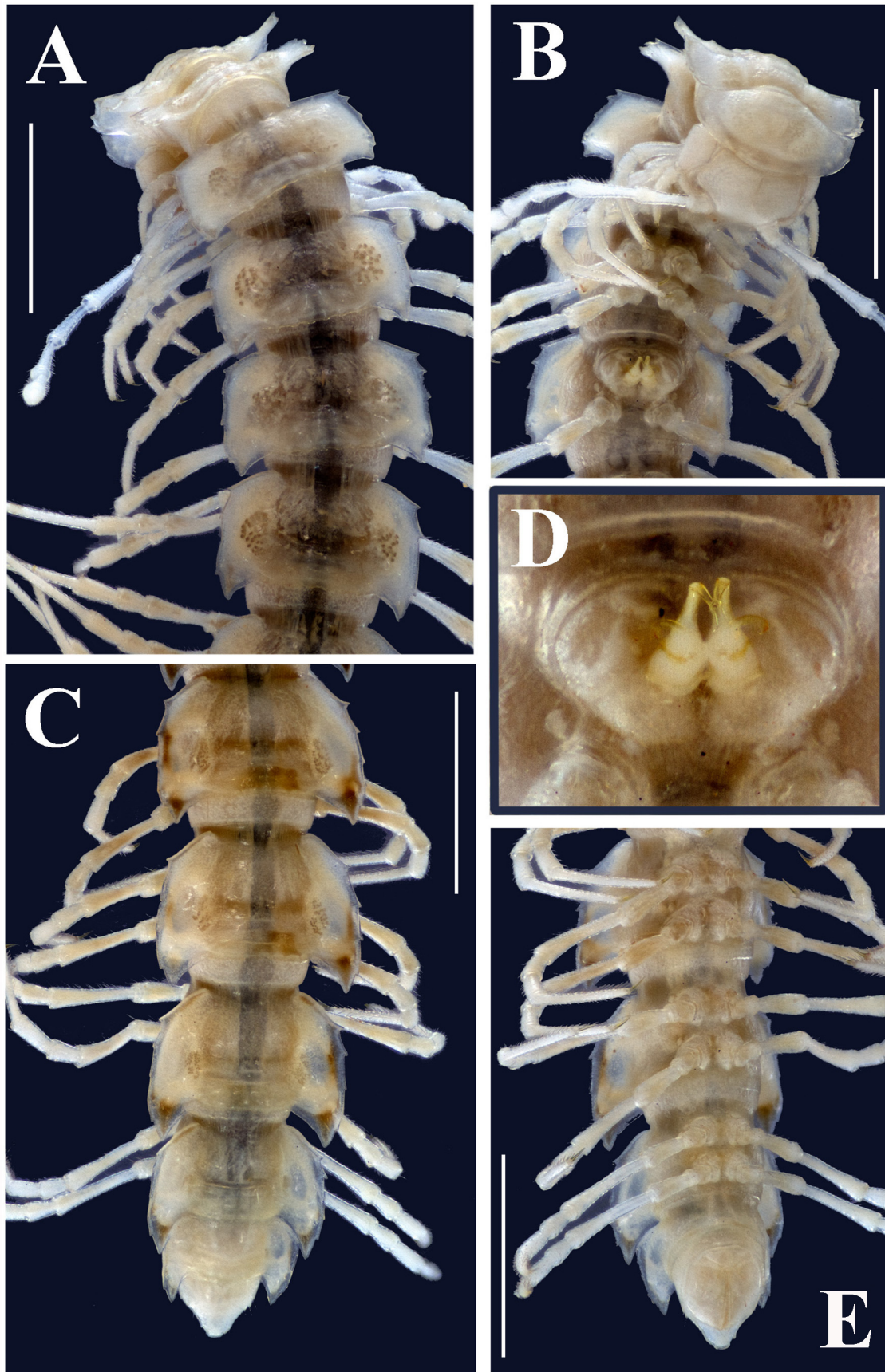


Fig. 1. *Pacidesmus whitteni*, new species, male paratype. A, anterior part of body, dorsal view; B, anterior part of body, ventral view; C, posterior part of body, dorsal view; D, gonopods in situ, ventral view; E, posterior part of body, ventral view. Scale bar: A–C, E = 0.25 mm; D, no scale.

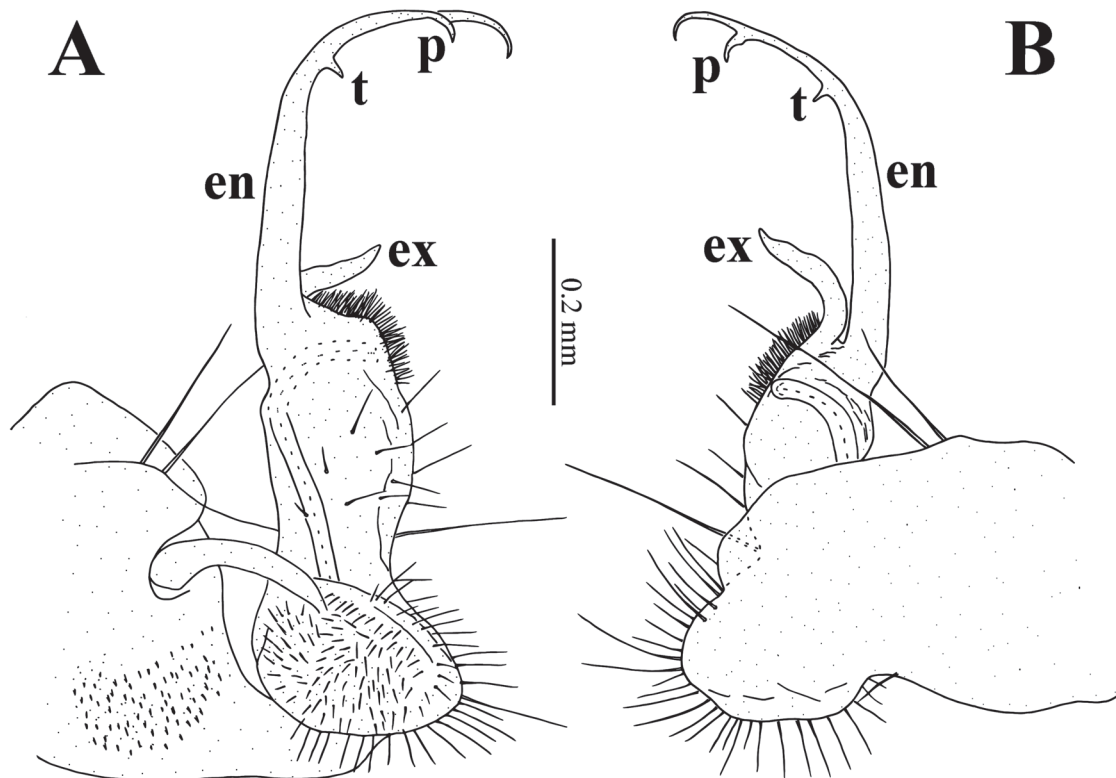


Fig. 2. *Pacidesmus whitteni*, new species, male paratype. A, left gonopod, mesal view; B, left gonopod, lateral view. Designations: en, endomere; ex, exomere; p, process; t, tooth.

convex dorsum, following paraterga flat and subhorizontal (Fig. 1A, B). Caudolateral corners of paraterga posterior to collum clearly acute-angled and projecting posteriorly past tergal margin, especially acute on rings 18–19 (Fig. 1C–E). Anterior margin of metaterga bordered and forming a distinct shoulder (Fig. 1A, C). Integument shining (Fig. 1), translucent, prozonae very delicately alveolate. Limbus regularly microdenticulate. Constriction between pro- and metazonae narrow, shallow and smooth (Fig. 1A, C). Metatergal sculpture faint, with three irregular transverse rows of setigerous polygonal bosses. Tergal setae very short. Sulcus between front and middle rows of setae a little deeper than that between middle and caudal rows (Fig. 1A, C). Three or four faint setigerous incisions at lateral margins of poreless and pore-bearing rings, respectively (Fig. 1A, C). Pore formula normal: 5, 7, 9, 10, 12, 13, 15–19, ozopores evident, dorsal, clearly set off from lateral margin and located between last and penultimate marginal incisions. Epiproct short, conical, pre-apical lateral papillae small. Hypoproct subtrapeziform, with two setigerous papillae at caudal margin. Pleurosternal carinae small, present only on ring 2. Sterna sparsely setose, cross-shaped impressions (both axial and transverse) shallow (Fig. 1E). Legs long and slender, about 2.5 times as long as body ring height in both sexes, without sphaerotrichomes or sternal cones, prefemora not bulging laterally (Fig. 1E).

Gonopods subfalcate (Figs. 1D, 2). Coxa large, as usual. Prefemur densely setose and nearly 1/4 as long as telopodite. Femorite about half the length of telopodite. Endomere (en)

curved, long and slender, carrying a sharp subapical process (p) and a small tooth (t) at about midway. Seminal groove starting mesally, recurved laterad at base of en; accessory seminal chamber opening on a strongly developed hairy pulvillus located near base of a stout, finger-shaped exomere (ex).

Note. Based on the long and slender antennae and legs, and an unpigmented cuticle, the species is most likely a troglobite.

Pacidesmus trilobatus, new species

(Figs. 3, 4)

Material examined. Holotype male (SCAU pYN1-1), China, Yunnan Province, Wenshan County, Liujing Town, Laozhai Village, I Dong Cave, coll. Mingyi Tian et al., 3 July 2013. Paratypes: 8 males, 30 females (SCAU pYN1-2), same data as the holotype. 5 males, 20 females (SCAU pYN2-1), from same province, Maguan County, Pojiao Town, Dayan Dong Cave, coll. Mingyi Tian et al., 3 July 2013.

Diagnosis. Adult males of *P. trilobatus* are distinct from most other *Pacidesmus* species, based on the following combination of characters: (1) endomere basically subfalcate, carrying three lobes; (2) exomere unciform (Fig. 4). *Pacidesmus trilobatus* seems to be especially similar to *P. sinensis* (from caves in Guizhou, China), but is distinguished by the gonopod showing a shorter exomere



Fig. 3. *Pacidesmus trilobatus*, new species, male paratype from Dayan Dong Cave. A, habitus, dorsal view; B, habitus, ventral view. Scale bar = 0.25 mm.

and a longer and more slender endomere carrying three lobes (Fig. 4) vs. a clearly longer exomere and a shorter and stouter endomere with only one process in *P. sinensis*.

Etymology. The name *trilobatus* emphasises the gonopodal endomere with three lobes. An adjective.

Description. Based on type specimens. Length of body ca. 14–16 mm (males) or 18–21 mm (females), width of pro- and metazonae 1.0–1.2 and 2.2–2.5 mm (males) or 1.2–1.5 and 2.8–3.0 mm (females), respectively. Colouration: in alcohol nearly pallid to light yellowish (Fig. 3).

Body. Adults with 20 rings. Width: head < collum < ring 2 <

3–5 < 6–7 < 8–13, thereafter body gradually tapering caudad towards telson (Fig. 3A).

Head. Only clypeus densely pilose, vertex smooth, epicranial suture conspicuous. Antennae long, reaching past middle of ring 3 when extended posteriorly, slightly clavate (Fig. 3). Antennomere 7 with a minute dorsoparabasal cone.

Exoskeleton. Collum transversely semi-lunar, with an evident lateral incision on each side. Paraterga broad (Fig. 3), midbody metaterga ca. 1.8 times as wide as prozonae. Paraterga 2–5 clearly upturned dorsally above a faintly convex dorsum, following paraterga flat and mostly subhorizontal (Fig. 3A). Caudolateral corners of paraterga

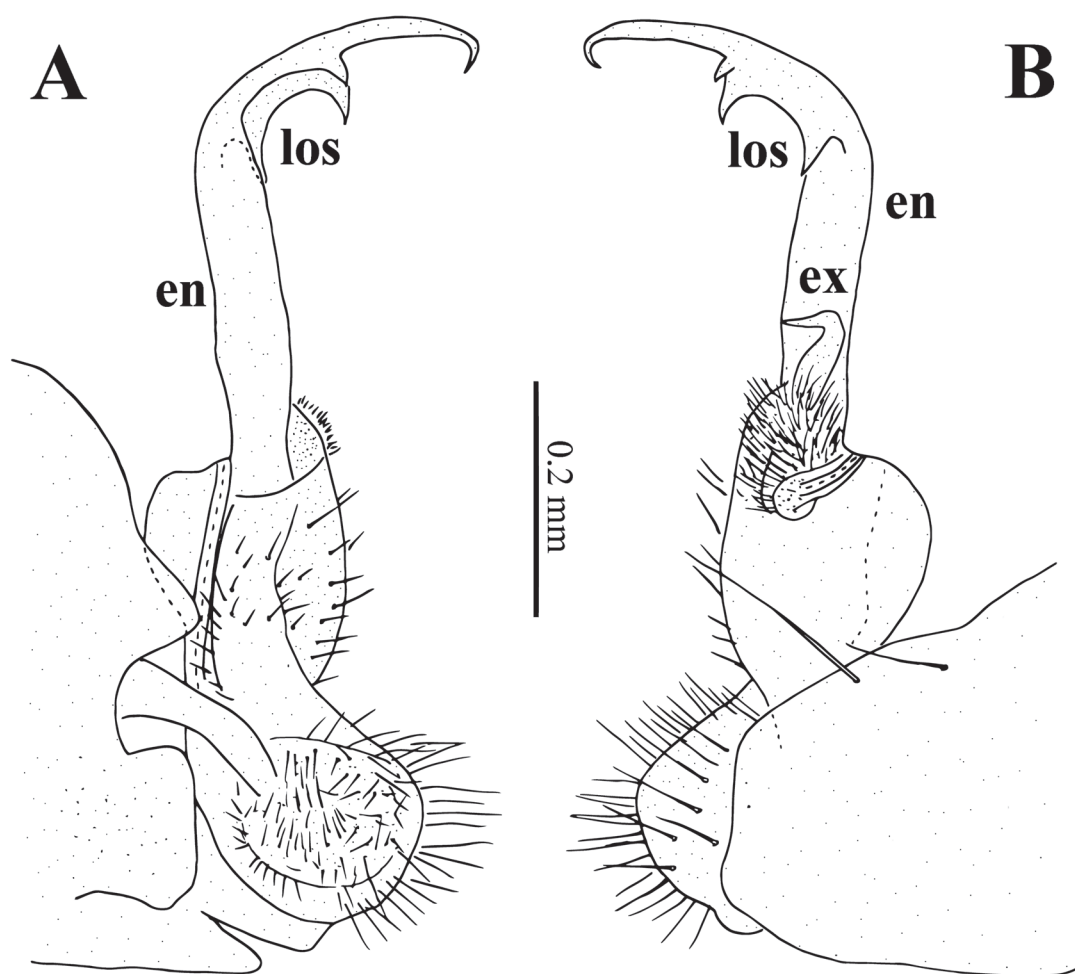


Fig. 4. *Pacidesmus trilobatus*, new species, male paratype from Dayan Dong Cave. A, left gonopod, mesal view; B, left gonopod, lateral view. Designations: en, endomere; ex, exomere; los, lobes.

increasingly acute-angled and projecting posteriorly past tergal margin, especially acute on rings 17–19 (Fig. 3A). Integument shining, translucent, prozonae very delicately alveolate. Limbus regularly denticulate. Constriction between pro- and metazonae narrow and smooth (Fig. 3A, B). Metatergal sculpture faint, with three irregular transverse rows of setigerous polygonal bosses. Tergal setae barely visible. Sulcus between front and middle rows of setae a little deeper than that between middle and caudal rows. Three or four faint setigerous incisions at lateral margins of poreless and pore-bearing rings, respectively. Pore formula normal: 5, 7, 9, 10, 12, 13, 15–19, ozopores evident, dorsal, clearly set off from lateral margin and located between last and penultimate marginal incisions. Epiproct truncate, coniform, pre-apical lateral papillae small (Fig. 3). Hypoproct subtrapeziform, with two setigerous papillae. Pleurosternal carinae small, present only on ring 2. Sterna sparsely setose, cross-shaped impressions shallow (Fig. 3B). Legs long and slender, about 1.5–1.8 times as long as body ring height in both sexes, with neither sphaerotrichomes nor sternal cones, prefemora not bulging laterally (Fig. 3).

Gonopods subfalcate (Fig. 4). Prefemur densely setose and about 1/4 as long as telopodite. Femorite short, about 1/3 as

long as telopodite. Endomere (**en**) long and slender, carrying three lobes (**los**), one at midway and two subapically; tip sharp and hook-shaped. Seminal groove starting mesally, recurved laterad at base of **en**; accessory seminal chamber opening on a strongly developed hairy pulvillus located near base of a short and unciform exomere (**ex**).

Note. Based on the long and slender antennae and legs, and an unpigmented cuticle, the species is most likely a troglobite.

Pacidesmus uncatus, new species
(Figs. 5, 6)

Material examined. Holotype male (SCAU pYN8-1), China, Yunnan Province, Qujing City, Zhanyi County, Tianshengqiao Dong Cave, coll. Mingyi Tian and Jiangli Cheng, 16 August 2015. Paratypes: 3 males, 7 females (SCAU pYN8-2), same data as the holotype. 3 males, 7 females (SCAU pYN7-1), same county, Caiyun Dong Cave, coll. Mingyi Tian and Jiangli Cheng, 16 August 2015.

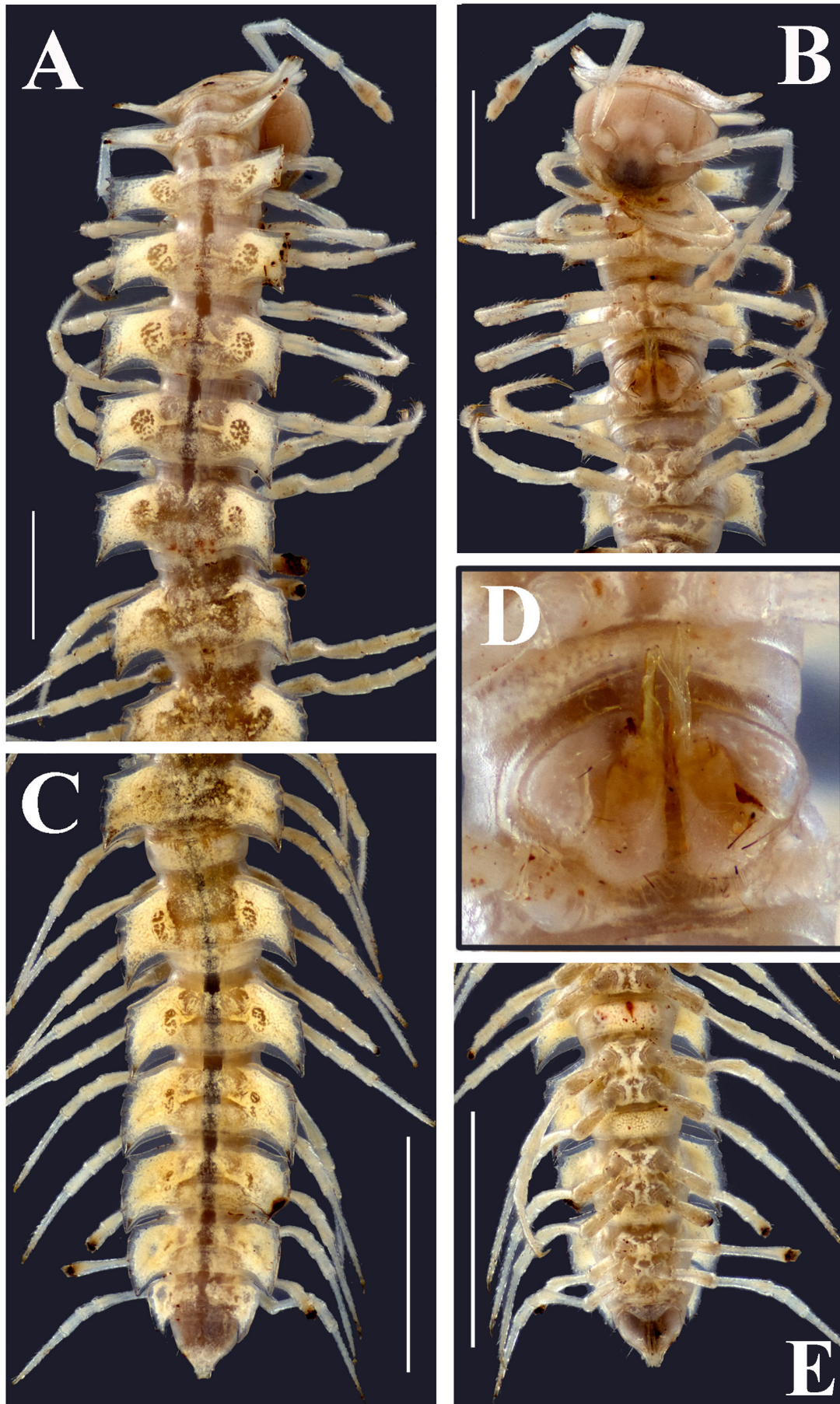


Fig. 5. *Pacidesmus uncatus*, new species, male paratype from Tianshengqiao Dong Cave. A, anterior part of body, dorsal view; B, anterior part of body, ventral view; C, posterior part of body, dorsal view; D, gonopods in situ, ventral view; E, posterior part of body, ventral view. Scale bar: A–C, E = 0.25 mm; D, no scale.

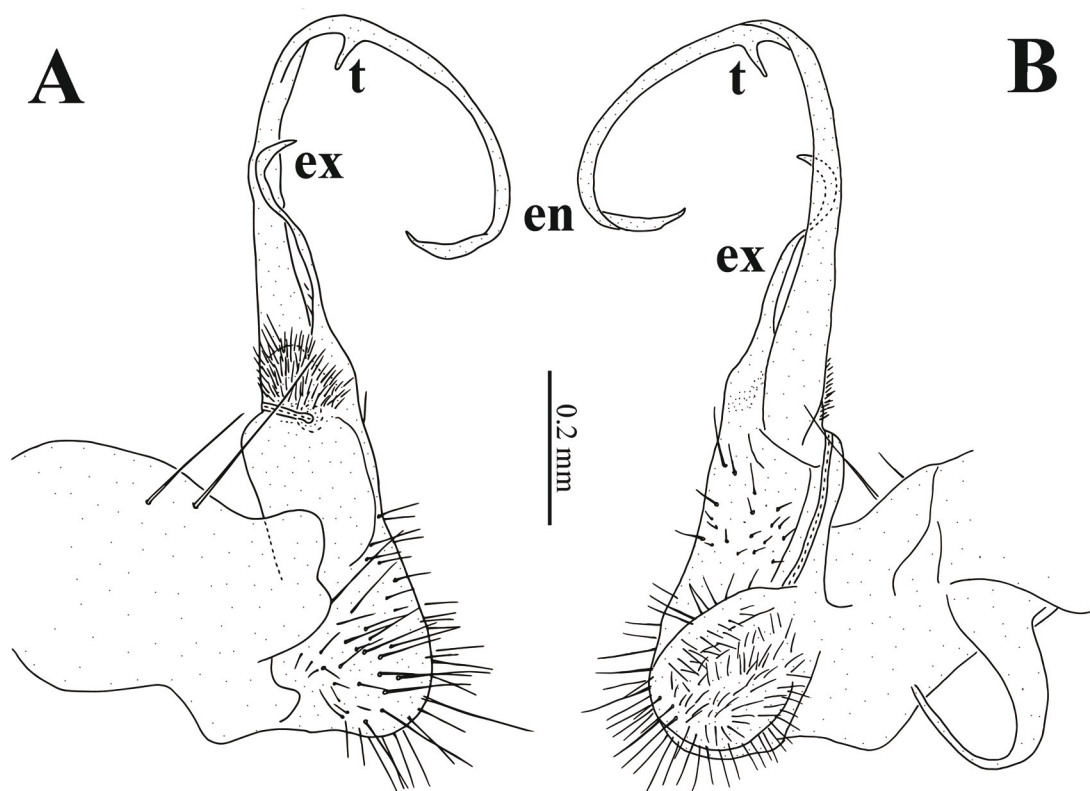


Fig. 6. *Pacidesmus uncatus*, new species, male paratype from Tianshengqiao Dong Cave. A, right gonopod, lateral view; B, right gonopod, mesal view. Designations: en, endomere; ex, exomere; t, tooth.

Diagnosis. Adult males of *P. uncatus* are distinct from other *Pacidesmus* species, based on the following combination of characters: (1) all paraterga clearly unturned above dorsum (Fig. 5A, C); (2) endomere strongly twisted, being hook-shaped; (3) exomere long and slender, also being unciform (Fig. 6). *Pacidesmus uncatus* seems to be particularly similar to *P. sinensis* (from caves in Guizhou, China), but is distinguished by (1) all paraterga being clearly upturned above dorsum (Fig. 5A, C) vs. only anterior paraterga upturned in *P. sinensis*; (2) endomere rather long and strongly twisted (Fig. 6) vs. endomere much shorter and subfalcate in *P. sinensis*.

Etymology. The name *uncatus* emphasises the hook-shaped gonopode. An adjective.

Description. Based on type specimens. Length of body ca. 15–17 mm (males) or 17–19 mm (females), width of pro- and metazonae 1.0–1.2 and 2.2–2.5 mm (males), or 1.2–1.5 and 2.8–3.0 mm (females), respectively. Colouration: in alcohol generally pallid. Mouthparts and gonopodal telopodites light yellowish (Fig. 5).

Body. Adults with 20 rings. Width: head < collum < ring 3–5 < 2 < 6–15, thereafter body gradually tapering posteriorly towards telson.

Head. Only clypeus densely pilose, vertex smooth, epicranial suture conspicuous (Fig. 5B). Antennae long, reaching past anterior margin of ring 4 (males) or 3 (females) when

extended posteriorly, slightly clavate (Fig. 5A, B). Antennomere 7 with a minute dorsoparabasal cone.

Exoskeleton. Collum transversely semi-lunar, with three transverse rows of 4(5)+4(5), 4+4, 3+3 tergal setae, and a faint lateral incision on each side. Paraterga evident (Fig. 5), midbody metaterga ca. 1.6 times as wide as prozonae. All paraterga clearly upturned dorsally above a faintly convex dorsum (Fig. 5A, C). Caudolateral corners of paraterga clearly projecting posteriorly past tergal margin (Fig. 5A, C). Integument shining, translucent, prozonae very delicately alveolate. Limbus regularly denticulate. Constriction between pro- and metazonae narrow and shallow. Metatergal sculpture faint, with three irregular transverse rows of setigerous, polygonal bosses. Tergal setae very short. Sulcus between front and middle rows of setae a little deeper than that between middle and caudal rows. Three or four faint setigerous incisions at lateral margins of poreless and pore-bearing rings, respectively (Fig. 5A, C). Pore formula normal: 5, 7, 9, 10, 12, 13, 15–19, ozopores evident, dorsal, clearly set off from lateral margin and located between last and penultimate marginal incisions. Epiproct tip slightly concave, pre-apical lateral papillae small (Fig. 5C, E). Hypoproct subtrapeziform, with two setigerous papillae at caudal margin. Pleurosternal carinae small, present only on ring 2. Sterna sparsely setose, cross-shaped impressions deep (Fig. 5B, E). Legs long and slender, about 2.0–2.2 (males) or 1.6–1.8 (females) times as long as body ring height, with neither sphaerotrichomes nor sternal cones, prefemora not bulging laterally.

Gonopods coiled (Figs. 5D, 6). Prefemur densely setose and about 1/5 as long as telopodite. Femorite short, nearly 1/4 as long as telopodite. Endomere (**en**) rather slender and strongly twisted, hook-shaped, with a small tooth (**t**) at midway. Seminal groove running mesally, recurved laterad at base of **en**; accessory seminal chamber opening up on a strongly developed hairy pulvillus located near a slender, long and curved exomere (**ex**).

Note. Based on the long and slender antennae and legs, and an unpigmented cuticle, the species is most likely a troglolite.

New records of *Pacidesmus* from China

Pacidesmus bifidus Golovatch & Geoffroy, 2014

Pacidesmus bifidus Golovatch & Geoffroy, 2014: 99, figs. 12–16, map 2.

Material examined. 1 male, 1 female (SCAU), China, Guangxi Zhuang Autonomous Region, Fengshan County, Fengcheng Town, Nongfeng Village, I Dong Cave, coll. Jujian Chen et al., 3 August 2015.

Remarks. Originally described from the male holotype from a single cave in Fengshan County, Guangxi. The new material examined comes from another cave in the same county and fully agrees with the original description (Golovatch & Geoffroy, 2014).

Pacidesmus martensi Golovatch & Geoffroy, 2006

Pacidesmus martensi Golovatch & Geoffroy, 2006: 364, figs. 1–12.

Material examined. 3 males, 3 females (SCAU), China, Guizhou Province, Qianxi County, Honglin Town, Jisha Village, I Dong Cave, coll. Mingyi Tian et al., 12 July 2013.

Remarks. *Pacidesmus martensi* has been described from a cave in Qianxi County and a cave in Dafang County, Guizhou Province. The material reported here was collected from another cave in Qianxi County. The new specimens fully agree with the original description (Golovatch & Geoffroy, 2006).

Pacidesmus sinensis (Golovatch & Hoffman, 1989)

Polydesmus hamatus Loksa, 1960: 137, figs. 12–16. A junior homonym of both *Polydesmus hamatus* Brandt, 1841 and *Polydesmus hamatus* Verhoeff, 1897 (Golovatch & Hoffman, 1989).

?*Epanerchodus sinensis* Golovatch & Hoffman, 1989: 159. Renamed to avoid homonymy, albeit the generic assignment remained questioned (Golovatch & Hoffman, 1989).

Polydesmus guizhouensis Chen & Meng, 1990: 277, figs. 1–7. Synonymised by Golovatch (1991).

Material examined. 9 males, 12 females (SCAU), China, Guizhou Province, Ziyun County, Getuhe National Geopark, Suidao Dong Cave, coll. Mingyi Tian et al., 29 December 2012.

Remarks. *Pacidesmus sinensis* has been recorded from two caves in Guizhou Province. The material quoted here was collected from a cave in Ziyun County, same province. The new specimens fully agree with the previous descriptions (Loksa, 1960; Chen & Meng, 1990).

CONCLUSION

In China, species of only a few genera of Polydesmidae such as *Epanerchodus* Attems, 1901, *Glenniea* Turk, 1945, and *Pacidesmus* have been known to occur in caves (Golovatch, 2015). In the two former genera, both troglolitic and epigean species are recorded. Conversely, *Pacidesmus* species are clearly confined to caves, as there are no epigean species of *Pacidesmus* yet recorded from China. This might be rooted in insufficient sampling, which appears to be biased towards troglolites (Liu & Golovatch, 2018), but it may also be the reality. We believe that more morphology-based taxonomy of *Pacidesmus* will be performed in the near future, hopefully coupled with molecular studies.

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