

Taxonomic review of some Chinese species of *Moellendorffia*, with the description of a new species from Guangdong (Gastropoda, Stylommatophora, Camaenidae)

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Abstract. The rich karst topography of southern China supports a high diversity of camaenid land snails, including *Moellendorffia* Ancey, 1887, but the taxonomy and phylogenetic relationships of several Chinese species remain insufficiently studied. Here, we present a taxonomic review of some Chinese *Moellendorffia* based on shell morphology, genital anatomy, and mitochondrial COI and 16S sequences. A new species, *Moellendorffia shenlong* sp. nov., is described from Guangdong Province. In addition, anatomical information is provided for selected species, and the phylogenetic placement of *Moellendorffia* is discussed.

Key words. Karst landform, new taxon, land snail, South China, taxonomy

Introduction

The camaenid genus *Moellendorffia* Ancey, 1887 is endemic to southern continental Asia and Hainan Island, mainly from China and Vietnam (Sutcharit *et al.*, 2020; Lin & Qiu, 2024). Conchologically, this genus is remarkable for its depressed-globular to globular shell, distinctive periostracal hairs, regular granulose shell surface in most species, and, especially, the detached aperture, which is usually heart-shaped and with three or four apertural teeth (Panha *et al.*, 2010; Sutcharit *et al.*, 2020; Lin & Lin, 2022). Before the present study, 13 species and three subspecies of *Moellendorffia* were known, of which ten species had been reported from China (Yen, 1939; Lin & Qiu, 2024; Lin & Lin, 2026). These Chinese species were recorded from Guangxi, Hong Kong, Hainan, Guangdong, Hunan, and Sichuan. Until now, taxonomic studies of *Moellendorffia* have relied mainly on morphology, and molecular phylogenetic data for the genus have been lacking.

Southern China, particularly the Guangxi Zhuang Autonomous Region, represents a global hotspot for karst topography, characterized by extensive limestone formations that harbour exceptional diversity of land snails. As the type locality for several *Moellendorffia* species, Guangxi provides critical insights into the evolution and distribution of this genus. In contrast, Guangdong Province, located in the southernmost part of mainland China and stretching from east to west, has comparatively fewer karst landforms, which are mainly concentrated in the eastern part of the province. In western Guangdong, karst landforms are only sporadically distributed in Yunfu and Yangjiang cities. Despite this relatively restricted habitat, the province still harbours diverse rock-

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<http://zoobank.org/urn:lsid:zoobank.org:pub:A26B8B1A-ED18-42B2-A095-246F7557730B>

dwelling gastropod groups, including *Moellendorffia*.

In this study, we present the first molecular phylogenetic analysis of the genus *Moellendorffia* based on partial mitochondrial COI and 16S sequences. We describe *Moellendorffia shenlong* **sp. nov.**, a morphologically distinctive species from karst habitats in Guangdong Province, and provide anatomical descriptions for several Chinese species.

Materials and Methods

Specimens were collected from Guangxi and Guangdong, China, from 2022 to 2024. Living specimens were initially frozen at -20 °C for 12 hours and subsequently thawed at room temperature for 12 hours to facilitate the extraction of soft parts. The soft parts were then fixed in 70% ethanol. Empty shells were cleaned, dried, and preserved at 4 °C. Photographs were taken with a camera (A6500, Sony, Minato City, Japan). Shell whorls were counted following Kerney & Cameron (1979). The distribution map (Fig. 1C) was produced and downloaded from <https://www.simplemappr.net> (Shorthouse, 2010).

Genomic DNA was extracted from foot tissues preserved in 70% ethanol using a TIANamp Marine Animals DNA Kit (Tiangen Biotech, China). The quality and concentration of the DNA were checked by 1% agarose gel electrophoresis and with a NanoDrop 2000 spectrophotometer (Thermo Scientific, USA). Partial fragments of the mitochondrial COI and 16S rRNA genes were amplified and sequenced for molecular phylogenetic analyses. Polymerase chain reaction (PCR) mixtures, conditions, and primer pairs are listed in Table 1. Sequences were aligned using MEGA v. 6.0 (Tamura *et al.*, 2013) and checked by eye. GenBank accession numbers for newly generated sequences and sequences obtained from previous studies are provided in Table 2.

Phylogenetic analyses were conducted using a concatenated dataset of the two mitochondrial genes and inferred using maximum likelihood (ML) and Bayesian inference (BI). Representatives of Camaenidae (25 taxa) and Helicidae (2 taxa) were used as outgroups for rooting the tree (Table 2; 27 outgroup taxa in total). ML analyses were performed in IQ-TREE v. 1.6.12 (Nguyen *et al.*, 2015) using the ultrafast bootstrap approach (Minh *et al.*, 2013) with 10,000 replicates. The most appropriate models of sequence evolution (GTR+I+G for COI and GTR+G for 16S) were selected using PartitionFinder2 v. 1.1 (Lanfear *et al.*, 2017). Bayesian inference was conducted in MrBayes v. 3.2.6 (Ronquist *et al.*, 2012). Four simultaneous runs with four independent Markov chain Monte Carlo (MCMC) chains were implemented for 10 million generations, and trees were sampled every 1,000 generations with a burn-in of 25%. Convergence was checked using the average standard deviation of split frequencies (< 0.01) and the potential scale reduction factor (PSRF; ~1). Trees were visualised in FigTree v. 1.4.3 (<http://tree.bio.ed.ac.uk/software/figtree/>).

Abbreviations. At – atrium; BC – bursa copulatrix; BCD – bursa copulatrix duct; Ep –

TABLE 1. Primer pairs and PCR conditions used in the analyses of the COI and 16S rRNA genes.

Gene	Primers	PCR conditions
COI	5'-GGTCAACAAATCATAAAGAT ATTGG-3' / 5'-TTAACTTCAGGGT GACCAAAAATCA-3'	95 °C for 2 min; 35 cycles of denaturing at 95 °C for 30 s, annealing at 50 °C for 30 s and extension at 72 °C for 30 s; final extension at 72 °C for 10 min.
16S	5'-CGGCCGCCTGTTTATCAAAA ACAT-3' / 5'-GGAGCTCCGGTTT GAACTCAGATC-3'	95 °C for 2 min; 35 cycles of denaturing at 95 °C for 30 s, annealing at 50 °C for 30 s and extension at 72 °C for 30 s; final extension at 72 °C for 10 min.

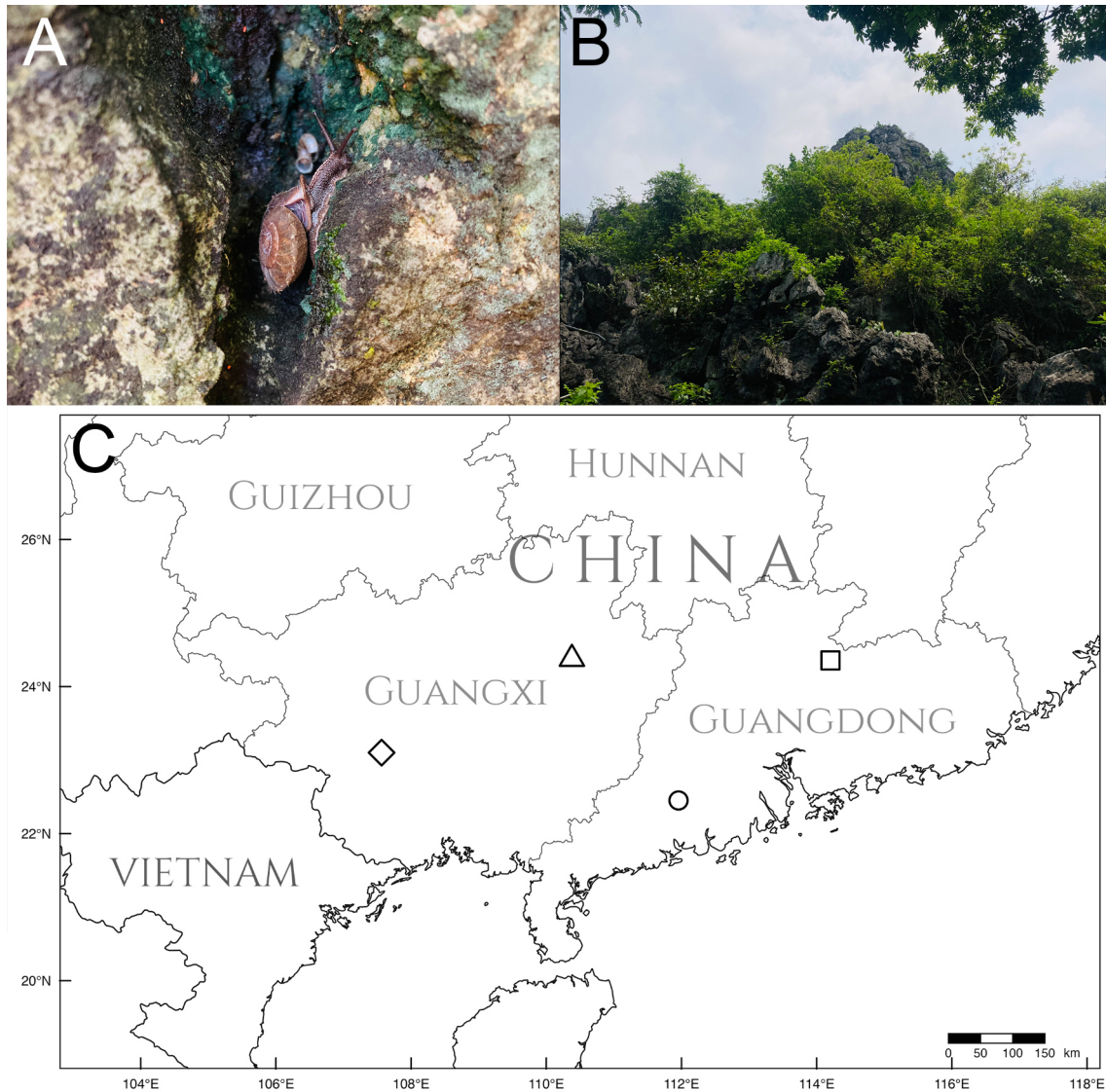


FIGURE 1. A. Living specimens of *Moellendorffia shenlong* sp. nov. B. Habitat of *Moellendorffia shenlong* sp. nov. C. Distribution of *Moellendorffia* species sampled in this study: triangle, *Moellendorffia eastlakeana* (Möllendorff, 1882); diamond, *Moellendorffia kuguaheshang* Lin & Lin, 2022; square, *Moellendorffia trisinuata sculpticoncha* Zilch, 1951; circle, *Moellendorffia shenlong* sp. nov.

epiphallus; Fl – flagellum; IZCAS – National Zoological Museum of China, Institute of Zoology, Chinese Academy of Sciences (Beijing, China); LRXC – Ran-Xi Lin's private collection; P – penis; PR – penial retractor muscle; SD – spermoviduct; V – vagina; VD – vas deferens.

Results

A concatenated dataset of COI and 16S sequences was employed for phylogenetic analyses. The dataset included 43 terminal taxa representing 33 nominal taxa: 16 *Moellendorffia* samples representing six *Moellendorffia* taxa, and 27 outgroup terminals from other Camaenidae and Helicidae (Table 2). The aligned lengths of the COI and 16S genes were 662 and 495 nucleotides, respectively. Within these sequences, 325 and 277 sites were variable, while 301 and 233 sites were

TABLE 2. GenBank accession numbers of the sequences used in this study.

Species	COI	16S
<i>Moellendorffia shenlong</i> sp. nov.	PZ211745	PZ211729
<i>Moellendorffia shenlong</i> sp. nov.	PZ211746	PZ211730
<i>Moellendorffia shenlong</i> sp. nov.	PZ211747	PZ211731
<i>Moellendorffia shenlong</i> sp. nov.	PZ211748	PZ211732
<i>Moellendorffia kuguaheshang</i>	PZ211749	PZ211733
<i>Moellendorffia kuguaheshang</i>	PZ211750	PZ211734
<i>Moellendorffia kuguaheshang</i>	PZ211751	PZ211735
<i>Moellendorffia trisinuata sculpticoncha</i>	PZ211752	PZ211736
<i>Moellendorffia trisinuata sculpticoncha</i>	PZ211753	PZ211737
<i>Moellendorffia trisinuata sculpticoncha</i>	PZ211754	PZ211738
<i>Moellendorffia eastlakeana</i>	OR282484	OR282484
<i>Moellendorffia</i> cf. <i>eastlakeana</i>	PZ211755	PZ211739
<i>Moellendorffia</i> cf. <i>eastlakeana</i>	PZ211756	PZ211740
<i>Moellendorffia loxotata</i>	PZ211757	PZ211741
<i>Moellendorffia loxotata</i>	PZ211758	PZ211742
<i>Moellendorffia loxotata</i>	PZ211759	PZ211743
<i>Trichelix hiraseana</i>	EF204842	EF204805
<i>Camaena cicatricosa</i>	KU061276	KU586471
<i>Camaenella platyodon</i>	OR187754	OR187754
<i>Aegista aubryana</i>	KT192071	KT192071
<i>Plectotropis trichotropis</i>	OR189512	OR189512
<i>Dolicheulota formosensis</i>	KR338956	KR338956
<i>Euhadra dixon</i>	AB916773	AF098711
<i>Acusta despecta</i>	LC656699	AY137578
<i>Bradybaena brevispira</i>	KF765755	PP668732
<i>Laeocathaica amdoana</i>	OP866270	OP866270
<i>Pseudobuliminus piligerus</i>	PP145292	PP145292
<i>Cathaica fasciola</i>	OQ955757	OQ955757
<i>Amphidromus buelowi</i>	OR978042	OR964321
<i>Amphidromus thachi</i>	OR978050	OR964328
<i>Amphidromus atricallosus</i>	MF983563	AB112368
<i>Aegistohadra delavayana</i>	OQ992197	OQ992197
<i>Nesiohelix moreletiana</i>	MW810788	PP668764
<i>Pseudostegodera qiului</i>	MW810790	MW810083
<i>Stegodera angusticollis</i>	OR353232	OR353232
<i>Traumatophora triscalpta</i>	OQ998972	OQ998972
<i>Yakuchloritis hungerfordianus</i>	EF204843	EF204806
<i>Amplirhagada burneriensis</i>	KC703098	HQ245372
<i>Exiligada gregoriana</i>	JX393756	JX393669
<i>Basedowena elfina</i>	PQ539708	KU519136
<i>Falspleuroxia overlanderensis</i>	PQ539709	HQ245460
<i>Cornu aspersum</i>	KU586502	MW443865
<i>Helix pomatia</i>	PQ304640	PQ304640

parsimony-informative. Phylogenetic analyses yielded ML and BI trees with largely congruent topologies, although minor discrepancies were observed in the placement of a few terminal taxa or in the support values of specific nodes (Fig. 2). The results supported the monophyly of *Moellendorffia*, with *M. shenlong* **sp. nov.** forming a distinct lineage within the genus. *Moellendorffia trisinuata sculpticoncha* and *M. loxotata* (Mabille, 1887) were each recovered as well-supported clades, whereas the samples of *M. kuguaheshang* clustered together with comparatively weak support. The new species was recovered as sister to *M. cf. eastlakeana* plus *M. eastlakeana*, with strong support in both BI and ML analyses. These findings indicate that *M. shenlong* **sp. nov.** represents a phylogenetically distinct and taxonomically well-supported new species within *Moellendorffia*, while also clarifying the relationships among certain other species in the genus.

Systematics

Family **Camaenidae** Pilsbry, 1895

Subfamily **Camaeninae** Pilsbry, 1895

Genus ***Moellendorffia* Ancey, 1887**

Type species. *Moellendorffia trisinuata* (E. von Martens, 1867), by subsequent designation of Pilsbry (1893–1895).

Diagnosis. Shell medium-sized, flattened to depressed-globular. Periostracum thick and covered with short to long hairs, but long hairs usually worn away upon maturity. Aperture trigonal or squarish, entirely free from preceding whorl, with barriers inside and externally marked with furrows. Parietal wall elevated to form one prominent nodule; one or two parallel palatal folds; one columellar fold.

***Moellendorffia eastlakeana* (Möllerndorff, 1882)**

伊氏多粒螺

(Figures 3A, 4C)

Helix eastlakeana Möllerndorff, 1882: 185.

Moellendorffia (*Moellendorffia*) *eastlakeana*: Zilch, 1966: 210, pl. 6, fig. 52.

Moellendorffia eastlakeana: Richardson, 1985: 184; Panha *et al.*, 2010: 21–24, figs 1–10; Schileyko, 2011: 44.

Type locality. “ad litus provinciae sinensis Guang-dung insulae Hongkong oppositmn” [on the coast of the Chinese province of Guangdong, opposite the island of Hong Kong]. Yen (1939), based on the lectotype, specified the locality as “Tai-mo-shan” [Tai Mo Shan (大帽山), Hong Kong SAR, China], which at the time of the original record formed part of Xin’an County (新安县), Guangdong.

Material examined. IZCAS TM 206994 (one mature shell), Xiajinji [下金鸡], Lipu City [荔浦市], Guilin City [桂林市], Guangxi Zhuang Autonomous Region, China, 110°22′44.4″E, 24°22′37.6″N, leg. Zhong-Guang Chen, April 10, 2024.

Description of Genitalia. Atrium short. Penis long, proximally inflated, smooth on the outside. Penial pilasters not visible through the penial wall. Epiphallus tubular, partly transparent, and distinctly longer than penis. Penial retractor muscle threadlike and very thin. Flagellum short,

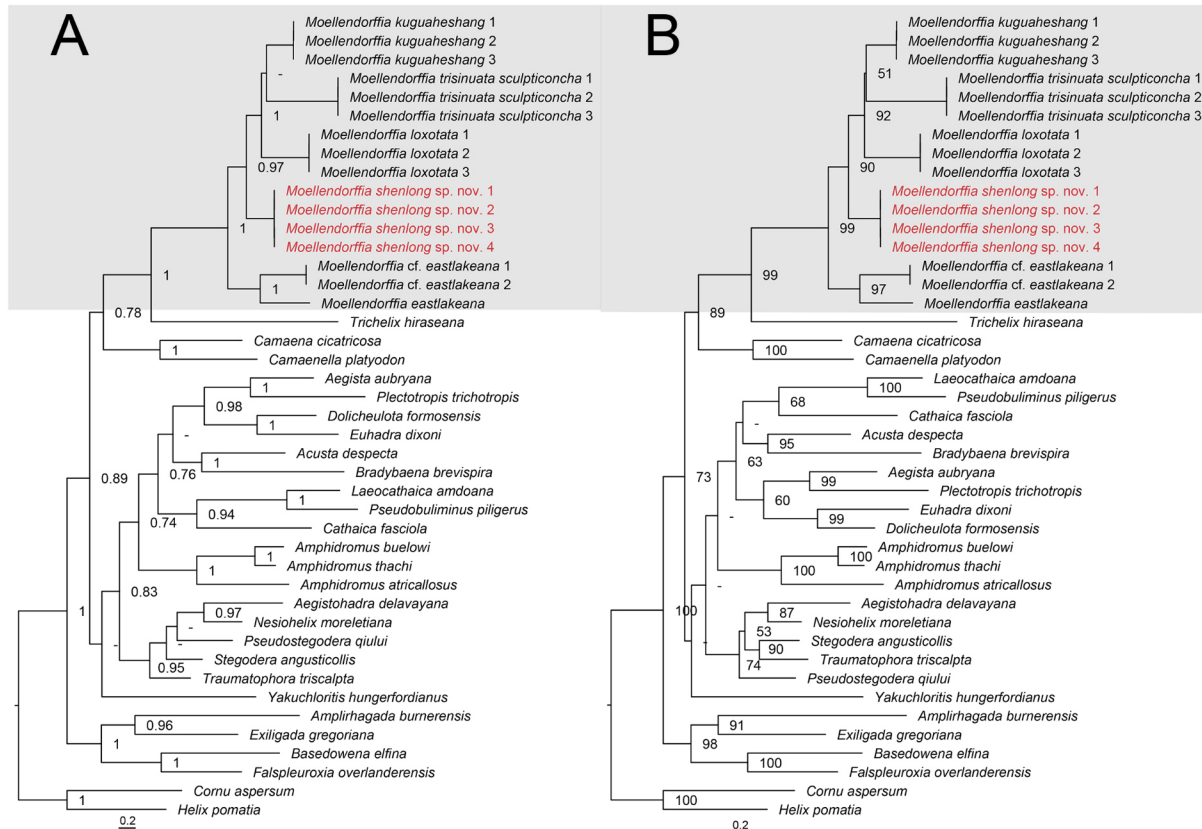


FIGURE 2. Bayesian inference (BI) tree (A) and maximum likelihood (ML) tree (B) inferred from COI and 16S gene sequences. In the BI tree, posterior probabilities (as decimal values) are labelled at nodes; in the ML tree, bootstrap support values (as integers) are labelled at nodes. The two trees exhibit largely congruent topologies with minor differences in branch placement and/or support values for a few taxa.

spiculate, and without appendix. Vas deferens extremely long, of uniform thickness, connected distally to epiphallus. Vagina moderately long, slightly swollen, and unpigmented. Spermoviduct long, narrower than vagina. Bursa copulatrix very long, with regularly striated organization; bursa copulatrix duct ovoid and approximately equal in size to the bursa copulatrix.

Distribution. CHINA: Guangdong, Guangxi, Hong Kong.

Moellendorffia kuguaheshang Lin & Lin, 2022

苦僧多粒螺
(Figure 4A)

Moellendorffia kuguaheshang Lin & Lin, 2022: 336, 337, figs 1–2.

Type locality. Dingdang Town [丁当镇], Longan County [隆安县], Nanning City [南宁市], Guangxi Zhuang Autonomous Region, China.

Material examined. IZCAS TM 206995 (one mature shell), Duofang [多放], Longan County [隆安县], Nanning City [南宁市], Guangxi Zhuang Autonomous Region, China, 107°33'48.8"E, 23°6'5.1"N, leg. Zhong-Guang Chen & Ran-Xi Lin, April 15, 2024. LRXC/1 (four mature shells),



FIGURE 3. Shells of *Moellendorffia* species. **A.** *Moellendorffia eastlakeana* (Möllendorff, 1882) from Guilin, Guangxi. **B.** *Moellendorffia trisinuata sculpticoncha* Zilch, 1951 from Shaoguan, Guangdong. **C.** *Moellendorffia shenlong* **sp. nov.**, holotype. Scale bars = 10 mm.

Bayang Mount [岵羊山], Dingdang Town [丁当镇], Longan County [隆安县], Nanning City [南宁市], Guangxi Zhuang Autonomous Region, China, 107°57'16.4"E, 23°6'59.7"N, leg. Xiao-Jun Xie, May 03, 2024.

Description of Genitalia. Atrium short. Penis relatively short, extremely inflated, smooth on the outside. Penial pilasters not visible through the penial wall. Epiphallus wrinkled, smaller than penis. Penial retractor muscle situated at the beginning of epiphallus, tubular, threadlike, and moderately long. Flagellum short and small, with its distal end integrated with the vas deferens. Vas deferens long, connected distally to epiphallus, gradually attenuated. Vagina extremely long, not swollen, non-transparent, and unpigmented. Spermoviduct moderately thick, distinctly narrower than vagina. Bursa copulatrix long and straight; bursa copulatrix duct ovoid and slightly inflated.

Distribution. CHINA: Guangxi.

***Moellendorffia trisinuata sculpticoncha* Zilch, 1951**

三凹多粒螺雕刻亚种

(Figures 3B, 4B)

Helix (Polygyra) trisinuata var. *sculptilis* Möllendorff, 1884: 310. (non *Helix sculptilis* Bland, 1858)
Moellendorffia trisinuata sculpticoncha Zilch, 1951: 86 (Replacement name for *Helix (Polygyra)*
trisinuata var. *sculptilis* Möllendorff, 1884); Zilch, 1966: 211, pl. 6, fig. 53; Richardson, 1985:
 186.

Type locality. “in monte Lo-fou-shan provinciae sinensis Guang-dung” [on Mount Lo-fou-shan [罗浮山] in the Chinese province of Guangdong] (Möllendorff, 1884).

Material examined. IZCAS TM 206996 (one mature shell), Longxian Town [龙仙镇], Wengyuan County [翁源县], Shaoguan City [韶关市], Guangdong Province, China, 114°12'16.5"E, 24°21'18.1"N, leg. Jian-Wei Chen, April 28, 2024.

Description of Genitalia. Atrium short and hidden. Penis moderately long, inflated, smooth on the outside. Penial pilasters visible through the penial wall. Epiphallus tube-shaped, glossy. Penial retractor muscle attached to epiphallus, threadlike and strong. Flagellum long, tapering, and without appendix. Vas deferens moderately long, of uniform thickness. Vagina thin, not swollen, transparent, unpigmented, and uniform in size. Spermoviduct moderately thick. Bursa copulatrix inconspicuous and smooth, without apical ligament. Bursa copulatrix duct thin, cystoid.

Distribution. CHINA: Guangdong.

***Moellendorffia shenlong* sp. nov.**

神龙多粒螺

(Figure 3C, 4D)

Type materials. *Holotype*. IZCAS TM 206997, Chunwan Stone Forest [春湾石林], Chunwan Town [春湾镇], Yangjiang City [阳江市], Guangdong Province, China, 111°57'23.5"E, 22°27'3.8"N, leg. Ji-Lin Jiang & Ran-Xi Lin, April 26, 2024. *Paratypes*. IZCAS TM 206998–207003, other information same as holotype.

Additional material. LRXC/1, Sun Yat-Sen Park [中山公园], Chunwan Town [春湾镇], Yangjiang City [阳江市], Guangdong Province, China, 111°56'31.3"E, 22°26'16.3"N, leg. Ji-Lin Jiang & Ran-Xi Lin, April 25, 2024; LRXC/1, Tongtianlazhu [通天蜡烛], Chunwan Town [春湾镇], Yangjiang City [阳江市], Guangdong Province, China, 111°56'27.0"E, 22°26'12.2"N, leg. Ji-Lin Jiang & Ran-Xi Lin, April 25, 2024.

Diagnosis. Shell medium-sized, depressed-conical, and relatively large for the genus. Peripheral keel with long bristles. Two palatal folds present, with corresponding deep furrows on the shell surface. Upper palatal fold very weak; basal palatal fold extending from the umbilical suture at about 1/8 of the body whorl anterior to the aperture to just behind the aperture, its external furrow deeper than that of the upper palatal fold. Aperture subtriangular, strongly downward sloping. Umbilicus broadly open and deep, its diameter approximately 1/3 of shell major diameter. Genitalia with the epiphallus relatively long, distinctly longer than penis, and the bursa copulatrix duct proximally inflated.

Description. *Shell* dextral, medium-sized, depressed-conical, rather lenticular, reddish brown, rather thick, with 4.25–4.5 whorls separated by a shallow suture. Protoconch with 1.5 smooth to

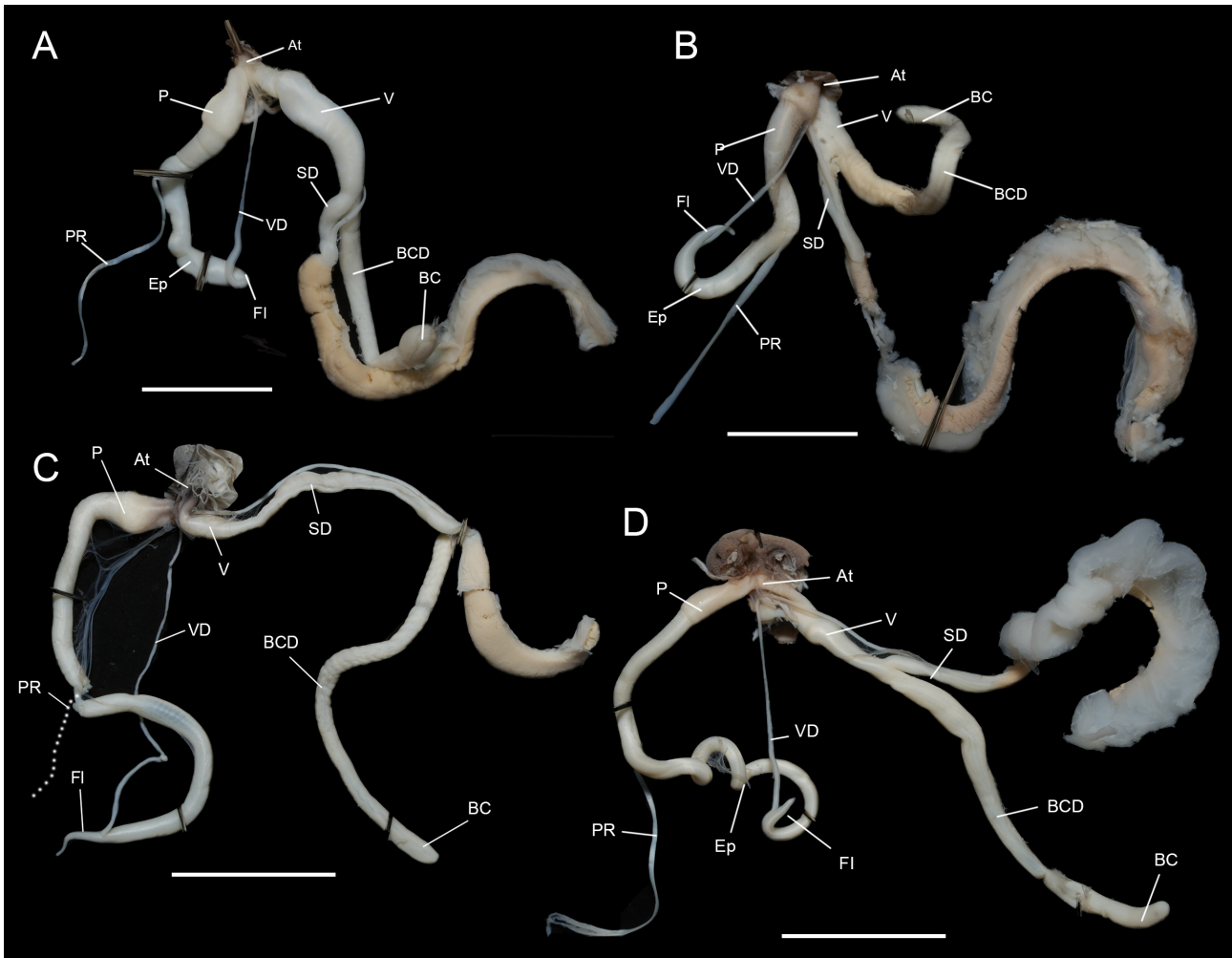


FIGURE 4. Genitalia of *Moellendorffia* species. **A.** *Moellendorffia kuguaheshang* Lin & Lin, 2022. **B.** *Moellendorffia trisinuata sculpticoncha* Zilch, 1951. **C.** *Moellendorffia eastlakeana* (Möllendorff, 1882). **D.** *Moellendorffia shenlong* **sp. nov.** Scale bars = 5 mm for A–B and 10 mm for C–D.

somewhat glossy whorls, bearing numerous regularly arranged rectangular granules. Body whorl with a strong keel above the periphery. Tubercles on the keel and its surrounding area covered with long hairs, approximately 1.1 mm in length. Second and third whorls with numerous regularly arranged rectangular granules. Aperture strongly expanded, subtriangular, free from the preceding whorl. Two palatal folds present, their highest parts oppositely positioned, with corresponding deep furrows distinctly present on the shell surface. Upper palatal fold weak. Basal palatal fold long, extending from about 1/8 of the body whorl anterior to the aperture to just behind the aperture. Columellar fold tiny but smooth. One small, prominent apertural nodule present. Peristome expanded and very slightly reflexed, with a yellowish-white margin. Umbilicus open, large, and deep, approximately 1/3 of shell major diameter, with the protoconch visible through it.

Genitalia. Atrium short. Penis medium in length, inflated, smooth on the outside. Penial pilasters weakly visible through the penial wall. Epiphallus glossy, partly coiled, and distinctly longer than penis. Penial retractor muscle attached to epiphallus near the boundary between penis and epiphallus, threadlike and thin. Flagellum tube-shaped and terminally sharp, without appendix. Vas deferens long and flat, connected to epiphallus. Vagina relatively long, swollen, straight, and unpigmented.

Spermoviduct moderately thick, distinctly longer than vagina. Bursa copulatrix long and straight, without apical ligament. Bursa copulatrix duct proximally inflated.

Measurements. Shell height 8.0–9.2 mm, shell width 20.1–22.2 mm ($n = 7$).

Etymology. The specific name *shenlong* is derived from the Chinese proverb "You see the head of the mystical Loong but not its tail", which refers to something elusive or mysterious. The name alludes to the elusive occurrence of the new species, which has so far been found only in karst habitats of Guangdong Province.

Remarks. The new species is easily distinguished from other *Moellendorffia* spp. by its depressed-conical shell, relatively sparser hairs, and enlarged aperture (Sutcharit *et al.*, 2020). The new species is remarkably similar in shell shape to *Moellendorffia kuguaheshang* Lin & Lin, 2022, but differs by having two palatal folds and a significantly larger shell. Additionally, the known distribution ranges of the two species are widely separated. In the genitalia, *M. shenlong* **sp. nov.** has a relatively longer epiphallus and a proximally inflated bursa copulatrix duct. Compared with *Moellendorffia hensaniensis* (Gredler, 1885), the new species has two palatal folds and a coarser shell. The new species is easily distinguished from *Moellendorffia daner* Lin & Lin, 2026 by the more subdued tuberculation on the keel. Specifically, the relative lengths of the bursa copulatrix and its duct are markedly shorter in *M. daner*, while the flagellum is blunter than the tapering, sharp-ended flagellum observed in the new species.

Distribution. CHINA: Guangdong.

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中国多粒螺属部分物种分类修订及广东省一新种记述 (腹足纲：柄眼目：坚齿螺科)

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摘 要

本文针对多粒螺属 *Moellendorffia* 的分类开展修订研究, 是该属首次分子系统学分析。研究基于 2022–2024 年采集于华南地区的标本, 结合线粒体 COI、16S 基因序列构建最大似然树与贝叶斯系统发育树, 结果支持多粒螺属为单系群。本文从广东阳江发现并描述新物种神龙多粒螺 (*Moellendorffia shenlong* sp. nov.), 该新种与近缘种 *M. cf. eastlakeana* 互为姐妹群, 遗传距离显著, 具分类独立性, 其壳体形态易与其他同属物种区分。研究同时补充了伊氏多粒螺 *M. eastlakeana*、苦僧多粒螺 *M. kuguaheshang*、三凹多粒螺雕刻亚种 *M. trisinuata sculpticoncha* 的解剖学特征, 明确了部分类群的系统发育关系, 进一步丰富了对华南岩溶地貌陆生蜗牛多样性的认识。

关键词: 陆生贝类, 华南地区, 分子系统发育, 分类学, 新物种, 岩溶地貌