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Three new rock-dwelling species of *Cathaica* Möllendorff, 1884 from the Taihang Mountains, northern China (Stylommatophora: Camaenidae)

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Abstract. Species of *Cathaica* are widespread in the temperate montane regions of China, exhibiting high diversity and a broad spectrum of shell morphologies that reflect adaptation to heterogeneous environments. Here we describe three new *Cathaica* species from the Taihang Mountains of Henan and Hebei, China: *Cathaica sculptilis* Wang, Chen, He & Zhang, **sp. nov.**, *C. zhangcunxiangi* Wang, Chen, He & Zhang, **sp. nov.**, and *C. wangjiaxunae* Wang, Chen, He & Zhang, **sp. nov.** Two of these, *C. sculptilis* **sp. nov.** and *C. wangjiaxunae* **sp. nov.**, share shell features with *C. multicostata* G. Zhang, 2023. Integrative morphological and molecular analyses support recognition of all three new species. The genital anatomical information of *C. mengi* is also provided for the first time.

Key words. Comparative morphology, molecular phylogeny, new species, northern China, rocky habitats

Introduction

Cathaica Möllendorff, 1884 is a specious genus in Camaenidae, with 53 species found in China (MolluscaBase, 2025). A subgenera system of *Cathaica* was proposed by Andreae (1900) and adapted by many authors (e.g., Gude, 1902; Thiele, 1931; Zilch, 1960; Richardson, 1983; Schileyko, 2004), namely *Cathaica* (s.str.), *Cathaica* (*Pliocathaica*) Andreae, 1900, *Cathaica* (*Xerocathaica*) Andreae, 1900, and *Cathaica* (*Campylocathaica*) Andreae, 1900. However, *Cathaica* is no longer considered monophyletic based on recent works, and the status of the subgenera also remains uncertain, as the type species of each requires a comprehensive study to confirm its placement (Wu *et al.*, 2023; Wu & Zhang, 2024). Two recurrent problems were produced by previous research relying solely on shell morphology: the unrelated species have been included in *Cathaica*, as with *Bradybaena brevispira* (H. Adams, 1870) (Wu & Zhang, 2024); and distinct species with similar shells have been treated as conspecific, as in *Cathaica pyrrhozona* (R. A. Philippi, 1845) and *C. fasciola* (Draparnaud, 1801), which were separated only recently through anatomical and

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phylogenetic evidence (Suzuki, 1939; Chen & Zhang, 2004; Wu, 2004; Zhang & Wade, 2023). These issues underscore the need for integrative evidence beyond shells.

Here we combine shell morphology, reproductive anatomy, and molecular phylogenetics to describe three new species of *Cathaica* from the Taihang Mountains of northern China, namely *C. sculptilis* **sp. nov.**, *C. zhangcunxiangi* **sp. nov.**, and *C. wangjiaxunae* **sp. nov.** All three exhibit a prominent keel, with *C. sculptilis* **sp. nov.** and *C. wangjiaxunae* **sp. nov.** also possess fine ribs. Among described congeners, only *C. multicostata* G. Zhang, 2023 and *C. mengi* Yen, 1935 present a distinct keel with strong ribs (Yen, 1939; Zhang *et al.*, 2020b; Zhang & Wade, 2023). To clarify relationships, we surveyed the type localities and adjacent areas of *C. multicostata* and *C. mengi* and provide additional conchological and anatomical information for *C. mengi*.

Materials and methods

Materials and morphological examination

All specimens were collected in the Taihang Mountains (Hebei, Henan, Shanxi) and Taishan Mountain (Shandong) in the years 2023 and 2024. Specimens were preserved in 95% ethanol and were deposited in the Mollusc collection of the Museum of Hebei University, Baoding, China (HBUMM), Yu-Xuan Huan private collection (HYX), Zhi-Yao Wang private collection (WZY) and Quan-Yu Zhang private collection (ZQY). Photographs were taken with a SOPTOP SZX12 stereomicroscope and a OD500F camera (Sunny Optical Technology, China).

DNA extraction, PCR amplification, and phylogenetic analyses

Total genomic DNA was isolated from a small piece of tissue taken from the foot of each ethanol-preserved specimen using a TreliefTM Animal Genomic DNA kit (Tsingke®). Partial sequences of *16S* rDNA were amplified using the universal primer set 16Sar and 16Sbr (Palumbi *et al.*, 1991). Partial sequences of *CO*I were amplified using LCO1490 and HCO2198 (Folmer *et al.*, 1994). A partial fragment of the ITS2 gene was amplified using the primer pair *LSU*-1 and *LSU*-3 (Wade & Mordan, 2000). Both ends of the sequences were obtained by automated sequencing on an Applied Biosystems 3730 platform at Sangon Biotech Co. Ltd. (Shanghai, China). Eighteen specimens representing eight species (based on *COI*, *16S* and ITS2 data) were used in this study (Table 1). Sequences were aligned using MAFFT v. 7.505 based on the L-INS-i method (Katoh & Toh, 2008). Pairwise distances between species were calculated using MEGA X (Kumar *et al.*, 2018). Aligned sequences were concatenated in PhyloSuite v.2.3 (Zhang *et al.*, 2020a). The best substitution model was selected using the corrected Bayesian Information Criterion (BIC) in ModelFinder v.2.2.0 (Kalyaanamoorthy *et al.*, 2017). For Bayesian analysis, two runs were performed simultaneously with four Markov chains starting from a random tree. Bayesian inference and maximum likelihood analysis were performed using MrBayes v.3.2.7 (Ronquist *et al.*, 2012) and IQ-TREE v.2.2 (Minh *et al.*, 2013), respectively, with reference to the selected model of sequence evolution. Bayesian posterior probabilities (BPPs) of nodes were determined using Metropolis-coupled Markov chains (one cold chain) for 2,000,000 generations, sampled every 1,000 generations. The first 25% of sampled trees were discarded as burn-in when the standard deviation of split frequencies from the two runs was less than 0.01; the remaining trees were then used to create a 50% majority-rule consensus tree and to estimate BPPs. Node support for the maximum likelihood analysis was determined using 1000 rapid bootstrap (BS) replicates.

TABLE 1. Vouchers, localities, and GenBank accession numbers for all samples used in phylogenetic analysis of this study.

Species	Voucher number	COI	16S	ITS2	Location
Cathaica mengi	HBUMM10083a	PV446475	PV446368	PV446359	Yuncheng City, Yongji City, Shanxi Province, China
Cathaica mengi	HBUMM10083b	PV446476	PV446369	PV446360	Yuncheng City, Yongji City, Shanxi Province, China
Cathaica mengi	HBUMM10083c		PV446370		Yuncheng City, Yongji City, Shanxi Province, China
Cathaica multicostata	WZY20240424A/1	PV446477	PV446371	PV446361	Zaozhuang City, Shandong Province, China
Cathaica multicostata	WZY20240424A/2	PV446478	PV446372	PX453178	Zaozhuang City, Shandong Province, China
Cathaica sculptilis **sp. nov.**	HBUMM10084	PV446479	PV446373	PV446363	Gongyi City, Zhengzhou City, Henan Province, China
Cathaica sculptilis **sp. nov.**	HBUMM10085a	PV446480	PV446374	PV446364	Gongyi City, Zhengzhou City, Henan Province, China
Cathaica zhangcunxiangi **sp. nov.**	HBUMM10086	PV446473	PV446366		Huixian City, Xinxiang City, Henan Province, China
Cathaica zhangcunxiangi **sp. nov.**	HBUMM10087a	PV446474	PV446367	PV446358	Huixian City, Xinxiang City, Henan Province, China
Cathaica wangjiaxunae **sp. nov.**	HBUMM10088	PV446471	see **Appendix 1**	PV446357	Wuan City, Handan City, Hebei Province, China
Cathaica wangjiaxunae **sp. nov.**	HBUMM10089a	PV446472	PV446365	PX453179	Wuan City, Handan City, Hebei Province, China
Cathaica sp1	WZY20240422A/1	N/A	N/A	N/A	Wuan City, Handan City, Hebei Province, China
Cathaica sp1	WZY20240422A/2	N/A	N/A	N/A	Wuan City, Handan City, Hebei Province, China
Cathaica sp1	WZY20240422A/3	N/A	N/A	N/A	Wuan City, Handan City, Hebei Province, China
Cathaica sp2	HYX20240714A/1	N/A	N/A	N/A	Zibo City, Shandong Province, China
Cathaica sp2	HYX20240714A/2	N/A	N/A	N/A	Zibo City, Shandong Province, China
Pseudiberus tectumsinense		PV391143	PV391021		Liantaishan Mout, Jinan City, Shandong Province, China
Ponsadenia duplocincta		MN369704	PP668898		N/A

TABLE 2. Genetic differentiation of *COI* by means of *p* distances.

ID	Species	1	2	3	4	5	6	7	8
1	*Cathaica* sp1								
2	*Cathaica wangjiaxunae* **sp. nov.**	0.46–0.92							
3	*Cathaica zhangcunxiangi* **sp. nov.**	5.86–6.93	5.39–6.33						
4	*Cathaica mengi*	8.17–8.78	8.01–8.47	8.47–9.55					
5	*Cathaica* sp2	6.63–7.55	6.63–6.78	5.7–5.86	7.55–7.86				
6	*Cathaica multicostata*	6.47–7.24	6.16–6.47	6.16–6.78	8.47–8.94	4.93–5.08			
7	*Cathaica sculptilis* **sp. nov.**	4.62–5.39	4.16–4.78	5.86–6.63	7.4–7.7	6.78–6.93	6.01–6.32		
8	*Pseudiberus tectumsinense*	17.41	16.95–17.1	17.87	17.26–17.41	18.34	18.34–18.49	16.95	
9	*Ponsadenia duplocincta*	18.06–18.23	18.06–18.23	18.58–18.75	17.19	17.88	18.92–19.1	17.36–17.71	14.24

Colour scheme for anatomical illustrations

To present the reproductive anatomy more clearly, we use a simple, consistent colour scheme in the line drawings that minimises confusion from overlapping structures. In genital overviews, the mucous glands are blue, the bursa copulatrix and its duct are red, and all remaining parts are yellow. In detailed dissected views, blue again denotes the mucous glands; red marks the opening of the proximal accessory sac, the entrances of the mucous glands, and the penial opening; yellow indicates the remaining structures.

Abbreviations

At, atrium; BC, bursa copulatrix; BCD, bursa copulatrix duct; DS, dart sac; Dt, love dart; DtC, love-dart chamber, the chamber secreting and containing the love dart; FO, free oviduct; MG, mucous glands; MGE, entrance(s) of mucous glands; P, penis; PAS, proximal accessory sac, a blind sac on

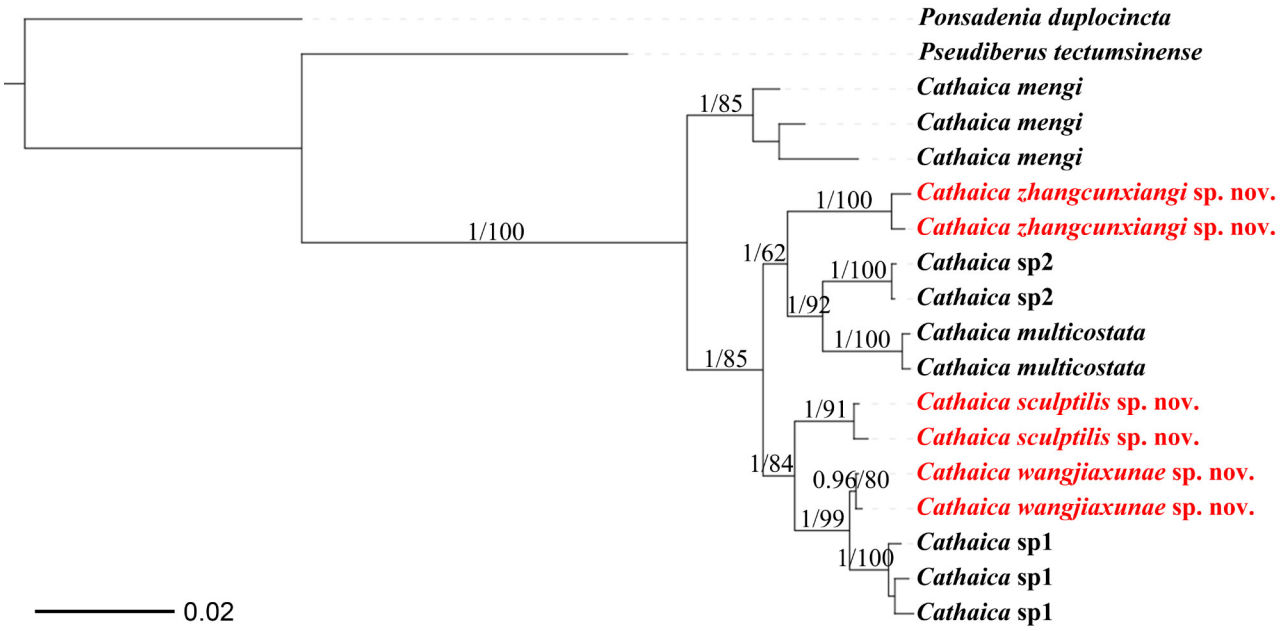

FIGURE 1. Bayesian inference (BI) tree for the Cathaica species. Values (BPP/BS) at nodes represent Bayesian posterior probabilities and Bootstrap values.

proximal dart sac and opening into dart sac chamber or elsewhere; PE, entrance of penis; PO, opening of proximal accessory sac; PR, penial-retractor muscle; PS, penis sheath; SD, dart-sac septum, a fleshy septum between the atrial opening and the opening of the DtC; VD, vas deferens. Directions used in descriptions of genitalia: proximal, towards the genital atrium; distal, away from the genital atrium; left and right side of dart sac (see Wu *et al.*, 2023: fig. 1A).

Results

The alignments of the *CO*I, *16S* and ITS2 sequences are 649, 359 and 891 base pairs, respectively. The HKY+I+F model was selected as the best-fit model of nucleotide substitution based on the BIC criterion. *Ponsadenia duplocincta* (Martens, 1879) was used as the outgroup to root the phylogenetic tree. Both Bayesian Inference (BI) and Maximum Likelihood (ML) methods produced identical topologies (Fig. 1). Three new species are supported: *Cathaica zhangcunxiangi* **sp. nov.** (BPP=1, BS=100), *C. sculptilis* **sp. nov.** (BPP=1, BS=91) and *C. wangjiaxunae* sp. nov. (BPP=0.96, BS=80). The species *Cathaica zhangcunxiangi* **sp. nov.**, *C.* sp2, *C. multicostata*, *C. sculptilis* **sp. nov.**, *C. wangjiaxunae* **sp. nov.** and *C.* sp1 are nested in a monophyletic group with good support (BPP=1, BS=85), and form a sister lineage to the *C.* mengi (BPP=1, BS=100). *Cathaica* sp2 is the sister lineage of *C. multicostata* (BPP=1, BS=92). *C. wangjiaxunae* **sp. nov.** and *C.* sp2 form a sister groups in the tree (BPP=1, BS=99), with *C. sculptilis* **sp. nov.** falling outside of this grouping (BPP=1, BS=84). The genetic distances among *Cathaica* species based on *CO*I sequences range from 4.16% to 9.55% (Table 2).

FIGURE 2. Shell of *Cathaica multicostata*. **A.** WZY20240424A/1. **B.** WZY20240424A/2. **C.** WZY20240424A/3.

Systematics

Family **Camaenidae** Pilsbry, 1895

Subfamily **Bradybaeninae** Pilsbry, 1934 (1898)

Genus ***Cathaica*** Möllendorff, 1884

Type species. *Helix pyrrhozona* Philippi, 1845, by original designation.

Cathaica multicostata G. Zhang, 2023

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(Fig. 2)

Cathaica multicostata G. Zhang in Zhang & Wade, 2023: 573, figs 1, 3E, 4D, 5, 6.

Type locality. "Baodu, Zaozhuang, Shandong; 34.984°N, 117.721°E, 520 m a.s.l."

Material examined. WZY20240424A (10 specimens). Mount Baodugu [抱犊崮], Zaozhuang City, Shandong Province, China, 34°59'N, 117°43'E, 500 m above sea level, leg. Zhi-Yao Wang, 24 April 2024. *Measurements* (n = 3): Shell width: 16.6–17.7 mm; shell height: 6–6.7 mm.

Cathaica mengi Yen, 1935

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(Figs 3, 4, 12A, 14D–F)

Cathaica mengi Yen 1935: 35, pl. 2, figs 12–12b; Zhang *et al.*, 2020b: 62, figs 5A–C.

Type locality. "In the mountain near Yu-hsiang Hsien, Shansi"

Material examined. HBUMM10083 (5 specimens), Yuxiang County [虞乡镇], Yongji City [永济市], Yuncheng City [运城市], Shanxi Province, China; 34°50'N, 110°38'E, 400–1000 m above sea level, leg. Shi-Yang Feng, Quan-Yu Zhang and Yue-Ming He, 24 April 2024; WZY20250621A (3 specimens), same location as above, leg. Zhi-Yao Wang, 21 June 2024; HYX20250905A (2 specimens), Shifosicun [石佛寺村], Yuxiang County, Yuncheng City, Yongji City, Shanxi Province, China, 34°49'N, 110°35'E, 500 m above sea level, leg. Yu-Xuan Huan, 5 September 2024.

Redescription. *Shell* (Fig. 3) slightly depressed to conoid, thin, dextral. Spire conoid, elevated. Whorls slightly convex. Suture superficial, slightly deeper on the last whorl. Umbilicus a slit to narrow; transition from shell to umbilicus gradual. . Columella oblique; columellar lip slightly expanded, slightly or almost completely covering umbilicus. Protoconch radially and densely granulate (Fig. 11A). Spiral furrows absent. Shell surface with low ribs, approximately 60–100 on body whorl, forming crenulations at periphery. Growth lines between ribs indistinct. Young shell carinate. Adult shell smooth; last whorl carinate at periphery, with base convex. Aperture roundedly quadrate, slightly expanded below, oblique, with a well-developed basal tooth. Peristome sometimes weakly sinuate, not continuous, thick. Parietal callus thin and indistinct. Shell glossy. Protoconch and conchial whorls show no obvious color difference, apically light brown to cream yellow. Ventral surface milk white, with a dark brown peripheral band under keel. *Measurements*: High altitude

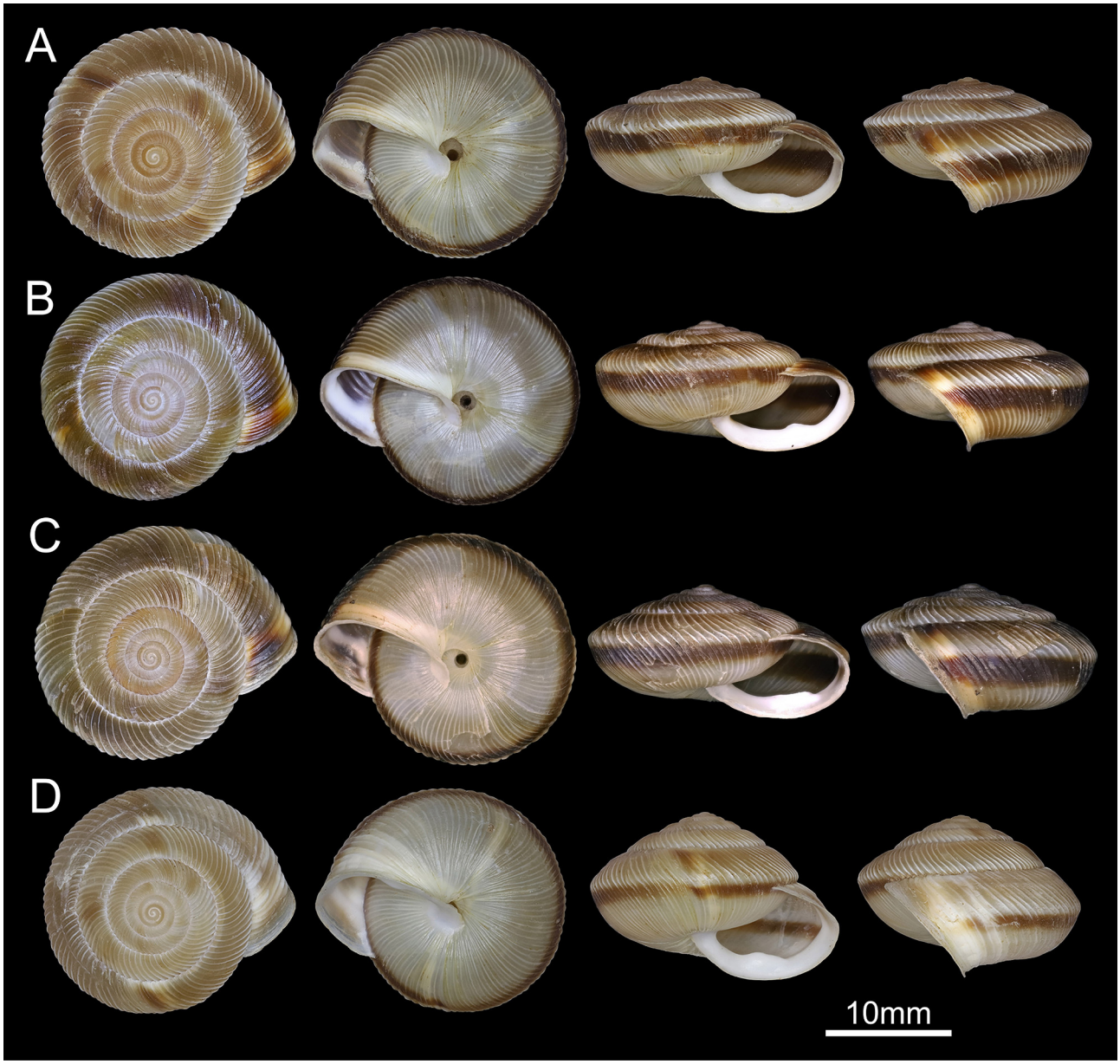

FIGURE 3. Shell of *Cathaica mengi*. **A.** HBUMM10083a. **B.** HBUMM10083b. **C.** HBUMM10083c. **D.** HBUMM10083d.

population (n = 3): Shell width: 17.6–18.4 mm; shell height: 9.4–9.4 mm. Low altitude population (n = 3): Shell width: 17.2–18.9 mm; shell height: 10.6–11.7 mm.

Genitalia (Fig. 4). Membranous sac surrounding terminal genitalia absent. Penial sheath approximately 1/3 penis length. Penis slender, simple outside. Flagellum absent. Vas deferens thickened near penial-retractor muscle, thickened portion accounts for about 2/5 of vas deferens. Mucous glands containing 10–15 tubules, similar in length to dart sac, inflated, straight and usually unbranched, if branched, then only simply so. Each tubule with a distinct peduncle, not attached to vagina by connective tissue, opening into dart-sac chamber. Proximal part of dart sac neither elongate nor forming a neck-like structure. Dart sac containing a single dart, curved and possessing chaeta, cross-section fusiform, surface covered with dense villi except at the distal end, approximately 8 mm in length. Proximal accessory sac absent. Vagina entering atrium. *Measurements* (average of three individuals): DS: 9.1 mm in length, 2.4 mm in width; MG: 6.0–9.0 mm; PS+P: 14.8 mm; VD: 19.3

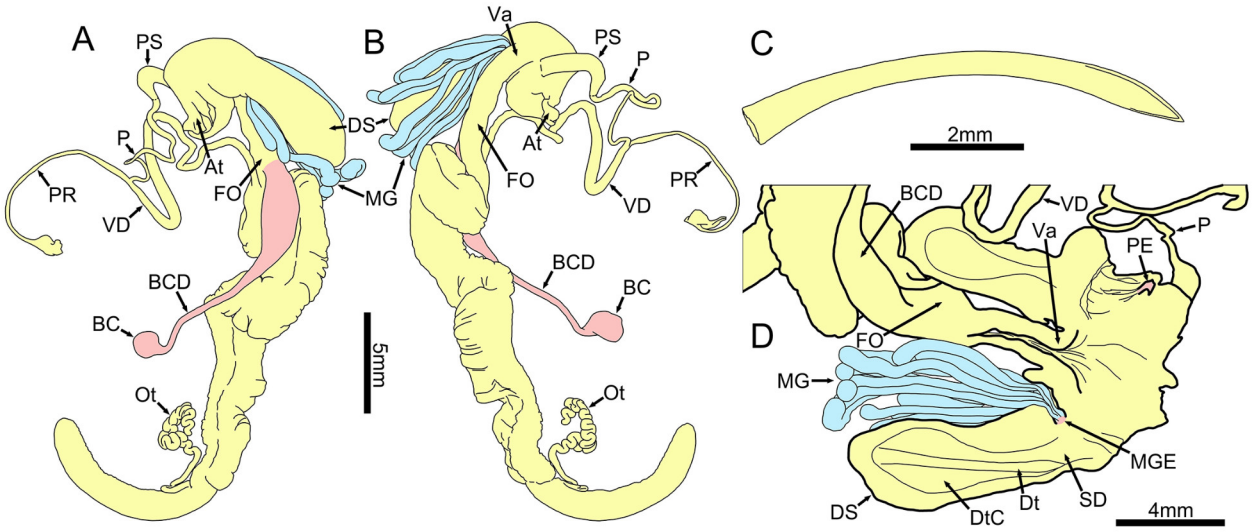

FIGURE 4. Genitalia of *Cathaica mengi*. **A–B.** both sides of the genitalia. **C.** love dart. **D.** exposed dart sac apparatus.

mm; PR: 10.6 mm; Va: 6.1 mm; FO: 1.1 mm; BC+BCD: 14.0 mm.

Distribution. China: Shanxi.

Ecology. *Cathaica mengi* occurs across a wide elevational gradient, from lowland farmland at the mountain base to exposed rocky habitats at higher elevations. (Fig. 14A–C).

Remarks. *Cathaica mengi* can be readily distinguished from other *Cathaica* species by its carinate periphery and densely spaced, low ribs. Among all *Cathaica* examined to date, *C. mengi* is the only species known to lack a proximal accessory sac. The species shows ecological adaptability. Foothill populations of *C. mengi* tend to have a higher spire (Fig. 3D), whereas populations on rocky cliffs have a lower spire with sparser, more sharply defined ribs (Fig. 3A–C). This pattern indicates a strong environmental influence on shell form, and a lower spire is likely advantageous in exposed rocky habitats.

Cathaica sculptilis Z.-Y. Wang, Y.-M. He, H. Chen & Q.-Y. Zhang, sp. nov.

雕刻华蜗牛

(Figs 5, 6, 12B, 16)

Type materials. Holotype. HBUMM10084, Qinglongshan Mount [青龙山], Dayugou County [大峪沟镇], Gongyi City [巩义市], Zhengzhou City [郑州市], Henan Province, China, 34°40’N, 113°04’E, 500 m above sea level, leg. Zhi-Yao Wang, 17 September 2023. Paratypes. HBUMM10085 (9 specimens), WZY20230917A (5 specimens), same data as holotype; ZQY20230126A (5 specimens), same location as holotype, leg. Quan-Yu Zhang, 26 January 2023.

Etymology. This new species is named for its prominent ribs and remarkable surface sculpture.

Description. *Shell* (Fig. 5) low-conic, thin, dextral; spire conoid. Whorls convex. Suture superficial. Umbilicus narrow, with a gradual transition from the shell base. Columella oblique; columellar lip dilated, partially covering umbilicus. Protoconch radially granulate (Fig. 11B). Spiral furrows densely distributed on spire. Body whorl clearly deflexed behind aperture. Shell surface bearing 60–70 strong ribs, each rib thickened and protruding at keel, forming crenulations at periphery. Growth lines between ribs indistinct. Both young and adult shells smooth. Young shell

FIGURE 5. Shell of *Cathaica sculptilis* **sp. nov. A.** HBUMM10084, holotype. **B.** HBUMM10085a, paratype. **C.** HBUMM10085b, paratype.

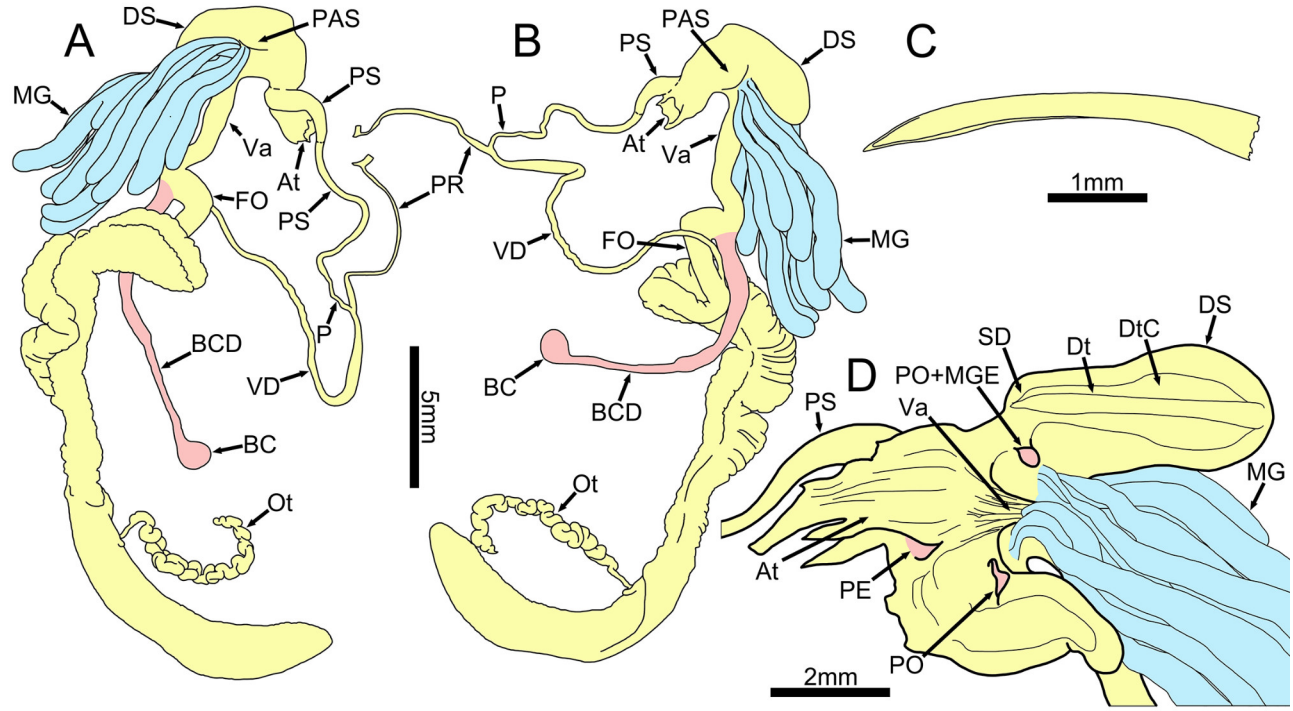

FIGURE 6. Genitalia of *Cathaica sculptilis* **sp. nov. A–B.** both sides of the genitalia. **C.** love dart. **D.** exposed dart sac apparatus.

carinate. Adult body whorl sharply carinate above the periphery, basally convex. Aperture peach-shaped quadrate, oblique, slightly expanded, with a very low, broad basal tooth near columella. 1-2 strongly, ring-like thickenings present within aperture present, disconnected from peristome. Peristome thick, not continuous, somewhat sinuate. Parietal callus thin and indistinct. Shell glossy and dull red, with the color slightly lighter around the umbilicus, peripheral bands absent. *Measurements* (n = 5): Shell width: 17.4–18.6 mm; shell height: 8.5–9.8 mm.

Genitalia (Fig. 6). Membranous sac surrounding terminal genitalia absent. Penial sheath approximately 1/4 penis length. Penis slender and externally simple. Flagellum absent. Vas deferens thickened near penial-retractor muscle, thickened portion accounts for about a quarter of vas deferens. Mucous glands containing 10–15 tubules, approximately three times length of dart sac, glands inflated, uncurved and usually unbranched, if branched then only slightly, each with a distinct peduncle; not attached to vagina by connective tissue, opening into dart-sac chamber. Vaginal region between dart sac and atrium short, about equal in length to dart sac. Proximal part of dart sac neither elongate nor forming a neck-structure. Dart sac containing one piece of dart, curved and possess chaeta, basal cross-section ovate, distal cross-section fusiform, surface covered with dense villi except at the distal end, approximately 6 mm in length. Two very small proximal accessory sacs are located on left and right sides of dart sac, each with an opening that leads into dart-sac chamber near insertion of mucous glands. Vagina entering atrium. *Measurements* (average of 10 individuals): DS: 6.5 mm in length, 2.0 mm in width; MG: 3.9–6.3 mm; PS+P: 12.3 mm; VD: 13.6 mm; PR: 6.4 mm; Va: 4.5 mm; FO: 1.9 mm; BC+BCD: 9.4 mm.

Distribution. China: Henan. This new species is known only from the type locality.

Ecology. *Cathaica sculptilis* sp. nov. lives on the limestone canyon walls with direct sunlight

FIGURE 7. Shell of *Cathaica zhangcunxiangi* **sp. nov. A.** HBUMM10086, holotype. **B.** ZQY-20230629/1, paratype. **C.** ZQY20230629/2, paratype.

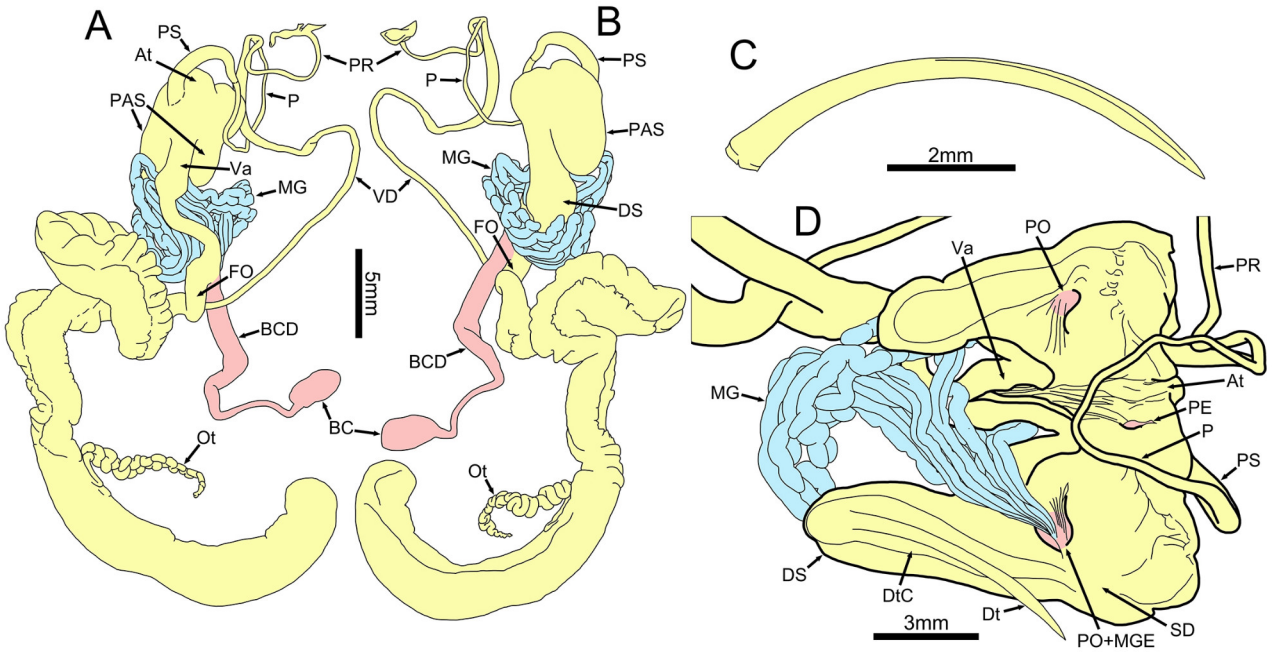

FIGURE 8. Genitalia of *Cathaica zhangcunxiangi* **sp. nov. A–B.** both sides of the genitalia. **C.** love dart. **D.** exposed dart sac apparatus.

(Fig. 16).

Remarks. The shell of *Cathaica sculptilis* **sp. nov.** is readily distinguished from most congeners by the combination of a sharp peripheral keel and strong axial ribs. It most closely resembles *C. multicostata* and *C. wangjiaxunae* **sp. nov.**, but differs in having a dull reddish shell, an oblique aperture, and a very low, broad basal tooth. *Cathaica sculptilis* **sp. nov.** can also be distinguished from other species by the inflated, uncurved mucous glands and the presence of two very small proximal accessory sacs.

Cathaica zhangcunxiangi Z.-Y. Wang, Y.-M. He, H. Chen & Q.-Y. Zhang, sp. nov.

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(Figs 7, 8, 12C, 17)

Type materials. Holotype. HBUMM10086, Northwest of Huixian City [辉县市], Xinxiang City [新乡市], Henan Province, China, 35°29’N, 113°26’E, 600 m above sea level, leg. Quan-Yu Zhang and Zhi-Yao Wang, 26 April 2024. Paratypes. HBUMM10087 (9 specimens), WZY20240426C (5 specimens), same data as holotype, leg. Quan-Yu Zhang and Zhi-Yao Wang, 26 April 2024; ZQY20210629A (5 specimens), same location as holotype, leg. Quan-Yu Zhang, 26 January 2023.

Etymology. The new species is named after the father of second author, Cun-Xiang Zhang [张存祥].

Description. *Shell* (Fig. 7) discoid, thin, dextral. Spire very low to slightly concave. Whorls flattish. Suture superficial. Umbilicus slightly narrow; shell transition to umbilicus gradual. Columella oblique; columellar lip slightly dilated, never covering umbilicus. Spiral furrows absent. Final part of last whorl usually slightly descending. Shell surface with dense and shallow ribs that do not form clear crenulations at periphery. Growth lines between ribs indistinct. Adult shell smooth, body whorl polymorphic, supra-peripherally sharply carinate, basally convex. Aperture peach-shaped

FIGURE 9. Shell of *Cathaica wangjiaxunae* **sp. nov. A.** HBUMM10088, holotype. **B.** HBUMM10089a, paratype. **C.** HBUMM10089b, paratype.

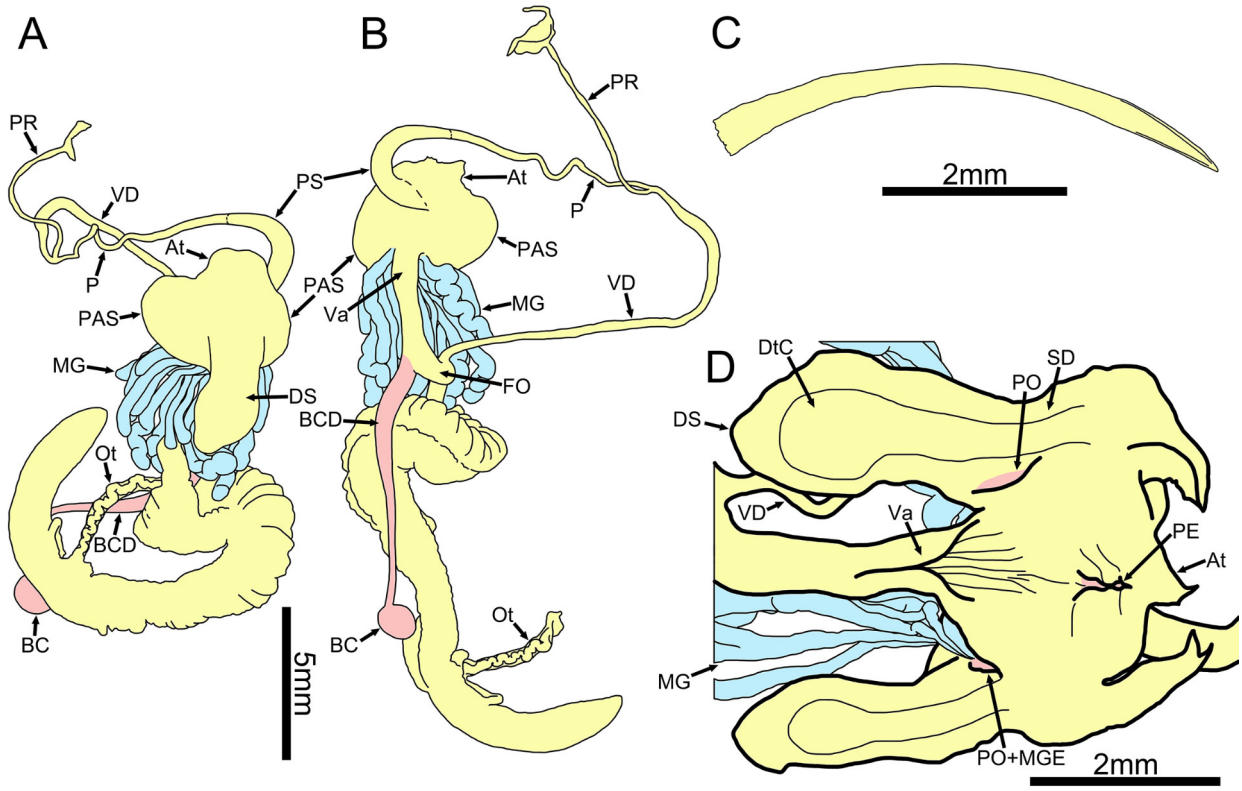

FIGURE 10. Genitalia of *Cathaica wangjiaxunae* **sp. nov. A–B.** both sides of the genitalia. **C.** love dart. **D.** exposed dart sac apparatus.

quadrate, slightly oblique, slightly expanded below, toothless. Ring-like thickening present within aperture. Peristome thin, somewhat sinuate, not continuous. Parietal callus thin and indistinct. Basal lip narrow. Protoconch radially granulate (Fig. 11C). Young shell smooth and carinate, without scales, angulate at periphery. Shell glossy, apically dirty yellow to chestnut-brown, ventrally white to dark yellow, with a dark brown blurry band at periphery under keel. *Measurements* (n = 5): Shell width: 18.6–21.4 mm; shell height: 8.4–11.9 mm.

Genitalia (Fig. 8). Membranous sac surrounding terminal genitalia absent. Penial sheath approximately 2/5 penis length. Penis slender and externally simple. Flagellum absent. Vas deferens thickened near penial-retractor muscle. Mucous glands containing 12–15 tubules, complexly branched, longer than dart sac, each with a distinct peduncle, opening into dart-sac chamber. Proximal part of dart sac neither elongate nor forming a neck-like structure. Dart sac containing one piece of love dart. Love dart curved, with basal cross-section ovate, distal cross-section fusiform, surface covered with dense villi except at the distal end, approximately 8 mm in length. Two proximal accessory sacs, equally developed, internally containing numerous parallel septa; both open into dart sac chamber near mucous glands entrance. Vagina entering atrium, proximally expanded. Measurements (average of three individuals): DS: 9.0 mm in length, 2.9 mm in width; MG: 4.5–15.0 mm; PS + P: 17.7 mm; VD: 26.7 mm; PR: 7.9 mm; Va: 10.3 mm; FO: 2.3 mm; BC + BCD: 16.4 mm.

Distribution. China: Henan. This new species is known only from the type locality.

Ecology. This new species lives on the canyon walls with direct sunlight and nearby water sources (Fig. 17).

Remarks. *Cathaica zhangcunxiangi* sp. nov. has a flat apex, a sharp keel, and a narrow basal lip; the ribs are very shallow, yielding a smoother shell. These features readily distinguish it from other species of *Cathaica*. Anatomically, the vagina of *C. zhangcunxiangi* sp. nov. is proximally expanded, similar to that of *C. fohuiensis* G. Zhang, 2023 (see Zhang & Wade, 2023), but it opens into the dart-sac chamber instead. *Cathaica zhangcunxiangi* sp. nov. is somewhat similar to *P. tectumsinense zenonis* and *P. futtereri*; however, the latter two have more conoid shells, distinct periostracal derivatives on the shell surface, and more strongly expanded lips.

Cathaica wangjiaxunae Z.-Y. Wang, Y.-M. He, H. Chen & Q.-Y. Zhang, sp. nov.

王氏华蜗牛

(Figs 9, 10, 12D, 18)

Type materials. Holotype. HBUMM10088, Kunlunyu Village [昆仑峪村], Wuan City [武安市], Handan City [邯郸市], Hebei Province, China, 36°55’N, 113°52’E, 1250 m above sea level, leg. Zhi-Yao Wang, 30 November 2024. Paratypes. HBUMM10089 (4 specimens), WZY20241130A (10 specimens), same data as holotype.

Etymology. The new species is named after the mother of first author, Jia-Xun Wang [王佳珣].

Description. *Shell* (Fig. 9) shape depressed, thin, dextral, spire low. Whorls flattish. Suture superficial. Umbilicus narrow, with a gradual transition to shell. Columella oblique; columellar lip dilated, slightly covering umbilicus. Protoconch radially granulate (Fig. 11D). Spiral furrows absent. Body whorl straight or slightly descending behind aperture. Shell surface with fine ribs; approximately 40–50 ribs present on the body whorl, forming crenulations at periphery. Growth lines between ribs indistinct. Young shell smooth and carinate. Adult shell smooth, body whorl supra-peripherally sharply carinate and basally convex. Aperture peach-shaped quadrate, slightly expanded below, toothless. Ring-like thickening within aperture present. Peristome thick, somewhat sinuate,

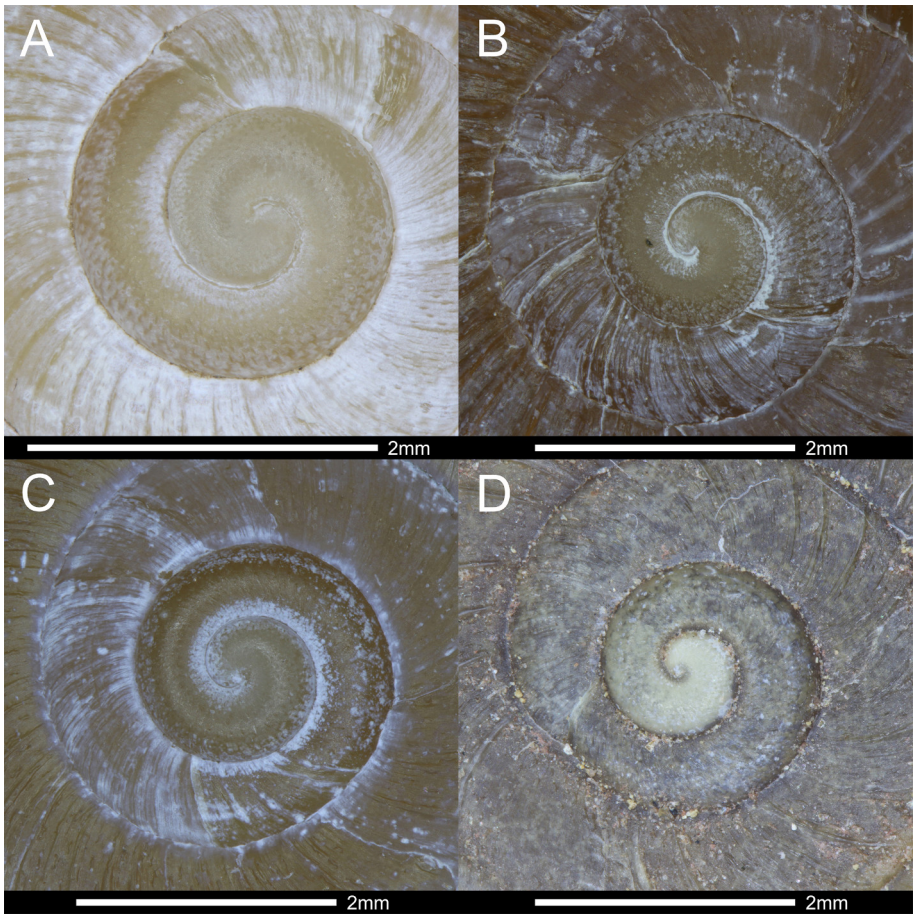

FIGURE 11. Protoconchs of *Cathaica* spp. **A.** *Cathaica mengi*. **B.** *Cathaica sculptilis* **sp. nov. C.** *Cathaica zhangcunxiangi* **sp. nov. D.** *Cathaica wangjiaxunae* **sp. nov.**

not continuous. Parietal callus thin and indistinct. Shell glossy, yellowish, whitish near umbilicus, slightly transparent, pigmented bands absent. *Measurements* (n = 5): Shell width: 16.1–18 mm; shell height: 7–9.1 mm.

Genitalia (Fig. 10). Membranous sac surrounding terminal genitalia absent. Penial sheath approximately 1/3 penis length. Penis slender and externally simple. Flagellum absent. Vas deferens slightly thickened near penial-retractor muscle. Mucous glands containing 12–15 single tubules with wavy distal ends, approximately the same length as dart sac, usually not branched, but if branched, then only simply. Each tubule has a distinct peduncle, opening into dart sac chamber. Proximal part of dart sac not forming a neck-like structure. Dart sac containing 1 piece of dart, curved and possess chaeta, basal cross-section ovate, distal cross-section fusiform, surface nearly smooth, with short villi restricted to the middle third, approximately 6 mm in length. Two proximal accessory sacs, on left and right sides of dart sac, unequally developed, right proximal accessory sac more developed. Each sac has an opening, opening into dart-sac chamber near insertion of mucous gland. Vagina entering atrium. Measurements (average of three individuals): DS: 6.2 mm in length, 2.1 mm in width; MG: 2.6–6.5 mm; PS + P: 7.1 mm; VD: 13.5 mm; PR: 6.5 mm; Va: 4.9 mm; FO: 1.6 mm; BC + BCD: 9.5 mm.

Distribution. China: Hebei. This new species is known only from the type locality.

Ecology. This new species lives on the limestone or sandstone canyon walls (Fig. 18).

Remarks. *Cathaica wangjiaxunae* sp. nov. most closely resembles *C. multicostata* and *C. sculptilis* sp. nov., but it differs from *C. multicostata* by its narrow umbilicus, and from *C. sculptilis*

FIGURE 12. Shell of *Cathaica* spp. **A.** *Cathaica* sp1, WZY20240422A/1. **B.** *Cathaica* sp1, WZY20240422A/2. **C.** *Cathaica* sp2, HYX20240714A/1.

sp. nov. by ribs that project along the keel, an (near-)orthocline aperture, and the absence of a basal tooth. It also differs from all the other *Cathaica* species in having mucous glands with undulate distal ends that are usually unbranched, and two proximal accessory sacs of unequal size.

***Cathaica* sp1**

(Figs 12A–B, 13)

Material examined. WZY20240422A (3 specimens), Northwest of Wuan City [武安市], Handan City [邯郸市], Hebei Province, China, leg. Zhi-Yao Wang, 22 April 2024. *Measurements* (n = 2): Shell width: 14.5–15.7 mm; shell height: 8.6–8.7 mm.

Remarks. *Cathaica* sp1 is similar in shell morphology to *C. fasciola* and *C. pyrrhozona*, but it is easily distinguished by its genital anatomy (Fig. 13). It differs from *C. pyrrhozona* by having two equally developed proximal accessory sacs. It also possesses approximately 12 swollen, non-curved mucous glands, which separates it from *C. fasciola*. The position of the dart-sac septum and the entry point of the proximal accessory sacs in *C.* sp1 further differs from both *C. fasciola* and *C. pyrrhozona*. Ecologically, *C.* sp1 is restricted to sandstone cliffs near mountain summits, whereas *C. fasciola* and *C. pyrrhozona* occur at mountain foothills or in plains.

Cathaica sp2

(Figs 12C, 14)

Material examined. HYX20240714A (3 specimens), East of Zibo City [淄博市], Shandong Province, China, leg. Huan-Yu Xuan, 14 July 2024. *Measurement* (n = 1): Shell width: 17.9 mm; shell height: 10.3 mm.

Remarks. The genital anatomy of *C.* sp2 closely matches the description of *C. fasciola* provided

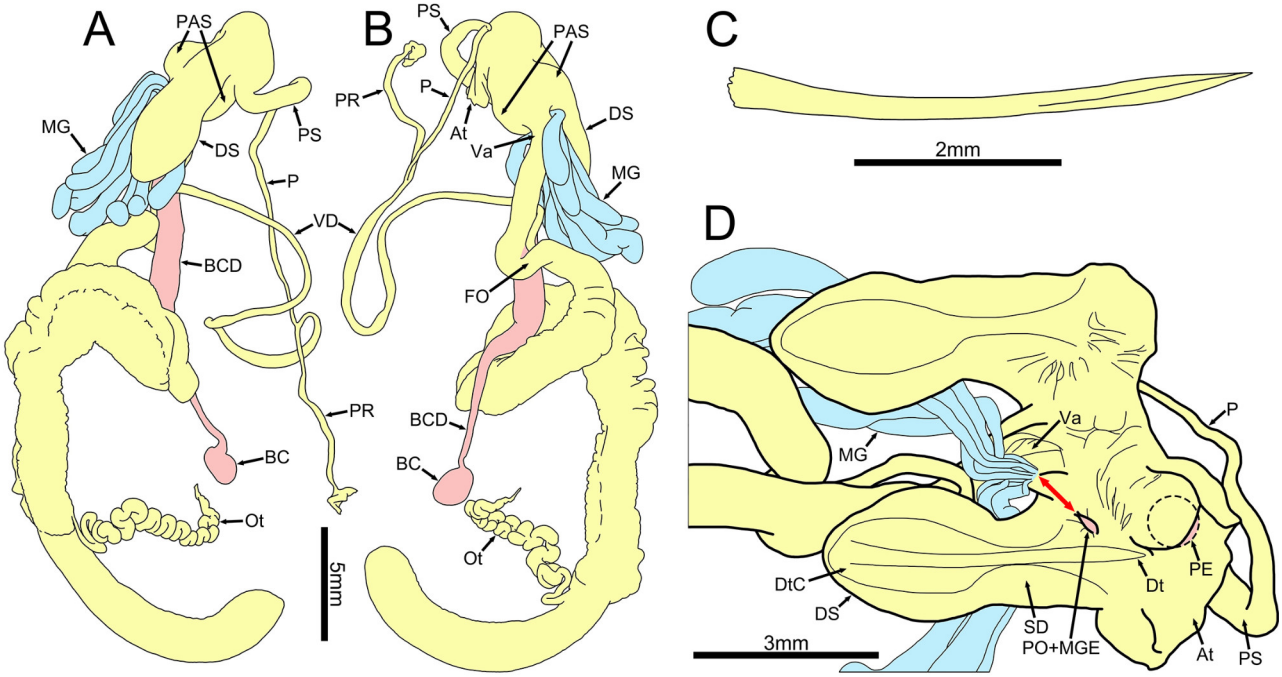

FIGURE 13. Genitalia of *Cathaica* sp1. **A–B.** both sides of the genitalia. **C.** love dart. **D.** exposed dart sac apparatus. The positions indicated by the red arrows were originally connected.

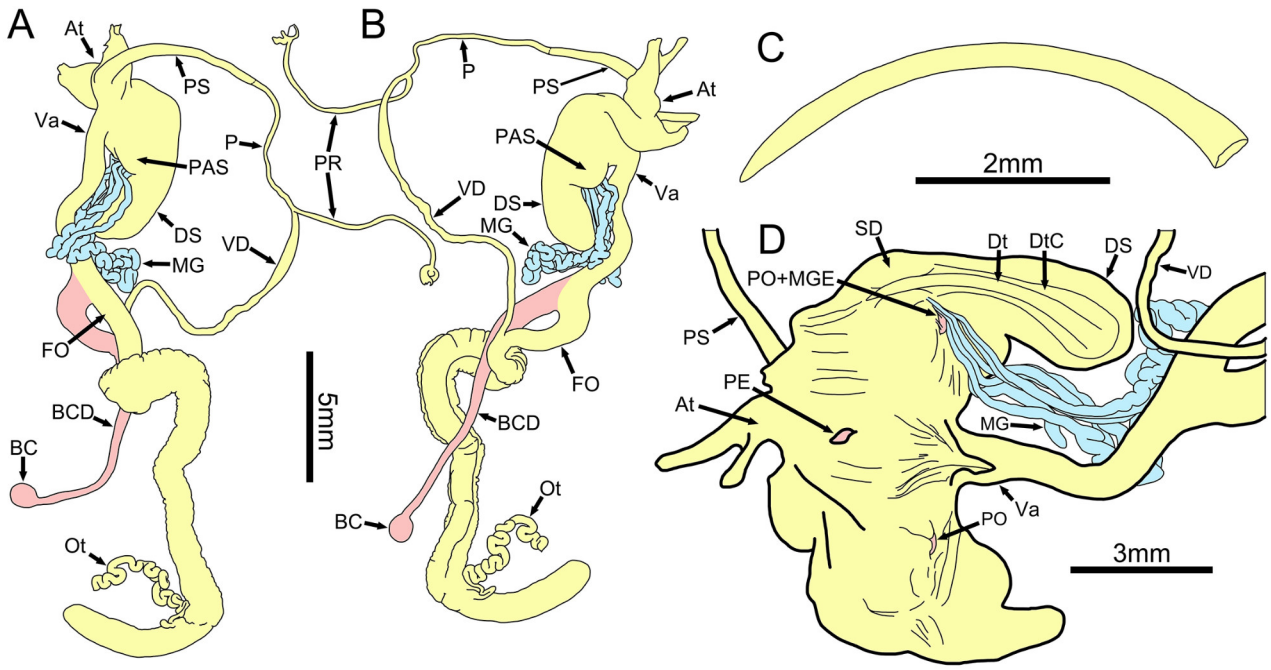

FIGURE 14. Genitalia of *Cathaica* sp2. **A–B.** both sides of the genitalia. **C.** love dart. **D.** exposed dart sac apparatus.

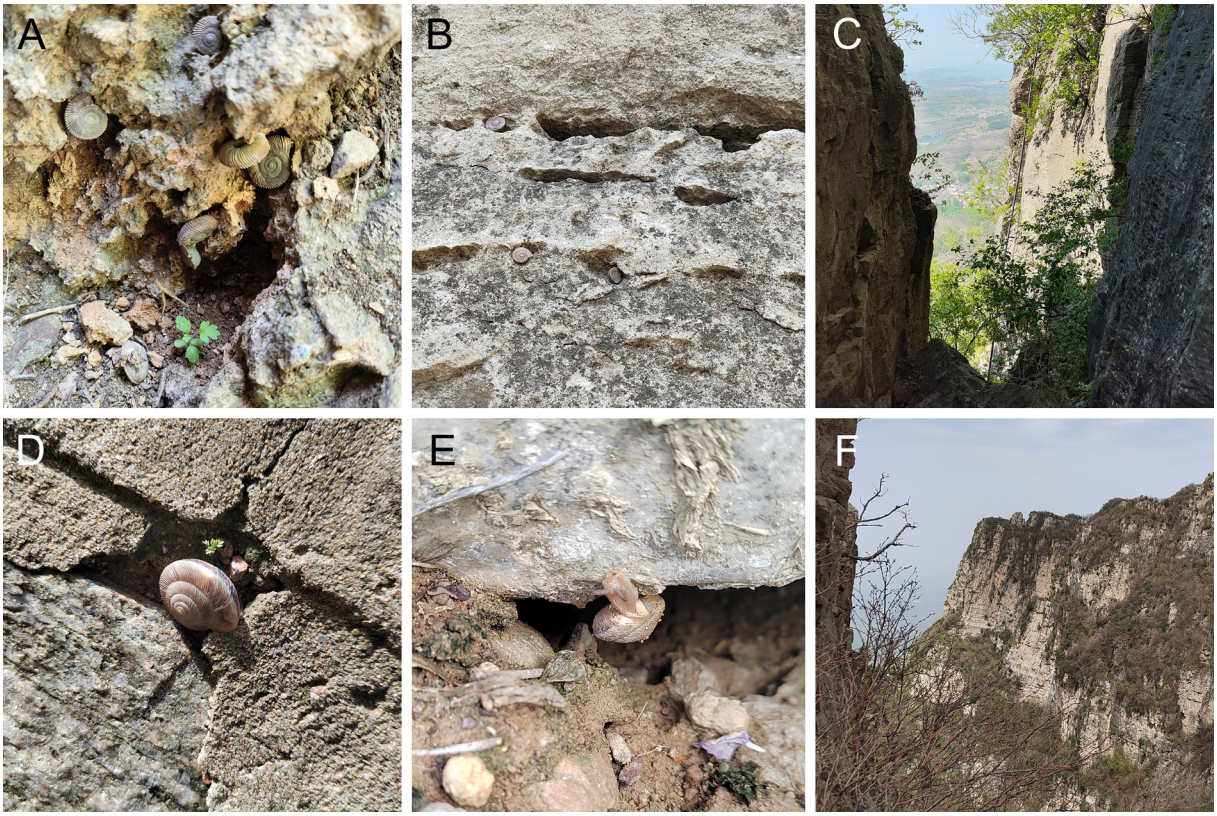

FIGURE 15. Natural habitats of *Cathaica* spp. **A–C.** *Cathaica multicostata*. **D–F.** *Cathaica mengi*.

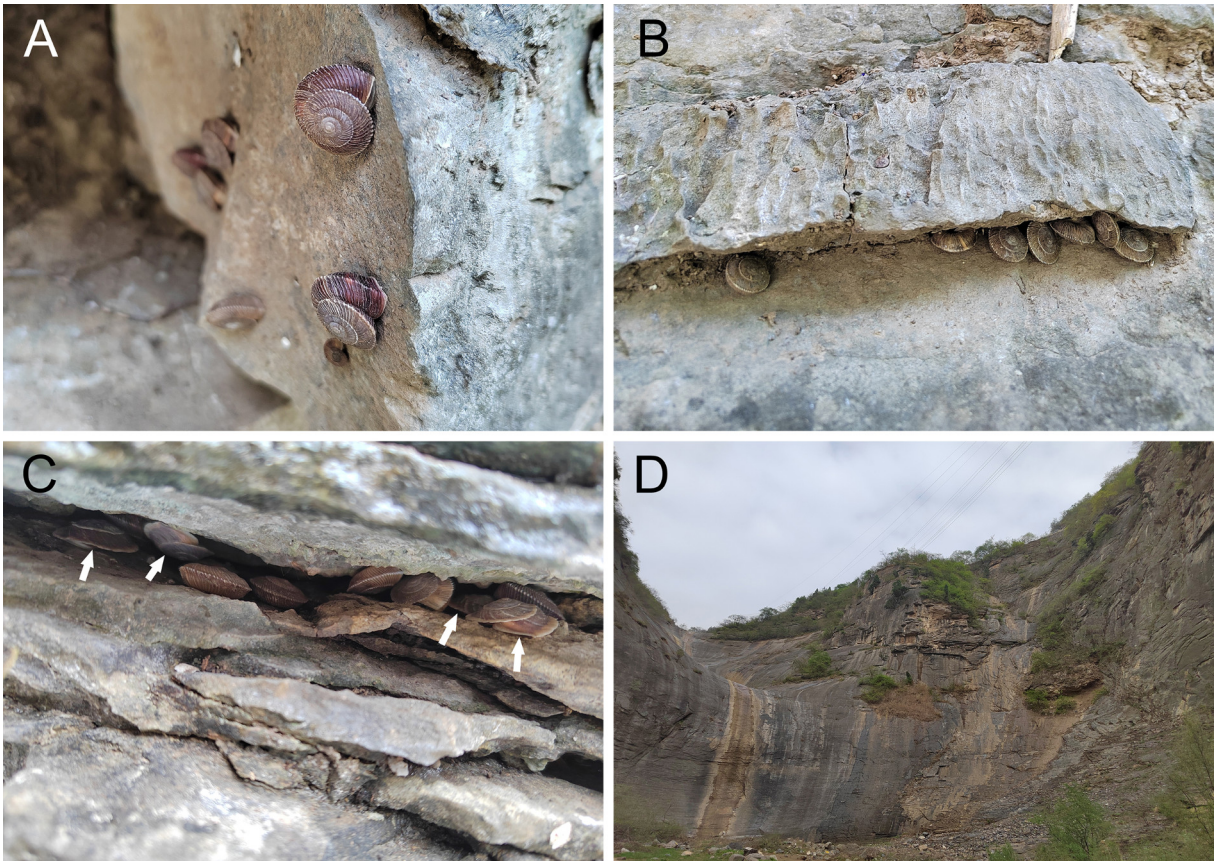

FIGURE 16. Natural habitats of *Cathaica sculptilis* **sp. nov.** White arrow in **C** shows the *Pseudiberus shanheicus* Zhang, Liu, Feng & Zhang, 2024 living in the same habitat.

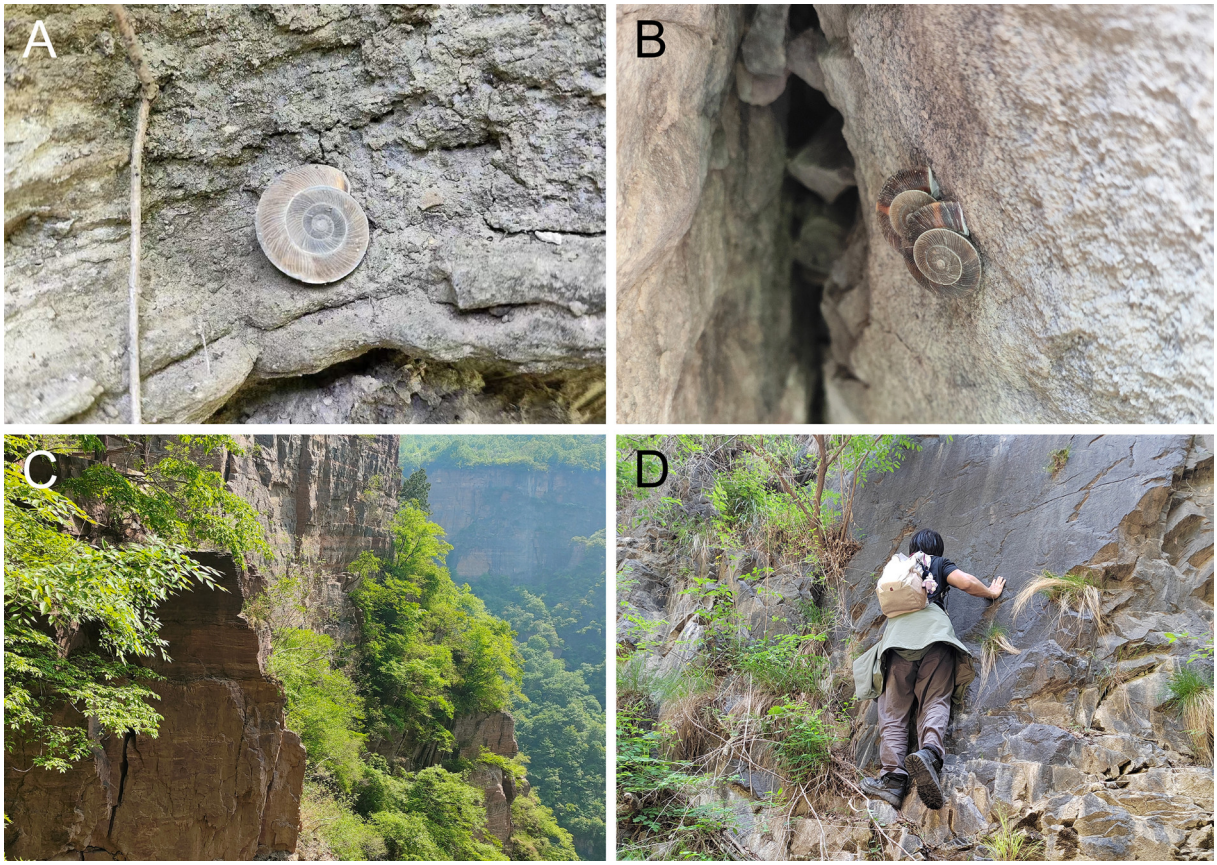

FIGURE 17. Natural habitats of *Cathaica zhangcunxiangi* **sp. nov.**

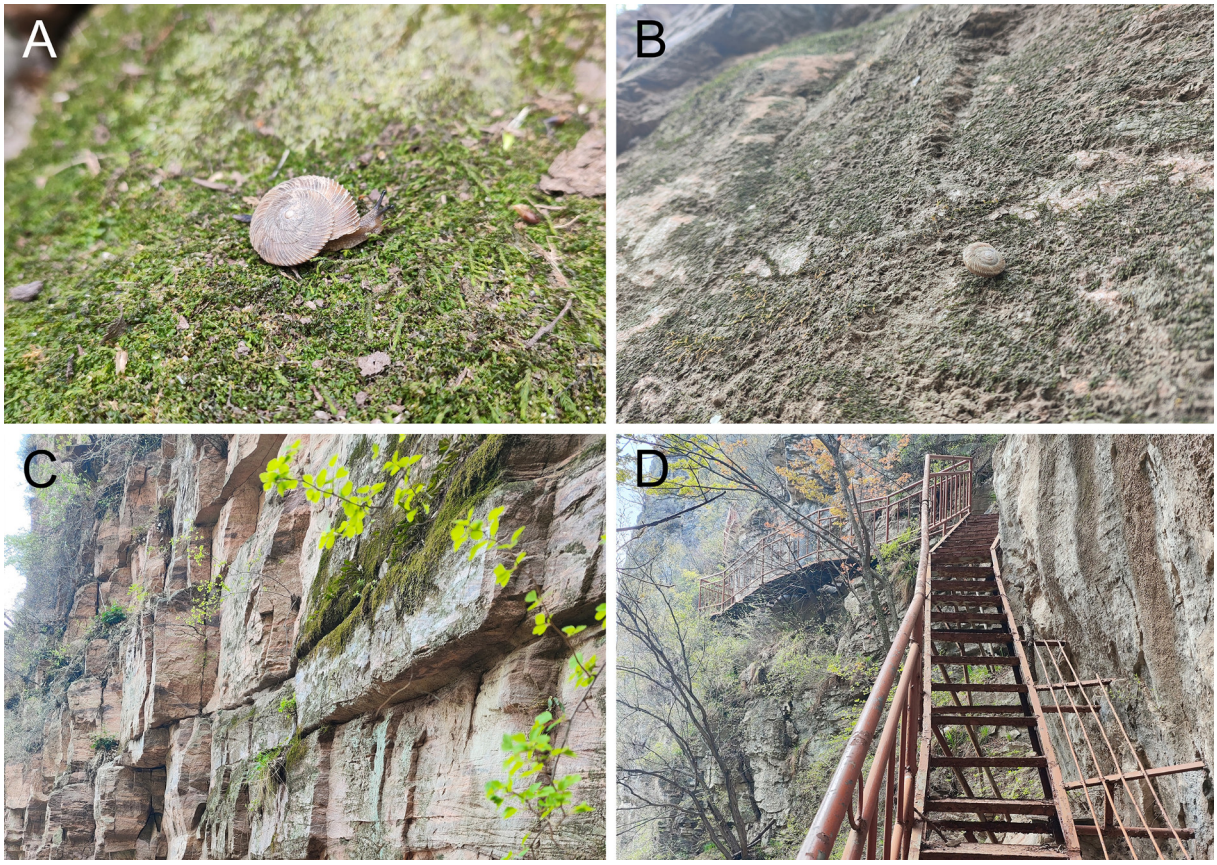

FIGURE 18. Natural habitats of *Cathaica wangjiaxunae* **sp. nov.**

by Zhang & Wade (2023), but its shell morphology is markedly different. *Cathaica* sp2 shows more strongly developed ribs, a conspicuously expanded lip, no colour bands, and an overall grayish-white appearance. Because reliable molecular data for *C. fasciola* are not yet available, the phylogenetic relationship between *C.* sp2 and *C. fasciola* remains unresolved.

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Appendix 1.

Mitochondrial 16S sequence of *Cathaica wangjiaxunae* sp. nov. (HBUMM10088):

CTGCTCATGATTTATTTTAATAGCCGCAGTACCCTGACTGTGCTAAGGTAGCATAATCAA
TTGGCTCATGATTGGAGTCTCGTATGAAAGAATTCATGGGGGTTGGCTGTTTCATATTA
ATATTATTAAATTACTTATTAAGTGAAAATACTTAAAAATAAAAAATAGACGAGAAGACCCT
AGAAATTTTAATTTAATTATACCTTTTTGTTGGGGCGACAAAGTAGCAAATAACCTACTTA
AGTTTTACTTGAATATTATATTATGAATGAATAAATTACTCTAGGGATAACAGCATAATATTT
AAAAGTTTGTGACCTCGATGTTGGATTAGGAAAACTATACCTAGAAGGTTAAT

中国中部太行山脉岩栖性华蜗牛属三新种（腹足纲：柄眼目：坚螺科）

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摘 要

华蜗牛属 *Cathaica* Möllendorff, 1884 的物种广泛分布于中国温带山地地区，它们表现出高度的多样性，并演化出多种形态以适应不同的环境。其中一些物种具有特化的外壳形态以适应特殊的环境，并且在其分布区及周边区域未发现形态相似的物种。例如，多肋华蜗牛 *C. multicostata* Zhang, 2023 和孟氏华蜗牛 *C. mengi* Yen, 1939，具有粗壮的肋和明显突出的龙骨。在本研究中，我们基于采自太行山区的标本，描述了华蜗牛属的三个新物种：雕刻华蜗牛 *C. sculptilis* Wang, Chen, He & Zhang, **sp. nov.**、张氏华蜗牛 *C. zhangcunxiangi* Wang, Chen, He & Zhang, **sp. nov.** 和王氏华蜗牛 *C. wangjiaxunae* Wang, Chen, He & Zhang, **sp. nov.**。这些新种在外壳上相似，都具有比较低矮的螺塔和突出的龙骨，但生殖器解剖与分子系统学的分析均支持这些新物种的独立性。同时为了更好地理解这些形态相似的物种之间的亲缘关系，我们还采集了周边地区的华蜗牛标本，对它们进行了形态学和分子系统学的研究，并对孟氏华蜗牛 *C. mengi* 进行了形态重新描述和生殖器补充描述。

关键词：比较形态学，分子系统发育，华北地区，新物种，岩石生境