

NEW SPECIES OF MICRO SNAILS FROM LAOS (PULMONATA: VERTIGINIDAE AND DIAPHERIDAE)

KHAMLA INKHAVILAY, CHIRASAK SUTCHARIT, PIYOROS TONGKERD & SOMSAK PANHA

Animal Systematics Research Unit, Department of Biology, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand

Abstract Five new species of minute vertiginid and diapherid snails, each with the characteristic apertural barriers for their genera (angular and parietal, collumellar and palatal), are described. *Paraboysidia anguloobtusus* n. sp. has a high conical shell, shouldered whorls with impressed sutures, and very fine spiral striae. The aperture contains seven robust barriers with distinct, blunt, angular lamella and a curved upper palatal plica. *Paraboysidia paralella* n. sp. has a high, ovate, embryonic shell with a very fine porous structure. The aperture contains five robust barriers, including angular and parietal lamellae located parallel to each other, a knob-like basal lamella and a short and thickened supracolumella tooth. *Gyliotrachela plesiolopa* n. sp. has a turbinated shell, embryonic whorls with a pitted, porous sculpture, sutures impressed and the final whorl ascends and expands to a trumpet shaped aperture. There are five major apertural barriers: angular, parietal, columellar, upper and lower palatal, plus six small additional plicae: two infraparietals, two interpalatals and two infrapalatal. *Angustopila singuladentis* n. sp. has a conical spire, suture depressed, embryonic with a porous sculpture, shell sculpture with fine spiral threads. The shell aperture contains one thick and strong parietal lamella. *Sinoennea euryomphala* n. sp. has a high pupa-shaped shell, aperture opened narrowly vertically and subcircular shaped. The shell aperture contains large and strong parietal-angular lamellae, bifurcation palatal and columellar lamellae. Umbilicus widely opened.

Key words limestone, taxonomy, Laos, Vertiginidae, Diapheridae

INTRODUCTION

Terrestrial pulmonate snails in Indochina exhibit a wide size range of shell dimensions, ranging from over 70mm diameter in *Hemiplecta distincta* to less than 5mm in the so-called micro-snails. The Vertiginidae and Diapheridae are the major families of pulmonate micro-snails in the region, and range from the east of India to Southeast Asia, including southern China and Japan (Panha *et al.*, 2002; Zhang *et al.*, 2014). Micro-snails are most diverse and abundant on limestone and many are restricted to limestone, leading to local endemism and highly restricted distribution ranges (Jochum *et al.*, 2014). Over a hundred nominal species of pulmonate micro-snails have been recorded from Indochina (Pilsbry, 1917; Richardson, 1988; Thompson & Upatham, 1997; Panha & Burch, 1999a, 2000, 2001, 2005). Most are known from Myanmar, Thailand and Vietnam, with only one species each of *Krobylos* Panha & Burch, 1999, *Paraboysidia* Pilsbry, 1917 and *Sinoennea* Kobelt, 1904 being reported from Laos (Panha & Burch, 2002; Panha *et al.*, 2004; Maassen, 2008).

The significant proportion of records are from areas nearby to Laos, such as Thailand, rather

than from within Laos, as indicated in several publications compiled in Burch and Panha (2002), and Panha and Burch (2005), and are comprised of 63 species of micro-Vertiginidae belonging to twelve genera (*Acinolaemus*, *Anauchen*, *Antroapiculus*, *Aulacospira*, *Boysidia*, *Gyliotrachela*, *Hypselostoma*, *Krobylos*, *Montapiculus*, *Paraboysidia*, *Pupisoma* and *Systemostoma*), and two species of micro-Diapheridae belonging to the genus *Sinoennea*. The present paper describes an additional five species from Laos in a different genus *Angustopila*, and re-arranges the family classification to Vertiginidae and Diapheridae.

MATERIALS AND METHODS

Field collections were performed in northern Laos at Houaphane, Luang Phrabang and Luang Namtha Provinces from September 2013 to December 2014 (Fig. 1). Various habitat types of limestone karst, including caves, were searched for samples. Leaf litter and topsoil were also collected and searched. Specimens were identified based on Bavay and Dautzenberg (1908, 1912), Pilsbry (1917), Benthem Jutting (1949), Panha and Burch (2005), Maassen (2008) and by comparison with type material in the Chulalongkorn University Museum of Zoology.

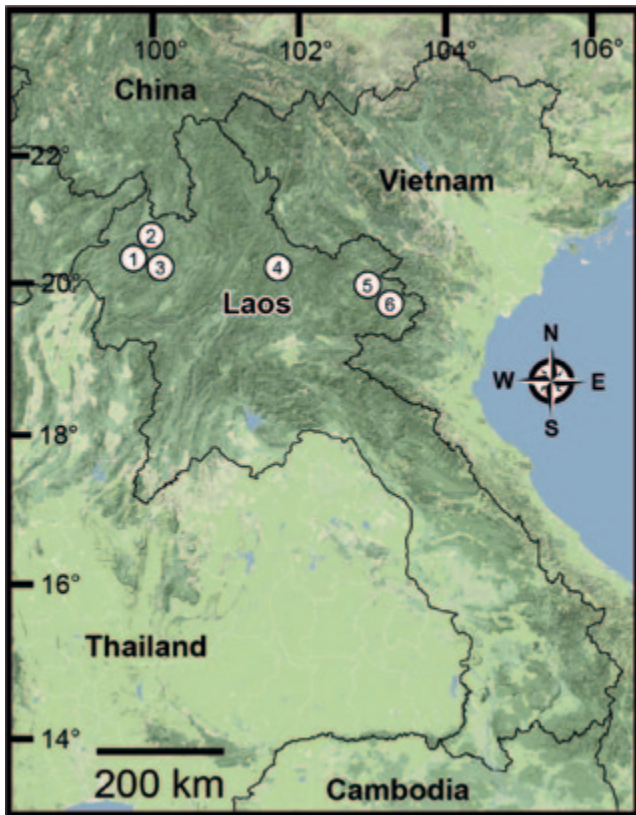


Figure 1 Map of Laos showing the approximate locations of the sampling sites and the type localities: (1) Sampling sites of *Paraboysidia gittenbergeri* and *Sinoennea lizae* from Luang Namtha; (2), Type localities of *Paraboysidia anguloobtusum* n. sp.; and *Paraboysidia parallela* n. sp.; (3), Type localities of *Paraboysidia gittenbergeri* and *Sinoennea lizae*; (4), Type locality of *Sinoennea euryomphala* n. sp.; (5), Type locality of *Angustopila singuladentis* n. sp.; (6), Type locality of *Gyliotrachela plesiolopa* n. sp.

Specimens were carefully cleaned with a delicate brush under a stereomicroscope and further examined under scanning electron microscopy (SEM; JEOL, JSM-5410 LV). To maximize resolution of informative characters, drawings were made with the aid of camera lucida. Cell'D imaging software was used for determining the shell height (H) and width (W) measurements.

The terminology of the shell shape and shell sculpture follows that of Pilsbry (1917), Benthem Jutting (1949), Schileyko (1998) and Panha and Burch (2005). The nomenclature of the shell apertural barriers follows that of Pilsbry (1917): A=angular; B=basal; C=columellar; c^1 =supracolumellar; c^2 =subcolumellar; c^2 and $c^{2.1}$ =subcolumellar; i^1 =infraparietal; i^2 =suprapalatal; i^3 =interpalatal; i^4 =infrapalatal; IPl=lower palatal; P=parietal; uPl=upper palatal.

Institutional abbreviations: CUMZ, Chulalongkorn University Museum of Zoology, Bangkok, Thailand; NHM, The Natural History Museum, London; NUOL, National University of Laos, Vientiane, Laos; SMF, Forschungsinstitut und Naturmuseum Senckenberg, Frankfurt am Main.

SYSTEMATICS

Family Vertiginidae Fitzinger, 1833

Subfamily Gastrocoptinae Pilsbry, 1918

Remarks The family treatment of the three following genera: *Paraboysidia* Pilsbry, 1917, *Gyliotrachela* Tomlin, 1930 and *Angustopila* Jochum *et al.*, 2014 (= *Systemostoma*) is still controversial. Originally, Pilsbry (1917) recognized and classified them within the family Pupillidae, subfamily Gastrocoptinae. Later, Zilch (1959) proposed the new classification by placing *Paraboysidia* and *Gyliotrachela* in the Hypselostomatinae and *Angustopila* in the Aulacospirinae, both of which were previously in the subfamily Chondrininae. Schileyko (1998) rearranged and recognized these three genera into the same family Hypselostomatinae by combining two of Zilch's subfamilies. The most recent classification by Bouchet and Rocroi (2005) rearranged the previous treatment from both Zilch (1959) and Schileyko (1998) as synonyms of the Vertiginidae: Gastrocoptinae. Therefore, in this paper we follow the most recent classification by placing *Paraboysidia*, *Gyliotrachela* and *Angustopila* into the family Vertiginidae, subfamily Gastrocoptinae.

Genus *Paraboysidia* Pilsbry, 1917

Type species *Boysidia paviei* Bavay and Dautzenberg, 1912, by original designation.

Boysidia (*Paraboysidia*) Pilsbry, 1917: 174, 201. Schileyko, 1998: 137, 138. Schileyko, 2011: 2.
Bensonella (*Paraboysidia*)—Zilch, 1959: 164.
Paraboysidia—Benthem Jutting, 1949: 5, 18. Panha & Burch, 2005: 113, 115.

Remarks This genus is characterized by having a minute, conical shaped shell, aperture adnate to the last whorl, and peristome continuous and usually expanded. Apertural barriers with parallel and separated angular and parietal lamellae, and other lamellae may be present or absent.

Boysidia Ancey, 1881 and *Anauchen* Pilsbry, 1917 differ from *Paraboysidia* by the genus *Boysidia* having fused angular and parietal lamellae to form a bi-lobed lamella; while the genus *Anauchen* performs only parietal lamella (Pilsbry, 1917; Benthem Jutting, 1949).

Currently, the genus *Paraboysidia* is comprised of 17 nominal species, which range from southern China to Indochina and peninsular Malaysia. Five species were reported from Indochina (three species from Vietnam and two species from Laos) and nine species were reported from Burma and Thailand (two species from Burma and seven species from Thailand) and the other 3 species were reported from Peninsula Malaysia (Pilsbry, 1917; Yen, 1939; Benthem Jutting, 1949; Panha & Burch, 2005; Maassen, 2008).

Paraboysidia gittenbergeri Maassen, 2008
Figs 1, 2A–C, 4A; Tables 1, 2

Paraboysidia gittenbergeri Maassen, 2008: 237–239, figs 5, 6.

Type locality 500m SE of Phou Lek Village, Oung Pra Ngiene, Vieng Phouka, Luang Namtha, Laos.

Material examined Limestone outcrop at Vieng Sawang Village, Vieng Phouka District, Luang Namtha Province, Laos (20°41' 14.9" N, 101°4' 8" E), 687m above mean sea level (amsl): CUMZ 7055 (1 shell, Fig. 2A), CUMZ 7056 (16 shells).

Remarks No living snails were found; only empty shells were collected from the top soil at limestone outcrop bases near the type locality (Figs 1 and 2). This species clearly differs from *P. robusta* (Bavay & Dautzenberg, 1912), *P. lamothei* (Bavay & Dautzenberg, 1912) and *P. pavei* (Bavay & Dautzenberg, 1912) in shell size and apertural barriers. In comparison, *P. robusta* has a sub-square aperture, angular and parietal lamellae that are not separated, infraparietal lamellae present with oblique columella lamella and strong upper palatal plica. *Paraboysidia lamothei* has a smaller shell (height 3mm) with nine apertural barriers, infraparietal and angular lamella, very strong seated at the edge of the peristome and running downwards almost adnate to the upper palatal plica. Likewise, *P. pavei* has a much smaller shell (height 1.8mm) with seven apertural barriers, infraparietal lamella and a larger subcolumella (Tables 1 and 2).

Paraboysidia anguloobtusus Inkhavilay & Panha, n. sp.
Figs 1, 2D–F, 4B

Holotype CUMZ 7057 (H=1.9mm, W=1.6mm; Figs 2D–F).

Paratypes CUMZ 7058 (8 specimens in ethanol), NHMUK (2 shells), SMF (2 shells).

Type locality Limestone wall outside of Kao Rao Cave, Vieng Phouka District, Luang Namtha Province, Laos (20°43' 30.1" N, 101°9' 4.3" E), 732m amsl.

Diagnosis *Paraboysidia anguloobtusus* n. sp. has a high conical shaped shell with a straightened spire and impressed sutures. The protoconch has spiral striae. Aperture heart shaped, peristome with seven major apertural barriers (angular, parietal, columellar, subcolumellar, upper and lower palatal and suprapalatal). The angular lamella is blunt, parietal and columellar lamellae form an embayment. Upper palatal plica bend in a deeper location, lower palatal distinct forming an embayment with basal lamella.

Description Shell minute, high conical, with 4¾ whorls, straight-sided spire, shell height 1.8–2.1mm and width 1.4–1.6mm (Fig. 2D). Embryonic shell about 1½ whorls with defined spiral incised lines (Fig. 2F). Teleoconch sculpture with thin irregular growth lines and very fine spiral striae. Last whorl largest, shouldered; impressed sutures. Peristome complete and adnate to last whorl. Aperture circular and open vertically. Six apertural barriers; angular, parietal, columellar, subcolumellar and lower palatal plica are well developed. Palatal edge at peristome invaginated making a distinct barrier. Angular lamella thickened, blunt at the tip, terminal located almost at apertural edge towards inside with slightly curved, upper palatal plica located deeper inside aperture. Parietal and angular lamellae spaced; parietal large and strong, located deeper from peristome; Columellar lamella thickened and located firmly at peristome edge, subcolumellar plica also prominent. Upper palatal plica short, thin, curved and seated lower than peristome edge. Lower palatal plica long and stout, reaching to aperture margin; suprapalatal plica short and thin; upward nearly meets parietal lamella. Umbilicus narrow and deep.

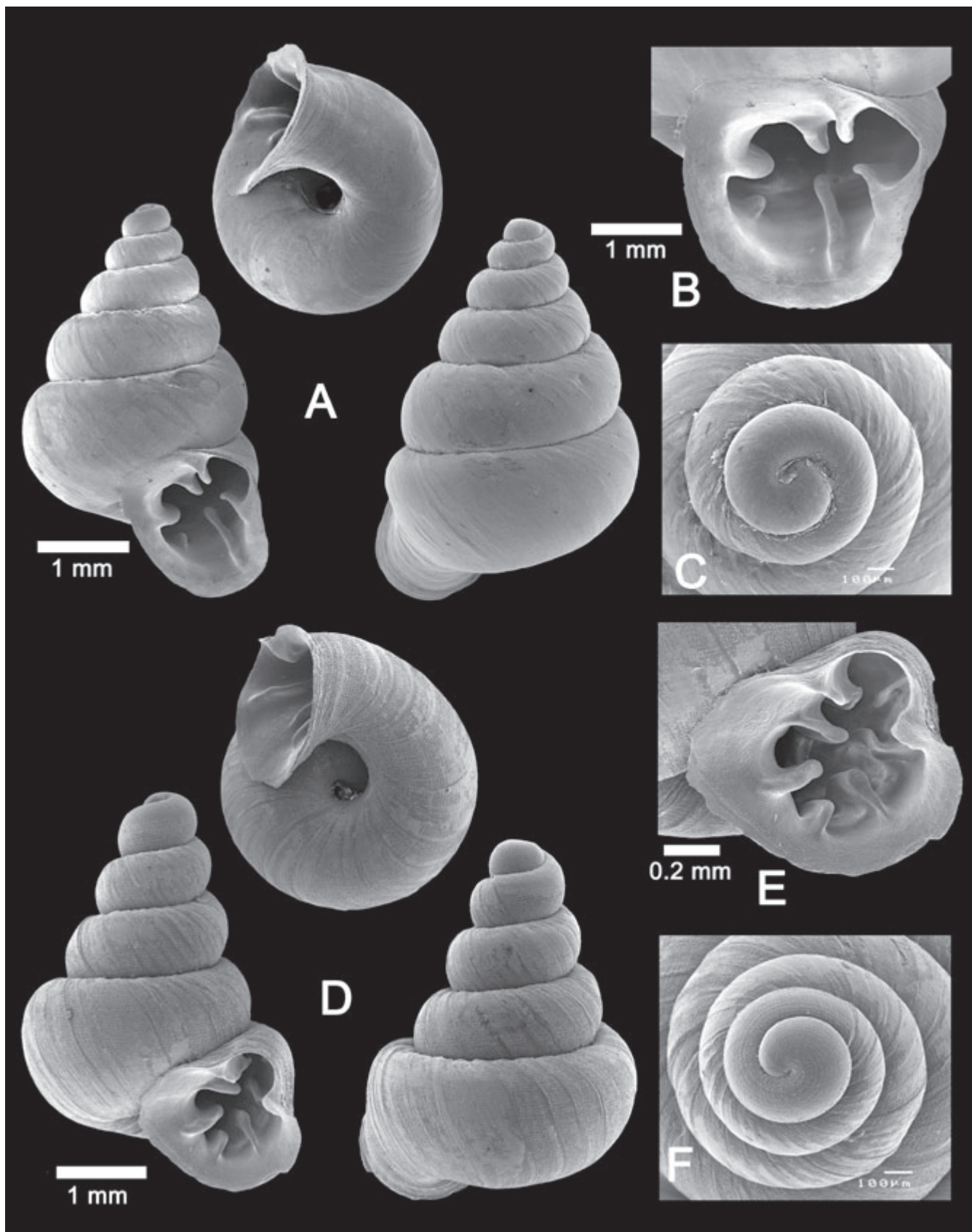


Figure 2 SEM images showing the shell shapes, apertural barriers and protoconch sculptures of (A–C), *Paraboydsidia gittenbergeri* (CUMZ 7055) from Luang Namtha and (D–F), *Paraboydsidia anguloobtusus* n. sp. (holotype CUMZ 7057).

Table 1 Shell measurements and catalogue numbers (indicated in parentheses) of the seven examined species.

Species and CUMZ nos.	No. of specimens	Ranges, mean \pm S.D. (mm)		
		H	W	H/W ratio
<i>Paraboysidia gittenbergeri</i> CUMZ 7055, 7056	17	4.1–5.2 4.4 \pm 0.26	2.5–3.0 2.7 \pm 0.14	1.4–1.9 1.6 \pm 0.10
<i>Paraboysidia anguloobtusus</i> n. sp. Holotype (7057), paratypes (7058)	9	1.8–2.1 1.9 \pm 0.11	1.4–1.6 1.5 \pm 0.04	1.2–1.3 1.2 \pm 0.05
<i>Paraboysidia paralella</i> n. sp. Holotype (7059), paratypes (7060)	43	2.3–2.9 2.7 \pm 0.16	1.6–2.2 1.8 \pm 0.14	1.1–1.7 1.4 \pm 0.13
<i>Gyliotrachela plesiolopa</i> n. sp. Holotype (7061), paratypes (7062)	29	1.5–2.2 2.0 \pm 0.16	2.6–3.4 3.2 \pm 0.16	0.4–0.7 0.6 \pm 0.05
<i>Angustopila singuladentis</i> n. sp. Holotype (7063), paratypes (7064)	50	0.7–1.0 0.6 \pm 0.06	0.6–0.9 0.8 \pm 0.05	0.9–1.2 1.1 \pm 0.06
<i>Sinoennea lizae</i> CUMZ 7065, 7066	7	4.2–4.9 4.5 \pm 0.22	1.7–1.9 1.8 \pm 0.06	2.2–2.7 2.4 \pm 0.15
<i>Sinoennea euryomphala</i> n. sp. Holotype (7067), paratypes (7068)	4	4.7–5.3 5.0 \pm 0.22	2.0–2.1 2.1 \pm 0.06	2.2–2.6 2.4 \pm 0.15

Derivation of name The specific name “*anguloobtusus*” is derived from the Latin word “*angular*”, meaning “tooth”, and “*obtusus*”, meaning “blunt”, and refers to the blunt angular lamellar tip, which is the prominent character of this species.

Distribution and habitat This new species were only found at the type locality. Snails occur on limestone wall, crevices with moss on the rock surface near the entrance of the cave and covered with thick vegetation (Fig. 1).

Comparisons *Paraboysidia anguloobtusus* n. sp. differs from *P. paviei* and *P. lamothei* in having blunt, angular lamella and a different shell shape. In comparison, *P. paviei* has infraparietal lamella seated closed to the parietal and angular lamellae, the latter of which are not curved, the suprapalatal lamella are absent and the peristome lip is less concaved, umbilicus widely opened. For *P. lamothei*, it has a larger shell size, inconspicuous growth line striae, more apertural barriers, infra-parietal present, angular lamella, very strong

seated at the edge of the peristome, and running downwards almost adnated to the upper palatal plica.

Paraboysidia anguloobtusus n. sp. differs from *P. nabhitabhatai* Panha & Burch, 2002, *P. wangviangensis* Panha & Tongkerd, 2002, *P. pangmapaensis* Panha & Burch, 2001 and *P. gittenbergeri* Maassen, 2008 in having a different shell shape, number of apertural barriers and their forms. In comparison, *P. nabhitabhatai* has a larger parietal lamella and the twisted, angular lamella has two cusps but is not curved, suprapalatal lamella is absent, and the embryonic shell is smooth. *Paraboysidia pangmapaensis* contains eleven apertural barriers, with upper palatal plica marginal and bifid, while *P. wangviangensis* has a smaller shell, a lower number of barriers, the largest and strong marginal angular lamella extends into the aperture and downwards closed to upper palatal plica, forming an angulo-palatal embayment. *Paraboysidia gittenbergeri* has a larger shell, descending aperture, fewer barriers and the angular and parietal lamellae locate downwards parallel to the upper and lower palatal plicae (Table 2).

Table 2 Comparative shell morphology of the *Paraboydsidia* spp., *Gyliotrachela* spp. and *Angustopila* spp.

Species	H×W (mm)	Whorls	Aperture shaped	Protoconch sculpture	Last whorl sculpture	Apertural barriers	Type locality	References
<i>Paraboydsidia</i>								
<i>P. puviet</i> *	1.8×1.5	5	Subtriangular	?	Scarcely growth striae	i ¹ present; long IPI.	Pac-Kha, Long-Ping, Vietnam	(Bavay & Dautzenberg, 1912)
<i>P. lamothai</i> *	3×2	5	Ssubquadrate	?	Inconspicuous growth-striae	A downward and meet uPI; i ¹ present	Muong-Kong, Vietnam	(Bavay & Dautzenberg, 1912)
<i>P. robusta</i> *	5×3.2	6	Subquadrate	Smooth	Irregular growth striae	A and P not separated; C oblique	Phong-Tho, Vietnam	(Bavay & Dautzenberg, 1912)
<i>P. nabhitabhatai</i>	1.7×1.3	4 ^{3/4}	Subcircular	?	Close-set, spiral striae	A with two cusps	Chaiyaphumi, Thailand	(Panha & Burch, 2001)
<i>P. wangciangensis</i>	1.2×1.0	4 ^{1/2}	Ovate	?	Spiral growth	A largest and strong	Vang Vieng, Laos	(Panha & Tongkerd, 2002)
<i>P. pangmapaensis</i>	1.7×1.1	4 ^{1/2}	subcircular	?	Spiral striae	P largest and twist	Mae Hongson, Thailand	(Panha & Burch, 2001)
<i>P. gittenbergeri</i>	4.1–5.8×2.5–3.0	5 ^{3/4}	Semi-rounded to ovate	Smooth	Irregular growth lines	A and P well separated	Luang Namtha, Laos	(Maassen, 2008)
<i>P. anguloobtusius</i> n. sp.	1.8–2.1×1.4–1.6	4 ^{3/4}	Heart-shaped	Carina spiral or striae	Fine spiral striae	A with curved	Luang Namtha, Laos	
<i>P. parallella</i> n. sp.	2.3–2.9×1.6–2.2	4 ^{3/4}	Oval to semi-circular	Spongy-like	Irregular growth lines	B present	Luang Namtha, Laos	
<i>Gyliotrachela</i>								
<i>G. crossei</i> *	3×4.5	5	Subtriangle	?	Irregular growth line or striae	c ¹ and B present	Tonkin	(Morlet, 1886)
<i>G. khaochongensis</i>	2.2×2.9	4	Rounded	Smooth	Irregular growth lines	c ¹ present; one i ¹ ; two i ³	Trang, Thailand	(Panha, 1997)
<i>G. saraburiensis</i>	2.2×2.9	4 ^{3/4}	Almost rounded, and upward about 17°	Pitted, spiral striae	Spiral striae	Three i ¹ ; i ³ ; five i ⁴ .	Saraburi, Thailand	(Panha & Burch, 2002)
<i>G. muangon</i>	1.8×1.3	4 ^{3/4}	Almost rounded	Spiral sulcus	Radial ribs	A and P well separated; c ² absent	Chiangmai, Thailand	(Panha & Burch, 2004)
<i>G. plesioloopa</i> n. sp.	1.5–2.2×2.6–3.4	4	Almost rounded, and upward about 20°	Distinct spongy-like	Irregular growth line or striae	A and P closed; two i ¹ ; one i ³ ; two i ⁴	Huaphan, Laos	

Species	H×W (mm)	Whorls	Aperture shaped	Protoconch sculpture	Last whorl sculpture	Apertural barriers	Type locality	References
<i>Angustopila</i>								
<i>A. concaea</i> *	1.0–1.2	4.6–5.3	Kidney-shaped	Reticulating granules	Spiral threads more apparent	Weak P	Nakhon Ratchasima, Thailand	(Thompson & Upatham, 1997)
<i>A. elevata</i> *	0.9×0.8	4	Ovate	Low granules	Fine raised spiral threads	P and PI absent	Chiangmai, Thailand	(Thompson & Upatham, 1997)
<i>A. tamlod</i>	1.0×0.8	4 ³ / ₄	Semicircular to oval	?	Spiral threads	P and PI	Mae Hong Son, Thailand	(Panha & Burch, 1999)
<i>A. huoyani</i> *	1.1×0.9	5	Semi-circular, oblique	Reticulating granules	Very fine irregular axial lamellae and reticulating microgranules	P and PI	Hunan, Huoyan, China	(Slapnik and Páll-Gergely, 2014)
<i>A. singuladentis</i> n. sp.	0.7–1.0× 0.6–0.9	4½	Almost circular	Spongy-like	Fine raise spiral crossed by irregular growth line	Only P	Houaphane, Laos	

? =Character not mentioned in the literature. *=Information was taken from the original descriptions.

¹=Characters in bold indicate the apertural barrier type, with the abbreviations as mentioned in the Materials and Methods.

Paraboysidia paralella Inkhavilay & Panha n.
sp.
Figs 1, 3A–C, 4C

Holotype CUMZ 7059 (H=2.7mm, W=2.3mm; Figs 3A–C).

Paratype CUMZ 7060 (42 specimens in ethanol), NHMUK (2 shells), SMF (2 shells).

Type locality Limestone wall near the entrance of Kao Rao Cave, Vieng Phouka District, Luang Namtha Province, Laos (20°43' 30.1" N, 101°9' 4.3" E), 732m amsl.

Diagnosis *Paraboysidia paralella* n. sp. has an elongate-heliciform shell shape. Embryonic shell large, perforated, with about 2¼ whorls. The aperture is semicircular shaped. Apertural barriers contain five major teeth (angular, parietal, columellar, and upper and lower palatal) with one small supracolumellar tooth and one basal tooth located in the deep of aperture. Peristome lip wide reflected.

Description Shell high spired, elongate-heliciform approaching oval with 4¾ whorls, straightened spire with deep sutures, shell height 2.3–2.9mm and width 1.6–2.3mm (Fig. 3A). Embryonic shell is large with about 2½ whorls and a perforated surface (Fig. 3C). Teleconch sculptured with thin and irregular growth lines. Seven apertural barriers: angular, parietal, columella and upper and lower palatal lamellae well developed. Angular lamella thickened, located almost at the apertural margin and extended downwards into aperture; parietal thickened and seated slightly deeper, parallel to angular lamella. Columellar lamella well developed; strong and oblique located at the apertural margin, oblique towards inside; a small supracolumellar lamella located deeper over columella lamella. Small convex knob-like basal plica located deeper inside. Upper and lower palatal plicae stout located inside after aperture (Fig. 3B, 4C). Umbilicus widely opened.

Derivation of name The specific epithet *paralella* is from the Latin "parallel", referring to the angular and parietal lamellae that are located parallel to each other.

Distribution and habitat The new species, *P. paralella* n. sp., is only found at the type locality, and is sympatric with *P. anguloobtusus* n. sp. The snails occurred on limestone walls and crevices with a moss covered rock surface near the entrance of the cave (Fig. 1).

Comparisons *Paraboysidia paralella* n. sp. differs from *P. pavei*, *P. lamothei* and *P. pangmapaensis*, the other large-shell snails in this genus. It has a shell height of over 2.3mm, the same as *P. lamothei*, but contains several types of apertural barriers. In comparison, *P. pavei* has a smaller shell (height 1.8mm), subtriangular aperture, supracolumellar and basal plica are absent, and the umbilicus is widely opened. *Paraboysidia lamothei* has a larger shell (height 3mm), nine apertural barriers, parietal lamella very strong and bended downwards with the upper palatal plica to form a rounded sinulus. *Paraboysidia pangmapaensis* has a smaller shell (height 1.7mm), eleven apertural barriers, shell sculptured with space spiral striae, and large, twisted parietal lamella (Table 2).

Genus *Gyliotrachela* Tomlin, 1930

Type species *Hypselostoma hungerfordianum* Möllendorff, 1891, by original designation.

Gyliauchen Pilsbry, 1917: 210.

Gyliotrachela Tomlin, 1930: 24 [nom. nov.]. Zilch, 1961. Schileyko, 1998: 140, 141.

Remarks The genus *Gyliotrachela* Tomlin, 1930 is characterized by having trumpet shaped tuba and a conical spire. Last whorl is straightened, short to long with regular, ascending or descending angles. Peristome expanded; angular and parietal lamellae separated and parallel. This genus differs from *Hypselostoma* Benson, 1856 in having separated angular and parietal lamellae, while these lamellae fused into a single or crescent in the *Hypselostoma* (Pilsbry, 1917; Panha and Burch, 2005).

Gyliotrachela is comprised of over twenty species recorded in Southeast Asia, West and North Australia (Schileyko, 1998), and over ten species have been recorded from Indochina, especially in Thailand and Vietnam (Panha & Burch, 2005; Schileyko, 2011). No *Gyliotrachela* species have been reported so far from Laos.

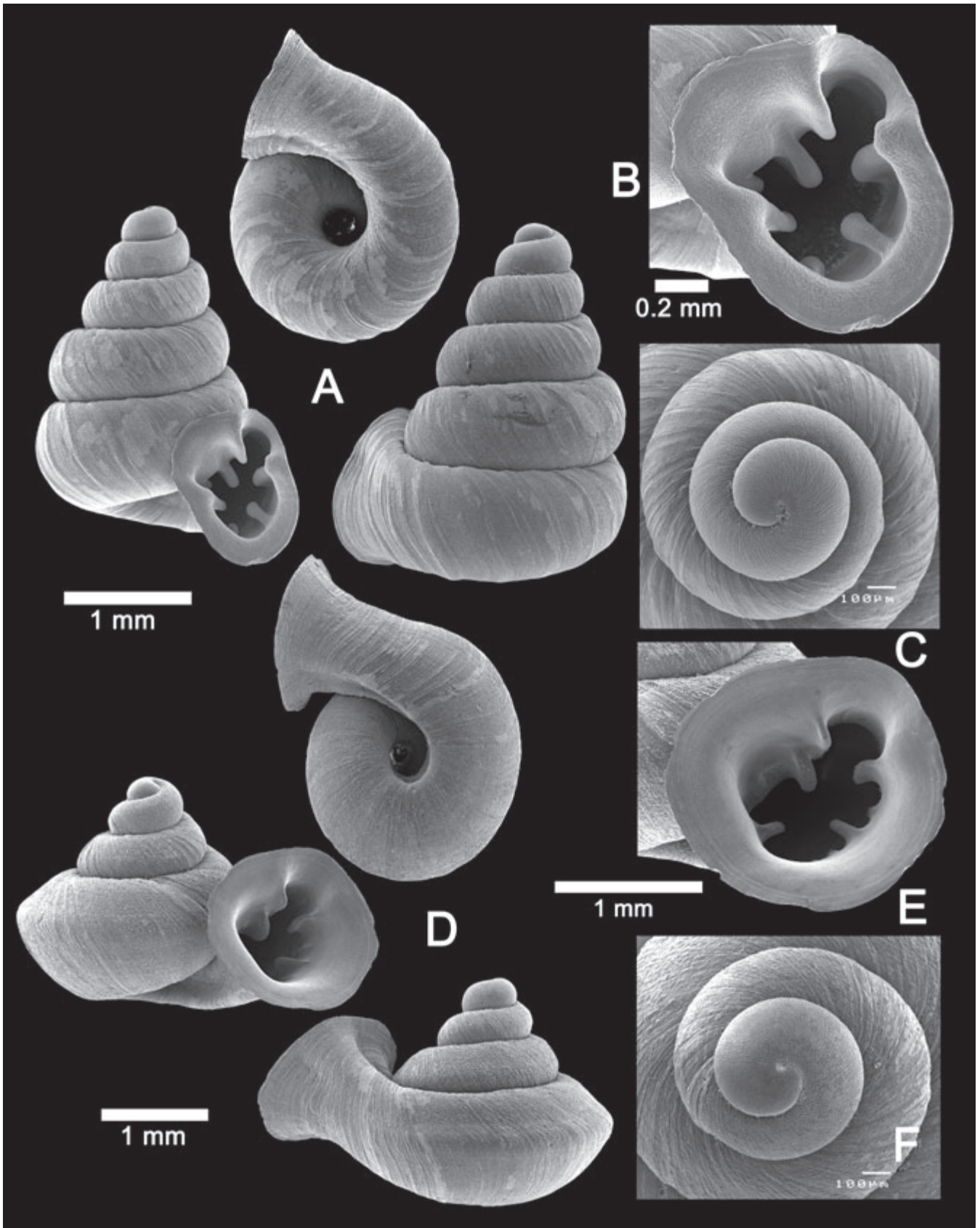


Figure 3 SEM images showing the shell shapes, apertural barriers and protoconch sculptures of (A–C) *Paraboyssidia paralella* n. sp. (holotype CUMZ 7059) from Luang Namtha and (D–F) *Gyliotrachela plesiolopa* n. sp. (holotype CUMZ 7061) from Houaphane.

Gyliotrachela plesiolopa Inkhavilay & Panha n. sp.

Figs 1, 3D–F, 4D

Type specimens Holotype CUMZ 7061 (H=1.9mm, W=3.5mm; Figs 3D–F).*Paratypes* CUMZ 7062 (28 specimens in ethanol), NHMUK (2 shells), SMF (2 shells).*Type locality* Limestone outcrop in Nawit Village, Viengxay District, Houaphane Province, Laos (20° 22' 37.3" N, 104° 16' 43.2" E), 695m amsl.*Diagnosis* *Gyliotrachela plesiolopa* n. sp. has a shell with slightly ascending tuba (about 20°). Protoconch distinct with perforated sculpture, teleoconch with a fine transverse or growth line or striae. Peristome has five major spinosed dentitions: angular, parietal, columellar and upper and lower palatal. There are two additional infraparietal plicae and one interpalatal plica. The angular lamella locates slightly superior outer, parietal lamella locates a bit lower inside.*Description* Shell minute, trumpet tuba, about four whorls and spire with short conic, shell height 1.5–2.2mm and width 2.6–3.5mm (Fig. 3D). Embryonic shell about 1½ whorls, with perforated sculpture (Fig. 3F). Teleoconch with fine and irregular growth line. Last whorl enlarged, with short and slightly ascending tuba, shouldered and weak angular; other whorls rounded. Sutures well impressed and deep. Aperture rounded; peristome free, continuous and broadly expanded. Apertural embayments are well developed, circular angulo-palatal, large oblong columellar-parietal, and shallow curved basal and rectangular palatal embayment. Numerous apertural barriers: parietal, angular, columellar and upper and lower palatal lamellae well developed. All of these barriers are spinosed and located deep inside the aperture, except the stout and elongate angular lamella is extended to the reflection of the peristome. Angular and parietal lamellae are elongated, located close to each other and nearly merge deep within the aperture, where the parietal lamella are seated lower than the angular lamella. Upper and lower palatal lamellae are well developed; two small interpalatal plicae: upper plica very small and lower plica large and prominent; two small infrapalatal plicae: upper plica large and more prominent

than lower plica; two small and weak infraparietal plicae present in curvature between parietal and columellar lamellae (Figs 3E, 4D). Umbilicus widely opened.

Derivation of name The specific epithet *plesiolopa* is derived from the Greek words “*plesios*”, meaning “near”, and “*lopas*”, meaning “plate”, and refers to the fact that the angular and parietal teeth are in close connection.*Distribution and habitat* This new species, *Gyliotrachela plesiolopa* n. sp., seems to be restricted to Houaphane Province, close to north Vietnam. The specimens were collected from a humid limestone wall, surrounded by anthropogenic settlements and dense fruit orchards (Fig. 1).*Comparisons* This new species differs from *G. crossei* (Morlet, 1886) from North Vietnam by its smaller shell and presence of four whorls, while *G. crossei* has a larger shell (shell height about 3mm) with five whorls. *Gyliotrachela plesiolopa* n. sp. differs from *G. saraburiensis* Panha & Burch, 2002 and *G. muangon* Panha & Burch, 2004 by having very closely located angular and parietal lamellae, a larger shell and perforated protoconch. *Gyliotrachela muangon* and *G. saraburiensis* can be clearly separated by the angular and parietal lamellae, while *G. muangon* has a smaller shell. *Gyliotrachela khaochongensis* Panha, 1997 has a larger shell size, last whorl is more ascending, and the peristome is continuous, thickened, expanded and with longer trumpet tuba (see Table 2).*Angustopila* Jochum, Slapnik and Páll-Gergely, 2014*Type species* *Systemostoma tamlod* Panha & Burch, 1999, by original designation.*Angustopila* Jochum *et al.* 2014: 26, 27.*Remarks* This genus is comprised of tiny veriginid snails with a conical shaped shell, reticulated protoconch, aperture slightly closed or adnated to the last whorl and with or without apertural lamella (Panha and Burch, 1999b; Jochum *et al.*, 2014). *Angustopila* is distinguished from *Tonkinospira* Jochum *et al.*, 2014 (= preoccupied name *Systemostoma* Bavay & Dautzenberg, 1908) by having a tiny shell (shell height ~1mm)

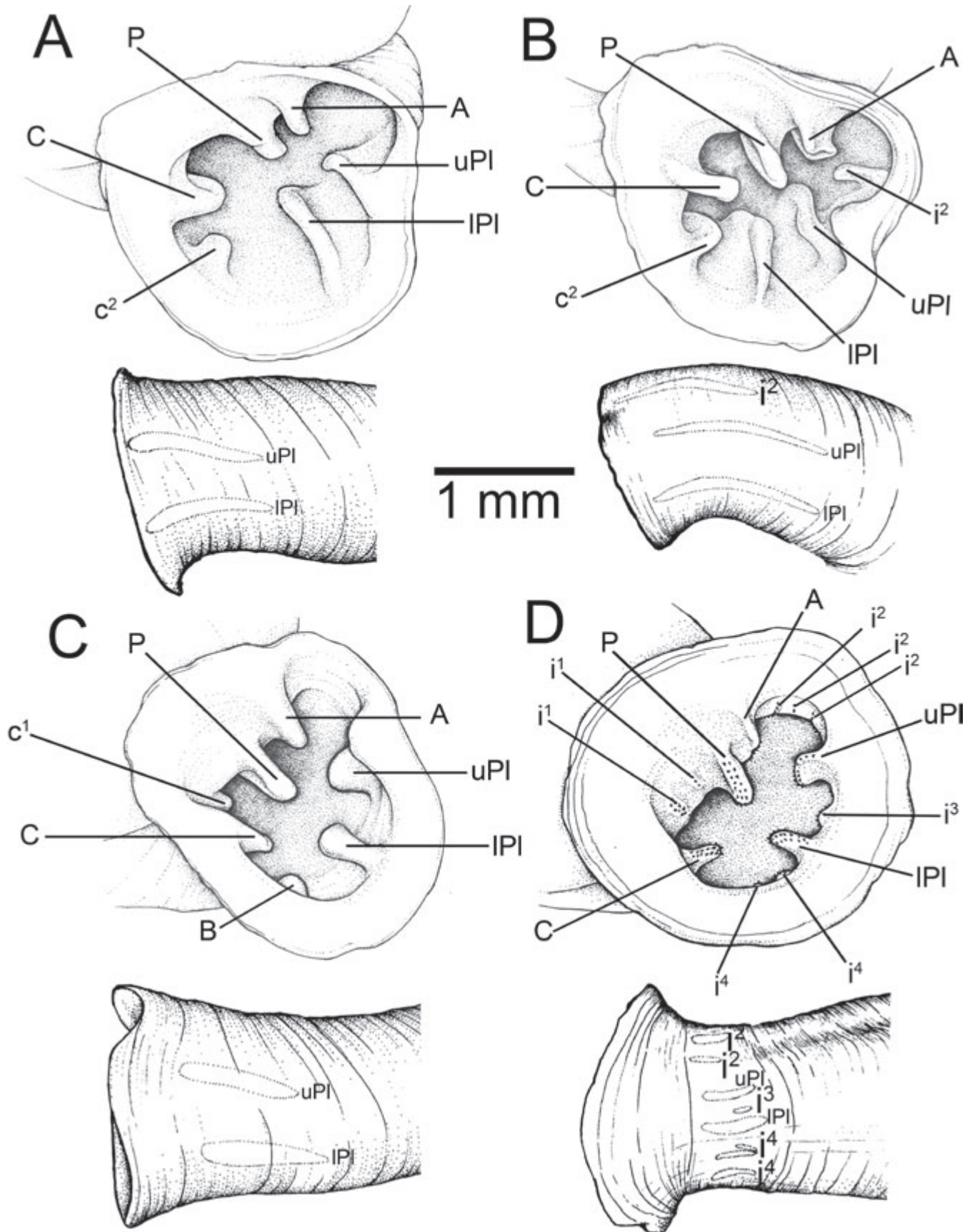


Figure 4 Illustrations of the shell apertural barriers showing the lamellae and plicae of (A) *Paraboydsidia gittenbergeri*, (B) *Paraboydsidia anguloobtusus* n. sp., (C) *Paraboydsidia paralella* n. sp. and (D) *Gyltiotrachela plesiolopa* n. sp.

usually with apertural lamella, while *Tonkinospira* have larger shells (shell height 1–2.5mm) and a lack of apertural lamella.

In addition, *Angustopila* is distinguished from *Krobylos* Panha & Burch, 1999 and *Montapiculus* Panha & Burch, 1999 by having a smaller shell (height usually < 1mm), with a rounded whorl, apertural dentition varies from absent to containing parietal lamella and palatal plicae. In comparison, *Krobylos* has a larger shell (height 1.5–2.3mm) with an angular whorl and no apertural dentition, and *Montapiculus* has a very wide and deep umbilicus, descending tuba and one palatal plica (Panha & Burch, 1999c) (Table 4).

Angustopila currently comprises of nine species; five species (*A. dominikae*, *A. fabella*, *A. huoyani*, *A. subelevata* and *A. szekeresi*) from China, three species (*A. concava*, *A. elevata* and *A. tamlod*) from Thailand and one (*A. neglecta*) from peninsular Malaysia. All of these species are restricted to limestone areas and three of them (*A. neglecta*, *A. huoyani* and *A. tamlod*) have only been discovered only in caves.

Angustopila singuladentis Inkhavilay & Panha
n. sp.
Figs 1, 5A–C

Holotype CUMZ 7063 (H=1.1mm, W=0.9mm; Figs 5A–C).

Paratype CUMZ 7064 (49 specimens in ethanol), NHMUK (2 shells), SMF (2 shells).

Type locality Xang Lod Cave, Viengxay District, Houaphane Province, Laos (20°24' 31.3" N, 104°13' 19.7" E), 882m amsl.

Diagnosis *Angustopila singuladentis* n. sp. has a conical shell, rounded whorls and shell sculptured with irregular growth line crossed with fine spiral striae. Protoconch is perforated. Aperture simple, peristome slightly expanded with a strong parietal lamella.

Description Shell minute, conical, white and transparent, about 3½ whorls, rounded, spire conical, suture depressed and blunt apex, shell height 0.7–1.0mm and width 0.6–0.9mm (Fig. 5A). Embryonic shell about 1½ whorls, nearly smooth with perforated sculpture (Fig. 5C). Teleoconch with irregular growth lines crossed

with fine spiral threads. Last whorl shouldered. Aperture circular, open vertically, peristome continuous, lip slightly thickened and slightly expanded. Parietal callus thickened and slightly elevated from the last whorl. Apertural barrier well developed, thickened with strong parietal lamella (Fig. 5B). Umbilicus narrow and deep.

Derivation of name The specific epithet *singuladentis* is derived from the Latin words “*singulus*”, meaning “one”, and “*dentis*”, meaning “tooth”, and refers to the single parietal lamella.

Distribution and habitat The new species, *Angustopila singuladentis* n. sp., is currently known only from the type locality. The specimens were collected on the wet stalactites and on the cave walls at about 100 to 200m inside from the cave entrance. However, the Xang Lod Cave (= pass through by the elephant) has become a famous tourist attraction site, the activities of which may impact negatively upon the population of these endemic cave dwelling snails (Fig. 1).

Comparisons This new species closely resembles *A. tamlod*, but is distinct in having only one parietal lamella and three whorls, while *A. tamlod* has one parietal lamella and a small palatal plica with four whorls. *Angustopila singuladentis* n. sp. differs from *A. huoyani* Jochum *et al.*, 2014 in having a smaller shell, three rounded whorls with thin spiral striae and one parietal lamella, whereas *A. huoyani* has a larger shell, five shouldered whorls with reticulated granules, and with one parietal lamella and one palatal plica.

This new species can be distinguished from *A. elevata* (Thompson & Upatham, 1997) and *A. concava* (Thompson & Upatham, 1997) by having three whorls, a rounded aperture, peristome adnate to the preceding whorl and a strong parietal lamella. In comparison, *A. concava* has 5–6 whorls, a wide umbilicus and curved parietal wall, while *A. elevata* has four whorls, peristome free from the preceding whorl and lamella absent (Table 1).

Family Diapheridae Panha & Naggs, 2010
Genus *Sinoennea* Kobelt, 1904

Type species *Pupa strophiodes* Gredler, 1881, by original designation.

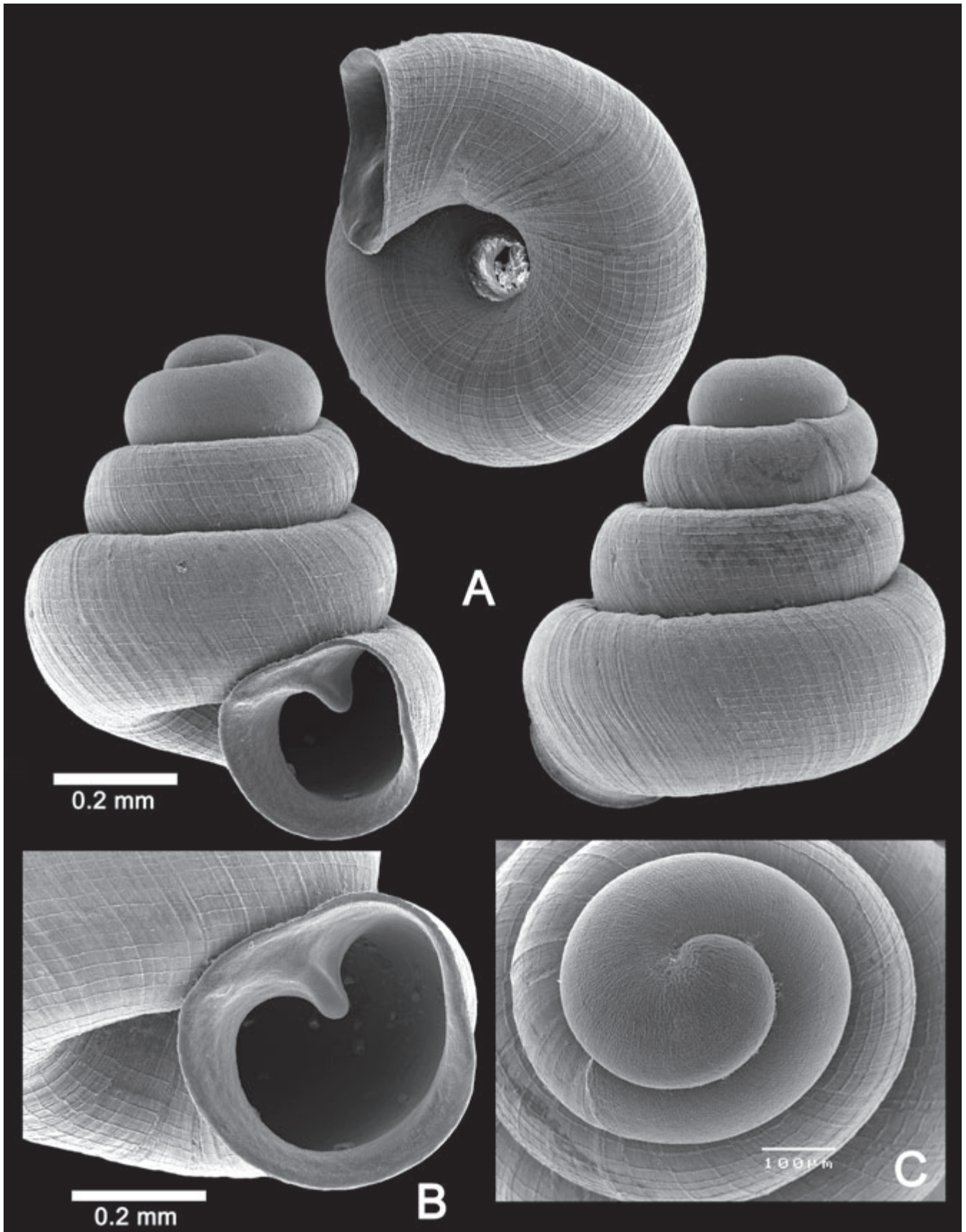


Figure 5 SEM images of shells showing the apertural barriers and protoconch sculpture of (A–C), *Angustopila singuladentis* n. sp. (holotype CUMZ 7063) from Houaphane.

Ennea (*Sinoennea*) Kobelt, 1904: 26, 30.
Sinoennea—Zilch, 1960: 573. Richardson, 1988: 154. Benthem Jutting, 1961: 8, 9. Schileyko, 2000: 800.

Remarks The genus *Sinoennea* is characterized by having a pupa- to long cylindrical-shaped shell with strong axial ridges to a smooth surface and a wide to narrow umbilicus. Aperture rounded to oval shaped, apertural barriers normally contain parietal, columellar and basal lamellae with small palatal lamella sometimes present (Kobelt, 1904; Zilch, 1959–1960; Benthem Jutting, 1961; Schileyko, 2000).

The genus is comprised of about 55 nominal species (Richardson, 1988), and two newly described species were recorded from Thailand (Panha & Burch, 2005). Over ten species have been recorded from Indochina areas, including South China (Yen, 1939; Panha & Burch, 2005; Schileyko, 2011).

Sinoennea lizae Maassen, 2008

Figs 1, 6A–C

Sinoennea lizae Maassen, 2008: 235, figs 1–4.

Type locality 500m SE of Phou Lek Village, Oung Pra Ngiene, Vieng Phouka, Luang Namtha, Laos.

Material examined Vieng Sawang Village, Vieng Phouka District, Luang Namtha Province, Laos (20°41' 14.9" N, 101°4' 8" E), and 687m amsl: CUMZ 7065 (1 shell, Fig. 6A); CUMZ 7066 (7 shells).

Remarks *Sinoennea lizae* differs from *S. macrodonta* (Bavay & Dautzenberg, 1912) and *S. hippocrepis* (Bavay & Dautzenberg, 1912) from north Vietnam in having a larger shell (height about 4–5mm), nine whorls, ovate aperture, and the parietal callus extended about two-thirds of the last whorl. *Sinoennea macrodonta* has a smaller shell (height about 3mm), six whorls, subcircular aperture and bifurcated palatal lamella, and *S. hippocrepis* has a larger shell (height 8mm), ten whorls, rounded peristome and a weaker palatal plica (Table 3).

Sinoennea lizae is only known from Luang Namtha, Northern Laos. All shells were collected from the ground among the thick leaf litter at a limestone outcrop base (Fig. 1).

Sinoennea euryomphala Inkhavilay & Panha n. sp.
 Figs 1, 6D–F,

Holotype CUMZ 7067 (H=5.1, W=2.2; Figs 6D–F).

Paratypes CUMZ 7068 (3 shells), NHMUK (1 shells), SMF (1 shells).

Type locality Phathok Cave, Ngoi District, Luang Phrabang Province, Laos (20°33' 17.6" N, 102°37' 47.0" E), 330m amsl.

Diagnosis *Sinoennea euryomphala* n. sp. has well developed transversed ribs (35 ribs on the last whorl); embryonic shell smooth. Aperture is ovate and free from the last whorl. Apertural barriers consist of a thick, strong curved angular lamella; upper and lower palatal lamellae are almost separated. Umbilicus is opened widely.

Description Shell is pupa shaped, much inflated compared to *S. lizae*, and white and transparent with 8–9 whorls. Preceding whorls gradually increasing in size to largest last whorl before transforming to tuba and aperture. Shell height 4.7–5.3mm and width 2.0–2.1mm (Fig. 6D). Apex obtuse; embryonic shell about 2¾ whorls, smooth surface (Fig. 6F), and subsequent whorls with strong radial ridges of about 35 ridges on last whorl. Last whorl flattened; other whorls moderately rounded; suture depressed and wide. Aperture narrow, subcircular shaped, opened vertically. Peristome continuous, broad and free from last whorl; lip thickened, expanded and slightly reflected. Parietal-angular lamella large, strong, crest-like shape and slightly curved entering the aperture. Palatal plica bifurcated and reaches to the apertural margin. Columellar long, high fold vertically located in the interior of the aperture (Fig. 6E). Umbilicus widely opened and deep.

Derivation of name The specific name "*euryomphala*" is derived from the Greek words "*eury*", meaning "broad or wide", and "*omphalos*", meaning "navel, and refers to the widely opened umbilicus, which is the prominent character of this species.

Distribution and habitat *Sinoennea euryomphala* n. sp. is known only from the type locality. The specimens were collected on the ground under thick leaf litter and some specimens were found

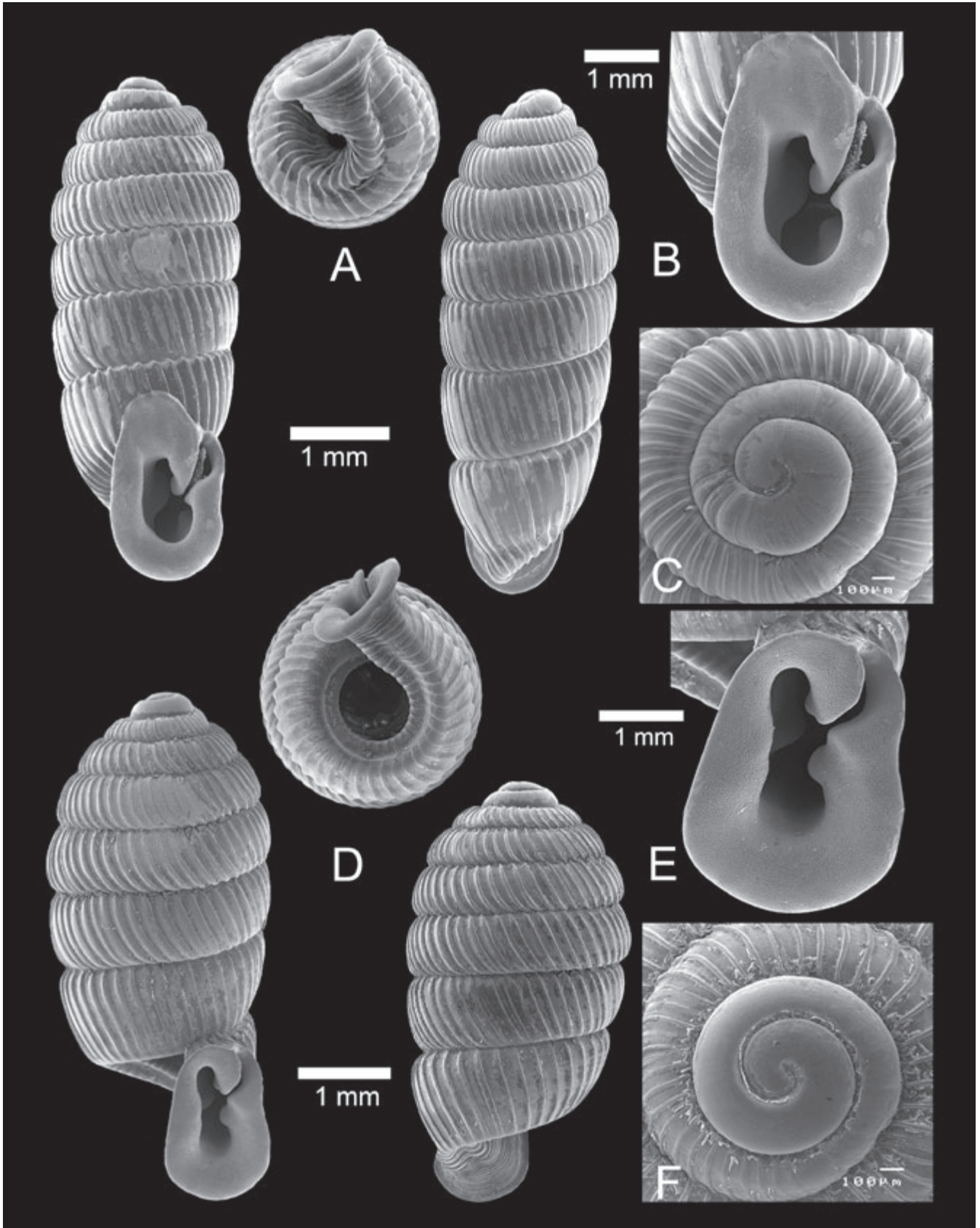


Figure 6 SEM images of shells showing the apertural barriers and protoconch sculptures of (A–C) *Sinoennea lizae* (CUMZ 7065) from Luang Namtha and (D–F) *Sinoennea euryomphala* n. sp. (holotype CUMZ 7067) from Luang Phrabang.

Table 3 Comparative shell morphological characters among the *Sinoennea* species.

Species	Height	Whorls	Aperture shaped	Apertural barriers ¹	Protoconch sculpture	Type locality	References
<i>S. larvula</i> *	3.45	6	Quadrangular	P, C and weak PI	?	Ning-Kuo-fu Anhwei, China	(Heude, 1882)
<i>S. fuchsi</i> *	5–5.5	8	Ovate-triangular	P, C and PI	Carina striae	Kwei-dshou, China	(Gredler, 1885)
<i>S. calva</i> *	4	6	Subcircular	P, C, PI and B	Smooth	Haiphong, Vietnam	(Dautzenberg, 1893)
<i>S. atomaria</i> *	2.5	5	Quadrangular?	P, C, PI and B	Smooth	Haiphong, Vietnam	(Dautzenberg, 1893)
<i>S. hippocrepis</i> *	8	10	Subcircular	P, C and PI	Smooth	Phong-Tho, Tonkin	(Bavay & Dautzenberg, 1912)
<i>S. macrodomia</i> *	3	6½	Subtriangle	P, C and bifid PI	?	Muong Kong, Tonkin	(Bavay & Dautzenberg, 1912)
<i>S. kwangsiensis</i> *	3.5	7	Rounded	P, C and two PI	Smooth	Kwangsi, China	(Yen, 1939)
<i>S. prima</i>	4.9	8½	Quadrangular-ovate	P, C and two PI	Smooth	Chiangmai, Thailand	(Panha & Burch, 1999)
<i>S. ranongensis</i>	2.7	5¾	Subtriangle to heart-shape	P, C and two PI	Fine striae	Ranong, Thailand	(Panha <i>et al.</i> , 2006)
<i>S. lizae</i>	3.4–3.6	8½	Long-oval	P, C and spaced PI	Smooth	Luang Namtha, Laos	(Maassen, 2008)
<i>S. euryomphala</i> n. sp.	4.7–5.3	9	Subcircular	P, C and PI	Smooth	Luang Phrabang, Laos	

? =Character not mentioned in the literature. * =Information was taken from the original descriptions.

¹ =Characters in bold indicate the apertural barrier type, with the abbreviations as mentioned in the Materials and Methods.

Table 4 Comparative shell morphological characters among the four genera: *Krobylos* Panha & Burch, 1999, *Montapiculus* Panha & Burch, 1999, *Tonkinospira* Jochum *et al.*, 2014 and *Angustopila* Jochum *et al.*, 2014.

Characters	<i>Krobylos</i> *	<i>Montapiculus</i> *	<i>Tonkinospira</i> *	<i>Angustopila</i> *
Type species	<i>K. pomjuk</i> Panha & Burch, 1999	<i>M. proboscidea</i> Panha & Burch, 1999	<i>Systemostoma pauperrima</i> Bavay & Dautzenberg, 1908	<i>Systemostoma tamlod</i> Panha & Burch, 1999
Shell shape	Helicoid, with a depressed to elongate spire	Mountain-shaped, raise spire	Conical or depressed conical	Conical
Shell height (mm)	1.4–2.3	1.6	1–2.5	0.9–1.2
Shell width (mm)	1.2–2.1	1.55	1.6–2.5	0.80–1.1
Whorl numbers	3–5	5	4–5	4–5
Aperture	Ovate to semi-circular and adnate to last whorl	D-shape with descending tuba	Oblique and adnate to Last whorl	Ovate, oblique or semi-circular and free from last whorl
Apertural barriers	Absent	Parietal and palatal	Absent	One or two barriers
Protoconch sculpture	Smooth	Smooth	Spiral line	Smooth
Last whorl	Ddescending	Directed downward	Descending	Descending
Last whorl sculpture	Without spiral striae	With spiral striae	Without spiral striae	Without spiral striae
Umbilicus	Narrow	Very wide and deep	Narrow to wide	Narrow
Distribution	Northern Thailand and Laos	Central Thailand	Northern Vietnam	Northern Thailand and South of China

?=Character not mentioned in the literature. *=Information was taken from the original descriptions.

in the rock crevices of a limestone wall outside the cave (Fig. 1). The evergreen forest vegetation was dense with mosses on limestone walls.

Comparisons *Sinoennea euryomphala* n. sp. differs from *S. macrodonta* and *S. hippocrepsis* in having nine whorls, a widely opened umbilicus and the peristome is free from the last whorl. In comparison, the two latter species have a narrow to rimate umbilicus and the peristome adnated to the last whorl. In addition, *S. macrodonta* has a smaller shell with six whorls, while *S. hippocrepsis* has a larger shell, 10 whorls and a rounded peristome (Table 3).

This new species can be distinguished from *S. calva* (Dautzenberg, 1893) and *S. atomaria* (Dautzenberg, 1893) in having a widely opened umbilicus and a peristome free from the penultimate whorl. In contrast, the latter two species have a peristome adnated to the last whorl and a very narrow umbilicus. In addition, *S. calva* has a smaller shell, aperture sub-circular, suture impressed, and six whorls. *Sinoennea calva* has a

strong columella, firmly located inside the aperture, while *S. atomaria* has a very small shell size with five whorls.

Sinoennea euryomphala n. sp. differs from *S. prima* Panha & Burch, 1999 and *S. lizae* in its widely opened umbilicus and peristome free from the last whorl. In comparison, *S. prima* has 27 radial ribs on the last whorl, the peristome is rounded, thickened and expanded, with very strong parietal and two palatal barriers nearly equal in size, while *S. lizae* has a smaller shell size that is cylindrical shaped, white, glossy and transparent, the aperture is adnated about 3/4 of the penultimate whorl, parietal lamella project downwards in close connection to the upper palatal lamella making a small parieto-palatal slit, the large columellar lamella are seated deeper inside (Table 3).

DISCUSSION

This paper is the first revision of the micro pulmonate snails in Laos since the first species,

Paraboydsidia wangviengensis Panha and Tongkerd, 2002, was described. The two limestone faunistic surveys in Laos from 2013–2014 showed that the malacofauna were not diverse even in limestone areas. Some larger snails, such as ariophantids, camaenids, plectopylids, streptaxids and subulinids, have been discovered, but these were less diverse compared to the records from the same latitude in Thailand and Vietnam or at a different latitude in Malaysia (Bentham Jutting, 1949; Panha and Burch, 2005; Schileyko, 2011). The apparently low species diversity in Laos may, however, reflect that the surveys in Laos had less sampling sites and also examined fewer caves, while the sampling period during September 2013 to December 2014 was quite dry with an average rainfall from 180mm in September gradually decreasing to 10mm in December (The National Hydrological and Meteorological Services, 2014). Therefore, repeat samplings are still needed to confirm whether northern Laos is less diverse for terrestrial snails.

Paraboydsidia anguloobtusus n. sp. and *P. paralella* n. sp. were collected from almost the same locality as *P. gittenbergeri* Maassen, 2008, in Luang Namtha province. However, they proved to be separate species because of the quite unique apertural barriers compared to the several described species from nearby areas, such as *P. lamothei* (Bavay & Dautzenberg, 1912), *P. nabhitabhatai* Panha and Burch, 2002, *P. pangmapaensis* Panha and Burch, 2001, *P. paviei* (Bavay & Dautzenberg, 1912) and *P. wangviangensis* Panha and Tongkerd, 2002. The great angular dentitions are prominent for both new species, although the palatal and parietal lamellae arrangements and size are quite varied (Figs 2, 3 and 4).

Gyliotrachela plesiolopa n. sp. is the first species of the genus recorded in Laos and had similar shell characters to the other described species, with a close location between the angular and parietal lamellae and an approximately medium sized shell compared with the other described species. The genus *Gyliotrachela* seems to be very conservative in showing almost identical shell characters and their trumpet shaped last whorls is an easily observed characteristic when attached to limestone walls.

Angustopila singuladentis n. sp. is also the first species of this genus recorded in Laos, and is a tiny cave dwelling species living mostly on wet stalactite structures. The three whorls and one

parietal lamella are the dominant characters. It seems that the new species has the lowest number of whorls (three) compared with other described species in this genus that have 4–6 whorls.

Sinoennea euryomphala n. sp. is the second diapherid species ever recorded in Laos, with *S. lizae* Maassen, 2008 being the first one. Both species are found in the north of Laos. *Sinoennea lizae* has a cylindrical-shaped shell, while the new species has a pupa shaped or inflation shell character. The close connection of the parietal lamella and upper palatal lamellae makes an embayment in *S. lizae* but becomes a parieto-palatal slit in *S. euryomphala* n. sp. are the diagnostic separating characters.

The identification of micro terrestrial snails by their shells is still a standard method for the family Vertiginidae, which has been found to be informative with a strong discriminatory power in many genera, such as *Boysidia*, *Paraboydsidia* and *Hyselostoma*, but is controversial in many other genera, such as *Acinolaemus*, *Anauchen* and *Gyliotrachela* (Thompson and Upatham, 1997; Panha and Burch, 2005). Systematic analysis using DNA sequencing has been employed and proved to support the shell identification in many genera (Tongkerd *et al.*, 2004; Schilthuisen *et al.*, 1999; 2004). However, further molecular analyses at both the species and population levels are needed for making a standard classification of terrestrial micro pulmonate snails.

ACKNOWLEDGEMENTS

The authors are grateful to members of the Animal Systematics Research Unit for kind help during field collecting. We express our gratitude to the Dean and Secretary Office members of the Faculty of Natural Science, National University of Laos for their kind support in processing the permission documents during the field surveys and data collection in Laos. This project was mainly funded by TRF Senior Research Scholar (2015–2018) (RTA5880002) to SP, and CU-ASEAN Scholarship Chulalongkorn University for a full Ph.D. study to KI to study at Department of Biology, Faculty of Science, Chulalongkorn University together with The 90th Anniversary of Chulalongkorn University Fund. Thanks also go to Thita Krutchuen for kindly providing the excellent illustrations.

REFERENCES

- ANCEY CF 1881 Description de mollusques terrestres nouveaux. *Le Naturaliste* **1** (47): 373–374.
- BAVAY A & DAUTZENBERG P 1908 Molluscorum terrestrium tonkinorum diagnoses. *Journal de Conchyliologie* **56**: 229–251.
- BAVAY A & DAUTZENBERG P 1912 Description de coquilles nouvelles de l'Indo-Chine. *Journal de Conchyliologie* **60**: 1–54.
- BENSON WH 1856 Description of *Tanystoma tuberiferum*, a Burmese form related to the genus *Anostoma* of Lamarck. *The Annals and Magazine of Natural History*, ser. 2, no. 17: 129–131.
- BENTHEM JUTTING WSS VAN 1949 The Malayan species of *Boysidia*, *Paraboysidia*, *Hypselostoma* and *Gyliotrachela* (Gastropoda, Pulmonata, Vertiginidae) with a catalogue of all the species hitherto described. *Bulletin of the Raffles Museum* **21**: 5–47.
- BENTHEM JUTTING WSS VAN 1961 The Malayan Streptaxidae genera *Hultonella* and *Sinoennea*. *Bulletin of the Raffles Museum* **26**: 5–33.
- BOUCHET P & ROCROI JP 2005 Malacologia classification and nomenclator of gastropod families. *Malacologia* **47**: 1–397.
- BURCH JB & PANHA S 2002 New taxa of Pupillidae (Pulmonata: Stylommatophora) from Thailand. *Walkerana* **13**: 129–187.
- DAUTZENBERG P 1893 Mollusques nouveaux recueillis au Tonkin par M. le Capitaine Em. Dorr. *Journal de Conchyliologie* **41**: 157–165.
- GREDLER V 1881 Zur conchylien-fauna von China II. Stück. *Jahrbücher der Deutschen Malakozoologische Gesellschaft* **8**: 110–132.
- JOCHUM A, SLAPNIK R, KAMPSCHULTE M, MARRTELS G, HENEKA M & PÁLL-GERELY B 2014 A review of the microgastropod genus *Systemostoma* Bavay and Dautzenberg, 1908 and a new subterranean species from China (Gastropoda, Pulmonata, Hypselostomatidae). *ZooKeys* **410**: 23–40.
- KOBELT W 1904 Die systematischen Stellung der chinesischen Fauna. *Nachrichtsblatt der Deutschen Malakozoologischen Gesellschaft* **36**: 26–30.
- MAASSEN WJM 2008 Remarks on a small collection of terrestrial molluscs from north-west Laos, with descriptions of three new species (Mollusca: Pulmonata: Streptaxidae, Vertiginidae). *Basteria* **72**: 233–240.
- MORLET L 1886 Liste des coquilles recueillies au Tonkin par M. Jourdy, chef d'escadron d'artillerie, et description d'espèces nouvelles. *Journal de Conchyliologie* **34**: 257–295.
- PANHA S 1997 A new species of *Gyliotrachela* from Thailand (Pulmonata: Vertiginidae). *Malacological Review* **30**: 123–126.
- PANHA S & BURCH JB 1999a [1998–1999] First records and new species of *Boysidia* and *Sinoennea* from Thailand. *Malacological Review* **31/32**(2): 117–122.
- PANHA S & BURCH JB 1999b New taxa of Pupillidae (Pulmonata: Systellommatophora) from Thailand. *Walkerana* **10**: 113–134.
- PANHA S & BURCH JB 1999c [1998–1999] Two new genera of pupillid snails from Thailand (Pulmonata: Pupillidae: Gastrocoptinae). *Malacological Review* **31/32**(2): 143–153.
- PANHA S & BURCH JB 2000 A new species of *Paraboysidia* from Thailand (Pulmonata: Pupillidae). *Walkerana* **11**: 107–112.
- PANHA S & BURCH JB 2001 The pupillid genus *Paraboysidia* in Thailand (Pulmonata: Stylommatophora). *Walkerana* **12**: 77–94.
- PANHA S & BURCH JB 2002 New pupilloid land snails from Thailand (Pulmonata: Pupillidae) *The Natural History Journal of Chulalongkorn University* **2**: 21–24.
- PANHA S TONGKARD P SUTCHARIT S TUMPEESUWAN S & VONGSOMBATH C 2002 A new species of *Paraboysidia* (Pupillidae: Gastrocoptinae) from Laos. *Walkerana* **13**: 123–128.
- PANHA S TONGKARD P SUTCHARIT S & BURCH JB 2004 New pupillid species from Thailand (Pulmonata: Pupillidae). *The Natural History Journal of Chulalongkorn University* **4**: 57–82.
- PANHA S & BURCH JB 2005 [2004–2005]. An introduction to the microsnails of Thailand. *Malacological Review* **37/38**: 1–155.
- PANHA S SUTCHARIT C & TONGKARD P 2005 [2005–2006] A new *Sinoennea* from Southern Thailand (Pulmonata: Streptaxidae). *Malacological Review* **33/34**: 105–110.
- PILSBRY HA 1917 [1916–1918] Pupillidae (Gastrocoptinae). Manual of Conchology. Second Series, Volume 24. The Conchological Department, The Academy of Natural Sciences of Philadelphia, Philadelphia. Pp. i-xii, 1–380, pls 1–49. [Published in parts, for dates see Clench and Turner, 1962].
- RICHARDSON L 1988 Streptaxacea: Catalog of species, Part I, Streptaxidae. *Tryonia* **16**: 1–326.
- SCHILEYKO AA 1998 Treatise on recent terrestrial pulmonate molluscs. Part 2. Gastrocoptidea, Hypselostomatidae, Vertiginidae, Truncatellinidae, Pachynodidae, Enidae, Sagdidae. *Ruthenica Supplement* **2**: 129–261.
- SCHILEYKO AA 2000 Treatise on recent terrestrial pulmonate molluscs. Part 6. Rhytididae, Chlamydephoridae, Systrophiiidae, Haplotrematidae, Streptaxidae, Spiraxidae, Oleacinidae, Testacellidae. *Ruthenica Supplement* **2**: 731–880.
- SCHILEYKO AA 2011 Check-list of land pulmonate molluscs of Vietnam (Gastropoda: Stylommatophora). *Ruthenica* **21**: 1–68.
- SCHILTHUIZEN M, CABANBAN AS & HAASE M 2004 Possible speciation with gene flow in tropical cave snails. *Journal of Zoological Sciences* JZS doi: 10.1111/j.1439-0469.2004.00289.133-138.
- SCHILTHUIZEN M VERMEULEN JJ DAVISON GWH & GITTEBERGER E 1999 Population structure in a snail species isolated Malaysian limestone hills, inferred from ribosomal DNA sequences. *Malacologia* **41**: 283–296.
- THE NATIONAL HYDROLOGICAL AND METEOROLOGICAL SERVICES OF LAO PDR 2014. Hydrological and Meteorological reports in Lao PDR for 2014.

- THOMPSON FG & UPATHAM ES 1997 Vertiginid land snails from Thailand (Gastropoda, Pulmonata, Pupilloidea). *Bulletin of Florida Museum of Natural History* **39**: 221–245.
- TOMLIN JR LE B 1930 Some preoccupied generic names II. *Proceedings of the Malacological Society of London* **19**: 22–24.
- TONGKerd P LEE T PANHA S BURCH JB & O FOIGHIL 2004 Molecular of certain Thai gastrocoptine micro land snails (Stylommatophora: Pupillidae) inferred from mitochondrial and nuclear ribosomal nuclear DNA sequences. *Journal of Molluscan Studies* **70**: 139–147.
- YEN TC 1939 Die Chinesischen Land-und Süßwasser-Gastropoden des Natur-Museums Senckenberg. *Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft* **444**: 1–235.
- ZHANG WH, CHEN DN & ZHOU WC 2014 Two new species of the genus *Boysidia* from China, with a preliminary discussion of its geography (Pulmonata: Stylommatophora: Pupillidae). *Zoological Systematics* **39**: 570–575.
- ZILCH A 1959–1960 Gastropoda, Teil 2, Euthyneura. In: Schindewolf O.H. (Ed.), *Handbuch der Paläozoologie*. Band 6. Gebrüder Borntraeger, Berlin, 833 pp. [Published in parts, 1959 (pp. 1–400) and 1960 (pp. 401–833)]
- ZILCH A 1961 Die Typen und Typoide des Natur-Museums Senckenberg **24**: Mollusca, Streptaxidae. *Archiv für Molluskenkunde* **90**: 79–120.