

THE LANDSNAIL GENUS *METODONTIA* MOELLENDORFF (PULMONATA: STYLOMMATOPHORA: BRADYBAENIDAE) OF CHINA

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Abstract The bradybaenid genus *Metodontia* Möllendorff is revised based on the literature and both loessial fossil and recent specimens. *M. yantaiensis* and *M. beresowskii* are re-described conchologically and/or anatomically. *M. bidentatus* and *M. wuduensis* are proposed to be new to science. *M. yantaiensis tetrodon* is sunk as a synonym of *M. yantaiensis*, due to the insufficient differentiation between them. Thus, a total of six valid species of the genus are known in China: *M. huaiensis*, *M. yantaiensis*, *M. griphodes*, *M. beresowskii*, *M. bidentatus* new species, and *M. wuduensis* new species. This study has failed to show the difference between fossil and recent *M. huaiensis huaiensis*, detected by the principal component analysis on the data comprising seven shell parameters. It suggests the distribution ranges of *M. yantaiensis* and *M. huaiensis* do not overlap each other. Illustrations of genital systems of *M. beresowskii*, *M. yantaiensis* and *M. bidentatus* new species, figures of shells and a key to the revised *Metodontia* species based on the shell, are provided.

Key words Helicoidea, Bradybaenidae, *Metodontia*, new synonym, new species, China.

INTRODUCTION

Metodontia Möllendorff, 1886 is a genus of the most ancient representatives of bradybaenid snails (Wu, 1999). It also occurs as a major component of terrestrial molluscs in the Chinese loessial regions (Odhner, 1925; Pilsbry, 1894; Ping, 1929, 1931; Yen, 1935; Li, 1966; Chen, 1987). Their distribution range, which is defined by local records of both fossils and living snails (Crosse & Debeaux, 1863, 1864; Möllendorff, 1881, 1886, 1899, 1901; Heude, 1882-1890; Sturany, 1901; Gude, 1902; Odhner, 1926; Yen, 1935, 1939, 1942; Liu, 1966; Chen & Gao, 1987, 1988), demonstrates that *Metodontia* is a native endemic to the northern and northwestern loessial regions of China. Detailed study of fossil landsnails and their recent corresponding representatives will be undoubtedly helpful to understand the environmental evolution process in Chinese loessial regions and their neighbouring areas (Liu, 1966).

However, the genus *Metodontia* has never been revised, so the comparisons both to other bradybaenid genera and within the genus are wanting. *Metodontia* is not species-rich in comparison to the other genera in the Bradybaenidae. Prior to this study, the genus included four species and two subspecies, which are *Metodontia beresowskii* (Möllendorff, 1899), *M. griphodes* Sturany, 1901, *M. huaiensis huaiensis* (Crosse, 1882), *M. huaiensis*

hemipleuris (Möllendorff, 1886), *M. yantaiensis yantaiensis* (Crosse & Debeaux, 1863), and *M. yantaiensis tetrodon* (Möllendorff, 1875) (Crosse & Debeaux, 1863; Crosse, 1882; Möllendorff, 1881, 1886, 1899; Sturany, 1901). None of the members of the genus have previously been examined anatomically.

The purpose of this paper is to supplement a revision of the genus with descriptions of two new species, and to supplement some anatomy data of genitalian system, where available.

MATERIALS AND METHODS

Specimens from 61 localities in Beijing, Tianjin, Jiangsu Province, Hebei Province, Henan Province, Shaanxi Province, Shanxi Province, and Gansu Province have been recently examined. These were collected over more than a century and are housed in Le Musée de Zi-ka-wei, the Museum of Zoology of Fan Institute of Biology (Johnson, 1973), and the Zoological Museum, Institute of Zoology of Chinese Academy of Sciences.

Very few *Metodontia* specimens were kept wet and if any, were preserved in 70% ethanol after relaxation. In preparation for the dissection, a tiny hole is carefully drilled in the shell apex to assist removal of the soft parts of the snail using water pressure. All the illustrations are drawn by

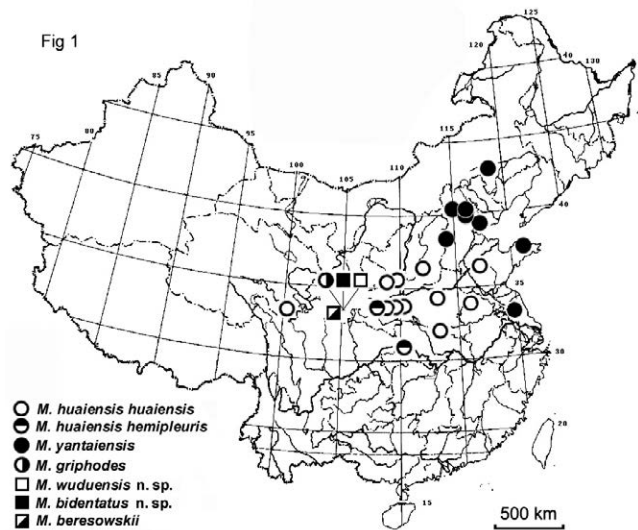


Figure 1 Distribution map of *Metodontia* species.

aid of camera lucida attached to a stereo-microscope. After dissection, any excised tissues have been placed in a small glass tube along with the remaining soft parts and shell.

Shell and genital measurements are taken with 0.01 mm and 0.1 mm accuracy respectively. Whorls are counted as described by Kerney and Cameron (1979), with an accuracy of $1/8$ (0.125) of a whorl. In the descriptions both colouration and dimensions of soft parts refer to those made on materials preserved in 70% ethanol.

Statistical descriptions and Principal Component Analyses (PCA, rotation method: Quartimax with Kaiser Normalization) are performed using SPSS for Windows 8.0.0 (Standard version). In the description, numbers underlined refer to means.

Anatomical and shell dimension abbreviations AL, aperture length; AS, accessory sac; At, atrium; diam., diameter; AW, aperture width; BC, bursa copulatrix; BCD, bursa copulatrix duct; DS, dart sac; PLs, polylayered structure; PWH, protoconch whorl (number); maj., major; MG, mucus glands; min., minor; P, penis; PS, penial sheath; R, penial retractor; RHD, ratio of shell height/shell diameter (maj.); RUD, ratio of umbilicus diameter/shell diameter (maj.); Umb, umbilicus; Va, vagina; VD, vas deferens.

INSTITUTIONAL ABBREVIATIONS

ZMIZ, the Institute of Zoology, Chinese Academy of Sciences.

SYSTEMATIC DESCRIPTIONS

Family Bradybaenidae Pilsbry, 1934
Genus *Metodontia* Möllendorff, 1886

Type species *M. huaiensis hemipleuris* (Möllendorff, 1886)

Metodontia Möllendorff, 1886: 193.

Metodontia Möllendorff, 1886--Pilsbry, 1895: 279.
--Zilch, 1960: 645 ("*Metodonta*" should be a print error here).

Distribution Northern and Northwestern China (Figure 1).

Diagnosis Aperture with 1 palatal tooth or 2 palatal teeth, with or without 2 parietal teeth.

Description Shell smaller in comparison to other bradybaenids. Roundly conoidal; height 3.85–10.00 mm; diam. (maj.) 6.50–14.00 mm; RHD 0.55–1.07. Shell thin or thick, solid. Apex distinct and blunt. Shell with $4^{1/4}$ – $8^{1/2}$ whorls; protoconch with $1-1^{7/8}$ whorls; whorls plain to fairly convex. Suture superficial to obviously impressing. Umbilicus as a crevice or broad, diam. up to 2.66 mm. Ratio of umb. diam./shell diam. (maj.) up to 0.25. Columella more or less oblique. Columellar lip dilate, slightly or almost completely covering umbilicus. Adult shell surface smooth or rough; young shell smooth or rough with short hairs; spiral furrows absent to indistinctly present; without ribs. Shell surface smooth or hairy with short hairs; perforates present but indistinct. Protoconch finely granulose (unknown in *M. griphodes*). Teleoconch ungranulose or upperly granulose. Immature shells rounded or obtusely angulated at periphery. Body whorl of mature shell angulated to rounded; spiral whorls increasing slowly. Body whorl obvious descending or not; basally convex or somewhat flat. Aperture roundly triangular; rather oblique; 2.93–6.49 mm in length; 1.93–5.44 mm in width. Aperture thickened within and forming a ring-like thickening; with a palatal tooth near columella, or with a tooth near columella and an outer palatal tooth, or with two palatal teeth and two parietal teeth. Lips never expanded. Peristome thin and not continuous. Callus indistinct. Shell dull to shiny; semi-transparent; in uniformly horny brown or lighter colour; bandless or with one peripheral

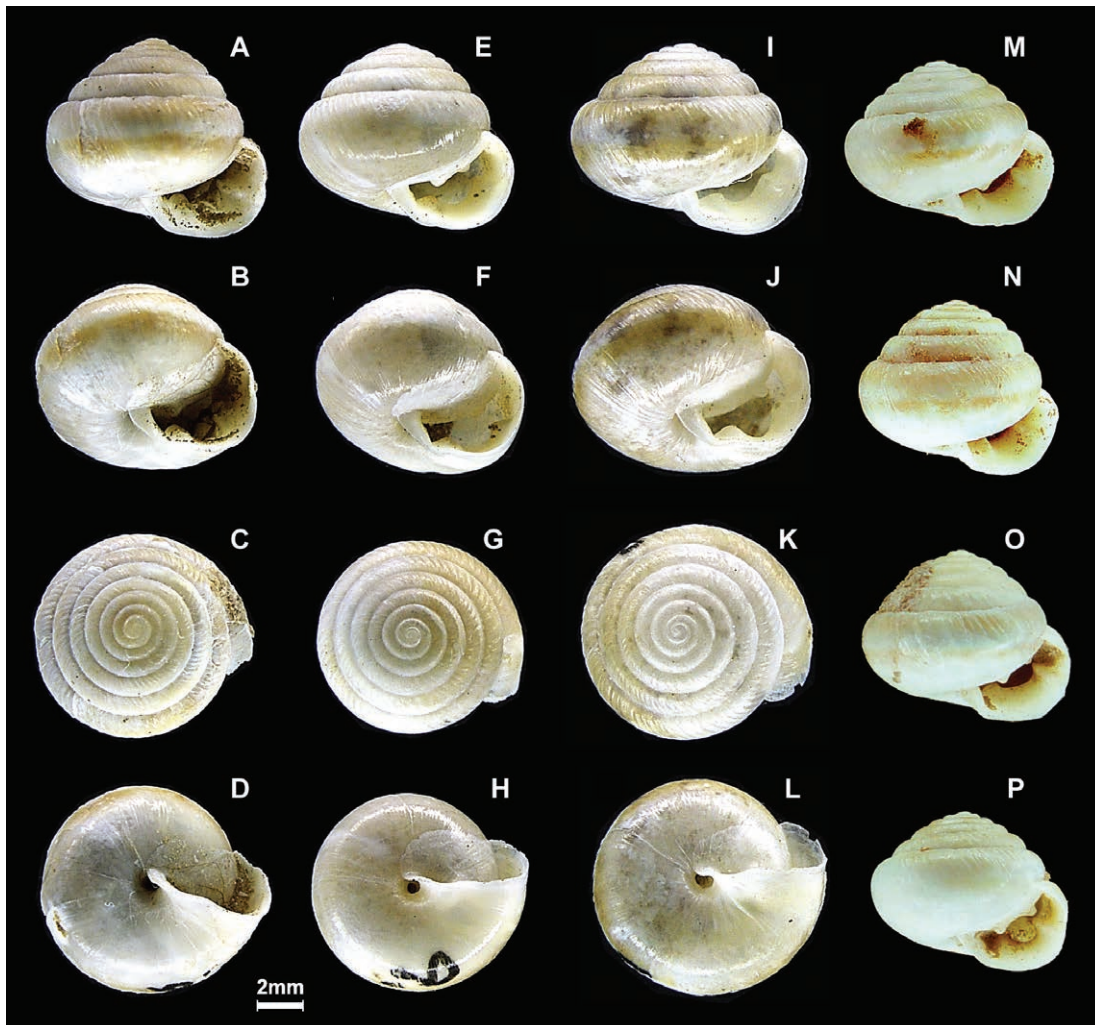


Figure 2 A-P. Shells of *M. huaiensis huaiensis*. A-D ZMIZ00890- specimen 6 A apertural view B showing apertural structure C apical view D bottom view. E-H ZMIZ00890- specimen 9 E apertural view F showing apertural structure G apical view H bottom view I-L ZMIZ00898- specimen 16 I apertural view J showing apertural structure K apical view L bottom view M ZMIZ00890- specimen 5, apertural view N ZMIZ00890- specimen 4, apertural view O ZMIZ00894- specimen 13, apertural view P ZMIZ00894- specimen 20, apertural view.

band. Base of body whorl in pale colour.

Soft part in creamy white. Jaw arcuate with 3 separate ribs dentating the concave margin (only observed in *M. beresowskii*, ZMIZ00473). Atrium relatively long. Penial sheath present (in *M. yantaiensis* and *M. beresowskii*) or absent (in the remaining anatomy-known species). Penis thin to slightly swollen, in moderate length to long. Epiphallic papilla absent. Flagellum absent. Membranate sac surrounding dart sac and/or distal region of vagina near to atrium absent. Retractor short. Dart sac elongated, without or with one tiny accessory sac; containing one dart. If present, accessory sac attaching at the center

of dart sac. Mucus glands 2-5, shorter or longer than dart sac; with distinct stalk; inserted on the center of dart sac. Mucus glands with a common simple entrance to dart sac, with lobules unexpanded distally. Inside dart sac, polylayered structure present (in *M. huaiensis huaiensis* and *M. yantaiensis*—see Fig. 4 in Wu, 2004) or absent (in the remaining anatomy-known species). Duct of bursa copulatrix short or somewhat long. Gonad glands palm-shaped; branched (The description on genitalia is based on the observation of *M. huaiensis huaiensis*, *M. beresowskii*, *M. yantaiensis*, and *M. bidentatus* new species).

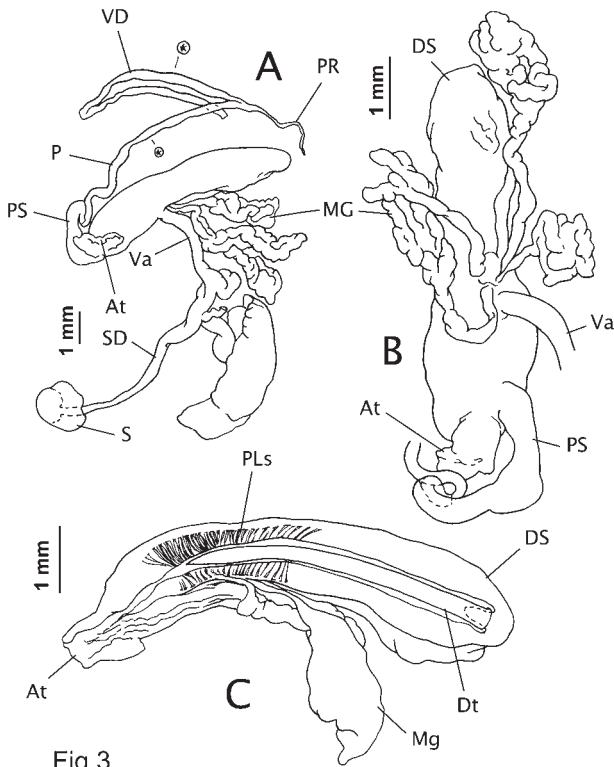


Fig 3

Figure 3 Genitalia of *M. huaiensis huaiensis*. **A** general view **B** detailed terminal part **C** sagittal section of dart sac.

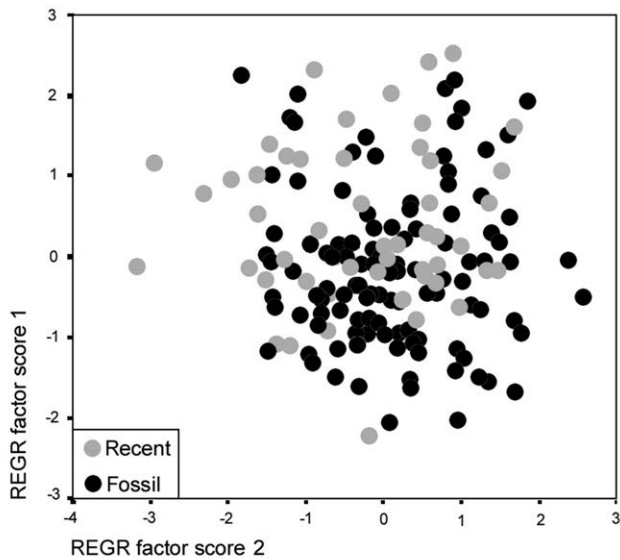


Figure 4 Principal component analysis. The two axes explain ca. 58.1% and ca. 18.9% of the variance respectively. Grey dots: recent specimens; black dots: fossil specimens and specimens with doubtful geological age.

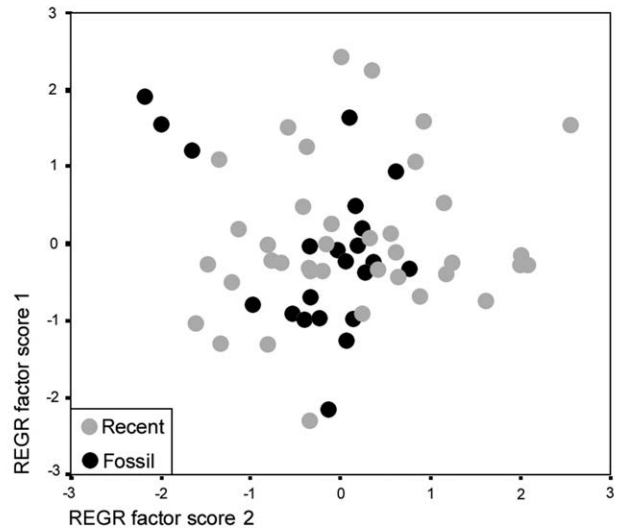


Figure 5 Principal component analysis. The two axes explain ca. 62.4% and ca. 15.0% of the variance respectively. Grey dots: recent specimens; black dots: fossil specimens.

Remarks 1) Some characteristics should be added to the diagnosis of *Metodontia*: Protoconch granulose; penial papilla and flagellum absent, dart sac with one dart within, with 2-5 mucus glands each with distinct and longish stalk and with a common simple entrance to dart sac. 2) Based on the hue, hairiness, the strong basal tooth on basal lip and some other shell characters, Möllendorff (1899) designed the section *Semibuliminus* under *Buliminopsis* Heude 1890 (= *Pseudobuliminus* Schmacker et Böttger, 1891) to accommodate *M. beresowskii*, which is also the type of the designed taxon. The present study follows the arrangement of this species in *Metodontia* by Yen (1939), due to the following two reasons: a) Horny brownish hue and hairiness / scaliness of periostracum of *M. beresowskii* are similarly shown in some recent species of *Metodontia*. In both fossils / subfossils and recent individuals, the presence of the scars left on the surface of shells also suggests their hairiness of scaliness. b) In *Metodontia*, both the species with only two palatal teeth and with two palatal teeth plus two parietal teeth had been reported. Furthermore, the present study suggests that in some cases, the number of the tooth is not so stable that it can be variable in different local populations. For instance, there are just three teeth, which are two palatal ones and one parietal one, occurred in full matured individuals of *M. yantaiensis*, as showed in ZMIZ00864, 00872 and 00902.

Therefore in *Metodontia*, the number of apertural tooth is variable but at least one present versus those completely absent in *Pseudobuliminus* (s. l.), although in the latter genus the aperture may be more or less thickened within.

KEY TO THE GENUS *METODONTIA* BASED ON SHELL FEATURES

- 1. Aperture with only 1 or 2 palatal teeth, parietal teeth absent.....2
- Aperture with 2 palatal teeth and 2 parietal teeth.....4
- 2. With one strong palatal tooth...*M. beresowskii*
- With two strong palatal teeth.....3
- 3. Shell with more than 8 whorls.....*M. griphodes*
- Shell whorls less than 85
- 4. Shell with more than 6 whorls, growth lines more or less rib-like.....*M. huaiensis*
- 6 Shell with less than 6 whorls, growth lines weak.....*M. yantaiensis*
- 5. Umbilicus open and deep *M. bidentatus* n. sp.
- Umbilicus mostly closed by penultimate whorl...
..... *M. wuduensis* n. sp.
- 6. Peripherally rounded.....*M. huaiensis huaiensis*
- Peripherally subangulated ...*M. huaiensis hemipleuris*

1. *M. huaiensis* (Crosse, 1882)

Diagnosis Aperture with 2 parietal teeth. Two palatal teeth connected by a callus ridge.

Description Shell with 5^{1/2}-8 whorls. Protoconch whorls 1-1^{5/8}. Height 5.20-10 mm, diam. (maj.) 6.70-14 mm. Spire with rib-like growth lines. Aperture with four teeth, two on the outer lip more prominent, the inner ones less developed, each of both pairs being connected by a callus ridge. Periphery rounded or subangulated. Umbilicus tiny.

Distribution range Qinghai, Shanxi, Shaanxi, Shandong, Anhui, Hubei, Gansu, Henan.

M. huaiensis huaiensis (Crosse, 1882)
Figures 2, 3

Helix obstructa Heude, 1882: 46, Pl. XVII. fig. 4.

Helix möltneri Gredler, 1884: 154.

Metodontia huaiensis (Crosse, 1882) —Möllendorff, 1899: 101. —Andreae, 1900: 58-59, 85, figs. 40-41. —Yen, 1935: 51, pl. III, figs. 16-16b. —Odhner, 1925: 17-18.

Hygromia (*Metodontia*) *houaiensis* (Crosse, 1882) —Ping, 1931: 15, text-fig. 7a-7i, plate I, figs. 7a-7i. — Ping, 1931: 18, text-fig. 8a-8c, plate I, figs. 8a-8f.

Hygromia (*Metodontia*) *tetrodon* (Möllendorff, 1875) —Ping, 1931: 18-19, Fig. 8a-8c.

Metodontia huaiensis huaiensis (Crosse, 1882) —Yen, 1939: 155, Taf. 16, Fig. 10.

Metodontia yantaiensis (Crosse, 1882) —Chen & Gao, 1988: 164.

Metodontia beresowskii (Möllendorff, 1899) —Chen & Gao, 1988: 164.

Material examined ZMIZ00258, 00606*, 00591**, 00851, 00852**, 00853, 00854**, 00855, 00856*, 00857**, 00858, 00859*, 00860**, 00861*, 00862*, 00882, 00883, 00884*, 00885, 00886*, 00887**, 00888*, 00889, 00890*, 00891, 00892*, 00893*, 00894*, 00895, 00896*, 00897, 00898, 00899*, 00901 (* fossil; ** recent or fossil not clear; the lots without asterisk are from recent populations; collection data see Appendix I, below of the same) .

Diagnosis Periphery rounded.

Description (Figure 3) Soft parts creamy white. Atrium slightly long. Penis short, minutely swollen near dart sac and rather thin near penial retractor. Retractor short. Dart sac elongated, without obvious accessory sac externally. With five mucus glands, shorter than dart sac; with distinct stalk; inserted on the centre of dart sac, with common entrance. Lobules furcate; radially arranged; not expanded distally. Duct of bursa copulatrix short. In ZMIZ04404: Dart sac 8.9 mm in length, 1.3 mm in width, ratio of width to length 0.1; mucus duct 5.0 mm; vagina 3.3 mm; bursa copulatrix duct with bursa copulatrix 8.9 mm; VD 8.7 mm; P 10.7 mm; PR 2.7 mm.

Distribution Qinghai, Shandong, Anhui, Hubei, Gansu, Henan (Figure 1).

Habitat Grassland and limestone hill (Heude, 1882).

Remarks *Metodontia moeltneri* (Gredler, 1884) was

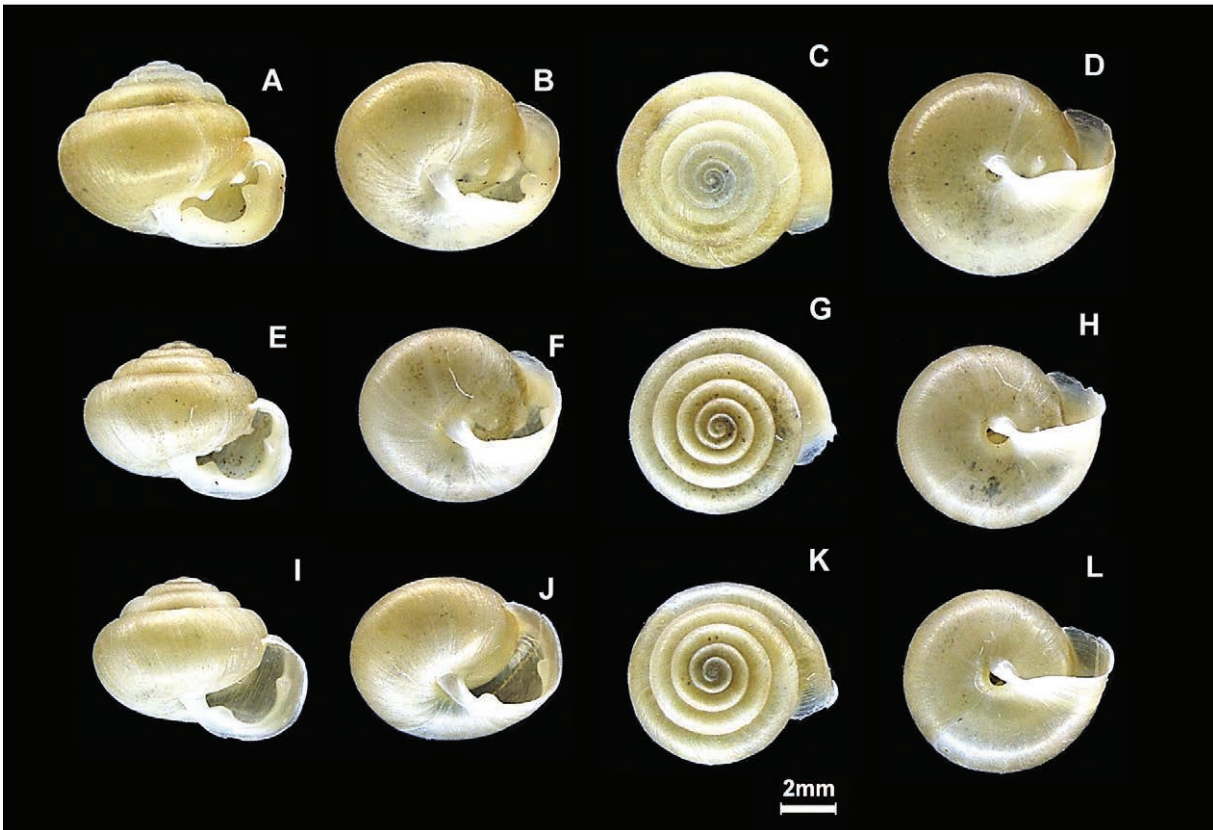


Figure 6 Shells of *M. yantaiensis*. A-D: ZMIZ00131- specimen 1. A, apertural view; B, showing apertural structure; C, apical view; D, bottom view. E-H: ZMIZ00864- specimen 1. E, apertural view; F, showing apertural structure; G, apical view; H, bottom view. I-L: ZMIZ00864- specimen 22. I, apertural view; J, showing apertural structure; K, apical view; L, bottom view.

synonymized by many authors (e.g. Möllendorff, 1886) as it was considered to be the young state of *M. huaiensis*. The present authors are in agreement with this.

Fossils of *M. huaiensis huaiensis* were collected from thirteen localities from Shaanxi Province. The recent shells of the same species were collected from neighbouring localities. The morphometrics and age composition of all shells including those lacking geological context were recorded. After the specimens of doubtful geological age have been excluded, a principal component analysis was performed using shell diam. (maj.), shell height, ratio of shell height/shell diam. (maj.), aperture length, aperture width, whorl number and protoconch whorl number as variables. The two eigenvalues of shell diameter (maj.) and the ratio shell height /shell diam. (maj.) account for more than 77.0% of the variance. Although the fossil and recent snails show no significant distinctions in their conchological morphometrics, the descendants of fossil *huaiensis*, appear to have relatively more flattened and larger shells (Figure 4).

However, comparisons between three fossil-recent pairs of samples from Shaanxi Province (ZMIZ00886 : ZMIZ00887, ZMIZ00892 : ZMIZ00898, ZMIZ00899 : ZMIZ00889) showed high similarity within and between pairs (figure 5). This result is somewhat questionable as the samples of fossils contained less than ten specimens each and may, therefore, be non random.

M. huaiensis hemipleuris Möllendorff, 1886

Helix (Metodontia) hemipleuris Möllendorff, 1886: 192.

Metodontia huaiensis hemipleuris Möllendorff, 1886—Möllendorff, 1899: 101.—Yen, 1939: 155, Taf. 16, Fig. 11.—Zilch, 1960: 645, Abb. 2259.

Diagnosis Periphery subangulate.

Examined material No specimen has been examined in the recent study.

Distribution Hubei, Shaanxi (Figure 1).

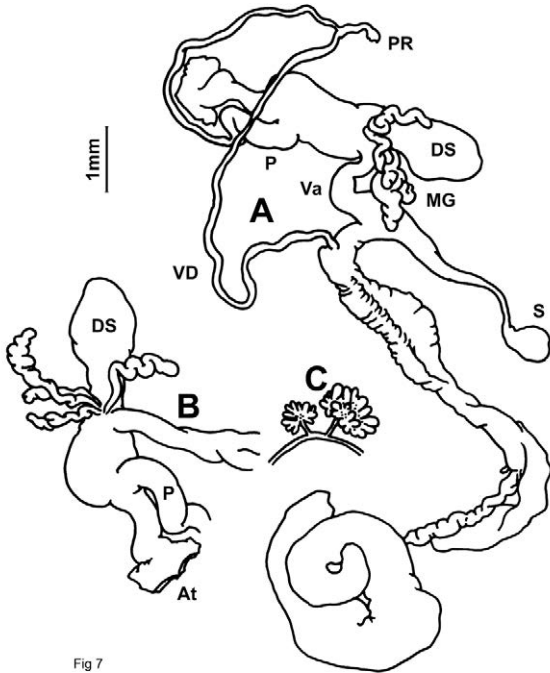


Fig 7

Figure 7 Genitalia of *M. yantaiensis*, ZMIZ00131-specimen 1. A, general view; B, detailed terminal part; C, two leaves of gonad glands.

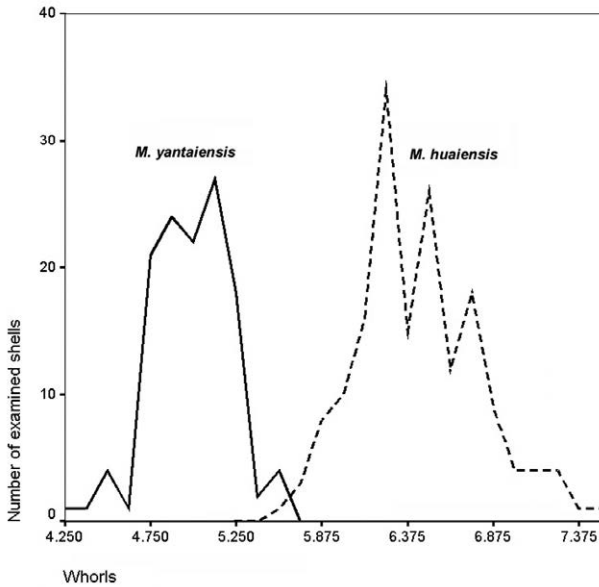


Figure 8 Clearly distinguished whorl number of *M. yantaiensis* and *M. huaiensis*.

Remarks Odhner (1925) suggested this species “seems to be a synonym of the present species (*M. houaiensis*)”. However, that was based on the original description, in which the subspecies was characterised only by the subangulated periphery (Möllendorff, 1886). Some specimens examined here (Figures 2M & O) appear identical to *M. huaiensis hemipleuris* (cf. Zilch 1960, Abb. 2259, Lectotypus SMF 9030), but are mixed with typical *M. huaiensis huaiensis* from the same locality. Resolution of this problem can only be determined from comparisons of more material and especially anatomical details, consequently the subspecies *hemipleuris* is retained.

2. *M. yantaiensis* (Crosse & Debeaux, 1863)
 Figures 6, 7

Helix yantaiensis Crosse & Debeaux, 1863: 387.
 —Crosse & Debeaux, 1864: 317, Pl. XII, fig. 2.
 —Heude, 1882: 46, Pl. XVII, fig. 5.
Metodontia yantaiensis yantaiensis (Crosse & Debeaux, 1863) —Yen, 1939: 155, Taf. 16, Fig. 12.
Helix (Perforatella) yantaiensis tetradon (Möllendorff, 1875) —Möllendorff, 1881: 36.
Metodontia yantaiensis tetradon (Möllendorff, 1875) —Yen, 1935: 50-51 (*tetradon* is a spelling error here).

Material examined ZMIZ00131; 00870; 00553; 00762; 00863; 00865; 00866; 00867; 00868; 00869; 00871; 00872; 00873; 00874; 00875; 00876; 00877; 00878; 00879; 00880; 00881; 00902; 00864; Jiangsu: Houai-ugan (“Huaian” in recent spelling, Jiangsu), metatypes, det. Crosse & Debeaux. Four full-grown animals are dissected.

Diagnosis Shell with less than 6 whorls. Aperture with 2 palatal teeth.

Description (Figure 6) Shell with 4^{1/4}-5^{1/2} whorls, protoconch with 1-1^{5/8} whorls. Height 3.85-6.00 mm, diam. (maj.) 5.11-8.0 mm. Parietal teeth small or as small strips opposite the large palatal teeth. Umbilicus tiny. Protoconch granulate; teleoconch with obscure or clear scars bearing scales.

Soft parts (Figure 7, Fig. 4 in Wu, 2004) creamy white. Atrium long. Penis long, swollen near

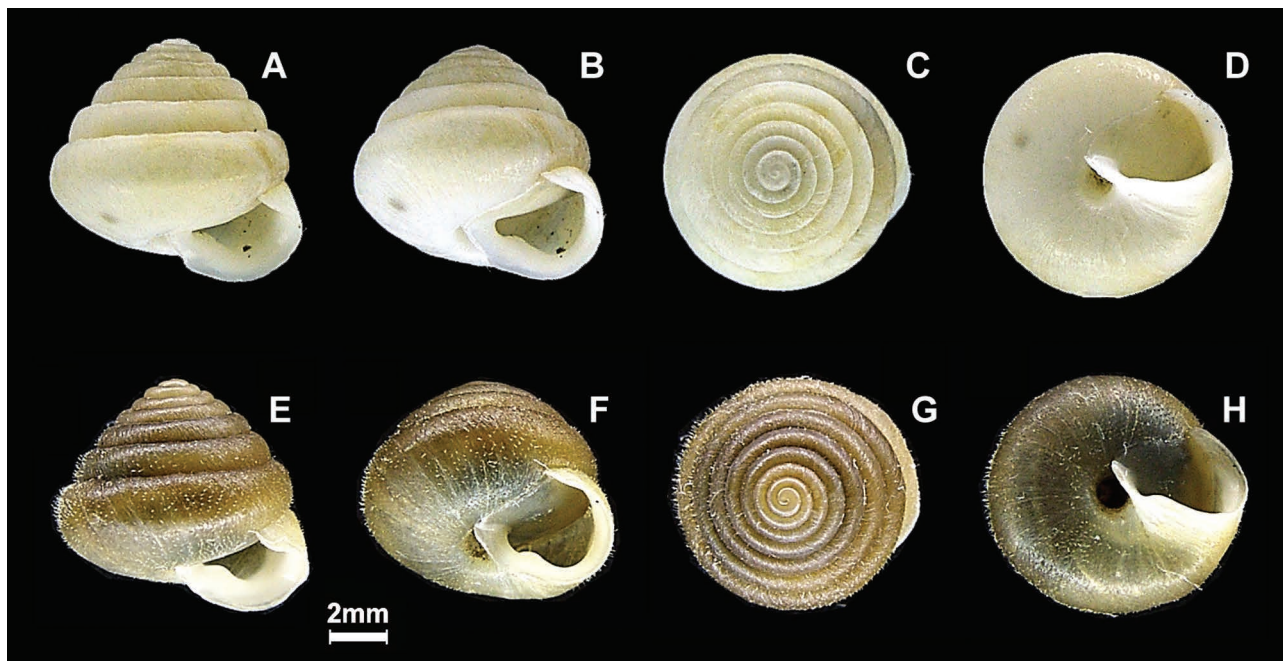


Figure 9 Shells of *M. beresowskii*. A-D: ZMIZ00473- specimen 1. A, apertural view; B, showing apertural structure; C, apical view; D, bottom view. E-H: ZMIZ00473- specimen 2. E, apertural view; F, showing apertural structure; G, apical view; H, bottom view.

dart sac and evenly thin near penial retractor. Retractor short. Dart sac elongated, without accessory sac. Poly-layered structure present (Fig. 4 in Wu, 2004). Mucus glands shorter than dart sac; with distinct stalk; inserted on the centre of dart sac; with four mucus ducts. Lobules not furcate; radially arranged; not expanded distally. Duct of bursa copulatrix short. Gonad glands palm-shaped; branched. In ZMIZ00131-specimen 1: Dart sac 3.5 mm long, 0.82 mm wide, ratio of width to length 0.3; mucus duct 2.2 mm; vagina 1.5 mm; bursa copulatrix duct with bursa copulatrix 3.9 mm; VD 8.0 mm; P 6.9 mm; PR 0.8 mm.

Distribution Hebei, Shandong, Shaanxi, Interior Mongolia, Shanxi, Jiangsu, Beijing, Tianjin (Figure 1).

Ecology Living snails have been observed by the author (Wu) in the field, only in Quyang, Hebei Province. They lived on the slopes of low hills, covered by sparse vegetation consisting of low boskage and gramineous weeds. This habitat is fairly exposed, dry and without high trees. The only available refuge is guessed to be the crevices of stones.

Remarks In the populations from Beijing and

Tianjin, the parietal teeth may be reduced in size (in ZMIZ00867, 00875; Figure 6F) or represented by the upper parietal tooth only (in partial specimens in ZMIZ00864, 00866, 00869, 00871, 00872, 00902), or may be completely absent (in partial specimens in ZMIZ00864, 00872, 00902; Figures 6J, 6L).

Ping (1931) was aware of the difficulty in distinguishing *M. yantaiensis* and *M. huaiensis*. However, he thought that the detailed apertural features rather than whorl numbers should be considered significant. Based on such an understanding, larger specimens with $6^{1/2}$ whorls, from Polycene sediments in Fenho Red Clay in Shanxi Province, were given the name *Hygroma (Metodontia) tetradon*. However, some shell features of *M. yantaiensis* and *M. huaiensis* frequently vary, for example in *M. huaiensis* the teeth can be strong in some localities and weaker in others, depending on whether or not the callus thickening within the aperture is fully developed. Giving too much credence to apertural features will consequently modify the definition of *M. yantaiensis* and *M. huaiensis*. In all the specimens examined here, the spire surface of *M. yantaiensis* is relatively smooth compared to the coarse and strong growth lines observed in *M. huaiensis*. They can also be distinguished by the whorl

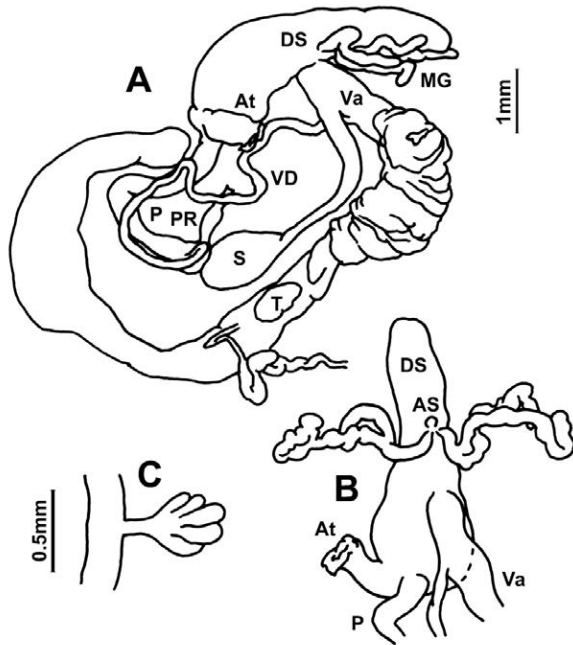


Fig 10

Figure 10 Genitalia of *M. beresowskii*, ZMIZ00473-specimen 1 **A** general view **B** detailed terminal part **C** a leaf of gonad glands.

number, $4^{1/4}$ - 5 - $5^{1/2}$ in *M. yantaiensis* compared to $5^{1/2}$ - $6^{1/2}$ - $7^{1/2}$ in *M. huaiensis* (Figure 8), along with other shell parameters such as shell height and width. According to this study, the species named *Hygroma (Metodontia) tetradon* described by Ping (1931: 18), which has riblet-like growth lines and $6^{1/2}$ whorls, might be referred to juvenile *M. huaiensis*.

When Möllendorff (1881) compared *Hygroma (Metodontia) tetradon* with *M. yantaiensis*, he gave an obscure description of the size of the aperture teeth, noting that they were somewhat "stronger" than those of the *M. yantaiensis*. Apart from this point, no other valuable difference has been indicated henceforth. In this study the authors have examined the specimens respectively labelled with "*M. yantaiensis* (Crosse & Debeaux, 1863), metatypes" and "*Helix tetradon* Moll.", and no remarkable differentiation of their tooth size has been detected. The material collected in Changping (ZMIZ00553), which is about 90 kilometers away from Xuanhua (Hebei Province), also shows the close similarity with *M. yantaiensis* collected from Huaian, Jiangsu Province. Hereby the authors are inclined to allow *M. yantaiensis tetradon* (Möllendorff, 1875) to be synonymised.

3. *Metodontia griphodes* Sturany, 1901

Metodontia griphodes Sturany, 1901: 23, Taf. I, Figs. 1-3. —Möllendorff, 1901: 302.—Gude, 1902: 6.

Examined material No specimen has been examined in the recent study.

Diagnosis Shell with 8 - $8^{1/2}$ whorls. Aperture with 2 strong palatal teeth.

Distribution Sichuan (Kutupa in Sturany, 1901 = Kuodaba in recent spelling; formerly Kutupa belonged to Gansu) (Figure 1).

Habitat Rocks and bushes (Sturany, 1901).

4. *M. beresowskii* (Möllendorff, 1899) Figures 9, 10

Buliminopsis beresowskii, Möllendorff, 1899: 133, Taf. VIII, Fig. 7.

Metodontia beresowskii (Möllendorff, 1899) —Yen, 1939: 156, Taf. 16, Fig. 7.

Material examined ZMIZ00473-specimens 1~29 from which 20 mature shells (ZMIZ00473-specimens 1~20) are randomly selected for measuring. Five specimens are dissected.

Distribution Gansu (Figure 1).

Diagnosis Aperture basally with 1 strong palatal tooth.

Description (Figure 9) Shell somewhat high and conoidal; height 6.36-6.70-7.62 mm; diam. (maj.) 7.10-7.36-7.69 mm; ratio of height to diam. (maj.) 0.85-0.91-1.07. Shell thin but solid. Apex distinct and blunt. Shell with 7 - $7^{3/8}$ - 8 whorls; protoconch with $1^{1/4}$ - $1^{3/8}$ - $1^{1/2}$ whorls; whorl fairly convex. Sutures obviously impressed. Umbilicus tiny. Columella oblique. Columellar lip dilate, slightly covering umbilicus. Adult shell surface rough; young shell rough with short hairs; spiral furrows absent; without ribs. Shell surface with short hairs; perforates present but indistinct. Protoconch finely granulose. Teleoconch smooth. Immature shells unkeeled but obtusely angulated. Body whorl rounded; spire whorls

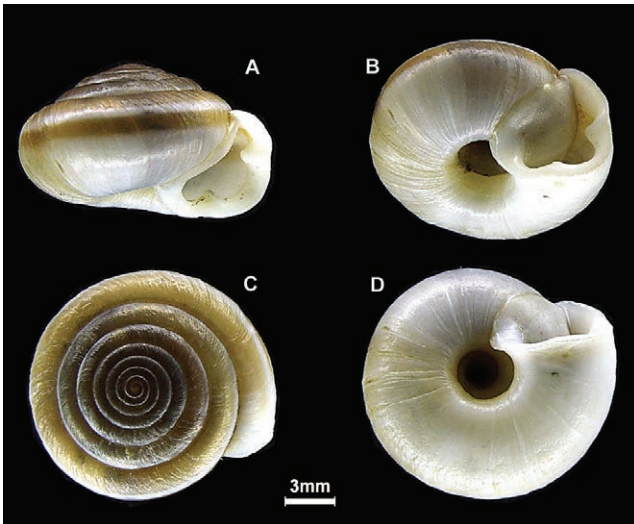


Figure 11 Shells of *M. bidentatus* n. sp. ZMIZ00083-specimen 1, holotype **A** apertural view **B** showing apertural structure **C** apical view **D** bottom view.

increasing slowly. Body whorl indistinctly enlarged; obvious descending; base flattened. Aperture roundly triangular; rather oblique; 3.45-3.70-3.84 mm in length; 2.81-3.15-3.41 mm in width. Aperture thickened within and forming a ring-like thickening; with 1 flat and strong tooth on base near columellar lip. Lips never expanded. Peristome thin and not continuous. Callus indistinct. Shell dull; semi-transparent; uniformly horny green; bandless. Base of body whorl paler in colour.

Soft parts (Figure 10) creamy white. Jaw arcuate with 3 separate ribs dentating the concave margin. Atrium somewhat long. Penis of moderate length, slightly swollen; without papilla. Penial sheath present. Retractor short. Dart sac elongated, with one tiny accessory sac; containing one dart. Accessory sac attaching at the centre of dart sac. Mucus glands shorter than dart sac; with distinct stalk; inserted on the center of dart sac; with two mucus ducts. Lobules bifurcate; radially arranged; not expanded distally. Duct of bursa copulatrix short. Gonad glands palm-shaped; branched. In ZMIZ00473-specimen 21: Dart sac 5.4 mm long, 1.5 mm wide, ratio of width to length 0.3; mucus duct 4.3 mm; vagina 1.2 mm; bursa copulatrix duct with bursa copulatrix 4.4 mm; VD 8.9 mm; P 5.6 mm; PR 0.4 mm.

Remarks The types in Möllendorff's original description (1899), with the measurements of $7\frac{1}{2}$ whorls, 6.9-7.5 mm high, 7.5-8 mm wide, are larger than the shells examined here. The

lectotype (cf. Zilch 1960, Abb. 2260: SMF 9172) is slightly flattened compared to the specimens examined here (ZMIZ00473).

5. *Metodontia bidentatus* new species Figures 11, 12

Material examined Gansu: ZMIZ00083: Yuxushan Mt., Wenxian (33°0'N, 104°36'E); 1000m above sea level, coll. Chen & Zhang, 1998-v-17 (ZMIZ00083-sp1~23 are randomly selected for conchological measuring. Holotype and three paratypes are dissected); ZMIZ00387, Wenxian, 1998-iv-21, 960m above sea level, coll. Chen & Zhang; ZMIZ00408, Wenxian, Gansu, 1998-iv-16, coll. Chen & Zhang.

Types Holotype ZMIZ00083-sp1, Yuxushan Mt., Wenxian, Gansu, 1000 m above sea level, coll. Chen & Zhang, 1998-V-17. Paratypes 128 shells (ZMIZ00083-sp2~129).

Diagnosis Shell with less than 8 whorls. Aperture with 2 strong palatal teeth.

Description (Figure 11) Shell depressed and conoidal; height 5.72-6.56-8.26 mm; diam. (maj.) 9.32-10.82-13.03 mm; RHD 0.55-0.61-0.69. Shell dextral; thin but solid. Apex distinct and blunt. Shell with $6\frac{7}{8}$ - $7\frac{1}{4}$ - $7\frac{3}{4}$ whorls; protoconch with $1\frac{1}{2}$ - $1\frac{3}{4}$ - $1\frac{7}{8}$ whorls; whorl convex. Suture obviously impressing. Umbilicus broad and profound; 1.84-2.26-2.66 mm wide; ratio of umb. diam./shell diam. (maj.) 0.17-0.21-0.25. Columella oblique. Columellar lip slightly dilate, hardly covering umbilicus. Adult shell surface rough; young shell rough; spiral furrows absent; without ribs. Shell surface scaly with small narrow lunar scales; perforates absent. Protoconch finely granulate. Teleoconch granulate on upper spiral whorls only; teleoconch unevenly granulated. Immature shells unkeeled nor angulated. Body whorl unkeeled; spire whorls increasing slowly. Body whorl not distinctly enlarged; not descending; base convex. Aperture triangular; slightly oblique; 4.68-5.22-6.49 mm in length; 3.35-4.15-5.44 mm in width. Aperture uniformly thickened within and forming a ring-like thickening; aperture with 2 palatal teeth, one on base and one on out side. Lips seldom expanded. Peristome thin and not continuous. Callus indistinct. Shell dull; semi-transparent; uniformly whitish yellow; with

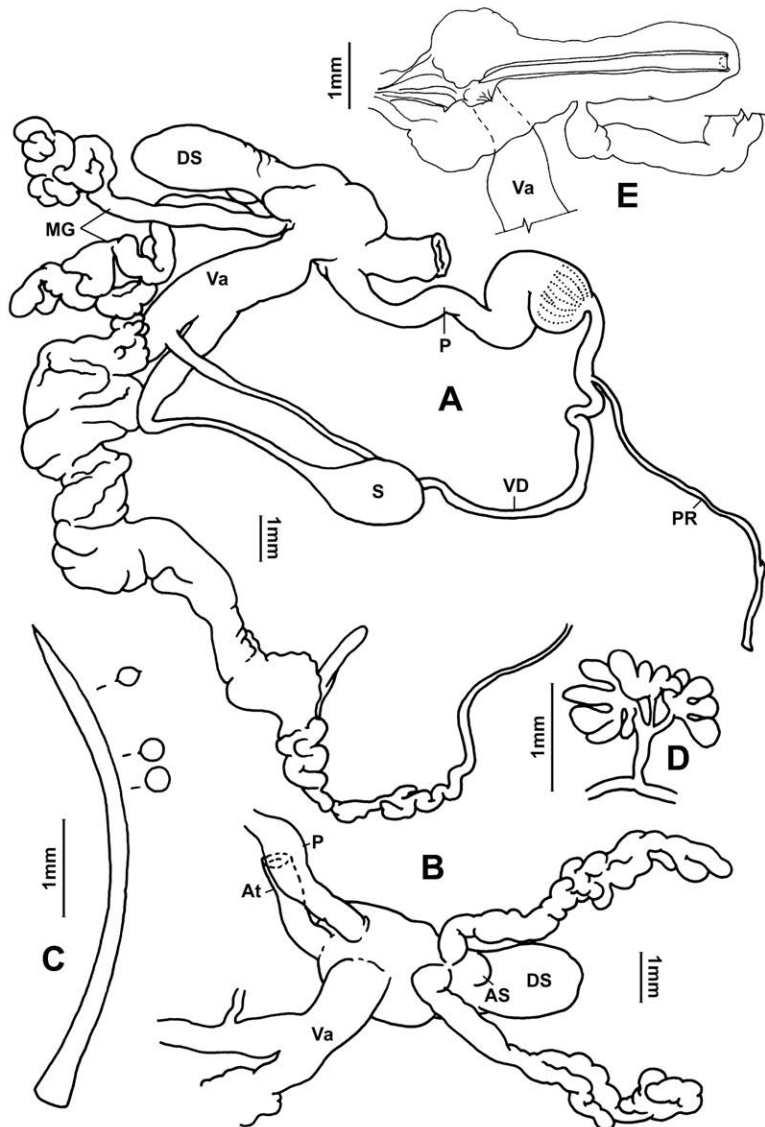


Figure 12 Genitalia of *M. bidentatus* new species, ZMIZ00083-specimen 1, holotype. A, general view; B, detailed terminal part; C, amatorial dart; D, a leaf of gonad glands; E, sagittal section dart sac.

a brown band peripherally and an indistinct brown band just beneath suture. Base of body whorl pale in colour. Measurements of holotype (ZMIZ00083-specimen 1): Shell height 7.54 mm, shell diam. (maj.) 10.95 mm, whorl number $7^{5/8}$, protoconch whorl number $1^{3/4}$, aperture length 5.36 mm, aperture width 4.33 mm, umb. diam. 2.05 mm.

Soft parts (Figure 12) unicoloured with several brown spots anteriorly. Jaw arcuate with 7 separate ribs dentating the concave margin. Atrium long. Penis short; swollen; without papilla. Retractor rather thin; long. Dart sac with one accessory sac; in moderate size; elongated;

containing one dart. Poly-layered structure absent. Dart about 5.0 mm in length; curved; basally expanded. Cross-section of dart not throughout rounded or ovate; cross section of apical dart 2-bladed and below it with an inner sharp blade. Ratio of bladed part to the whole length of dart 0.25; accessory sac attaching at the center of dart sac. Mucus glands longer than dart sac; with distinct stalk; inserted on the center of dart sac; with two mucus ducts. Lobules radially arranged, simply branched at apical part, not expanded distally. Duct of bursa copulatrix inserted low on vagina; short. Gonad glands palm-shaped; branched. In holotype: dart sac 6.1 mm long, 1.6 mm wide, ratio of width to length 0.3; mucus duct 10.3 mm; vagina 6.3 mm; bursa copulatrix duct with bursa copulatrix 10.3 mm; VD 15.8 mm; P 7.9 mm; PR 8.7 mm.

Derivation of name The name *bidentatus* is derived from the Latin prefix *bi-*, and the Latin *dentatus*, meaning two and toothed respectively.

Distribution This species is only known from type localities (Figure 1).

Remarks The absence of parietal teeth and the presence of two palatal teeth render this species most similar to *M. griphodes* and *M. wuduensis*. It differs from *M. griphodes* in having less than 8

whorls, and from *M. wuduensis* in having a wide and deep umbilicus.

6. *Metodontia wuduensis* new species

Figure 13

Type Material Holotype (ZMIZ00610-specimen 1), Wainaxiang, Wudu County (33°24'N, 104°54'E), Gansu Province, 820 m above sea level; coll. Chen & Zhang, 1998-IV-29. Paratypes 9 (ZMIZ00610-specimens 2~10), the same data as holotype. All specimens are empty shells.

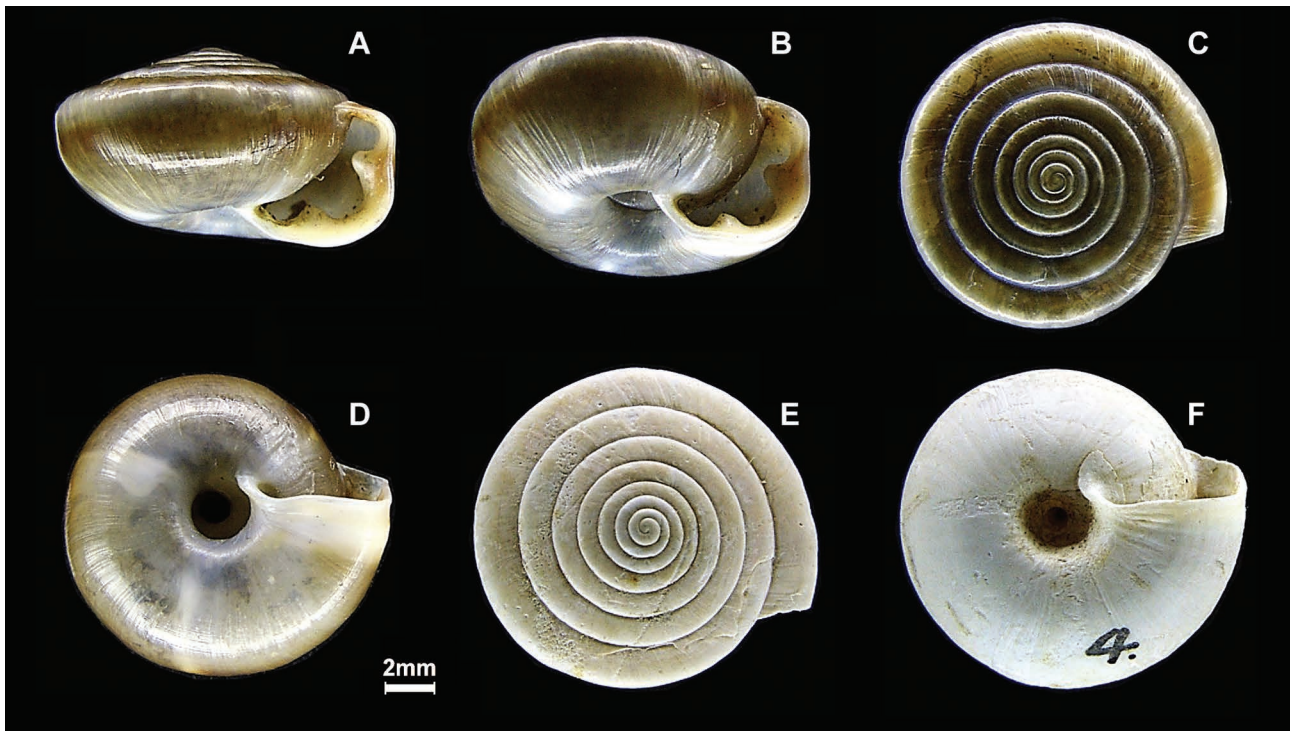


Figure 13 Shells of *M. wuduensis* new species. A-D: ZMIZ00610- specimen 1, holotype. A, apertural view; B, showing apertural structure; C, apical view; D, bottom view; E-F: ZMIZ00610- specimen 4, paratype. E, apical view; F, bottom view.

Diagnosis Shell shiny. Aperture with 2 strong palatal teeth, parietal tooth absent, less than 8 whorls, umbilicus mostly closed.

Description (Figure 13) Shell depressed, spiral low; height 5.93-6.49-7.06 mm; diam. (maj.) 10.13-11.08-12.19 mm; RHD 0.57-0.59-0.60. Shell dextral; thin but solid. Apex distinct and blunt. Shell with $6^{7/8}$ - $7^{1/4}$ - $7^{1/2}$ whorls; protoconch with $1^{3/8}$ - $1^{1/2}$ - $1^{5/8}$ whorls; whorl flat. Suture obviously impressing. Umbilicus broad but mostly closed by penultimate whorl; 1.87-2.08-2.40 mm wide; ratio of umb. diam./shell diam. (maj.) 0.17-0.19-0.21. Columella fairly oblique. Columellar lip not dilated; never covering umbilicus. Adult shell surface smooth; young shell smooth; spiral furrows indistinctly present; without ribs. Protoconch finely granulose. Teleoconch ungranulose. Immature shells strongly angulated above periphery. Body whorl roundly angulated superperipherally; spiral whorls increasing slowly. Body whorl not distinctly enlarged; not descending; base convex. Aperture triangular; almost vertical; 5.28-5.68-6.17 mm in length; 3.47-3.64-3.96 mm in width. Aperture uniformly thickened within and forming a ring-like thickening; aperture with 2 palatal teeth, one

on base and one on out side. Lips not expanded. Peristome thin. Callus indistinct. Shell shiny; semi-transparent; in horny brown, and with a white band on the shoulder. Base of body whorl, especially the region around umbilicus in pale color. Measurements of holotype (ZMIZ00610-specimen 1): Shell height 6.02 mm, shell diam. (maj.) 10.16 mm, whorl number $6^{7/8}$, protoconch whorl number $1^{1/2}$, aperture length 5.28 mm, aperture width 3.53 mm, umb. diam. 1.95 mm

Derivation of name The species name *wuduensis* is derived from the type locality: Wudu County, Gansu Province.

Distribution (Figure 1) This species is only known from the type locality.

Remarks This new species in shell is most similar to *M. bidentatus* sp. nov. However, the umbilical structure, the smooth and shining shell surface (reminiscent of *Stilpnodiscus*) and the prominent superperipheral shoulder are significant. The anatomy is not yet known for this species. PCA analysis based on the morphometrics composed of shell diam. (maj.), shell height, ratio of shell height/shell diam. (maj.), aperture length, aper-

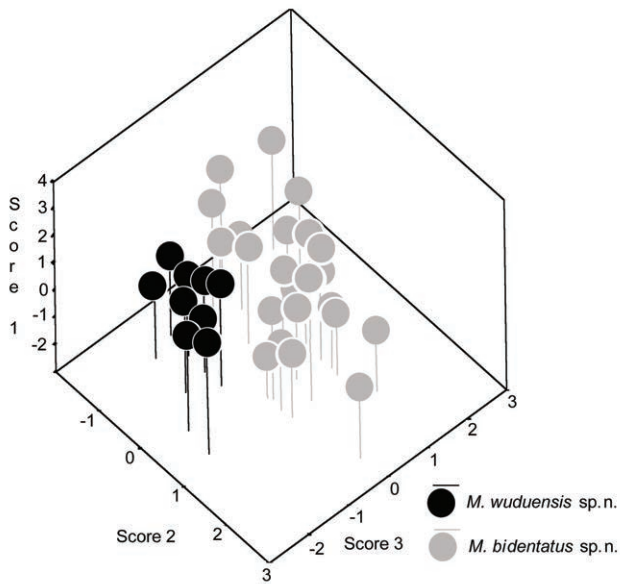


Figure 14 Difference in shell between *M. bidentatus* new species and *M. wuduensis*, showed by Principal component analysis. The three eigenvalues of shell height, umbilical diameter, and protoconch whorls account for more than 86.2% of the variance. The three axes explain ca. 47.0%, ca. 24.4% and ca. 14.8% of the variance respectively. Grey dots: *M. bidentatus*; black dots: *M. wuduensis*.

ture width, whorl number and protoconch whorl number shows this species is distinctly different from *M. bidentatus* sp. nov., although they are geographically neighbouring (Figure 14).

DISCUSSION

Species of *Metodontia* are distributed in arid areas, a typical habitat for landsnails (Heller, 1984; Solem & Christensen, 1984), and widely seen in the loess area north of the Changjiang River in Northern and Northwest China. The only exception is *M. huaiensis hemipleuris* recorded from Badong, situated on the southern bank of Changjiang River (Yangtze River), Hubei Province. Chen & Gao (1988, figure 62) show the distribution of both fossil and recent *Metodontia*, extending far to the south of the Changjiang River but this is not supported by any literature. Past confusion between *M. huaiensis* and *M. yantaiensis* led to an overlapping distribution pattern (Ping, 1931; Li, 1966; Chen & Gao, 1988), in contrast with the disjunct pattern shown here. Accordingly, more evidence is needed before

making any interpretation of the formation of Chinese loessial landscape based on the study of *Metodontia* and other land snails as attempted by Chen and Gao (1988).

Corresponding to a complex evolution route as well as comprising a fair amount of information closely relevant to the interaction with its environment, aperture structure is especially important for land snails (Goodfriend, 1983 & 1986; Pokryszko, 1997). The revised *Metodontia* species, showing a range of tooth number varying from one to four, might be guessed to have some significance as indicated to be associated with either limiting water loss or reduction of predation. Although it is possibly related to the explanation of the relationship among the animals and their historically altered environments, it is obviously out of the scope of this revision work and will be intensively examined in the future.

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APPENDIX I

The collection data of the examined materials are:

ZMIZ00083: Yuxushan Mt., Wenxian, Gansu (33°0'N, 104°36'E), 1000m above sea level; coll. Chen & Zhang, 1998-v-17; ZMIZ00387, Wenxian, Gansu, 1998-iv-21, 960m above sea level, coll. Chen & Zhang; ZMIZ00408, Wenxian, Gansu, 1998-iv-16, coll. Chen & Zhang; ZMIZ00553, Changping, Beijing, 1998-viii-2, coll. Wu Min; ZMIZ00481, Yuxushan Mt., Wenxian, Gansu, 1998-v-17, 1000 m above sea level, coll. Chen & Zhang; ZMIZ00473, Yuxushan Mt., Wenxian, Gansu, 1998-v-17, 1000 above sea level, coll.

- Chen & Zhang; ZMIZ00387, Wenxian, Gansu, 1998-iv-21, 960 m above sea level, coll. Chen & Zhang; ZMIZ00606, lower part of loess, Luochuan, Shaanxi; ZMIZ00610, Wainaxiang, Wudu, Gansu, 1998-iv-29, 820 m above sea level, coll. Chen & Zhang; ZMIZ00591, Heimugou, Luochuan, Shaanxi, 1984-viii-10; ZMIZ00408, Wenxian, Gansu, 1998-iv-16, coll. Chen & Zhang; ZMIZ04404, Lingbi, Anhui, 1986-v, coll. Chen; ZMIZ00852, Dazhuangxiang, Chunhua, Shaanxi, 1992-iv, coll. Chen & Gao; ZMIZ00853, Zhaoling, Liquan, Shaanxi; ZMIZ00854, Qinzhuangxiang, Jiuzhuangcun, Linyou, Shaanxi, 1992-iv, coll. Chen & Gao; ZMIZ00855, Chunhua, Shaanxi, 1992-iv, coll. Chen & Gao; ZMIZ00856, Majia, Chunhua, Shaanxi, 1992-iv, coll. Chen & Gao; ZMIZ00857, Huangling, Shaanxi, 1992-iv-24, coll. Chen & Gao; ZMIZ00858, Anze County, Shanxi; ZMIZ00859, in loess, μ 1-74-03 Luochuan, Shaanxi; ZMIZ00860, Luochuan, Shaanxi, 1978; ZMIZ00861, bottom layer of Malan Loess, LA4, 1978-viii; ZMIZ00862, in top layer of ancient soil, VI layer, Heimogou, Luochuan, Shaanxi, M-74-08, 1974-viii-1; ZMIZ00863, Zhongshan Park, Beijing; ZMIZ00864, Tanggu, Tianjin, 1930-IV-24; ZMIZ00865, Zoo of Beijing; ZMIZ00866, Badachu, Beijing, 1931-VIII-31, ZMIZ00867, Beihai, Beijing; ZMIZ00868, Central Park, Beijing, 1934-X-1; ZMIZ00869, Qinghuayuan, Beijing, 1957-VII-17; ZMIZ00870, Langshan, Hebei; ZMIZ00871, Taoranting, Beijing; ZMIZ00872, campus of Peking University, 1957-vii-31; ZMIZ00873, Beijing; ZMIZ00874, Xiangshan, Beijing; ZMIZ00875, Jingshan, Beijing, 1931-IX-18; ZMIZ00876, campus of Peking Univ., Beijing, 1957-vii-19; ZMIZ00877, Wofosi Temple, Beijing; ZMIZ00878, Natural Museum, Beijing, 1931-IX-21; ZMIZ00879, Erdaofu Temple, Badachu, Beijing; ZMIZ00880, Tiantan, Beijing, 1934-VII-30; ZMIZ00881, Andingmenwai, Beijing; ZMIZ00883, Yuanxi, Shaanxi, orig. no. 84001; ZMIZ00884, Yaoxian, in Malan Loess, Shaanxi, orig. no. 84003, 145 crushed and young, 19 good mature shells; ZMIZ00885, Ximenwai, Luochuan, Shaanxi, in Malan Loess, orig. no. 84004; ZMIZ00886, 210 km southern to Luochuan, Shaanxi, in Malan Loess, orig. no. 84007, 236 crushed or young, 9 old shells in good condition; ZMIZ00887, 210 km southern to Luochuan, on ridge of field, orig. no. 84008; ZMIZ00888, Shaanxi, between lower part of Malan Loess and Lishi Loess, orig. no. 84009, 86 young or crushed, 6 good old shells; ZMIZ00889, in the field of Jiaokou, Luohe River, southern region of Shaanxi, orig. no. 84011; ZMIZ00890, southern to Luochuan, Shaanxi, orig. no. 84012, 100 crushed or young, 12 mature shells in good condition; ZMIZ00891, Dongpo, Luochuan, Shaanxi, in middle layer of Malan Loess, orig. no. 84015; ZMIZ00892, Upper layer of Malan Loess, Potou, Luochuan, Shaanxi, orig. no. 84002, 26 crushed and young, 7 good mature specimens; ZMIZ00893, Qiaoxi, border of Yuan, in Malan Loess, Luochuan, Shaanxi, orig. no. 84013, ZMIZ00894, Xizuitou, Q3 loess, Shaanxi, orig. no. 84018, 146 young or crushed, 39 senile shells in good condition; ZMIZ00895, Qinjiazhai, upper layer of Malan Loess, Luochuan, Shaanxi, orig. no. 84006; ZMIZ00896, 241km northern to Luochuan, Q3 loess, Shaanxi, orig. no. 84016, 46 young and crushed shells, 13 good mature shells; ZMIZ00897, Jiaojiagelao, Shaanxi, in Malan Loess, orig. no. 840; ZMIZ00898, Potou, Luochuan, Shaanxi, orig. no. 84001?, 239 young or crushed shells, 19 good senile shells; ZMIZ00899, beside roads, Jiaokou, Luohe River, Q3 loess, Shaanxi, orig. no. 84010; ZMIZ00258, Lishan, Zhaolingxiang, Liquan, Shaanxi, 1992-iv-13, coll. Chen & Gao; ZMIZ0083, Yuxushan Mt., Wenxian, 1998-v-17, 1000 m above sea level, coll. Chen & Zhang; ZMIZ00901, bank of Yellow River, Zhengzhou, Henan prov., 1988-v, coll. M. Pommer; ZMIZ00131, near town, Quyang County, 1998-xi-7, coll. Wu Min; ZMIZ00762, Songshan Mt., Beijing, 1997-v-2, coll. Wu Min; ZMIZ00851, Guanzhuangxiang, Chunhua, Shaanxi, 1992-iv, coll. Chen & Gao; ZMIZ00882, Guanzhuangxiang, Chunhua, Shaanxi, 1992-iv, coll. Chen & Gao; ZMIZ00902, Houaigan ("Huaian" in recent spelling), Jiangsu, metatypes.

