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Some Late Cambrian molluscs from Liaoning Province, China

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Abstract – *Pilina liaoningensis* sp. nov. is described from the Late Cambrian Wanwankou Member of the Fengshan Formation, Benxi, Liaoning, China. Muscle scars and other internal structures are preserved very well in the paratype; bifurcate bundle scars are described for the first time from the fossil Tergomya. This is the oldest known occurrence of *Pilina*. Three species of Late Cambrian gastropods, *"Maclurites" ulrichi* (Kobayashi), *Matherella walcotti* Kobayashi and *Lytospira wanwankouensis* sp. nov. are also described from the Late Cambrian of northeastern China. *Lytospira* has been previously reported in the Lower Ordovician to the Middle Silurian of North America and Europe.

INTRODUCTION

The fossil Tergomya and Gastropoda described and illustrated in this paper were collected in 1980 by Xu Jun-tao and his colleagues of the Nanjing Institute of Geology and Palaeontology, Academia Sinica. They are from the Wanwankou Member of the Fengshan Formation exposed in two sections. The Chiushukou section is located at the Qiushugou village of Niuxintai, northeastern Benxi County, Liaoning Province, and the Doufangkou section is near the Yingzi village of Huolianzhai, in the northern part of Benxi.

The collection contains four species placed in four genera: *Pilina liaoningensis* sp. nov.; *"Maclurites" ulrichi* (Kobayashi); *Matherella walcotti* Kobayashi and *Lytospira wanwankouensis* sp. nov. The first two taxa are from the Doufangkou section; *Matherella walcotti* and *Lytospira wanwankouensis* are from the Chiushukou section (Figure 1). Apparently among these fossils, *Pilina liaoningensis* represents the oldest known species of the genus; its excellently preserved muscle scars and other internal structures are highly significant.

GEOLOGICAL SETTING

Cambrian sediments, especially Upper Cambrian, are extensively distributed in Liaoning, Shandong and Shanxi Provinces and Inner Mongolia in North China. The Upper Cambrian rocks are well developed and contain a diversity of fossils. Kobayashi (1931) established the Wanwankou Series in Taizihe Valley, Liaoning Province, to include the Wanwankou Limestone, Wanwankou Dolomite, Chiushukou Shale and Hsiapingkou Dolomite. He considered the Series to be Early Ordovician in age. Kobayashi (1933) studied the fauna, which included a great variety of molluscs from the Wanwankou Dolomite of the Wanwankou Series exposed in the Niuxintai Basin of Liaoning Province. In that work he described the following gastropods: *Helicotoma wanwanensis* Kobayashi, *Matherella walcotti* Kobayashi, *Clisospira niuhsintaiensis* Kobayashi, *Archinacella wanwanensis* Kobayashi, *Proplina bridgei* Kobayashi, *P. ampla* Kobayashi, *P.* (?) sp., *Scenella* sp. indet., *Stenotheca* (?) *manchurica* Kobayashi, *Scaevogyra ulrichi* Kobayashi and *S. naticaformis* Kobayashi. Two decades later, after restudying the strata of the Taizihe Valley, Wang and others revised the age of the Wanwankou Limestone, Wanwankou Dolomite and Chiushukou Shale, and assigned those three formations to the Late Cambrian Fengshan Formation (Wang *et al.*, 1954; Lu, 1962; Lu *et al.*, 1974; Chen *et al.*, 1979, 1983; Chen and Teichert, 1983).

The Fengshan Formation in Liaoning Province is divided into three members, in ascending order: the Yenzhou Member, the Wanwankou Member and the Chiushukou Member (Wang *et al.*, 1954; Lu, 1962; Chen *et al.*, 1979, 1983; Chen and Teichert, 1983). The Wanwankou Member is about 20 to 50 m thick, and is noteworthy for its rich fauna of cephalopods, rostroconchs, gastropods, trilobites, brachiopods and conodonts. It is composed mainly of stromatolitic limestone and stromatolitic dolomite, interbedded with intraformational limestone conglomerate (Chen and Teichert 1983). The molluscs described herein are generally well preserved. Associated with them are the cephalopods *Sinoeremoceras wanwanense* (Kobayashi), *S. taiziense* Chen and Teichert and *Wanwanoceras peculiare* Kobayashi, and trilobites.

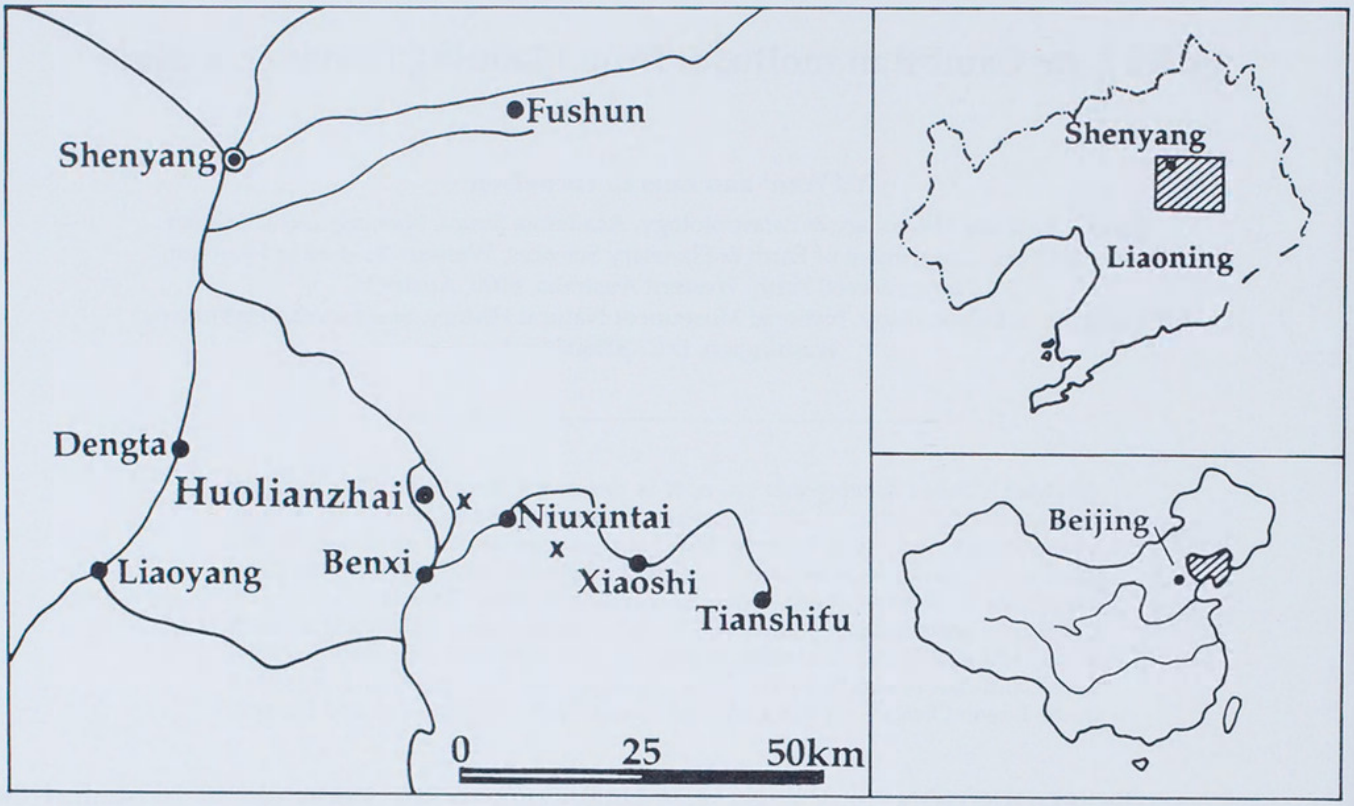


Figure 1 Sketch map showing the two fossil localities.

The fauna contains characteristic fossils of the Upper Cambrian which is widely distributed in the Upper Cambrian of Shandong, Anhui, and Zhejiang Provinces (Lu, 1962; Chen *et al.*, 1979; Chen and Teichert, 1983; Chen *et al.*, 1983).

Illustrated specimens are deposited in the Nanjing Institute of Geology and Palaeontology (NIGP), Academia Sinica.

SYSTEMATIC PALAEONTOLOGY

Class Tergomya Horný, 1965

Order Tryblidiida Lemche, 1957

Superfamily Tryblidiacea Pilsbry, in Zittel-Eastman, 1899

Family Tryblidiidae Pilsbry, in Zittel-Eastman, 1899

Genus *Pilina* Koken, in Koken and Perner, 1925

Pilina liaoningensis sp. nov.
Figures 2, 3a–i, 4a–e

Material Examined

Holotype

The holotype (NIGP 113849) shows the external surface covered with ornament.

Other material

The three paratypes, NIGP 113850–113852 are more or less complete to fragmentary, but all contribute information on the musculature.

Type locality

DoufangKou section exposed near Yingzi village, Huolinanzhai, Benxi Liaoning Province, China (see Figure 1).

Diagnosis

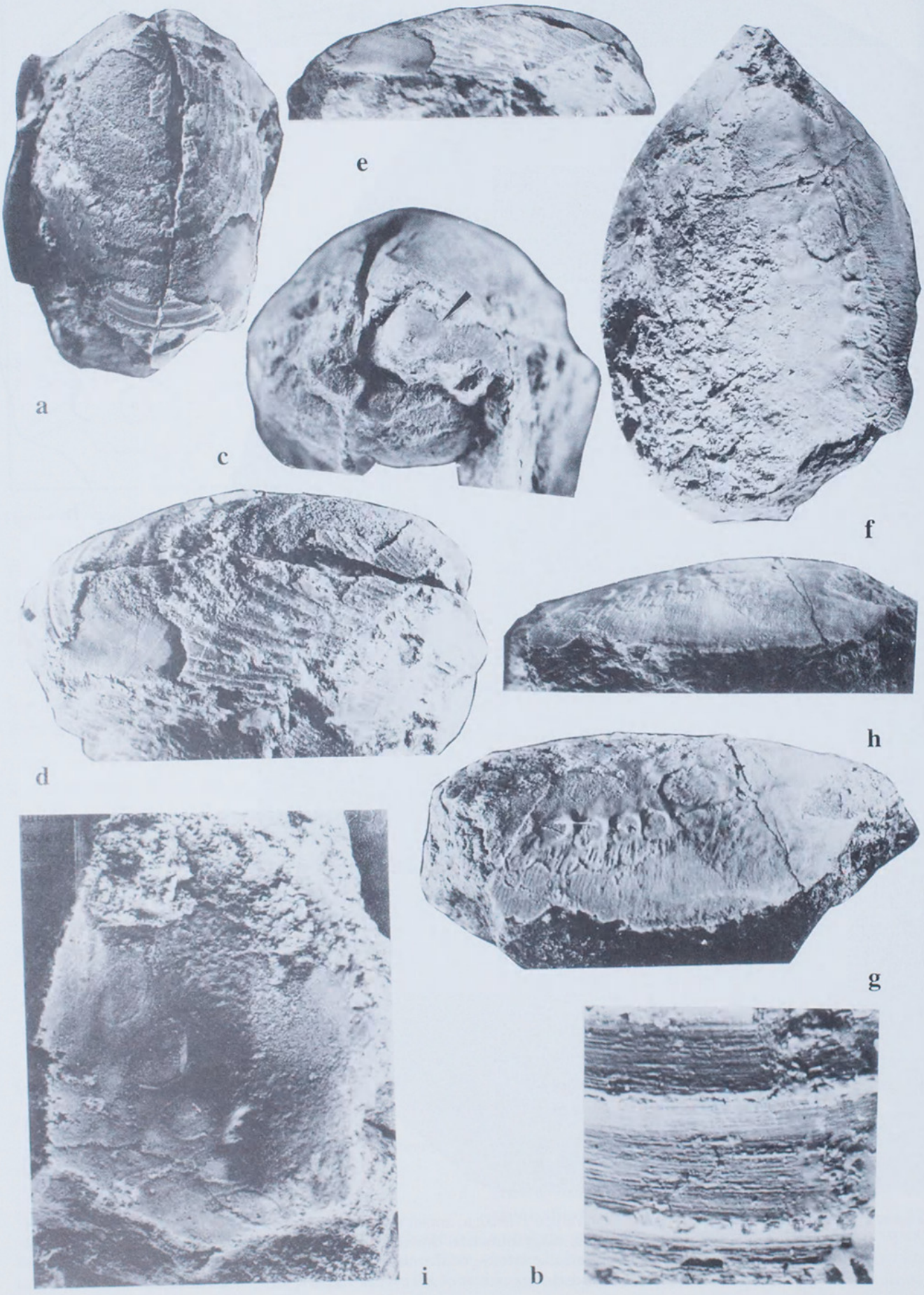
Shell large, tryblidiform, elliptical in dorsal view. Protoconch symmetrically conical. Apex overhanging adapical margin. Surface ornamented with stout comarginal rugae, fine growth lines and radiating threads. Interior with eight metametric pairs of muscle scars, one pair of radular muscle scars, and other internal structures on dorsal side of steinkern.

Description

Shell large, elliptical in dorsal view. Protoconch small, about 5 mm wide, symmetrically conical in dorsal view, protruding strongly forward, broadly rounded in the basal part, slowly and gradually increasing in size away from the apex. Tip and external features of protoconch are not preserved (Figure 3c). Dorsum gently flattened, oblique toward the abapical margin, with greatest shell width just behind midlength. Abapical margin rounded; adapical margin narrowly rounded, though not known in detail. Lateral margins more broadly curved but also not known in detail.

Shell surface ornamented with comarginal rugae, growth lines and radiating threads. Comarginal rugae stout and evenly distributed, more than 20 in number, gradually becoming stronger from apex toward abapical margin, with the distance between rugae also gradually becoming wider. Growth lines

Figure 2 *Pilina liaoningensis*, sp. nov. a, b. Paratype 113850. a, dorsal view, showing the serially arranged muscle scars on the right side of the dorsum, x 5. b, diagrammatical drawing of NIGP 113850: A–H = pedal retractor muscle scars; 1 = medio-pedal muscle scar; 2 = latero-pedal muscle scar; 3 + 4 = musculus branchialis and pallial muscle; ra. m. s. = radular muscle scars; s.g.c. = scar of gill cavity; b.m.f. = bifurcated muscle fibres, x 2.25.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rather fine, closely spaced. Radiating threads crossing rugae and growth lines to form a concellate sculpture.

In lateral view of steinkern (Figure 3g), apex protruding and overhanging adapical margin, dorsal side flattened and inclined gradually downward to the abapical margin. Dorsum of steinkern broadly rounded in the central part with a rather shallow dorsal furrow, bounded by two obtuse ridges. On the outer side of these, muscle scars are present raised above the general level of the steinkern. Scars are interpreted as one pair of radular muscle scars and eight metameric pairs of composite muscle scars (i.e. Figure 2 A to H), other interior shell marking are present.

Details of musculations

Radular muscle scars are largest and most pronounced of internal features. These scars are subelliptical in plan view, complex, being composed of more than thirty small scars, and situated one-third of distance between adapical margin and midline.

The A to C pairs of muscle scars are situated on both sides of the radular muscle scars. All three pairs of muscle scars are linked together in the anterior portion of the shell. The D to H pairs of muscle scars are discrete and are located in the posterior of the shell. They are all similar and nearly horseshoe-shaped (Figure 2). Each muscle scar can be divided into four parts; two larger and two smaller. Part (3) gradually becomes smaller and weaker from D to H coordinate with Part (4) which becomes larger and stronger and develops two small pits. Each muscle scar set but particularly in D to H, is flanned by eight or more small scars is distributed. These muscles extend outward and display a secondary, tertiary or more bifurcation.

In addition, on the outer sides of the muscle scars sets are smaller scars. These are on the outside of the main scars. Their placement is in the lateral gill cavities, extending backward from C to G pairs. The anterior pairs are thinner and shallower, than those toward the posterior which wider and deeper; these latter display a regular wave-like curvature.

As the adapical part of this internal mould has been slightly damaged, the muscle scars of the anterior body region are not completely known on this steinkern, there are three pairs of muscle scars on both sides of the anterior body region. The first pair being larger and rope-like in appearance, situated anterior to A to C pairs of muscle scars. The second pair are located near the anteriorly lateral side and are stripe-like in appearance and extend posteriorly. The third pair are subcircular, situated near the lateral margin and next to the second pair. Furthermore, between the stripe-like muscle scars and the subcircular muscle scars, there are five small grain-like muscle scars (Figures 2, 3f,g). On both sides of A to C pairs there are at least two pairs of muscle scars parallel to the radular muscle scars.

A broken steinkern is shown on Figure 3i. Preserved on the right of the inner side are five preserved muscle scars, which are similar in shape and size to the D–H pairs of muscle scars illustrated in Figure 2, 3f, g, h, 4a, b.

A more or less weathered specimen is figured in Figure 4c, d, e. It has the traces of the radular muscle scars, and the A to H muscle scar sets on the right side are clearer than those on the left side.

Dimensions (mm)

	Length	Height	Width
NIGP 113849, Holotype	45.50	12.00	29.50
NIGP 113850, Paratype	43.50	–	23.00
NIGP 113851, Paratype	34.00	–	21.50

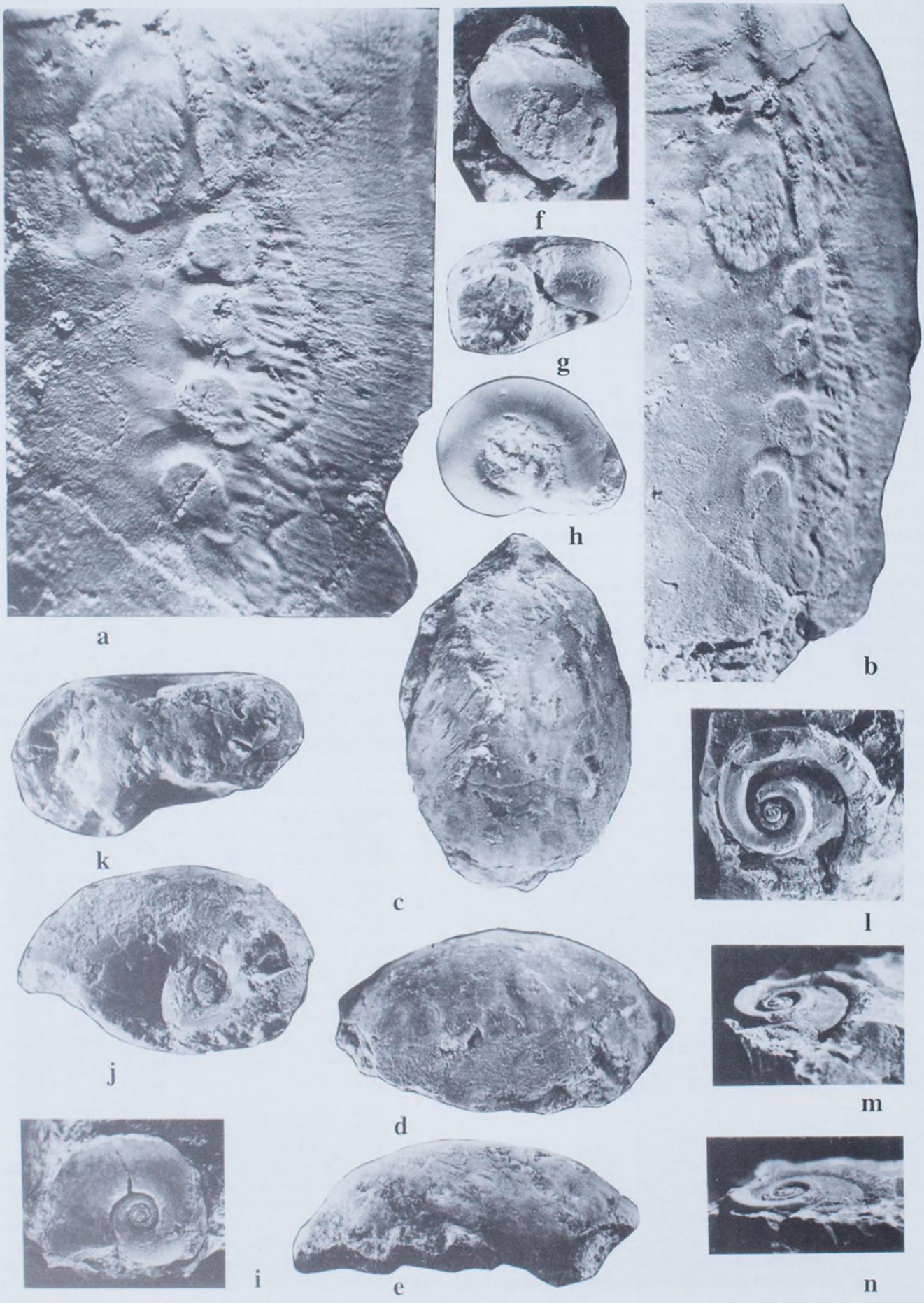
Remarks

Species of *Pilina* have mainly been reported from the Upper Ordovician of the Baltic Region (Koken and Perner, 1925) and Oklahoma (Peel, 1977), and from the Middle Silurian of Gotland, Sweden (Lindström *in* Angelin and Lindstrom, 1880; Lindström, 1884). The new species of *Pilina* described herein represents the earliest record of the genus. The species is peculiar in its protoconch, more complex muscle scars and thereby differs from the all known species.

Proplina Kobayashi, 1933 is known from the Upper Cambrian to Lower Ordovician of North America and Northeast Asia. Musculature is more prominent in species of *Pilina*. *Proplina* has a higher more rounded cross-section than *Pilina*. Thus we felt justified in extending the downward range of *Pilina*.

Judging from the broadly flattened dorsum, the presence of eight pairs of pedal muscle scars, *Pilina liaoningensis* is similar to *Proplina sibeliusi*

◀ **Figure 3** *Pilina liaoningensis*, sp. nov., a–e, holotype NIGP 113849. a. dorsal view, showing comarginal rugae, radiating threads and growth lines; b. enlargement of ornament. c. anterior view, showing the symmetrical protoconch (black arrow); d. right-lateral view, showing profile and rugose comarginal ornament; e. oblique right-lateral view; f–h, paratype NIGP 113850. f. dorsal view, showing the eight metameric muscle scars and radular muscle scars; g. right-lateral view, showing the scars of gill cavity and other internal structures on the right side of the shell; h. oblique right-lateral view; i. paratype NIGP 113852, interior view of a substantial specimen, showing five muscle scars on the right side of the shell. Scales = (a, e, h) x 1.5; (b) x 10; (c, d, f, g) x 2; (i) x 4.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Stinchcomb (1986, p. 613, figs. 2.6–2.8, 3.11–3.13) from the Lower Ordovician Gasconade Formation of Missouri, U.S.A., but differs from the latter species in the shell being elliptical in dorsal view, in the flatter dorsal side, in the narrower A to C pairs of pedal muscle scars and in having bifurcated muscle fibres.

In some respects, particularly in the flattened dorsal side, this species resembles *Bipulvina croftsae* Yochelson (1958, p. 10, figs. 5–9; Knight and Yochelson, 1960, p. I78, fig. 46–5; Wingstrand, 1985, p. 49, fig. 19) from the Lower Ordovician, Gasconade Formation of Missouri. That form is lower and flatter and its muscle scars have a more triangular shape.

Horizon and locality

Wanwankou Member of Fengshan Formation, at Doufangkou.

Class Gastropoda Cuvier, 1797

Order Archaeogastropoda Thiele, 1925

Suborder Macluritina Cox and Knight, 1960

Superfamily Macluritacea Fischer, 1885

Family Macluritidae Fischer, 1885

Genus *Maclurites* LeSueur, 1818

Remarks

The type species of *Maclurites* is from the Middle Ordovician and the limits of the genus are not clear at this time. Thus the generic name is used in a quotational sense. This taxon does not seem to be closely allied to *Scaevogyra*.

"Maclurites" ulrichi (Kobayashi, 1933)

Figures 4g–4k

Scaevogyra ulrichi Kobayashi, 1933: 266, pl. V, figs. 5–7; Yu *et al.*, 1963: 96, pl. 27, figs. 7–9.

Scaevogyra naticaformis Kobayashi, 1933: 267, pl. V, fig. 8; Yu *et al.*, 1963: 96, pl. 27, figs. 5–6.

"Maclurites" ulrichi (Kobayashi): Yu, 1990: 145.

Material Examined

Four specimens, NIGP 113853–113856.

Diagnosis

Spire depressed. Base flattened. Whorls increasing slowly in early stages, more abruptly in body whorl, embracing about half of penultimate whorl on basal surface. Width of body whorl about two times that of inner whorls. Approximately seven whorls at maturity. Pseudoumbilicus wide and deep, about one-half diameter of shell. Aperture ovate. Growth lines closely spaced.

Description

Shell of medium size, very low-spired, sinistral in orthostrophic orientation. Protoconch unknown. Whorls five to seven in number, increasing slowly and gradually in the early ones, abruptly in the body whorl, especially near the apertural region and embracing about one-half of the penultimate whorl on its basal surface. Width of the body whorl about two times that of the inner whorls and the height about two-thirds of the width. Basal surface slightly convex in early stages, gently rounded at maturity. Basal suture distinctly impressed. Outer whorl surface gently rounded, the juncture of basal and upper faces following the arc of a small circle. Upper surface inclined inward, following the arc of a circle of smaller diameter than the basal one. Pseudoumbilicus wide and deep, approximately one half the diameter of the shell. Pseudoumbilical walls inclined steeply downward. Aperture not well known, but generally ovate in shape. Surface of shell mainly smooth but faint lines of growth are present near aperture (Figure 4j, k). Operculum unknown.

Dimensions (mm)

	Length	Height	Width	Ap. height
NIGP 113853	38.00	21.50	16.00	15.00
NIGP 113854	23.00	14.50	11.50	10.50
NIGP 113855	21.50	–	–	9.00

Remarks

The description is based on three specimens and one incomplete internal mould. The shell is characterized by a distinct, but very low-spired and rapidly expanded body whorl.

◀ **Figure 4** a–e. *Pilina liaoningensis*, sp. nov. a–b, paratype NIGP 113850. a,b, dorsal views, enlargement of muscle scars; c–e, paratype NIGP 113851. c, dorsal view, showing the eight paired muscle scars on the right and left sides of the dorsum. d, e. right-lateral and left-lateral views, showing the muscle scars on the right and left sides of the shell. f. *Matherella walcotti* Kobayashi, abapertural view. NIGP 113857. g–k. *"Maclurites" ulrichi* (Kobayashi), g–h, apertural and top views, NIGP 113854; i, basal view, showing the depressed spire, NIGP 113855. j, k. basal and apertural views, showing the growth lines and the form of aperture, NIGP 113853. l–n, *Lytospira wanwankouensis*, sp. nov., holotype NIGP 113858. l. apical view, m, n oblique apical views. Scales: (a) x 7.5; (b) x 4; (c, d,e) x 2; (f, i, j, k, l) x 1.5; (g, h, m, n) x 1.

In the general outline of the shell, in the well rounded outer surface, especially the wide pseudoumbilicus, this species resembles *"Maclurites" thomsoni* Webers *et al.* (1992, p. 200, pl. 6, figs. 1–8; pl. 7, figs. 1–7), from the Upper Cambrian Minaret Formation of Heritage Range, West Antarctica. It differs from the Antarctic species in having a depressed spire, more slowly increasing early whorls and in the proportion between the height and the diameter of the shell and in the ovate aperture.

In some respects, this species is also closely allied to *Maclurites niuhsintaiensis* Kobayashi (1931, p. 97, pl. 10, figs. 5a–c; Yu, 1961, p. 379, pl. V, figs. 10–12; pl. VIII, figs. 8–10; Yu *et al.*, 1963, p. 86, pl. 25, figs. 4–6) from the Lower Ordovician Machiakou Formation of Niuxintai Basin, Liaoning. It is easily distinguished from *M. niuhsintaiensis* by its depressed spire, more rounded basal edge, more obtusely rounded umbilical edge and by the ovate form of the aperture.

Horizon and locality

Wanwankou Member of Fengshan Formation, at Doufangkou.

Family Scaevogyridae Wenz, 1938

Genus *Matherella* Walcott, 1913

Remarks

The genus *Matherella* Walcott, 1913 is Late Cambrian in age. It is widely distributed, having been originally described from the Upper Cambrian Hoyt Limestone of eastern New York and subsequently from the Upper Cambrian Minaret Formation of Heritage Range, West Antarctica (Webers *et al.*, 1992).

Matherella walcotti Kobayashi, 1933

Figure 4f

Matherella walcotti Kobayashi, 1933, p. 261, pl. IV, fig. 7; pl. V, fig. 9.

Matherellina walcotti (Kobayashi): Knight 1941: 189, pl. 90, figs a–c; Knight *et al.*, 1960: I187, Fig. 104–5; Yu *et al.*, 1963: 97, pl. 27, figs. 12–13; Yu, 1987: 93, text-fig. 30a–b; 1990: 145.

Material Examined

One internal mould, NIGP 113857.

Diagnosis

High spired, trochiform, sinistral in orthostrophic orientation. Outer face slightly convex, sutures distinctly impressed. Surface ornamented with rugae.

Remarks

The specimen figured here agrees in general character with those described by previous authors. However, our specimen is larger than any previously illustrated for the taxon.

Horizon and locality

Wanwankou Member of Fengshan Formation, at Qiushugou.

Superfamily Euomphalacea de Koninck, 1881

Family Euomphalidae de Koninck, 1881

Genus *Lytospira* Koken, 1896

Remarks

This genus superficially resembles *Ecculiomphalus* Portlock, 1843, but differs in having a blunt, spiral angulation on or near the midline of the upper whorl surface.

To the best of our knowledge multiwhorled open-coiled gastropods have not been reported from beds as old as Upper Cambrian. Despite the limited amount of material we deem it worthwhile to name a species so as to emphasize the early development of this type of morphology.

Lytospira wanwankouensis, sp. nov.

Figure 4l–n

Material Examined

A single internal mould, NIGP 113858 (holotype).

Type locality

Chiushukou section, Niuxintai, Liaoning Province, China (see Figure 1).

Diagnosis

Shell discoidal, with blunt spiral angulation near midline of upper whorl. Whorls four to five in number, first two whorls in contact, but later ones openly coiled.

Description

Shell small and discoidal. Whorls four to five in number, the first two in contact, with later whorls open-coiled and rapidly increasing in size. A blunt, spiral angulation is near the midline of the upper whorl surface, sloping inward towards the inner whorl surface. Outer whorl surface is gently convex. Suture in the first two whorls is distinctly impressed. Surface of the steinkern is smooth. Aperture and the characters of base unknown. Growth lines unknown.

Remarks

According to previous records, the genus

Lytospira occurs from the Lower Ordovician to the Middle Silurian in North America and Europe. The present record of the genus from north-east China thus extends the time-range of *Lytospira* back to the Late Cambrian.

In apical view, this species is somewhat similar to the type species *Lytospira angelini* (Lindström) (1884: 138, pl. XIII, figs. 36–38; Knight *et al.* 1960: I191, fig. 107–6) from the Middle Ordovician of Sweden. *Lytospira wanwankouensis* differs in having the whorls discoidal in the same plane and in having a more obtuse spiral angulation. It also shows some affinities to *Lytospira valida* Koken *in* Koken and Perner (1925, p.115, pl. XIII, fig. 3), but differs from the latter in having tightly coiled early whorls and a more concave inner whorl surface.

Horizon and locality

Wanwankou Member of Fengshan Formation, at Qiushugou.

DISCUSSION

Tergomya are rare in the Fengshan Formation but *Pilina liaoningensis*, sp. nov. deserves special note because of its excellent preservation of the ornate shell, muscle scars and other internal structures, which projects like a raised platform in outlook, including one pair of radular muscle scars and eight metameric pairs of composite muscle scars (i.e. the A–H pairs of muscle scars) (Lemche and Wingstrand, 1959). The overall shape shows a configuration similar to that of the type species *Pilina unguis* Lindström (Lindström, *in* Angelin and Lindström, 1880; Lindström, 1884) from the Middle Silurian of Gotland, Sweden and that of *P. cheyennica* Peel from the Upper Ordovician Keel Member of the Chimneyhill Limestone, Oklahoma (Peel, 1977).

The paired radular muscle scars in *P. liaoningensis* are well preserved and are the biggest in the muscular field. In detail these scars are subelliptical in plan view and very complex, composed of more than thirty small scars. The radular scars are situated high on the dorsum just about one-third of the distance along the length of the shell. In the type species *P. unguis* (Lindström), the radular muscle scars are nearly tadpole-shaped and smaller in size (Lindström, *in* Angelin and Lindström, 1880: 16, pl. II, figs. 10–14, excl. fig. 15; Lindström, 1884: 56, pl. I, figs. 33–37; pl. XIX, fig. 2; Knight, 1941: 246: 4, figs. 1–3; Knight and Yochelson, 1960: I78, Fig. 48–6; Lemche and Wingstrand, 1959: 44, figs 133, 134 162A–D; Wingstrand, 1985: 449, Fig. 19) while in *Pilina cheyennica* Peel, the radular muscle scars are subrectangular in shape (Peel, 1977, 117–121, text-figs. 1–3; Wingstrand, 1985: 46, fig. 19; Peel 1991: 7, fig. 3c).

The A to C muscle scars pairs are situated laterally both sides of the radular muscle scars closer to the shell margin. These three pairs of elongate muscle scars are linked together. The D to H pairs of muscle scars are located posterior to the midlength of the shell. They are all similar and nearly horse-shoe-shaped (Figure 2).

The recent *Neopilina galatheae* Lemche (1957) has been studied in detail. (Lemche 1957; Lemche and Wingstrand 1959; Wingstrand 1985). According to Lemche and Wingstrand (1959) each pedal retractor muscle can be divided into two parts: (1) and (2), we interpret D–H as pedal retractors in part because of their position and in part because of the similarity of the muscles to those of *Neopilina*. Even though we can discern four parts, the overall shape of the scars is basically bipartite. The same bipart division can be seen in the scar of *P. liaoningensis*. Latero-posteriorly on the D to H pairs of muscle scars there is a small distinct scar (part 3) is situated in the left corner and another clear small scar (part 4) is located at the right corner of each main muscle scar. We present that the two main biparts of each scar control: parts (1) and (2) control the foot and provide for clamping and crawling movement; parts (3) and (4) more likely control activity of gill lobes and pallial muscles. As noted part (3) tends to gradually become smaller and weaker from D to H; while part (4) becomes larger and stronger and has two small pits. In *P. unguis*, the A to C sets are bigger and wider than those in *P. liaoningensis*, and the D to H sets are subdivided into more than four smaller parts (Lemche and Wingstrand 1959, figs. 133, 134). In *P. cheyennica* the A and B sets are coalesced, the C to H sets are not subdivided into the various minor scars.

The bundled impressions lateral to the pedal muscle scars appear unique. They show secondary and tertiary bifurcation and extend to the lateral margin. These do not stand in relief like the presumed pedal scars. It is possible that these are the marks of blood vessels. We doubt that blood vessels would be impressed into the shell. Our interpretation is that this muscle extends to edge of the mantle which would shape the contours of the lateral gill cavity.

The scars of the gill cavity are between the pedal muscle scars and the shell margins, and are another interesting structure in this species. They extend backward from C pair to G pair, the anterior ones being thinner and obscure, while those toward the posterior are wider and deeper, displaying a regular wave-like curvature. The concavely curved surface is broader than the convex side, whereas in *P. cheyennica* the scars of the gill cavity are obscure.

In addition, there are at least three pairs of muscle scars on both sides of the anterior body region. The first pair being larger and rope-like in appearance, situated anterior to A to C pairs of muscle scars. The second pair are located near the anteriorly

lateral side and are stripe-like in appearance and extend posteriorly. The third pair are subcircular, situated near the lateral margin and next to the second pair. Furthermore, between the stripe-like muscle scars and the subcircular muscle scars, there are five small grain-like muscle scars (Figures 2, 3f, g). On both sides of A to C pairs of muscle scar sets, there are at least two pairs of muscle scars parallel to the radular muscle scars.

The protoconch of *Pilina liaoningensis* sp. nov. is a small, symmetrical cone, protruding strongly forward (Figure 3c). Although external features and tip of the protoconch are not preserved, this specimen further establishes that the Tergomya have a symmetrical protoconch (Clarke and Menzies 1959; Menzies and Layton 1963; Peel 1977; Wingstrand 1985). In *P. cheyennica* (Peel 1977), from the Upper Ordovician, the protoconch is a small mamillate protuberance.

Ornament in *Pilina* varies among species. In *P. liaoningenensis*, the outer surface is covered with more than twenty stout and evenly distributed comarginal rugae, the interspaces between the rugae being covered with fine lines of growth. This ornament is crossed by radiating threads, resulting in a cancellate pattern. In *P. unguis*, the ornament comprises growth lines and faint, widely spaced grooves, where as in *P. cheyennica*, the outer surface is covered with lamellar growth increments, which may be irregularly rugose.

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