A silicified Middle Permian (Wordian) gastropod fauna is reported from the Tak Fa Limestone from Northern Thailand. It is the first diverse Permian gastropod fauna known from Thailand. The fauna comes from shallow water carbonates that are rich in fusulinids, sponges and calcareous algae. Forty gastropod species are reported, among them 17 nominate species and 23 species in open nomenclature. Thus, this fauna represents one of the richest Permian gastropod faunas known from Southeast Asia. Twelve species and one genus are new to science (all new taxa authored by Nützel & Ketwetsuriya). The new genus is Takfaia. The new species are Pharkidonotus khaonoiensis, Khumerspira thailandensis, Baylea? umbilicata, Takfaia kuesi, Glabrocionigulum magnus, Knightinella ornata, Anomphalus lateumbilicatus, Yunanima pulchra, Microdoma carinata, Trachydomia takhiensis, Goniusma tricornata and Cambodgia acuminata. The gastropod fauna is dominated by typical Late Palaeozoic cosmopolitan genera with bellerophontoids and pleurotomariines being most abundant. • Key words: Gastropoda, Late Palaeozoic, Thailand, silicification, diversity.


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The present contribution reports and describes a Middle Permian (Wordian) gastropod fauna from the Tak Fa Formation of the Saraburi Group, Nakhon Sawan, North Thailand (informally known as Tak Fa Limestone). The Tak Fa Limestone is fossiliferous and yields a diverse Permian invertebrate fauna. The present gastropod fauna has previously been reported in a preliminary note by Ketwetsuriya et al. (2014) based on silicified shells weathering out at the surface of calcareous rocks. Meanwhile, the carbonate samples have been dissolved and numerous silicified gastropod shells have been recovered. With 40 species, the present fauna is one of the most diverse Permian gastropod faunas from Southeast Asia supplementing our knowledge of Middle Permian gastropod distribution in this region considerably.

Previously, there have been few reports or mentions on Permian gastropods from Thailand. Grant (1976) studied Permian brachiopods from South Thailand and mentioned the presence of platyceratids and pleurotomarioids. Waterhouse (1982) studied an early Permian invertebrate fauna from the Kaeng Krachan Group and mentioned presence of the gastropod genus Peruvispira. Sone (2010) reported the species Magnicapitatus huazhangae from the Middle Permian (Guadalupian) of East Thailand and this is the only Permian gastropod species described from Thailand (type locality) to this point.

Geological setting

The Permian limestones yielding the studied gastropods are exposed along Khao Noi hill, located in Takhli district, Southeast of Nakhon Sawan province, ca 80 km south of Nakhon Sawan City, Northern Thailand, 15° 18’ 51.801”N, 100° 26’ 30.358”E (Fig. 1). The Permian limestone succession in the study area is part of the Tak Fa Formation of the Saraburi Group. The Tak Fa Formation was named by Nakornsri (1977, 1981) who published a geological map of the Amphoe Ban Mi area. The
Tak Fa Formation comprises limestone interbedded with argillaceous limestone, mudstone and dolostone. Parts of the limestone succession yield chert nodules and are fossiliferous. The invertebrate fossils in this formation comprise fusulinids, corals, brachiopods, gastropods, bryozoans and others.

The Tak Fa Formation is the part of Khao Khwang platform (Wielchowsky & Young 1985, Ueno & Charoen-stitirat 2011) located at the western margin of the Indochina Terrane (Metcalfe & Sone 2008). Fusulinids indicate a Yakhtashian or Artinskian (late Early Permian) to Midian or Capitanian (late Middle Permian) age for the fusulinoidean limestones of the Tak Fa Limestone in the East of the Nakhon Sawan province (Napradit 2005). In the studied section yielding the gastropods, the Tak Fa Limestone has a Wordian age.

The exposed section of fossiliferous limestones of the Tak Fa Formation yielding the studied gastropods has a thickness of approximately 35 meters. It consists of thick to very thick-bedded, light grey (lower part) to dark grey (upper part) limestones. The beds dip with 30° to the West. The lower part of the section is dominated by thick-bedded

Figure 1. Geological map and locality of the studied section that produced the silicified gastropods at Khao Noi hill, Takhlai district, Nakhon Sawan province, North Thailand.

Figure 2. The fossiliferous limestone (middle layer) from which the studied samples were collected.
packstones. Fusulinids, rugose corals, bryozoans, crinoid stems and gastropods are commonly found (only few samples were collected from this bed). The middle part of the sections consists of thick-bedded wackestones. The upper part of the section is composed of very thick-bedded, grey to dark-grey packstones with black chert nodules at the base and locally interbedded with laminated dark-grey shale (Fig. 2). Most of the studied samples were collected from the upper beds. In these beds, gastropods and fusulinids are abundant. Silicified gastropods weather out from the rock (Figs 2, 3). In the field, colonial and solitary rugose corals, brachiopods, crinoid stems and sponges could be observed.

Biota in the studied samples

Most of the samples that were dissolved were very fossiliferous and produced abundant silicified fossils. However, most of the fossil material consists of unidentifiable shell fragments. Remains of calcareous algae such as codiaceans (Fig. 4A) and the dasycladacean Mitzia sp. (Fig. 4B) were abundant in some of the gastropod-rich samples. Silicified fusulinids are abundant in most of the samples (Fig. 4C) and thin-sections showed that fusulinids are present in rock-forming quantities. The presence of these algae and foraminiferans suggest a tropical shallow water environment. The samples also yielded rather large sclerites probably deriving from sponges (Fig. 4D, E). Among other invertebrates, gastropods are by far the most diverse and abundant group. They are commonly fragmented but more or less complete specimens are also present. The strong dominance of gastropods is remarkable but it must be taken into account that gastropod-rich rocks were sampled preferentially in the field. The samples also yielded few small articulate brachiopods (Fig 4F, left), scaphopods (Fig. 4F, right), polyplacophoran plates (Fig. 4G), small nuculoid bivalves (Fig. 4H, I) and other bivalves (Fig. 4J, K). The few present brachiopods and bivalves have commonly attached valves indicating that the fauna is basically autochthonous and not transported.

A quantitative census of the fossils in the studied samples is difficult because of the high degree of fragmentation and the problematic preservation of many of the fossils. However, it seems clear that the fauna is very diverse with a low dominance. A comprehensive study

Materials and methods

Samples were preferentially taken where silicified gastropods weathered out from the rock. The samples yielding the silicified fauna were collected by the first author in 2010, 2013 and 2015. They were dissolved in formic acid at the Bayerische Staatssammlung für Paläontologie und Geologie in Munich, Germany. Most samples came from two stratigraphic layers at the north of an isolated hill (Fig. 1). After etching, the material was sieved under rinsing water at a mesh size of 0.5 mm. All fossils including the gastropods were picked from the washed residues. Gastropods were sorted according to species and samples. Representatives of each gastropod species and some other species were whitened with ammonium-chloride and documented with microphotography.

Figure 3. Limestone block as an example for preservation; silicified shell material weathered out from a grey, micritic limestone; width ca 15 cm.
on the diversity of the Tak Fa fauna will be attempted at a later point.

General remarks on the gastropod fauna

As mentioned, except for fusulinids, gastropods are the most abundant and diverse group in the present collection from the Tak Fa Limestone. According to the present genera, it is a typical Late Paleozoic gastropod fauna encompassing cosmopolitan genera such as *Euphemites*, *Pharkidonotus*, *Glabrocingulum*, *Anomphalus*, *Yunnania*, *Microdoma*, *Trachydolmia*, *Goniasma* and others. Other genera seem to be restricted to Southeast Asia according to the current state of knowledge. Although a complete census is difficult because of the poor preservation and fragmentation of many of the gastropods, it is obvious that bellerophontoids, pleurotomariines and trochoids represent the most abundant groups with *Warthia* and other bellerophontoids as well as *Glabrocingulum magnum* sp. nov. being most abundant. This dominance of basal gastropod clades is certainly a Paleozoic aspect of this fauna. This separates it from the diverse fauna of Perak, Malaysia and the Japanese Akasaka Limestone in which caenogastropods play a much larger role (Batten 1985, Nützel & Nakazawa 2012). As mentioned, the strong gastropod dominance in the studied samples is a remarkable aspect of this fauna but the picture is biased because rocks with gastropods were preferentially sampled. Further studies are needed to test whether gastropod dominance is a real phenomenon in the Tak Fa Limestone.

Preservation

The silicification is relatively coarse so that certain morphological features are obscured *e.g.* the growth line pattern is not visible in most of the specimens. This represents a major handicap for identification, especially in pleurotomariines and muchisomines in which presence and position of the selenizone or sinus is of great diagnostic relevance. Protoconchs are not or not sufficiently preserved in the present collection. As a consequence open nomenclature was used for many species. On the other hand, preservation was sufficiently good to assign specimens to genera and to characterize several species including new taxa.

Repository

The studied material is housed in the Bayerische Staatsammlung für Paläontologie und Geologie (Bavarian State Collection for Palaeontology and Geology) in Munich, Germany under the general repository number SNSB-BSPG 2014 XI. Some of the paratypes are housed in the Chulalongkorn University, Museum of Zoology, Bangkok, Thailand (CUMZ).

Systematic palaeontology

by Alexander Nützel & Chatchalerm Ketwetsuriya

The classification used herein is based on Wenz (1938–1844), Knight et al. (1960), Bouchet et al. (2005) and Bouchet et al. (in review).

Class Gastropoda Cuvier, 1795
Subclass Amphigastropoda Simroth, 1906
Order Bellerophontida Ulrich & Scofield, 1897
Superfamily Bellerophontoidae McCoy, 1852
Family Euphemitidae Knight, 1956

Genus *Euphemites* Warthin, 1930

*Type species.* – *Bellerophon urii* Fleming, 1828, Great Britain, Carboniferous.

*Euphemites graffhami* Moore, 1941

Figure 5F–L

1941 *Euphemites graffhami* sp. nov.; Moore, p. 142, pl. 2, figs 1–5.


*Description.* – Shell bellerophontiform, anomphalous, with geniculate curvature of body whorl in lateral view; larger specimen 30 mm long, 28 mm wide, 25 mm thick; first geniculation in aperture, second on opposite side; shell ventrally flattened between geniculations and rounded dorsally; body whorl smooth, probably covered with secondary shell deposits, neither growth lines, selenizone or slit observable; dorsal part of body whorl with broad shallow central furrow; inductura inside aperture with about 10 spiral lirae; aperture strongly bent kidney-shaped in transverse section with steep lateral lips, rounded anterior lip with central sinus (where shallow median furrow is situated) and a rounded triangular inner lip formed by the previous whorl; lateral lips joining body whorl with an U-shaped sinus in lateral view.

*Remarks.* – Despite the differences in age and region, we assign the present material to *Euphemites graffhami* Moore, 1941 from the late Pennsylvanian of Kansas, USA because there are no obvious morphological differences between our material and Moore’s (1941) type material as illustrated by this author. The geniculation was not mentioned in
Moore’s description but becomes obvious from his illustrations (Moore 1941, figs 4b, 5b). As pointed out by Yochelson (1960), there are not many distinctly geniculated species of the genus *Euphemites*. *Euphemites imperator* Yochelson, 1960 from the Permian of Texas is the most similar species. However, in this species, the spirally ornamented inductura extends much farther outside the aperture. Moreover, the shell *Euphemites graffhami* is much more flattened ventrally. *Euphemites graffhami* is similar to *E. nodosocarinatus* (Hall, 1858) from the Pennsylvanian of the USA as reported by Kues & Batten (2001). However, this species has many more inductural lirae and according to Yochelson (1960), it has nodes near the selenizone as is also the case in *E. callosus* (Weller, 1930).

**Genus Warthia Waagen, 1880**

*Type species.* – *Warthia brevisinuata* Waagen, 1880, Permian, India.
Warthia cf. brevisinuata Waagen, 1880
Figure 5A–E

cf. 1880 Warthia brevisinuata sp. nov.; Waagen, p. 161, pl. 15, fig. 6.
2014 Bellerophon sp. 1; Ketwetsuriya et al., p. 139, pl. 1, figs a, b.

Material. – SNSB-BSPG 2014 XI 2, 27 and several other specimens.

Description. – Shell globular bellerophontiform, anomphalous; larger illustrated specimen 4.9 mm long, 5.3 mm wide, 4.3 mm thick (SNSB-BSPG 2014 XI 27); whorl profile and anterior lip evenly rounded; whorls smooth, probably covered with secondary shell layers; whorls kidney-shaped, low in transverse section.

Remarks. – Several relatively small smooth bellerophontoids representing the genus Warthia are present in this collection. Of the numerous described Late Palaeozoic Warthia species, Warthia brevisinuata Waagen, 1880 from the Permian of the Salt Range, Pakistan seems to be most similar. But because of the preservation and the relatively uncharacteristic shell morphology, a safe identification is impossible.

Warthia sp.
Figure 5M–O

Material. – One specimen, SNSB-BSPG 2014 XI 106.

Remarks. – This shell representing the genus Warthia (31 mm long, 32 mm wide) resembles the much smaller specimens of Warthia cf. brevisinuata as described above but has callus (inductural) pads on the umbilical region and on the lateral lips. It is possible that these smaller specimens representing Warthia cf. brevisinuata are juveniles and are conspecific with the present mature shell.

Family Bellerophontidae McCoy, 1852
Subfamily Bellerophontinae McCoy, 1852

Genus Bellerophon de Montfort, 1808

Type species. – Bellerophon vasulites de Montfort, 1808; Devonian, Germany.

Bellerophon sp.
Figure 6A–E

Material. – Three specimens, SNSB-BSPG 2014 XI 49, 65 (fragment), 107 (fragment).

Description. – Bellerophontid with deeply umbilicated shell; whorls low, broad in transverse section ornamented with distinct collabral lirae separated by wider interspaces; selenizone narrow, bordered by undulating lirae, with distinct lunulae.

Remarks. – Although only fragments are present, the characteristic selenizone and ornament suggest the presence of an additional bellerophontid species in the Tak Fa fauna.

Bellerophon? sp.
Figure 6F, G

Material. – One specimen, SNSB-BSPG 2014 XI 60.

Remarks. – This anomphalous bellerophontoid shows growth lines and a faint spiral striation. It is 24 mm long, 28 mm wide and 26 mm thick and seems to have a slight depression at the supposed position of the selenizone. The anterior lip is evenly rounded. Preservation is insufficient for a taxonomic assignment. It could represent the genera Bellerophon, Retispira or Warthia with outer shell layers peeled off.

Genus Pharkidonotus Girty, 1912

Type species. – Bellerophon percarinatus Conrad, 1842; Pennsylvanian, USA.

Pharkidonotus khaonoiensis sp. nov.
Figure 7A–K

2014 Bellerophon? sp. 2; Ketwetsuriya et al., p. 139, pl. 1, fig. c.

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca 80 km south of Nakhon Sawan City, Northern Thailand, 15° 18´51.801˝ N, 100° 26´30.358˝ E (Fig. 1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.


Etymology. – After the Khao Noi hill at which the studied gastropod material was found.

Description. – Shell bellerophontiform, globose, longer than wide, anomphalous; holotype 30 mm long, 23 mm
wide, 26 mm thick; whorl profile round in lateral view; whorls with pronounced, steeply sided median crest with selenizone; borders of selenizone undulating on last part of the body whorl; outer lip as reflected by growth lines sickle-shaped; aperture kidney-shaped in transverse section with rounded anterior lip, U-shaped at crest; induc-
tura extending from umbilici over some area outside the aperture.
Remarks. – *Pharkidonotus khaonoiensis* sp. nov. resembles *Khumerspira thailandensis* sp. nov. but is more slender and lacks or has much weaker lateral angulations. *Pharkidonotus khaonoiensis* has a much more bent aperture in transverse section and the crest is much more pronounced. It also differs in these respects from *Bellerophon* (*Pharkidonotus*) *altitropis* Kulas & Batten, 1997 (Permian, USA) and moreover, that species is phaneromphalous. *Bellerophon deflectus* Chronic, 1952 from the Permian of the USA is much broader and its aperture is less bent in transverse section and has a much more pronounced callus. *Pharkidonotus khaonoiensis* sp. nov. differs from the vast majority of species assigned to *Bellerophon* in having a strongly elevated crest with steep sides hosting the selenizone. However, some species of *Bellerophon* including its Devonian type species also have a distinctly elevated crest. *Khumerspira* and *Pharkidonotus* are so close to each other morphologically that they may represent synonyms (Mazaev 2016, written communication). *Sorobanobaca* is also quite similar and might also be synonymous to the other two genera. However, it is beyond the scope of the present contribution to present a formal synonymization.

**Figure 6.** A–C – *Bellerophon* sp., SNSB-BSPG 2014 XI 49. • D – *Bellerophon* sp., shell fragment showing collabral lirae and selenizone bordered by undulating lirae, SNSB-BSPG 2014 XI 65. • E – *Bellerophon* sp., fragment of umbilical region, SNSB-BSPG 2014 XI 107. • F, G – *Bellerophon*? sp., SNSB-BSPG 2014 XI 60.

**Genus Khumerspira** Murata, 1974

**Type species.** – *Khumerspira ishii* Murata, 1974 (*in Ishii & Murata*), Middle Permian, Cambodia.

**Remarks.** – The present species *Khumerspira thailandensis* sp. nov. is assigned to the genus *Khumerspira* Murata, 1974 (*in Ishii & Murata*) because it has lateral edges, a wide low, subrectangular aperture in transverse section and a sharply projecting median crest. Accordingly, *Khumerspira* has also strongly reflexed lateral lips but judging from the illustration of the type species given in Ishii & Murata (1974), it is not quite clear what this means. *Khumerspira thailandensis* sp. nov. also resembles species of the genus *Pharkidonotus* Girty, 1912. However, *Pharkidonotus* has usually rather strong collabral transverse undulations on the shell and some species also have nodules. Given the shape and gross morphology, *Khumerspira thailandensis* sp. nov. is closer to the type species of *Pharkidonotus* as shown by Knight (1941) and Girty (1915) than to that of *Bellerophon* although this species (type of *Pharkidonotus*) has much stronger transverse rugae. The subgenus *Bellerophon Sorobanobaca* Nishida, 1969 (proposed as subgenus of *Bellerophon*) from the Middle Permian of Japan is also similar but is umbilicated and has a spiral ornament.

*Khumerspira* and *Pharkidonotus* are so close to each other morphologically that they may represent synonyms (Mazaev 2016, written communication). *Sorobanobaca* is also quite similar and might also be synonymous to the other two genera. However, it is beyond the scope of the present contribution to present a formal synonymization. Preliminarly, we suggest treating bellerophontoids with median crest, wide subrectangular aperture and lateral shoulders as follow:

*Pharkidonotus*: anomphalous, with transverse rugae and also with nodes in several species.

*Khumerspira*: anomphalous, ornament with growth lines only.
Sorobanobaca: phaneromphalous; spiral ornament present.

In that sense, Khumerspira might be regarded as a Pharkidonotus lacking strong ornament of rugae and nodes.

Khumerspira thailandensis sp. nov.

Figure 7L–N

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca 80 km south of Nakhon Sawan City, Northern Thailand, 15° 18´51.801˝ N, 100° 26´30.358˝ E (Fig. 1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.

Material. – Only the holotype, SNSB-BSPG 2014 XI 93.

Etymology. – After the country of Thailand.

Description. – Shell bellerophontiform, broad with sharp, distinctly elevated crest with selenizone and lateral rounded edges; holotype 22 mm long, 21 mm wide, 16 mm thick; shell concave between crest and lateral edges; shell slightly convex below edges; whorls approximately rectangular in transverse section; whorl surface largely smooth, only...
weak traces of collabral rugae on dorsal side; growth lines very faint, not well-preserved; aperture broad, anterior lip thin, V-shaped at crest; posterior lip concave due to previous whorl, with parietal inductura and two lateral pads, smooth and thick; umbilici completely covered.

Remarks. – As mentioned above, *Khumerspira thailandensis* sp. nov. resembles species of the genus *Pharkidonotus* in gross morphology but lacks strong rugae and nodes. It resembles *Bellerophon (Sorobanobaca) matsumotoi* Nishida, 1969 from the Middle Permian of Japan. However, this species and subgenus has a collabral and spiral ornament, which is lacking in the present material. Moreover, Nishida (1969) mentioned that his species is phaneromphalous.

*Khumerspira thailandensis* sp. nov. is also similar to *Bellerophon khaonoiensis* sp. nov. as described above but the shoulder of this species is rounded or only slightly angulated and the anterior lip has steeper sides. *Pharkidonotus thailandensis* sp. nov. also resembles *Bellerophon deflectus* Chronic, 1952 (which may be transferred to *Khumerspira*) from the Early Permian of Arizona but the dorsal crest is less elevated in the latter and it is much larger. Yochelson (1960) reported a similar species from the Permian of Texas as “*Bellerophon (?)* species” but this shell is widely phaneromphalous. Yochelson (1960) stated that because of the crest, this species would not represent *Bellerophon* in a strict sense.

Genus *Retispira* Knight, 1945

Type species. – *Retispira bellireticulata* Knight, 1945, Middle Permian, Texas.

*Retispira lyelli* (Gemmellaro, 1890) Figure 8A–C

1972 *Retispira lyelli* (Gemmellaro, 1890). – Batten, p. 13, figs 6, 7 (here more synonymy).

Material. – Two specimens, SNSB-BSPG 2014 XI 26, 32.

Remarks. – This rather characteristic species was originally described from the Sosio Limestone of Sicily, Italy. Batten (1972) reported it from the Permian of Perak, Malaysia and considered several taxa described from Asia and North America to represent synonyms. The larger present specimen is 6.3 mm long, 5.7 mm wide and 4.4 mm thick. It is distinctly phaneromphalous, has low whorls and an ornament of strengthened growth lines and densely spaced spiral threads.

Genus *Discotropis* Yochelson, 1956

Type species. – *Discotropis publicus* Yochelson, 1956, Permian, USA.

Remarks. – *Discotropis* was previously placed in Omphalotrochidae (Knight et al. 1960) but was placed in Euomphalidae by Linsley & Kier (1984) without explaining on what grounds. The present material does not contribute to solve the question which of these assignments would be the better choice.

*Discotropis*? sp. Figure 9A–C

Material. – One specimen, SNSB-BSPG 2014 XI 91.

Description. – Discoidal, widely phaneromphalous dextral shell with lower umbilicus somewhat deeper than upper umbilicus; diameter 2.9 mm, height 1.2 mm; strong angulation above mid-whorl and a further angulation on the upper side of whorls; whorl profile asymmetrical with slope ca 45° above angular periphery and much steeper below it; lower side of whorls distinctly convex; transition from whorl face
to base distinctly angular; distinct spiral cords present on whorl face, four below periphery and at least one above; suture distinct; aperture subcircular, as wide as high.

Remarks. – The present specimen resembles *Discotropis klobukowskii* Mansuy, 1912 from the Carboniferous of Yunnan, a species also reported by Delpey (1941) from the Permian of Cambodia. However, that species has a slightly elevated spire, axial sculptural elements and an upper edge. The present species probably represents a new species that may represent the genus *Discotropis* but the single specimen is too poorly preserved for a sufficient characterization. The generic and suprageneric assignment of this species is uncertain because tiny planispiral shells are present in various gastropod groups (e.g., Bandel 1988).

Genus *Euomphalus* Sowerby, 1814

Type species. – *Euomphalus pentangulatus* J. Sowerby, 1814, Carboniferous, Great Britain.

*Euomphalus*? sp.

Figure 9D

Material. – One specimen, SNSB-BSPG 2014 XI 69.

Description. – Discoidal, widely phaneromphalous shell with both umbilici equally deepened; diameter 23 mm; whorls round, almost circular in transverse section; whorl surface smooth; suture deep.

Remarks. – This small planispiral shell may represent early whorls of an unknown euomphalid.

Unassigned to superfamily
Family Raphistomatidae Koken, 1896
Subfamily Omospirinae Wenz, 1938

Genus *Baylea* de Koninck, 1883

Type species. – *Trochus yvanii* Léveillé, 1835, Carboniferous, Belgium.


*Baylea*? umbilicata sp. nov.

Figure 10


Locus typicus. – Khao Noi hill, Takhi district, Southeast of Nakhon Sawan province, ca 80 km south of Nakhon Sawan City, Northern Thailand, 15° 18´51.801˝ N, 100° 26´30.358˝ E (Fig. 1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.


Etymology. – For the distinctly umbilicated base.

Description. – Shell turbinate, moderately high-spired, gradate; holotype comprises about 6 whorls, 8.2 mm high, 6.4 mm wide; largest specimen 9.8 mm high, 6.8 mm wide; whorls sharply angulated at about mid-whorl and somewhat below middle of spire whorls; whorls with distinctly inclined subsutural ramp above and vertical, concave below angulation; angulation forms crest-like periphery of whorls; transition to base angular; whorls ornamented with numerous densely spaced spiral threads; up to eight spiral
threads present on ramp and at least four below angulation; growth line pattern including selenizone obscured due to preservation; selenizone probably at peripheral angulation of whorls; base flatly convex, without visible ornament, distinctly phaneromphalous with umbilicus surmounted by a rounded edge.

Remarks. – Due to the coarse silicification, growth line pattern including selenizone are obscured in the present material and thus, the generic placement is uncertain. It is likely that the selenizone is situated at the peripheral angulation of the whorls. Baylea? umbilicata sp. nov. is placed tentatively in the genus Baylea based on the gradate spire and the ornament of spiral lirae. The distinctly phaneromphalous base and the angular transition from whorl face to base are unusual for Baylea and differentiate the present species from other species of this genus. It is also possible that Baylea? umbilicata sp. nov. belongs in the genus Knightinella Knight, 1945. The type species of Knightinella is only minutely phaneromphalous and the whorls are usually not strongly angulated but rounded.

A well-preserved specimen of Baylea yvanii, type species of Baylea, from the Mississippian of Belgium was illustrated by Lindström & Peel (2005, fig. 1a). It is more high-spired than Baylea? umbilicata sp. nov., has a much shallower ramp and thus the spire is more gradate and the transition from whorl face to base is evenly rounded. Its base has only a pseudo-umbilicus. Several Middle Permian species from Russia have been assigned to Baylea. Most are much more high-spired than Baylea? umbilicata sp. nov. and have stronger spiral lirae which are more distant from each other and none of them has such a wide umbilicus. Baylea perthensis Dickins, 1963 from the Permian of Australia is much more low-spired and less distinctly gradate and has a spiral ornament on the base. Baylea? umbilicata sp. nov. resembles species of the genus Biarmeaspira Mazaev, 2006 for instance the Middle Permian species B. angulata (Nechaev, 1894) and B. yakowlewi (Licharev, 1967) but both have strong spiral cords on the base and they are not distinctly phaneromphalous.

Superfamily Trochonematoidea Zittel, 1895
Family Trochonematidae Zittel, 1895

Genus Knightinella Licharev, 1975

Type species. – Pleurotomaria humerosa Meek & Hayden, 1858, Carboniferous, USA.

Remarks. – Knightinella was proposed as a subgenus of Amaurotoma Knight, 1945.
Knightinella ornata sp. nov.

Figure 11A–F

2014 Worthenia? sp.; Ketwetsuriya et al., p. 140, pl. 1, fig. i.

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca 80 km south of Nakhon Sawan City, Northern Thailand, 15° 18’51.801˝ N, 100° 26´30.358˝ E (Fig. 1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.


Etymology. – Latin ornamented.

Description. – Shell acutely turbiniform, moderately high-spired; holotype (largest specimen) consisting of ca 5 whors, earliest whors missing, 13.5 mm high, 10.2 mm wide; early teleoconch whors evenly convex; later, an angulation develops at middle of whorl face; angulation separates adapical slightly convex ramp and a subvertical, slightly convex abapical portion (outer whorl face); base evenly convex with rounded transition to whorl face, anomphalous; early teleoconch whors with four to six spiral cords, abapical cords stronger; five to six spiral cords and weaker axial ribs or strengthened growth lines present on ramp in mature whors; strengthened growth lines on ramp curving backward towards angulation; intersections of axial ribs and spiral cords slightly nodular; outer whorl face below angulation ornamented with three strong spiral cords and few weak spiral lirae; base with ca 10 distinct spiral cords; aperture circular columellar lip reflexed.

Remarks. – We assign Knightinella ornata sp. nov. to the genus Knightinella Licharev, 1975 based on the gross morphology and the dominant spiral ornamentation. Due to preservation, the growth line pattern is unclear i.e., whether a selenizone is present and if so, how it would look like (these features are not well documented for the type species of Knightinella as well). The juvenile specimen illustrated in Fig. 11F shows backward curving growth lines on the ramp and this suggests that a selenizone is present at the angulation. If the present species had a selenizone at the angulation of the whors, it could represent the genus Biarmoaspira Mazaev, 2006 (see also Mazaev 2015). Knightinella humerosa (Meek & Hayden, 1858), the Carboniferous type species of Knightinella has a shallower ramp and the spiral cords are narrower (see Knight 1945, Kues & Batten 2001).
Amaurotoma subsinuata (Meek & Worthen, 1861), type species of the genus Amaurotoma Knight, 1945, lacks ramp and angulation of the whorls according to an illustration given by Knight et al. (1960, fig. 139/4). Apachella Winters, 1956 is more high-spired and the whorls are less angulated. The genus Worthenia yields similar species but is characterized by an elevated, nodular selenizone.

Knightinella sp.
Figure 11G–I

2014 Worthenia? sp.; Kettwetsuriya et al., p. 140, pl. 1, fig. j.

Material. – Two specimens, SNSB-BSPG 2014 XI 43, 110.

Description. – Turbinate shell with distinctly gradate spire; larger specimen ca 6 whors, 11.2 mm high, 11.5 mm wide; whorls with sharp angulation above mid-whorl; ramp between adapical suture and angulation rather shallow, concave with fine spiral threads which are slightly nodular when intersecting with strengthened growth lines; adapical spiral threads somewhat stronger and more nodular than those lower on ramp; outer whorl face below angulation vertical, slightly concave; outer face with several sharp spiral threads of variable strength but generally stronger than threads on ramp; transition to base angular; base not preserved.

Remarks. – Knightinella sp. resembles Knightinella ornata sp. nov. but has a lower spire, a weaker spiral ornament and the spire is more gradate because the ramp is shallower. As in Knightinella ornata sp. nov., presence and nature of the selenizone are unclear due to preservation. The present shells resemble Knightinella uralica Licharev, 1975 from the Carboniferous of Russia but this species has fewer spiral lirae on whorl face.

Genus Amaurotoma Knight, 1945

Type species. – Pleurotomaria subsinuata Meek & Worthen, 1861, Pennsylvanian, USA.

Amaurotoma? sp.
Figure 12

Material. – Three specimens, SNSB-BSPG 2014 XI 16, 64, 89.

Description. – Shell small, turbinate; largest specimen (SNSB-BSPG 2014 XI 16) comprises ca 3.5 whors, 5.5 mm high, 3.6 mm wide (apex missing); whorls convex, ornamented with three strong spiral cords in abapical
portion of whorls; second cord forms periphery at about mid-whorl; adapical portion of whorls forms steep, straight or slightly convex ramp with three weaker spiral cords second of which somewhat more pronounced and angulating whorl face; adapical spiral cords slightly nodular; base convex, minutely phaneromphalous with up to seven distinct, narrowly spaced spiral cords; growth line pattern and aperture unknown.

Remarks. – *Amaurotoma*? sp. is distinct in this collection. Unfortunately neither growth line pattern nor aperture is known so that a further assignment is impossible. It is also possible that the species belongs to Pleurotomariida. We assign it preliminarily to *Amaurotoma* because it resembles species such as *Amaurotoma subangulatum* (Hall, 1858) from the Mississippian of the USA (see Cumings 1906, pl. 25, fig. 32). An assignment to *Baylea* or *Apachella* Chronic, 1952 is also possible. *Rhabdotocochlis* Knight, 1933 from the Late Carboniferous of the USA has a lower spire and less convex whorls.

Subclass Vetigastropoda Salvini-Plawen, 1980
Order Pleurotomariida Cox & Knight, 1960
(in Knight et al.)
Superfamily Eotomarioidea Wenz, 1938
Family Eotomariidae Wenz, 1938

**Genus Takfaia gen. nov.**

Type species. – *Takfaia kuesi* sp. nov.

Etymology. – After the Tak Fa Limestone.

**Diagnosis.** – Shell low-spired, trochiform with flattened spire; mature shell broadly trochiform with almost straight to slightly convex whorl face; last portion of body whorl distinctly deflected abapically; selenizone immediately above suture, forming periphery, bordered by distinctly elevated, sharp crests; selenizone concave, vertical, parallel to shell axis; adapical border of selenizone forming angulation with sloping whorl face; whorls smooth, base convex, distinctly phaneromphalous with umbilicus vertical sided, surmounted by a distinct edge.

Remarks. – *Takfaia* resembles the genus *Ambozone* Batten, 1972 (type species *Ambozone rasmusseni* Batten, 1972 from the Middle Permian of Malaysia). However, *Ambozone* is more low-spired (almost planispiral). *Euconospira* Ulrich & Scofield, 1897 is more high-spired and is either anomphalous or only minutely phaneromphalous. The Devonian genus *Oehlertia*, Perner, 1907 is similar but the selenizone is well above the suture, it is more high-spired and the shell is ornamented with fine but distinct axial lirae. The eotomariid *Bradyospira* Batten, 1964 from the Permian of Arizona is similar but has a conical, non-depressed spire and the umbilicus is much narrower.

**Takfaia kuesi** sp. nov.

Figure 13

2014 *Discotropis* sp.; Ketwetsuriya et al., p. 142, pl. 2, fig. e.

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca 80 km south of Nakhon Sawan City, Northern Thailand, 15° 18’ 51.801” N, 100° 26’ 30.358” E (Fig.1).
Description. – Shell low-spired, trochiform with flattened apical whorls; holotype comprises ca 5 whorls, 7.7 mm high, 11.4 mm wide; largest specimen 9.8 mm high, 11.4 mm wide (SNSB-BSPG 2014 XI 10); earliest whorls convex, evenly rounded, very low-spired with spire only slightly elevated; after ca three whorls the shell becomes broadly trochiform with almost straight to slightly convex whorl face; last portion of body whorl distinctly deflected abapically; selenizone immediately above suture, forming periphery, bordered by distinctly elevated, sharp crests; selenizone vertical, parallel to shell axis; adapical border of selenizone forming angulation with sloping whorl face; adapical crest bordering selenizone emerges at suture; suture distinct; selenizone fully exposed when last portion of body whorl becomes deflected downward; whorls smooth, circular in transverse section; base convex, distinctly phaneromalous with umbilicus opened throughout including initial whorls; umbilicus of last two whorls with vertical, slightly convex whorl sides; umbilicus surmounted by a distinct edge.

Etymology. – After Barry Kues for his work on Late Palaeozoic gastropods.

Genus Glabrocingulum Thomas, 1940

Type species. – Glabrocingulum (Glabrocingulum) beggi Thomas, 1940, Carboniferous, England.

Glabrocingulum magnum sp. nov.

Figure 14

2014 Treposira sp.; Ketwetsuriya et al., p. 139, pl. 1, figs d–g.
2014 Glabrocingulum sp.; Ketwetsuriya et al., p. 140, pl. 1, fig. h.

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca 80 km south of Nakhon Sawan City, Northern Thailand, 15° 18’ 51.801” N, 100° 26’ 30.358” E (Fig. 1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.


Remarks. – With up to 40 mm in height and width, Glabrocingulum magnum sp. nov. is a rather large representative of the genus Glabrocingulum. The strong subsutural nodes and the angulations on the base and at the transition to the base are especially characteristic for this species. There are numerous Late Palaeozoic species of Glabrocingulum most of which are smaller and have a finer ornament. Glabrocingulum coronatum Chronic, 1952 from the Permian Kaibab Formation of Arizona, USA is much smaller, has a lower spire, a much finer ornament and it lacks a carinated and ornamented base (see also Batten 1989, pl. 1, figs 1–23). Glabrocingulum beedei (Mark, 1912) from the Pennsylvanian of Ohio and the Pennsylvanian/Permian transition of New Mexico has a lower spire, is much smaller, subsutural nodes are not as pronounced and it has no pronounced carination at the transition to the base (see Sturgeon 1964, Kues 2004). The Permian species Glabrocingulum sarrauti (Mansuy, 1912) and Glabrocingulum stankovski Mazaev, 2006 are similar but have a lower spire, differ in details of the ornament and have no pronounced basal angulation (see Batten 1972, figs 12, 13; Mazaev 2006, fig. 1).

Order Trochida Cox & Knight, 1960 (in Knight et al.)

Superfamily Trochoidea Rafinesque, 1815

Family Anomphalidae Wenz, 1938
Genus Anomphalus Meek & Worthen, 1866

Type species. – Anomphalus rotulus Meek & Worthen, 1867, Carboniferous, USA.

Anomphalus lateumbilicatus sp. nov.

Figure 15A–G

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca 80 km south of Nakhon Sawan City, Northern Thailand, 15° 18´51.801˝ N, 100° 26´30.358˝ E (Fig. 1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.


Etymology. – Latin widely umbilicated.

Description. – Shell minute, discoidal with almost flat, only slightly elevated spire; holotype comprising ca five whorls, diameter 2.7 mm, 1.5 mm high, whorls smooth, with distinctly convex periphery and flatly convex adapical side; whors increasing slowly in diameter; suture distinct; base with wide umbilicus with circumumbilical rounded edge.

Remarks. – Anomphalus lateumbilicatus sp. nov. differs from all its congeners by its minute size, its very wide
umbilicus and the slow increase in whorl diameter. The most similar species is *Anomphalus straparoliformis* Mazaev, 1997 from the Middle Carboniferous of the Russian Platform. However, this species is much larger (at a comparable number of whorls), the whorls do increase faster in diameter and the umbilicus is smaller in relation to the total width of the shell.

*Anomphalus* sp.  
Figure 15H–N

2014 *Anomphalus cf. japonicus* Nützel, 2012. – Ketwetsuriya et al., p. 140, pl. 2, figs a, b.

**Material.** – Three specimens, SNSB-BSPG 2014 XI 6, 20, 28.

**Description.** – Shell small, low-spired, rotelliform; largest specimen with diameter of 5.2 mm, height 4.3 mm; whorls smooth, with convex periphery and flattened ab- and adapical sides, round, circular in transverse section; base distinctly umbilicated with circumumbilical edge; suture shallow, indistinct.

**Remarks.** – The present specimens are typical representatives of *Anomphalus* but the preservation is too poor to establish species identity. They resemble *Anomphalus japonicus* Nützel, 2012 (*in Nützel & Nakazawa*) from the Middle Permian of Japan. However, *A. japonicus* has a much deeper suture and the adapical portion of the whorl is much more convex. Moreover, this species is much smaller. The Late Carboniferous *Anomphalus rotulus* Meek & Worthen, 1867 as illustrated by Knight (1933) is similar but has an umbilical plug. *Anomphalus umbilicatus* Knight, 1933 from the Pennsylvanian of the USA is also very similar. *Anomphalus* sp. from the Permian of Perak, Malaysia is more high-spired and its umbilicus is
filled with a plug (Batten 1979, figs 10, 11). Anomphalus? sundaicus Wanner, 1942 (according to Yochelson 1956 not a representative of Anomphalus) from the Permian of Timor has a flatter spire and more rapidly increasing whorls. The Anomphalus species that were illustrated by Yochelson (1956) from the Permian of the USA have a flatter spire.

Family Araeonematidae Nützel, 2012 (in Nützel & Nakazawa)

Genus Yunnania Mansuy, 1912

Type species. – Yunnania termieri Mansuy, 1912, Late Carboniferous, China.

Yunnania pulchra sp. nov.

Figure 16

2014 Tapinotomaria? sp.; Ketwetsuriya et al., p. 140, pl. 1, fig. k.

Locus typicus. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca 80 km south of Nakhon Sawan City, Northern Thailand, 15° 18´ 51.801˝ N, 100° 26´ 30.358˝ E (Fig. 1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.


Etymology. – Latin beautiful.

Description. – Shell turbiniform; holotype comprising ca 4 whorls (apex missing), 9.3 mm high, 9.7 mm wide; suture impressed; whorls slightly convex and slightly shouldered; whorls embrace at periphery so that periphery is at suture; base convex with evenly rounded transition to whorl face; whorls ornamented with evenly spaced distinct spiral cords; distance between cords about twice as wide as cords; cords have approximately same strength; whorls also ornamented with numerous collabral, densely spaced, slightly prosocline axial threads; intersections of spiral cords and axial threads slightly nodular; base shallowly convex, anomphalous, ornamented with up to 10 strong spiral cords and a smooth circumbilical area; aperture approximately as high as wide; outer and inner
lip convex, parietal lip concave; aperture acute adarily.

**Remarks.** – *Yunnania meridionalis* Mansuy, 1914b from the Permian Productus Limestone of Cambodia is similar to *Yunnania pulchra* sp. nov. but *Y. meridionalis* has more convex whorls and the axial ribs are not sharp and thread-like but broad and low – Mansuy (1914b) described them as “ondulations transverses”, i.e., transverse undulations. Moreover, the spiral cords are stronger in *Yunnania meridionalis*. The illustration of *Yunnania meridionalis* given by Delpey (1941) resembles the present specimens in shape but especially the nature of the axial ornament cannot be inferred from this illustration. The illustration of the specimen from the Permian of Malaysia determined as *Yunnania meridionalis* by Batten (1972) seems to be much more high-spired than *Y. meridionalis* and *Yunnania pulchra* sp. nov. so that it is not clear whether this specimen really represents *Y. meridionalis*. Other gastropod species assigned to *Yunnania* generally lack axial ornament.

**Family Trochidae Rafinesque, 1815**

**Genus Anticonulus** Cossmann, 1918

*Type species.* – *Trochus mariae* d’Orbigny, 1853, Early Jurassic, France.

**Anticonulus? sp.**

Figure 17A, B

2014 Pleurotomarioid indet. – Ketwetsuriya et al., p. 140, pl. 1, fig. 1.

**Material.** – One specimen, SNSB-BSPG 2014 XI 8.

**Description.** – Shell acutely conical, small, comprising ca 9 whors (apex missing), 5.8 mm high, 3.8 mm wide; flanks straight; whorl face straight with periphery at transition to base; suture shallow; transition to base markedly angular with a protruding edge; base flat, slightly conical, smooths.

**Remarks.** – This small conical shell resembles the Mesozoic (Triassic/Jurassic) genus *Anticonulus*.

**Genus Coeloconulus** Nützel, 2012

*(in Nützel & Nakazawa)*

*Type species.* – *Coeloconulus panae* Nützel, 2012 *(in Nützel & Nakazawa)*, Middle Permian, Japan.

**Coeloconulus panae Nützel, 2012 (in Nützel & Nakazawa)**

Figure 17D–F


**Remarks.** – This tiny conical, coeloconoid and phaneromphalous shell is obviously identical with *Coeloconulus panae* as reported from the Middle Permian Akasaka Limestone from Japan (Nützel & Nakazawa 2012) although it is much larger and has a more convex base.

**Genus Eocalliostoma** Haas, 1953

*Type species.* – *Calliostoma interruptum* Cox, 1949, Late Triassic, Peru.

**Eocalliostoma sp.**

Figure 17C

**Material.** – One specimen, SNSB-BSPG 2014 XI 81.

**Remarks.** – A single acutely trochiform shell (ca 4.5 whors, 2.7 mm high, 1.8 wide) with straight and slightly prosocline axial ribs that do not continue onto the base represents a distinct species in this collection. It resembles the Triassic genus *Eocalliostoma* Haas, 1953 (see also Knight et al. 1960, Nützel & Erwin 2004). The present specimen also resembles juvenile specimens of the caenogastropod *Pulaeostylus lateapicatus* Nützel, 2012 *(in Nützel & Nakazawa 2012, p. 149, fig. 23o)* from the Permian of the Akasaka Limestone, Japan but the latter species has lower whors and orthocline axial ribs.

**Family Microdomatidae** Wenz, 1938

**Genus Microdoma** Meek & Worthen, 1866

*Type species.* – *Microdoma conicum* Meek & Worthen, 1866; USA, Carboniferous.

**Microdoma carinata** sp. nov.

Figure 18

2014 *Babylonites?* sp.; Ketwetsuriya et al., p. 142, pl. 2, figs f–h.
**Locus typicus.** – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca 80 km south of Nakhon Sawan City, Northern Thailand, 15° 18’ 51.801” N, 100° 26´ 30.358” E (Fig. 1).

**Stratum typicum.** – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.


**Etymology.** – For the angular transition from whorl face to base.

**Description.** – Shell high-spired trochiform, conical with an apical angle of 50–60°; holotype consisting of about six whorls, 10.6 mm high, 7 mm wide; largest specimen (SNSB-BSPG 2014 XI 62) comprising about 5 whorls (apex missing), 12.0 mm high, 8.3 mm wide; sutures distinct; flanks straight; whorl face straight to very slightly convex with narrow adapical shoulder in some specimens; whorls largely smooth except of weak reticulate ornament of collabral axial ribs and spiral cords with nodular intersection on early teleoconch whorls; growth lines straight, prosocline; pronounced carina with spiral cord present low on the whorls, emerging from abapical suture, fully exposed on last whorl forming the periphery and angular transition to base of whorls; last part of last whorl somewhat deflected so that carina becomes fully exposed; base convex with pseudo-umbilicus formed by twisted inner lip of aperture; aperture subcircular, somewhat higher than wide; columellar lip slightly twisted forming a fold.

**Remarks.** – *Microdoma carinata* sp. nov. resembles the Pennsylvanian type species of *Microdoma*, *Microdoma conicum* Meek & Worthen, 1866. However, *Microdoma conicum* has rather strong nodes as teleoconch ornament and lacks a twisted inner lip. Some of the Carboniferous Russian species assigned to *Microdoma* by Mazaev (1997) resemble *Microdoma carinata* sp. nov. but these species have much stronger nodes or ribs at the suture. *Anematina permiana* (Yakowlew, 1899) as reported by Mazaev (1997) from the Late Carboniferous of the Russian Platform resembles *Microdoma carinata* sp. nov. but lacks the strong basal carination. *Euconodoma gavinae* Kues, 1990, type species of the genus *Euconodoma* Kues, 1990, from the Pennsylvanian of New Mexico is similar but *Euconodoma* has strong nodes at the basal angulation and lacks the twisted inner lip of the aperture. *Euconodoma* was considered to represent a synonym of *Microdoma* by Batten (1995). However, it seems possible that *Euconodoma* represents a distinct genus.

Subclass Neritimorpha Koken, 1896
Order Cycloneritimorpha Frýda, 1998
Superfamily Naticoidea Waagen, 1880
Family Naticopsidae Waagen, 1880

**Genus Naticopsis McCoy, 1844**

**Type species.** – *Natica ampliata* Phillips, 1836, Carboniferous, Ireland.

**Naticopsis spp.**

Figure 19A–I

2014 *Naticopsis* sp.; Ketwetsuriya et al., p. 144, pl. 2, fig. k.

**Material.** – Six specimens, SNSB-BSPG 2014 XI 57, 66, 68, 72, 79 95.

**Remarks.** – Several naticiform, low spired, smooth shells, all smaller 10 mm are present in this collection representing probably two to three species of the wide-spread and late Palaeozoic genus *Naticopsis*. The preservation of the
specimens (especially the apertures) is not sufficient for identification.

Family Trachyspiridae Nützel, Frýda, Yancey & Anderson, 2007

**Genus Trachydomia Meek & Worthen, 1866**

**Type species.** – Naticopsis nodosa Meek & Worthen, 1861, Carboniferous, USA.

**Trachydomia takhliensis sp. nov.**

Figure 19J–M

2014 Trachydomia sp.; Ketwetsuriya et al., p. 144, pl. 2, fig. j.

**Locus typicus.** – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca 80 km south of Nakhon Sawan City, Northern Thailand, 15° 18’ 51.801” N, 100° 26´ 30.358” E (Fig. 1).

**Stratum typicum.** – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.

**Material.** – Holotype: SNSB-BSPG 2014 XI 41; paratypes SNSB-BSPG 2014 XI 37, CUMZ 7013, 7014.

**Etymology.** – After the district of Takhli where the species occurs.

**Description.** – Shell naticiform to turbiniform; holotype 11.7 mm high, 9.8 mm wide; largest specimen (SNSB-BSPG 2014 XI 87) 30 mm high (apex missing),
31 mm wide; spire acute distinctly elevated; body whorl much higher than spire with height about 85% of total height; whorls round, convex with a narrow subsutural ramp; whorls embracing at periphery; whorls ornamented with distinct nodes which are strongest on the body whorl; suture distinct; base round, convex with evenly rounded transition to base; growth lines prosocline; aperture D-shape with thickened outer lip and parietal inductura; columellar lip straight, oblique to shell axis, widened with a crescent-shaped furrow; outer lip evenly convex; base anomphalous, convex.

**Remarks.** – *Trachydomia takhliensis* sp. nov. is a typical representative of the genus *Trachydomia*. *Trachydomia dassaulti* Mansuy, 1913 from the Permian Productus Limestone of Laos is similar in shape but has finer and denser nodes. *Trachydomia dassaulti* has also been reported from the Permian of Perak, Malaysia by Batten (1979) and the specimen he illustrated has much finer nodes which are arranged in prosocline lines. Moreover, its ramp is less pronounced. *Trachydomia gobbeti* Batten, 1979 from the Permian of Perak, Malaysia has nodes which are strictly arranged in spiral lines and the adapical nodes are much stronger than the abapical ones. *Trachydomia imbricata* Batten, 1979 and *T. gemmulata* Batten, 1979, both from the Permian of Perak, Malaysia differ strongly from *Trachydomia takhliensis* sp. nov. in shape and ornament. *Trachydomia* cf. *nodosa* (Meek & Worthen, 1866) from the Middle
Permian of Japan as reported by Nützel & Nakazawa (2012) has nodes which are strictly arranged in spiral lines. *Trachydomia nodosa*, type species of the genus *Trachydomia*, is broader and has fewer but much coarser nodes. *Trachydomia minuta* Pan & Erwin, 2002 from the Late Permian of China is much more high-spired. *Trachydomia deprati* Mansuy, 1914b from the Permian Produktus Limestone of Cambodia is broader and has less convex whorls.

Subclass Caenogastropoda Cox, 1960
Superfamily Orthonematoidea Nützel & Bandel, 2000
Family Goniasmatidae Nützel & Bandel, 2000
Subfamily Goniasmatinae Nützel & Bandel, 2000

Genus *Goniasma* Tomlin, 1930

Type species. – *Murchisonia lasallensis* Worthen, 1890, Pennsylvanian, USA.

*Goniasma tricarinata* sp. nov.

Figure 20A–D

*Locus typicus*. – Khao Noi hill, Takhli district, Southeast of Nakhon Sawan province, ca 80 km south of Nakhon Sawan City, Northern Thailand, 15° 18´51.801˝ N, 100° 26´30.358˝ E (Fig. 1).

*Stratum typicum*. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.

*Etymology*. – Latin, with three carinae (spiral cords).


*Description*. – Shell high-spired; holotype comprises about 9 whorls, 9.5 mm high, 5.6 mm wide; suture distinct; whorls angulated at about mid-whorl with a broad, steep subsutural ramp; whorl face vertical, parallel to shell axis below angulation; abapical portion of whorls with three equally spaced prominent spiral cords; strongest spiral cord located at mid-whorl at angulation forming periphery; ramp largely smooth, straight with very weak spiral cord near the suture; base slightly rounded.

*Remarks*. – The present specimens resemble the Late Carboniferous type species of *Goniasma*, *Goniasma lasallensis* Worthen, 1890 (see also Mazaev 2011, p. 1564, pl. 1, figs 9–13) but in that species, the angulation is lower on the whorls and it lacks the three strong spiral cords low on the whorls. *Goniasma fortecarinata* Nützel, 2012 (*in* Nützel & Nakazawa) from the Middle Permian Akasaka Limestone, Japan is similar but the upper two spiral cords are much stronger than the abapical one.

Genus *Stegocoelia* Donald, 1889

Type species. – *Murchisonia (Stegocoelia) compacta* Donald, 1889, Early Carboniferous, Scotland.

*Remarks*. – The subgenus *Hypergonia* Donald, 1892 has been considered to represent a synonym of *Stegocoelia* by Mazaev (2001, 2011).

*Stegocoelia sp. 1*

Figure 20E, F

Remarks. – These small, high-spired slender murchisoniiform gastropods have a prominent ornament of four spiral cords on whorl face. The whorls are distinctly convex and somewhat angulated. They resemble several Late Palaeozoic species, for instance some species from the Carboniferous of Russia as described by Mazaev (2001). Murchisonia dussaulti Mansuy, 1914b from the Productus Limestone of Cambodia could be similar but is too poorly known for a meaningful comparison (see also Delpey 1941, fig. 42). Stegocoelia akasakaensis Nützel, 2012 from the Middle Permian Akasaka Limestone of Japan is similar but this species is much smaller and the spiral cords have a different position (Nützel & Nakazawa 2012).

Stegocoelia sp. 2
Figure 21C

2014 Stegocoelia sp. 2; Ketwetsuriya et al., p. 145, pl. 2, fig. p.

Material. – One specimen, SNSB-BSPG 2014 XI 94.

Description. – Shell small, high-spired, slender, comprising about 9 whorls, 7.2 mm high, 2.3 mm wide; suture shallow; whorl face straight; whorls ornamented with four distinct spiral cords; adapical spiral cord in subsutural position; second spiral cord somewhat weaker, situated above mid-whorl; third spiral cord strongest, forming periphery, low on the whorl; fourth spiral cord weak, emerging from abapical suture; base flat with angular transition to whorl face.

Remarks. – This shell is poorly preserved but clearly represents a distinct species in the present collection. Similar shells, poorly preserved as well, were reported by Kulas & Batten (1997) as Stegocoelia (Hypergonia) percostata (Girty, 1939) and Stegocoelia (Hypergonia?) sp. from the Permian of Wyoming. Stegocoelia turabievoensis Mazaev, 2001 from the Carboniferous is also similar but much larger.

Family Orthonematidae Nützel & Bandel, 2000

Genus Orthonema Meek & Worthen, 1862

Type species. – Eunema (?) salteri Meek & Worthen, 1860, Carboniferous, USA.

Orthonema sp.
Figure 21A, B

Material. – One specimen, SNSB-BSPG 2014 XI 53.

Description. – Shell high-spired, slender, ca 8 whorl with apex missing, 16 mm high, 7 mm wide; suture shallow but distinct; whorls largely smooth, ornamented with a distinct, sharp subsutural spiral cord bordering a narrow ramp; abapical spiral lira emerging just at suture; whorl face concave.

Remarks. – This specimen resembles species of the genus Orthonema as, for instance, reported from the Carboniferous of Russia (Mazaev 2002) and the Permian of the Southwestern USA (Erwin 1988a).

Genus Protostylus Mansuy, 1914a

Type species. – Protostylus lantenoisi Mansuy, 1914a, Carboniferous, SE Asia.

Remarks. – Based on Middle Permian high-spired, smooth gastropods, Nützel & Nakazawa (2012) discussed the poorly known genus Protostylus. The type species as well as the other species assigned to this genus are poorly preserved and thus, identity and systematics of this genus remain uncertain. Batten (1995) placed Protostylus in Procerithiidae based on the presence of an anterior siphonal canal. Nützel in Nützel & Nakazawa (2012) placed Protostylus tentatively in the family Orthonematidae.

Protostylus sp.
Figure 23A–F

**Description.** – Shell high-spired; largest specimen consists of about 10 whorls, 20 mm high, 6.8 mm wide; sutures distinct; whorls low, slightly convex with periphery somewhat below mid-whorl, embracing low on previous whorl; whorls smooth; base rounded, convex; aperture subovate, somewhat higher than wide.

**Remarks.** – The present specimens resemble *Protostylus* sp. from the Middle Permian Akasaka Limestone from Japan as reported by Nützel & Nakazawa (2012). However, the Japanese species is somewhat more slender. The studied specimens show a narrow spiral breakage high on the whorls. If this reflects the presence of a selenizone or sinus, this species could be related to genera like *Altadema* Kues, 2002 or *Kazanella* Mazaev, 2015. *Streptacis? complanata* Hoare, Sturgeon & Anderson, 1997 from the Pennsylvanian of the USA resembles *Protostylus* sp. and could be a representative of the genus *Protostylus* rather than *Streptacis* – the latter is usually more slender. The Chinese Carboniferous species *Protostylus lantenoisi* Mansuy, 1914a and *P. dussaulti* Mansuy, 1914a closely resembles the present species as far as can be inferred from the original illustrations. *Protostylus lantenoisi* has also been reported from the Permian of Perak, Malaysia by Batten (1985).

**Superfamily Soleniscoidea Knight, 1931a**

**Family Soleniscidae Knight, 1931a**

**Subfamily Soleniscinae Knight, 1931a**

**Genus Soleniscus Meek & Worthen, 1861**

*Type species.* – *Soleniscus typicus* Meek & Worthen, 1861, Carboniferous, USA.

**Soleniscus sp.**

Figure 22A, B

**Material.** – One specimen, SNSB-BSPG 2014 XI 120.

**Remarks.** – This relatively slender, fusiform, smooth soleniscid shell (13 mm high, 4 mm wide) shows a distinct col umellar fold. Shells like this have been repeatedly reported from the Late Palaeozoic of the world for instance *Soleniscus variabilis* Erwin, 1988b from the Permian of the USA is quite similar (see also Nützel et al. 2000, Batten 1995).

**Genus Strobeus de Koninck, 1881**

*Type species.* – *Strobeus ventricosus* de Koninck, 1881, Mississippian, Belgium.

**Strobeus sp.**

Figure 22C, D

**Material.** – One specimen, SNSB-BSPG 2014 XI 119.

**Remarks.** – This broad, smooth incomplete soleniscid shell (7.3 mm high, 5.1 mm wide) shows a distinct col umellar fold. *Strobeus* is wide-spread and diverse in Late Palaeozoic deposits for instance *Strobeus girtyi* Erwin, 1988b from the Permian of the USA and the Late Permian *Strobeus dongluensis* (Pan & Yu, 1993) (see also Nützel & Nakazawa 2012) are similar. However, more and better-preserved specimens are needed for species identification.

**Genus Cylindritopsis Gemmellaro, 1890**

*Type species.* – *Cylindritopsis ovalis* Gemmellaro, 1890, Permian, Italy.

**Cylindritopsis spheroides** Erwin, 1988b

Figure 22E–G

1988b *Cylindritopsis spheroides* sp. nov.; Erwin, p. 65, fig. 4.1–4.4.

**Material.** – One specimen, SNSB-BSPG 2014 XI 52.

**Description.** – Shell spherical, oval, low-spired, 5.1 mm high, 5.2 mm wide; spire small; whorls smooth, convex, inflated; suture indistinct; aperture crescent shaped, acute adapically, rounded abadically; aperture with two strong col umellar folds of equal strength with perpendicular orientation against inner lip; parietal callus present; base evenly rounded, amphialous.

**Remarks.** – The present specimen closely resembles *Cylindritopsis spheroides* Erwin, 1988b from the Permian of the southwestern United States. *Cylindritopsis spheroides* could also represent the neritid genus *Oncochilus* Pethö, 1882 (in Zittel) which is based on a Jurassic type species. In fact, *Oncochilus* matches *Cylindritopsis spheroides* better than the usually more high-spired *Cylindritopsis*. Yochelson & Saunders (1967) listed two Permian species assigned to *Oncochilus* and stated that the genus was clearly present in the Late Palaeozoic.

**Family Meekospiridae Knight, 1956**

**Genus Meekospira Ulrich, in Ulrich & Scofield, 1897**

*Type species.* – *Eulima peracuta* Meek & Worthen, 1861, Carboniferous, USA.
Meekospira sp.

Figure 23G

2014 Meekospira sp.; Ketwetsuriya et al., p. 144, pl. 2, fig. m.


Remarks. – This single slender fusiform shell (7.8 mm high, 5.8 mm high) with straight flanks and slightly convex, smooth whorls is a typical representative of the genus Meekospira which is widespread and diverse in the Late Palaeozoic (e.g., Knight 1932, Erwin 1988b, Nützel et al. 2000). Meekospira melanoides and M. ligonensis, both described by Batten (1985) from the Permian of Perak, Malaysia are more slender and have higher whorls.

Genus Ceraunocochlis Knight, 1931a

Type species. – Ceraunocochlis fulminula Knight, 1931a, Pennsylvanian, USA.

Ceraunocochlis sp.

Figure 23H


Description. – Cigar-shaped shell, slender, high-spired, asymmetrical, with convex flank opposed to a to slightly concave flank; shell comprising ca 7 whors, 5.1 mm high, 1.4 mm wide; last whorl incomplete but seemingly slightly constricted; whorls high, smooth; suture obscure, very shallow; whorl face almost straight; aperture not preserved.

Remarks. – The generic assignment of this specimen is beyond doubt. It resembles Ceraunocochlis fulminula Knight, 1931a from the Pennsylvanian of the USA and Ceraunocochlis sp. as reported by Nützel & Nakazawa (2012) from the Middle Permian Akasaka Limestone, Japan.

Genus Cambodgia Mansuy, 1914b

Type species. – Cambodgia sinistrorsa Mansuy, 1914b, Permian, Cambodia.

Cambodgia acuminata sp. nov.

Figure 24A–C

2014 Cambodgia cf. sinistrorsa Mansuy, 1914b. – Ketwetsuriya et al., p. 144, pl. 2, fig. l.
Locus typicus. – Khao Noi hill, Takli district, Southeast of Nakhon Sawan province, ca 80 km south of Nakhon Sawan City, Northern Thailand, 15° 18´ 51.801˝ N, 100° 26´ 30.358˝ E (Fig. 1).

Stratum typicum. – Tak Fa Formation of the Saraburi Group, Middle Permian, Wordian.


Etymology. – Latin needle-shaped, acute.

Description. – Shell sinistral, small, high-spired, very slender with an apical angel of less than 30° and numerous whorls; largest specimen comprising 9 whorls with apex missing, 12.7 mm high, 3.3 mm wide; holotype comprising ca 14 whors, 7.4 mm high, 4.0 mm wide; early shell slightly coeloconoid; whorls smooth, weakly convex; sutures shallow but distinct; aperture unknown.

Remarks. – The sinistral species Cambodgia acuminata sp. nov. is extremely needle-shaped. It resembles Cambodgia sinistrorsa Mansuy, 1914b from the Permian Productus Limestone of Cambodia. However, Cambodgia acuminata sp. nov. is much more slender. The sinistral, needle-shaped species Methorthonema sinistrale Erwin, 1988a from the Early Permian of the Southwestern USA is more pronoucedly coeloconoid in the early whorls and later whorls are straight-sided so that the teleoconch is almost cylindrical which is not the case in Cambodgia acuminata sp. nov.

Family Palaeostylidae Wenz, 1938

Genus Trepsipleura Kues, 2002

Type species. – Trepsipleura chordanodosa Kues, 2002, Pennsylvanian, USA.

Remarks. – Kues (2002) discussed the assignment of Trepsipleura and placed it in Pseudozygopleuridae Knight, 1930 but also discussed a possible assignment to Palaeozygopleuridae. We think that an assignment to Palaeostylidae is the better choice because of the low whorls and the lack of the typical Pseudozygopleurid larval shell as far as it is known [shown for Palaeozygopleura? perversa (Knight, 1930) by Nützel 1998]. Synonymy of the three species Palaeozygopleura? perversa (Knight, 1930), Palaeostylus? (Pseudozygopleura) bella Carew, 1980 and Trepsipleura chordanodosa Kues, 2002 seems to be possible. The sinistral species Palaeozygopleura retroflexa Licharev, 1968 is distinct by having a denser ribbing.

Superfamily Zygopleuroidea Wenz, 1938

Family Pseudozygopleuridae Knight, 1930

Genus Pseudozygopleura Knight, 1930

Pseudozygopleura? sp. Figure 24F

Material. – One specimen, SNSB-BSPG 2014 XI 55.

Description. – Shell high-spired to fusiform, comprising ca 6 whors, 12.6 mm high, 5.3 mm wide; whors convex with strong axial ribs numbering about 14 to 16 per whorl; ribs round, as wide as interspaces, distinctly prosocline; ribs reduced on last preserved whorl; suture distinct; base rounded, anomphalous.

Remarks. – The present shell with zygopleurid morphology could represent the diverse Late Palaeozoic gastropod family Pseudozygopleuridae but knowledge of the protoconch is needed for a meaningful taxonomic treatment.
Genus *Streptacis* Meek, 1871

Type species. — *Streptacis whitfieldi* Meek, 1871, Carboniferous, USA.

*Streptacis*? sp.

Figure 24G, H


Description. — Shell high-spired, slender; larger specimen 11.3 mm high (apex missing), 3.5 mm wide; whorls smooth, strongly convex; suture impressed; base convex, rounded.

Remarks. — High-spired, small, smooth shells like the present ones have been commonly reported from Late Palaeozoic deposits of the world, for instance *Streptacis whitfieldi* Meek, 1871 from the Carboniferous of the USA and *Streptacis orientalis* Nützel, 2012 as well as *Streptacis*? sp. from the Middle Permian Akasaka Limestone of Japan (Nützel & Nakazawa 2012).

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