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A new Permian gastropod fauna from the Tak Fa Limestone, Nakhonsawan, Northern Thailand – a report of preliminary results

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Abstract

A new silicified Middle Permian gastropod fauna is reported from the Tak Fa Limestone from Northern Thailand. It is the first diverse Permian gastropod fauna known for Thailand. The fauna comes from shallow water carbonates which are rich in fusulinids. Twenty gastropod species are reported in open nomenclature and are illustrated. Ongoing dissolution of limestone blocks will yield additional taxa. Thus, this fauna represents one of the richest Permian gastropod faunas known to date from Southeast Asia. Although identifications are preliminary, the presence of typical late Palaeozoic taxa such as Bellerophontidae, several Pleurotomarioidea, Meekospiridae and Goniasmatidae is evident. Some of the species present are undescribed.

Key words: Gastropoda, late Palaeozoic, Permian, Thailand, silicification, diversity.

Zusammenfassung

Eine neue verkieselte mittelpermische Gastropodenfauna wird aus dem Tak Fa Kalk Nordthailands nachgewiesen. Dies ist die erste diverse Gastropodenfauna, die aus Thailand bekannt ist. Die Fauna entstammt Flachwasserkalken, die reich an Fusulinen sind. Zwanzig Gastropodenarten werden nachgewiesen und abgebildet. Die noch andauernde Auflösung der Kalke wird weitere Taxa erbringen. Somit ist diese Fauna eine der diversesten Gastropodenfaunen Südostasiens. Die vorläufigen Bestimmungen zeigen die Präsenz typisch spät-paläozoischer Taxa, z. B. Bellerophontidae, einige Pleurotomarioidea, Meekospiridae und Goniasmatidae. Einige der vorhandenen Arten sind noch unbeschrieben.

Schlüsselwörter: Gastropoda, spätes Paläozoikum, Perm, Thailand, Verkieselung, Diversität.

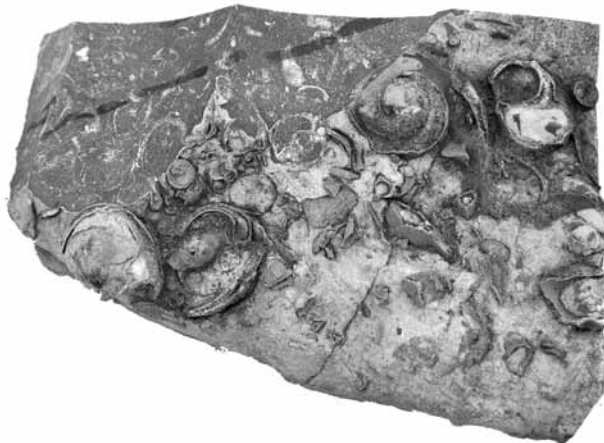
1. Introduction

There exist only few reports on Permian gastropods from Thailand. Sone (2010) described a relatively large but poorly preserved neritopsid, *Magnicapitatus panhuazhangae*, from the Middle Permian of East Thailand. This gastropod taxon is based on an internal mould (steinkern) that is 3 to 4 cm in size. Moreover, Waterhouse (1982) mentioned the presence of *Peruvispira* sp. in the Asselian Kaeng Krachan Group from the Tong Lang Bay and Ko Phi Phi Island but neither illustrated nor described this taxon. Grant (1976) reported the presence of undetermined gastropods representing platyceratids and pleurotomarioids from the Roadian of South Thailand. However, neither descriptions nor illustrations were provided. Permian gastropods from Thailand therefore remain poorly known. However, rich gastropod faunas have

been reported from other parts of Southeast Asia, including Perak, Malaysia (e.g., Batten 1985), China (e.g., Mansuy 1914; Pan Hua-zhang & Erwin 2002; Pan Yun-tang & Yu Wen 1993) and Japan (Nützel & Nakazawa 2012).

The present study represents a preliminary account on a hitherto undescribed Middle Permian gastropod fauna from the Tak Fa Limestone, Nakhonsawan, northern Thailand. The fauna consists of at least 20 species and is therefore the richest gastropod fauna reported to date from Thailand. The fauna is silicified. Several limestone blocks have been recovered by the first author and were transported to Munich. The gastropods are naturally weathered out at the surfaces of these limestone blocks (Textfig. 1). As a first step of the study of this significant gastropod fauna, the weathered-out gastropods were photographed and are documented here. The identifica-

tions are preliminary and open nomenclature is used throughout. For a more detailed study, specimens must be entirely etched from the samples.



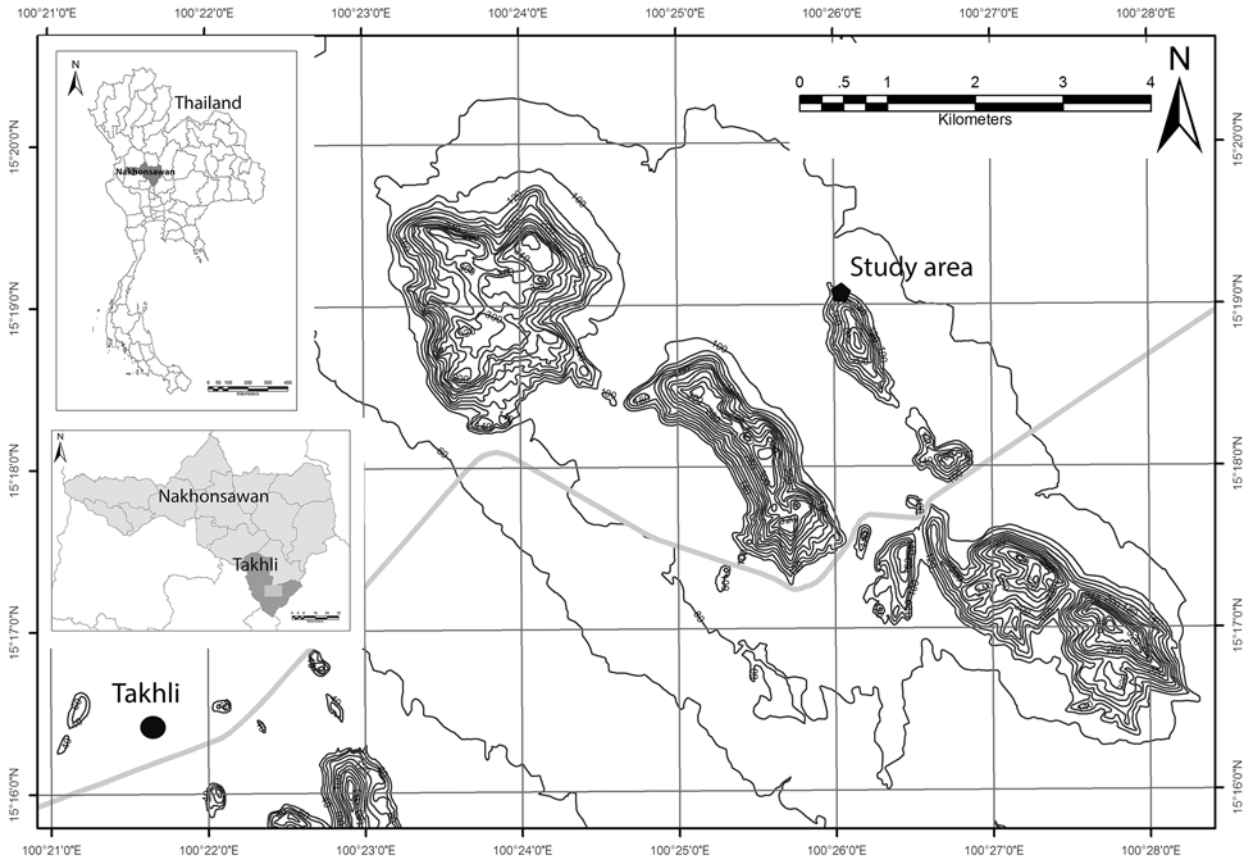
Textfigure 1: Block D as example for preservation; shell material weathers out from a grey, micritic limestone; width ca. 15 cm.

2. Geological setting

Khao Noi is the small limestone hill in the Takhli district, located 80 km (Latitude: 15° 18' 51.801" N Longitude: 100° 26' 30.358" E) south of Nakhonsawan City, northern Thailand (Textfig. 2). The Permian

limestone succession in the study area belongs to the Tak Fa Formation, Saraburi Group, and is Middle Permian in age (Nakornsri 1977, 1981). Yanagida (1964, 1988) reported the presence of the fusulinid *Verbeekina verbeeki* and thus assigned an Early Permian (Artinskian to Kungurian) age to the Tak Fa Formation. However, Fontaine et al. (1994) suggested that the Tak Fa formation has a late Middle Permian (Murghabian) age based on bryozoans, brachiopods and the coral fauna. So far, this age has not been corroborated for the study area by findings of conodonts and ammonites.

At the studied outcrop, the section is about 10 meters thick and consists predominantly of fossiliferous limestones. The fauna is rich in fusulinids and gastropods; silicified shell fragments are abundant. Material was collected from dark grey, micritic limestone beds. The shell beds are highly fossiliferous and gastropod shells occur in abundance. The silicified shell material weathers out nicely (Textfig. 1). The presence of fusulinids in large numbers suggests deposition in shallow water. The carbonate succession also contains abundant chert nodules. Corals and sponges are also abundant but have not yet been studied. Some of the gastropods are relatively large (several centimetres). The silicification is rather coarse but details of the ornament are sufficiently preserved for a preliminary characterization of the taxa.



Textfigure 2: Map showing location of gastropods described herein, at Takhli district, Nakhonsawan City, North Thailand.

3. Methods

The limestone beds were sampled by the first author in 2010 and 2013. The samples consist of eight blocks (Blocks A–H), which show numerous silicified gastropods on the surfaces (Textfig. 1). The blocks were photographed and then whitened with ammonium chloride at the Bayerische Staatssammlung für Paläontologie und Geologie (SNSB-BSPG) in Munich, Germany. All gastropods visible on the surface of the blocks were documented with microphotography. These images are used for the preliminary descriptions and identifications presented in this study. After microphotography, the blocks were inundated in formic acid for separation of the specimens. This process continues to date. After complete dissolution of the limestone, the resulting fossil material will be studied in greater detail. We expect to find many additional species, most of which probably are comparatively small.

4. Systematic palaeontology

The following descriptions and identifications are preliminary. The material is housed at the Bayerische Staatssammlung für Paläontologie und Geologie in Munich, Germany. Because the material represents part of an ongoing investigation (see above), only tentative accession numbers have been assigned to the specimens; for instance, number A-06 refers to a specimen from limestone block A that has the image number 06. The higher-level accession number SNSB-BSPG 2014 XI has been assigned to the bulk of the material. After separation by etching and completion of the analysis, specific numbers in the form of specifications of the SNSB-BSPG 2014 XI number will be assigned to the individual specimens.

Order Bellerophontida Ulrich & Scofield, 1897
Family Bellerophontidae McCoy, 1852

Genus *Bellerophon* Montfort, 1808

Type species: *Bellerophon vasulites* Montfort, 1808, Middle Devonian, Germany.

Bellerophon sp. 1
Pl. 1, Fig. A, B

Material: Three specimens, A-06, D-11, G-05-06

Description: Fragments of a largely smooth, involute bellerophontoid shell of approximately 5.7 mm height. The specimen illustrated in Pl. 1, Fig. B shows traces of lines (strengthened growth lines).

Remarks: This involute, bilaterally symmetrical shell fragments might belong to the genera *Bellerophon* or *Warthia*. The presence of growth lines is

suggestive of *Bellerophon*, rather than *Warthia*.

Bellerophon? sp. 2
Pl. 1, Fig. C

Material: Four specimens, B-03, B-07, H-09–11, H-42

Description: A bellerophontoid shell with a median crest; shell smooth with rounded angular edges; umbilici not seen. The specimen shows traces of lines (strengthened growth lines).

Remarks: Smooth bellerophontoids with distinctly elevated crests have not been reported from the late Palaeozoic to date. Such crests occur in *Pharkidonotus* which has a stronger ornament and also in some *Bellerophon* species. As in *Bellerophon* sp. 1, the presence of growth lines seems suggestive of *Bellerophon*, rather than *Warthia*.

Subclass Vetigastropoda Salvini-Plawen, 1980
Family Raphistomatidae Koken, 1896

Genus *Trepospira* Ulrich & Scofield, 1897

Type species: *Pleurotomaria sphaerulata* Conrad, 1842, Late Carboniferous, Pennsylvania, USA.

Trepospira sp.
Pl. 1, Figs D, E, F, G1, G2

Material: Five specimens, A-05, H 14-17, H 19-21, H 27-28, H 33-35

Description: The shell is broad and low-spired; the largest specimen is 18.2 mm high and 21.4 mm wide; the whorls are ornamented with a row of strong, round, axially elongated subsutural nodes and up to six spiral cords; two abapical spiral cords are more pronounced and probably border the selenizone which is not visible due to preservation.

Remarks: This form is probably new to science; it might belong to *Trepospira* although this genus usually lacks additional spiral cords. However, *Trepospira* is also low-spired and has strong subsutural nodes. There are several species of *Glabrocingulum* which are similar, including *Glabrocingulum (Glabrocingulum) stankovskyi* Mazaev, 2006 (Mazaev 2006: pl. 5, fig. 1) from the Permian of Russia, but *Glabrocingulum* has an angulated whorl-face which is not the case in the present specimens.

Family Eotomariidae Wenz, 1938

Genus *Glabrocingulum* Thomas, 1940

Type species: *Glabrocingulum beggi* Thomas, 1940, Carboniferous, Scotland.

Glabrocingulum sp.

Pl. 1, Fig. H

Material: Two specimens, C-16-18, D-15-16.

Description: The fragmentary shell is trochiform with gradate spire; one specimen is 17 mm high and 18 mm wide; the whorls are angulated below the mid-whorl; the ramp above the angulation shows an ornament of spiral cords.

Remarks: The material is too poorly preserved for a safe generic assignment but it resembles the widespread genus *Glabrocingulum*.

Family Lophospiridae Wenz, 1938

Genus *Worthenia* De Koninck, 1883

Type species: *Turbo tabulatus* Conrad, 1835, Late Carboniferous, USA.

Worthenia? sp.

Pl. 1, Figs I, J

Material: Two specimens, F-07-10, 13-14.

Description: Shell, trochiform with gradate spire, 7.2 mm high and 7.9 mm wide; whorls angulated at about upper third of whorl-face; above angulation, a steep ramp is present; ramp slightly concave with three spiral cords and weak axial ribs; ornament of ramp reduced on mature whorls; whorl face below ramp approximately parallel to shell axis and ornamented with four strong spiral cords; base not fully seen but apparently convex with spiral cords; selenizone not observed due to preservation.

Remarks: The specimens closely resemble *Worthenia* which is a wide-spread and very diverse genus in the late Palaeozoic. *Ananias* and *Baylea* comprise similar shells.

Family Portlockiellidae Batten, 1956

Genus *Tapinotomaria* Batten, 1956

Type species: *Tapinotomaria rugosa* Batten, 1956, Middle Permian, USA.

Tapinotomaria? sp.

Pl. 1, Fig. K

Material: One specimen, E-01-03.

Description: Shell trochiform, 5.0 mm high and 6.5 mm wide; whorls slightly convex with seven spiral cords; suture deep and distinct; base with umbilicus and slightly convex with several spiral cords.

Remarks: The specimen resembles *Tapinotomaria* species as reported by Batten (1958) from the Permian of the U.S. However, the specimen from Thailand does not show a selenizone. If it lacks a selenizone, then it belongs to another genus and is of trochoid relation. *Pareuryalox* Haas, 1953 is similar (Knight et al. 1960, p. 1306 fig. 202-2a) but has a wide selenizone low on the whorl.

Family uncertain

Pleurotomarioid indet.

Pl. 1, Fig. L

Material: One specimen, C-02.

Description: Shell acutely conical with straight sides, 4.7 mm high, 3.9 mm wide; whorls flat to slightly concave with strong ornament of spiral cords.

Remarks: Although characteristic in this collection, this shell is too poor in diagnostic features to permit generic assignment. It is probably a pleurotomarioid but a selenizone is not visible. It could be related to the late Palaeozoic family Phymatopleuridae, e.g., the genus *Paragoniozona* Nelson, 1947.

Family Anomphalidae Wenz, 1938

Genus *Anomphalus* Meek and Worthen, 1867

Type species: *Anomphalus rotulus* Meek and Worthen, 1867, Pennsylvanian, USA.

Anomphalus cf. *japonicus* Nützel, 2012 in

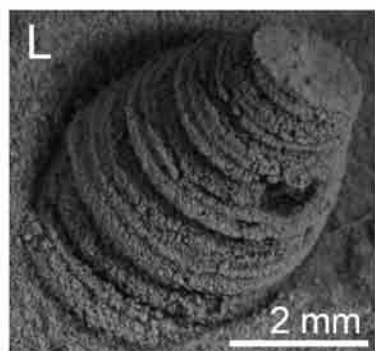
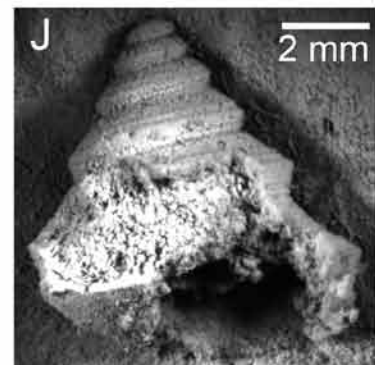
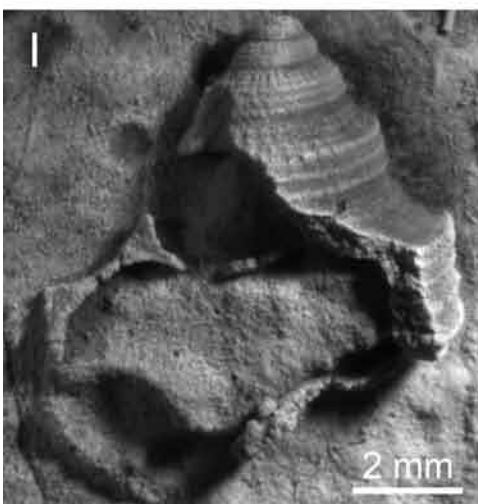
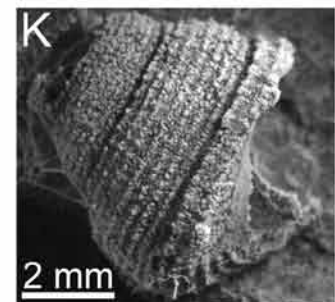
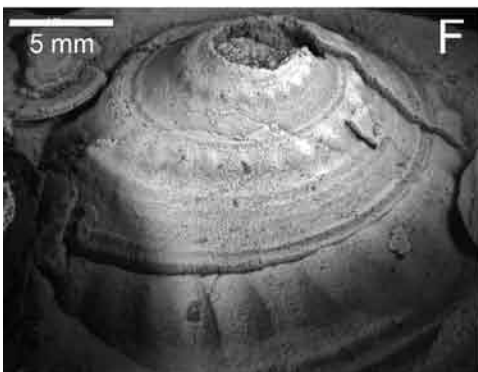
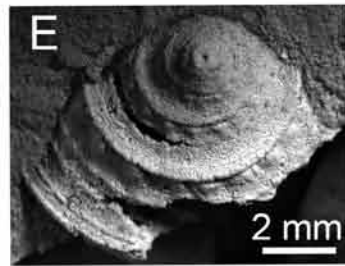
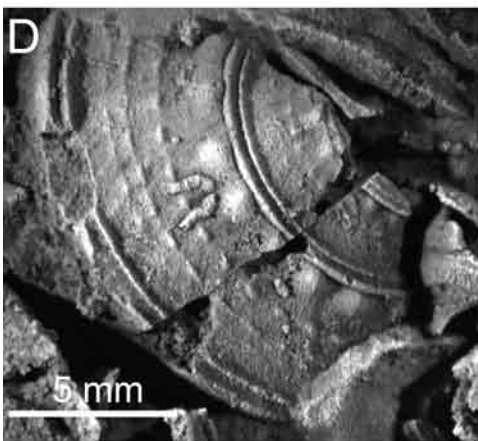
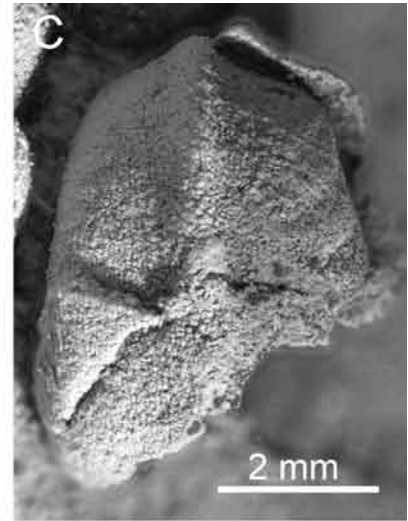
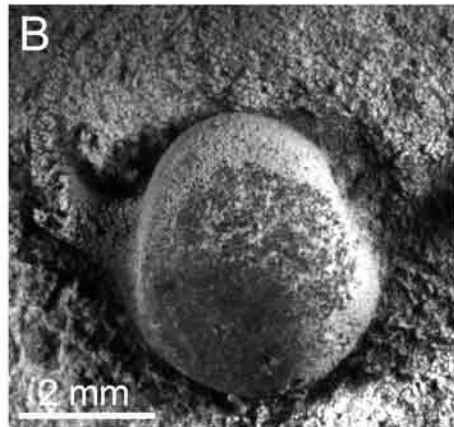
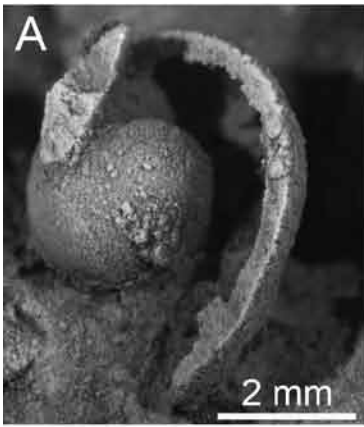
Nützel & Nakazawa

Pl. 2, Figs A, B1, B2, B3

Material: Four specimens, C-09, D-01=C-19=D-17-20, D-03-04, H05-08.

Description: Shell small, very low-spired, rotelliform; shell with about 3.5 whorls 2.5 mm wide, 2.2 mm high; whorls smooth, convex, round, circular in transverse section; base flattened and distinctly umbilicated; circumumbilical callus present at aperture; suture distinct.

Remarks: Species representing the genus *Anomphalus* are known from several late Palaeozoic gas-



tropod faunas. The present material closely resembles *Anomphalus japonicus* Nützel, 2012 (in Nützel & Nakazawa) from the Middle Permian of Japan and *Anomphalus fusuiensis* Pan Hua-zhang & Erwin, 2002 from the Late Permian of China.

Family uncertain

Trochoid sp.
Pl. 2, Fig. C

Material: One specimen, H-38-40.

Description: Shell small, trochiform; shell with about 4 whorls 2.5 mm wide, 2.2 mm high; whorls convex, shouldered, with step-like profile and weak spiral cords (two or three); suture deep and distinct.

Remarks: This trochiform specimen is distinct in the present collection but shows too few characters to permit systematic placement.

Family Omphalotrochidae Knight, 1945

Genus *Omphalotrochus* Meek, 1864

Type species: *Euomphalus (Omphalotrochus) whitneyi* Meek, 1864, Permian, California, USA.

Omphalotrochus? sp.
Pl. 2, Fig. D

Material: Several fragments, A-07.

Description: Fragments representing single whorls derive from a conical trochiform shell without ornament except straight slightly opisthocline growth lines. The largest fragment is 9.0 mm high and 15.5 mm wide; the whorls are angulated at base with a pronounced bulge on the edge.

Remarks: Similar shells have been reported from the Permian of the U.S. by Yochelson (1956) as *Omphalotrochus*. However, *Omphalotrochus* usually has curved growth lines. More complete specimens are required for a substantiated assignment.

Genus *Discotropis* Yochelson, 1956

Type species: *Discotropis publicus* Yochelson, 1956, Middle Permian, USA.

Discotropis? sp.
Pl. 2, Fig. E

Material: One specimen, E-08.

Description: Shell very low-spined, almost discoidal; 7.8 mm wide; suture distinct; spire whorls concave with prominent subsutural bulge.

Remarks: *Discotropis* species reported by Yochelson (1956) are similar but have a median crest rather than a sutural bulge on the spire whorls.

Genus *Babylonites* Yochelson, 1956

Type species: *Babylonites carinatus* Yochelson, 1956, Middle Permian, USA.

Babylonites? sp.
Pl. 2, Figs F1, F2, G, H

Material: Three specimens, C-14-15, G-01-02, G-03-04

Description: Shell trochiform, up to 7.7 mm wide; whorls smooth, flat to slightly convex and with a pronounced carination at the transition to the base; the carination bears a spiral cord; the base is flatly convex with a narrow umbilicus; growth lines straight, orthocline to slightly prosocline, suture distinct.

Remarks: The specimens resemble *Babylonites* species as reported by Yochelson (1956) from the Permian of the U.S. However, the latter genus is characterized by a concave whorl face and two crests low on the whorl instead of a single spiral cord at the suture. Thus, it is possible that the present material represents a yet undescribed genus.

Genus *Euconodoma* Kues, 1990

Type species: *Euconodoma gavinae* Kues, 1990, Middle Pennsylvanian, New Mexico

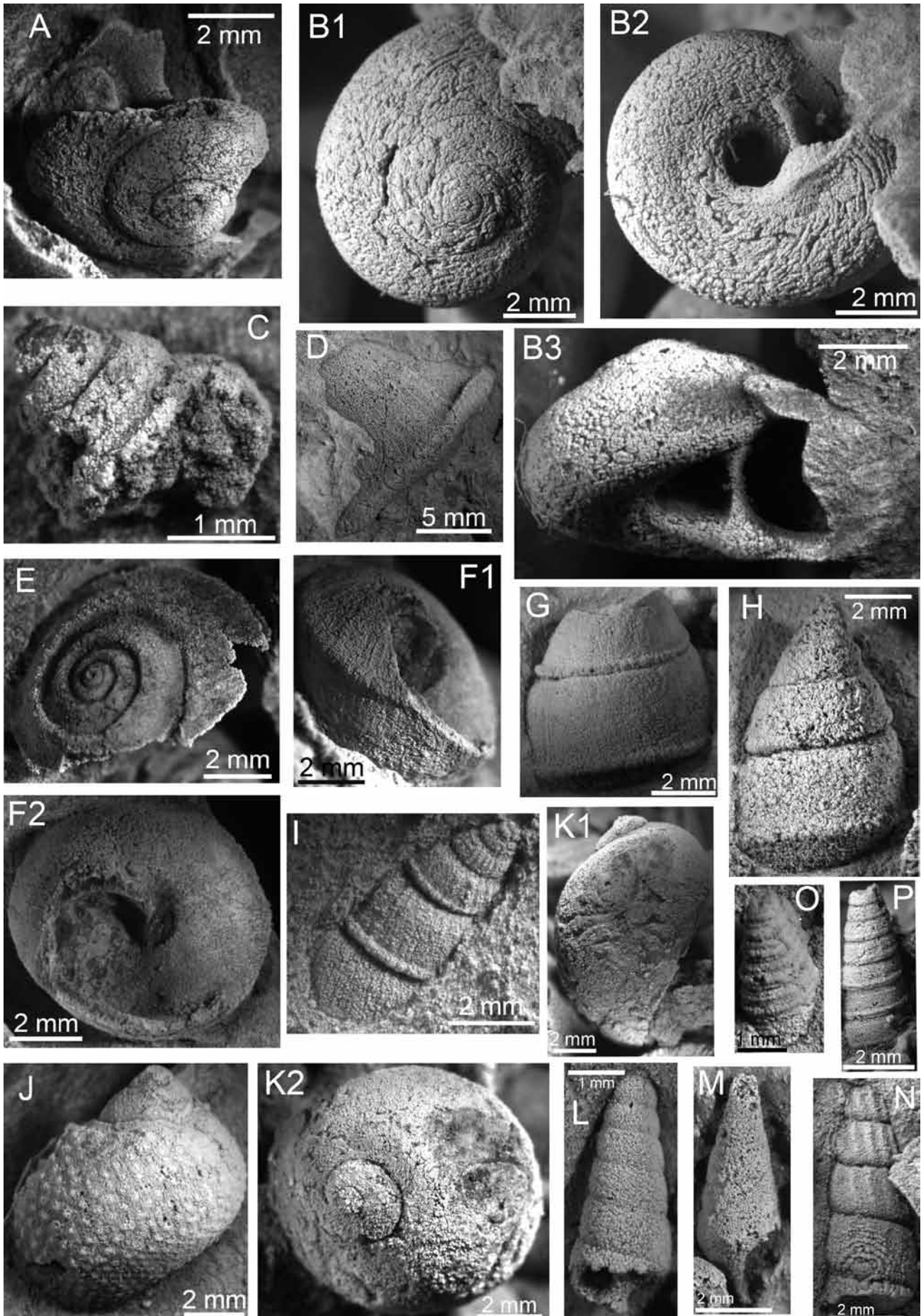
Euconodoma sp.
Pl. 2, Fig. I

Material: Two specimens, E-04, 16.

Description: Shell high conical, small, 10.1 mm high, 3.7 mm wide; earliest preserved whorls with straight prosocline axial ribs; ribs reduced to strengthened growth lines in later whorls; transition from whorl face to base angular with strong spiral cord.

Remarks: This shell resembles *Euconodoma gavi-*

Plate 2: (A) *Anomphalus* cf. *japonicus*, Block D. (B1) *Anomphalus* cf. *japonicus*, Block H. (B2) *Anomphalus* cf. *japonicus*, Block H. (B3) *Anomphalus* cf. *japonicus*, Block H. (C) Trochoid sp., Block H. (D) *Omphalotrochus?* sp., Block A. (E) *Discotropis?* sp., Block E. (F1) *Babylonites?* sp., Block C. (F2) *Babylonites?* sp., Block C. (G) *Babylonites?* sp., Block G. (H) *Babylonites?* sp., Block G. (I) *Euconodoma* sp., Block E. (J) *Trachydomia* sp., Block H. (K1) *Naticopsis* sp., Block E. (K2) *Naticopsis* sp., Block E. (L) *Cambodgia* cf. *sinistrorsa*, Block A. (M) *Meekospira* sp., Block A. (N) *Palaeostylus* sp., Block H. (O) *Stegocoelia?* sp. 1, Block F. (P) *Stegocoelia?* sp. 2, Block H.



nae Kues, 1990: p. 253, figs 90–19) from the Pennsylvanian of New Mexico. However, this species has nodes at the basal carination. This gastropod respectively the genus *Euconodoma* could represent a caenogastropod but information on the protoconch morphology is required to corroborate assignment to a higher taxon.

Subclass Neritimorpha Koken, 1896
Family Trachyspiridae Nützel *et al.*, 2007

Genus *Trachydomia* Meek and Worthen, 1866

Type species: *Trachydomia nodosa* Meek and Worthen, 1866, Carboniferous, USA.

Trachydomia sp.
Pl. 2, Fig. J

Material: One specimen, H-01-04.

Description: Shell naticiform; whorls round, convex with a narrow ramp; shell with about 3 whorls, 6.8 mm wide, 10.2 mm high; last whorl much higher than spire; whorls ornamented with nodes which are strongest near the ramp; nodes not present on ramp; suture distinct; base round, convex; growth lines prosocline.

Remarks: This is a typical representative of the genus *Trachydomia* which is widespread and diverse in the Carboniferous and Permian (e.g., Kues & Batten 2001; Nützel & Nakazawa 2012).

Family Naticopsidae Waagen, 1880

Genus *Naticopsis* McCoy, 1844

Type species: *Naticopsis philippsi* McCoy, 1844, Carboniferous, Ireland.

Naticopsis sp.
Pl. 2, Figs K1, K2

Material: Two specimens, E-09-10, G-10

Description: Shell relatively large (24.8 mm wide) with egg-shaped, naticiform shape; spire low but distinctly elevated; whorls smooth, round, convex; last whorl much higher than spire; base round, convex.

Remarks: This is a typical representative of the genus *Naticopsis* which is widespread and diverse in the Carboniferous and Permian (e.g., Kues & Batten 2001; Nützel & Nakazawa 2012; Nützel *et al.* 2007).

Subclass Caenogastropoda Cox, 1960
Family Meekospiridae Knight, 1956

Genus *Cambodgia* Mansuy, 1914

Type species: *Cambodgia sinistrorsa* Mansuy, 1914, Permian, Phnom Ta Maol, Cambodia (former French Indo-China).

Cambodgia cf. *sinistrorsa* Mansuy, 1914
Pl. 2, Fig. L

Material: One specimen, A-02.

Description: Shell small, high-spined, slender, sinistral; whorls smooth and moderately convex; whorl face rounded; comprises about six whorls, 4.3 mm high, 1.8 mm wide; sutures shallow but distinct.

Remarks: This specimen resembles *Cambodgia sinistrorsa* as illustrated by Mansuy (1914: pl. 4, fig. 18) from the Productus Limestone of Southeast Asia (Cambodia).

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

Type species: *Eulima? peracuta* Meek and Worthen, 1861, Upper Carboniferous, Illinois, USA.

Meekospira sp.
Pl. 1, Fig. M

Material: One specimen, A-01.

Description: Shell high-spined, conical, comprises about six whorls, 6.2 mm high, 2.1 mm wide; higher than wide, apex not preserved; shell dextral; sutures shallow, indistinct; whorls slightly convex and smooth; base strongly convex; aperture broken with inner lip evenly concave.

Remarks: This specimen is a typical representative of the widespread and diverse late Palaeozoic genus *Meekospira*.

Family Palaeostylidae Wenz, 1938

Genus *Palaeostylus* Mansuy, 1914

Type species: *Palaeostylus pupoides* Mansuy, 1914, Permian, Cambodia, French Indo-China.

Palaeostylus sp.
Pl. 2, Fig. N

Material: Two specimens, H-36-37, H-18, 29

Description: Shell high-spined, sinistral with cyrtoconoid shape, 2.3 mm high, 1.4 mm wide; sutures distinct; whorls with rounded, slightly opisthocline axial ribs that are probably reduced on the mature teleoconch whorls.

Remarks: Nützel (1998) reported on a similar sinistral species with zygopleuroid habitus from the

Pennsylvanian of the U.S.

Family Goniasmatidae Nützel & Bandel, 2000

Genus *Stegocoelia* Donald, 1889

Type species: *Stegocoelia compacta* Donald, 1889, Lower Carboniferous, Scotland.

Stegocoelia? sp. 1
Pl. 2, Fig. O

Material: One specimen, F11-12.

Description: Shell small, high-spined, 3.2 mm high, 1.6 mm wide; whorls with three prominent spiral cords, middle one strongest forming periphery of shell rather below mid-whorl; the adapical spiral cord is situated at the suture; a third weak spiral cord emerging at the adapical suture; suture distinct.

Remarks: Small, high-spined caenogastropods of genera such as *Stegocoelia* or *Orthonema* are diverse in the late Palaeozoic (e.g., Kues & Batten 2001; Nützel & Nakazawa 2012). The present fossil probably represents one of these genera but better preserved material is needed to confirm this assumption.

Stegocoelia? sp. 2
Pl. 2, Fig. P

Material: One specimen, H-32.

Description: Shell high-spined, consisting of 7 whorls, 4.7 mm high, 1.8 mm wide; whorl face straight; whorl with a weak subsutural spiral thread and a strong suprasutural spiral cord forming periphery; area between spiral cords wide, smooth; suture distinct.

Remarks: This species resembles the one described above but is characterized by two instead of three spiral cords.

5. Discussion

The silicified Middle Permian gastropod fauna from the Tak Fa Limestone (Northern Thailand) represents the first account of a diverse Permian gastropod fauna from Thailand. It comes from shallow water carbonates rich in fusulinids. With twenty different species currently recognized, and additional ones that likely will become available in near future through the continued etching of the limestone blocks, this fauna represents one of the richest Permian gastropod faunas known to date from Southeast Asia. Although identifications are preliminary, the presence of typical late Palaeozoic forms such as Bellerophontidae,

several Pleurotomarioidea, Meekospiridae and Goniasmatidae is evident. A more detailed study of this fauna will provide important new information on the diversity and palaeogeographic distribution of Permian gastropods in Southeast Asia.

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