

Original article

Middle Permian Ostracods from Tak Fa Limestone, Phetchabun Province, Central Thailand

Ostracodes du Permien moyen du Calcaire de Tak Fa, Province Phetchabun, Thaïlande centrale

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Abstract

This paper presents the first Permian ostracod fauna discovered in Thailand. The ostracods are recovered from the Tak Fa Limestone (Middle Permian) in Phetchabun province, central Thailand. The ostracods belong to eight genera and 15 species. Four species are newly described: *Sargentina phetchabunensis* nov. sp., *Geffenina bungsamphanensis* nov. sp., *Reviya subsompongensis* nov. sp. and *Bairdia takfaensis* nov. sp. The ostracod assemblages characterize a shallow marine, near shore environment at the time of deposition. Except for one species, which shows palaeobiogeographical links between Central Thailand and South China, all the other species are endemic.

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Résumé

Ce papier présente la première faune d'ostracodes permienne découverte en Thaïlande. Les ostracodes proviennent du calcaire de Tak Fa (Permien moyen) dans la province de Phetchabun, Thaïlande centrale. Les ostracodes appartiennent à huit genres et 15 espèces. Quatre espèces sont nouvelles et décrites ici : *Sargentina phetchabunensis* nov. sp., *Geffenina bungsamphanensis* nov. sp., *Reviya subsompongensis* nov. sp. et *Bairdia takfaensis* nov. sp. Les assemblages d'ostracodes caractérisent un environnement marin peu profond, proche du rivage. Mise à part, une espèce commune attestant des liaisons paléobiogéographiques existant entre la Thaïlande centrale et la Chine du Sud, toutes les autres espèces sont endémiques.

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Keywords: Permian; Ostracods; Thailand

Mots clés : Ostracodes ; Permien ; Thaïlande

1. Introduction

Permian rocks in Thailand, mostly marine sequences, are well exposed throughout the country. However, different facies realms of deposition have been mentioned by Ingavat-Helmcke and Helmcke (1994). In central Thailand, three palaeo-

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graphic units are recognized from West to East: Khao Khwang Platform, Num Duk Basin and Pha Nok Khao Platform (Wielchowsky and Young, 1985) (Fig. 1). The Khao Khwang Platform is represented by shallow marine carbonates, which are rich of fusulinaceans and local corals and brachiopods. Limestones of the Khao Khwang Platform are assigned from Early to Middle Permian (Asselian to Capitanian) with reference to fusulinaceans (Nakornsri, 1977; Charoenprawat et al., 1976; Dawson, 1978; Chonglakmani and Sattayarak,

1979; Chonglakmani et al., 1979; Hinthong, 1985; Wielchowsky and Young, 1985). Brachiopods and corals have also been identified (Yanagida, 1964, 1988; Chonglakmani and Fontaine, 1990), but ostracods are still unknown. This paper presents the systematics of Permian ostracods recovered from the Bung Sam Phan section on the Khao Khwang Platform. Additional data are given on palaeoenvironment and palaeobiogeographical relationships. Even we cannot go very far in the interpretations because the material is not so abundant, all

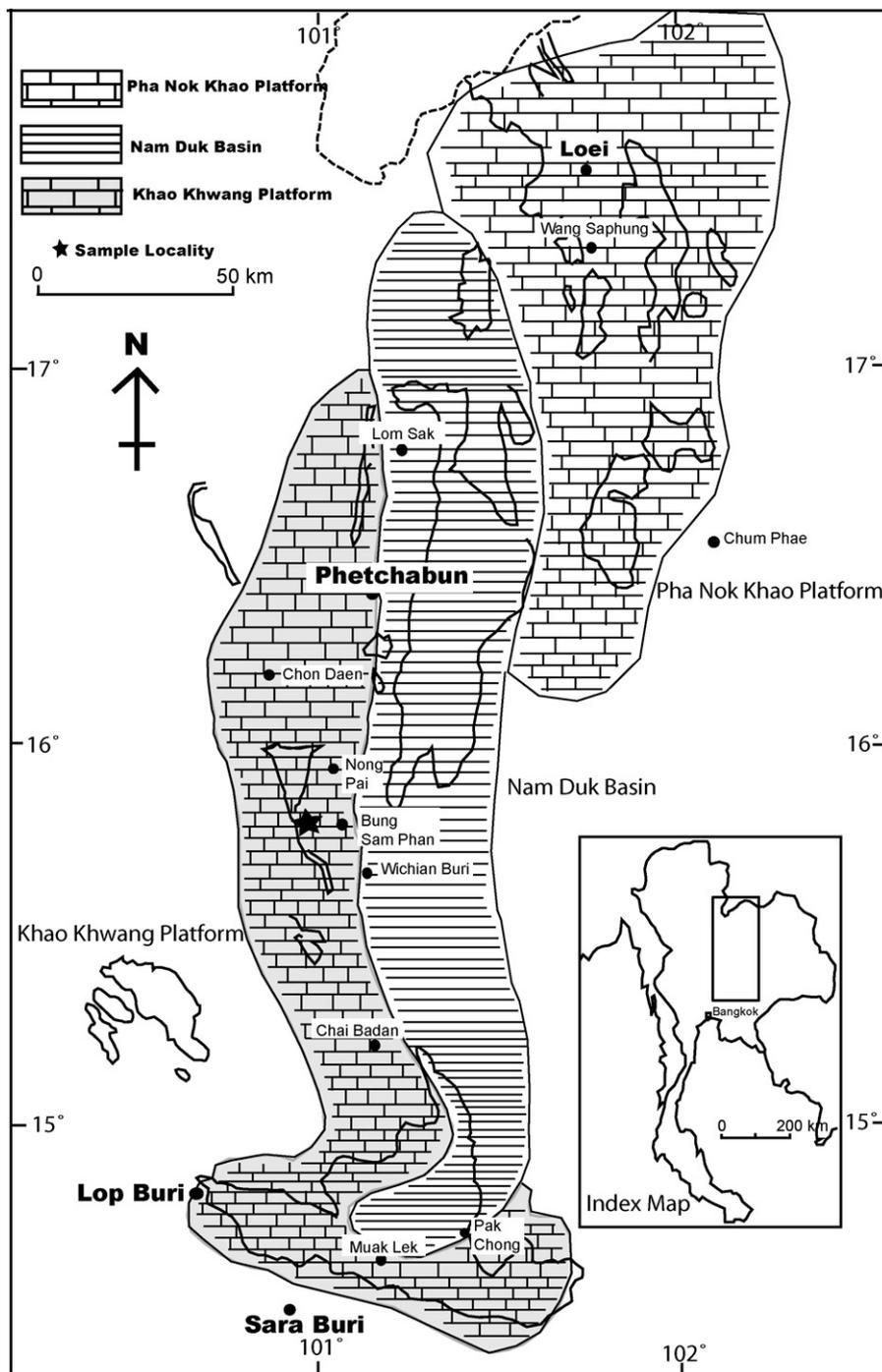


Fig. 1. A nonrestored palaeogeographic map of Permian environment in Central Thailand (modified from Chonglakmani and Fontaine, 1990).

Fig. 1. Carte paléogéographique non restaurée des environnements du Permien en Thaïlande centrale (modifié d'après Chonglakmani et Fontaine, 1990).

the data are of importance in the frame of the study of Permian–Triassic analysis. Ostracods are efficient tools for palaeoenvironment characterization.

2. Geologic setting

The Bung Sam Phan section is located 70 km southwest of Phetchabun city or about 9 km west of Bung Sam Phan district (15°50'03.3 "N, 100°55'35.9" E) (Fig. 2). On the Palaeogeographic viewpoint, the section situated on the Khao Khwang Platform of Wielchowsky and Young (1985) during Early to

Middle Permian (Asselian–Wordian). The section of about 70 m thick, showing the intercalations of medium-to-thick bedded limestones and shales. Limestones are grey to dark-grey wackestones to grainstones and contain brachiopods, fusulinids, gastropods, crinoid stems, shells and fragments.

The Bung Sam Phan section belongs to the Tak Fa formation (Nakornsri, 1977), which was assigned previously to Early Permian (Artinskian - Kungurian). Later on, Jeungyusuk and Kositanont (1979) found *Verbeekina*, *Parafusulina* and *Neoschwagerina* in the vicinity, which indicate Middle Permian, age for the Tak Fa formation exposed in Phetchabun

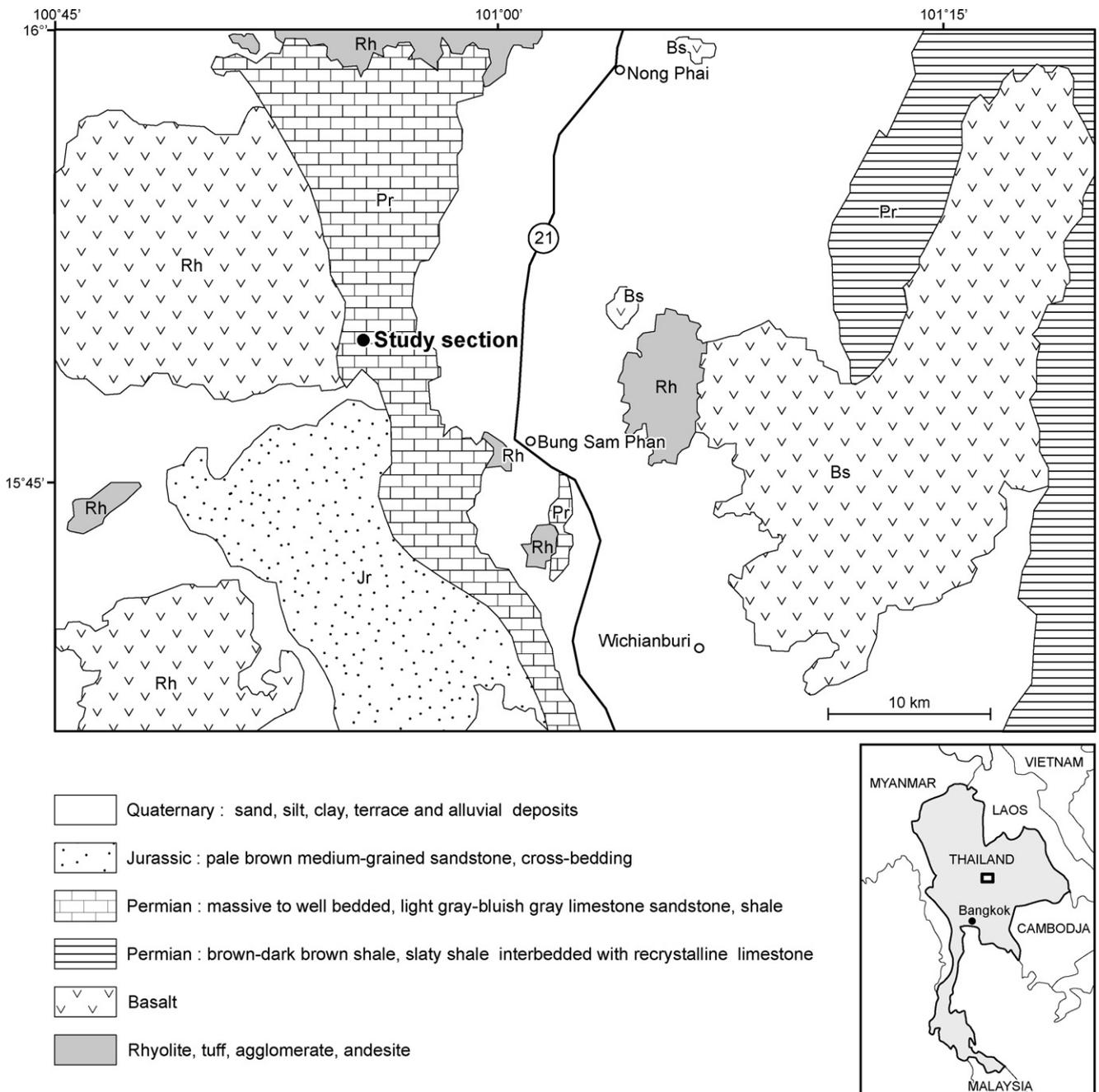


Fig. 2. Geological map and location of the Bung Sam Phan section.
 Fig. 2. Carte géologique et localisation de la coupe de Bung Sam Phan.

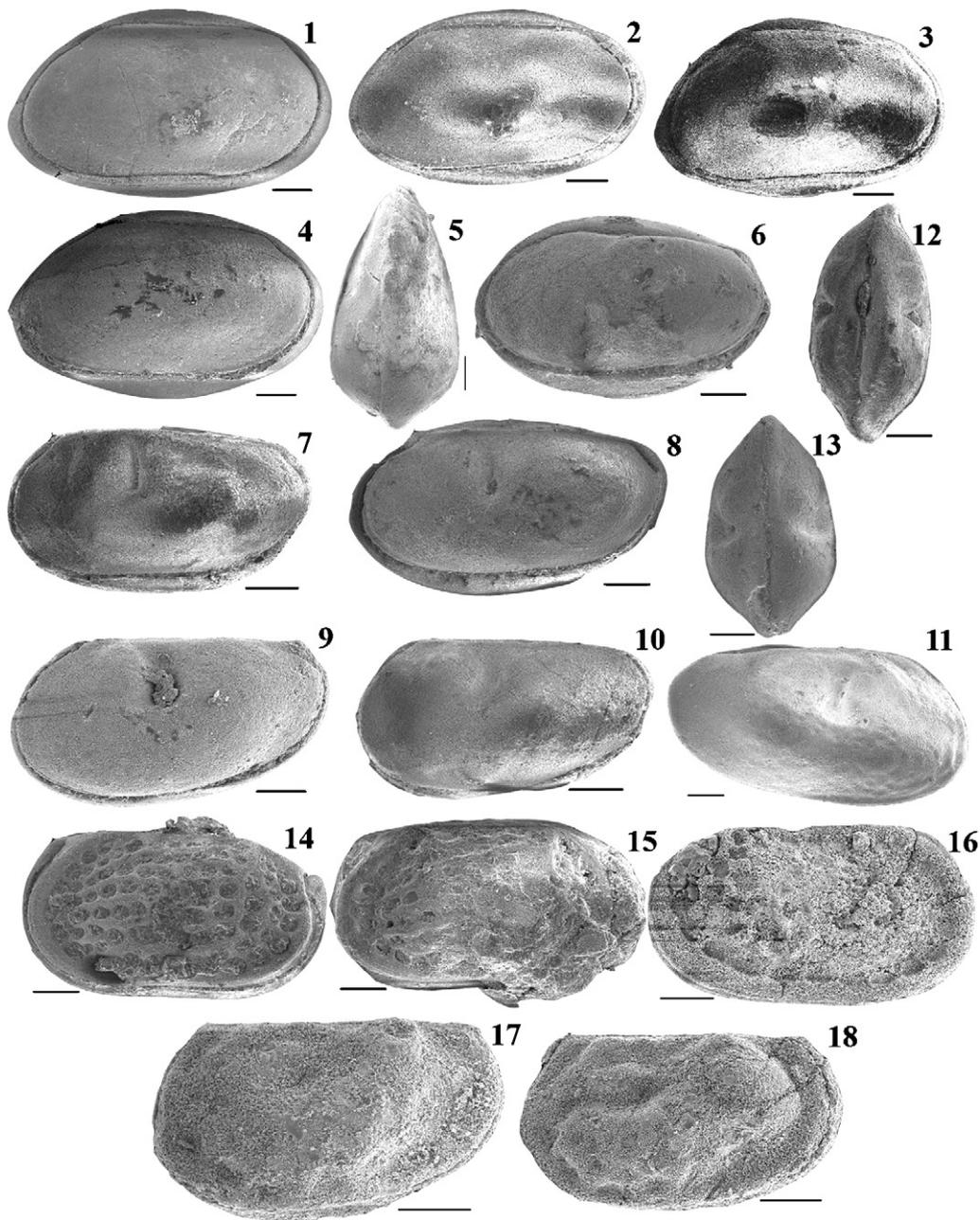


Fig. 3. Specimens from Bung Sam Phan section. Scale bar is 100 μ m. All the specimens are stored in the collection of Suranaree university of technology (collection number: SUT_). **1–5**: *Sargentina? phetchabunensis* nov. sp., **1**: holotype, left lateral view of complete carapace, sample 02TH46, SUT_02PB01; **2**: paratype, left lateral view of complete carapace, sample 02TH46, SUT_02PB02; **3**: left lateral view of complete carapace, sample 02TH46, SUT_02PB03; **4**: left lateral view of complete carapace, sample 02TH46, SUT_02PB04; **5**: dorsal view of complete carapace, sample 02TH46-07, SUT_02PB05. **6**: *Sargentina* cf. *tumida* Cooper, 1946, left lateral view of complete carapace, sample 02TH46, SUT_02PB06. **7–13**: *Geffenina bungsamphanensis* nov. sp., **7**: holotype, heteromorph, left lateral view of complete carapace, sample 02TH46, SUT_02PB08; **8**: paratype, heteromorph, left lateral view of complete carapace, sample 02TH46, SUT_02PB07; **9**: tecnomorph, left lateral view of complete carapace, sample 02TH46, SUT_02PB66; **10**: tecnomorph, left lateral view of complete carapace, sample 02TH46, SUT_02PB09; **11**: Tecnomorph, right lateral view of complete carapace, sample 02TH46, SUT_02PB67; **12**: heteromorph, dorsal view of complete carapace, sample 02TH46, SUT_02PB11; **13**: tecnomorph, dorsal view of complete carapace, sample 02TH46, SUT_02PB14. **14–16**: *Reviya subsompongensis* nov. sp., **14**: holotype, left lateral view of complete carapace, sample 02TH46, SUT_02PB15; **15**: paratype, left lateral view of complete carapace, sample 02TH46-07, SUT_02PB16; **16**: right lateral view of complete carapace, sample 02TH46-07, SUT_02PB17. **17, 18**: Kloedenelloidea indet., **17**: left lateral view of complete carapace, sample 02TH46, SUT_02PB18; **18**: left lateral view of complete carapace, sample 02TH46, SUT_02PB19.

Fig. 3. Spécimens de la coupe de Bung Sam Phan. La barre d'échelle est de 100 μ m. Tous les spécimens sont conservés dans les collections de l'université technologique Suranaree (numéros de collection : SUT_). **1–5** : *Sargentina phetchabunensis* nov. sp., **1** : holotype, vue latérale gauche d'une carapace complète, échantillon 02TH46, SUT_02PB01 ; **2** : paratype, vue latérale gauche d'une carapace complète, échantillon 02TH46, SUT_02PB02 ; **3** : vue latérale gauche d'une carapace complète, échantillon 02TH46, SUT_02PB03 ; **4** : vue latérale gauche d'une carapace complète, échantillon 02TH46, SUT_02PB04 ; **5** : vue dorsale d'une carapace complète, échantillon 02TH46-07, SUT_02PB05. **6** : *Sargentina* cf. *tumida* Cooper, 1946, vue latérale gauche d'une carapace complète, échantillon 02TH46, SUT_02PB06. **7–13** : *Geffenina bungsamphanensis* nov. sp., **7** : holotype, hétéromorphe, vue latérale gauche d'une carapace complète, échantillon 02TH46, SUT_02PB08 ; **8** : paratype, hétéromorphe, vue latérale gauche d'une carapace complète, échantillon 02TH46, SUT_02PB07 ; **9** : tecnomorph, vue latérale gauche

area. However, other researchers (e.g., Yanagida, 1964, 1988; Altermann, 1989; Chonglakmani and Fontaine, 1990) suggested that the age of the Tak Fa formation range up to late Middle Permian (Capitanian). Nevertheless, the study section is overlain unconformably by Late Triassic conglomerate of Huai Hin Lat Formation (Chonglakmani and Sattayarak, 1978). Hence, the Bung Sam Phan section can be correlated lithologically to Middle Permian (Wordian) limestones of Pha Nok Khao formation (Chonglakmani and Sattayarak, 1979) nearby.

3. Ostracod systematic

Seventeen limestone samples were processed by the hot acetolysis method (Lethiers and Crasquin-Soleau, 1988; Crasquin-Soleau et al., 2005). From the seven samples that yielded ostracods, more than 400 specimens were recovered. They belong to eight genera and 15 species, including four newly described species. For the Kloedenellocopina, we follow here the classification of Lethiers (1978, 1981).

Abbreviations: LV: left valve; RV: right valve; DB: dorsal border; VB: ventral border; AB: anterior border; PB: posterior border; ADB: anterodorsal border; AVB: anteroventral border; PDB: posterodorsal border; PVB: posteroventral border; ACA: anterior cardinal angle; PCA: posterior cardinal angle; S₂: median sulcus; L₂: median lobe.

Class OSTRACODA Latreille, 1806

Order PALAEOCOPIIDA Scott, 1961

Suborder KLOEDENELLOCOPINA Scott, 1961 emend.

Lethiers, 1978

Superfamily SANSABELLOIDEA Sohn, 1961

Family SERENIDIDAE Rozhdvenskaya, 1972

Genus *Sargentina* Coryell and Johnson, 1939

Sargentina? *phetchabunensis* nov. sp.

Fig. 3(1–5)

Etiology: From the province of Phetchabun, where the section is located.

Holotype: One carapace (♀), figured Fig. 3(1), collection number SUT_02PB01.

Paratype: One carapace (♀), figured Fig. 3(2), collection number SUT_02PB02.

Type level: Sample number 02TH46, Tak Fa formation, Middle Permian, Bung Sam Phan section (N 15°50'03.3 secondes, E 100°55'35.9 secondes), Central Thailand.

Diagnosis: A species doubtfully attributed to *Sargentina* with very blurred sulcus, DB straight at LV and arched at RV, maximum of convexity of anterior border located low.

Description: Carapace subelliptical in lateral view, tumid; surface smooth; RV strongly overlapping LV around the

carapace, maximum overlapping at DB and VB, minimum convexity at ADB and PDB; DB straight on LV, convex on RV; PCA at LV = 140°; PDB bent showing a sharp shoulder at LV; PB of both valves rounded with large radius of curvature, maximum convexity located at midheight; posterodorsal and anterodorsal regions of both valves oblique; median and ventral regions of both valves swelling; posteroventral and anteroventral regions of both valves oblique; VB straight to slightly concave on LV, slightly convex on RV; maximum of height on RV located at midlength; AB rounded with smaller radius of curvature than the posterior one, maximum convexity located ventrally at one-third of height, carapace preplete; ADB long and almost straight on both valves; ACA at LV = 150°, Kloedenellid dimorphism recognized by more swelling in posteroventral region; S₂ observable in mid-dorsal region.

Discussion: The species is doubly attributed to *Sargentina* because of the obscured subcentral sulcus. *Sargentina?* *phetchabunensis* nov. sp. is close to *Sargentina asulcata* Cooper, 1941 with its shallow sulcus, but differs by its more elongated shape and the lower position of AB. The outline of *Sargentina phetchabunensis* nov. sp. also resembles that of *Sargentina woutersi* Crasquin-Soleau, 1999 from the Middle Permian of Oman (Crasquin-Soleau et al., 1999), but is different in having a straight DB on LV and PB with small radius of curvature.

Material: 21 carapaces and 11 fragments.

Size: H = 0.35–0.49 mm; L = 0.60–0.86 mm.

Distribution: Sample: 02TH46 (see Fig. 4), Middle Permian, Tak Fa formation, Bung Sam Phan section, Phetchabun province, Thailand.

Sargentina cf. *tumida* Cooper, 1946

Fig. 3(6)

Description: Carapace oval in lateral view, tumid; surface smooth; RV larger and overlapping all around LV; DB slightly concave on LV, slightly convex on RV; PCA of LV obtuse (158°); PB rounded with maximum convexity located just above midheight; VB convex on both valves showing strong overlap; maximum height located at midlength; AB rounded with maximum convexity located at midheight; ADB sloped, ACA of LV obtuse (165°); shallow S₂ observed in mid-dorsal region.

Discussion: The species is close to *Sargentina tumida* Cooper, 1946 from Pennsylvanian of Illinois (USA), which has posterior and anterior borders of equivalent height. The difference is that *S.* cf. *tumida* has a slightly concave DB at LV, whereas *S. tumida* has a convex DB.

Material: One carapace.

Size: H = 0.41 mm; L = 0.68 mm.

d'une carapace complète, échantillon 02TH46, SUT_02PB66 ; **10** : tecnomorphe, vue latérale gauche d'une carapace complète, échantillon 02TH46, SUT_02PB09 ; **11** : tecnomorphe, vue latérale droite d'une carapace complète, échantillon 02TH46, SUT_02PB67 ; **12** : hétéromorphe, vue dorsale d'une carapace complète, échantillon 02TH46, SUT_02PB11 ; **13** : tecnomorphe, vue dorsale d'une carapace complète, échantillon 02TH46, SUT_02PB14. **14–16** : *Reviya subsompongensis* nov. sp., **14** : holotype, vue latérale gauche d'une carapace complète, échantillon 02TH46, SUT_02PB15 ; **15** : paratype, vue latérale gauche d'une carapace complète, échantillon 02TH46-07, SUT_02PB16 ; **16** : vue latérale droite d'une carapace complète, échantillon 02TH46-07, SUT_02PB17. **17, 18** : Kloedenelloidea indet., **17** : vue latérale gauche d'une carapace complète, échantillon 02TH46, SUT_02PB18 ; **18** : vue latérale gauche d'une carapace complète, échantillon 02TH46, SUT_02PB19.

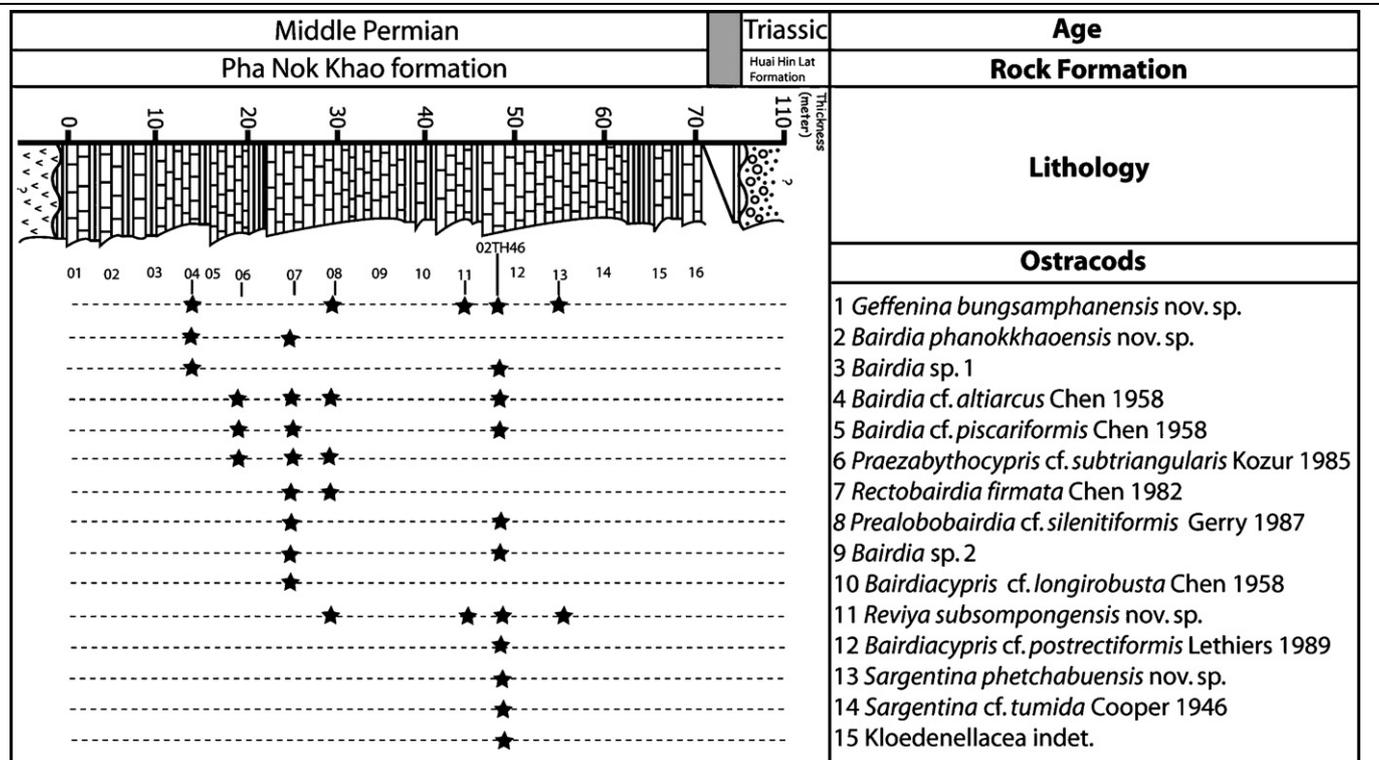


Fig. 4. Distribution of ostracods from the Bung Sam Phan section.

Fig. 4. Distribution des ostracodes dans la coupe de Bung Sam Phan.

Distribution: Sample: 02TH46 (see Fig. 4), Middle Permian, Tak Fa formation, Bung Sam Phan section, Phetchabun province, Thailand.

Superfamily KLOEDENELLOIDEA Ulrich and Bassler, 1908

Family BEYRICHOPSIDAE Henningmoen, 1953

Genus *Geffenina* Coryell and Sohn, 1938

Geffenina bungsamphanensis nov. sp.

Fig. 3(7–13)

Etymology: From the district of Bung Sam Phan, where the section is located.

Holotype: One complete carapace (♀, Fig. 3(7), collection number SUT_02PB08.

Paratype: One complete carapace (♀, Fig. 3(8), collection number SUT_02PB07.

Type level: Sample 02TH46, Tak Fa formation, Middle Permian, Bung Sam Phan section (15°50′03.3 secondes N, 100°55′35.9 secondes E), Central Thailand.

Diagnosis: A species of *Geffenina* with elongate shape, S_2 narrow and long, maximum curvature of PB above midheight.

Description: Carapace suboval in lateral view, tumid; surface smooth to finely punctate; RV overlapping on LV all the margins, except at cardinal angles, maximum overlapping at VB; DB straight to slightly convex on both valves; PCA of both valves obtuse (142°); PDB convex at RV, concave at LV; PB rounded with maximum convexity located above midheight (60%); PVB convex on both valves; VB convex on RV, nearly straight on LV, maximum of height located at midlength; anterior region laterally flattened, AB rounded with large radius

of curvature, maximum convexity located below midheight; ACA of both valves obtuse (135°); S_1 in anterodorsal region narrow and long; S_2 distinct, narrow and long with the lower part located in dorsomedian region; L_2 distinct and rounded; dimorphism clearly observed by carapace swelling in posterior region; dorsal view trilobate, subfusiform, showing strong overlap, maximum thickness located posteriorly; hinge strongly invaginated.

Remarks: The species clearly shows kloedenellid dimorphism. Sexual dimorphism can be observed. The heteromorphs are inflated in the posterior part (posterodorsal and midposterodorsal regions) of both valves making the carapace swelled and appearing oblong or as a parallelogram. The invagination of the hinge is very distinct. RV is clearly larger than LV causing it to strong overlap all around the carapace, except at DB. S_2 is located in front of midlength. Heteromorphs are trilobate with a prominent L_2 . Tecnomorphs are slender with the posterodorsal and mid-posterodorsal regions flat. They are preplete with inflation in venteromedian and midventral regions. RV is slightly larger than LV causing moderate overlapping all around the carapace, except at DB. The invagination is present, but not as clear as in the heteromorph. S_2 is wider and located at midlength.

Discussion: The species belongs to *Geffenina* due to the presence of hinge invagination and a distinctive S_2 . The species is quite different from other representatives of the genus by a more elongate shape, well-defined cardinal angles and a trilobate form.

Material: 221 carapaces, 153 fragments.

Size: H = 0.26–0.47 mm; L = 0.56–0.90 mm.

Distribution: Samples 02TH46-04, 02TH46-08, 02TH46-11, 02TH46-13 and 02TH46 (see Fig. 4), Middle Permian, Tak Fa formation, Bung Sam Phan section, Phetchabun province, Thailand.

Kloedenelloidea indet.

Fig. 3(17–18)

Description: Carapace small, subquadrangular in lateral view, inequivalve, LV slightly larger than RV showing an overlap at ADB; DB straight; PCA = 110°, ACA = 140°; PB rounded, maximum convexity located at midheight; AB rounded, with larger radius of curvature, maximum convexity located ventrally at about one-third of height; two punctuated lobes shown in median region, protruding over DB and separated by a well defined S₂, in dorsomedian region; other areas outside the median region flattened, making a platform all along the free margin, except at DB, area of posterior platform larger than the anterior one; maximum of thickness just behind midlength.

Discussion: The preservation does not allow going further in the determination.

Material: Four carapaces.

Dimension: H = 0.25–0.32 mm; L = 0.46–0.59 mm.

Distribution: Sample: 02TH46 (see Fig. 4), Middle Permian, Tak Fa formation, Bung Sam Phan section, Phetchabun province, Thailand.

Suborder BEYRICHIOCOPINA Scott, 1951

Superfamily KIRKBYOIDEA Ulrich and Bassler, 1906

Family KIRKBYIDAE Ulrich and Bassler, 1906

Genus *Reviya* Sohn, 1961

Reviya subsompongensis nov. sp.

Fig. 3(14–16)

Etymology: From Ban Sub Som Pong, the village where the section is located.

Holotype: One complete carapace, Fig. 3(14), collection number SUT_02PB15.

Paratype: One complete carapace, Fig. 3(16), collection number SUT_02PB16.

Type level: Sample 02TH46, Tak Fa formation, Middle Permian, Bung Sam Phan section (15°50′03.3 secondes N, 100°55′35.9 secondes E), Central Thailand.

Diagnosis: A species of *Reviya* with thick smooth marginal rim extending from cardinal angles, parallel to entire free margin and presence of posterodorsal shoulder.

Description: Carapace subquadrate in lateral view, tumid; surface coarse reticulated with thick smooth marginal rim parallel to entire free margin except at DB; RV slightly larger than the LV showing an overlap at ADB; anterior and posterior regions laterally flattened; median region swelled; DB straight and prolonged by posterior shoulder; PCA of both valves unclear; PB and AB rounded with large radius of curvature, maximum convexity located at midheight; VB concave; ACA of both valves obtuse (136°); central kirkbyan pit.

Discussion: The general outline of *Reviya subsompongensis* nov. sp. is close to the other representatives of the genus, such as *R. obesa* (Croneis and Gale, 1939), the type species, from the Carboniferous of North America. Here, there is no parallel

ridge to VB and the reticulation is larger and parallel to dorsal and ventral borders.

Size: H = 0.31–0.40 mm; L = 0.56–0.76 mm.

Material: 27 carapaces, 19 fragments.

Distribution: Samples 02TH46-08, 02TH46-11, 02TH46-13 and 02TH46 (see Fig. 4), Middle Permian, Tak Fa formation, Bung Sam Phan section, Phetchabun province, Thailand.

Order PODOCOPIDA Müller, 1894

Suborder PODOCOPINA Sars, 1866

Superfamily BAIRDIOIDEA Sars, 1888

Family BAIRDIIDAE Sars, 1888

Genus *Bairdia* McCoy, 1844

Bairdia takfaensis nov. sp.

Fig. 5(1–7)

1982. *Ceratobairdia?* sp. – Chen and Shi, p. 128, Pl. 5, Figs. 11, 12, 15.

Etymology: From the rock formation to which the section belongs.

Holotype: One complete carapace, Fig. 5(1), collection number SUT_02PB28.

Paratype: One complete carapace, Fig. 5(2), collection number SUT_02PB29.

Type level: Sample 02TH46-07, Tak Fa formation, Middle Permian, Bung Sam Phan section (15°50′03.3 secondes N, 100°55′35.9 secondes E), Central Thailand.

Diagnosis: A species of *Bairdia* with arched dorsal outline, DB fused with ADB and PDB and shoulders in dorsomedian part.

Description: Carapace subfusiform to suboval in lateral view, surface smooth to finely punctate, LV strongly overlapping on RV all around the carapace, maximum overlap at DB, carapace laterally flattened in mid-anterior and mid-posterior regions; DB equally arched; hinge short; ADB long and concave, AB rounded with small radius of curvature, maximum convexity located above midheight (61% of height); AVB nearly straight; ventral outline equally convex with truncation of AVB and PVB; VB of both valves slightly concave; VB prolonged to tapering posterior end, located ventrally (30% of height); PVB bent in the lower part, but slightly convex in the upper part; angle between DB and PDB not clear, between DB and ADB = 145°; maximum of height located anteriorly.

Discussion: *Ceratobairdia?* sp. from the Late Permian of China (Chen and Shi, 1982) belongs to *Bairdia takfaensis* nov. sp. The genus is not *Ceratobairdia* Sohn, 1954, which is characterized by the presence of thick spines or knobs along the dorsum of the larger valve and by a ventrolateral alate ridge (Sohn, 1954).

Material: 18 carapaces.

Size: H = 0.40–0.60 mm; L = 0.81–1.25 mm.

Distribution: Samples 02TH46-04 and 02TH46-07 (see Fig. 4), Middle Permian, Tak Fa formation, Bung Sam Phan district, Phetchabun province, Thailand and Hubei province, South China.

Bairdia cf. piscariformis Chen, 1958

Fig. 6(1, 2)

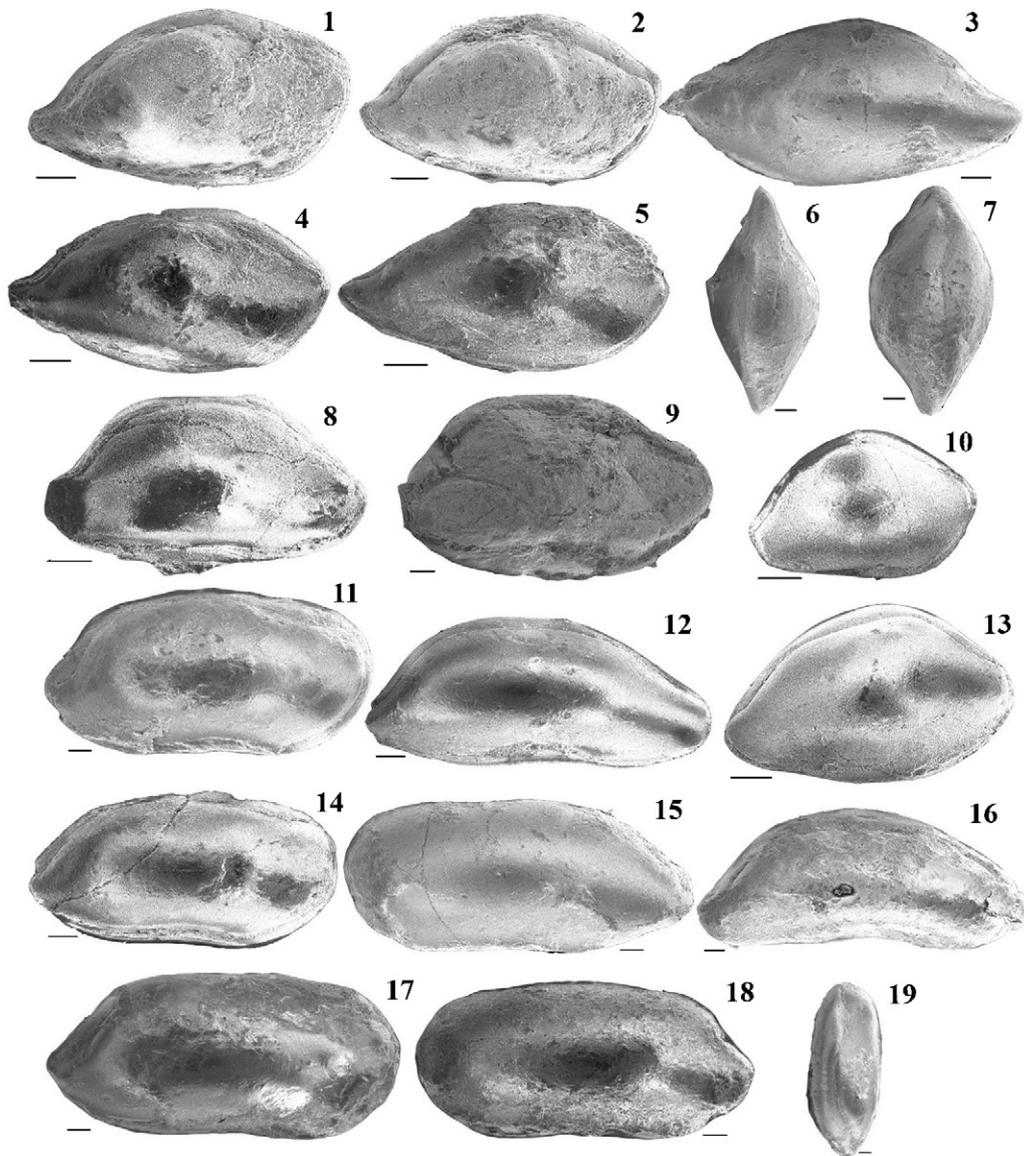


Fig. 5. Specimens from Bung Sam Phan section. Scale bar is 100 μ m. All the specimens are stored in the collection of Suranaree university of technology (collection number: SUT_). **1–7**: *Bairdia takfaensis* nov. sp., **1**: holotype, right lateral view of complete carapace, sample 02TH46-07, SUT_02PB28; **2**: paratype, right lateral view of complete carapace, sample 02TH46-07, SUT_02PB29; **3**: left lateral view of complete carapace, sample 02TH46-07, SUT_02PB32; **4**: right lateral view of complete carapace, sample 02TH46-07, SUT_02PB34; **5**: right lateral view of complete carapace, sample 02TH46-07, SUT_02PB35; **6**: dorsal view of complete carapace, sample 02TH46-07, SUT_02PB31; **7**: ventral view of complete carapace, sample 02TH46-07, SUT_02PB33. **8, 9**: *Praelobairdia* cf. *silenitiformis* Kozur, 1985, **8**: right lateral view of complete carapace, sample 02TH46, SUT_02PB54; **9**: right lateral view of complete carapace, sample 02TH46-07, SUT_02PB55. **10, 13**: *Bairdia* cf. *altiaricus* Chen, 1958, **10**: right lateral view of complete carapace, sample 02TH46, SUT_02PB46; **13**: right lateral view of complete carapace, sample 02TH46, SUT_02PB47. **11, 14, 15, 17–19**: *Rectobairdia firmata* Chen, 1982, **11**: right lateral view of complete carapace, sample 02TH46-07, SUT_02PB21; **14**: right lateral view of complete carapace, sample 02TH46-07, SUT_02PB22; **15**: left lateral view of complete carapace, sample 02TH46-07, SUT_02PB23; **17**: right lateral view of complete carapace, sample 02TH46-07, SUT_02PB24; **18**: left lateral view of complete carapace, sample 02TH46-07, SUT_02PB25; **19**: dorsal view of complete carapace, sample 02TH46-07, SUT_02PB26. **12, 16**: *Bairdia* sp. 2, **12**: right lateral view of complete carapace, sample 02TH46-07, SUT_02PB58; **16**: right lateral view of complete carapace, sample 02TH46-07, SUT_02PB59.

Fig. 5. Spécimens de la coupe de Bung Sam Phan. La barre d'échelle est de 100 μ m. Tous les spécimens sont conservés dans les collections de l'université technologique Suranaree (numéros de collection : SUT_). **1–7** : *Bairdia takfaensis* nov. sp., **1** : holotype, vue latérale droite d'une carapace complète, échantillon 02TH46-07, SUT_02PB28 ; **2** : paratype, vue latérale droite d'une carapace complète, échantillon 02TH46-07, SUT_02PB29 ; **3** : vue latérale gauche d'une carapace complète, échantillon 02TH46-07, SUT_02PB32 ; **4** : vue latérale droite d'une carapace complète, échantillon 02TH46-07, SUT_02PB34 ; **5** : vue latérale droite d'une carapace complète, échantillon 02TH46-07, SUT_02PB35 ; **6** : vue dorsale d'une carapace complète, échantillon 02TH46-07, SUT_02PB31 ; **7** : vue ventrale d'une carapace complète, échantillon 02TH46-07, SUT_02PB33. **8, 9** : *Praelobairdia* cf. *silenitiformis* Kozur, 1985, **8** : vue latérale droite d'une carapace complète, échantillon 02TH46, SUT_02PB54 ; **9** : vue latérale droite d'une carapace complète, échantillon 02TH46-07, SUT_02PB55. **10, 13** : *Bairdia* cf. *altiaricus* Chen, 1958, **10** : vue latérale droite d'une carapace complète, échantillon 02TH46, SUT_02PB46, **13** : vue latérale droite d'une carapace complète, échantillon 02TH46, SUT_02PB47. **11, 14, 15, 17–19** : *Rectobairdia firmata* Chen, 1982, **11** : vue latérale droite d'une carapace complète, échantillon 02TH46-07, SUT_02PB21 ; **14** : vue latérale droite d'une carapace complète, échantillon 02TH46-07, SUT_02PB22 ; **15** : vue latérale gauche d'une carapace complète, échantillon 02TH46-07, SUT_02PB23 ; **17** : vue latérale droite d'une carapace complète, échantillon 02TH46-07, SUT_02PB24 ; **18** : vue latérale gauche d'une carapace complète, échantillon 02TH46-07, SUT_02PB25 ; **19** : vue dorsale d'une carapace complète, échantillon 02TH46-07, SUT_02PB26. **12, 16** : *Bairdia* sp. 2, **12** : vue latérale droite d'une carapace complète, échantillon 02TH46-07, SUT_02PB58 ; **16** : vue latérale droite d'une carapace complète, échantillon 02TH46-07, SUT_02PB59.

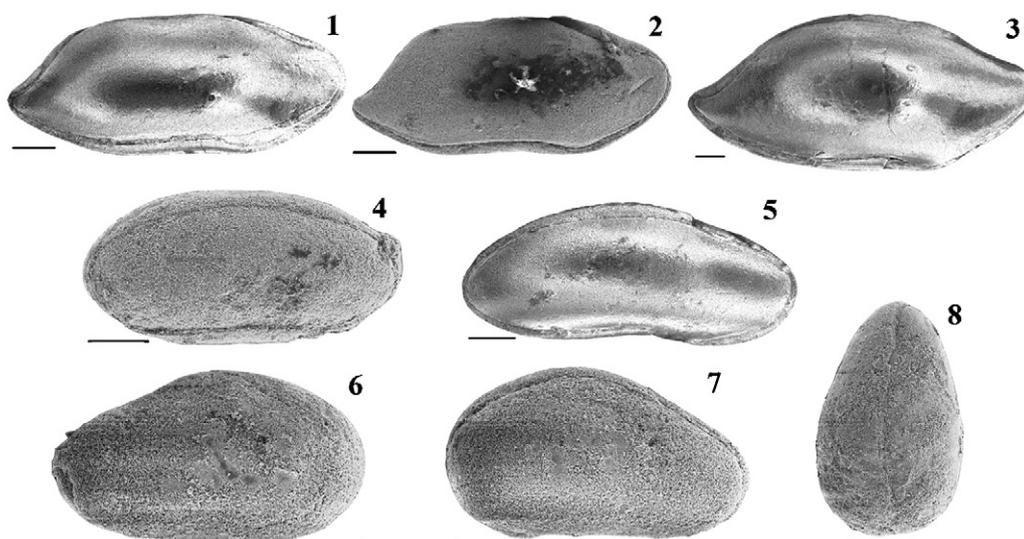


Fig. 6. Specimens from Bung Sam Phan section. Scale bar is 100 μ m. All the specimens are stored in the collection of Suranaree university of technology (collection number: SUT_). **1, 2:** *Bairdia* cf. *piscariformis* Chen, 1958, **1:** right lateral view of complete carapace, sample 02TH46-07, SUT_02PB39; **2:** right lateral view of complete carapace, sample 02TH46, SUT_02PB40. **3:** *Bairdia* sp. 1, right lateral view of complete carapace, sample 02TH46, SUT_02PB43. **4:** *Bairdiacypris* cf. *longirobusta* Chen, 1958, right lateral view of complete carapace, sample 02TH46-07, SUT_02PB60. **5:** *Bairdiacypris* cf. *postrectiformis* Lethiers, 1989, right lateral view of complete carapace, sample 02TH46, SUT_02PB61. **6–8:** *Praezabythocypris* cf. *triangularis* Kozur, 1985, **6:** left lateral view of complete carapace, sample 02TH46-07, SUT_02PB62; **7:** right lateral view of complete carapace, sample 02TH46-07, SUT_02PB63; **8:** dorsal view of complete carapace, sample 02TH46-07, SUT_02PB64.

Fig. 6. Spécimens de la coupe de Bung Sam Phan. La barre d'échelle est de 100 μ m. Tous les spécimens sont conservés dans les collections de l'université technologique Suranaree (numéros de collection : SUT_). **1, 2 :** *Bairdia* cf. *piscariformis* Chen, 1958, **1 :** vue latérale droite d'une carapace complète, échantillon 02TH46-07, SUT_02PB39 ; **2 :** vue latérale droite d'une carapace complète, échantillon 02TH46, SUT_02PB40. **3 :** *Bairdia* sp. 1, vue latérale droite d'une carapace complète, échantillon 02TH46, SUT_02PB43. **4 :** *Bairdiacypris* cf. *longirobusta* Chen, 1958, vue latérale droite d'une carapace complète, échantillon 02TH46-07, SUT_02PB60. **5 :** *Bairdiacypris* cf. *postrectiformis* Lethiers, 1989, vue latérale droite d'une carapace complète, échantillon 02TH46, SUT_02PB61. **6–8 :** *Praezabythocypris* cf. *triangularis* Kozur, 1985, **6 :** vue latérale gauche d'une carapace complète, échantillon 02TH46-07, SUT_02PB62 ; **7 :** vue latérale droite d'une carapace complète, échantillon 02TH46-07, SUT_02PB63 ; **8 :** vue dorsale d'une carapace complète, échantillon 02TH46-07, SUT_02PB64.

Description: Carapace subfusiform in lateral view, surface smooth, slightly overlapping all around the carapace, except at DB, maximum overlapping at ADB; DB long and straight, oriented horizontally; ADB slightly concave on RV, nearly straight on LV; AB rounded with small radius of curvature, maximum convexity located at midheight; AVB long and slightly convex; AVB and PVB prominent, maximum of height located at midheight; VB slightly concave; PVB straight, shorter than AVB; posterior end tapering with maximum convexity located at lower third of height; PVB steep, slightly concave at the lower part, nearly straight at the upper part; angle between DB and PDB = 150°, between DB and ADB = 168°.

Discussion: The species looks similar to *Bairdia piscariformis* Chen, 1958 from the Early Permian of Lungtan, South China, in lateral view, especially in the ventral part. However, *B. piscariformis* has the arched DB at left valve, which overlaps the RV.

Material: Four carapaces.

Size: H = 0.28–0.34 mm; L = 0.69–0.84 mm.

Distribution: Samples 02TH46-06, 02TH46-07, 02TH46 (see Fig. 4), Middle Permian, Tak Fa formation, Bung Sam Phan section, Phetchabun province, Thailand.

Bairdia sp. 1

Fig. 6(3)

Description: Carapace subfusiform in lateral view; dorsal outline moderately arched; DB slightly convex; ADB and PDB

long and upward terminally; AB tapering, anterior end sharply pointed with maximum convexity located dorsally (at 62% of height); AVB long and straight; VB concave on RV, nearly straight on LV; PVB long and slightly convex; posterior end tapering and sharply pointed with maximum convexity located ventrally (at 35% of height); angle between DB and PDB = 158°, between DB and ADB = 160°; maximum of height located at midlength.

Discussion: *Bairdia* sp. 1 resembles *Rectobairdia hexensis* Harlton, 1929 sensu Shi and Chen, 2002 from the Late Permian of Guangxi, South China. Here, the AB is narrower and has a maximum of convexity located lower. *Bairdia* sp. 1 differs from *B. cf. piscariformis* Chen, 1958 (Fig. 7(1, 2); see above) in having the upward pointing, tapering posterior end.

Material: Three carapaces

Size: H = 0.54 mm; L = 1.21 mm.

Distribution: Samples 02TH46-04 and 02TH46 (see Fig. 4), Middle Permian, Tak Fa formation, Bung Sam Phan section, Phetchabun province, Thailand.

Bairdia sp. 2

Fig. 5(12, 16)

Description: Carapace subelliptical in lateral view; surface smooth; LV moderately overlapping RV all around the carapace, except at anterior and posterior ends; dorsal outline broadly arched, hinge long; DB nearly straight on RV, convex on LV; ADB long, straight, slightly concave in lower part; AB

rounded with small radius of curvature, maximum convexity located ventrally at lower third of height; AVB slightly convex; VB concave on both valves showing strongly overlapping; PVB slightly convex; posterior end tapering, maximum convexity located ventrally at one-fourth of height; PDB slightly concave in lower part, but slightly convex in upper part; angle between DB and PDB = 148–168°, between DB and ADB = 160–140°; maximum of height located posteriorly.

Discussion: The outline of *Bairdia* sp. 2. is reminiscent of *Bairdia delicata* Morey in Shi and Chen, 2002 from the Late Permian of Guangxi; here ADB has maximum of convexity AB located lower and DB longer.

Material: Two carapaces.

Size: H = 0.55–0.71 mm; L = 1.30–1.70 mm.

Distribution: Sample O2TH46-07 and O2TH46 (see Fig. 4), Middle Permian, Tak Fa formation, Bung Sam Phan section, Phetchabun province, Thailand.

Bairdia cf. *altiaricus* Chen, 1958

Fig. 5(10, 13)

Description: Carapace subtriangular in lateral view; surface smooth; LV moderately overlapping RV all around the carapace especially in DB and VB; dorsal outline convex; hinge short; DB straight; ADB nearly straight; AB rounded with small radius of curvature, maximum convexity located at midheight; AVB nearly straight; VB concave on RV, nearly straight on LV; PVB short and nearly straight; posterior end tapering with maximum convexity located ventrally (27% of height); PDB nearly straight on both valves; angle between DB and PDB = 150°, between DB and ADB = 130°; maximum of height located in front of midlength.

Discussion: This species resembles *Bairdia altiaricus* Chen, 1958 from the Early Permian of Nanjing, South China in lateral view. The difference is that here the radius of curvature of anterior end is narrower. The maximum of height of *B. altiaricus* is located at midlength, whereas it is here located anteriorly. The AVB of *B. altiaricus* is broadly rounded, whereas it is narrower in *B. cf. altiaricus*. The PDB of *B. cf. altiaricus* is located lower.

Material: Eight carapaces.

Size: H = 0.36–0.48 mm; L = 0.55–0.76 mm.

Distribution: Sample: O2TH46, O2TH46-06, O2TH46-07, O2TH46-08 (see Fig. 4), Middle Permian, Tak Fa formation, Bung Sam Phan section, Phetchabun province, Thailand.

Genus *Rectobairdia* Sohn, 1960

Rectobairdia firmata Chen, 1982

Fig. 5(11, 14, 15, 17–19)

Description: Carapace subrectangular in lateral view, laterally flattened, surface smooth to punctate; LV larger and overlapping all around RV, strongly overlapping in DB; dorsal outline broadly arched, DB straight on both valves; hinge short; ADB long, slightly convex on LV, straight and concave terminally on RV; AB rounded with large radius of curvature, maximum convexity located at midheight; AVB slightly convex on both valves; PVB slightly convex; posterior end tapering with maximum convexity located below midheight; PDB straight to slightly convex; angle between PDB and DB = 148°,

between DB and ADB = 166°; maximum of height located at midlength.

Material: 34 carapaces, four fragments.

Size: H = 0.48–0.72 mm; L = 1.00–1.54 mm.

Distribution: Sample: O2TH46-07, O2TH46-08 (see Fig. 4), Middle Permian, Tak Fa formation, Bung Sam Phan section, Phetchabun province, Thailand and Late Permian of Jiangsu province, South China.

Genus *Praelobobairdia* Kozur, 1985

Praelobobairdia cf. *silenitiformis* Kozur, 1985

Fig. 5(8, 9)

Description: Carapace subtrapezoidal in lateral view, surface smooth; laterally flattened; LV strongly overlapping all around RV except at anterior and posterior ends, maximum overlapping shown at DB, where DB of RV smooth and slightly convex, but DB of LV convex and flattened; ADB straight and steeply sloping; AB rounded with small radius of curvature, maximum convexity located ventrally (39% of height); AVB short and slightly convex; VB concave on RV, nearly straight on LV showing strong overlapping; maximum of height located at midlength; PVB short and slightly convex; PB rounded with small radius of curvature, maximum convexity located almost at the same level as of the anterior one (lower 40% of height); PDB steep, bent in lower part, nearly straight in upper part; angles between DB and PDB and between DB and ADB = 150°.

Discussion: The species is similar in lateral view to *Praelobobairdia silenitiformis* Kozur, 1985 from the Middle Permian of Hungary (Kozur, 1985) and Israel (Gerry et al., 1987). However, a difference is observed at DB of the LV, which is thicker in *P. silenitiformis*.

Material: Six carapaces, five fragments.

Size: H = 0.43–0.82 mm; L = 0.84–1.39 mm.

Distribution: Sample: O2TH46, O2TH46-07 (see Fig. 4), Middle Permian, Tak Fa formation, Bung Sam Phan section, Phetchabun province, Thailand.

Genus *Bairdiacypris* Bradfield, 1935

Bairdiacypris cf. *longirobusta* Chen, 1958

Fig. 6(4)

Description: Carapace elongate, kidney-shaped in lateral view; dorsal outline slightly convex; DB broadly arched with truncation of anterior and posterior portions; ADB long, nearly straight; AB rounded with maximum convexity located at midheight; AVB short, nearly straight; VB slightly concave on LV, straight on RV; PVB short, nearly straight; PB rounded with maximum convexity located at midheight; PDB short and slightly convex; maximum of height located at midlength.

Discussion: The species is similar to *Bairdiacypris longirobusta* Chen, 1958 from the Early to Late Permian of South China (Chen, 1958; Shi and Chen, 2002). However, the carapace of *B. longirobusta* is more arched and contacts between DB and AB and PB are angular. The species differs from *Bairdiacypris wangi* Kozur, 1985 by its smaller radius of curvature of PB.

Material: One carapace.

Size: H = 0.27 mm; L = 0.56 mm.

Distribution: Sample: 02TH46-07 (see Fig. 4), Middle Permian, Tak Fa formation, Bung Sam Phan section, Phetchabun province, Thailand.

Bairdiacypris cf. *postrectiformis* Lethiers, 1989

Fig. 6(5)

Description: Carapace long and slightly arched, surface smooth, moderately overlapping all around the carapace, maximum overlapping at DB, weakly overlap at AB and PB; DB broadly arched; ADB long and straight, AB rounded with small radius of curvature, maximum convexity located below midheight (41% of height); AVB convex; AVP and PVP developed; VB equally concave on both valves; PVB slightly convex; PB rounded with small radius of curvature, maximum convexity located ventrally (29% of height); PDB short, slightly convex; maximum of height located at midlength.

Discussion: The species is similar to *Bairdiacypris postrectiformis* Lethiers, 1989 from the Late Wordian of Tunisia (Lethiers et al., 1989) in lateral view. The two species are different in position of maximum of height, posteriorly in *B. postrectiformis*, but at midlength in *B. cf. postrectiformis*. The VB of *B. postrectiformis* is nearly straight with distinct ventral overlapping, but concave in *B. cf. postrectiformis*.

Material: One carapace.

Size: H = 0.34 mm; L = 0.78 mm.

Distribution: Sample: 02TH46 (see Fig. 4), Middle Permian, Tak Fa formation, Bung Sam Phan section, Phetchabun province, Thailand.

Genus *Praezabythocypris* Kozur, 1985

Praezabythocypris cf. *subtriangularis* Kozur, 1985

Fig. 6(6–8)

Description: Carapace suboval in lateral view, surface smooth; moderate overlapping of RV on LV; the posterior part larger than the anterior one; dorsal outline arched; DB arched; ADB long and nearly straight; AB rounded with small radius of curvature, maximum convexity located ventrally, at one-third of height; AVB and PVB short and slightly convex; VB straight; PB rounded with large radius of curvature; maximum convexity located at midheight; PDB truncated; maximum of height located posteriorly.

Discussion: The species is similar to *Praezabythocypris subtriangularis* Kozur, 1985 from the Middle Permian of Hungary (Kozur, 1985) and Oman (Crasquin-Soleau and Baud, 1998). Here, the AB is more rounded with a larger radius of curvature, the PB has a smaller radius of curvature and overlap is stronger all around the carapace.

Material: 74 carapaces.

Size: H = 0.25 mm, L = 0.43–0.73 mm.

Distribution: Sample: 02TH46-06, 02TH46-07, 02TH46-08 (see Fig. 4), Middle Permian, Tak Fa formation, Bung Sam Phan section, Phetchabun province, Thailand.

4. Palaeoenvironmental features

Ostracods are used as tools for palaeoenvironmental interpretation (e.g., Crasquin-Soleau et al., 1999). According to Melnyk and Maddocks (1988), ostracod assemblages at the

Percentage of ostracod specimens at Superfamily and Family level

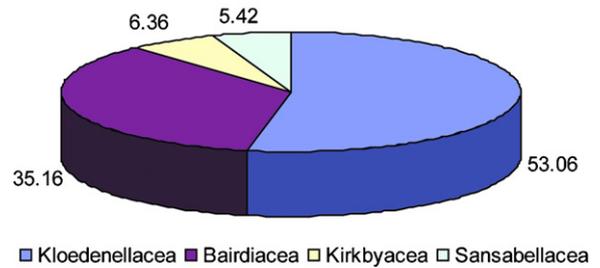


Fig. 7. Percentage of ostracods specimens at superfamily and family level (Kloedenelloidea 53.06%, Bairdioidea 35.16%, Kirkbyoidea 6.36%, Sansabelloidea 5.42%).

Fig. 7. Pourcentage de spécimens d'ostracodes au niveau des familles et superfamilles (Kloedenelloidea 53,06 %, Bairdioidea 35,16 %, Kirkbyoidea 6,36 %, Sansabelloidea 5,42 %).

superfamily and family levels provide interesting data for the reconstruction of the depositional environment. The Kloedenelloidea occupied very shallow, euryhaline environments; the Kirkbyidae are inhabitant of subtidal, marine environments; Bairdioidea occupied shallow to deep environments with normal salinity; and the genus *Sansabella* is an onshore inhabitant.

From the studied section, more than 400 specimens were recovered from limestone samples. We recognized Kloedenelloidea (53.06%), Bairdioidea (35.16%), Kirkbyoidea (6.36%) and Sansabelloidea (5.42%) (Fig. 7). This general composition points out a shallow marine, euryhaline, nearshore environment during the time of deposition. This interpretation conforms with other researches on the *Geffenina*. Green (1963) concluded that *Bairdia* and *Geffenina* represent a shallow water shelf environment, possibly on lime silt-sand substrate. Crasquin-Soleau (2003) recovered *Geffenina wangi* Crasquin-Soleau, 2003 from Middle Permian limestone of Central Oman, which also accumulated in shallow water facies. Perez-Huerta et al. (2007) report the occurrence of compositid brachiopods (?*Composita* sp. A and sp. B, pp. 511–512) at about the upper part of this section. The Permo–Carboniferous compositid brachiopods were likely to live in shallow water (5–20 m depth), normal salinity and on firm substrate (Melnyk and Maddocks, 1988). The abundance of these brachiopods, thus, are in agreement with our conclusions about shallow water, subtidal, normal marine, nearshore environment.

If we analyze the composition of the ostracod assemblages bed by bed (Fig. 8), we can follow the variations in the palaeoenvironments. After a relatively open marine setting with normal conditions of salinity and temperature at levels 6 and 7, the environment become more restricted, with the arrival (level 8) and preponderance (level 11) of typical nearshore ostracods (*Sargentina* and Kloedenelloidea). These last forms are indicative of very shallow water with variations of salinity and temperature. Level 46 presented some Bairdiidae and could show a little more external position. In the last level (13), we found exclusively nearshore markers. So, we can propose a

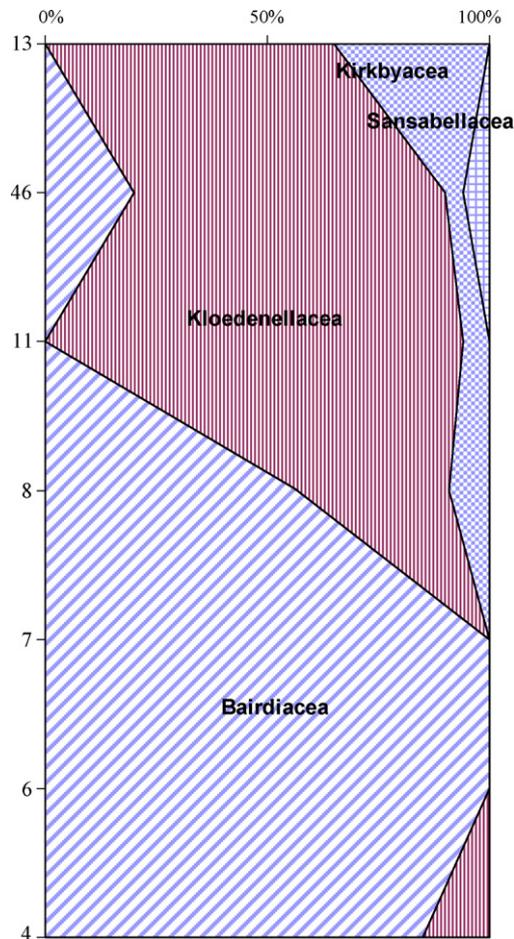


Fig. 8. Variation of ostracod assemblages along the Bung Sam Phan section (in percentage of species).

Fig. 8. Variation de la composition des assemblages d'ostracodes le long de la coupe de Bung Sam Phan (en pourcentage d'espèces).

general shallowing from the base to the top of the analyzed series.

The general composition of ostracod assemblages from the studied section is similar to those reported from Middle Permian rocks all along the southern margin of the Palaeo-Tethys (as in Tunisia, Lethiers et al., 1989 or in Oman, Crasquin-Soleau et al., 1999, for example). To establish the palaeobiogeographical links between different areas using ostracods, the only valid systematic level is the specific one. Here, we have only one species in common with another area (*Bairdia firmata* Chen, 1982 from South China). This testifies that there was a shallow water connection between Central Thailand and South China. All the other species are, for the time being, endemic and this could emphasize a relative isolation of the central Thailand basin during the Wordian. Further investigations are necessary to increase the precision of the Thai Permian ostracod palaeobiogeography.

5. Conclusion

Ostracods were recovered from Middle Permian limestones, which are exposed in Phetchabun province, central Thailand. Fifteen species have been identified. The percentages of

ostracod assemblages at superfamily/family level give evidence for a shallow marine, euryhaline, nearshore environment. The ostracod assemblages seem to indicate a shallowing along the studied section. One species is in common with South China and testifies to the proximity of this area and central Thailand during the Middle Permian. The endemism of all other species provides evidence in favour of the relative isolation of Khao Khwang Platform at this time.

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