Biostratigraphy and palaeobiogeography of Lower Permian (lower Kungurian) conodonts from the Tak Fa Formation (Saraburi Limestone), Thailand

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Abstract

Lower Permian (lower Kungurian) conodonts are reported from the Indochina Block of Southeast Asia. The fauna from the Tak Fa Formation of the Saraburi Limestone Group exposed in limestone hills NNW of Khok Samrong, Thailand, includes Swee-tognathus subsymmetricus Wang, Ritter and Clark (early forms) and Pseudosweetognathus costatus Wang, Ritter and Clark. The co-occurrence of these species indicates a Lower Permian age (upper half of the lower Kungurian) for the sampled limestones representative of the Mesogondolella siciliensis–S. subsymmetricus Zone of South China. Sweetognathus and Pseudosweetognathus are for the first time reported from the Indochina terrane located in the palaeoequatorial belt in the Kungurian. Pseudosweetognathus appears restricted to the Kungurian of the South China and Indochina terranes thus supporting palaeogeographic reconstructions that isolate these terranes within the Palaeo-Tethys during the Kungurian.

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1. Introduction

Permian limestones widely distributed in Thailand, represent a wide range of depositional environments, indicating they were deposited in differing tectonic settings and on different tectono-stratigraphic terranes (see Fig. 1 and Metcalfe, 2006 for discussion of principal SE Asian terranes). “Lower Permian” conodonts that have been previously reported from Thailand and the Indochina Terrane are from southeast of Wang Saphung, NE Thailand (Igo, 1974). However, based on the current definition of the base of the Permian, this fauna, dominated by Streptognathodus elegantulus (Stauffer and Plummer) has been reinterpreted as Pennsylvanian (Upper Carboniferous) in age (Mei and Henderson, 2002). The only other Permian conodonts known from Thailand are Upper Permian conodonts from the Pha Huat Formation, northern Thailand, NE of Lampang and interpreted as Wordian in age (Carey et al., 1995). Mei and Henderson (2002) reinterpreted this fauna and based on revision of taxa, suggested the presence of Clarkina liangshanensis and Iranognathus socioensis indicates an upper Wuchiapingian age. The fauna was originally interpreted to represent a warm-water setting which they noted was at odds with its position west of the Nan-Uttaradit suture. We now know that the main Palaeo-Tethys suture lies further to the west (see Metcalfe 2005, 2006) and there is thus no
palaeogeographic conflict with this fauna. The other Lower Permian conodonts known from the SE Asian region are a small fauna from the Kanthan Limestone of NW Peninsular Malaysia (Sibumasu Terrane) including *Mesogondolella bisselli* and *Hindeodus* (Metcalfe, 1981), and a small Asselian fauna from the Terbat Formation of Sarawak, Borneo (SW Borneo Block) that includes *S. elongatus* and *Hindeodus* (Metcalfe, 1985).

We here report Kungurian conodonts from the Tak Fa Formation of the Saraburi Limestone Group of central Thailand which was deposited on the western margin of the Indochina Terrane. This is the first report of Kungurian conodonts from the Indochina Terrane and the first report of conodonts from the Saraburi Limestone Group.

2. Location, stratigraphy and sampling

Permian limestone, exposed as numerous limestone hills, is widely distributed in the Saraburi to Phetchabun
Fig. 2. Distribution of Permian rocks of the Loei–Petchabun Fold Belt in Central Thailand (Khao Khwang and Pha Nok Khao Platforms and Nam Duk Basin) and location of the study area.
Fig. 3. Map of limestone hills and exposures of the Permian Tak Fa Formation, NNW of Khok Samrong showing conodont sample locations.
region, central Thailand (Fig. 2). These limestone deposits are stratigraphically termed the Saraburi Limestone Group, and form the Khao Khwang Carbonate Platform of the western margin of the Indochina Terrane (Wielchowsky and Young, 1985). Foraminifers, corals, brachiopods, and bryozoans indicate that the Saraburi Limestone Group ranges in age from Kungurian to Capitanian (Yanagida, 1964; Sakagami, 1975; Toriyama, 1975, 1978, 1984;

Fig. 4. Conodont and fusulinid zonations and ranges of important conodont taxa for the Cisuralian and Guadalupian of South China, showing the stratigraphic overlap of _Pseudosweetognathus costatus_ Wang, Ritter and Clark and _Sweetognathus subsymmetricicus_ Wang, Ritter and Clark in the upper half of the Lower Kungurian and interpreted age of the Tak Fa Formation conodont fauna. After Mei et al., 2002 and Henderson and Mei, 2003.
Toriyama and Kanmera, 1977, 1979; Toriyama et al., 1974; Sugiyama, 1982; Yanagida et al., 1988; Chonglakmani and Fontaine, 1990; Igo, 1992; Yanagida and Nakomsri, 1999). Conodonts have not previously been reported from these limestones.

In the area between Saraburi and Phetchabun, massive to well bedded, light grey to bluish-grey limestones with intercalated sandstones and shales are extensively distributed. They were mapped as the Tak Fa Formation and assigned a Middle Permian age by Nakornsri (1977, 1981). In this study, three limestone hills north of Khok Samrong town, from south to north, Khao Wang, Khao Krachieo, and Khao Khok (Fig. 3), were visited, and samples for conodont extraction collected.

2.1. Khao Wang limestone

Khao Wang is a relatively large limestone hill just southwest of the road junction at the Ban Nong Muang village, about 2km NNW of the temple Wat Khiri Nakharattanaram along Route 1. Both macrofossils and fusulinoids are highly abundant in many exposures of this hill.

Three conodont samples (KW4, KW1 and WTS2) were collected from Khao Wang hill via the footpath accessible from the temple Wat Tham Sangtsisuk located on the northern side of the hill (Fig. 3). The sampled beds show a strike and dip of $180/20^\circ$W. The limestone is dominantly bioclastic with abundant brachiopods, compound rugose corals, and foraminifers (both fusulinoids and smaller foraminifers). Limestones exposed 2km to the SSE at Wat Khiri Nakharattanaram have yielded the fusulinoids *Nankinella (?)* sp., *Neofusulina saraburiensis* Toriyama, Kanmera and Ingavat, *Parafusulina gigantea* (Deprat), *Verbeekina verbeeki* (Geinitz), *Pseudodoliolina pseudolepida* (Deprat) and *Sumatrina annae* Volz indicating a lower Middle Permian age (Toriyama and Pitakpaivan, 1973).

Plate I. All specimens from sample KH1. Scale bars represent 100 μm unless otherwise indicated (see page 145).


1–7. Oral, inner lateral, aboral, outer lateral, posterior and oral details (showing reticulate ornament) of specimen IM043

8–10. Oral, aboral and outer lateral views of specimen IM044

11–13. Oral, aboral and inner lateral views of specimen IM045

14. Oral view of specimen IM046

15–17. Oral and oral detail views of specimen IM047

18. Oral view of specimen IM048

19–21. Inner lateral, oral and oral detail views of specimen IM049

Plate II. 1–5. *Pseudosweetognathus costatus* Wang, Ritter and Clark Pa elements (sample KH1) (see page 146).

1. Oral view of specimen IM050

2. Oral view of specimen IM051

3. Oral view of specimen IM052

4, 5, 12. Sc elements (sample KH1)

6. Lateral view of specimen IM054

7. Lateral view of specimen IM055

12. Lateral view of specimen IM058

8–9. Oral and lateral views of Sa element IM056. (Sample KH1)

10. Lateral view of Pb element IM060. (Sample KK1)

11. Lateral view of Pb element IM057 (Sample KH1)

13. Shark scale, specimen IM059 (Sample KH1)

Plate III. All specimens from sample KH1. Scale bars represent 100 μm unless otherwise indicated (see page 147).


1, 2. Oral and inner lateral views of specimen IM035

3, 4. Oral and inner lateral views of specimen IM036

5–7. Oral, outer lateral and basal views of specimen IM038

8–10. Oral, outer lateral and oral detail (showing pustulos ornament) views of specimen IM039

11–13. Oral, inner lateral and basal views of specimen IM040

14, 15. Oral and inner lateral views of specimen IM041

16–20. Oral, inner lateral, aboral and two oral view details showing carinal ornament of specimen IM042

21, 22. Oral and lateral views of specimen IM037
2.2. Khao Krachieo limestone

A single conodont sample (KK1) was collected from the small limestone hill Khao Krachieo at N15°14.618′, E100°39.033′ about 12km NE of Khao Wang (Fig. 3). The temple Wat Khao Krachieo sits on this hill, and thinly bedded limestone with a strike and dip of 005/10W are exposed on a short slope below the temple. The
Plate II (caption on page 144).
Plate III (caption on page 144).
limestone here is dark grey in colour, and is not apparently as rich in fusulinoids as that of Khao Wang, yet cross sections of some Verbeekina tests were occasionally observed on the weathered surface in the field. Although not abundant, small brachiopod shells, often silicified, were found. One Pb conodont element was recovered. The Khao Krachieo limestone is interpreted, based on bedding structure, as stratigraphically younger than Khao Wang and Khao Khok.

2.3. Khao Khok limestone

Khao Khok is the southeastern portion of a large limestone massif about 10km in length: a large hill Khao Phu Chongkho makes up the northern portion of the massif. A 31.5kg conodont sample KH1 was collected together with abundant brachiopods from the large limestone hill Khao Khok about 7km east of Khao Krachieo (Fig. 3). The sampled locality is in the core of an anticline near the foot of the southeastern end of the hill at N15°18.945′, E100°38.587′. The sampled limestones are probably near the lowest stratigraphic level of the Tak Fa Formation exposed in the study area.

Brachiopods are abundant at this locality, yet species diversity is low, with only three species represented. Some small pectinoid, bivalves, crinoids and bryozoans are also rarely present, but no corals or fusulinoids were observed. The fossil beds comprise dark grey limestone, and thin sections made from the limestone reveal no foraminifers, unlike typically fusulinoid-rich limestone of other nearby hills.

3. Conodont fauna and age

The three samples from Khao Wang (KW4, KW1 and WTS2) did not yield any conodonts. Sample KK1 from Khao Krachieo, yielded only one Pb conodont element (Plate II,10) from 5 kilograms of limestone. This element is not age diagnostic.

The large (31.5kg) sample KH1 sample from Khao Khok however, yielded:

- **Pseudosweetognathus costatus** Wang Ritter and Clark 1987
- **Sweetognathus whitei** Tian, 1983, p. 344, pl. 77, fig. 11 (only)
- **Pseudosweetognathus costatus** Wang Ritter and Clark, 1987, pp. 105–151

**Original diagnosis (from Wang et al., 1987):** Known only from pectiniform element with free blade adenate, fixed carina on left side, no median ridge connecting transverse costule ridges, microstructure reticulate.

**Original Description (from Wang et al., 1987):** Pectiniform element with thin free blade, very slightly curved laterally in contrast with platform, and much higher anteriorly than posteriorly in lateral view. Anterior edge straight, forming an angle somewhat less than 90° with lower margin. Upper edge nearly straight in upper view, adenticate, and extended on left side of platform as a longitudinal ridge (fixed carina) for about one-third length of platform. Three to five relatively short transverse ridges on right side of platform connect perpendicularly with fixed carina, in anterior part of the platform (Type III...
carina). Transverse ridges extend to posterior tip and are widest and most complete at midpoint, becoming shorter and less complete posteriorly.

Upper surface of transverse ridges, free blade, and fixed carina covered by pentagonal and hexagonal microreticulations rather than pustulose micro-ornamentation as seen in species of *Sweetognathus*. Basal cavity occupies entire underside of platform and is excavated deeply. Outer side is expanded more widely than inner on some specimens. Lower edge of unit strongly arched. Posterior part of platform and free blade bend downwards. Anterior termination of blade is highest point of unit.

**Remarks:** This is a very distinctive genus and species, readily distinguishable from other similar forms. The specimens recovered from Khao Khok are mainly Pa elements which are essentially identical to those previously described from South China and possess the characteristic polygonal microreticulate ornament on the platform ridges and furrows (Plate I,6,7,16 and Plate II,4,5). We did not recover other elements of the apparatus except one Pb element tentatively assigned (Plate II,11). The transverse ridges on the Pa element platforms tend to bifurcate or become somewhat disrupted or irregular in the posterior part of the platform (e.g. Plate I,1,7,20 and 21).

### Sweetognathus subsymmetricus Wang Ritter and Clark 1987

**Plate III,1–22**

**Synonomy:**

- *Sweetognathus subsymmetricus* Wang et al., 1987, figs. 6.1–6.7.
- *Sweetognathus paraguizhouensis* Wang et al., 1987, figs. 6.14, 6.15.
- *Sweetognathus* sp. Beyers and Orchard, 1991, pl. 2, figs. 1, 2, 7.
- *Sweetognathus subsymmetricus* Wang, Ritter and Clark; Gullo and Kozur, 1992, fig. 6, H, I.
- *Sweetognathus iranicus* Kozur, Mostler et Rahimi-Yazd; Wang and Dong, 1991, pl. I, fig. 3.
- *Sweetognathus whitei* (Rhodes); Wang and Dong, 1991, pl. I, fig. 17.
- *Sweetognathus subsymmetricus* Wang, Ritter and Clark; Wang and Shen, 1994, pl. 47, figs. 1–6, 8.
- *Sweetognathus behnkeni* Kozur; Wang and Shen, 1994, pl. 47, fig. 7.
- *Sweetognathus sweeti* Kozur, Mostler and Rahimi-Yazd; Wang and Shen, 1994, pl. 47, figs. 9.
- *Sweetognathus paraguizhouensis* Wang, Ritter and Clark; Wang and Shen, 1994, pl. 48, figs. 5, 6.
- *Sweetognathus inornatus* Ritter; Wang and Shen, 1994, pl. 48, figs. 3, 4, 8.
- *Sweetognathus subsymmetricus* Wang, Ritter and Clark; Mei et al., 2002, p. 86, figs. 10.23, 10.24.

**Emended diagnosis (Mei et al., 2002):** A species of *Sweetognathus* with a Pa element possessing a discrete carina on which the anterior ridges reduce in width anteriorly, but distinctly more on one side than the other in the asymmetrical morphotype. In the wide morphotype the anterior one to three ridges are the widest.

![Fig. 5. Palaeogeographic reconstruction for the Early Permian (Kungurian) showing the geographic distribution of biogeographically important conodonts and conodont provinces. T = Tarim Block, S = Sibumasu Terrane, WB = West Burma Block, SI = Simao Block. After Metcalfe, 2006; Mei et al., 2002.](image-url)
and the following ridges reduce gradually in width posteriorly.

**Remarks:** *Sweetognathus subsymmetricus* can be differentiated from *S. guizhouensis* by the latter normally having the second anteriormost ridge as widest in the asymmetrical morphotype. The population of *S. subsymmetricus* reported here includes near symmetrical forms that resemble *Sweetognathus whitei* (e.g., Plate III, 3, 11) and forms that have a “rhomboid” carina similar to early forms of *S. subsymmetricus* reported elsewhere. This population thus represents an early development of *S. subsymmetricus* (post *S. whitei*).

5. Palaeobiogeography

Provincialism of Permian conodonts has been established over the last decade with three latitudinally controlled provinces recognised, a southern peri-Gondwana Cool Water Province, an Equatorial Warm Water Province, and a North Cool Water Province, and the presence of *Sweetognathus whitei* (e.g., Plate III, 3, 11) and forms that have a “rhomboid” carina similar to early forms of *S. subsymmetricus* reported elsewhere. This population thus represents an early development of *S. subsymmetricus* (post *S. whitei*).

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6. Conclusions

Kungurian conodonts occur in the Saraburi Limestone Group of Thailand.

The co-occurrence of *Sweetognathus subsymmetricus* and *Pseudosweetognathus costatus* from the limestone hill Khao Khok of the Tak Fa Formation of the Saraburi Limestone Group, Central Thailand indicate a lower Kungurian age.

These conodonts represent the Equatorial Warm Water Province, and the presence of *Pseudosweetognathus costatus* on the Indochina terrane indicates close geographic proximity between South China and Indochina in the Kungurian.

Palaeogeographic reconstructions that place South China and Indochina in close proximity but isolated from other continental masses in the Kungurian are supported by the findings of this paper.

References


