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THE PERMO-CARBONIFEROUS FACIES DEVELOPMENT IN THAILAND: A PLATE-TECTONIC DISCUSSION

Wladyslaw Altermann
(Institut für Angewandte Geologie, Freie Universität Berlin, Wichernstr. 16, D-1000 Berlin 33, FR Germany)

ABSTRACT

The Permo-Carboniferous sedimentary facies development in Thailand reflects the late Variscan orogeny in SE Asia.

During the Carboniferous and Permian, a N-S trending trough separated the "Shan Thai Craton" and the "Indosinia Craton". In this pelagic basin, deposition of ribbon cherts continued from pre-Asselian to Kubergandian. In Lower Permian, carbonatic and tuffitic turbidites were transported from the neighbouring platforms into the basin.

The Middle Permian flysch sedimentation resulted from a strong orogenic activity. The basin was E-vergent, isoclinally folded and overthrusted. Parts of the basin are metamorphosed into the greenschist facies.

In the eastern marginal parts Kubergandina to Midian molasse was deposited from the new rising fold belt.

The intensity of folding of the molasse decreases towards the east or the younger strata.

The total width of the basin was probably not greater than 200 km. The pelagic sediments, flysch and molasse represent a thick pile of a coarsening-upwards sequence, typical of subduction related sutures. Folding affected a marginal marine basin and was caused by a westward directed subduction (A-subduction) under the volcanic arc.

West of the arc, pebbly mudstones were laid down on the trench slope or the continental margin of Paleoeurasia. The deposition of these mixtites continued through the Carboniferous to Lower Permian and came to an end contemporary with the relative uplift of the "Shan Thai Craton" and the onset of the A-subduction under the Petchabun marginal basin. The Benioff-subduction must have been located west of the depositional area of the pebbly mudstones and directed towards the east.

INTRODUCTION

In the recent literature two main scientific hypotheses on the geological evolution

of SE Asia can be distinguished.

According to the first theory, parts of Burma, Thailand, Malaysia and Sumatra "Shan Thai Craton", drifted away most probably from NW Australian, part of Gondwanaland in the Upper Paleozoic.[1] After crossing the Tethys Ocean this sub-continent collided with Cathaysia or Eurasia (Indosinia) in the Triassic-Jurassic. The main arguments in support of this theory are:

i. Angular unconformity between the lower Upper Permian and Triassic and unconformity between the Scythian and Carnian.

ii. "Flysch-like" sediments of Anisian-Ladinian age in north Thailand (Hong Hoi Formation).

iii. Upper Paleozoic "tillites" (Phuket and Singha Formations) which give evidence for the Permian Gondwana glaciation.

The second theory denies the Late Paleozoic Gondwana provenance of mainland SE Asia. According to this theory, SE Asia was formed during Variscan orogeny, in the Devonian-Carboniferous and Permian times. The flysch character of the Hong Hoi Formation and the tillite origin of the Phuket and Singha pebbly mudstones are disputed. The main arguments in support of the Variscan orogeny are:

i. K/Ar metamorphosis ages of the Nan-Uttaradit "ophiolites" (N Thailand) of 344± 22 Ma.[2]

ii. The occurrence of folded, faulted and overthrusted Permian pelagic, flysch, and molasse sedimentary orogenic suite (Petchabun Fold Belt).

iii. Occurrence of Upper Paleozoic, Cathaysian, and Eurasian fossils all over SE Asia.

iv. Mainly unfolded and continental character of Triassic and younger sediments.

THE PETCHABUN FOLD BELT

The Petchabun Fold Belt of central Thailand is located east of the Nan-Uttaradit collision suture of the "Shan Thai Craton" and the "Indosinia Craton". It consists of eastward folded and overthrusted Carboniferous and Permian carbonate, siliciclastic and volcanoclastic sediments and has been interpreted as the eastern external zone of a huge Variscan fold belt.[2]

Wielchowsky and Young[3] devided the Petchabun Fold and Thrust Belt into the Khao Khwang Carbonate Platform in the west, the Nam Duk Pelagic Basin east of the Khao Khwang Platform and the Pha Nok Khao Platform, located east of the Nam Duk Basin.

The Devono-Carboniferous Nan-Uttaradit suture most probably marks a pre-Permian orogeny, formed at a continental edge or by an arc-continent collision. The suture does not contain MOR-basalts but high pressure-low temperature metamorphic, glaucophane-bearing schists typical of subduction zones.[4] The occurrence of volcanic (mainly andesitic?) belts in this area suggests the existence of a subduction zone from Siluro-Devonian to the end of the Paleozoic or even Triassic.[1]

The Shan Thai orogenic realm was widely covered by mainly shallow marine car-

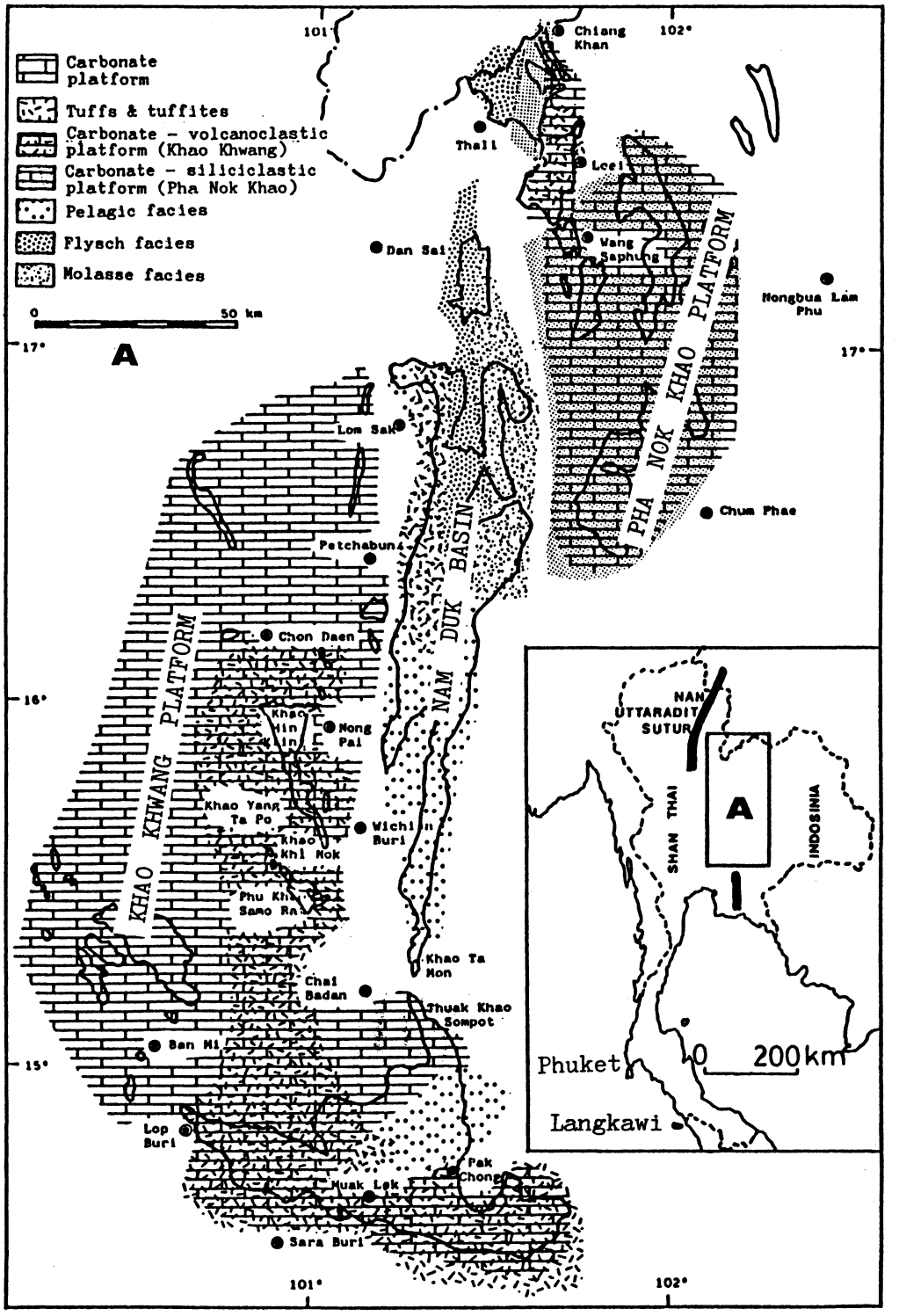

Fig. 1 Non-restored facies distribution in the Petchabun Fold and Thrust Belt (Upper Carboniferous to Midian)

bonates during the Middle Carboniferous to Upper Permian. All over west Thailand and the Malay Peninsula, gently folded platform carbonates, not younger than lower Upper Permian, are widespread. They are clearly post-orogenic sediments. The eastern edge of this Carboniferous to Permian realm is represented by the Khao Khwang Platform. Limestone sedimentation was dominant here, but tuffites in the Lower Permian, and rare psammitic and pelitic siliciclastic sedimentation also occurred. This siliciclastic influx is more frequent in the southern part of the platform. In its northern parts the siliciclastics are often in red-bed facies and mainly Visean and Middle Permian. Fontaine et al.[5] described upper Tournaisian to Visean and Bashkirian rocks of shallow marine facies with periods of emergence in the Visean. These strata are followed by Moscovian to Upper Carboniferous limestones of inter- to sub-tidal environment. In the Upper Carboniferous also keratophyric tuffites were deposited on the Khao Khwang Platform.

For the Early Permian a wide carbonate platform (ramp) has been traced all over the Khao Khwang Platform. During Asselian, Sakmarian and Yahtashian reef buildups, patch reefs and associated facies belts existed on this ramp.

The Yahtashian appears often as conglomerate facies. The age is based on foraminifers within the clasts. The conglomerates, interpreted as intraformational breccias and transgressive conglomerates are interbedded with red siliciclastic psammites and pelites.

Also the onset of Bolorian on the Khao Khwang Platform seems to be marked by a transgression. The sediments often start with conglomerates and sandstones and pass into thin bedded limestones. The Murgabian is of widespread coral patch reefs.

The few Midian outcrops on the Khao Khwang Platform consist of red and gray, fossil rich, sparritic limestones and gray coral boundstones which evidence platform interior environment.

The volcanic activity in the Lower Permian has no oceanic character. The volcanism was limited to structural highs, which were surrounded by shallow marine platforms. Continental fractionation patterns for the keratophyres and quartzkeratophyres have been demonstrated and similarities to an island arc development have been suggested.[6]

The E-W extension of the N-S trending, ?Upper Carboniferous to Middle Permian Nam Duk Basin was probably not greater than 100 or 200km.[3] This assumption is supported by the lack of oceanic crust under the radiolarites and shales and by the occurrence of carbonate- and keratophyric tuffite- turbidites with the pelagic sediments. The thickness of the sediments of $2\,000 \pm 1\,000$m and the width of the non- restored E-W extension of the the Petchabun Fold and Thrust Belt of 40 to 50km also support this calculation.

According to Winkel,[7] the strongest activity of the allodapic sedimentation was in the Middle Permian. In the upper Middle Permian the flysch sedimentation started, marking a strong convergent and uplift movement of the basin floor. This E-W directed tectonic activity led to and E-vergent, isoclinal folding of the basin.

In the eastern marginal part of the basin, Kubergandian to Midian molasse sediments were deposited as a result of the new rising mountain belt. The eastward prograd-

ing folding front affected in a less spectacular manner also the molasse sediments. The intensity of the folding in the molasse decreased toward the east and toward the younger strata. In the Midian carbonate sedimentation become dominant in the molasse.

The Pha Nok Khao Platform does not show any effects of strong tectonic activity.

On the Pha Nok Khao Platform, in Loei Province, the lowermost Tournaisian starts with conglomerates which are probably conformably overlying Devonian sandstones and shales. The Visean, Serpukhovian and Bashkirian in this region are represented by shales, limestones, and interbedded thin cherts. A sub-reefal paleoenvironment is suggested by Fontaine and Ingavat.[8] Moscovian is not reported from this area.

The Lower Permian of the Pha Nok Khao Platform exhibits siliciclastic and carbonate sediments. Asselian, Sakmarian and Yahtashian marginal marine and platform deposits have been already described by Wielchowsky and Young.[3]

The sedimentation changes in the Bolorian-Kubergandian from predominantly carbonate to siliciclastic. The environment is not much different from the one described from the same area for the Lower Permian.

On the Pha Nok Khao Platform no Midian was found.

At Thai-Laotian border the flysch is overthrusted on the marginal marine strata of the eastern platform. Overthrusting on a large scale was observed by Winkel,[7] Wielchowsky and Young[3] and was strongly implied by Helmcke and others[9] on the basis of illite crystallinity and vitrinite reflectance measurements. Overthrusting is also indicated by the outcrops along Huai Nam Lao (east of Petchabun), where the low grade metamorphosed, pelagic facies is overthrusted on the molasse sediments and the flysch is missing.

It seems possible, that the whole sequence of the pelagic, flysch and molasse sediments has been tectonically transported from the west to its present position.

The deformation style of the Petchabun Fold and Thrust Belt can be listed as follows:

i. ? Pre-Asselian, metamorphosed to a greenschist facies. The suitable sediments are phyllitized. Rocks are folded to isoclinal folds with steeply dipping B-axes and show two well-developed cleavage directions.

ii. Lower and Middle Permian pelagic and flysch strata, low grade-subgreenschist facies metamorphosed, are single act folded into E-vergent, isoclinal folds. Slaty cleavage is well developed. Kink bands are inclined towards the west. The strata are overthrusted.

iii. Kubergandian to Midian molasse strata are folded to mainly upright and tight folds. Some folds are slightly inclined towards the west. Cleavage and kink bands are generally not developed. Steep faults are frequent.

The sedimentary sequence of pelagic, flysch, and the molasse strata represents a thick pile of coarsening-upwards sediments typical of subduction related sutures. The E-vergent folds prove that the crustal shortening (subduction) was westwardly directed. This activity continued into the Upper Permian. The youngest deformed strata are Midian.

The Midian is followed by the Triassic (Carnian-Norian) with an angular uncon-

formity. The Mesozoic starts with andesitic pillow lavas and local basal conglomerates containig Asselian pebbles. These sediments and volcanics are conformably followed by red beds for nearly the entire Mesozoic.

In some places the Paleozoic is overthrusted onto the Mesozoic.

The conclusion, that the Nam Duk Basin is of a marginal sea character (back-arc basin?), is supported by the facts listed above. This marginal basin was closed by a westward dipping subduction. Because the main continental mass was located to the east ("Indosinia Craton") and the volcanic arc was in the west ("Shan Thai Craton"), the westward subduction can only be represented by an A-subduction. The Benioff zone and B-subduction had to be directed towards the east and had to be located west of the volcanic belts.[2]

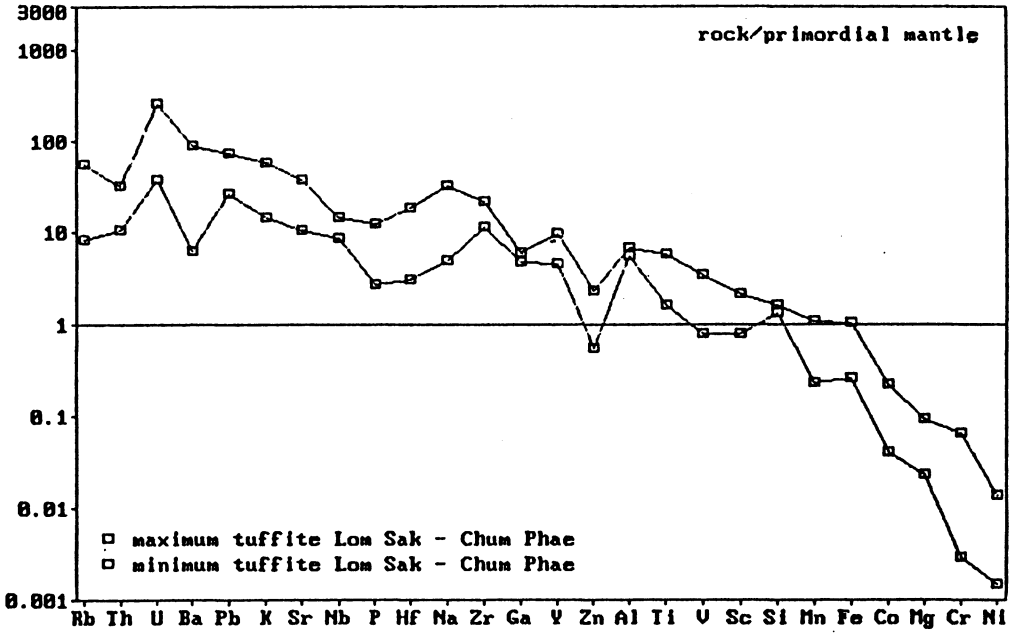

Fig. 2 Rock/primordial mantle diagram (Schermerhorn, pers. comm.) of the tuffites from the Lom Sak-Chum Phae Highway

The enrichment of incompatible elements suggests continental input.

THE PEBBLY MUDSTONES

The Phuket Group and the Singha Formation are part of the SE Asian pebbly mudstone belt, stretching from southern Tibet to Sumatra and marking the western edge of the "Shan Thai Craton".

Mitchell and others divided the Phuket Group into the Lower Formation and the Upper Formation consist of eight different sedimentary facies.[10]

In their facies D (pebbly mudstones), these authors found rugose corals and the trilobite *Cytoymbole (Waribole) perlisensis* and estimated this fauna to be Late Devonian.

Stauffer[11] and Bunopas and Vella[12] are the main advocates of the theory that the

"Shan-Thai Microcontinent" rifted away from Gondwana (most probably from northwestern Australia) in Carboniferous times and collided with Indosinia in Late Triassic times and caused the Indosinian orogeny. The rifting occurred with a clockwise rotation of more than 180° which became more rapid with time. Of course with this theory also a puzzling of paleomagnetic data began.

McElhinny and others[13] published paleomagnetic results from Malay Peninsula, which showed that this part of SE Asia was positioned at 15° N during the Paleozoic.

The results by Bunopas gave a Carboniferous position of the "Shan Thai Craton" as 13° S and for the Permian a paleolatitude of 19° S.[1]

The following facies types could be distinguished during authors' fieldwork in Thailand and Malaysia:

Lower Formation

1) Thin-bedded or laminated mudstones.
2) Thin-bedded or laminated siltstones and sandstones.
3) Thin-bedded mudstones to sandstones with scattered pebbles.
4) Structureless pebbly mudstones to pebbly sandstones.
5) Conglomeratic layers.
6) Sharp based, graded sandstones.
7) Slumped units.

Upper Formation

8) Bryozoan bed.
9) Thick-bedded sandstones and shales.

These observations correspond with the description given by Mitchell and others[10] and the interpretation as of a continental margin deposits is identical.

As for the paleogeography of these deposits, according to Helmcke,[2] the main tectonic activity in SE Asia subsided during the Middle to lowermost Upper Permian. If during the deposition of the pebbly mudstones the "Shan Thai Craton" was closely connected with Paleoeurasia, then the pebbly mudstones must have been deposited on the former southern (present western) slope of this continent.

Furthermore, we can speculate that at the Devonian-Carboniferous boundary, the tectonic activity (Nan-Uttaradit "ophiolites") caused the beginning of the pebbly mudstone sedimentation. Later, with the folding of the Petchabun Marginal Basin between the "Shan Thai Craton" and mainland Paleoeurasia ("Indosinia"), the depositional area of the pebbly mudstones was up-lifted. The sedimentation turned to shallow marine sandstones and later to limestones. Such an evolution could be caused by eastward subduction which took place somewhere in the present west of these continental slope deposits (comp. Helmcke[2]).

Models explaining the interaction of Benioff and Ampferer subduction zones have been widely introduced in the last decade. Most of them deal with plate convergence rates and the gradient of inclination of the plunging oceanic crust. Ziegler applied such a model to the European Variscides.[14] In this model an A-subduction is triggered by a high convergence rate when flat subduction angle is present in a B-zone. The back-arc rifting

occurs during a low convergence rate and a steep subduction angle in the B-zone. Such a model can be applied also to the Paleozoic of Thailand.

Of interest is the fact that if the model described above is correct, the direction of the subduction has not changed since Paleozoic to recent times, when we restore the Cenozoic clockwise rotation of SE Asia.

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