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On the geology of the Petchabun Fold-Belt (Central Thailand)–implications for the geodynamic evolution of Mainland S.E. Asia

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Abstract: Investigations in the Petchabun fold and thrust belt (Central Thailand) revealed a Permian succession indicative of a Late Variscan (Permian) orogeny. These data do not fit into the attractive plate-tectonic scenario of an Upper Triassic continent/continent-collision between the Indosinia Craton and the Shan-Thai Craton but require the model of an extensive Late Variscan orogen. Preliminary data from the region of Uttaradit (Northern Thailand) indicate that the main orogenic event, which is accompanied by low grade metamorphism, occurred already during the Upper Devonian–Lower Carboniferous in this region. The data prove that this orogen has a complicated and long lasting history. The information provides some constrains on the much discussed Gondwana connection of the Shan-Thai Craton.

INTRODUCTION

During the last decade it was widely accepted that the geodynamic evolution of the central parts of mainland Southeast Asia is governed by a continent/continent collision which occured during the Upper Triassic Indosinian orogeny. It was argued that this timing of the collision is documented for example in the Mesozoic sediments: a part of the Triassic Lampang Group was described as "flysch-like" or "flysch" while the Upper Triassic–? Lower Tertiary Khorat Group was interpreted as "red-molasse".

The two microcontinents involved in this collision–"Indosinia" in the present east, "Shan-Thai Craton" (Bunopas & Vella, 1978) in the present west–are regarded by many authors as displaced terranes. Many authors believe that at least the Shan-Thai Craton rifted off Gondwana (Ridd, 1971) and collided with the Indosinia Craton after closure of the Permo-Triassic "Palaeotethys" (or a branch of the "Palaeotethys"). Remnants of this oceanic realm were described from the regions of Nan and Uttaradit in northern Thailand and from the Bentong–Raub area in Malaysia.

Recent investigations (Helmcke & Kraikhong, 1982; Helmcke & Lindenberg, 1983) in the Petchabun fold and thrust belt revealed a Permian succession indicative of a Late Variscan (Permian) orogeny (Wielchowsky & Young, 1983). These new field-data from central Thailand do not fit into the attractive plate-tectonic scenario of an Upper Triassic continent/continent-collision but require a new model: the model of an extensive Late Variscan orogen which covers most of central mainland Southeast Asia (Helmcke, 1983).

This model differs from the as yet widely accepted view not only in the timing of the orogenic events but it questions also the existence of a former real huge oceanic

realm (the Permo-Triassic "Palaeotethys" or a branch of the "Palaeotethys") within the defines of the mentioned regions of Thailand and Malaysia in favour of a different setting (a different scenario was already described for example by Tan & Khoo, 1981). It questions also a Gondwana connection of the Shan-Thai Craton at any point of time during the Upper Palaeozoic (this does not necessarily exclude a Gondwana connection during the Lower Palaeozoic; see Burrett & Stait (1984).

EVOLUTION OF THE PETCHABUN FOLD AND THRUST BELT

The geology of the Petchabun fold and thrust belt (Wielchowsky & Young, 1983) which is situated east of the southern, not exposed continuation of the "Nan-Uttaradit-Suture," can be best studied in the excellent outcrops along the Lom Sak–Chum Phae highway in Petchabun and Chaiyaphum Provinces of Central Thailand. Separated by zones exposing strata of the Mesozoic Khorat Group, this section shows in three areas W–E sections across N–S trending Palaeozoic strata (Chonglakmani & Sattayarak, 1978) which are intensively deformed.

The stratigraphy and facies evolution of this region is summarized Table 1 which is based mainly on Helmcke & Kraikhong (1982), Winkel *et al.* (1983), Altermann *et al.* (1983), and Wielchowsky & Young, (1983). The stratigraphic position of all Palaeozoic units is based on fossil-identifications (courtesy R. Ingavat, DMR).

Table 1 shows that this succession displays all stages of an ongoing orogeny: it covers the pre-orogenic stage, the flysch stage, the molasse stage, the stage of post-orogenic uplift and erosion, and the stage of post orogenic volcanism and sedimentation. The onset of flysch sedimentation is interpreted as an information about uplift in more internal zones of the orogen and may indicate the onset of contractional tectonics in the Petchabun fold and thrust belt (Helmcke & Lindenberg, 1983; Wielchowsky & Young, 1983). The youngest still deformed strata which are typical molasse sediments are interpreted as an indication of the cessation of the contractional deformation.

This succession is typical for an external zone of an orogen. This is confirmed by the style of deformation which is also typical for an external zone: while the sequences comprised of the "pelagic"-type and the flysch are strongly deformed and display cleavage in suitable rock-types the molasse strata are less deformed and do not show cleavage. These field-data are confirmed by the results of investigation on the illite-crystallinity and coalification measurements (Chonglakmani *et al.*, in preparation).

The geometry of the folds and thrusts (vergent towards E) in the strongly deformed "pelagic" strata and the flysch indicate that the more internal zones of the orogen must be located farther to the west (West of Chiang Mai; Helmcke, 1983). This is confirmed by the geology of the outcrops farther to the east: west of Chum Phae only slightly deformed Permian strata (Wielchowsky & Young, 1983) are exposed which indicate the foreland region. Farther to the north (best exposed along the Chiang Khan–Pak Chom highway which follows the banks of the Mekong River) even the deformed basement of this foreland-massif (the main folding occurred in this region approx. at the Devonian/Carboniferous-boundary, Altermann *et al.*, 1983) is exposed.

TABLE 1

THE MAIN UNITS FOUND IN THE PETCHABUN FOLD AND THRUST BELT (OUTCROPS ALONG THE LOM SAK—CHUM PHAE HIGHWAY KM 16–KM 42.2).

Age	Description	Interpretation
Carnian/Norian and younger	Sediments of the lower formations of the Khorat Group (Huai Hin Lat and Nam Pong Formations)	Post-orogenic platform type sediments
	? Unconformity	
	Volcanics (Pho Hai Volcanics), mainly andesitic	subsequent volcanism, mainly calc-alcaline
	Angular unconformity	erosional stage after isostatic uplift
Murgabian-Midian (foraminifera in limestones)	Clastic sequence with intercalations of autochthonous limestones in the upper part of the sequence. This very thick sequence was deposited rapidly in a subsiding basin which became more and more shallow	typical molasse succession, final stages of orogeny
Middle Permian (Agathiceras sp.)	Clastic sequence which shows the typical characteristics of the BOUMA-cycle and was deposited by turbidity currents. This sequence again is very thick	typical flysch succession, onset of flysch sedimentation marks the beginning of orogenic activity in more internal zones of the orogen
? Upper Carboniferous, Lower Permian–Kubergandian and possibly lower part of Murgabian (foraminifera in allodapic limestones prove Asselian, Sakmarian, Bolorian, and Kubergandian to Murgabian)	Shales (grey to greenish), banded cherts (dark grey to whitish), allodapic limestones deposited by turbidity currents, volcano-clastic sediments	typical pre-flysch succession, "pelagic"-type, preorogenic (geosynclinal) stage

The geological situation found in the Petchabun fold and thrust belt can be explained in plate-tectonic terms in the following manner: the collision between the Shan-Thai Craton and the Indosinia Craton must have happened at the latest during the Middle Permian since the uppermost Middle Permian is developed as molasse.

This leads to the following conclusions:

—the main contractional deformation in the more internal zone towards west should even be older (Helmcke & Lindenberg, 1983);

—the Mesozoic strata in this region must have been deposited on continental crust; younger deformation in this region must be intracontinental and therefore of minor importance.

EVOLUTION OF THE LAMPANG AND UTTARADIT AREAS

In the regions of Lampang and Uttaradit it can be demonstrated that the Triassic Lampang Group was sedimented on continental crust and that this sequence does neither include "pelagic" sediments nor real flysch (admittedly a thick member of the Lampang Group–the Hong Hoi Formation–may look "flysch-like" but a careful examination will show that this is not a real flysch–therefore the expression "flysch-like" should be used very carefully or should be avoided).

Since the sedimentological investigation of these strata is not finished yet only some brief remarks shall be given here: north of Lampang the "flysch-like" clastics follow without any break in sedimentation on top of limestones crowded by oncolites which indicate very shallow water conditions. Therefore these clastics cannot be transported by turbidites. North of Phrae the lower part of these "flysch-like" clastics is characterized by changes from marine to non-marine conditions (Macdonald, 1978). Map sheet "Uttaradit" 1:250.000 (Piyasin, 1974) shows clearly that these "flysch-like" clastics overlap with a basal unconformity complex structures build up by Palaeozoic strata.

Therefore these strata cannot be interpreted as a flysch but they are molasse strata which were sedimented in intramontaneous basins of the Variscan orogen. Their deformation during the Upper Triassic must be described as an "activation (Diwa)" (Staritskiy *et al.*, 1973), i.e., widespread intensive folded-block movements which may reach geosynclinal proportions and occur on a rigid basement with a continental crust within regions that have ended their geosynclinal development (regions of completed folding and platforms) (Staritskiy *et al.*, 1973).

In the Palaeozoic sequence of the Uttaradit region low grade metamorphic rocks occur. These metamorphic rocks can be found for example near the Sirikit Reservoir, that means in the same region in which the basic and ultrabasic rocks of the "Nan-Uttaradit-Suture" outcrop. Thanasuthipitak (1978) described these metamorphic rocks as "Silurian–Devonian". According to his data these metamorphics are unconformably overlain by sedimentary sequences of Carboniferous age, which can be divided into volcanogenic sediments, flysch-type sediments, and molasse-type sediments.

This information may turn out to be of great importance. This metamorphic event is the only one found in this region until now and it is likely that this event accompanies the "obduction" of the "ophiolites"–which would be in this case quite old (Hahn, in print). The author's preliminary studies on the "ophiolites" (Damm *et al.*, in preparation) point in this direction. The first K/Ar ages (courtesy of D. Müller-Sohnius and P. Horn, Min. Petr. Inst. Univ. Munich) we obtained from a metamorphosed ultrabasic rock sample from this region indicates the interval Upper Devonian–Lower Carboniferous. We interpret this result as the age of the metamorphic event respectively as the age of the "uplift". This would indicate that the main orogenic event (closure of the "oceanic" realm) has to be dated in the Uttaradit region as Upper Devonian–Lower Carboniferous. This is older than that based on our

data from the Petchabun region and that we originally suggested (Helmcke & Lindenberg, 1983; Hahn, in print).

The fact that the main orogenic event, accompanied by low grade metamorphism, occurred in the Uttaradit region already during the Upper Devonian–Lower Carboniferous is compatible with important fossil-finds in a region north of Uttaradit (Hahn, in print) and also with the finding of Lower Carboniferous fossils in the Chon Daen area (Fontaine *et al.*, 1983; Chonglakmani *et al.*, 1983).

It indicates that the orogenic history of the huge Variscan orogen which comprises the central parts of mainland Southeast Asia is much more complicated and lasted longer than originally proposed (Helmcke & Lindenberg, 1983; Helmcke, 1983). Such a long standing orogenic history is also found in the European Variscides, where the Cadomian, the Caledonian, and the Variscan orogenies are (more or less) involved.

REGIONAL EXTENSION OF THE LATE VARISCAN OROGEN

In a first tentative approach I presented a highly speculative reconstruction of the whole Late Variscan orogen which comprises most of central mainland Southeast Asia (Helmcke, 1983). The preliminary results from the Uttaradit region will require one important change in the still speculative reconstruction. Now we know we can expect unmetamorphic fossiliferous sediments of Carboniferous age in a rather huge belt west of the Petchabun fold and thrust belt (Hahn, in print; Chonglakmani *et al.*, 1983) since low grade metamorphism happened earlier (Thanasuthipitak, 1978; this paper).

For the time being, it looks therefore more likely that the southern continuation of the Petchabun fold and thrust belt has to be searched for, east of the Malay Peninsula under the South China Sea. This is contrary to the speculation (Helmcke, 1983) that the Eastern Deformation Front of this Late Variscan orogen might be found within the defines of the peninsula. Most likely the eastern belt of the Malay Peninsula has to be regarded as the southern continuation of the zone to the west of the Petchabun fold and thrust belt.

CONCLUSIONS

In attempting to include the results from the Petchabun fold and thrust belt into a geodynamic scenario for mainland Southeast Asia a new tectonic model started to emerge. The model of an extensive Late Variscan orogen. The incorporation of data recently obtained in the Uttaradit region favours some corrections to the extension of this orogen and shows that the history of this orogen is much more complicated and lasted longer than originally thought.

Work during the past few years added some new information on the timing of the orogenic events (and this information should be considered when possible Gondwana connections of the Shan-Thai Craton are discussed since they contain some constraints) but I feel that it is not the time yet for definitive statements on the driving mechanisms which caused this orogen. Besides the much discussed model of displaced terranes

(Gondwana connection of the Shan-Thai craton) it might be advisable to encourage the search for and to test alternative models. Even for the European Variscan fold belt which is much more studied than mainland Southeast Asia, extremely diverging geodynamic models are still being discussed.

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