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On the stratigraphy of Ban Rai area, Changwat Uthai Thani : implication for tectonic history

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ABSTRACT : The (meta)sedimentary strata of Ban Rai area comprise five stratigraphic units: Cambro-Ordovician (meta)clastic rocks; Ordovician argillaceous limestone and calcareous clastic rocks; Silurian-Devonian chert and fine-graind (meta)clastic rocks; Carboniferous conglomerate; and Permian massive limestone.

The evolution of the area can be divided into five stages. The first stage (Cambro-Ordovician to Ordovician) is characterized by deposition in shallow marine environment. The second stage (Silurian - Devonian) is marked by deposition in deep-sea, back-arc environment. The third stage (Carboniferous to Permian) involved regional deformation and metamorphism, and deposition in fluviatile to shallow marine environment. The fourth stage (Triassic) is dominated by S-type granite magmatism with associated REE mineralization, and contact metamorphism. The fifth stage (Cretaceous to Tertiary) is characterized by NW-trending faulting with mineralized pegmatite.

INTRODUCTION

The study area of about 765 km^2, is located in Amphoe Ban Rai, Changwat Uthai Thani, about 220 km north of Bangkok. It is bounded by latitudes 15° 02' 19" and 15° 21' 55" N, and longitudes 99° 26' 49" and 99° 45' 00" E.

Geologic observation in this area was first made by Ingavat and others (1975) who discovered index fossils in Permian and Ordovician limestone strata. Bunopas (1980) described the regional stratigraphy, structure, and economic geology. Nakhapadungrat (1985) and Saengmanee (1990) studied granitic rocks and semidetailed geology. Geology students of Chulalongkorn University (1990) studied stratigraphy and structural geology at a scale of 1:25,000, and in 1991 also studied petrology of the rock samples subjected to metamorphism. The objectives of this paper are to describe the geology, particularly the detailed stratigraphy, and to discuss the environment of deposition and relationship to tectonic setting of the area.

GEOLOGY

Stratigraphy

The area are mainly underlain by metamorphic and sedimentary rocks with minor igneous rocks (Figs. 1 and 2). Five groups of rocks sequences are recognized:

1. Khao Phu Nam Sai-Ban Huai Plu Group (Cambro-Ordovician - Lower Ordovician) : The type section of this group is exposed in Ban Huai Plu and Khao Phu Nam Sai in the central part of the study area. The rocks include metamorphosed clastics with thickness of 500 to 1,000 m increasing towards the north. This group can be subdivided into two formations as follows :

Khao Phu Nam Sai Formation : This is the oldest formation of the area composing of brownish white, laminated to massive (up to 10-30 cm thick) quartzite. The formation is about 200 m thick.

Ban Huai Plu Formation : This formation (about 300-800 m thick) is conformable with the Khao Phu Nam Sai Formation. Two members are recognized. The lower member(100-200 m thick) is composed of micaceous quartzite and quartz schist. The upper member (200-600 m thick) consists mainly of phyllite, quartz-mica schist, and some folded mica schist.

The micaceous quartzite (10-30 cm thick) is pale green showing well-defined foliation. It is interbedded with greenish purple quartz-mica schist (up to 20 cm thick). The mica schist, in some places, grade to phyllite and phyllitic schist.

Rocks of the Khao Phu Nam Sai-Ban Huai Plu Group form a large anticline with some overturned folds in the central part of the study area. The axial plane is in a NW-SE direction with average dip varying from 10° to 75°. The rocks of this group show gradational and inter-fingering contact with rocks of the younger group.

The group is interpreted to be of Cambro-Ordovician age which is inferred equivalent to the Tarutao Group (Javanaphet, 1969) and the Pong Nam Ron Formation (Bunopas, 1981).

2. Khao Tam Yae Group (Upper-Middle Ordovician) : The rock sequence of this group is well-exposed all over the Khao Tam Yae showing cliff-like features. The thickness varies from 600 to 1,000 m, with thicker sequence towards the south. The age of this group can be assumed by paleontological evidence, including cephalopod nautiloid, graptolite (Ingavat and others, 1975), fauna of *Selkirkoceras* aff. *Yokusenense Kobayashi* indicating Middle Ordovician age, and *Osthaceras* sp. (Fig. 3). The Khao Tam Yae Group comprises two formations :

Khao Tam Yae Formation : The lower formation (400-800 m thick) consists mainly of carbonate rocks. This formation contains index fossils and serves as a marker bed of the area. The lower part (200-600 m thick) of this formation is argillaceous and massive limestone, and the upper part (200 m thick) is (meta)calcareous shale and some (meta) argillaceous limestone.

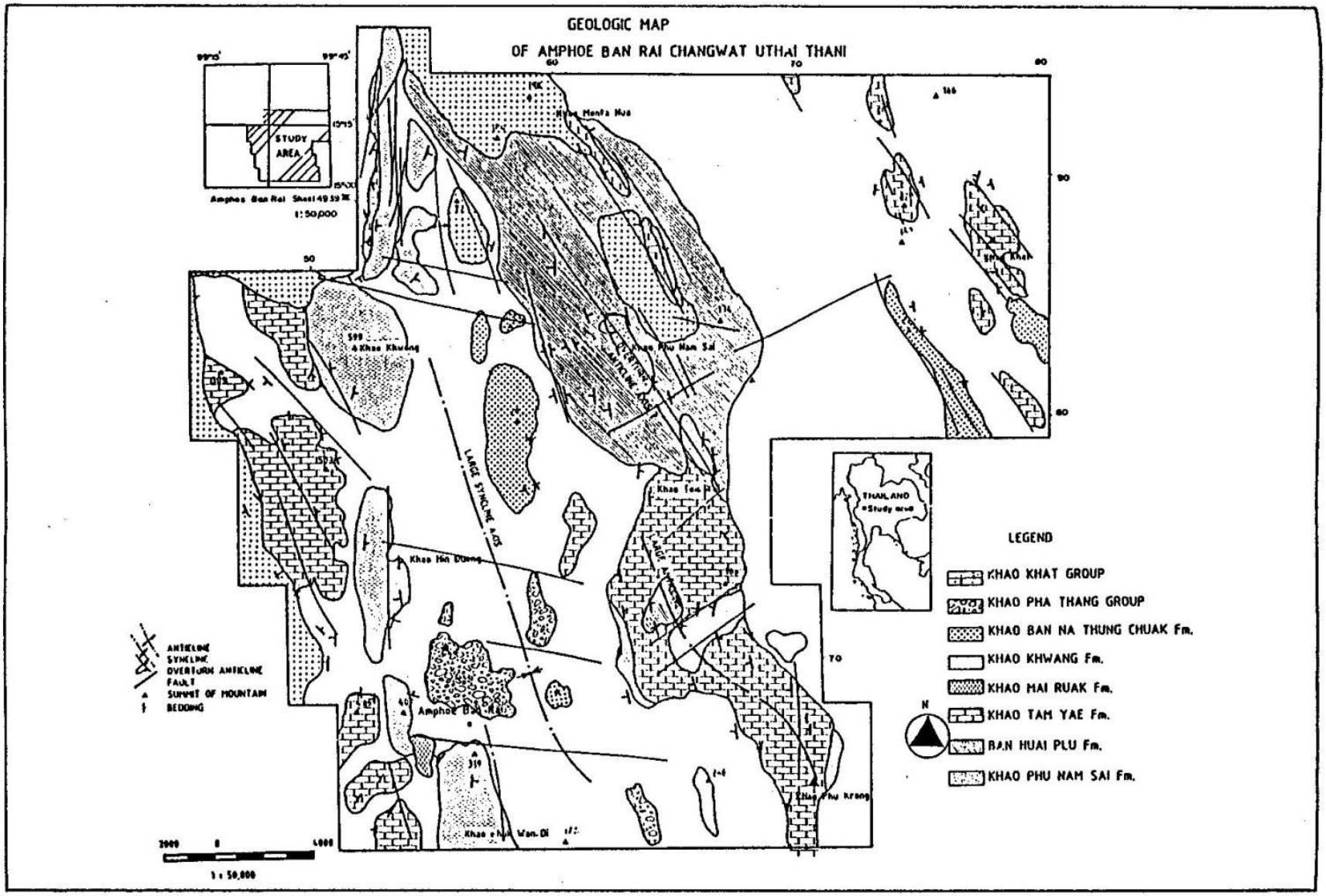

Figure 1 Generalized geologic map of the Ban Rai area.

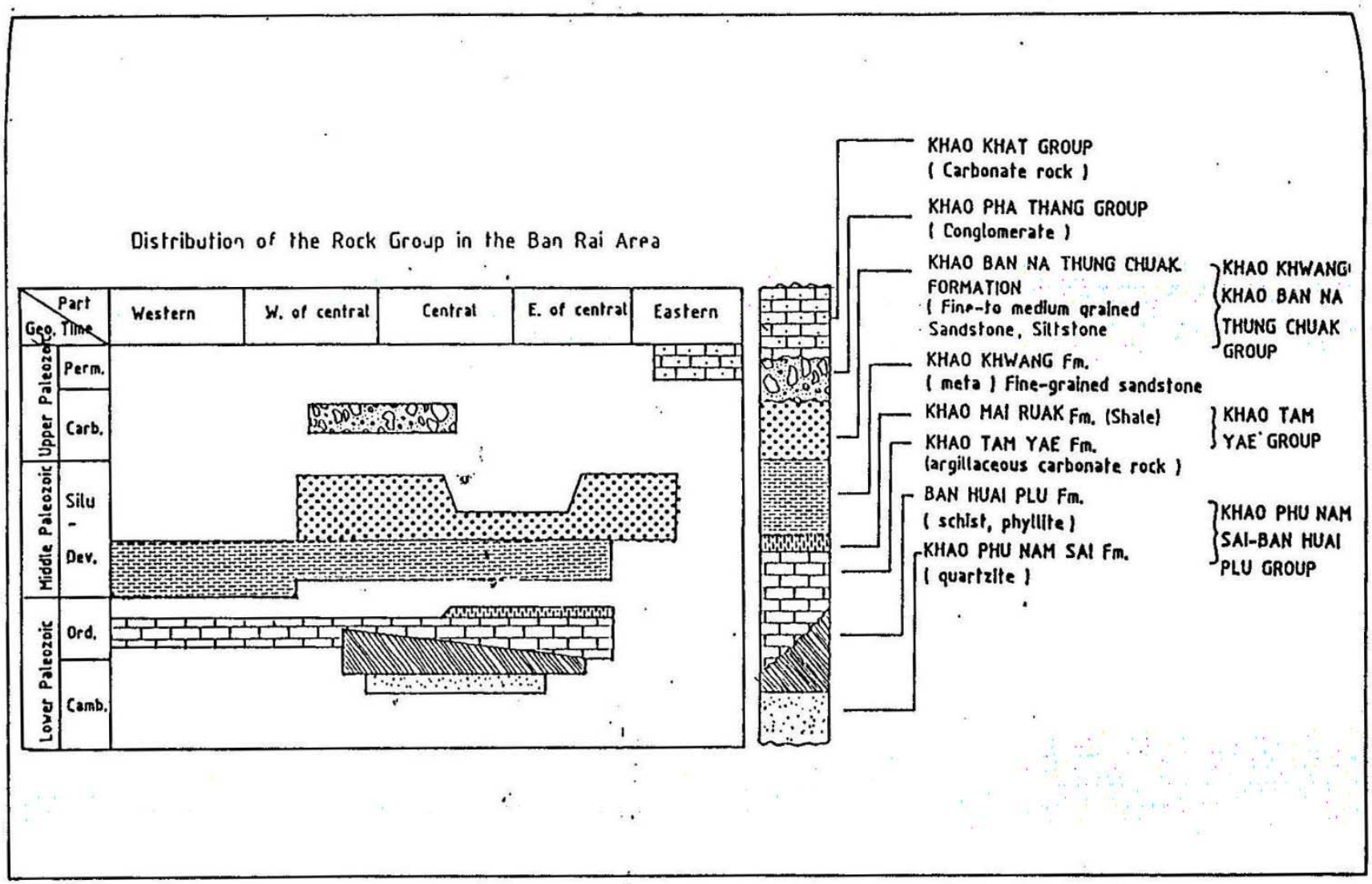

Figure 2 Distribution and stratigraphic column of the rock groups in the Ban Rai Area (Camb. = Cambrian, Ord. = Ordovician, Silu-Dev. = Silurian-Devonian, Carb. = Carboniferous ,Perm. = Permian).

The argillaceous limestone (3 to 4 cm thick band) of the lower part is bluish green consisting of alternating calcite-rich and clay-rich layers clearly indicated on weathered surface. Limestone bands show recrystallized texture whereas argillite bands exhibit slaty cleavage in the metamorphosed area (Fig. 4). The rocks were, in some places metamorphosed to calc-silicate marble and dark grey calc-silicate phyllite, showing well-defined schistosity. Grey calcareous shale beds (up to 2 m thick) are locally associated with argillaceous limestone. The massive limestone (up to 2 m thick bed) is grey to dark grey, always shows weathering effect by solution and appears as elephant skins on weathered surface which possibly suggest massive dolomitic origin. In several places, stromatolite and fossiliferous limestones are observed as lapies. The rocks of this formation in the western part of the area contain garnet, epidote, and diopside (Fig. 5) as a result of contact metamorphism.

Khao Mai Ruak Formation : The upper formation is about 200 m thick, exposed at the base of low-lying hills. It is composed mainly of interbedded calcareous shale and calcareous sandstone (5-10 cm thick), locally intercalated with argillaceous limestone. In the north central part of the area,this formation was subjected to dynamic metamorphism showing strong deformation texture, as indicated by well-developed cataclastic fabric. The rocks become dark grey to dark bluish grey calc-silicate phyllite. Under the microscope, they are defined as phyllonite (Fig. 6). Locally, the interbedded (meta)calcareous shale and calcareous sandstone show some disturbance by closely-spaced joints and minor folds.

Rocks of the Khao Tam Yae Group form parts of both flanks of a large syncline in the western and eastern parts of the area. Structural trend in this group is N-S to NW-SE direction. Average dip varies from 15° to 40°. The group forms a gradational contact with the older group and shows minor unconformity with the younger group.

3. Khao Khwang - Khao Ban Na Thung Chuak Group (Silurian-Devonian) : This group consists mostly of metaclastics, interbedded fine-grained sandstone and siltstone, of about 1,000 m thick. The apparent age can be assumed by stratigraphic position. They were subjected to subsequent low grade metamorphism. Two formations are recognized :

Khao Khwang Formation : The lower formation (about 600 m thick) comprises micaceous quartzite, metasiltstone, and phyllite in the lower part and massive quartzite, metasandstone, and (meta)siltstone-mudstone in the upper part.

The micaceous quartzite (5-20 cm thick bed) is pale green, invariably interbedded with phyllite and grey to dark brown metasiltstone (< 5 cm thick bed) and shows minor fracture. Light green phyllite (10-30 cm thick), interbedded with micaceous quartzite, shows less developed mica minerals and schistosity than those of the Cambro-Ordovician phyllite. The massive quartzite (up to 15 cm thick bed) is brownish grey, interbedded with dark brown (meta)mudstone and (meta)shale (5-10 cm thick bed). The latter shows well-developed fissility and minor folds.

Khao Ban Na Thung Chuak Formation : This upper formation is about 400 m thick. The lower part is composed of (meta)feldspathic sandstone, graywacke and (meta)siltstone. The upper part consists mainly of mudstone, argillite, graywacke, and limestone lens with lenticular chert.

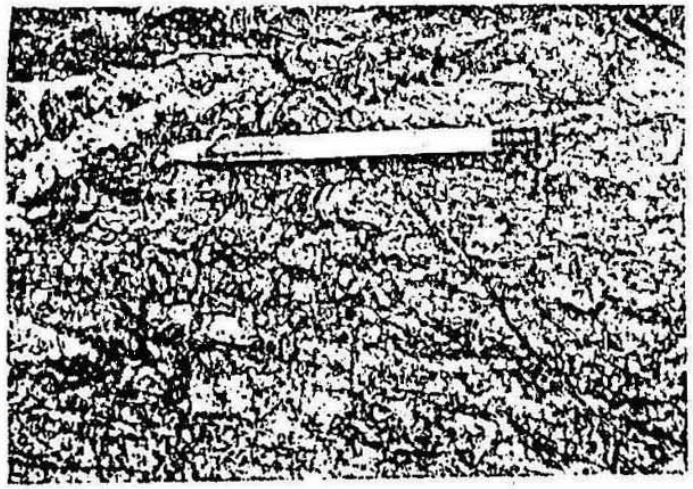

Figure 3 *Ostraceras* sp. (4x2 cm) at Khao Mai Ruak,grid 622701. They were first identified by Ingavat and others (1975), indicating Upper - Middle Ordovician Period.

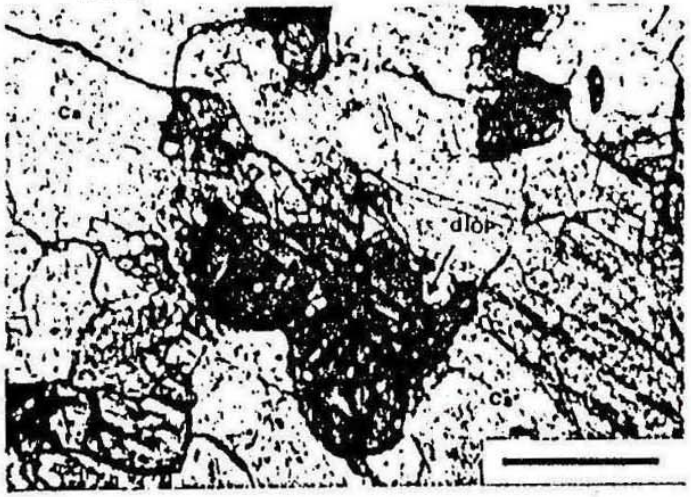

Figure 5 Photomicrograph of subhedral diopside(diop) which fill in the boundaries of recrystallized calcite (Ca) (Bar-scale = 0.23 mm, transmitted light, x-nicols).

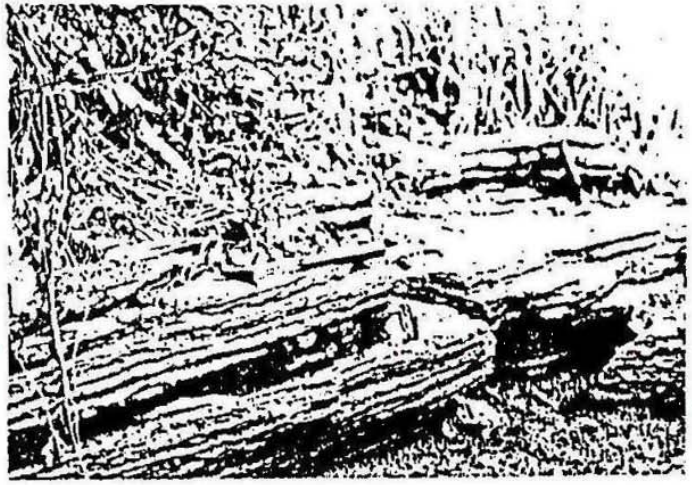

Figure 4 Natural outcrop exposure of argillaceous limestone at Huai Tam Yae (grid 645749) showing the well-developed slaty cleavage of the typical rock of Khao Tam Yae Formation.

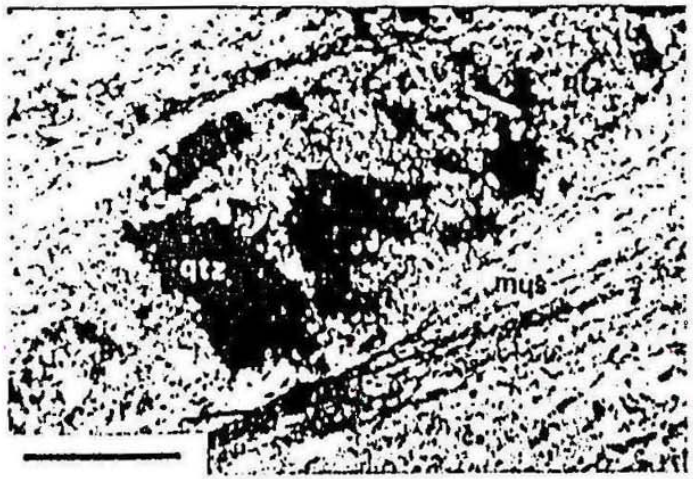

Figure 6 Photomicrograph of augen-like structure and distinctively crushed quartz (qtz) grains, and muscovite-like sheared cal cite (Ca), typical of the phyllonite (Bar-scale = 0.23 mm, transmitted light, x-nicols).

Rocks of the Khao Khwang - Khao Ban Na Thung Chuak Group form both flanks of a large syncline trending in a N-S direction with average dip varying from 15°-60°. In general, the group forms a minor unconformity with the older rocks and major unconformity with the younger ones.

4. Khao Pha Thang Group (Upper Carboniferous) : Type section of this group (up to 300 m thick) is exposed at Khao Pha Thang in the middle part of the area. Bunopas(1980) referred to this group as the Ban Rai Conglomerate of Carboniferous Period. Apparent age of this group can be assumed by its stratigraphic position. The rocks comprising the group are mainly reddish brown conglomerate and coarse-grained graywacke. They form the central part of a large syncline. In general, the group forms a major unconformity with the older rock and cannot be correlated with the younger ones.

5. Khao Khat Group (Upper-Middle Permian) : Physiographically, the rocks of this group (about 550 m thick) form steep slope and show cliff and karst topography. The apparent age of this group can be deduced from index fossil: Pseudofusilinid; *Neoschwa gerina* sp. and *Rugosa* sp. The group consists almost entirely of dark grey, impure, massive to well-bedded carbonate rock (up to 3 m bed). They were metamorphosed to marble in several places. Massive layers and closely-spaced joints are characteristic features. The general strike direction of the bedding is NNW-SSE, with average dip vary from 40° to 70°. The rocks of this group are equivalent to those of the Ratburi Group (Javanaphet, 1969) or the Saraburi Group (Bunopas, 1981).

Igneous Rocks

Igneous rocks in the study area comprise mainly felsic plutonic rocks and some minor volcanic rocks. Most of the plutonic rocks are granitoid of Triassic Period (Nakapadungrat, 1983; Charusiri, 1989), located at the western and the north central parts of the area. The volcanic rocks, exposed in the southern part of Khao Khat, are rhyolitic in composition, and were also given a Triassic age (Bunopas, 1980).

Structure

Regional structure of the area is a syncline with axis in a N-S direction. The width of both flanks of the syncline is about 20 km. Beddings on the western flank of the syncline dip 40° - 50° ESE. On the eastern flank, beddings dip 30° - 40° WSW. The syncline plunges, 5° - 10° south. A small overturned south-plunging anticline with high-angle dipping, developed to the east of the syncline. Both flanks of the anticline are inclined to the west. Fault and fracture lines from aerial-photo interpretation are observed from straight streams. The other evidence are fault breccia at a mesoscopic scale and cataclastic texture under the microscope. In the north of the area, N-S and NW-SE faults are quite distinct whereas in the south , NW-SE and NE-SW faults are dominant.

DISCUSSION ON TECTONIC AND PALEOENVIRONMENT

In terms of tectonic history, the area was part of the Shan-Thai microcontinent of Bunopas and Vella (1983) and was subjected to several tectonic events. The evolution of the area comprises five stages as described below.

The First Stage

During the first stage (Cambrian to Ordovician), namely the Early Paleotectonic stage (Bunopas and Vella, 1983), the area was located at the eastern margin of the Shan-Thai block, connected to Gondwana supercontinent (Bunopas, 1981) and had been in a relatively stable condi-tion of a passive margin. The Precambrian gneissic rocks were exposed in the northwestern part immediately outside the study area (Nakapadungrat, 1983). The intercalated metaclastics of the Khao Phu Nam Sai - Ban Huai Plu Group, regarded as the marine sediments of Cambrian to Ordovician age, deposited as continental shelf facies onto the Precambrian Shan-Thai block. The lower Paleozoic shallow marine sea might have transgressed over the Prepaleozoic continent, forming supratidal or deltaic to tidal flat environments.

The originally laminated sandstone in the lower part of the group is assumed to be derived from the exposed, high to intermediate relief, Precambrian basement (or Shan-Thai). The depositional environment of the area were tidal flat to intertidal as indicated by changing from arenaceous, well-sorted silicic clastic rocks to interbeds of micaceous clastic (quartzite) and argillaceous (phyllite) rocks in the upper part. Interfingering of non-carbonate and carbonate lithofacies of the Khao Tam Yae Group followed due to rising of sea level causing the low energy marine condition. The total landmass was submerged until carbonate were deposited. The sea of this stage probably was an open sea (transgression-estuarine). The land-derived sediments influx slightly decreased and diminished by the Ordovician, possibly due to the low relief of the Precambrian Shan-Thai. The facies change between carbonate and clastic units, might be strong, particularly in the southern part. This is presumably due to a deeper sea water condition of that area at the time.

During the Ordovician, the occurrence of nautiloid and stromatolite fossils, and the development of dolomitic and limestone beds indicate that the environment of deposition were more quiet and stable than during the Cambrian. The lower unit containing dominantly argillaceous limestone is conformable with the Cambrian. The deposition was under intertidal condition on the continental shelf. Fluctuation of sea level and changing of on-land weathering surface caused carbonate precipitation and supply of fine-grained terrigenous sediments to the submerged area, hence the alternation of argillites and carbonates. In the middle part, the intertidal to subtidal type of shallow marine environment is assumed. The thick massive and stromatolite limestones indicate quiet marine condition and lack of terrigenous sediments. The condition of shallow marine is suitable for extensive development of planar stromatolite. The shallow marine condition together with clear and warm water is appropriate for some marine animals such as crinoids to survive. Furthermore, characteristic fossils such as *Ostraceras* sp., graptolite, and nautiloid also indicate shallow marine environment. However, in the late stage of the middle part, lagoonal-type condition is favoured because of increasing salinity (or hypersaline sea water) as indicated by the occurrence of dolomitic limestone (Tucker, 1982). This might have been brought about by the appearance of some local barriers from tectonic development in the Late Ordovician. Shan-Thai was probably obducted as a result of subduction of Paleotethys oceanic slab underneath, creating closed-sea basin and hypersalinity condition in some local areas. In late Ordovician, intertidal type of the short period regression condition occurred, as

represented by the nonfossiliferous argillaceous and arenaceous clastics intercalated with argillaceous carbonate. This suggests that unstable condition occurred in late Ordovician slightly prior to the initiation of the second tectonic period. A schematic facies evolution of this stage is depicted in Figure 7.

The Second Stage

This stage covers the Silurian-Devonian Period (Middle Paleotectonic stage of Bunopas and Vella, 1983). It is characterized by a rapid rifting of Shan-Thai from Gondwana to the north, and a collision of Shan-Thai with paleotethys. Hercynian (or Caledonian) Orogeny, developed at this stage, caused west dipping subduction of paleotethys oceanic slab beneath Shan-Thai and produced a series of island system in a regional scale, with marine sediments at the continental margin of Shan-Thai craton.

In the area, volcanic activity had not been recorded and only the marine clastic sediments of the Khao Khwang - Khao Ban Na Thung Chuak Group represent this stage. The depositional basin was deeper than that of the Ordovician as evident by the occurrence of banded chert. They are regarded as marginal miogeosynclinal deposit that were laid down either in a back-arc basin or arc-trench gap. The thickly bedded chert possibly indicates that the basin was rapidly subsided. The back-arc basin is preferred due to the presence of rhyolitic and volcaniclastic rocks to the east of the area and the inferred Precambrian to the west. The former is regarded as volcanic-arc system, and the latter represents a stable cratonic landmass. In addition, and more importantly, the sequence of poorly-sorted sandstone (graywacke) intercalated with mudstone and chert with limestone lenses, and graded-bedding structures definitely indicate turbidite (or flysch-like) facies. The area under study might be far away from the volcanic arc as indicated by disappearance of volcanic by-products.

The interpretation of depositional conditions during this stage follows. During the early phase, the sediments were derived mostly from detrital fragments of the newly exposed landmass from the west since volcanic arcs were far away. Compression of the paleotethys oceanic slab probably caused a deep and unstable condition, therefore only the fine-grained sediments were deposited.

In a later phase, graywacke and dark-grey siltstone (collectively termed flysch) were preserved in the area. The condition was more severe and chert could not be preserved. The presence of graded-bedding structures in some parts indicates turbidity development along slopes when the velocity changes suddenly (Tucker, 1982), because of rapid subsidence of the basin and very unstable condition of the depositional area. The lack of fossils might indicate high suspension, muddy condition, and low oxygen environment. The lack of sedimentary structures such as ripple marks and mudcrack, and the dark colour of the siltstone suggest reducing environment. Subsequently, the basin were gradually uplifted, producing a rather calm condition suitable for chert and carbonate deposition. Figure 8 summarizes facies development during this stage.

The Third Stage

This is a Paleotectonic stage developed during Carboniferous to Permian. Separation of Shan-Thai from Gondwana took place because Gondwana rapidly rotated clockwise causing Australia to shift sharply southwards (Bunopas, 1981). The rift opened

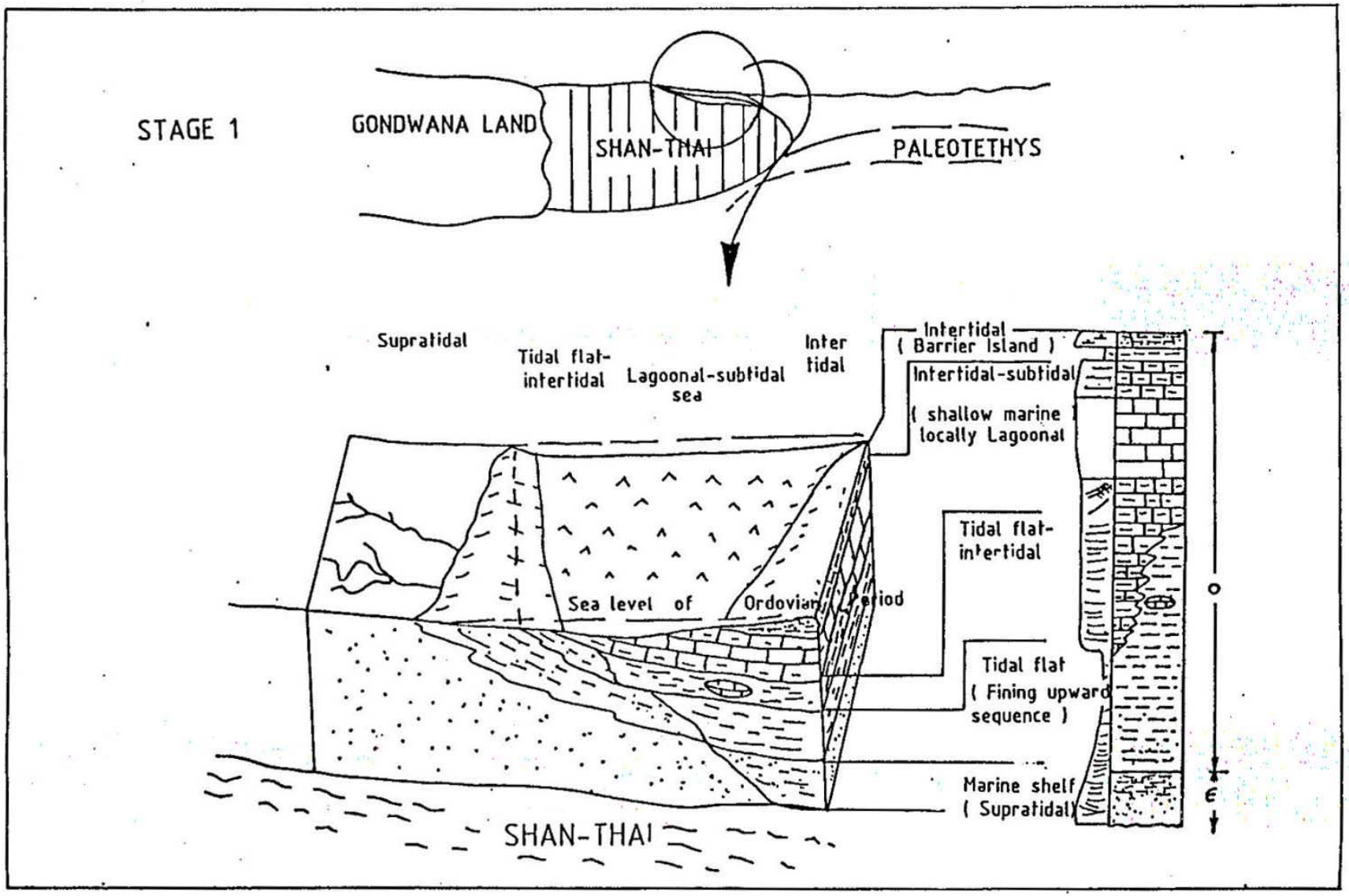

Figure 7 Schematic model of plate tectonic and environment of deposition of the First Stage (Cambrian to Ordovician).

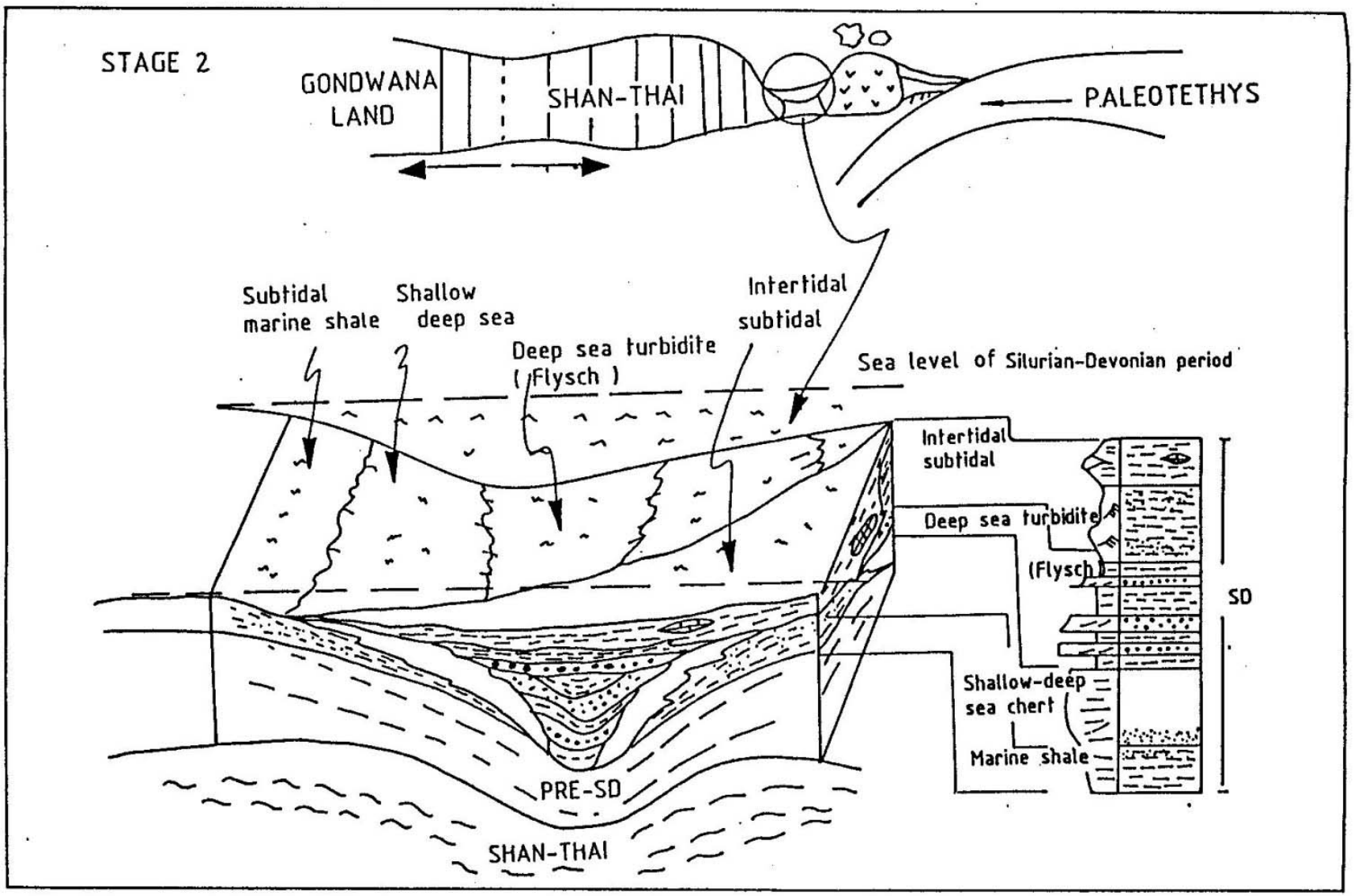

Figure 8 Schematic model of plate tectonic and environment of deposition of the Second Stage (Silurian to Devonian).

up a Mesozoic tethys (or Neotethys). Subsequently, the paleotethys closed along the consuming plate margin as a result of final subduction. A regional metamorphism, up to medium-grade greenschist facies (Imsamut, 1992) and deformation developed. Parts of the area were uplifted. In Late Carboniferous, deposits of non-marine clastic rocks (reddish brown conglomerate of the Khao Pha Thang Group) took place. Fining-upward sequence of red sediments indicates oxidizing condition prevailing in the alluvial fan environment. Sources of sediments were the Precambrian to Silurian-Devonian rocks since pheno-clasts are mainly quartz, feldspar and limestone fragments. However, in a regional scale, the environment of deposition in the Shan-Thai microcontinent is likely to be rift-margin condition (Bunopas, 1981).

During Permian, Shan-Thai moved to low latitude towards Indochina. As a result, the Neotethys became narrower and submersion of the land occurred. The environment of deposition of the area became shelf conti-nental margin. Lithological and paleontological data indicate that the condition of deposition might be deeper than that of the Ordovician, and this caused prolong deposition of marine carbonate shelf facies with intercalated shale. Fossils such as rugosa, crinoids, and fusulinids indicate shallow marine (neritic zone) and warm climate (Ingavat and others, 1975). It is interpreted that the area was a subtidal zone. Figure 9 summarizes facies development of this stage.

The Fourth Stage

The fourth stage is marked by the collision between Shan-Thai and Indochina during Triassic (Mesotectonic of Bunopas and Vella, 1983). In the study area, this condition is advocated by the widespread occurrence of S-type granite (Nakapadungrat, 1983). The igneous intrusion caused contact metamorphism (low grade hornblende-hornfels facies) of the surrounding rocks (Imsamut,1992). Skarn and tin, tungsten and REE mineralization in the area were probably formed during this period.

The Fifth Stage

This final stage (the Neotectonic stage) occurred during Cretaceous-Tertiary and is represented by the collision of Shan-Thai and Western Burma (or Peninsular Thailand) blocks (Charusiri, 1989). The collision revived sinistral movement of the Mae Ping Fault in a NW-SE direction. Several K-feldspar pegmatite dikes in a NNW direction probably occurred as a result of the fault movement (Saengmanee, 1990). The second stage of tin, tungsten, and REE mineralization may be associated with pegmatite. The probable source of these pegmatite dikes are the rarely-exposed, minor-phase granitic intrusion in the area.

CONCLUSION

The study area was part of the Shan-Thai microcontinent. The tectonic evolution of the area can be divided into 5 stages as follows :

A) The Early Paleotectonic episode - is marked by transgression of shallow marine onto the Precambrian Shan-Thai microcontinent, causing deposition of the lower silicic clastic and carbonate sediments.

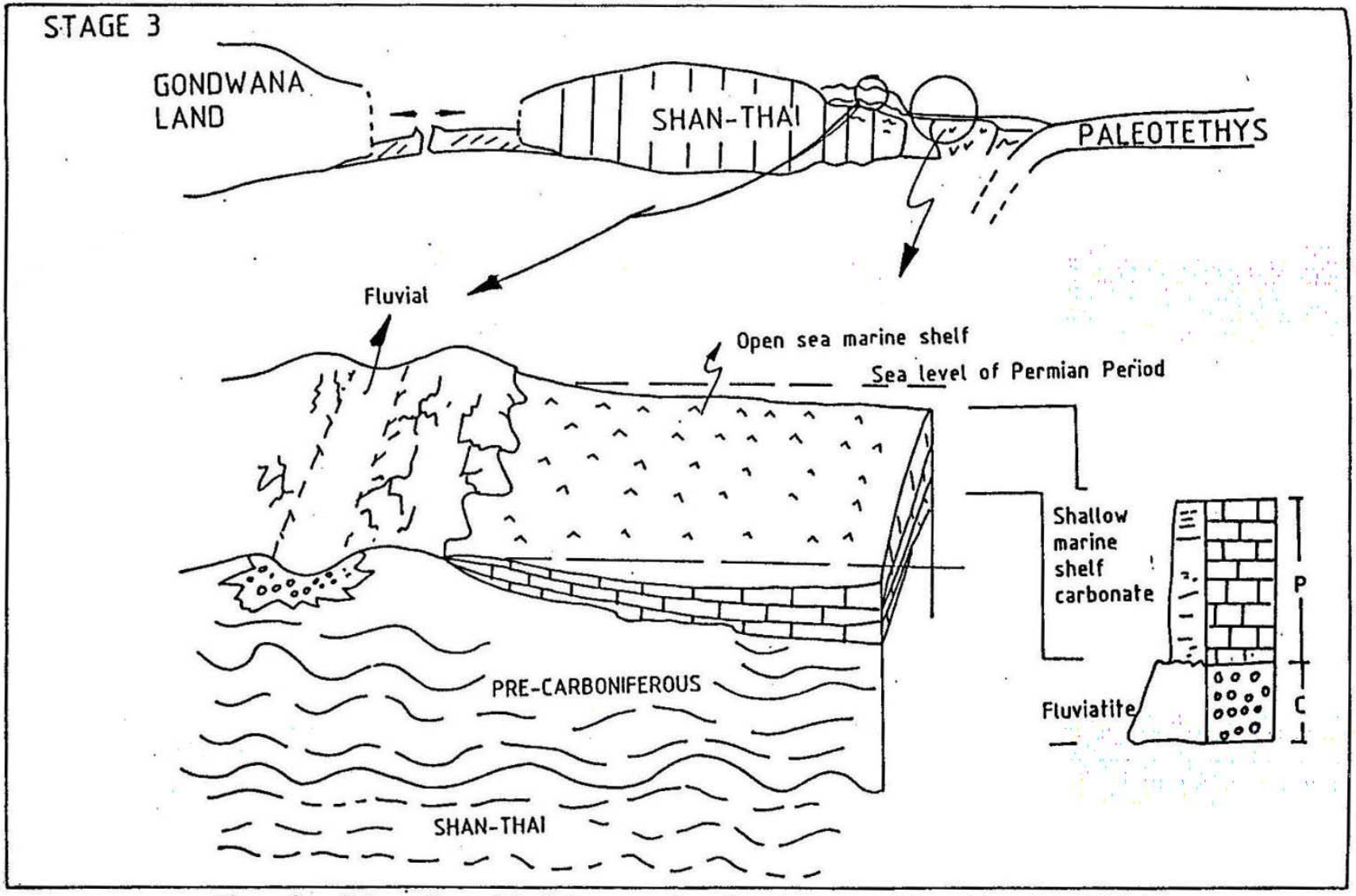

Figure 9 Schematic model of plate tectonic and environment of deposition of the Third stage (Carboniferous to Permian).

B) The Middle Paleotectonic episode - is represented by the wide-spread occurrence of middle Paleozoic deep marine sediments in the back-arc basin just west of the Shan-Thai. Volcanic activity also started.

C) The Late Paleotectonic episode - commenced with the submergence of part of the landmass during Carboniferous due to nearby volcanic activity and subduction of Paleotethys oceanic slab. This caused the appearance of non-marine, mollasse-type red beds along with regional metamorphism and structural deformation of the rocks in the area. The final phase of this episode is marked by marine transgression and marine shelf carbonate facies of Permian age.

D) The Mesotectonic episode - occurred during Triassic and is expressed by the occurrence of S-type granite and temporally related Sn-W-REE mineralization. This episode was a result of collision of Shan-Thai and Indochina continental blocks.

E) The Neotectonic episode - was a result of the interaction between the Western Burma block and the Shan-Thai block. This revived sinistral movement along the NNW-trending Mae Ping Fault. Such movement possibly triggered the emplacement of muscovite granite and Sn-W-REE-related pegmatite.

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