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REVIEWS OF METAMORPHIC ROCKS OF THAILAND

W. Pongsapich
Department of Geology,
Faculty of Science,
Chulalongkorn University,
Bangkok 10500, Thailand

P. Charusiri
Department of Science,
Faculty of Science,
Chulalongkorn University,
Bangkok 10500, Thailand

S. Vedchakanchana
Department of Geology,
Faculty of Science,
Chulalongkorn University,
Bangkok 10500, Thailand

INTRODUCTION

Regional dynamothermal metamorphic rocks in Thailand are considerably limited or restricted both in spatial distribution and in stratigraphic units. A major zone or belt of metamorphism concentrates along the western mountain range of the country starting from Changwat Mae Hong Son and Changwat Chiang Rai, two northernmost provinces, and it extends down southerly through the western part of Changwats Chiang Mai, Lampang, Lamphun, Tak, Kamphangphet, Nakhon Sawan, Uthai Thani, Kanchanaburi, then it pinches out in Changwat Prachuab Khirikhan (Figure 1). The metamorphic rocks cropped out again in Thai Peninsula just to the south of Changwat Surat Thani and they extend to the Thai-Malaysian border. Two minor separate belts of metamorphic rocks are located, one in Uttaradit area and the other in the eastern portion of the country.

These metamorphic rocks are tentatively divided into two portions. The first group belongs to the inferred Precambrian age which is characterized by high grade metamorphic rocks and anatexites, the other belongs to the Lower Paleozoic (Cambrian-Devonian) and is characterized by low grade metamorphic rocks. However, it should be noted that not all rocks of the Lower Paleozoic age were subjected to the metamorphic events.

INFERRED PRECAMBRIAN METAMORPHIC ROCKS

Rocks of inferred Precambrian age form a narrow high grade metamorphic belt and apparently acts as the lower metamorphic zones. The belt commences at the area just to the west of Changwat Chiang Mai and extends southward more or less in the north-south direction to the west of the Bhumiphol Dam making a distance of approximately 200 km. It then bends eastward to Changwat Tak and again resumes continues in the north-south trending for another 200 km long till west of Changwat Uthai Thani. Further to the south, the continuation of the high grade metamorphic belt is interrupted resulting in the occurrences of several small isolated masses at the north, the northwest, and the southeast of

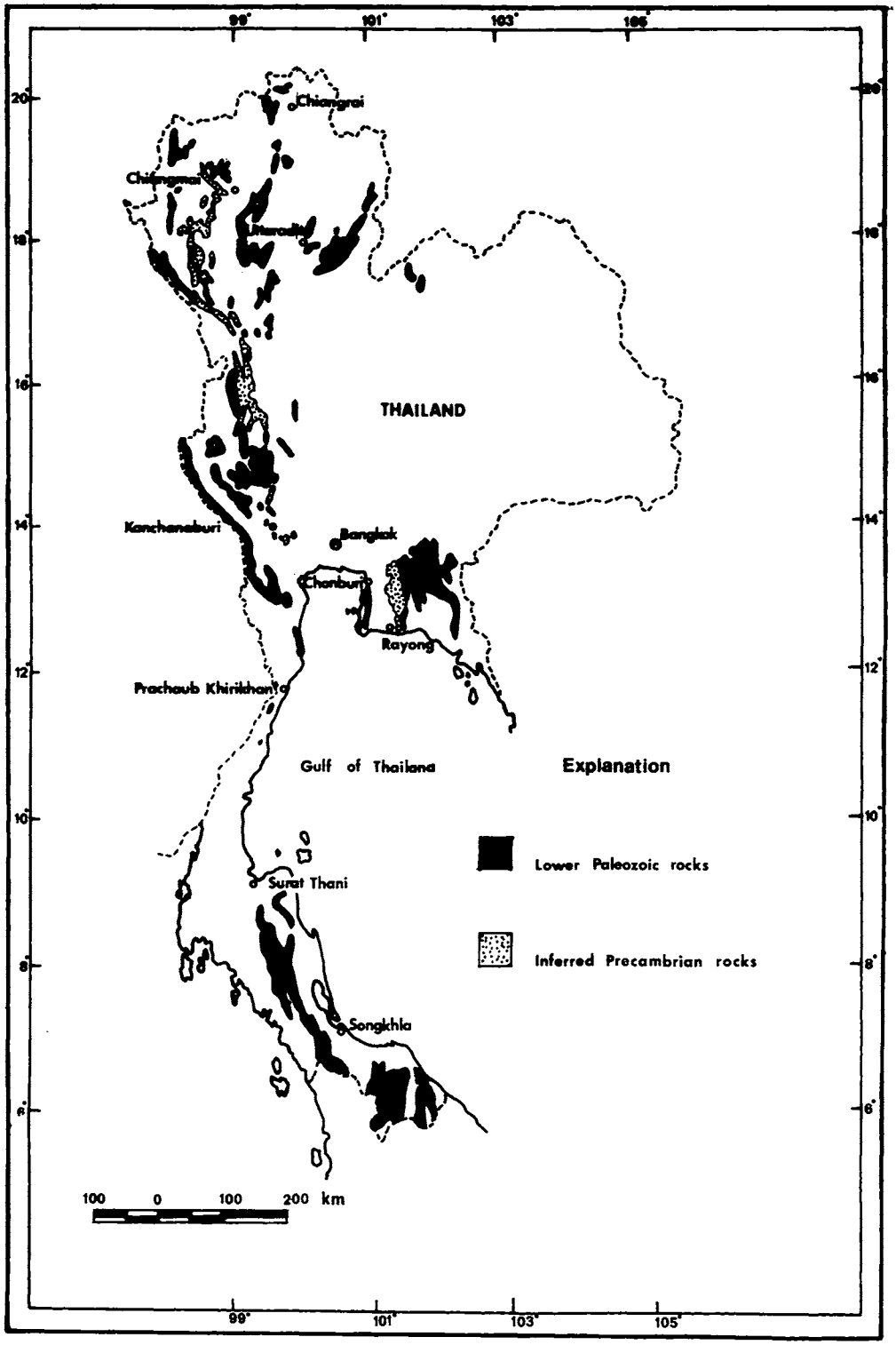

Fig.1. Distribution of regional dynamothermal metamorphic rocks in Thailand

Changwat Kanchanaburi. At Hua Hin-Pranburi area of Changwat Prachaub Khirikhan a narrow belt about 50 km long of high grade metamorphic rocks crops out again along the coastal line. Based upon the available reports, the metamorphic rocks of Changwat Prachaub Khirikhan have been considered to be the southernmost extension of the high grade regional dynamothermal metamorphic rocks in Thailand.

Another separate belt of high grade metamorphosed rocks is approximately 100 km long extending in the north-south direction from Amphoe Phanat Nikhom of Changwat Chonburi to Ban Phae area of Changwat Rayong. Again, it acts as a core of the younger and lower grade metamorphic units. Several field evidence indicated that this metamorphic zone was intruded by the series of younger granitic phases.

Metamorphic Rock Sequences

Lithologic sequences of the high grade metamorphic rocks were previously described in variable detail by many workers (Baum and others, 1972; Dheeradilok, 1973; 1975; Campbell, 1973; 1975 a; 1975 b; Nutalaya, 1974; Bunopas and Bunjitradulya, 1975; Piyasin, 1975; Bunopas, 1976 a; 1976 b; 1980 a; 1980 b; Vedchakanchana and others, 1978; Chuaviroj and others, 1980; Pongsapich and others, 1980; Macdonald, 1981; Thanasuthipitak and Sinthusan, 1981). Surprisingly, the results of the lithologic sequences are rather uniform all over the country. Thus it is possible to summarize the sequences of high grade metamorphic rocks starting from the lowermost unit to the uppermost unit as (1) paragneiss - orthogneiss unit, (2) schist unit, (3) calcsilicate-marble unit, (4) quartzite unit, and (5) marble unit. The units 1-3 are almost invariably present in each high grade unit area whereas the units 4 and 5 are scarcely present. Bunopas and Bunjitradulya (1975) and Bunopas (1976 b) reported that mica-quartz schist and quartz schist, which are probably equivalent to the quartzite unit, overlie the calcsilicate-marble unit in the metamorphic areas of Changwat Kanchanaburi and Changwat Tak respectively. In Hua Hin-Pranburi metamorphic complex of Changwat Prachaub Khirikhan the quartzite and the higher successive units of marble are found overlying on the calcsilicate-marble rocks (Pongsapich and others, 1980).

It is noteworthy to point out here also that according to the field evidence the metamorphic sequences at the western area of Changwat Tak was observed to become in reverse order (Piyasin, 1975). However, by using graded bedding features Bunopas (1976 b) was able to indicate structurally overturned sequence in this area.

High grade metamorphic rocks in Phanat Nikhom area of Changwat Chonburi include an extra amphibolitic rock into the sequence. The amphibolite is believed to be metamorphic product of the formerly intercalated basaltic lava flows.

General Petrographic Description of the Lithographic Sequence

Paragneiss-Orthogneiss unit Paragneisses are generally light gray in colour. They range from fine-grained equigranular to coarse-grained porphyroblastic. Commonly it is laminated to banded presumably due to differences

in grain sizes and mineralogical constituents of formerly sedimentary layers prior to metamorphism. Quartz, plagioclase, potash-feldspar, and biotite are very common minerals. As a result, quartz-feldspar-biotite gneiss and quartzofeldspathic gneiss have been frequently used to represent this paragneiss unit. Potash feldspar, i.e., microcline and/or orthoclase, is usually porphyroblastic with varying shapes (lenticular to tabular) and sizes. Therefore, the augen structure has been repeatedly mentioned. Plagioclase ranges in composition from oligoclase (An_{20}) to Andesine (An_{37}). Seldomly it shows weak normal zoning. Almandine garnet and sillimanite have also been observed to be minor mineral constituents of the paragneiss in few places, e.g., in the gneiss of Changwat Tak (Campbell, 1975; Piyasin, 1975), in the gneiss of Changwat Prachaub Khirikhan (Dheeradilok, 1973; Pongsapich and others, 1980), and in the gneiss of Changwat Chonburi (Areesiri, 1983). In a number of occurrences , thin calcsilicate rock and schist are found interlayered with the gneiss (Bunopas, 1976 b; 1980 b; Pongsapich and others, 1980). Quartzofeldspathic rocks such as graywacke, subgraywacke, and arkose are believed to be the main original sediments of this unit.

Orthogneiss is invariably found in close association with the paragneiss. Texturally, it is gray and always shows excellent gneissosity. Its major mineralogical compositions are similar to those of the paragneiss.

The gneisses are cross-cut by a number of aplites, pegmatites, and quartz veins. These leucocratic granitic components are considered to be the product of anatectic process during the culmination of the metamorphic episode (Baum and others, 1970; Campbell, 1975; Pongsapich and others, 1980).

Mylonitization processes caused by dynamic metamorphism affected mainly upon the gneisses and to the less extent on the metamorphic rocks of the higher stratigraphic sequences (Dheeradilok, 1973; Bunopas, 1976 b; Campbell, 1975; Vedchakanchana and others, 1978; Pongsapich and others, 1980; Thanasuthipitak, 1981).

Schist unit Metapelitic and metacalcareous sediments of the high grade metamorphic complex are intimately associated. In several metamorphic terrains the metapellite is present in subordinate amount in comparision with the metacalcareous sediment, therefore, many workers have omitted to mention the metapelite separately in detail and rather included it in the descriptive context of metacalcareous sediment. However, for the general convenience the metapelite or herein the schist unit will be separately discussed prior to the discussion of the calcsilicate-marble unit.

The schist is commonly light gray to gray, fine-to medium-grained, and well foliated. In the northern part of Thailand the unit is represented mainly by quartz-mica schist or mica schist (Nutalaya, 1974; Chuaviroj and others, 1980). Minor amount of almandine garnet, sillimanite and possibly cordierite were observed by Piyasin (1975) in the mica schist of Amphoe Samngao-Phumipol Dam area, Changwat Tak. Sillimanite-mica schist with characteristic mineral assemblage of quartz-biotite-muscovite-sillimanite-orthoclase was reported by Dheeradilok (1975) from the metamorphic area to the southwest of Amphoe Tha Maka, Changwat Kanchanaburi. The rocks with characteristic mineral assemblages of

quartz-biotite-sillimanite-garnet,
quartz-biotite-sillimanite-garnet-ortholcase, and
quartz-biotite-sillimanite-garnet-orthoclase cordierite
were classified by Pongsapich and others (1980) from the Hua Hin-Pranburi metamorphic complex in Changwat Prachuab Khirikhan. Recently, petrographic determination of rocks collected from the metamorphic area near Amphoe Om Koi in Changwat Chiangmai reveals staurolite and garnet characteristic minerals (Piyasin and Pongsapich, personal communication). It can be suggested that the schist unit is resulted from high grade regional dynamothermal metamorphism of originally pelitic sediments contemporaneous with the paragneissic core.

Calcsilicate-marble unit The calcsilicate rocks are metamorphic products of formerly alternating layers of quartzofeldspathic-rich and argillaceous-rich impure carbonate (calcitic and/or dolomitic) sediments. The calcsilicate rocks may grade into or alternate with considerably pure calcitic or dolomitic marble beds of variable thickness. The calcsilicate rocks are light green, green, light gray, to light brown while the marble is light gray, yellowish white, to white. The calcsilicate rocks which are well banded and laminated comprise the layers of different composition.

Though many of the metamorphic mineral assemblages of calcsilicate rocks reported are not in accordance to the layered composition but rather in the order of grouping, it can, however, be summarized as assemblage of quartz-plagioclase-diopside-calcite. Additional minerals such as microcline, biotite, calcic amphibole, and garnet to the mineral assemblage depend much upon the impured component either potassium-rich and/or aluminous-rich. Minerals of the epidote group have been reported to exist stably with the assemblage in most places. They are coexisting with plagioclase of andesine composition for instance in Lan Saeng area of the Changwat Tak (Campbell 1975).

However, they are considered to be retrogressive products in the assemblage which observed plagioclase composition is andesine and higher in anorthite content. Sphene, chlorite, muscovite, apatite, and opaque minerals are accessory minerals. Scapolite was observed from Tak (Bunopas 1976, NE 47-15, Campbell, 1975) and as well as in Pranburi (Pongsapich and others 1980). Periclase and chondrodite were reported only in the dolomitic marble of the Hua Hin-Pranburi area (Pongsapich and others, 1980).

Quartzite-quartz schist unit The calcsilicate-marble unit grades upward into calcsilicate quarzite, quartzite, quartz schist, and quartz-mica schist. These gradations may represent the lithological transition from carbonates to psammitic sediments. In most area the sequence of metamorphic rocks is terminated by the calc-silicate marble unit either by the interruption of faults or unconformities. However, continuation of the higher metamorphic sequence was reported by Bunopas (1976, NE 47-15) on the metamorphic complex along the western part of Tak-Kamphaengphet provinces and by Pongsapich and others (1980) in the Hua Hin-Pranburi areas. The quartzitic rocks range from fine-to medium-grained quartz and potash feldspar. Biotite and muscovite, if sufficiently present, will commonly mark an impersistent foliation.

Marble unit The quartzitic rocks are believed to be overlain by marble which is the uppermost unit of this metamorphic sequence (Pongsapich and others, 1980). The marble is light gray to white and relatively fine-grained. It consists mainly of calcite and dolomite and perhaps chert nodules in certain layers of the marble.

Metamorphic Grade and Chronology

It is widely accepted among the workers that the grade of metamorphic rocks at the time of culmination of dynomothermal metamorphism belongs to the amphibolite facies (Piyasin, 1975; Dheeradilok, 1975; Bunopas, 1980, ND 47-7; Bunopas, 1980, ND 47-39; Bunopas, 1980, NE 47-17, Chuaviroj and others, 1980). Further subdivision into andesine-epidote subfacies was attempted by Campbell (1973). Bunopas and Bunjitradulya (1975) proposed upper amphibolite facies. Pongsapich and others (1980), though not mentioned facies pertinently, proposed a high grade metamorphic condition for the Hua Hin-Pranburi rocks; i.e. 2.25-3.65 kb and 610-680°C. Areesiri (1983) proposed the physical condition for the peak of metamorphism in Amphoe Phanat Nikhom, Changwat Chonburi as 4.6-6.5 kb and 675-700°C. Regarding to the age of this high grade metamorphic rock, it was inferred by several authors as Precambrian (e.g., Campbell, 1973; Dheeradilok, 1975; Workman, 1975; Bunopas, 1976; etc.). This deduction was primarily based on the ground that none of the known Lower Paleozoic rocks, if they might have ever been affected by regional dynamothermal metamorphism, have their grades of metamorphism higher than the green schist facies. By the same token, none of the high grade metamorphic terrains, that have been studied, grade continuously into non-metamorphosed rocks of known ages. The boundary contacts between the high grade metamorphic rocks and the cover of the Paleozoic rocks, if found, are always planes of faults or intrusive contacts with much younger granites. Furthermore, based upon the consistency of the stratigraphic sequence of this high-grade metasediments from the north to the central part of Thailand and their lithologies which are considerably different from the shallow-shelf sandstones of Cambrian and limestone of Ordovician, it should be posible to rule out the local metamorphism by high thermal effect of the Lower Paleozoic rocks. Therefore, it could be suggested that the high grade metamorphic rocks have experienced their culmination of metamorphic episode during the Precambrian time.

Field and petrographic observations indicated that there were at least two regional dynamothermal metamorphic events which acted upon these high grade rocks (Campbell, 1973; Nutalaya, 1973; Bunopas, 1975; Dheeradilok, 1975; Chuaviroj, 1980; Macdonald, 1981; Aresiri, 1983). Campbell (1973) has reported from his work in the Lan Sang Gneiss of Changwat Tak that the high grade Precambrian metamorphic event was succeeded by Carboniferous metamorphic event that has led to development of low grade greenschist facies upon many Lower Paleozoic rocks. He further pointed out that many of the dynamic faulting found in these metamorphic terrains might have as well occured in this orogenic episode.

LOWER PALEOZOIC REGIONAL METAMORPHIC ROCKS

Regional dynamothermal metamorphic rocks of the Lower Paleozoic, though are wider in distribution, have received less attention than the comparative high grade rocks of inferred Precambrian ages during the past decades. Many workers have briefly mentioned them as in a part of geology in the area under study.

Regional metamorphic rocks of the Lower Paleozoic age are found all over the country; however, the rocks are more widely distributed in the eastern part than in the south (Figure. 1). This feature is rather comformable to those of the high grade regional metamorphic rocks of the inferred Precambrian ages.

Lower Paleozoic rocks affected by regional dynamothermal metamorphism are of Cambrian, Ordovician, and Silurian-Devonian in ages. Not all of these Lower Paleozoic rocks, however, were transformed by the metamorphic processes, parts of them still retain their sedimentary characteristic origins, particularly in the s South. Koch (1973) reported that the dynamothermal metamorphism affected only those parts of the sequence that have were downfolded enough to attain sufficient temperature and pressure.

Collective information from works of von Braun and others (1970); Piyasin (1972; 1975); Sripatanawat (1972); Hagen and Kenper (1976); Bunopas (1976 a; 1976 b; 1980 a; 1980 b), Thanasuthipitak (1976); Chuaviroj and others (1980); and Thanasuthipitak and Sinthusan (1981) can be summarized as follows. The Cambrian metamorphic rocks concentrate, in general, along the western mountain chains and run from Fang and Mae Hong Son to Kanchanaburi province in the southern part. They are mainly massive quartzite, quartz schist, mica-quartz schist and quartzofeldspathic schist of approximately 500 meters thick. These Cambrian metamorphic rocks grade conformably upwards with increasing carbonate and clay content to massive and well-bedded recrystallized limestone of Ordovician age. In Chonburi, Ko Sichang marbles of inferred Ordovician ages are found underlying the quartzite of possibly Cambrian age Metamorphic rocks of Silurian-Devonian ages are found in the western range from Lampang to perhaps Uthai Thani, in Uttaradit area and its vicinity, and in the eastern and southern part of Thailand. They consist mainly of varieties of low grade schist, phyllite, slate, and quartzite.

Lithological structures and mineral assemblages of metamorphic rocks of the Lower Paleozoic sequence indicated the greenschist facies of regional dynamothermal metamorphic event of Carboniferous Period (von Braun and others, 1970; Piyasin, 1972; Campbell, 1973).

REFERENCES CITED

Areesiri, S., 1983. Genetic Consideration of Amphibolite and Related Rock of Bo Kwang Thong, Amphoe Phanat Nikhom, Changwat Chonburi (Abst.), In the Proceeding of Annual Technical Meeting, 1982, Dept. Geol. Sci., Chiangmai Univ.

Baum, F., Braun, E.V., Hahn, L., Hess, A., Koch, K.E., Kurse, G., Guarch, H., and Siebenhuner, M., 1970. On the Geology of Northern Thailand : Beiheft Geol. Jahrb., V. 102, 23 p.

Bunopas, S. and Bunjitradulya, S., 1975, Geology of Amphoe Bo Ploi, North Kanchanaburi, with special notes on the "Kanchanaburi Series", Jour. Geol. Soc. Thailand, V. 1, p. 51-67.

————, 1976 a, Geology and Mineral Resources of Pitsanulok, Sheet NE 47-15, Rept. Invest. No. 16, Part I, Dept. Min. Res., Thailand, 152 p.

Bunopas, S., 1976 b. Geology and Mineral Resources of Pitsanulok, Sheet NE 47-15, Rept. Invest. No 6, Part II, Dept. Min. Res., Thailand, 65 p.

————, 1980 a. Geological Survey Report No 1, Sheet Nakhon Sawan (ND 47-3), Scale 1:250,000, Dept. Min, Res., Thailand, 75 p.

————, 1980 b. Geological Survey Report No 2, Sheet Suphan Buri (ND 47-7), Scale 1:250,000, Dept. Min. Res., Thailand, 73 p.

Campbell, K.V., 1973. Structural Setting and Metamorphic Grade of Lansang Gneiss, Geol. Soc. Thailand Newsl., V. 6, no. 2, p. 32-44.

————, 1975 a. Basement Complex, Dept. Geol. Sci., Univ. Chiangmai, Spec. Pub. no. 1, V. 1, p. 3-12.

————, 1975 b. Lower Paleozoic Metamorphic Rocks of Thailand, Dept. Geol. Sci. Univ. Chiangmai, Spec. Pub. no. 1, v. 1, p. 13-21.

Chuaviroj, S. and others, 1980. Final Report on Geology of Geothermal Resources of Northern Thailand, Sankamphaeng, Fang, and Mae Chan Areas, Dept. Min. Res., Thailand.

Dheeradilok, P., 1975. On the Structural features and Metamorphism of the Inferred Precambrian Rocks, Southeast Amphoe Tha Maka, Khanchanaburi Province, Jour. Geol. Soc. Thailand, v. 1, p. 21-29.

Hagen, D, and Kenper, E., 1976. Geology of Thong Pha Phum Area (Kanchanaburi Province, Western Thailand), Geol. Jahr., Reihe B., Heft 21, p. 53-91.

Koch, K.E., 1973. Geology of the Region Sri Sawat-Thong Pha Phum Area - Sangkhlaburi (Kanchanaburi Province, Thailand), Geol. Soc. Malaysia Bull., no. 6, p. 177-185.

Macdonald, D.R., 1981. Study of Strata in Southern Laos Equivalent to the Khorat Group of Thailand Using Satellite Imagery, Jour. Geol. Soc. Thailand, v. 4, no. 1-2, p. 1-12.

Nutalaya, P., 1974. Geology of Bhumiphol Dam Area, Tak Province, Thailand, Conf. on the Geology of Thailand, Dept. Geol. Sci., Chiangmai Univ., Dec., 1973.

Piyasin, S., 1972. Geology of Lampang Sheet NE 47-7, 1:250,000, Rept. Invest., no. 14, Dept. Min. Res. Thailand, 98 p.

————————, 1975. Stratigraphy and Sedimentology of the Kaeng Krachan Group (Carboniferous), Dept. Geol. Sci. Univ. Chiangmai, no. 1, v. 2, p. 25-36.

Pongsapich, W., Vedchakanchana, S., and Pongprayoon, P., 1980. Petrology of the Pranburi - Hua Hin Metamorphic Complex and Geochemistry of Gneisses in It, Bull. Geol. Soc. Malaysia, no. 12, p. 55-74.

Sripatanawat, V., 1972. Report on the Preliminary Geological Survey of Nakhon Sawan Province Quadrangle, ND 47-3, Dept. Min. Res., Thailand (in Thai).

Thanasuthipitak, T., Sinthusan, A., 1981. Geology and Stratigraphy of Li and Doi Tao Area, Northern Thailand, Proc. Annual Tech. Meeting, Dept. Geol. Sci., Univ. Chiangmai, Spec. Publ. no. 3, p. 1-24.

Vedchakanchana, S., Pongprayoon, P., and Pongsapich, W., 1978. Cataclastic Rocks and Fault Zone in Pranburi Area, Rept. Sci. Res., Fac. Sci., Chulalongkorn Univ., v. 3, p. 121-131.

Workman. D.R., 1975. Tectonic Evolution of Indochina, Jour. Geol. Soc. Thailand, v. 1-2, p. 3-11.

Von Braun, E., 1970. The Age of Granites in Northern Thailand, Proc. and Tech. Conf. Tin, Bangkok, 1969, p. 151-157.

————————, Besang, C., Eberle, W., Harre, W., Krenzer, H., Muller, P., and Wendt, I., 1976. Radiometric Age Determination of Granites in Northern Thailand, Geol. Jahr., Reihe B., Heft 21, p. 171-204.