WORKSHOP ON STRATIGRAPHIC CORRELATION OF
THAILAND AND MALAYSIA

Haad Yai, Thailand
8-10 September, 1983

IGNEOUS ROCKS OF THAILAND: A REVIEW OF PLUTONIC ROCKS WITH INTERMEDIATE-ULTRABASIC COMPOSITIONS AND VOLCANIC ROCKS

Y. Panjasawatwong
Department of Geological Sciences
Chiang Mai University
Chiang Mai, Thailand

W. Yaowanoiyothin
Department of Geological Sciences
Chiang Mai University
Chiang Mai, Thailand

INTRODUCTION

Igneous rocks in Thailand consist mainly of plutonic, volcanic and volcaniclastic rocks. Hypabyssal rocks are known in some localities. Mafic and ultramafic rocks and their associates are present in the northern highlands, the eastern coast and the peninsula. Very few records of volcanic and volcaniclastic rocks have been reported in the peninsula. Amongst the igneous rocks, volcanic rocks appear to be ambigously classified by many workers since the geochemical data are rare.

Reviews of igneous rocks of Thailand were previously made by Natalaya (1973), Thanasuthipitak (1978) and Bunopas (1981). At present, the last review is generally up to date. The aim of this paper is to review igneous rocks other than granites and related rocks based on recently available information since 1981. The rocks presented here include syenite and volcanic rocks in some localites. The reviews carried out by Nutalaya (1973), Thanasuthipitak (1978) and Bunopas (1981) will be briefly discussed.

THE WORK OF NUTALAYA (1973)

In the first review, Nutalaya divided igneous rocks of Thailand into 2 main groups; viz., intrusive and extrusive rocks. The intrusive rocks are made up of granitic rocks of Carboniferous, Triassic-Jurassic, and Cretaceous-Tertiary ages, and Carboniferous mafic and ultramafic rocks. The rocks belonging to the Carboniferous mafic and ultramafic rocks are diorite, gabbro, pyroxenite and peridotite. The extrusive rocks comprise rhyolite, andesite and associated pyroclastic rocks of different ages (Carboniferous, Permo-Triassic, Triassic-Jurassic, Cretaceous and Tertiary) and Quaternary basalts. Descriptions of mafic, ultramafic, volcanic and pyroclastic rocks were given on the basis of petrographic study.

THE WORK OF THANASUTHIPITAK (1978)

Thanasuthipitak, in the second review, dealt with the rocks in 4 separated parts; viz., the granitic rocks of the north and the west, the granitic rocks of the south and the peninsula, ultramafic and mafic rocks, and volcanic rocks. The ultramafic and mafic rocks comprise pyroxenite, dunite, serpentinite, hornblende peridotite, hornblendite and diabase. The volcanic rocks can be divided into 2 groups according to their compositions, i.e., andesite-dacite-rhyolite series and Quaternary basalts.

Ultramafic and mafic rocks have been reported from many localities in the northern highlands and the eastern coast. The ultramafic and mafic fields in the northern highlands include the areas being mapped by the German Geological Mission in Thailand as ophiolite (pyroxenite embedded in andesite) and the Uttaradit area. Thanasuthipitak interpreted the pyroxenite, dunite, serpentinite, hornblende peridotite, and diabase together with their associated volcanic and sedimentary rocks in the Uttaradit area as part of an ophiolite typical of a consuming plate juncture. The ultramafic-mafic assemblage in the northern highland has an estimated age of Late Carboniferous. In the eastern coast and adjacent parts, pyroxenite and hornblendite are found at Sra Kaew, Prachinburi. Hornblendite occurs at Pak Chong, Saraburi. Gabbro and diabase are found at Khao Wai, Rayong.

Two episodes of volcanic activities leading to andesite-dacite-rhyolite series (andesite, dacite and rhyolite with their volcaniclastic equivalents) have been depicted. The first episode began probably in Silurian and ended in the Middle Triassic time while the last episode started in Cretaceous and died out the Late Tertiary. The products of the activities during Silurian-Devonian were volcaniclastic sedimentary rocks only; the true volcanic and pyroclastic rocks did not appear till Middle Carboniferous. The most intensive activities took place in the Middle Carboniferous and Permo-Triassic times producing extensive volcanic and pyroclastic rocks in the median part of the country (extending from Chaing Rai to the southeast). The geochemical studies of Permo-Triassic volcanics around Vichianburi, Petchabun and east of Pai Sali, Nakhon Sawan indicate the rocks being calc-alkali. Some of the volcanic and pyroclastic rocks occur in the lower parts of Permian sequence and Lampang Group. The activities of the last episode were restricted only in an area bordering the Khorat Plateau.

Quaternary basalts occur in the vicinities of Trat, Chanthaburi, Kanchanaburi, Phrae, Lampang, Chiang Rai, Loei, Srisaket, Buriram, Surin, Petchabun, Lopburi, Saraburi and Nakhon Ratchasima. These basalts can be classified as corundum-bearing basalts and corundum-barren basalts. The corundum-bearing basalts are characterized by the presence of peridotite xenoliths and megacrysts of plagioclase feldspar, spinel, aluminous pyroxene, ilmenite, magnetite and zircon. In addition, the corundum-bearing basalts have lower SiO_2 and higher TiO_2 in relation to the corundum -barren basalts. Chemically, the Quaternary basalts comprises alkali-olivine basalt, hawaiite, mugearite, basanite, nepheline hawaiite and tholeiite.

THE WORK OF BUNOPAS (1981)

Bunopas carried out an intensive review of igneous rocks of Thailand. His work is still up to date in general. He divided the rocks into 3 main groups namely granites and granitoids, volcanic rocks, and basic to ultrabasic plutonic rocks.

Volcanic rocks

Volcanic rocks can be divided on the basis of stratigraphy into 4 groups viz., Silurian to Lower Permian metavolcanics, Upper Permian to Lower Triassic volcanics, Upper Triassic to Lower Jurassic rhyolites, and Upper Cenozoic basalts. The Silurian-Lower Permian metavolcanics were subdivided into 3 sets viz., Silurian-Devonian metavolcanics, Carboniferous metavolcanics, and Lower Permian tuffs.

Silurian-Devonian metavolcanics occur along a narrow belt from Suphanburi through Tak to Chiang Rai. Their stratigraphic position lying in between fossiliferous Ordovician and fossiliferous Carboniferous sediments is indicative of Silurian-Devonian ages. The rocks comprise chiefly volcaniclastic sediments with sporadic amounts of pyroclastic rocks and lavas. As the result of regional metamorphism, the volcaniclastic sediments were altered to green schist. Their chemical compositions probably range from acid to basic. The Silurian-Devonian metavolcanics might initially be the same unit as those found in the eastern coast of Thailand and the Malay Peninsula. It is believed that the belt of Silurian-Devonian metavolcanics was part of a volcanic arc.

Carnoniferous metavolcanics consist predominantly of agglomerate and volcanic conglomerate with some associated tuff and tuffaceous sandstone and shale. Their ages was thought to be largely or entirely Lower Carboniferous. The Carboniferous metavolcanics include the lower parts of the Phrae Group, and the upper and lower parts of the Dan Lan Hoi Group. Furthermore, they also form a north-south trending belt east of the Silurian-Devonian metavolcanic belt in the northern highlands especially in the mountain range between Lampang and Phrae. Consequently, they were interpreted as products of arc volcanisms.

Lower Permian tuffs are locally recognized in the areas north of Lampang and between Lampang and Phrae. They form the lower parts of the Ngao Group and are composed of tuffaceous sandstone, tuffaceous shale, gray sandstone, gray shale and interbedded calcareous shale and thin limestone band. In the thin limestone layer, there are fusulinids of Lower Permian age. The Lower Permian tuffs probably were not confined to a volcanic arc because they did not form a linear belt.

Upper Permian-Lower Triassic volcanics expose in 3 main areas; namely, northern highlands, Loei, and eastern coast. The volcanic rocks in the northern highlands and Loei are underlain by fossiliferous Permian sediments and are overlain by fossiliferous Middle Triassic sediments. The ages of rocks in the eastern coast are dated by the underlying fossiliferous Upper Permian sediments. In the northern highlands, the volcanics comprise extensive flows, pyroclastic rocks and their plutonic

equivalents together with volcaniclastic sediments. They either form a linear belt between the Silurian-Devonian metavolcanics and the Carboniferous metavolcanics or are found east of the Carboniferous metavolcanics especially in areas northeast of Tak through Lampang and Chiang Rai. In addition, the rocks mapped by the German Geological Mission in Thailand as Carboniferous ophiolites around the vicinities of Chiang Mai and Chiang Rai are also included in this unit. In the Chiang Mai and Chiang Rai areas, the volcanics are tholeiitic and made up of basalt flows, gabbros, pyroxenites, tuffs and agglomerates. The metabasites (basalt-basic andesite) at quarries near Sirikit dam and at Saraburi are also parts of the Permian-Lower Triassic volcanics. A linear belt of the rocks excluding those in the Chiang Mai and Chiang Rai areas represented a volcanic arc with westward dipping subduction zone. The volcanics in the vicinities of Chiang Mai and Chiang Rai was thought to be the product of back-arc spreading. The Loei volcanics lie adjacent to the Khorat Plateau with the same north-south trending as that of the belt in the northern highlands. The rocks include tuffs, agglomerates and flows of andesitic composition and were interpreted as a Permo-Triassic arc with eastward subduction beneath Indochina. In the eastern coast, the Upper Permian-Lower Triassic volcanics are spilitic pillow lava, andesite, tuff and agglomerate. The spilite and associated chert occurring at Sra Kaew, Prachinburi was considered to represent an ancient ocean floor between Shan-Thai craton and Indochinese craton. Andesite, tuff and agglomerate between Rayong and Chanthaburi were probably products of an arc volcanism.

Upper Triassic to Lower Jurassic rhyolites were dated by their stratigraphic positions. They comprise alkaline rhyolite flows and associated pyroclastic rocks which were interlayered with the lower parts of Khorat Group in the Sukhothai fold belt (immediately west of the Carboniferous ophiolite belt) and the Loei fold belt (immediately east of the Carboniferous ophiolite belt). These rhyolites are also found injected along the Triassic granite contacts in the northern highlands. Chemically, they are extrusive equivalents of the S-type Upper Triassic-Lower Jurassic granites. The volcanics are typically less altered and less deformed relative to the older volcanics and are not confined to a narrow belt.

Upper Cenozoic basalts occur as small fields in many areas of Thailand except the peninsula. Most of the basaltic flows have individual flow thickness of up to 5 m. The total thickness of the flows in each field is commonly less than 100 m. Their pyroclastic equivalents, plugs, and dikes are present at a few localities. The widespread distribution of basaltic rocks in Southeast Asia within a short time interval has been depicted as a sudden release of magmas near the base of the continental crust.

Basic to ultrabasic plutonic rocks

Bunopas (1981) categorized the basic to ultrabasic plutonic rocks in Thailand as Phasom ultramafics, Sra kaew ultramafics and Narathiwat ultramafics. The Phasom ultramafics occur in the vicinity of Uttaradit. His interpretation, however, is different from that of Thanasuthipitak. Bunopas considered the rocks to be ophiolites characteristic of a tectonic slice or several tectonic slices within the fore-arc facies of the Sukhothai fold

belt, or of the obducted ocean floor along the Nan-Uttaradit suture. The ultramafics probably mark a zone of westward subduction of the oceanic crust in Late Permian time. The Sra Kaew ultramafics are found at many localities in the eastern coast particularly at Sra Kaew, Prachinburi. The Narathiwat ultramafics are exposed in the region of Narathiwat and are made up of serpentinized peridotite associated with tuffaceous sandstone. It is possible that all ultramafics are parts of an ophiolite belt extending northward from Bentong ophiolite in Malaysia.

PRESENT REVIEW

Since the last review (Bunopas, 1981), additional information on intermediate-ultrabasic plutonic rocks and volcanic rocks become available. Therefore even though the review carried out by Bunopas (1981) is generally up date, additional information on syenite, pre-Cenozoic volcanic rocks and Cenozoic volcanic rocks in some areas will be described in this section.

Syenite

Syenite in Thailand was first recognized in 1976 by Leow and Wannakasem, then students at the Department of Geological Sciences, Chiang Mai University. It was found immediately southeast of Khao Chamao, approximately 4 km northwest of Khao Nam Tok and 2 km west of Nong Khan, Chanthaburi. According to Leow and Wannakasem (1976), the syenite is definitely older than the Late Cretaceous granites of Khao Chamao. Panjasawatwong and Yaowanoiyothin (in preparation) conducted petrochemical studies of one syenite sample which is available at the Department of Geological Sciences, Chiang Mai University. The syenite is classified as miaskitic nepheline syenite based on major-element geochemistry and petrography. The syenite sample has an appearance of a rock of multi-layered intrusion. It shows distinct as preferred orientation of tabular alkali feldspars in planes. Under the microscope, the rock is composed predominantly of perthitic orthoclass and soda amphibole with sporadic biotite, nepheline, allanite (?), sphene, apatite and zircon. The orthoclass feldspar and soda amphibole appear to be cumulus phases whereas the others occur as intercumulus phases. Clay minerals, sericite, epidote and chlorite are present as secondary minerals.

Pre-Cenozoic volcanic rocks

Volcanic rocks of pre-Cenozoic age are found in many places in Thailand, however very few records of volcanic and volcaniclastic rocks from the Thai Peninsula have been reported. Andesites are known along the Thai-Malay border in the 1:250,000 scaled maps of Narathiwat Sheet and Betong Sheet. Permo-Triassic pyroclastic rocks (tuff and agglomerate) are poorly exposed in the region of Narathiwat. Volcaniclastic samples from the area around the Krabi basin were found to resemble the marine Triassic volcaniclastic sedimentary rocks in the Mae Chang area, Lampang (Chantaramee et al., 1980).

Panjasawatwong et al. (in preparation) studied the rocks exposed along the road-cut at km 43-44 Lampang-Denchai highway which appear in the *Excursion Guide* of Tansathien and Muenlek (1981) as Permo-Triassic rocks. The rocks are classified according to their petrochemical data as leucogranite, nepheline bearing diorite, hornblendite, rhyolite, trachyte are peralkaline rocks whereas hornblendite is metaluminous rock, Only brief descriptions of undersaturated diorite, rhyolite, trachyte, hornblendite and pyroclastic rocks are given. The undersaturated diorites occur as small irregular veins in the hornfelsic rocks and are grayish green in color. They consist chiefly of plagioclase feldspar (An-contents up to 34%) with subordinate amount of hornblende. Their accessory minerals are nepheline, apatite, Fe-Ti oxides, zircon, calcite, epidote and chlorite. The rhyolites have colors ranging from grayish black to greenish gray and are microporphyritic. Microphenocrysts include plagioclase feldspar, orthoclase feldspar and altered mafic minerals. The groundmass minerals are made up chiefly of quartz and alkali feldspar. Spherulitic intergrowths between alkali feldspar and quartz are commonly observed. Chlorite, zircon, epidote and Fe-Ti oxide minerals occur as accessories. Chemically, the rhyolites have the calc-alkali affinities similar to the Permo-Triassic rocks found in Vichianburi, Petchabun and east of Pai Sali, Nakhon Sawan (Ounchanum, 1977). The trachytes are found as small veins in hornfelsic rocks. They are dense rocks with albite microphenocrysts and have grayish white color. The albite microphenocrysts set in the groundmass consisting of quartz and alkali feldspar. Spherulitic intergrowths between quartz and alkali feldspar were detected in parts. Zircon, epidote and opaque minerals are common accessories. The hornblendites are present as small veins in the rhyolitic rocks. The principal constituent of hornblendite is hornblende. Quartz, calcite, epidote and zircon are occasionally observed. The crystal-vitric tuffs have an appearance similar to leucogranites, however they comprise approximately 44% quartz and feldspar, 40% devitrified glass and 16% leucogranite fragments. The crystal tuffs are generally white in color, where alteration has taken place, they turn purplish to brownish in color. The crystal tuffs are composed principally of quartz and feldspar (approximately 65-70%) with subordinate devitrified glass. The chemical compositions of all pyroclastic rocks suggest that they are rhyolitic.

The ultramafic and mafic rocks and their associates which occur in the areas west, north and northeast of Chiang Rai, north and northeast of Chiang Dao, northeast of Chiang Mai, and east and southeast of Nan have been discussed by a number of geologists. In the final report of the German Geological Mission in Thailand (1972), pyroxenite and associated andesite in the described areas were mapped as Carboniferous ophiolites. MacDonald and Barr (1978) studied the geochemistry of mafic-ultramafic assemblages in the same areas as appear in the German final report (excluding the areas east and southeast of Nan) and the area southeast of Lumphun. They classified the rocks into 4 main groups namely tholeiitic basalts, gabbros (diabases), cumulates and pyroclastic equivalents. The term 'tholeiitic basalts' have been used instead of andesites because they are composed largely of clinopyroxene (augite or titanaugite) and

plagioclase (andesine-labradorite) with subordinate forsteritic olivine. The cumulates are made up of wehrlite and clinopyroxenites. Gabbros occur either as fragments in breccias or as massive bodies. The gabbros may represent diabase dikes or interior parts of flows. The presence of agglomerates, tuffs and pyroxenites and the absence of pillow lavas, peridotite and dunite make the term 'ophiolites' inappropriate. They have considered the rock assemblages as products of arc volcanism. The ultramafic, mafic and related rocks occur mainly within the Carboniferous sedimentary rocks underlying the base of te Rat Buri limestone (Late Carboniferous-Permian) suggest that the rocks are Late Carboniferous in age (German Geological Mission in Thailand, 1972; MacDonald and Barr, 1978). However, Bunopas (1981) found that the rock assemblages were faulted against the Rat Buri limestone and suggested that they are younger than Rat Buri limestone. This suggestion is supported by Aiumpiya et al. (1982) and the Japan International Cooperation Agency (1983). The ages for the volcanic rocks and their associates are considered to be Upper Permian-Lower Triassic.

Cenozoic volcanic rocks

Cenozoic basaltic rocks (lava flows with minor plugs and pyroclastic rocks) occur as small flows scattering in the Trat and Chanthaburi areas, in the Bo Phloi area (Kanchanaburi), along the southern boundary of the Khorat Plateau, along the western edge of the Khorat Plateau, in the Denchai (Phrae), Lampang, Mae Lama (Mae Hong Son), Ban Chiang Khian (near Thoeng, Chiang Rai), an Chiang Khong area (Chiang Rai). No basaltic rock has been reported in the Thai Peninsula. The basaltic rocks in Thailand are of particular interest since they are a source of gem-quality corundum. The compilation of zircon fission track data and K-Ar data by Barr and MacDonald (1981) and paleomagnetic data (Haile and Tarling, 1973; Barr et al., 1976) indicate that the ages of these basaltic rocks are Late Cenozoic.

Reconnaissance geochemical studies of the Late Cenozoic basaltic rocks were carried out by Vichit et al. (1978) and Barr and MacDonald (1978). They categorized the rocks into 2 series, viz. tholeiitic and alkalic. Nearly all basaltic rocks are of alkalic affinities except for the basaltic rocks from Thoeng (Chiang Rai). Barr and MacDonald (1978) further divided the rocks of alkalic series into basanitoid basalts (including nephelinite, basanite, nepheline hawaiite and nepheline mugearite) and hawaiitic basalts (including alkaline olivine basalt,hawaiite and mugearite). Corundum appears to associate with the basanitoid basalts which contain peridotite nodules and megacrysts of sanidine, anorthoclase, black spinel, aluminous clinopyroxene, garnet, zircon, ilmenite and magnetite. Vichit et al. (1978) concluded that corundum might have crystallized from differentiated basaltic magma at pressures less than 12 kb (?). On the contrary, corundum was interpreted by Barr and MacDonald (1978) as the high-pressure cognate megacrysts. In 1981, Barr and MacDonald collected the petrochemical data of Late Cenozoic basaltic rocks in South-east Asia. They recognized some more tholeiitic rocks from Khok Samrong (Lopburi), from southern part of the Khorat Plateau (as a minor rock type)

and from southwest of Mae Sariang (Mae Hong Son). They considered the late Cenozoic basaltic rocks as a typical continental basaltic province in a region of comple tectonic interactions.

Detailed petrochemical studies were conducted on basalts from some certain area. Barr and MacDonald (1979) divided the Denchai basalts along the Denchai-Sukhothai highway into seven flows. Their compositions range from transitional hawaiite to tholeiite (the lower parts consisting of flows 1, 2, 3 and 4) to true hawaiite (flows 5 and 6) and then to basanite (flow 7, the uppermost flow). However, the geochemical data of a single basaltic flow of the Denchai basalts at km 76 Lampang-Denchai highway can be correlated with those 1 to 6 flows (Panjasawatwong, 1983). The fresh samples with sporadic zeolites appear to be tholeiites of calc-alkalic series. The appearance of hawaiites is due to the subsequent process called zeolitization. In the same manner, the basaltic rocks at km 567.5 Pahonyothin highway between Lampang and Sop Prap, which were previously classified by Vichit et al. (1978) as strongly alkaline basalts and by Barr and MacDonald (1981) as hawaiite, are basaltic andesite of calc-alkalic affinities (Panjasawatwong and Yaowanoiyothin, in preparation). The parental magma of the basaltic andesites might be calc-alkali tholeiite produced by partial melting of the pyrolite mantle under high water pressure at depths of about 70-100 km. Subsequent eclogite or amphibolite or olivine fractionation would lead the tholeiite to basaltic andesite.

Other detailed petrochemical studies were done on the basalts of Saphan Hin area, Chanthaburi (Sirinawin, 1981), the Ban Nong Bon area, Trat (Sirinawin, loc. cit.) and the Bo Phloi area, Kanchanaburi (Yaemniyom, 1982). At Saphan Hin, the basaltic rocks are about 40 meter-thick and consist of 2 main units. The lower unit is made up of pillow lavas and hyaloclastites while the upper unit comprise massive and vesicular basalts. Their chemical compositions appear to be hawaiitic. The hawaiites were postulated to be low-pressure differentiated products of alkali-olivine basalt magma produced by partial melting (5-20%) of mantle peridotite at depths equivalents to pressures of 15-18 kilobars. The Nong Bon basalts are about 30 m thick and are classified as differentiated olivine nephelinites. They contain abundant ultramafic nodules and megacrysts of clinopyroxene, garnet, ilmenite and magnetite including corundum. The parental magma for the differentiated olivine nephelinites might be originated by low-degree partial fusion of peridotite mantle at pressures of 20-25 kilobars. Subsequently, suppression of clinopyroxene at pressures slightly higher than 20 kilobars gave rise to the differentiated olivine nephelinites. Corundum might be picked up from the mantle at a depth corresponding to the pressure of approximately 20 kilobars or a little higher. The Bo Phloi basalts are chemically classified as nepheline hawaiite with slightly high K_2O content. They contain paridotite nodules and megacrysts of clinopyroxene, black spinel and sanidine. The genesis of nepheline hawaiites were depicted that the magma might be generated at pressures of 18-25 kilobars and ascended rapidly with a minor effect of crystal fractionation. The corundum found in the Bo Phloi area was considered to be originated

with other megacrysts in the basalts.

In the thesis of Bunopas (1981), neither rhyolitic rock nor andesitic rock was included in Cenozoic volcanic rocks. However, Thanasuthipitak (1978) included andesite, rhyolite and tuff in the Lam Narai region as Cenozoic volcanic rocks according to the presence of vitric tuff with well-preserved glass and rhyolite flow overlying semiconsolidated sediments. Such a volcanic suite is also found in the Ko Chang area, south of Trat. At present, detailed studies in the region of Lam Narai carried out by the Geological Survey Division, Department of Mineral Resources are still in progress (Jingyusuk and Sirinawin, personal communication).

REFERENCES

Aiumpiya, N., Aimwattana, K. and Setsathien, T., 1982, Geology of Ban Mae On, San Kampaeng, Chiang Mai, Thailand: Rept. submitted to the Department of Geological Sciences, Chiang Mai University as part of the requirement for B.S. degree in geology.

Barr, S.M. and MacDonald, A.S., Haile, N.S. and Reynolds, P.H., 1976, Palaeomagnetism and age of the Lampang basalt (Northern Thailand) and age of the underlying pebble tools: J. Geol. Soc. Thailand, v. 2, no. 1 and 2, p. 1-10.

Barr, S.M. and MacDonald, A.S., 1978, Geochemistry and petrogenesis of Late Cenozoic alkaline basalts of Thailand: Geol. Soc. Malaysia Bull., no. 10, p. 25-52.

_____, 1979, Palaeomagnetism, age and geochemistry of the Denchai basalt, Northern Thailand: Earth Planet. Sci. Lett., v. 46, p. 113-124.

_____, 1981, Geochemistry and geochronology of Late Cenozoic basalts of Southeast Asia: Geol. Soc. Am. Bull., v. 92, p. 1069-1142.

Bunopas, S., 1981, Paleogeographic history of western Thailand and adjacent parts of South-East Asia - A plate tectonics interpretation: Ph.D. Thesis, Victoria University of Wellington, New Zealand, 810 p; reprinted 1982, Geological Survey Paper no. 5, Geological Survey Division, Department of Mineral Resources, Thailand.

Chantaramee, S., Panjasawatwong, Y. and Lerdthusnee, S., 1980, Geology of the Mae Chang Reservoir Area: Rept. submitted to Electricity Generating Authority of Thailand.

German Geological Mission in Thailand, 1972, Final report: Bundesanstaltfur Bodenforschung, Hannover.

Haile, N.S. and Tarling, D.H., 1973, Note on the reversed magnetism of young Cenozoic basalts near Lampang, Northern Thailand: Paper presented at the Conference on the Geology of Thailand, Department of Geological Sciences, Chiang Mai University, Chiang Mai. Dec. 5-9, Published in Spec. Publ. no. 1, v.2, Department of Geological Sciences, Chiang Mai University, 1976 p. 67-73.

Japan International Cooperation Agency, 1983, The San Kampaeng Geothermal Development Project in the Kingdom of Thailand: Interim Report.

Leow, N. and Wannakasem, S., 1976, Geology of Khao Wong, Amphoe Klang, Changwat Chanthaburi, Thailand: Rept. submitted to the Department of Geological Sciences, Chiang Mai University as part of the requirement for B.S. degree in geology. nent for B.S. degree in geology.

MacDonald, A.S. and Barr, S.M., 1978, Tectonic significance of a Late Carboniferous volcanic arc in Northern Thailand: In P. Nutalaya (ed.), Proceedings of the Third Regional Conference on Geology and Mineral Resources of Southeast Asia, p. 151-156.

Nutalaya, P., 1973, Igneous rocks of Thailand: Paper presented at the Conference on the Geology of Thailand, Department of Geological Sciences, Chiang Mai University, Chiang Mai. Dec. 5-9, Published in Spec. Publ. no. 1, v. 1, Department of Geological Sciences, Chiang Mai University, 1975, p. 143-154.

Ounchanum, P., 1977, Geology and mineral deposits of the Khao Sammun area, Changwat Petchabun and Nakhon Sawan, Thailand: M.S. Thesis submitted to the Department of Geological Sciences, Chiang Mai University.

Panjasawatwong, Y., 1983, Chemical variation within a single basalt flow at Denchai, Phrae: Paper presented at the Annual Technical Meeting, Department of Geological Sciences, Chiang Mai University, Chiang Mai. Feb. 1-2, in press.

Panjasawatwong, Y., Kongkiatnatee, S., Kuttikun, P. and Thongcharoenkiat, P., in preparation, Petrochemical classification of rocks at km 43-44 Lampang-Denchai highway, northern Thailand.

Panjasawatwong, Y. and Yaowanoiyothin, W., in preparation, Major-element geochemistry of a syenite sample from Chanthaburi.

_____, in preparation, Petrochemistry of basaltic rocks at km 567.5 Pahonyothin highway, northern Thailand.

Sirinawin, T., 1981, Geochemistry and genetic significance of gem-bearing basalt in Chanthaburi-Trat area: M.S. Thesis submitted to the Department of Geological Sciences, Chiang Mai University.

Tansathien, V. and Muenlek, S., 1981, Excursion guide on the geology of Lampang-Denchai highway.

Thanasuthipitak, T., 1978, A review of igneous rocks of Thailand: In P. Nutalaya (ed.), Proceedings of the Third Regional Conference on Geology and Mineral Resources of Southeast Asia, p. 775-782.

Vichit, P., Vudhichativanich, S. and Hansawek, R., 1978, The distribution and some characteristics of corundum-bearing basalt in Thailand: J. Geol. Soc. Thailand, v. 3, p. M4 1-38.

Yaemniyom, N., 1982, The petrochemical study of corundum-bearing basalts at Bo Phloi District, Kanchanaburi: M.S. Thesis submitted to the Department of Geology, Chulalongkorn University.