EXCURSION GUIDE BOOK

CHIANG MAI
THAILAND

PREPARED FOR
62nd CCOP STEERING COMMITTEE MEETING
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at 62nd CCOP STEERING COMMITTEE MEETING

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Message from Director General, Department of Mineral Resources (DMR)

On behalf of the host country and as the permanent representative of Thailand to CCOP, I am delighted to have an opportunity to welcome all of you who can participate this post 62^{nd} CCOP Steering Committee Meeting excursion to Fang District, Chiang Mai Province. The excursion route runs through one of the key areas of geological importance of the country. As the third highest mountain in Thailand (peak at 2275 m ASL), Doi Luang Chiang Dao and its famous Chiang Dao Cave are examples of interesting sites attracting a large number of tourists annually. Sedimentary rocks of Carboniferous – Permian, e.g., chert and limestone, are underlain by basaltic rocks of older age. One can also find fascinating sites to visit in term of geology, i.e., petroleum, hydrothermal activity and geohazards, and the communities of local and minority groups that can live in harmony with nature. Fang District is famous for the petroleum production facility own by the Defense Energy Department, with current research and development focusing on Coal Bed Methane. General public can learn and enjoy their visit at Fang Hot Spring recreation area located in Doi Pha Hom Pok National Park. Hydrothermal energy has been used for electrical generating for the use of agricultural purpose. Furthermore, participants would enjoy staying at Doi Ang Khang, where the first Royal Project of the country is situated.

With this special field excursion prepared by DMR staff in cooperation with CCOP Technical Secretariat, I am confident that all participants would gain knowledge and, at the same time, enjoy your visit to all interesting sites arranged for this exucrsion. I would like to thank all DMR staff for their hard work on organizing the trip as well as preparing this excursion guidebook. I would also like to apologize for the inconvenience, if there any, that some participants may face during the excursion.

Finally, I wish all of you best of luck and have a good time and a safe trip.

(Mr. Praneet Roibang)

Director General, Royal Thai Department of Mineral Resources

Permanent Representative of Thailand to CCOP.

Message from Director, CCOP Technical Secretariat

The 62nd CCOP Stering Committee Meeting may not be completed without this post-meeting excursion. The trip provides participants a rare opportunity to explore this part of Thailand where the importance of geology has integrated with the way of living of the local communities. Most importantly, the excursion offers examples of key issues, which are, community based geohazards (landslide and debris flash flooding) along Mae Ngon tributary; and the Coal Bed Methane project at Fang Oilfield, Defense Energy Department. These issues have been currently implementing into CCOP's New Initiatives. This excursion would provide all participants the opportunity to learn more about these two issues, as well as to further comment and discuss on the matters. This activity may provide positive input to the better implementation of relevant CCOP's New Initiatives.

Finally, I would like to express my sincere appreciation to DMR for their great support and contribution to the hosting of 62nd SC CCOP Meeting and the arrangement of this post-meeting excursion. I wish all of the participants a successful excursion with good memory and impression of Chiang Mai, Thailand.

(Dr. Adichat Surinkum)

Director, CCOP Technical Secretariat Office

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Excursion Programme

62nd CCOP Steering Committee Meeting

Wednesday 5th March 2014

08.00	Depart from Imperial Mae Ping Hotel, Chiang Mai
10.30	**STOP 1:** Visit The First Royal Factory at "Fang The Museum", impacted area from debris flows.
11.30	Leaving for Ban Din Lao Jang restaurant.
11.45	Lunch at Ban Din Lao Jang restaurant.
12.45	Leaving for the Fang Hot Springs.
13:15	**STOP 2:** Visit Fang Hot Springs and Fang geothermal power plant.
14.15	Leaving for "Museum and Learning Center for Knowledge of Petroleum Defense Energy Department".
14.30	**STOP 3:** Visit "Museum and Learning Center for Knowledge of Petroleum Defense Energy Department" and "Defense Energy Department Coal Bed Methane Project (DED CBM Project)".
16.30	Leaving for Doi Ang Khang.
19.00	Farewell dinner/Overnight at Angkhang Nature Resort, Doi Ang Khang.

Thursday 6th March 2014

08.00-13.00	Sightseeing at "Angkhang Royal Agricultural Station Project", established by King Bhumibol to help tribal people, seeing the agricultural knowledge center, beautiful flowers and bonsai gardens alongside fruits, vegetables and herb gardens.
13.00	Leaving for Chiang Mai City.
17.00	Arrival at Chiang Mai City/Overnight at Imperial Mae Ping Hotel.

End of Excursion

General information of Chiang Mai

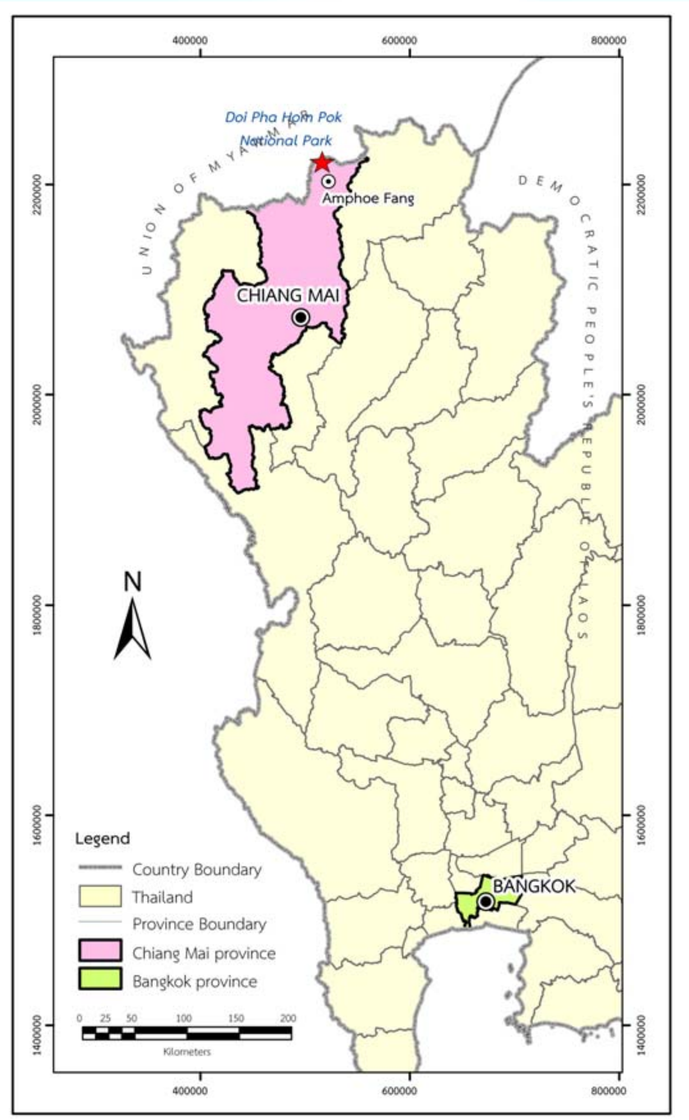
Chiang Mai is the largest and most culturally significant city in northern Thailand. It is located approximately 700 km (435 mi) north of Bangkok, among the highest mountains in the country. The city is along the Ping River, a major tributary of the Chao Phraya River.

History

"Chiang Mai" was a capital of the Lanna Kingdom after its founding in 1296, during the same period of time as the establishment of the Sukhothai Kingdom. From then, Chiang Mai became the capital and cultural core of the Lanna Kingdom, the first capital of Thailand. Chiang Mai had also been the centre of Buddhism in northern Thailand and King Meng Rai built innumerable temples.

In 1599 the kingdom lost its independence and became part of the Ayutthaya Kingdom, the second capital of Thailand. This ended the dynasty founded by King Meng Rai which had lasted for 300 years. The Burmese occupiers, had a powerful Burmese influence on the architecture which can still be seen today.

In 1932 Chiang Mai province became the second level subdivision of Thailand when the administrative unit of *Monthon Phayap*, the remains of the Lanna Kingdom, was dissolved.



The figure shows location of Bangkok and Chiang Mai province.

Local Culture

The north of Thailand's culture is Lanna in origin and the people are very proud of their northern roots. The region is home to distinctly different food, music, arts, way of life and even language. Chiang Mai is also a melting pot of hill tribes and their own unique cultures.

Events and Festivals

Bo Sang Umbrella Festival is normally held in January at Bo Sang Handicraft Centre. The festival features paper products, paper parasols in particular, cultural shows, a parade showing traditional ways of life, and several contests.

Flower Festival is held in February. The festival includes ornamental garden flower contests, floral floats parade in the morning and beauty pageants. The parade begins at Chiang Mai Railway Station and passes Nawarat Bridge and ends at Nong Buak Hat Park.

Songkran Festival is held annually from 13 to 15 April. The 13th of April is the Great Songkran day featuring the revered Phra Phuttha Sihing Buddha image parade around Chiang Mai town for bathing, sand pagoda forming, blessing of elders, and water splashing.

Doi Suthep Pilgrimage, The worshippers gather to light candles and make the 7-kilometre pilgrimage up to Doi Suthep Temple, on the night of Visakha Bucha Day.

City Pillar Inthakin Festival is held to invoke blessings of peace, happiness and prosperity for the city and its residents. Buddha images are paraded around the city. It is held at Wat Chedi Luang for 7 auspicious days and nights in the 7th lunar month.

Yi Peng Festival is held annually on Loy Krathong day. The festival features the release of lanterns into the sky to worship the gods. There are also fireworks, lantern contests, and beauty pageants.

Song Kran Festival

Yi Peng Festival

Umbrella handicraft

Wat Prathat Doi Suthep

The photographs above show events and festivals related to Lanna culture.

General Geology

Tectonic province in northern Thailand confined in the belt 1 to belt 5 of the Shan-Thai terrane (Bunopas and Vella, 1992). The terrane consists of rocks ranging in age from Precambrian to Quaternary where the oldest rocks of Precambrian age exposed in the western part and rocks become younger towards the east and extending in N-S direction.

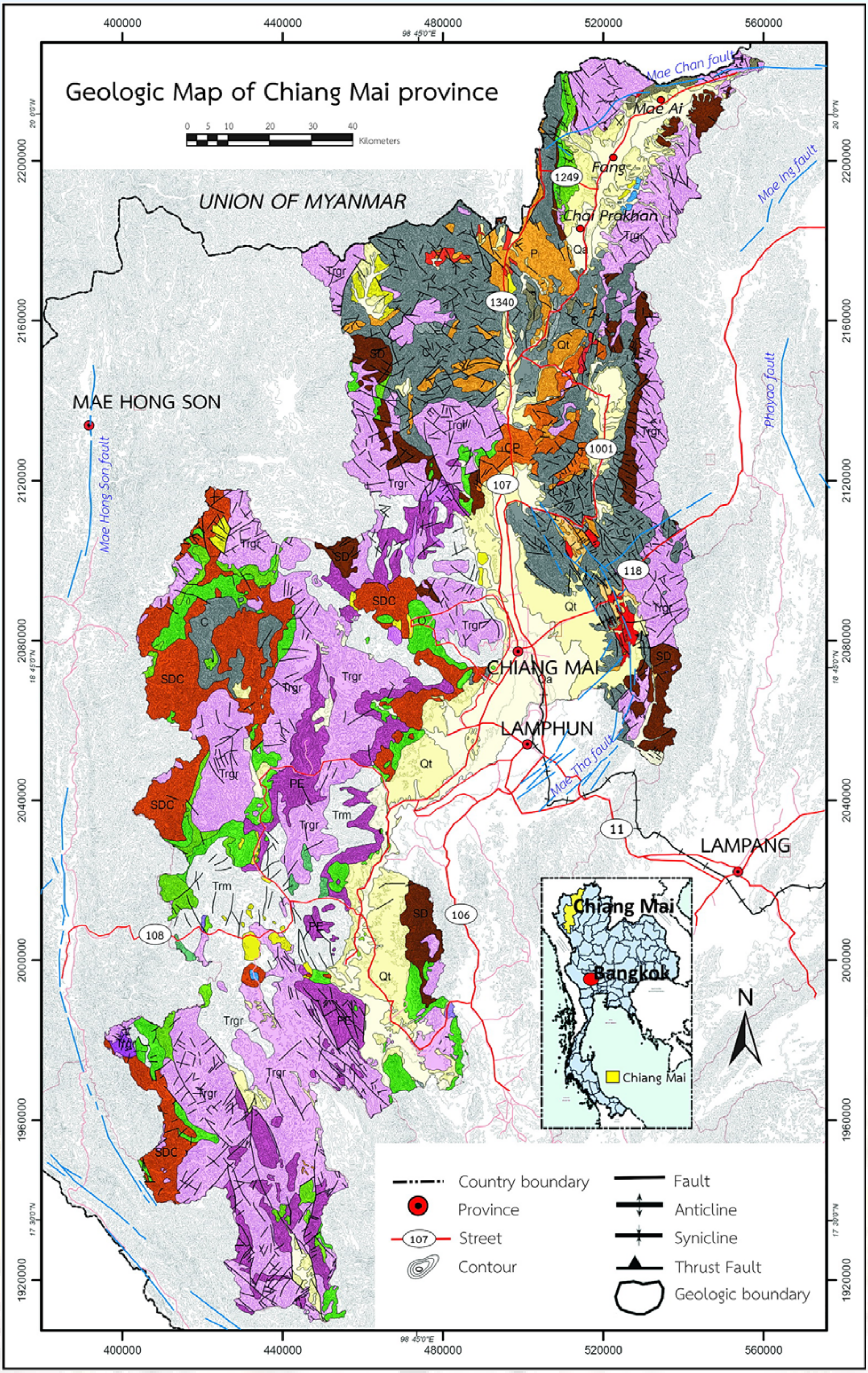
The Precambrian rocks, inferred to high-grade metamorphic rocks of amphibolite facies, expose in western part of the Chiangmai province, are unconformably overlain by the Lower Paleozoic rocks. The whole sequences of the Paleozoic rocks are mainly of marine origin. A siliciclastic carbonate shelf developed on the western and central Thailand whereas the volcanic island arc developed on the central Thailand.

The Mesozoic sequence can be lithologically subdivided into two main facies, namely, the marine and the continental facies. The marine Triassic and Jurassic sequences are restricted to the long narrow fault-bounded basins. The younger continental Mesozoic rocks are composed of the Jurassic and Cretaceous red beds and evaporites covering most of the Khorat Plateau. The Cenozoic rocks are entirely terrestrial siliciclastics with the associated hydrocarbons deposited in the extensional Tertiary and Quaternary basins both onshore and offshore (Bunopas, 1981; 1983; 1992 Suensilpong and Putthapiban, 1979; Mantajit, 1997).

The oldest igneous rocks are volcanic rocks and volcanogenic sediments mainly of andesitic and rhyolitic, stratigraphically dated Silurian to Devonian. These rocks expose due to westward subduction beneath the Shan-Thai terrane and lie to the east of the known Precambrian rocks. The volcanic rocks distribute in central north Thailand and age range until Middle Permain-Early Triassic. Rb-Sr whole-rock isochron data indicated that there were four periods of granite magmatism. i.e. Early Triassic, Late Triassic, Early Cretaceous and Late Cretaceous, These granites (including granodiorite and diorite) can be divided into three belts lying N-S direction (Nakapadungrat and Putthapiban, 1992) but only two belts exposed in northern Thailand. *The Central Belt Granites* occur as major batholiths and large complex plutons of mainly Triassic age and disclose S-type affinity. *The Western Belt Granites* comprise a mixed population of S-type and I-type, indicate Cretaceous. The S-type granites occur as large batholiths whereas I-type granites occur as small plutons. The Indian-Eurasia collision during the Cenozoic caused tensional faulting which indicated by widespread fields of late Tertiary and early Quaternary alkaline basalts in Thailand and Indochina (Bunopas, 1981; Mitchell, 1981; Gatinsky, 1986; Peltzer and Tapponnier, 1988; Bunopas and Vella, 1983, 1992).

There are four major fault zones located in northern Thailand (Chaturongkawanich, 1995,). The micro-earthquake study indicated that the northern Thailand is active. Shallow earthquakes of depth 30-40 kilometers have been detected weekly or even daily (EGAT, 1980; Nutalaya et al., 1985). These fault zones play an important role in taking hot fluid percolated beneath the earth and circulated upward to the surface.

1. **Mae Chan fault zone**: This fault zone is roughly E-W trending strike-slip fault extend about 150 meters (Geotermica, 1984; Chaturongkawanich, 1995). The fault is sinistral movement cutting through Triassic granites and connecting two structural depression of Fang and Mae Chan
2. **Mae Sariang fault zone**: The regional N-S fault separates the western boundary of the Western Mountain range recent uplift, extends approximately 200 kilometers. This tectonic lineament corresponds to a depressed area and cutting through Mesozoic and Paleozoic rock units.
3. **Mae Tha fault zone**: This fault envisages as semicircular structure appeared in air-photo map with approximate length 150 kilometers. The fault cut through the mesozoic rocks and Triassic granites.
4. **Phrae fault zone**: This fault lies in NE-SW direction extented approximately 200 kilometers. The fault cut through Paleozoic to Mesozoic rocks and Permo-Triassic volcanic rocks.



The figure shows Geological map of Chiang Mai province.

EXPLANATION

SEDIMENTARY ROCKS AND METAMORPHIC ROCKS		GEOLOGIC TIME
Qa	Alluvium deposit: gravel, sand, silt and clay	QUATERNARY
Qt	Terrace deposits: gravel, sand, silt and laterite	
T	Semi-consolidate rock, claystone, siltstone; locally lignite	CENOZOIC
K	Sandstone, claystone	MESOZOIC
J	Conglomerate, sandstone, interbedded with shale and claystone	
TrJ	Conglomerate, sandstone, reddish brown, intercalated with shale and claystone	
Trn	Migmatite, unclassified granite, gneiss, schist, quartzite, sandstone	
Tr2	Shale, chert, thin-bedded; limestone	
P	Limestone, dolomitic limestone, chert lens and layers	PERMIAN
CP	Sandstone, argillaceous limestone, shale, chert	CARBONIFEROUS - PERMIAN
C2	Phyllitic conglomerate, phyllite, tuffaceous sandstone	CARBONIFEROUS
C1	Conglomerate, sandstone, shale, slate, chert, limestone	
DC	Chert, tuff, shale, volcanic rocks, mostly are metamorphose	DEVONIAN - CARBONIFEROUS
SDC	Shale, chert, siltstone, calcareous; limestone	SILURIAN - DEVONIAN - CARBONIFEROUS
SD	Phyllite, carbonatic phyllite, silicified phyllite	SILURIAN - DEVONIAN
O	Argillaceous limestone, limestone, dolomitic limestone, marble, interbedded with shale, silty sand	ORDOVICIAN
EO	Marble, quartz mica schist	CAMBRIAN - ORDOVICIAN
E	Quartzite, ortho-quartzite, sandstone, calcareous shale	CAMBRIAN
PE	Amphibolites, schist, quartzite, marble, calc-silicate, migmatite, pegmatite	PRECAMBRIAN

IGNEOUS ROCKS		
Trgr	Biotite granite, tourmaline granite, granodiorite, biotite-muscovite granite	TRIASSIC
Ptrv	Rhyolite, andesite, tuff, volcanic breccia, rhyolitic tuff, andesitic tuff	PERMIAN - TRIASSIC
Cgr	Granite, cataclasite	CARBONIFEROUS
Cb	Basic rocks, quartz grabbro	
DCv	Basalt, tuff	DEVONIAN - CARBONIFEROUS
	Geologic boundary	

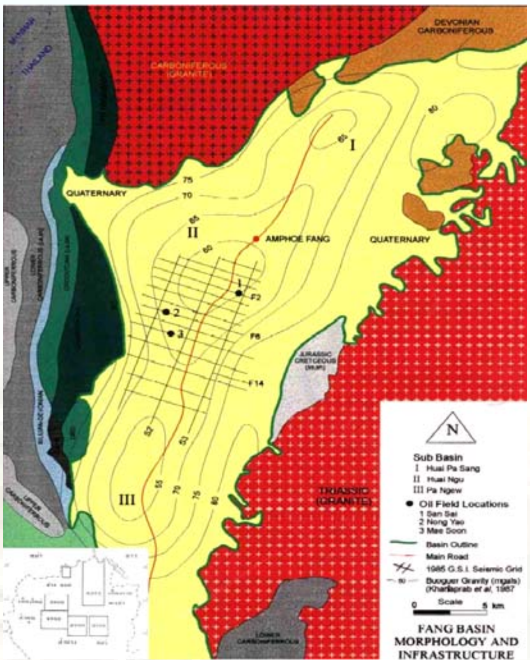
Regional geology of the Fang basin

Fang basin is a small intermountain Tertiary basin with relatively narrow width. Topography of the Fang basin is generally flat to slightly rolling with the average attitude of the central plain of the basin about 480 meters ASL. The basin is bounded by a steep, rugged mountain ranges of somewhat lower elevation than those along the boundary of the basin located on the east (Chinabutr, 1987).

The sedimentary rocks in the Fang basin are of Paleozoic to Holocene in age. The highland range to the west of the basin is composed of Paleozoic rocks of various ages ranging from Cambrian to Permian. There are both clastic and carbonate rocks, slightly to intensively metamorphosed. The degree of metamorphism appears to depend mainly on their extended structural deformation. In the lower part of the western margin of the Fang basin, there are intercalations of shale, phyllite, talcose schist, quartzite, sandstone, shale and recrystalline limestone. These rocks lay on the north south trend as several parallel strips in decreasing chonological order westwardly. The Paleozoic rocks are emplaced by foliated granite of Carboniferous age. These granite rocks appear in the form of small stocks and also dike-like bodies (Kaewsang, 1987).

The southern part of the basin is bordered by Permian limestone and clastic rocks as well as mafic volcanic rocks of Carboniferous age (Kaewsang, 1987).

The northwestern convex side of the basin is bordered by the Carboniferous foliated granite which emplaced into the Paleozoic rocks as batholith. Further north, the basin is bordered by Devonian-Carboniferous rocks with some Carboniferous mafic vocalnic rocks, and Triassic granite-granodiorite porphyry (Kaewsang, 1987). The eastern concave side of the basin is bordered by the Jurassic continental deposits which lie nonconformably on the Triassic granite-granodiorite porphyry. The basal units are gray arkosic sandstones and conglomeratic grits which grade upwardly into well-bedded, medium-grained sandstone intercalated with red and gray.



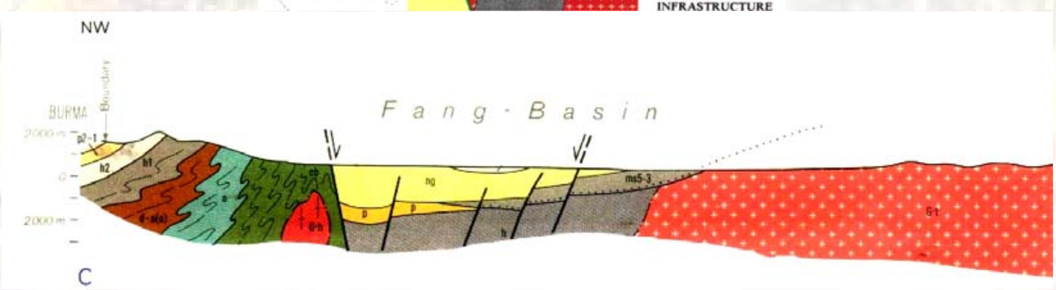
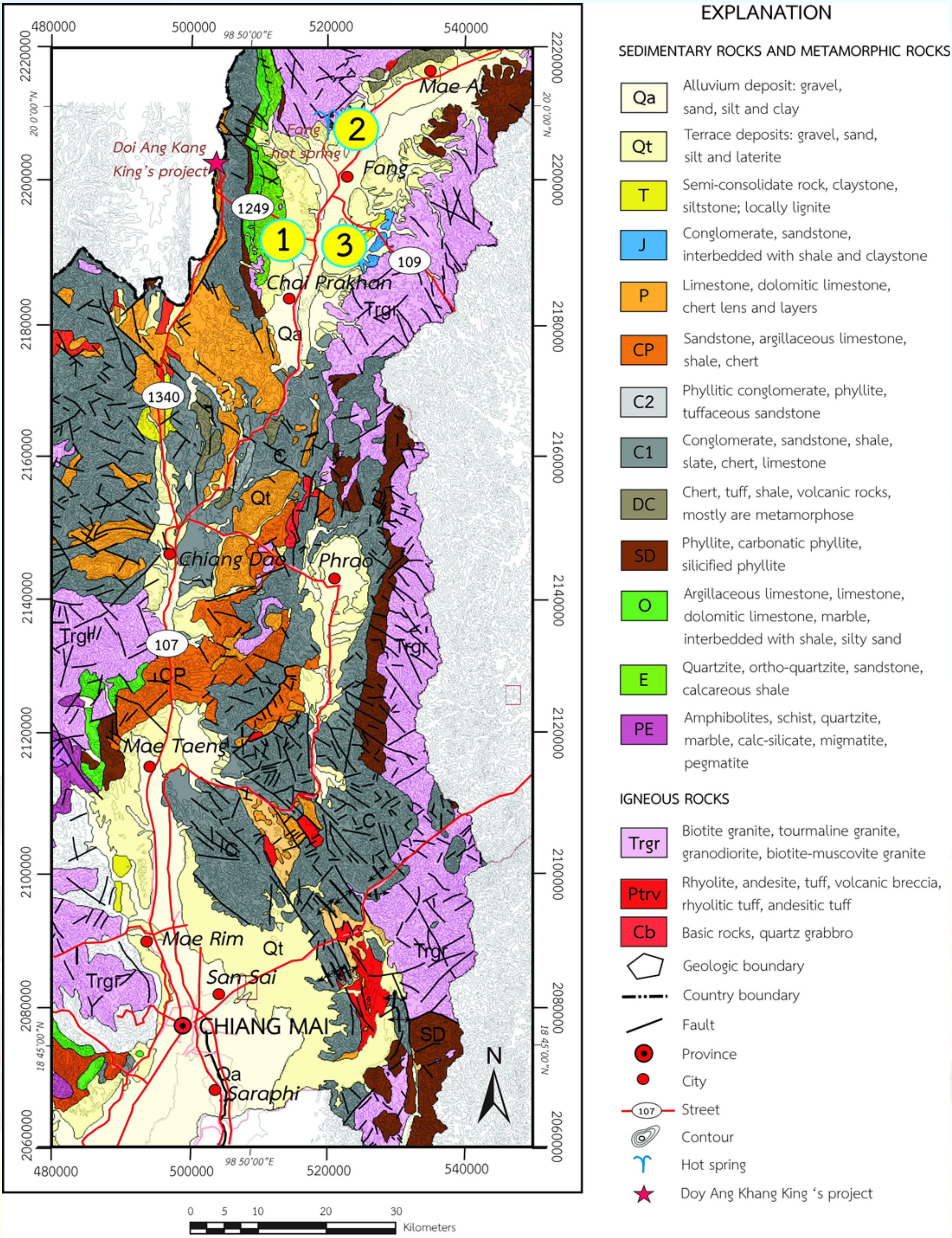


Figure shows Schematic east-west cross section of the Fang basin (Khantaprab, 1987).



The figure shows simplified geology along the excursion route (Modified from DMR, 2007). Number 1, 2 and 3 represent number of stops for this field excursion.

STOP 1

The First Royal Factory at Fang The Museum

Location : Thambon Mae Ngon, Amphoe Fang, Chiang Mai Province

Highlight : Living site museum and geological hazard site

1. Living site museum

This is a platform for leaning according to the royal thought of His Majesty the King for holistic and sustainable country development in form of a living site museum with the contexts of agriculture, environmental conservation, and various culture and traditions. The site museum consists of exhibition building, The First Royal Factory At Fang The museum, Ban Yang community and website.

Exhibition Building

Inside the building is concealed with an idea of construction design reflecting lifestyle of community together with energy saving. It has the exhibition related to the integrated solution according to the royal thought of His Majesty the King in economic, social and environmental problems on the highland of northern region.

The Royal Factory

It is a model of agro-industrial processing plant, which is environment-friendly and community-friendly. There is also a restaurant called "Jin Sun" providing service of foods and drinks to tourists in standard price and quality.

Ban Yang Community

Ban Yang Community is a village surrounded by mountains. The visitors will gain an experience on the way of lives of the community which is a variety of ethics, cultures and religions and warm welcome of people in village.

The photographs show the building and exhibitions inside "The First Royal Factory At Fang The Museum".

2. Geological Hazard Event

Geological hazard in this area is land slide. Land slide is a geological phenomenon which includes a wide range of ground movements, such as rock falls, deep failure of slopes and shallow debris flows. Although gravity acting on an over steepened slope is the primary reason for a landslide, there are other contributing factors affecting the original slope stability by rainfall, geological factors, morphological factors, physical factors and factors associated with human activity.

Debris Flows at Ban Yang

During the night of October 8th, 2006, a deluge of debris flows from the mountains caught the people of Ban Yang unaware. The debris flows carried countless of big rocks, trees and roots that caused seven deaths and damaged over 100 homes. Particularly, the first Royal Food Factory (Fang), suffered a great loss as it was situated at the upper end of the communities where the full impact of the debris flows was felt. For the most part, the factory's infrastructures as well as machineries were beyond repaired. It was the worst disaster ever to be experienced by the employees and staff of the first Royal Food Factory (Fang) and the entire Ban Yang community as a whole.

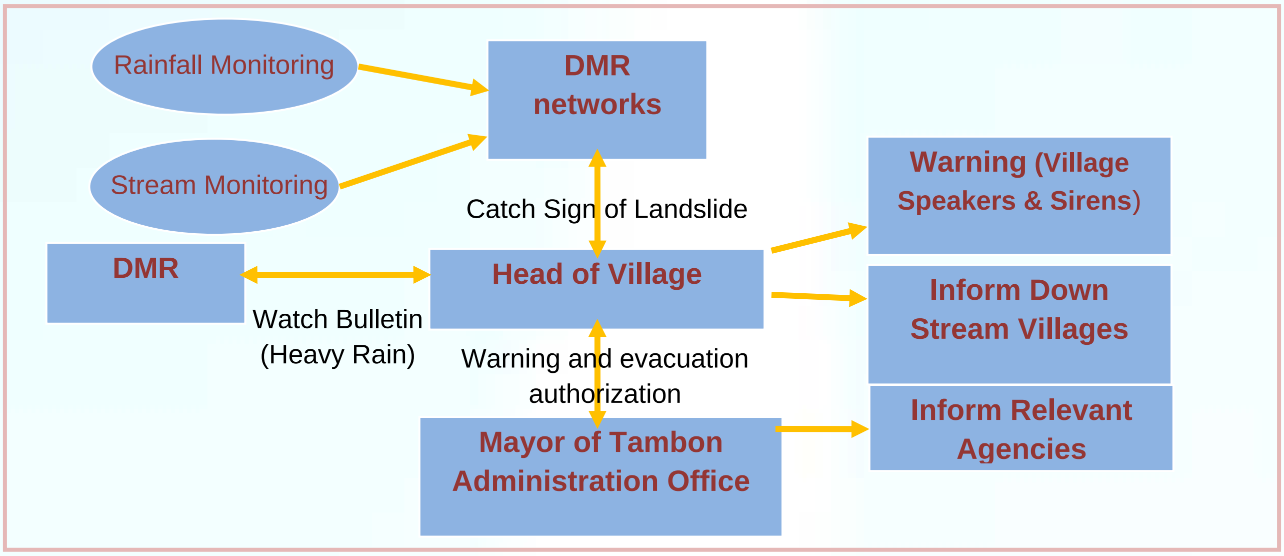
The figure shows buildings of the first Royal Food Factory, were destroyed by debris flows at Ban Yang in October 8th 2006.

Land Slide Mitigation

Department of Mineral Resources (DMR) is responsible for geohazards management, which also includes landslide mitigation. Therefore landslide mitigation measurements have been conducted via many projects.

DMR has been started landslide hazard mapping project in 2001 by using predictive model which runs under Geographic Information System (GIS) and launched the landslide risk mapping in community level in scale 1:10,000. The project was conducted in high landslide risk areas of 70 tambons or subdistricts in 17 provinces in northern and southern parts. In the mapping the areas where prone to be affected by landslide are delineated and rechecked by geologist in field. The map is valuable for local administration offices in planning for landslide disaster management. To raise capacity building in communities the landslide watch network training courses have been conducted since 2003. The local people have been trained to have basically knowledge in landslide behavior, landslide signs, watch, warning, and evacuation. Presently, there are 61 local volunteers working to protect their villages in Fang district.

In critical condition, the networks will be supported weather and landslide information by the Geohazards Operation Center of DMR because the center can access data and information from multi agencies and digests them to be ease data then sends them to the networks. The center is also working as the landslide focal point coordination. Incase landslide, tension crack and soil creep occurs in some areas and the villagers fear not safe DMR will sent urgent team to investigate and to recommend how to prevent and mitigate the impact.



The flowchart shows the community – based landslide watch network.

STOP 2

Fang Hot Springs and Fang Geothermal Power Plant

Location : Thambon Ban Pin, Amphoe Fang, Chiang Mai Province

Highlight : Fang Hot Springs and Fang geothermal power plant

1.Fang Hot Spring

Fang is situated approximately 140 kilometers north of Chiang Mai province and located between latitude of 19° 54′ N to 20° 02′ N and longitude of 99° 06′ E to 99° 14′ E. It covers the area of 1,561 km^2. The landscape consists of Fang basin and mountainous area in western part.

Fang can be accessed by road. From Chiang Mai province by a highway number 107. The major districts along the way are Amphoe Mae Rim, Amphoe Mae Taeng, Amphoe Chiang Dao, Subamphoe Chai prakarn and Amphoe Fang.

Fang Geothermal Field

The Fang geothermal field is in a map sheet 4848 IV of topographic map scale 1:50,000. The area is covered by Carboniferous granite in the north, Precambrian gneiss and schist in the northwest, Lower Carboniferous limestone in the west and Middle-Upper Carboniferous sandstone in the east and west.

Generally, high mountain ranges lie approximately in the N-S and NNW-SSE directions on northern side of the hot springs. The highest altitude of the mountain ranges is 1,231 meters ASL at Doi Khun Chai.

The figure shows hot spring characteristic in the Fang Geothermal field.

The working group has conducted geophysical, geochemical, hydrological explorations and shallow drilling wells since 1977. The explorations predicted that there was sufficient potential to install a 300 kW pilot geothermal power plant. A joint technical cooperation project between the BRGM, Geowatt, Agency for Energy Management (AFME) of France and the EGAT was formulated during 1981-1984. The purposes are to model geothermal reservoir and to appraise geothermal enthalpy targeting for electrical generation (EGAT, 1998).

Geology of Fang Hot Spring Area

The hot spring area is geologically underlain by the oldest Precambrian to the youngest Quaternary alluvial deposits. There are Precambrian gneiss to Carboniferous sedimentary rocks, two granite plutons aged Carboniferous and Triassic and Volcanic rocks extruded as sill in the lower Carboniferous limestone (Chaturongkawanich et al., 1980; Lerdthusnee et al., 1990).

Precambrian rocks: occur in a high mountain range of Doi Liam and extend to the north and the west of Huai Mae Chai. They are bounded by two normal fault named Doi Kia and Mae Chai faults and another thrust fault. The rocks are moderate to high graded metamorphism and can be classified into three units: quartz biotite gneiss; quartz biotite schist; and calc-silicate units.

Cambrian rocks: occur along the high mountain ranges of Doi Khun Mae Chai in the northwest. They are bounded by Mae Mao fault and thrust fault. The rocks comprised fine to coarse-grained quartzite interbedded with quartzo-feldspathic schist and quartz mica schist.

Lower Carboniferous rocks: exposed on the southwest of the hot spring manifestation and were previously dated as Ordovician by Chaturongkawanich, et al (1980). They are composed of thick bedded to massive limestone, partly recrystallized with plenty of calcite veins. This rock is aged by Mrs. Chanya Chamnongthai using fossil content (in Lerdthusnee et al., 1990).

Middle-Upper Carboniferous rocks: exposed about one third of the mapped area and were previously dated as Sirulian-Devonian by Chaturongkawanich, et al (1980). They are composed of quartzitic sandstone with yellowish brown shale at lower stratigraphic sequence and graded to Lower Carboniferous limestone. The upper stratigraphic sequence comprised yellowish brown shale and black slaty shale or phyllite.

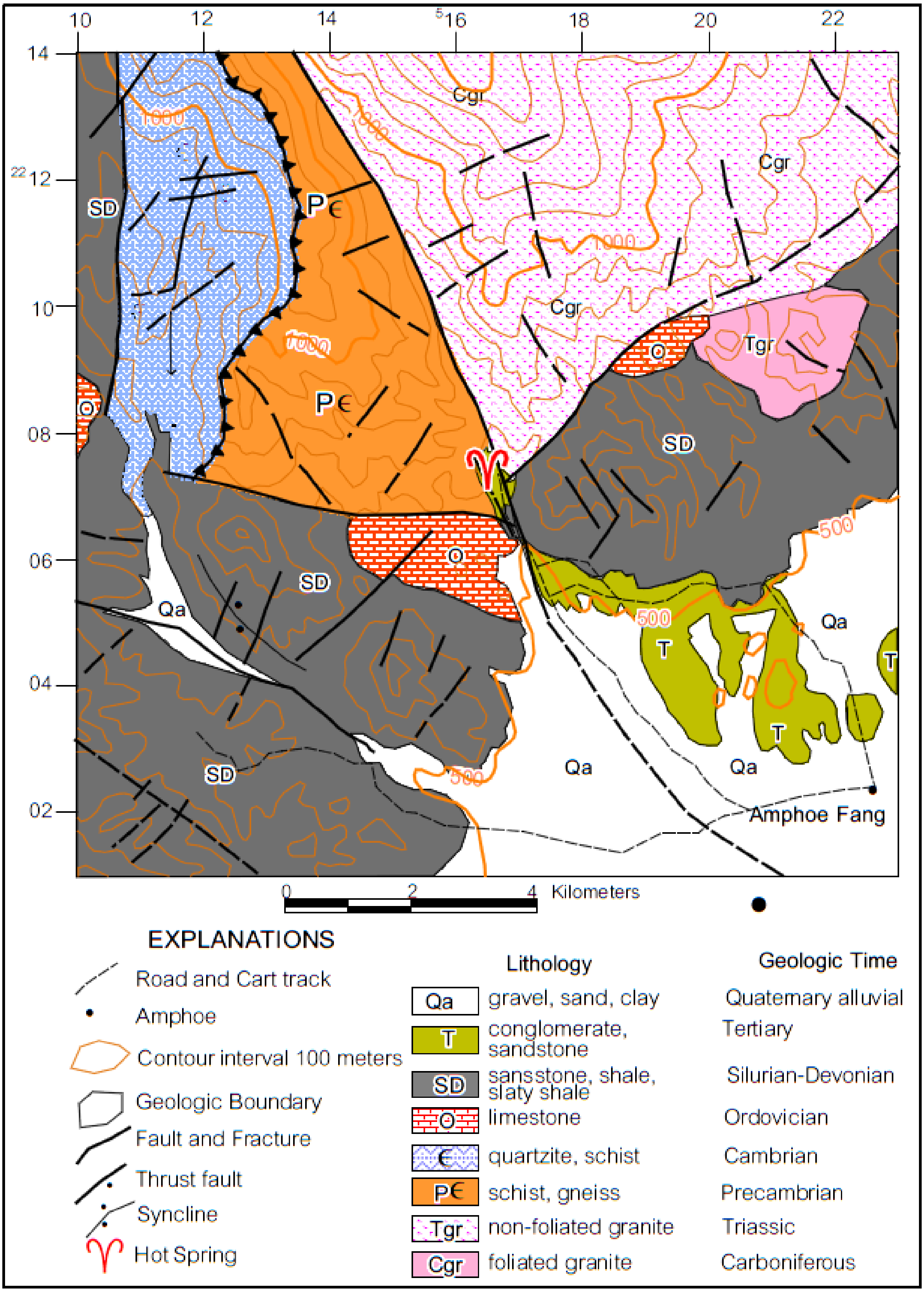
Tertiary rocks: exposed to the south of the hot spring manifestation. They are composed of gray semiconsolidated conglomerate with pebble of quartz or chert, yellow to light gray semiconsolidated sandstone with quartz grains and pale brown semiconsolidated siltstone. All of them are cemented by clays and were altered from feldspar.

Quaternary: distributed along floodplain of Nam Mae Chai, Nam Mae Mao, Huai Hian and Huai Bon at altitude approximately 480 to 550 meters above mean sea level.

Carboniferous granite: recognized as foliated or stress granite. It is gray to dark gray medium to coarse grain, composed of quartz, feldspar, biotite, muscovite and sericite. The general trend of the foliation is about north-south direction with low to moderate inclination angles dominantly in the east direction.

Triassic granite: cropped out at northeastern part of the hot springs. It is composed of biotite-muscovite porphyritic granite and leucogranite.

Chaturongkawanich et al. (1980) proposed that there are three major faults "Mae Chai fault, Doi Kia fault and Thrust fault" occurred at the study area. The thrust fault between the Precambrian and the Cambrian rocks is considered to be the oldest one. Lerdthusnee et al. (1990) suggested that Doi Kia and Mae Chai faults were caused by tectonic movement. During Tertiary, this fault was considered to be a left lateral strike-slip fault with horizontal displacement of a few tens of kilometers. Mae Chai fault is a normal fault that cuts across Doi Kia fault near the hot spring area.

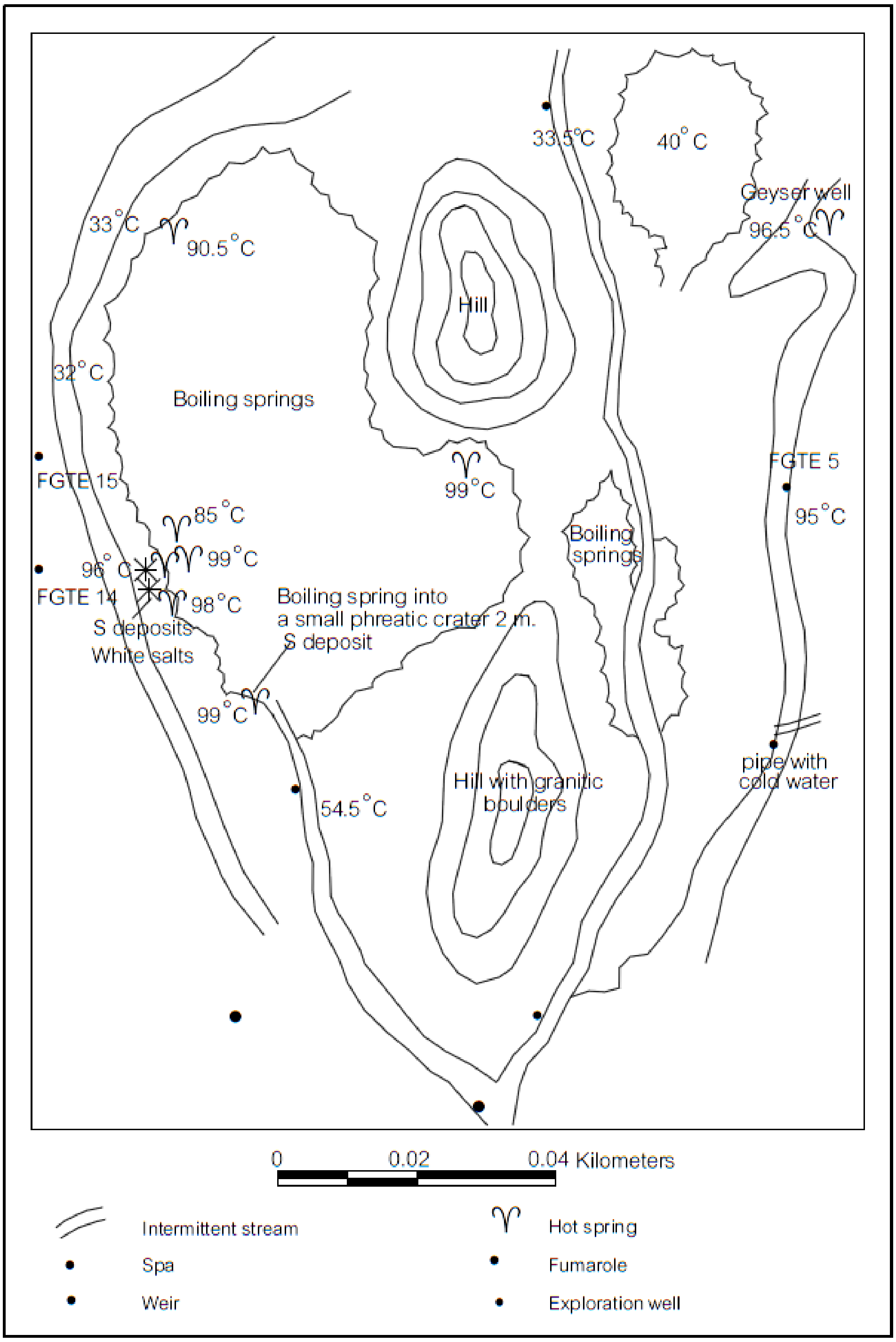


The figure shows Geological map of the Fang Geothermal field, Chiang Mai province (modified from Chaturongkawanich et al., 1980).

Hot Springs

Fang hot springs occur near Huai Mae Chai valley, cover area about 60,000 square meters. There are more than one hundred of sprouting pools and seepage pools manifested in a partly dissected terrace of foliated granite boulder and quartz veins. Diameter of pool sizes is varied from smallest 5 centimeter to the largest 1 meter. Most of the springs are hot-pool type, bubbling out at regular intervals provided surface temperature higher than 90°C. Some hot springs are shooting out 15-30 centimeters above surface at intervals of 15-45 seconds. Flow rate measured at weir is 22.4 liters/second (Geotermica, 1984).

At present, The Electric Generating Authority of Thailand has developed the resources for multipurpose utilizations.

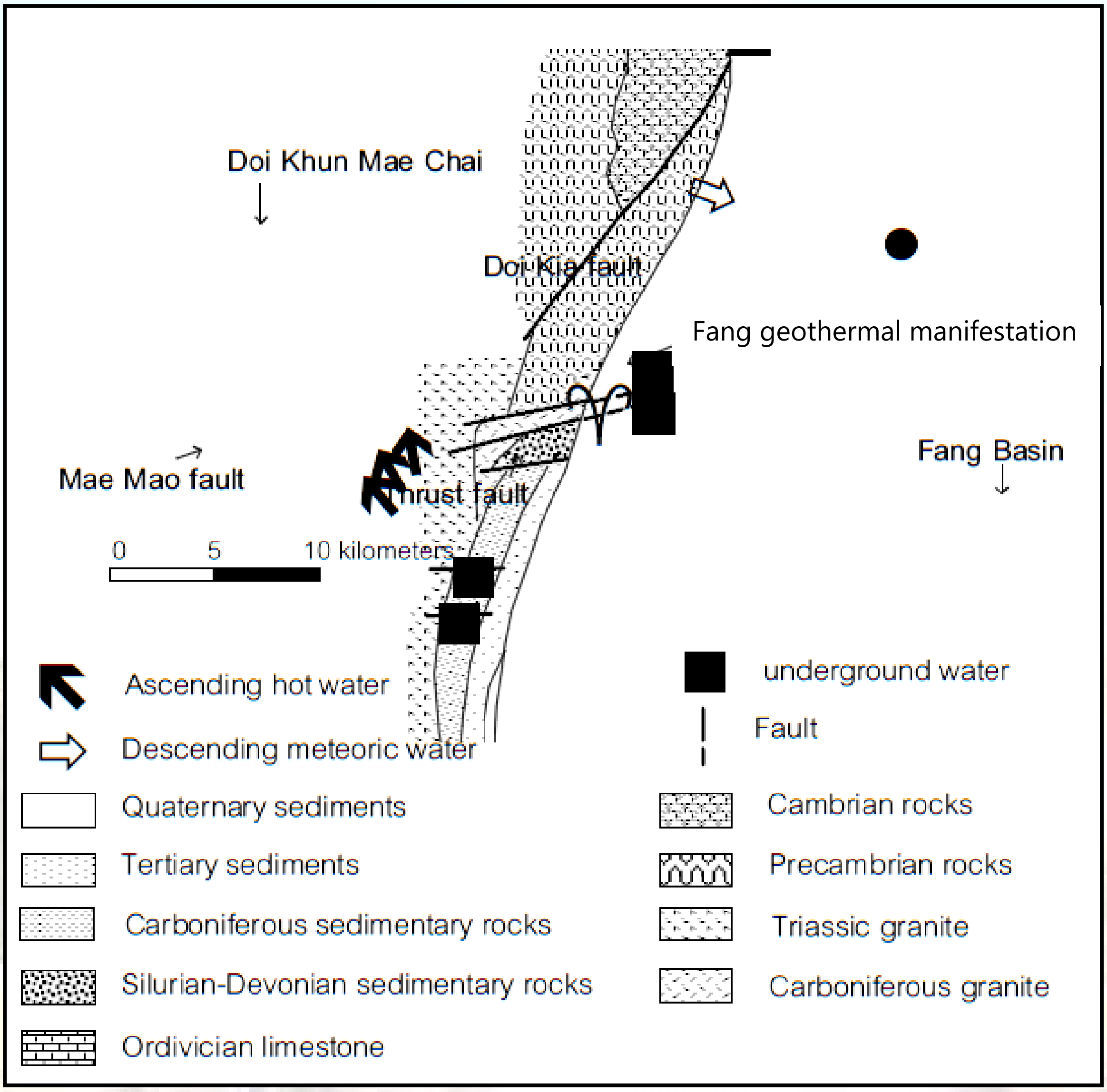


The figure shows hot spring manifestation occurs at the Fang Geothermal field, Chiang Mai province. (modified from Geotermica, 1984).

Geochemical Characteristic of thermal water

Thermal water of the Fang geothermal field characterized as sulphur deposit and hydrogen. The water is clear, colorless and expressed high concentration of bicarbonate, Na, F, SiO_2, TDS contents and high pH (7.25 - 9). It is suggested that source of the hydrothermal solution is likely to depend upon neither magmatic fluid nor connate water.
Ratanasathien et al (1985) studied isotope hydrogeochemistry analysis of three isotopic elements: oxygen-18, deuterium and tritium. They anticipated that the thermal fluid is very young and probably has been derived from local precipitation, possibly from somewhere higher altitudes before being heated up and discharged as hot springs. In addition, a seasonal fluctuation in concentration of some chemical species in thermal water such as Na, K, Ca and bicarbonate species has been observed, suggesting that the Fang geothermal system represented a secondary reservoir.

Water samples were collected and analyzed by many workers both from hot springs and drilled holes. Subsurface temperature estimated by water chemical geothermometer ranges between 130 - 190 °C.



The figure shows geothermal reservoir model of Fang geothermal field, Chiang Mai province (modified from Geotermica, 1984).

Geothermal Reservoir Model

Chaturonkawanich, et al. (1980) indicated the heat source possibilities of the Fang geothermal field derived from deep magma chamber, frictional heat along fracture plane and decay of radioactive elements in the granitic rocks. The secondary reservoir should be in the granitic rocks or the Upper Paleozoic sedimentary rocks.

Hochstein (1987) suggested that the Fang geothermal reservoir was a fracture reservoir. The main feeder fracture zone trends approximately in a N-S direction and has been intersected by drill holes at shallow depth (less than 100 meters). Narkswasdi (1990) applied 2-D natural state simulation model of the Fang Geothermal reservoir. The study disclosed that permeability in the eastern part of the production zone was quite large ragning between 10-100 millidarcy, but the size of the reservoir was small and recirculation of convecting fluids were not found in the model.

Utilization

A joint technical cooperation project between Bureau de Recherches Géologiques et Minières (BRGM), Geowatt of France and Electricity Generating Authority of Thailand (EGAT) was formulated during 1981-1984. Purposes are to model geothermal reservoir and to appraise geothermal enthalpy targeting for electrical generation. The study anticipated that the geothermal field could be capable of installing a pilot electricity plant of no less than 120 kW, using binary cycle system technology.

1. Electric generation: The first geothermal power plant in Thailand and the first binary cycle in geothermal plant in Southeast Asia was installed and completed in December 1989. The inlet vaporizer temperature, flew through the air released tank, varies between 115°C to 120°C and inlet pressure is 4.5 bar. Temperature of hot water released from vaporizer outlet is approximately 80°C (Korjedee and Prasatkhetwittaya, 1997). The thermal water released from the power plant are very clean, thus are planned to be exploited downstream for non-electrical utilizations and will be discussed later. Output from the 300 kW generator is connected to the local distribution grid system of the Provincial Electricity Authority (PEA) and is provided 1.2 million kWhr annually to the grid.

Fang is one of the predominantly agricultural producing areas in the Chiang Mai province. After harvesting, many crops can be stored at room temperature for a short period of time and a large proportion of these crops have to throw away due to sprouting. Major cultivation is garlic, onion, rice, lichee, chili, tobacco potato, soybean, maize, cotton, etc. The geothermal energy released from the binary power plant can be exploited at downstream for agricultural-industrial and so on.

Concepts to extract the released thermal water for agricultural-industrial utilization are considered into two categories.

2. Drying process: Faculty of Engineer at Chiang Mai University, incorporated with the Mae Cho Agricultural Technology Institute and the EGAT, had collaborated in the extraction of the geothermal energy for tobacco curing and drying agricultural products in 1986. The first pilot drying house had been constructed at the GTE-6 well in the San Kamphaeng geothermal field. Experiment for curing and drying tobacco, banana, chili, garlic, maize, peanut etc. shows satisfactory results compared to an old drying style using firewood and lignite. At present, the government enterprise encourages local community to renovate there pre-existing drying houses to accommodate the use of geothermal energy.

At the Fang geothermal field, two drying houses have been built and experiments have been performed on chili and tea. Thermal water released from the binary cycle power plant with the temperature of 77°C, is fed to the process. Charge rate for drying chili which takes 3 days, is 1.20 baht per one kilogram. Fresh chili weight will reduce 70%, e.g. ,from 100 kg. of fresh chilli, down to 30 kg. of dry chili.

3. Cooling storage room process: Hypothesis of this research, technically and economically consideration, is to extract energy of the released thermal water to develop a cool storage. The project, using the absorption refrigeration system, commenced in 1988. The pilot cool storage room, with a dimension of 3x4x2.2 meters could store 5 tons of agricultural products, was insulated by polystyrene. The cooling capacity was 24,000 btu/hr and provided cool temperature at 4°C. Agricultural products used in the experiment were lemon, onion and lichee. The periodical evaluation of the system performance indicated that spoliation of the products has been decreased to only 8.2% loss of lemon and 10% loss of lichee within one month. The large cooling storage approximately 2,000,000 btu/hr is designed and planned to construct at the Fang geothermal field in the near future.

Down stream utilization of thermal water released from the drying and the cooling storage room is piping to recreational bathing and medical therapy. The released thermal water contains an average temperature higher than 40°C, is suitable for therapeutic bathing. Many private sectors as well as local communities express their interests in promoting hot spring water for the touring places sites. Hot spring bathing in a prestigious spa, usually offered at expensive hotels, is one of the best alluring commercial in Thailand.

Finally, parts of the lukewarm water is sent through natural stream to provide extra recharge of surface water for crop cultivation.

2. Fang Geothermal Power Plant

The Fang Geothermal Power Plant is located at Mon Pin in the Fang District of Chiang Mai Province. To reach the site, one must travel from Chiang Mai, 150 km. on Chiang Mai-Fang Highway No.107 through a mountainous area, then turn left heading west on a side road for 10 km. The power plant is located in an area abounding with hot springs and hot pools.

Survey

To determine the potential of geothermal energy resources, surveys at San Kampaeng and at Fang, Chiang Mai province have been in progress since 1978; these surveys being made by the Electricity Generating Authority of Thailand (EGAT) in cooperation with the Department of Mineral Resources (DMR) and Chiang Mai University (CMU).

From the initial surveys at Fang, it was determined that there was a sufficient potential to justify the installation of a pilot geothermal power plant. Studies were therefore commenced in 1981, in collaboration with the French Environment and Energy Management Agency (ADEME), formerly known of French Agency fo Energy Management (AFME), of France, to determine the size and type of powerplant that should be developed. This resuted in selection of a 300 kW binary cycle power plant for shallow reservoir utilization.

Installation

Installation of this plant commenced in January 1989, with commissioning during December 1989. This is the first geothermal power plant in Thailand and the first binary cycle geothermal plant in South-East Asia.

Plant Operation

The energy source for the binary cycle system is hot water from wells reaching approximately 100 metres below ground surface into a shallow hot water reservoir (formed in fractured rock). The natural pressure in this subterranean reservoir provides a maximum water flow rate of 22 litres per second at a temperature of 130°C through these wells.

This hot water is passed through a vaporizer (heat exchanger) which transfers the heat to a low boiling point fluid to give a heat exchanger outlet pressure of 74 psia at a temperature of 87.7°C. This pressurized working fluid is then used to drive the turbine which is connected to the electrical generator. On discharge from the turbine, the working fluid is passed through a cooling condenser, the cooled working fluid is then being returned to the vaporizer. The cooling water for the condenser is obtained from a nearby stream which has a seasonal temperature variation of 15 C to 30 C and sufficient flow capacity to provide the maximum cooling water flow requirement of 94 litres per second.

The output from the 300kW generator is connected to the local distribution grid system of the Provincial Electricity Authority and will provide 1.2 million kWh annually to the grid

Additional Benefits

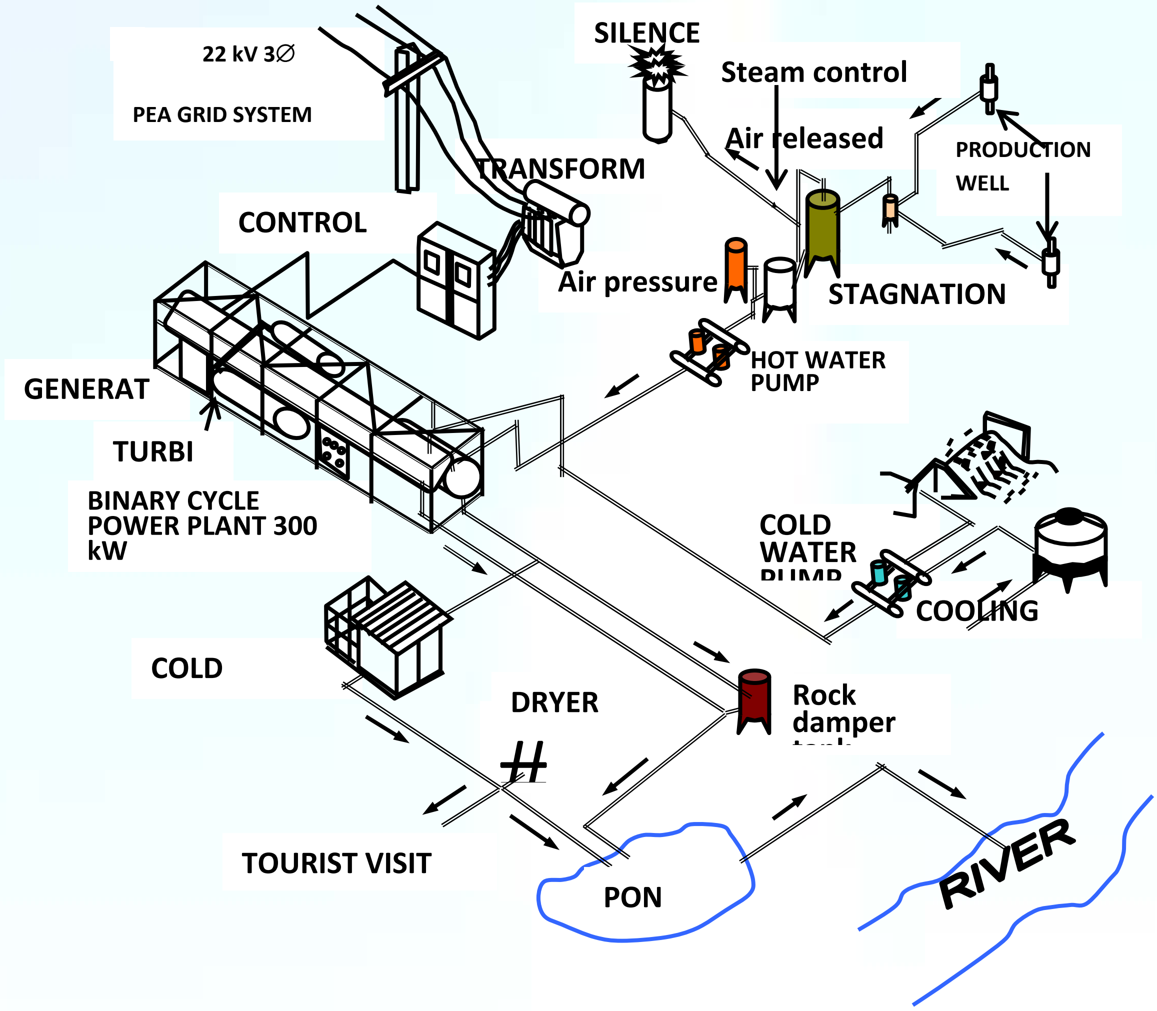
Entering the heat exchanger at 115°C, the hot water from the underground reservoir, which enters, looses a lot of its heat in the heat exchanger at a temperature of 77 °C. This water is discharged into a reservoir, giving an annual capacity of over 500,000 cubic meters that can be withdrawn for commercial and agricultural use.

Research, undertaken by Fang Horticultural Experiment Station and Chiang Mai University, has confirmed that the hot water can be used satisfactorily on a commercial basis for hot processing requirements, as required for drying unit, and for cold storage applications. By EGAT, hot water has been utilized for cold storage application and absorption air-conditioning system in the office. Hot water have also been used for agricultural developments. Besides, the Royal Forestry Department is proceeding with plans for hot water baths and other related tourist facilities

Future Development

Analyses of the data obtained from the operation of this pilot geothermal power plant, together with evaluation of the additional benefits which are obtained, will be utilized in the planning of future developments which are expected to be of considerable magnitude. In order to ensure maximum future benefits, additional knowledge of the extent and capacity of the geothermal field is required. To obtain this data, EGAT and ADEME have agreed to undertake a 5 years large scale project (1990-1995) to define the potential of Fang deep reservoir resources.

The figure shows 300kW binary cycle geothermal power plant.



This diagram demonstrates the 300 kW binary cycle power plant and downstream utilization at Fang geothermal field (modified from Korjedee and Prasatkhetwittaya, 1997).

STOP ❸

Museum and Learning Center for Knowledge of Petroleum Defense Energy Department and Defense Energy Department Coal Bed Methane Project (DED CBM Project)

Location : Tambon Maeka, Amphoe Fang, Chiang Mai Province

Highlight : Coal Bed Methane Extraction Site

1.Museum and Petroleum Learning Center

The refinery plant of Fang Oil Field was established in 1958 by the defense energy department, and the petroleum products are operated at Northern Petroleum Development Center (NPDC). The center's tasks cover all aspects of petroleum including the exploration, drilling, production and refining operations.

The museum and petroleum learning center is employed as a center of quality learning and training people to make use of petroleum and non-petroleum energy exhibition as well as to promote tourism around Fang district area. The museum is divided in to 5 zones covering the origins of petroleum, history of Fang oil field operation, production process and petroleum products, petroleum exploration and refining, energy statistics, and energy in the future.

The exhibition Zone 1 illustrates the geological description of how fossil energy in Thailand was created.

The exhibition Zone 2 presents the crude oil discovery in Fang basin.

The exhibition Zone 3 presents petroleum exploration, drilling processes, petroleum production, and petroleum refining in Fang basin and northern area of Thailand.

The exhibition Zone 4 illustrates the energy revolution in Thailand.

The exhibition Zone 5 presents the future trend of energy usage.

These photographs show the current exhibitions displayed in the museum and petroleum learning center.

2. Defense Energy Department Coal Bed Methane Project (DED CBM Project)

Development project of Coal Bed Methane for Fang basin is the beginning of Methane usage 's study. Other potential areas have been found in Chaiprakarn and Prao District, Chiang Mai, where potential Coal bed Methane should be explored and developed as Methane production of Defense Energy Department. This will benefit the military and the country as a whole.

Benefits of Methane

1. It fuels electric generator in order to provide light and run crude oil pump.
2. It fuels the official vehicles and distribute to private sector.
3. It is a resource for local agriculture and distribute to Northern industry.

Objectives of Methane Project

1. To proceed the Methane project at coal bed by using Hydraulic Fracturing method in order to increase the gas efficiency and quantity. The product will be used for the official vehicles and then distribute to private sector. With the cooperation between 7 departments as mentioned above, gas station in Amphur Fang will be established, or the product will be provided to PTT PLC's gas station in Chiang mai.

2. To produce Methane as a main product along with crude oil. This can increase revenue for Northern Petroleum Center of Defense Energy Department.

3. To promote the security of military's energy resource by distributing NGV gas to the army for their vehicles.

4. To reduce energy import and provide clean alternative energy resources.

Generate of Methane Theory

Methane is hydrocarbon compound that has the bond between hydrogen and carbon (CH_4). It generated by the changing of accumulated dead plants for a long time with the influence of increased temperature and pressure until it forms into a coal (Coalification Process). Bituminous is one of the coal type that collects the most methane.

Concept

The development of methane utilization from coal is one of the approaches that can reduce negative impact on environmental. Methane is relatively clean of the fuel can be used as the renewable energy. According to the survey and analysis of coal samples from the oil wells in Fang Basin, the accumulated coal bed that also contain methane is found in suitable depth to produce methane and that coal also contain methane. Therefore, Fang basin is a suitable site for the study and development of methane from coal (CBM).

History

Northern Petroleum Development Center of Defense Energy Department (NPDC-DED) is responsible for the areas covering six northern provinces for Petroleum exploration. From 1956, NPDC-DED began to produce crude oil, known as Fang Oil Field that was the first oil field in Thailand. More than 56 years, NPDC-DED has never stopped with the exploration and production of crude oil and learning geological data of Fang basin. So the coal that determined a good feature to collect methane was discovered in Fang basin or called CBM.

Subsequently, Northern Petroleum Development Center of Defense Energy Department conducted a research and analysis of CBM with Chiang Mai University (CMU). The satisfactory achievement the finding of the good coal source in Pong Sai Kum Field which was the good quality of Sub Bituminous and Bituminous. This coal source has been determined as a coal level that can provide maximum methane.

BPDC-DED has expanded the scope of operations and cooperated the technical agreement with Banpu Public Company Limited (Thailand) to interpret seismic data using three dimensional (3D Seismic). In conclusion, Fang basin contains a layer of CBM that spreads about 50 square kilometers. The calculated CBM reserves are approximately 2,396 million tons and natural gas (methane) reserves are about 38,000 billion cubic feet.

CBM Project

2006 : The beginning of CBM project in Fang basin through core analysis in Ban Rai Field, in cooperation with Department of Mineral Fuels and Chiang Mai University.

2007 : Studying and analyzing of the CBM core from Pong Sai Kum Field and Mea Pa Pai Field.

2008 : Cooperating with the Department of Mineral Fuels, Chiang Mai University and Banpu Public Company Limited on the study and analysis of data from CBM and methane characteristic.

2009-2010 : Studying, gathering and analyzing on CBM data in Fang basin.

2011 : Beginning the experiment on the use of methane from coal used to fuel the electric generator in FA-BT-44-05 well.

2012 : Beginning the experiment of methane from coal in Fang Basin to fuel a test car.

2013 : Fracturing one abandoned well (FA-BT-44-05) estimated potential gas flow, studied and optimized the methane from coal in Fang Basin.

The photograph shows coal bed methane production well and gas storage site of DED CBM Project.

Sightseeing

Angkhang Royal Agricultural Station Project

Sightseeing Program at Angkhang Royal Agricultural Station Project

07.00 - 09.30 Leave from the resort and walk through the Royal Project Angkhang or the Angkhang Agricultural Station from the resort to learn more about temperate Flowers House. This area is rich of fauna and flora and many kinds of plants. It is the center to distribute the products from the Royal Project. The garden exhibits long-lived bonsai. There is a hexagonal building and smallest orchid flowers that you can walk around to see several kinds of forest trees. Visitors can learn about the green tea factory have a taste of green tea of Angkhang. After that go to the center of learning of the Royal Project and walk through apricot and preach plantation to the English rose garden

09.30 - 12.00 Visit Baan Khob Dong School, the first primary school on Doi Angkhang, registered in 1983, It was established by the wishes of His Majesty the King. Meet Director and teacher of the Khob Dong School. Will tell visitors about the Riam Sing-Torn, outstanding teacher who has devoted herself for hill-tribes school. After that visit Black Muser Village and talk to Jamo Jana, Black Muser leader to learn about his way of life and community.

12.00 - 13.30 go to green tea plant and Lunch

The figure shows the spectacular view of green tea plantation and flower garden inside temperate house at Angkhang Royal Agricultural Station Project.

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APPENDIX

Geological Study of Oil Sand from Lower Mae Sot Formation, Fang Basin, Changwat Chiang Mai

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Abstract

This study concentrates on investigating the geochemical and petrological characteristics of oil sand in Mae Sot Formation, in Fang District, Chiang Mai province for assessing its potential as energy resource Oil sand geochemistry data can be used in correlation with oils produced from Fang basin. Data from this study will be useful for further s exploration planning in Fang basin.

Keywords: oil sand; Mae Sot Formation; Fang basin

1. Introduction

Over the past decade the petroleum industry has increasingly recognized that hydrocarbon production because of the industrial needs will continue to use energy from fossil fuel until new clean and economical energies can replace them. At the present time, the petroleum is increasingly used for many purposes. Most of the petroleum production in Thailand has been obtained from Tertiary basins. Therefore, numerous exploration programs have been planned and executed in these basins.

The Fang basin (Fig.1), one of the Tertiary basins, is located in the northern part of Chiang Mai province, Northern Thailand. There has been explorations and production of petroleum in the Fang basin for 53 years. . Although the petroleum reserve in this basin is not significant, increased production from this basin can help to decrease the petroleum imports in Thailand. Many countries have started to look for alternative energy sources, such as oil sand. More than 30 countries worldwide reported oil sands in their countries. The estimated value of oil sand reserve is much more than the conventional oil reserves known. However, the production of petroleum from oil sand being more complicated and difficult than conventional oil production, oil sand has been so far overlooked in Thailand. The Exploration and Production Division, Northern Petroleum Development Centre reported that oil sand is found Mae Sot Formation but there has been no detailed study of oil sand in the Fang basin.

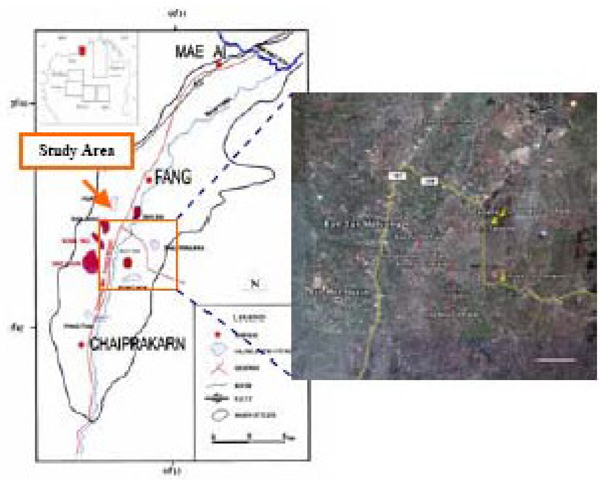

Figure 1: Study area, the Eastern of Fang basin, Changwat Chiang Mai, Thailand

2. Experimental Results and Discussion

The lithology and geochemical characteristics including detailed petrography of three oil sand samples and two crude oils from Fang Basin are described in this research paper. These characteristics from laboratory indicate that the oil sand can be devided into two units. (Fig.2)

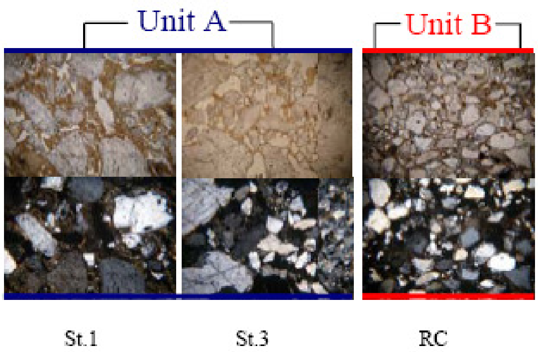

Figure 2: Petrographical characteristic of oil sand in Fang basin.

Unit A is dominated by very poorly sorted fine to coarse sandstone having about 90-92% quartz and about 8-10% rock fragments, with sub-angular to sub-rounded grains. Unit B sandstone consists of well -sorted fine to medium grained sandstone with subrounded to rounded grains having 93-95% quartz and 5-7% rock fragments. The porosity of Unit A is about 40% and the porosity of Unit B is about 30% of the rock volume (Fig.3).

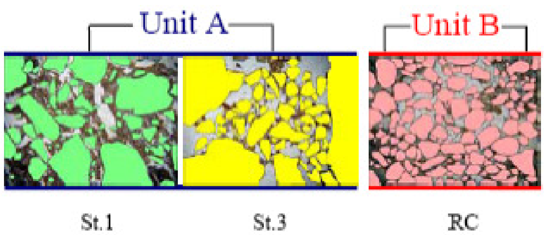

Figure 3: Determination of porosity using Arcview program.

In geochemistry laboratory, the bitumen from extracted oil sand and crude oil was separated using TLC method (Fig.4). After that, each fraction was analyzed by Gas Chromatography Mass Spectrometer (GC-MS) for understanding the geochemistry. Source rock of PN and BR crude oils were deposited under oxic condition with varying amount of terrestrial organic input. Source rocks for oils that seep into St.1 and St.3 oil sand were deposited under anoxic conditions. Source rocks for oils that seep into RC oil sand can be deposited under oxic conditions similar to those of PN and BR crude oil (shown by Pr/Ph ratios, Pr/*n*C17 and Ph/*n*C18 and Ts/(Ts+Tm) ratios).

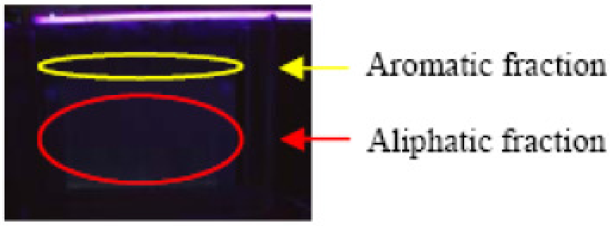

Figure 4: Thin layer chromatography method applied for hydrocarbon analysis.

3. Discussion and Conclusion

The depositional environments may be showing a change from lacustrine into floodplain and channels, characterized mainly by poorly sorted deposits of the Mae Fang Formation in Unit A and well-sorted deposits of Mae Sot Formation in Unit B. The high porosity value may have been caused by released feldspar grains.

4. Acknowledgement

This research could not have been accomplished without the assistance of PTT EP geologists, who gave very useful advice.

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The Doi Chiang Dao Limestone: Paleo-Tethyan Mid-oceanic Carbonates in the Inthanon Zone of North Thailand

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Abstract

The Doi Chiang Dao Limestone distributed in the Inthanon Zone of North Thailand represents mid-oceanic carbonates formed upon seamount (or oceanic plateau) bases in the Paleo-Tethys Ocean. It consists essentially of oceanic island basalt at the base and overlying thick, pure and massive carbonates that are essentially free from continental siliciclastic input. Shallow-marine microfacies such as bioclastic grainstone, ooid grainstone, oncoidal rudstone and bioclastic packstone, are dominant in the carbonates. The limestone records an almost continuous, Carboniferous-Permian foraminiferal faunal succession of a Paleo-Tethyan pelagic shallow-marine setting, ranging from the Visean (Mississippian/Early Carboniferous) to the Changhsingian (latest Permian) over approximately 90 m.y. Moreover, conodonts suggest that it could range up to the Dienerian (early Early Triassic) crossing the Permian-Triassic boundary. The Doi Chiang Dao Limestone is comparable in origin with huge carbonate bodies distributed in the Central zone of the Changning-Menglian Belt of West Yunnan, Southwest China and well-studied Panthalassan seamount carbonates (such as the Akiyoshi Limestone) found within accretionary complexes in the Japanese Islands. It is regarded as a unique medium recording long-term environmental and biotic changes in a Paleo-Tethyan mid-oceanic domain.

Keywords: Doi Chiang Dao Limestone, Inthanon Zone, mid-oceanic carbonates, North Thailand, Paleo-Tethys

1. Introduction

In recent studies, mainland Thailand is generally subdivided into four major geotectonic domains (Barr and Macdonald, 1991; Ueno, 1999, 2002, 2003; Ueno and Hisada, 1999; Sone and Metcalfe, 2008). They are, from east to west, the Indochina Block, Sukhothai Zone, Inthanon Zone and Sibumasu (or Shan-Thai) Block. Of them, the Inthanon Zone is bounded to the east with the Sukhothai Zone of a Permo-Triassic Island Arc system by the Chiang Rai Tectonic Line and to the west with the Sibumasu Block (proper) by the Mae Yuam Fault (Fig. 1). In most previous studies, the Inthanon Zone has often been regarded as a closed remnant of the Paleo-Tethys Ocean in Southeast Asia (e.g., Ueno, 1999; Sone and Metcalfe, 2008). As has been argued by Ueno (2002), however, the zone itself is now better interpreted as primarily belonging to the Sibumasu Block in a basic geotectonic context but widely exposing Paleo-Tethyan oceanic rocks as tectonic outliers upon Sibumasu basements. The Inthanon Zone, thus, forms a unique geotectonic domain in the eastern part of the Sibumasu Block in the wide sense in North Thailand, which essentially exhibits a “two-layered” geotectonic structure consisting of the lower Sibumasu basements and the upper tectonic slices (nappes) containing various kinds of Paleo-Tethyan oceanic rocks.

In the Inthanon Zone, there are two different kinds of mid-oceanic sedimentary rock units showing highly contrasted stratigraphic and paleontologic characteristics. The Fang Chert, ranging from the Early Devonian to the Middle Triassic, is regarded as representing pelagic deep-marine deposition in the Paleo-Tethys Ocean once existed in the Indochina and Sibumasu blocks (Sashida and Igo, 1999; Wonganan and Caridroit, 2005). The distributions and age-range of the Fang Chert are well-

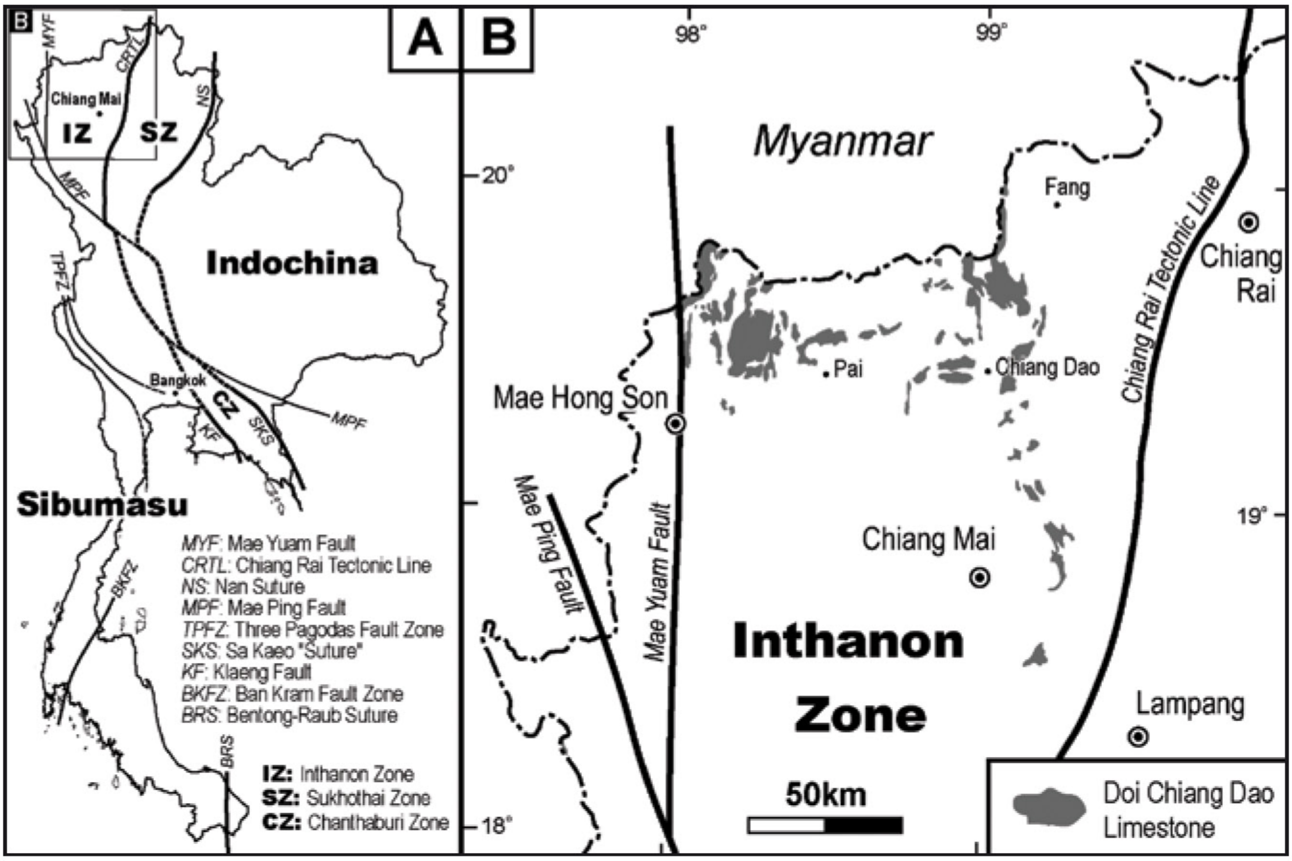

Figure 1 *Index map of Inthanon Zone in basic geotectonic subdivisions of Thailand (A) and distributions of Doi Chiang Dao Limestone in northern part of Inthanon Zone (B).*

known by a number of radiolarian studies (e.g., Sashida & Igo, 1999; Saesaengseerung et al., 2007). In contrast, the Doi Chiang Dao Limestone represents mid-oceanic shallow-marine deposition within the Paleo-Tethys Ocean. Foraminifers are the main fossil group from this limestone for establishing its chronostratigraphic framework (e.g., Vachard et al., 1992; Fontaine et al., 1993; Ueno and Igo, 1997). Stratigraphic and paleontologic study of the Doi Chiang Dao Limestone, however, has not been very progressed compared with that done in the Fang Chert.

In the last few years, we carried out systematic field survey mainly in the Chiang Dao area of Chiang Mai Province, North Thailand, to understand the foraminiferal faunal succession and to establish the detailed chronostratigraphic framework of the Doi Chiang Dao Limestone. In this paper, we review general stratigraphy of the Doi Chiang Dao Limestone with special references to its foraminiferal faunal succession and refer to its significance as Paleo-Tethyan mid-oceanic carbonates.

2. The Doi Chiang Dao Limestone

Prior to Fontaine et al. (1987), it has been little known that huge carbonate bodies of mainly Late Paleozoic ages, generally showing spectacular karst topography, are extensively distributed in northernmost Thailand such as the Pai and Soppong (Pangmapa) areas in the northern part of Mae Hong Son Province and the Wiang Haeng, Chai Prakan and Chiang Dao areas in the northern part of Chiang Mai Province (Fig. 1). Bunopas (1981) referred to some of the relevant large-scale carbonates in North Thailand as the "Pai and Doi Chiang Dao limestones" without any particular stratigraphic description. Following his volition, we call them the Doi Chiang Dao Limestone, named after Doi Chiang Dao (a 2194-m, huge karst mountain to the west of Amphoe Chiang Dao, consisting entirely of the Doi Chiang Dao Limestone: Fig. 2), one of the most typical and remarkable bodies of these huge carbonates.

The Doi Chiang Dao Limestone consists mostly of pale-gray massive limestone but partly more dark-colored

Figure 2 *Doi Chiang Dao west of Amphoe Chiang Dao, Chiang Mai Province, North Thailand.*

Figure 3 *Weathered basalt, partly showing pillow structure, exposed at Ban Sin Chai Tai about 40 km north of Amphoe Chiang Dao, Chiang Mai Province, North Thailand.*

and moderately bedded particularly in their lowermost part, with frequent dolomitic (or dolostone) levels and is essentially free from siliciclastic materials throughout thick successions. The total thickness is hard to measure due to its massive occurrence without good key horizons, still poor state of stratigraphic investigation compared with their rather extensive distributions over the wide areas of North Thailand and more practically physical difficulties to have proper geologic fieldwork in steep karst topography, but is at least more than 1000 m totally in rough estimation. These current conditions of research progress prevent to further subdivide such thick carbonate strata into lower lithostratigraphic units. Thus, we simply refer to them as a whole as the Doi Chiang Dao Limestone. The microfacies are generally dominant in bioclastic grainstone, ooid grainstone, oncoidal rudstone and bioclastic packstone with a minor amount of algal-coral-microbial boundstone, suggesting their open shallow-marine origin.

There are occurrences of pillow basalt in possibly the basal part of the carbonate succession at some localities in the Chiang Dao area (Fig. 3), although the very contact between the basalt and carbonate is not generally exposed. The basal basalt is probably Visean or slightly older judging from the age of just overlying carbonates (Fig. 4). It is also important to note here that, elsewhere in the Chiang Dao area, Phajuy et al. (2005) studied geochemistry of basalt that generally has a close association in the field with the Doi Chiang Dao Limestone. They concluded that some of the studied mafic volcanic rocks have an oceanic intra-plate affinity, implying that they had been originally formed as oceanic volcanic islands, although their Permian age assignment of the relevant basalt is highly equivocal.

3. Faunal succession

Various kinds of fossils, mostly foraminifers and minor corals, have been reported by some papers from the Doi Chiang Dao Limestone since the first documentations of fusulines and corals by Japanese students (Toriyama 1944; Minato 1944). These studies includes Konishi (1953), Hahn and Siebenhüner (1982), Caridroit et al. (1990), Vachard et al. (1992), Fontaine et al. (1993), Ueno and Igo (1997) and Fontaine et al. (2005). Our recent field investigations further supplemented foraminiferal faunal information from the Doi Chiang Dao Limestone, particularly for the Pennsylvanian (Upper Carboniferous) and Cisuralian (Lower Permian). Although the data are still fragmental from many isolated localities and/or small sections due to unfrequented, steep karst topography of these carbonates and heavy vegetation in the field, almost continuous Carboniferous-Permian foraminiferal faunas (mostly fusulines) have been recognized in the Doi Chiang Dao Limestone (Fig. 4). Paleobiogeographically, they have essentially paleo-tropical Tethyan affinities (Ueno and Igo 1997).

Very recently, Savage et al. (2006) reported an interesting conodont fauna from thin-bedded micritic limestone exposed at Ban Pang Ma Kong approximately 12 km northwest of Phrao in Chiang Mai Province. This conodont-bearing outcrop is isolated from surrounding strata but only few kilometers apart from a nearby massive carbonate body of the Doi Chiang Dao Limestone. The fauna consists of several species belonging to the Neospathodus dieneri group and is referable to the Dienerian of the early Early Triassic. Although the exact stratigraphic relationship between this Early Triassic bedded limestone and the Doi Chiang Dao Limestone proper is still being uncertain and their lithology is not

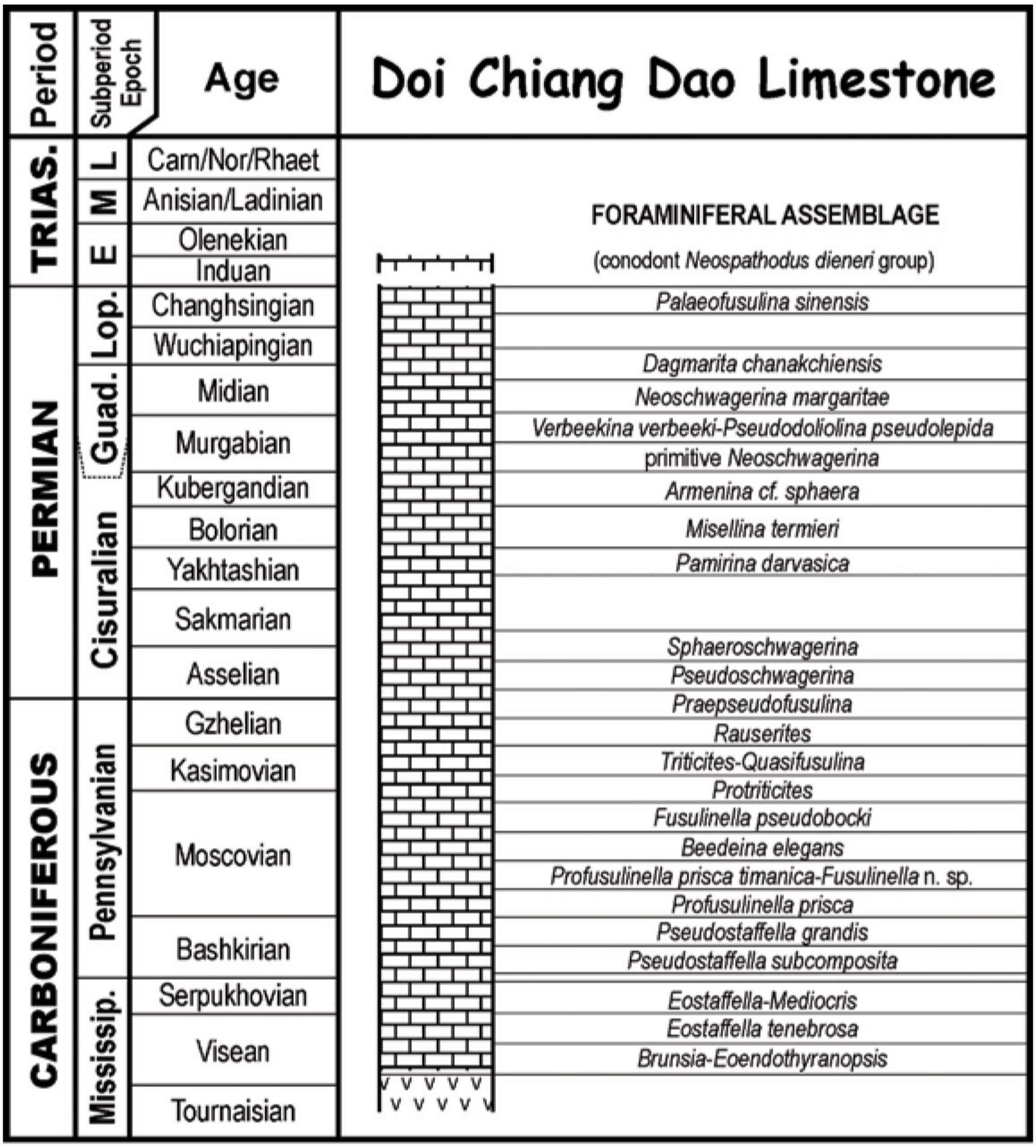

Figure 4 *General stratigraphy and foraminiferal faunal succession of Doi Chiang Dao Limestone.*

very similar each other, it seems most plausible to regard that the former is also one of components of the latter. If this is the case, the deposition of the Doi Chiang Dao Limestone continued up until Early Triassic time across the Permian-Triassic boundary (Fig. 4).

4. Significance of the Doi Chiang Dao Limestone as Paleo-Tethyan mid-oceanic carbonates

Ueno (1999) first proposed a potential oceanic seamount origin for these thick carbonates in the Inthanon Zone, which are now attributed to the Doi Chiang Dao Limestone. He argued that they had been developed as seamount-capping carbonates in the Paleo-Tethys Ocean and later incorporated structurally within its closed remnant. This idea is based on a number of observations that; 1) the carbonates are exclusively pure without detrital grains and essentially massive throughout the succession, 2) they had been accumulated continuously during the Visean to the Changhsingian, which nearly corresponds to 90 m.y. (Gradstein et al. 2004), 3) they likely have a basaltic basement and 4) these unique lithologic characters markedly contrast with those of normal shelf carbonates such as the Saraburi Group in the Indochina Block of East and Northeast Thailand. He concluded that their unusually long-term continuous deposition without any siliciclastic input in a stable tectonic setting can only be accomplished in mid-oceanic isolated buildups such as seamount- or oceanic plateau-top carbonates. Ueno and Hisada (1999) also noted that the carbonates are of seamount-capping shallow-marine buildups resting probably upon a base of ocean island basalt (OIB), which can be compared with, for example, the Panthalassan Akiyoshi Limestone contained in a Permian accretionary complex of Southwest Japan (Sano and Kanmera 1988).

Moreover, thick carbonates having similar lithologic and paleontologic characteristics are also known in the Central zone of the Changning-Menglian Belt in West Yunnan, Southwest China (Liu et al. 1991, 1996), which is widely accepted also as part of closed remnants of the Paleo-Tethys Ocean in East Asia (e.g., Wu et al. 1995; Metcalfe 1999) and considered as the direct northern extension of the Inthanon Zone in view of geotectonic subdivisions (Ueno 1999, 2002; Sone and Metcalfe 2008). Their mid-oceanic origin is clearly shown and depositional ages based on fusuline biostratigraphy are reported (Ueno et al. 2003; Ueno and Tsutsumi, in press; Nakazawa et al., in press). This is also a good support for the seamount origin of the Doi Chiang Dao Limestone. The idea that the limestone has a Paleo-Tethyan mid-oceanic seamount origin is essentially accepted by later workers (Ueno 2002, 2003; Metcalfe 2002; Sone and Metcalfe, 2008). The Doi Chiang Dao Limestone is a unique medium recording long-term environmental and biotic changes within a mid-oceanic shallow-marine setting of the Paleo-Tethys Ocean.

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