# Preliminary Study of Metamorphic Rocks from Lan Sang National Park Indication of Ancient Tectonic Events in Western Thailand

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**Abstract**

Metamorphic rocks have been widely exposed in all regions of Thailand. Lan Sang Metamorphic rocks have been considered as part of Chiang Mai-Lincang belt. The Lan Sang National Park located in the west of Changwat Tak is part of the affected area from northwest-southeast striking Mae Ping fault. Local rocks along the fault zone have been strongly deformed yielding steep foliation and lineation. Gneissic rocks ranging from fine- to coarse-grained textures mainly consist of quartz, plagioclase, K-feldspar, biotite and minor of amphibole and chlorite. Calc-silicate and impure marble are partly interlayered and composed of calcite, quartz, feldspar, amphibole and garnet. These rocks should have undertaken high-grade metamorphism belonging to greenschist facies to amphibolite facies Geochemical of these rocks appear to have the evolution stages of this area probably started from granitic and sedimentary protoliths prior to regional metamorphism. Subsequently, dykes and veins cross cut into these gneissic and calc-silicate rocks. Finally, after India and Eurasia plate collision may reach the ductile-brittle stage before uplifting onto the surface.

**Keywords:** Lan Sang, High-Grade Metamorphism, Thailand

## 1. Introduction

Metamorphic rocks have been exposed in all regions of SE-Asia, structural evolution following India and Eurasia collision, after that the continental extrusion have occurred. The Chiang Mai-Lincang Belt (CM-LB) have widely distribute of high grade metamorphic core complex and granitic rocks, prominently exposed in western Thailand. Western metamorphic belt elongated within the north-south direction has been considered as part of Chiang Mai-Lincang belt. Based on tectonic setting, the Western Thailand is located in the Shan-Thai microcontinent. It situates about 200 km east of the dextral Sagaing fault of Burma and 1500 km south of the eastern Himalayan syntaxis (Lacassin et al., 1993; Palin et al., 2013).

Northwest of Thailand is an important area which many authors have been attended to study characteristics of metamorphic core complex (Macdonald et al., 1993, 2010; Dunning et al., 1995; Lacassin et al., 1993; 1997; Rhodes et al., 1997; 2000; Morley, 2004; Morley et al., 2007; Kanjanapayont et al., 2011). Their expansion was determined by lithology and geological structure which form mountainous terrain with moderate to high elevations of north-south elongate dome-shaped structures (Baum et al., 1970). The mountain range extends stretchy towards Mae Ping fault or Wang Chao fault; then it gradually changes orientation to northwest-southeast along the fault direction which is the sinistral strike-slip fault. That is located nearby the Lan Sang National Park in western Tak.

Macdonald et al. (1993) reported that these rocks have locally undertaken metamorphism under low pressure prior to ductile shearing (mylonization) which can be used to separate basement and the covered rocks. Temperature-Pressure ranges during the prograde metamorphism were determined at 1-3 Kb and 400-650°C for the gneissic rocks. Singharajwarapan and Saengsrichan (1999) worked on geothermobarometry which indicates peak metamorphism of 650±70°C and 3.5±1 kb at the core of orthogneiss and mantling paragneiss located around Doi Inthanon and Mae Wang areas. According to 40Ar/39Ar dating of K-feldspar, it may present the end of ductile left-lateral shear at about 30.5 Ma yielded 400 °C to 185 °C before rapid cooling at about 23 Ma (about 75 °C); these events were clearly taken place in Tertiary period (Lacassin et al., 1997). Fission-track dating of apatite and zircon indicates cooling period between 22 Ma and 18 Ma from 320-200 °C to 110-60 °C. Meanwhile, the Lan Sang gneiss had uplifted during a period of Lower Oligocene to Early Miocene. Moreover, strike-slip movement led to north-south elongated deformation overprinting in this region (Morley et al., 2007).

In addition, Kanjanapayont et al. (2011) studied U-Pb analyses of zircon with clear zone found in gneissic rocks from Lan Sang areas in which temperature of ≥ 800 °C was reported by Tilton et al. (1991). Ending shear behavior may be at between 191 ± 10 and 206 ± 4 Ma under high temperature, baed on U-Pb zircon dating by LA-MC-ICP-MS technique. During this period, the high-grade metamorphism was caused by sinistral shear movement of the Mae Ping fault. This event appears to have been associated with the collision of Shan-Thai and Indochina in Permo-Triassic (Charusiri et al., 2002). Monazite of the Lan Sang orthogneiss yielded Th-Pb ages of about 123-114 Ma which indicates magmatic protholith emplacement in Early Cretaceous prior to metamorphism in Eocene (about 45-37 Ma) and subsequent ductile shearing (Palin et al., 2013).

However, ages of these metamorphic rocks are still ambiguous due to lacking of evidence. Therefore, petrographic study and geochemical analyses of these metamorphic rocks will be crucial information for indication of metamorphism and protolith of this area. Specific P-T condition of metamorphic assemblages may lead to interpretation of tectonic process of the region.

## 2. General Geology

Thailand consists of two main micro-continents, Shan-Thai to the west and Indochina to the east. Complex tectonic setting was reported by Bunopas and Vella (1992) and Charusiri et al. (1997). Tectonic evolutions in this region can be subdivided into four stages. In the Archeotectonic stage, Shan-Thai and Indochina were cratonic part of Gondwana and Pan-Cathaysia respectively prior drifted away parent craton. High grade metamorphic basement were deposit during Precambrian period. Paleotectonic stage during Middle Paleozoic to Early Triassic, the both micro-continent were separate and rotate from parent craton. Begin to building sedimentary basins in both continents. The new blocks including Nakhon-Thai ocean floor and Lampang- Chiang Rai volcanic arc was occurring in this stage. Continent-continent collision during the Middle Triassic, because of Shan-Thai move nearby to Indochina and to South China. That was being a part of Indosinian Orogeny. After collision in the Mesotectonic stage, granitic were intruded into sedimentary rock and volcanic were erupted to surface. In the Neuvotectonic stage, rapidly rifting and opening of the gulf of Thailand during Late Cretaceous to Tertiary after collision of Indian plate and Eurasia plate. Three main direction faults after Indian and Eurasia plate collision including north-south, northwest-southeast and northeast-southwest.

Study area is a part of metamorphic basement complex in Northwest Thailand. Previous researches have established that area of shear zones is associated with the Mae Ping fault that was developed in Lower Cretaceous to Upper Cenozoic during tectonic extension (Morley et al., 2004) in the Neuvotectonic stage. Mae Ping fault zone in western Thailand extend for about

500 km. This zone is clearly northwest-southeast trending, roughly parallel with Red River fault zone in Vietnam (Morley et al., 2007). Left-lateral strike-slip fault was cross cut metamorphic complex along Hui Lan Sang offset left laterally approximately 100 km (Cambell and Nutalaya, 1973; Bunopas, 1981).

Geochronology studies using U-Pb zircon dating after Dunning et al. (1995), determined the Doi Inthanon massif contains orthogneisses with initial parentage of I-type granite

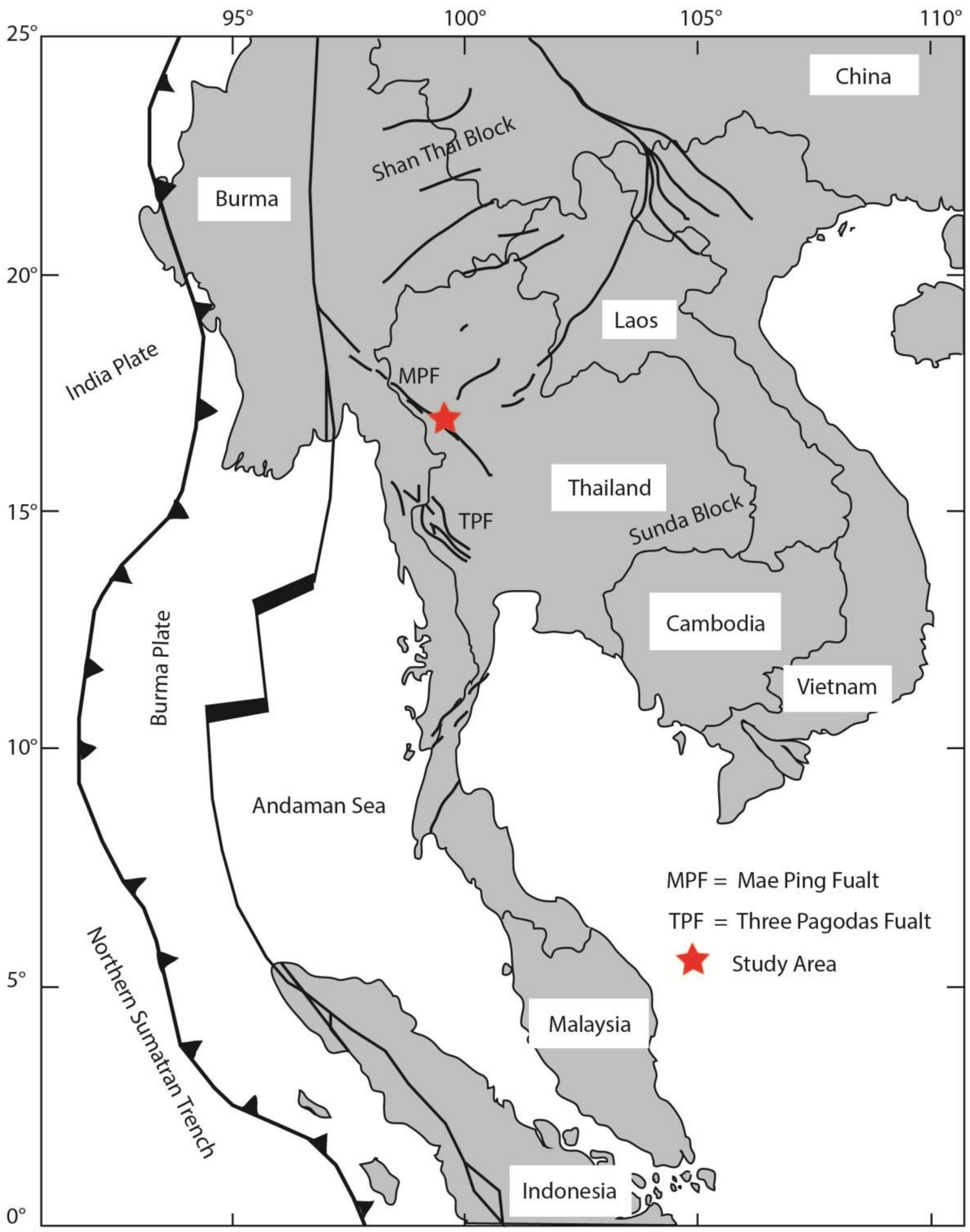


**Figure 1.** Map showing tectonic setting of Thailand. Mae Ping northwest-southeast striking fault are clearly observed in the Shan-Thai terrane (revised from Rhodes et al., 2005). Red star showing study locations around the Lan Sang National Park, Changwat Tak.

emplacement age of c. 211-203 Ma, which had metamorphism at c. 84-72 Ma. Additional from Macdonald et al. (1993) mentioned granitic emplacement age occurred during at the same time at 203 ± 4 Ma prior metamorphism during 72 ± 1 Ma. A younger age obtained from luecrogranite cross cut Mae Klang Pluton between 26.8 ± 0.5 Ma reported by Dunning et al. (1995). Unpublished age of high-grade metamorphic event during Late Triassic from Umphang gneiss and Khlong Lhan gneiss which having slightly younger age about 174 ± 6 Ma (U-Pb zircon) and 117 ± 3 Ma (U-Pb monazite), was reported by Mickein, 1997; Morley et al., 2007).

Moreover, Fission track ages from Umphang gneiss from zircon at 47±3 Ma and apatite at 40±2 Ma suggest that deep metamorphic rock were uplift the surface during Early Eocene (Upton, 1999; Morley et al., 2011). These younger ages are overlapping with the Mogok metamorphic belt, that was interpreted represent age of high-grade metamorphism between c.47-29 Ma using U-Pb zircon and monazite dating method (Barley et al., 2003; Searle et al., 2007). Age of granitic rocks cross cutting host rock in Mogok belt have been dating by U-Pb zircon at c. 72, 48 and 44 Ma (Mitchell et al., 2012). Therefore, Geochronological data suggesting tectonic process may starting from crustal melting, metamorphism and deformation on a regional scale at the same time before developing of metamorphic core complex and sedimentary basin during Late Oligocene-Miocene (Morley et al.,2007;2009; Macdonald et al., 2010; Morley and Racey, 2011).

Lan Sang National Park located in the west of Tak Province is part of effected area from Mae Ping northwest-southest striking fault which show cross cut and sinistral displacement into the metamorphic belt of this area. Previous researches have established that area of shear zones is associated with the Mae Ping fault that was developed in Lower Cretaceous to Upper Cenozoic during tectonic extension (Morley et al., 2004). Geochronological data are suggested that magmatic protholith crystallization during Early Cretaceous before occurring of metamorphism stage during Eocene prior to ductile shearing in later (Palin et al., 2013). According to Department of Mineral Resources (2007) and Macdonald et al. (1993), stratigraphic rock in NW Thailand consists of rocks several age varies from Precambrian to Quaternary sediment.

## 3. Field observation

Lan Sang National Park located in the west of Tak Province is part of effected area from Mae Ping northwest-southest striking fault which show cross cut and sinistral displacement into the metamorphic belt of this area. Along the fault zone, rocks have been strongly deformed yielding steep foliation and lineation. These rocks are mainly characterized by gneiss, calc-silicate and plutonic intrusion.

Local rocks in Lan Sang area dip toward northwest direction. They mostly reveal mylonitic texture and shear ductile-brittle deformation. Intrusions are found widely distributed as concordant to disconcordant dykes. These dykes are described as foliated biotite-microgranite seems likely gneiss, deformed leucogranite and pegmatite veins. Their foliations are parallel to the host rocks in this area. In addition, evidences of ductile shear and brittle stages are also observed as subsequent process of these rocks.

## 4. Petrogrphic Study

Representative rock samples were collected prior to petrographic study. The study of these rocks is mainly characterized by gneiss ranging from fine- to coarse-grained and these mostly show mylonitic ductile stage. Thin to thick band of calc-silicate and impure marble are strongly deformed and interbeded with gneissic rock (see Figure 2A). Foliated granites appear to have intruded into host rocks. Petrographic descriptions of Lan

Sang metamorphic suites are present in Figure 2.

### Gneissic rocks

The gneissic rocks are mostly found in Lan Sang National Park, large outcrop are natural exposures along Huai Lan Sang. These samples clearly consist of quartz, feldspar and biotite in hand specimen. Gneissic rocks can be separated into two large groups which are characterized by grain sizes in field observation including fine-grained and coarse-grained gneissic rocks associated with pegmatite vein, luecrocratic vein and dyke of plutonic rock. Fine-grained rock layers show foliated interbeded coarse-grained crystals, porphyroblastic to augen gneissic texture of quartz, plagioclase and K-feldspar. Stretched of porphyroblasts are evidences of ductile shear stage including boudinage, rotating of clast, and σ-type of leucocratic vein. Moreover, some areas show brittle stage including minor fault, cracks and joint overprint ductile shear texture.

From these studies can be subdivided gneissic rocks into three groups including fine-grained gneiss, augen gneiss and mylonitic gneiss, based on average grain size, texture and mineral compositions.

### Calc-silicate rocks

Calc-silicate rocks and impure marble are found interbeded with gneissic rock with strongly deformation that show foliation parallel with other rocks in this area. These rock outcrop are natural outcrop occur as thin layer to thick band (> 1m) especially Lan Sang waterfall area is clearly. Calc-silicate rock made by several layers of green, purple, brown, white bands and dark grey of impure marble which are show ductile stretched of clast from luecrocratic vein which cross cut into these rocks before shear-lateral.

### Foliated-granite

Foliated-granite in this area is found in association with gneissic rock and calc-silicate. These rocks intruded into migmatitic augen gneiss and calc- silicate. These intrusions show foliation parallel to host rocks. In addition, pegmatite, leucocratic and micogranites also show deformation ductile with similar to the host rocks.

These rocks contain quartz, feldspar and small amount of biotite with accessories of zircon, monazite and opaque mineral (see Figure 3.7). Grain size ranging between 0.05-1.0 cm in diameter. Granoblastic of quatz, feldspar and biotite are usually form anhedral. Petrogrphic feature of rocks are isogranular to hetrogranular texture with other textures are poikilitic texture, mosaic texture and triple junction.

Consequently, all rock types are significantly corresponding probably to amphibolite and greenschist facies based on their mineral assemblages (after Woudloper, 2009).

## 5. Geochemical data

Whole-rock geochemistry generally shows the analyzed gneissic rocks, calc-silicate rocks and foliated-granite. The tectonic process can be interpreting lead from characteristic investigation. Samples were analyzed for major and minor oxides by X-ray Fluorescence (XRF) Spectrometer. Trace elements and rare earth elements (REE) concentrations of gneissic rocks and foliated-granite were also determinate by Inductively Coupled Plasma-Mass Spectrometer (ICP-MS). The results are compared each rock patterns with other published data, that considerate initial source of rock and tectonic setting.

In addition, mineral chemistry of each rock type is also analyzed by Electron Probe Micro-Analyzer (EPMA). Peak metamorphism can be estimate P-T condition, which taken from chemical composition of main phase of metamorphic mineral. Therefore, these analyses use to discuss tectonic model of this region area.

ACF diagram of Eskola (1915) in Figure 3 show plot of mole propotions between A ($Al2O3 + Fe2O3 - (Na2O + K2O)$), C ($CaO - 3.33P2O5$) and F ($FeO + MgO + MnO$), the investigated gneissic rocks and foliated granite plots mainly within quartzo-feldspartic rock field, that can be derived from greywacke sandstone, siltstone and granitiod protoliths. Calc-silicate rock and impure marble are plotted

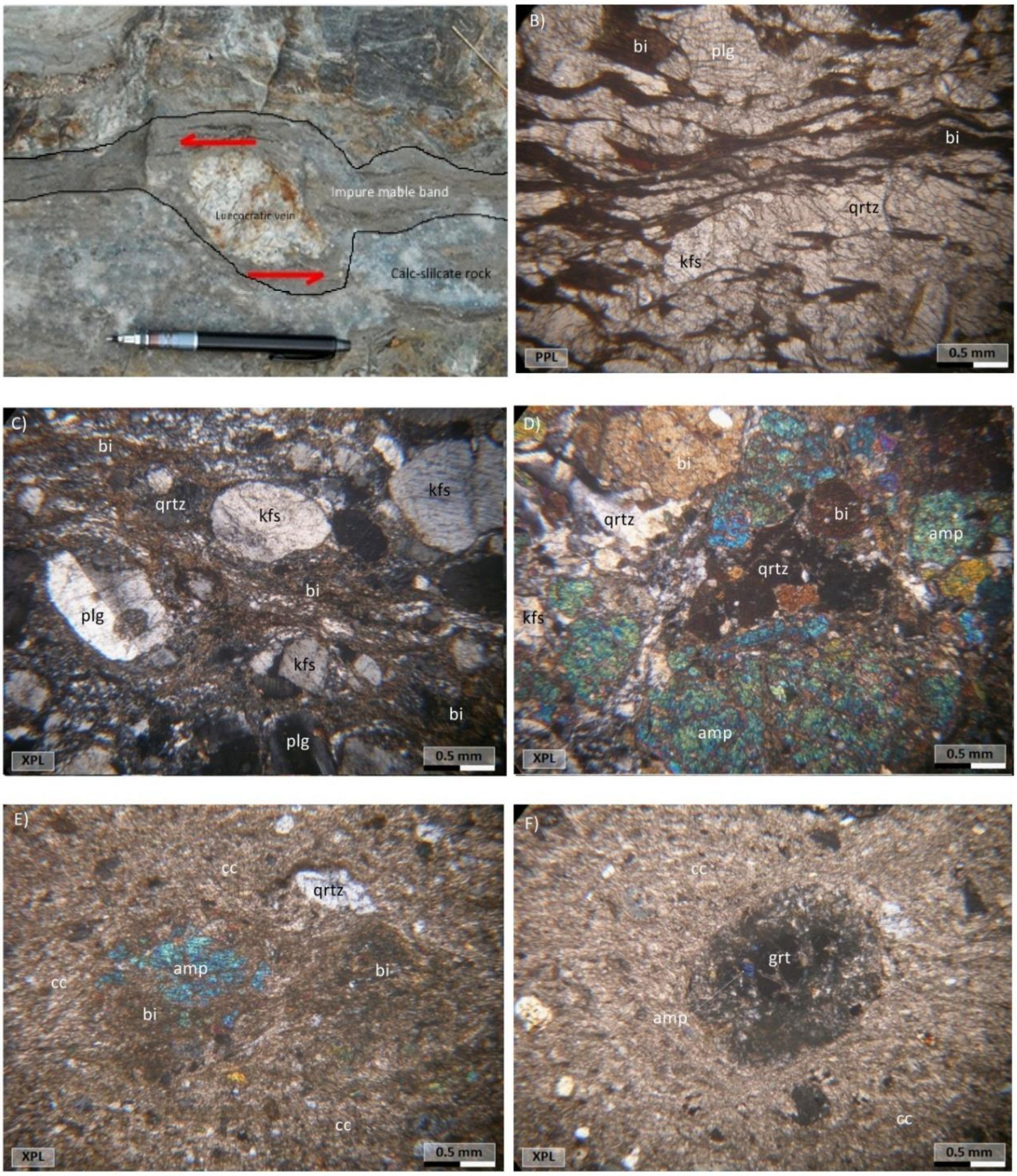


**Figure 2.** A) Sheared luecocratic vein with marble band of calc- silicate rock show intense movement; B) photomicrograph of gneissic rocks showing granoblast of quartz and feldspar interbanded with biotite and lepidoblastic texture (PPL); C) hetrogranular texture with clast rotation (XPL) in mylonitic gneiss; D) mineral composition of amphibole, biotite, calcite, plagioclase and quartz (XPL) in calc-silicate rocks; E) photograph of impure marble showing fine-grained calcite matrix with porphyroblast of amphibole (XPL); F) garnet pophyroblast showing reaction rim beside fine-grained of quartz and amphibole in impure marble.

within calcareous rock. In addition, chondrite-normalized REE patterns (chorndrite composition after Sun and McDonough, 1989) (see in Figure 4) all of gneiss and granite were collected to compared with shade pattern of paragneiss of from the Çine submassif of the Menderes massif, Western Anatolia (after Firat et al., 2006). REE element values are used as indicators of sedimentary provenance.

## 6. Tectonic Evolution

Analytical data of gneissic rocks and related rocks represent initial such as granitic rocks and sedimentary rocks prior to metamorphism at different metamorphic grades.

The main tectonic event may start from Western Burma block and Shan-Thai collision during Cretaceous (Metcalfe, 1996). According to Macdonald et al. (1993) and Dunning et al. (1995) studies metamorphic event from Doi Inthanon metamorphic core complex in northern Thailand. U-Pb zircon dating of megacrystic orthogneiss indicate that initial age of granitic during Late Triassic-Early Jurassic (c. 203±4 Ma and between 203-211 Ma), which have been high grade metamorphosed in Late Cretaceous (c. 72±1 Ma, 84±2 Ma and 72±1 Ma; U-Pb monazite from orthogneiss).

Consequently, the initial granite of coarse-grined gneiss from Lan Sang produces Early Cretaceous (c.123-114 Ma; Th-Pb monazite) (Palin et al., 2013), probably occur from partial melt after Western Burma subducted beneath into Shan Thai during Late Jurassic-Early Cretaceous.

In Late Cretaceous to Paleocene, thermal overprinting event from regional metamorphism has been identified in metamorphic core complex in Thailand. Radiometric dating studies this evidence (age between 80 and 60 Ma) was investigated and interpreted as partial melting of granitic dyke cross cutting into host rock are observed in area (Ahrendt et al., 1997; Palin et al., 2013). Data of U-Pb dating of Monazite can be confirmed which indicates upper amphibolite facies

Subsequently, ductile stage evidences from Mae Ping strike-slip fault (MPF fault) during the period about 45-37 Ma (Palin et al., 2013) after India and Eurasia collision during Early Eocene between 50-55 Ma (Hutchison, 2007), which is indicated the lower limit of maximum age of left-lateral shear fabrics and initiation of MPF prior transpressional uplifting of mylonite zone about 23.5 Ma observation have been corroborated by 40Ar-39Ar biotite cooling age (Lacassin et al., 1997)

## 7. Conclusion

The metamorphic basement of the Lan Sang metamorphic suites are made up of Precambrian high grade metamorphism can be described as follow:

1. Lan Sang Metamorphic Suites located in Lan Sang National Park, Tak. These metamorphic suites can be divided in to three main groups according to their petrographic studies, whole- rock geochemistry and mineral chemistry. They are composed of gneissic rock (i.e., fine-grained gneiss, coarse-grained gneiss and mylonitic gneiss), calc-silicate rock (i.e., calc-silicate and impure marble) and foliated granite.

2. Gneissic rocks and foliated granite have similar or close to mineral assemblages mainly consisting quartz, plagioclase, K-feldspar, biotite and minor of hornblend, chlorite. Geochemically, these rock probably have initial rock parentage of granitic and sedimentary composition.

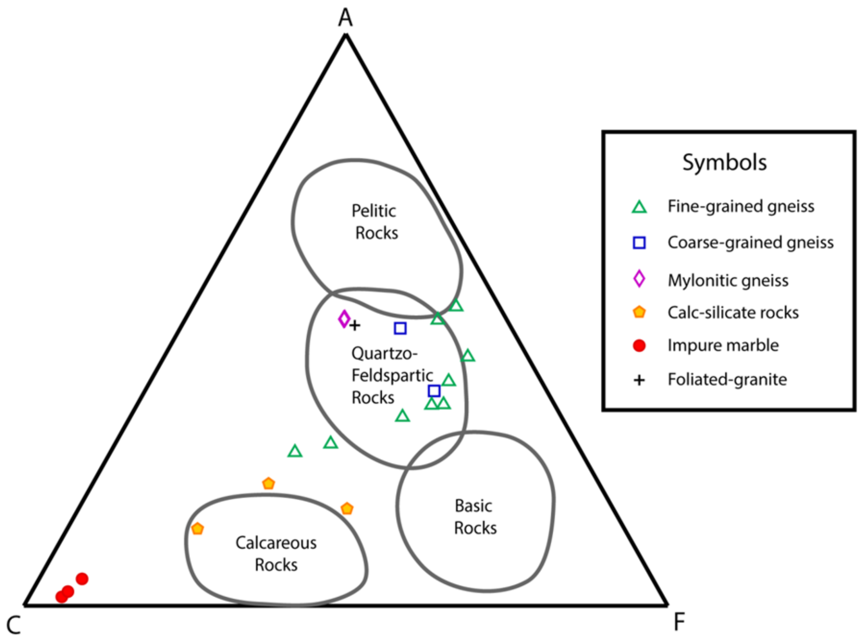


**Figure 3.** The field of metamorphic suites in ACF diagram (after Eskola, 1915) showing the parentage of each rock in Lan Sang National Park area.

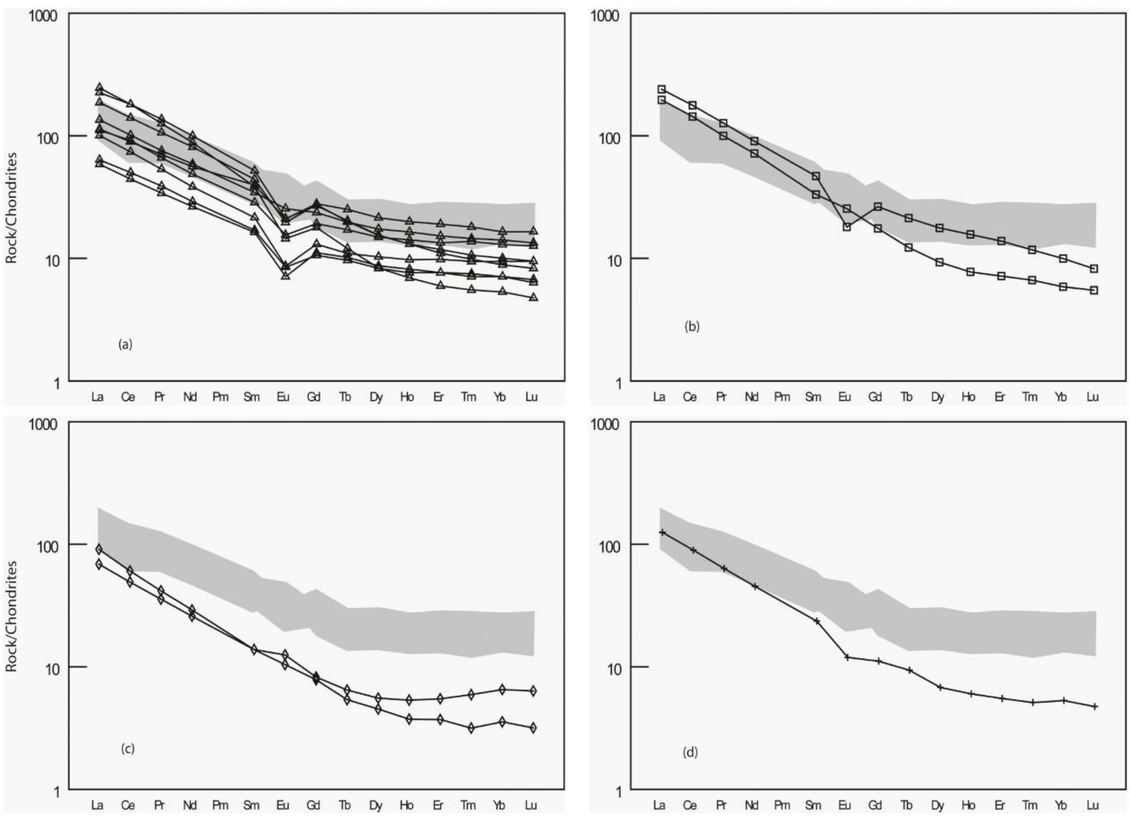


**Figure 4.** Chondrite-normalized REE diagrams of (A) fine-grained gneiss samples; (B) coarse-grained gneiss samples; (C) mylonitic gneiss samples and (D) foliated granite. Normalizing values taken from Sun & McDonough (1989) and compared to shade pattern of paragneiss from the Çine submassif of the Menderes massif, Western Anatolia (after Firat et al., 2006).

3. Calc-silicate rocks and impure marble are found interbeded with gneissic rock with strongly deformation that show foliation parallel with other rocks. Their mineral assemblages are composed of quartz, feldspar, calcite, garnet and minor amounts of pyroxene, hornblende. In addition, there whole-rock geochemistry is different from gneissic rock and foliated granite, because of they have different of protolith, may occurred from initial rock that have impure limestone composition.

4. All available rocks are closely to high-grade metamorphism belonging to greenschist to amphibolite facies.

5. Tectonic evolution of study area in Lan Sang National Park, Changwat Tak (revise after Charusiri et al., 2002). Starting from initial rock of granitic pluton and sedimentary rocks after Western Burma block (WB) subducted beneath Shan-Thai (ST) in Jurassic-Cretaceous. Subsequently, metamorphism in study area occurred prior Indian plate and Western Burma plate collision. After the Shan Thai and Western Burma block collision and Indian plate collision with Eurasian plate may reached to ductile-brittle stage in these rock along the sinistral strike-slip Mae Ping Fault during Eocene period before transpressional uplifting of mylonize zone.

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