

Petrology and geochemical characters of metalimestone from Ban Maepong Limestone Mine, Doi Saket District, Chiang Mai Province, Northern Thailand

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Abstract

The limestones are economically the most abundant mineral resource in Chiang Mai Province, and it has already been excavated for industrial purposes within Chiang Mai and nearby provinces for decades. Geologically, the Ban Maepong limestone mine, Chiang Mai, consists of sedimentary rocks, metamorphic rocks, and igneous rocks. According to the geological map, the study area is located within two rock units, such as the Permian rock unit and the Permian-Triassic volcanic rock unit. The metalimestones collected from the limestone mine are divided into two types, including calcic slate and metalimestone. The result of mineral chemistry revealed that calcite is the sole carbonate rock-forming mineral in both types. In terms of protoliths of these rocks, the protoliths of the calcic slate and metalimestone from the Ban Maepong limestone mine are argillaceous limestone and limestone, respectively. Moreover, this study can suggest that the metamorphism of the metalimestone in the Ban Maepong limestone mine was affected by Permian-Triassic volcanic rock due to the volcanic eruption.

Keywords: Petrography, Mineralogy, Geochemistry, Limestone, Slate, Thailand

1. Introduction

The limestones are economically the most abundant mineral resource in Chiang Mai Province, and it has already been excavated for industrial purpose within Chiang Mai and nearby provinces for decades, and the largest production volume of limestone in Chiang Mai has been produced from Ban Maepong limestone mine in the Doi Saket district about 23.6% of 198.63 metric tons. (Department of Primary Industries and Mines, 2009).

Ban Maepong limestone mine is generally made up of igneous rock, metamorphic rock and sedimentary rock, and

locates it the two units of lithology based on the geology map of Thailand such as the Permian rock units (P1 and P2) and Permian-Triassic rock unit (PTrv) (Fig. 1). The metalimestone was found between the contact of rock units and has already been crushed into an industrial aggregate as well as other rocks that have been excavated from Ban Maepong limestone mine. However, the study on petrology and geochemistry of metalimestones from Ban Maepong limestone mine, Doi Saket district, Chiang Mai province in northern part of Thailand has not been done.

Therefore, this study aims to study the petrography together with mineralogy, mineral chemistry, and whole-rock geochemistry of the metalimestone from the study area in Ban Maepong limestone mine, Doi Saket district,

Chiang Mai province, Northern Thailand. The obtained results can lead to understand the geological characters and protolith of metalimestones from the study area.

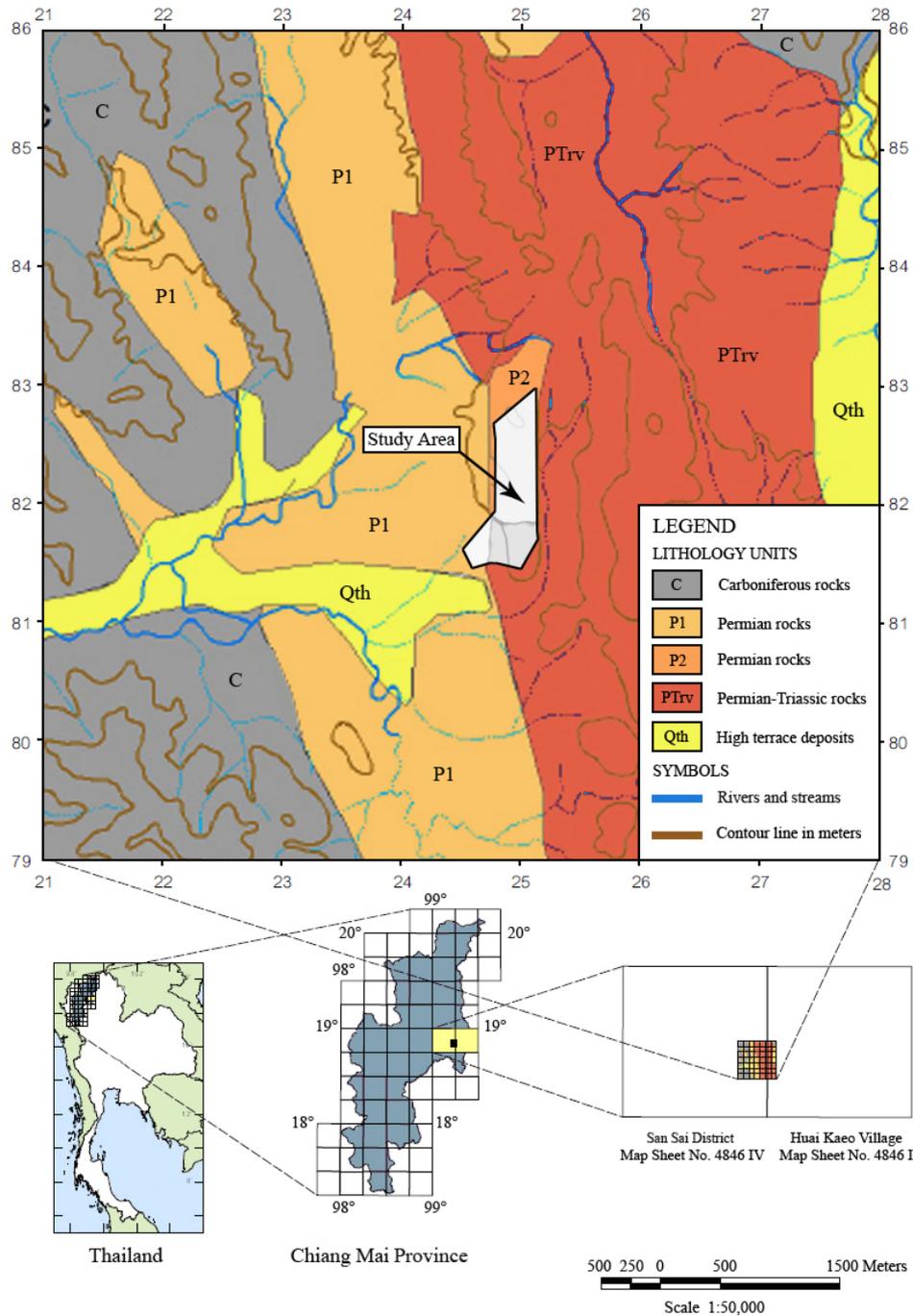


Figure 1 The geological map of Ban Maepong limestone mine that is located between map sheet no. 4846 IV and map sheet no. 4846 I of Chiang Mai province in the northern part of Thailand (modified after Department of Mineral Resources, 1993a, 1993b).

2. Geological Background

Ban Maepong limestone mine is located in Doi Saket District, Chiang Mai Province in the northern part of Thailand. Geologically, the study area consists of the Permian rocks and the Permian-Triassic volcanic rocks (Department of Mineral Resources, 1993a, 1993b) (Fig. 1).

According to the recent studies about tectonic evolution, Thailand is subdivided into four tectonic domains from west to east respectively including Sibumasu or Shan-Thai block, Inthanon zone, Sukhothai zone, and Indochina block (Ueno and Hisada, 1999; Sone and Metcalfe, 2008; Morley et al., 2012). The study area is located in the east of Inthanon zone that has been regarded as a close remnant of the Paleo-Tethys Ocean (Ueno, 1999; Sone and Metcalfe, 2008). The limestone formation in the study area is part of Doi Chiang Dao Limestone that represents mid-oceanic shallow-marine deposition within the Paleo-Tethys Ocean (Wonganan and Caridroit, 2005). The general stratigraphy and foraminiferal faunal succession of Doi Chiang Dao limestone indicate that the Paleo-Tethys Ocean had existed between Tournaisian of Carboniferous and Changhsingian of Permian (Ueno et al., 2008).

The limestone of Ban Maepong limestone mine mainly belongs to Pa Huat group (P2) of the Middle Permian rock unit. The limestone is dense massive cliff-forming light-gray to pinkish crystalline limestone (Piyasin, 1972). However, limestone in the western part of Ban Maepong limestone mine belongs to Ratchaburi group (P1) which is perhaps the most distinctive and widely distribute formation in Thailand. This

formation is found throughout Thailand with the exception of Khorat Plateau (Javanaphet, 1969).

The volcanic rock found in Ban Maepong limestone mine and nearby area belongs to Chiang Rai-Chiang Mai volcanic belt that extends from the western part of Chiang Rai province through the north part and eastern part of Chiang Mai province to Li district of Lamphun province. The volcanic rock of Chiang Rai-Chiang Mai volcanic belt was formed during the volcanic eruption around Permian to Triassic (Chuaviroj et al., 1980; Bunopas and Vella, 1983; Panjasawatwong, 1999).

3. Methodology

Eight rock samples were collected within Ban Maepong limestone mine during the field investigation, and they were chosen as the representative samples. These representative samples including three calcic slate samples (CM1, CM2 and CM8), two argillaceous limestone samples (CM4 and CM16_3), two limestone samples (CM11 and CM28), and one metalimestone sample (CM21_1). All representative rock samples were prepared as thin section for petrographic study under polarized-light microscope at the Department of Geology, Faculty of Science, Chulalongkorn University, Thailand.

The four representative thin sections including calcic slate sample (CM2), argillaceous limestone sample (CM16_3), limestone (CM28), and metalimestone (CM21_1) were coated with carbon for mineral chemistry analysis using an Electron Probe Micro-analyzer (EPMA) model JOEL JXA-8100, based at Department of Geology, Faculty

of Science, Chulalongkorn University. The nine major and minor oxides (i.e., SiO₂, TiO₂, Al₂O₃, Fe₂O₃, MnO, MgO, CaO, Na₂O, and

K₂O) were measured for carbonate rock-forming mineral identification.

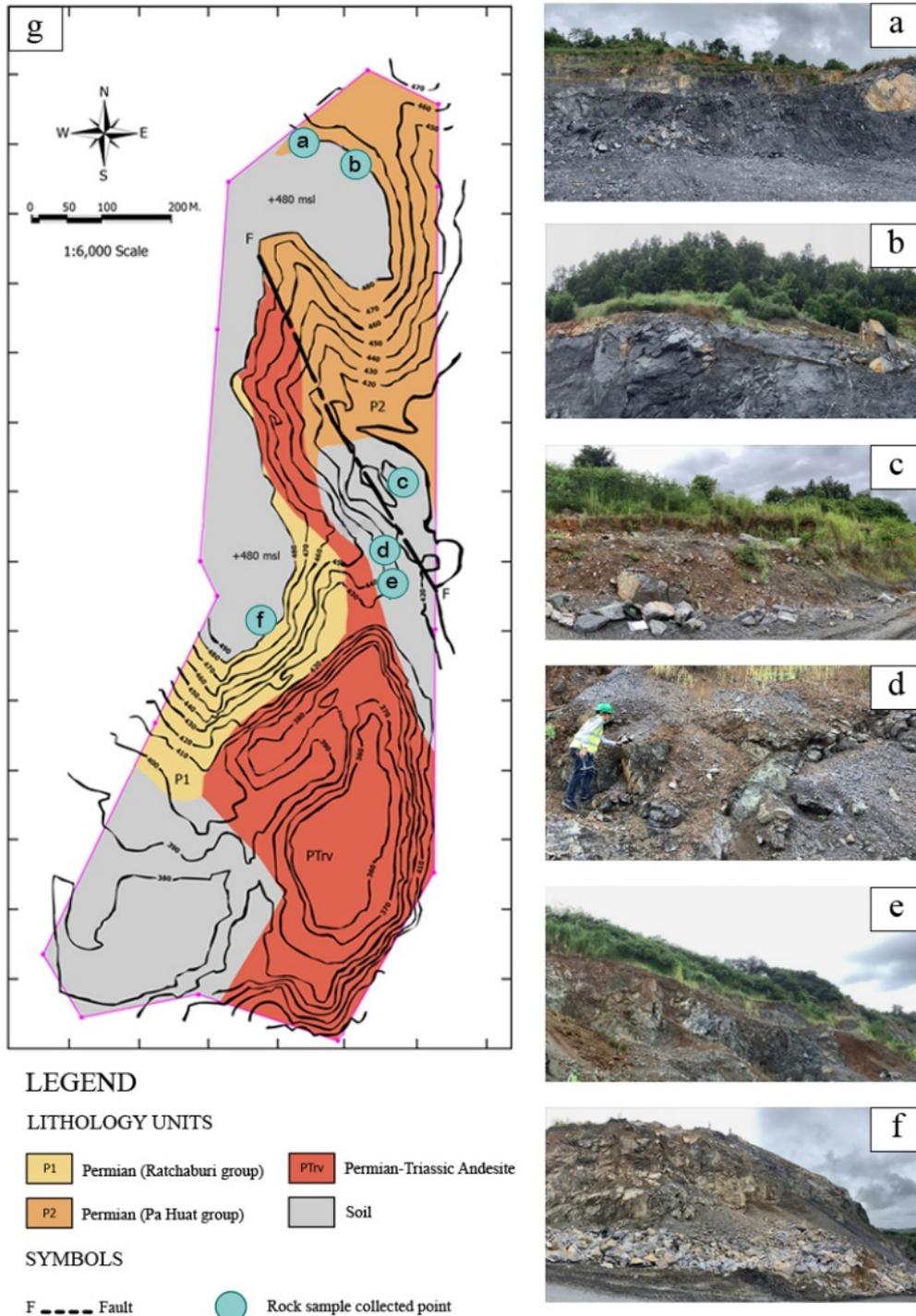


Figure 2 (g) The rock sample collected points within Ban Maepong limestone mine based on geological map (provided by Siamstone Aggregate Co, Ltd.): (a) calcic slate (CM1, CM2) and argillaceous limestone (CM4), (b) calcic slate (CM8), (c) limestone (CM11), (d) argillaceous limestone (CM16_3), (e) metalimestone (CM21_1), (f) limestone (CM28.)



Figure 3 The field occurrence of the rocks in the study area: (a) the landscape of Ban Maepong limestone mine, (b) andesite, (c) limestone, (d) argillaceous limestone, (e) calcic slate.

The whole-rock geochemistry of six powdered representative samples, including three metamorphosed limestone samples (CM1, CM2, and CM8) and three non-metamorphosed limestone samples (CM4, CM16_3, and CM28), were analyzed using an X-ray Fluorescence (XRF) spectrometer, model BRUKER S4 Pioneer, based at Department of Geology, Faculty of Science, Chulalongkorn University. The eleven major and minor oxides (i.e., SiO₂, TiO₂, Al₂O₃, Fe₂O₃, MnO, MgO, CaO, Na₂O, K₂O, P₂O₅ and SO₃) were measured for possible protolith of metalimestone identification together Loss on ignition (LOI) of six powdered representative samples that measured before and after heating at 1,050 °C for 3 hours by furnace, model Linn HT with 1800 Vac, based at Department of Geology, Faculty of Science, Chulalongkorn University. The mineral assemblage of four powdered representative samples were analyzed using an X-ray diffraction (XRD) model BRUKER D8 Advance, based at Department of Geology, Faculty of Science, Chulalongkorn University.

4. Results

4.1 Field observation

The Permian sedimentary rocks that have been covered by red soils are overlapped by the Permian Triassic volcanic rocks (Fig. 3a). The fault within Ban Maepong limestone mine is oriented from northeast to southwest (Fig. 2g), and can be observed on the cliff in the western part of the mine.

The limestones that have been excavated in the northern part of Ban Maepong limestone mine (Fig. 2a) are identified as an argillaceous limestone with slaty blue color

(Fig. 3d), and calcic slate of the same color were found next to an argillaceous limestone (Fig. 3e). However, the calcic slate in the northeast of Ban Maepong limestone mine have dark gray color with greasy surface (Fig. 2b). These rocks commonly have fractures that were filled by calcite veins and some quartz veinlets.

The limestones were found in the eastern part (Fig. 2c) and the western part (Fig. 2f) of Ban Maepong limestone mine. These rocks have lighter color than those rocks from the northern part of Ban Maepong limestone mine. However, the specimen of metalimestone (Fig. 3c) that was collected from the eastern part (Fig. 2e) of Ban Maepong limestone mine cannot be distinguished from limestones.

In the contact zone between the andesite and limestone, calc-silicate rocks are locally found in the eastern part of Ban Maepong limestone mine. Their color ranges from kiwi green to dark yellowish green. Sometimes these rocks occur like a thin sheet between volcanic rock and limestone, and pyrite is usually found in quartz veins. However, the study about petrogenesis of the calc-silicate rocks from Ban Maepong limestone mine has not been reported.

The volcanic rocks from Ban Maepong limestone mine typically have an aphanitic texture and dark green color. These rocks can be distinguished from calc-silicate rocks by amygdaloidal vesicles filled with zeolites. These volcanic rocks have been classified as andesite (Thanasuthipitak, 1978). The cracks of these rocks were filled with either quartz veins or calcite veins (Fig. 3b).

The eight representative samples were collected from six points (Fig. 2), and all of

them were cut into a slab and later prepared for thin section for petrographic study.

4.2 Petrography

The calcic slate is composed of calcite, quartz, and an accessory mineral as clay mineral. However, only calcite grains and quartz grains can be identified through the microscope, while other forming minerals of carbonate rocks despite calcite are not found,

even though they have similar crystal habit. All quartz grains are anhedral shape while calcite grains are subhedral to anhedral shape, but most of calcites are smaller than quartz, with the exception of sample CM8 showing equigranular grains and foliated texture (Fig. 7d).

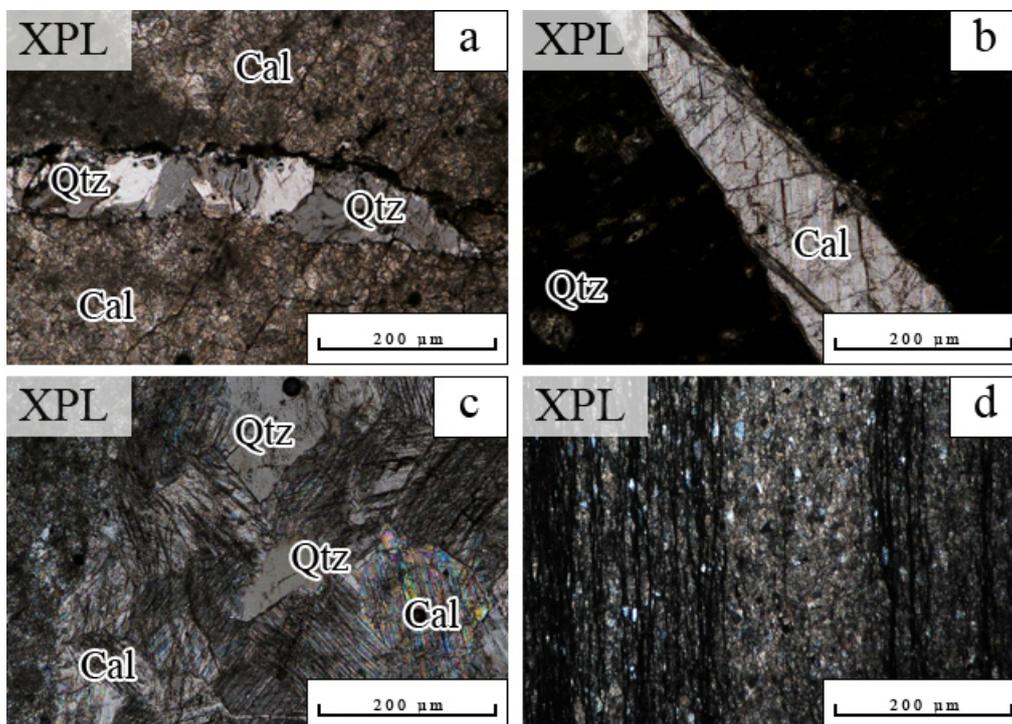


Figure 4 The photomicrographs under cross-polarized light (XPL) showing mineral assemblages of four representative samples: (a) limestone (CM11), (b) argillaceous limestone (CM16_3), (c) metalimestone (CM21_1), (d) calcic slate (CM1). Mineral abbreviations: Qtz (quartz); Cal (calcite).

The argillaceous limestone is composed of calcite, quartz and accessory mineral as clay mineral. The fractures of rock are filled with calcite veins (Fig. 4b). All quartz grains have anhedral shape while calcite grains are subhedral to anhedral shape. The calcite grains tend to be larger than those of the calcic slate (Fig. 7c) in sample CM4. The appreciable amount of quartz and clay minerals in

argillaceous limestone is lesser than 50 percent, and all clay mineral grains are smaller than silt size.

The limestone is composed mainly of calcite. All calcite grains are euhedral to anhedral shape. Quartzs are found as small veinlets in some samples. Many calcite grains in limestone are larger than 0.1 millimeters

(Fig. 4a). The textures of rocks can be observable under plane-polarized light (PPL; Fig. 7e).

The metalimestone is composed of mainly calcite and an accessory mineral of quartz. All calcite grains have subhedral to anhedral shape while quartz grains have anhedral shape (Fig. 4c). Their textures can be observed as the granoblastic texture of recrystallized calcite and quartz with the tiple junction (Fig. 7f).

4.3 Mineral chemistry

Mineral chemistry, including major and minor compositions of carbonate minerals, from four rock types, e.g., calcic slate, argillaceous limestone, limestone, and metalimestone, was investigated in this study. Each rock type has four representative mineral grains.

Table 1 The mineral chemistry of calcite in the unmetamorphosed rocks from Ban Maepong limestone mine (major and minor oxide in wt%).

Oxides	Limestone				Argillaceous limestone			
	CM11A	CM11B	CM11C	CM11D	CM16_3A	CM16_3B	CM16_3C	CM16_3D
SiO ₂	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO ₂	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.008
Al ₂ O ₃	0.00	0.019	0.005	0.031	0.012	0.007	0.00	0.013
Fe ₂ O ₃	0.131	0.209	0.003	0.011	0.165	0.296	0.235	0.181
MnO	0.023	0.073	0.000	0.004	0.192	0.293	0.290	0.307
MgO	0.211	0.311	0.190	0.097	0.079	0.098	0.039	0.081
CaO	55.099	55.545	54.747	55.470	54.710	55.381	54.871	55.296
Na ₂ O	0.00	0.004	0.037	0.170	0.00	0.003	0.00	0.00
K ₂ O	0.00	0.007	0.014	0.002	0.005	0.008	0.002	0.00
Total	55.464	56.168	54.996	55.632	55.163	56.086	55.437	55.886

Table 2 The mineral chemistry of calcite in the metamorphic rocks from Ban Maepong limestone mine (major and minor oxide in wt%).

Oxides	Calcic slate				Metalimestone			
	CM2A	CM2B	CM2C	CM2D	CM21_1A	CM21_1B	CM21_1C	CM21_1D
SiO ₂	0.222	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO ₂	0.00	0.017	0.012	0.00	0.00	0.014	0.003	0.00
Al ₂ O ₃	0.017	0.032	0.00	0.00	0.007	0.027	0.002	0.000
Fe ₂ O ₃	1.166	1.342	1.362	1.288	0.481	0.274	0.298	0.339
MnO	0.276	0.125	0.069	0.054	0.068	0.034	0.021	0.015
MgO	0.470	0.787	0.779	0.728	0.341	0.191	1.028	0.921
CaO	53.153	53.976	53.926	53.934	54.368	54.983	55.796	54.615
Na ₂ O	0.060	0.078	0.007	0.000	0.00	0.019	0.005	0.019
K ₂ O	0.014	0.030	0.006	0.019	0.00	0.00	0.003	0.00
Total	55.378	56.387	56.161	56.023	55.265	55.542	57.156	55.909

The representative calcite grains were analyzed, and the results are summarized in Table 1 for sedimentary rocks and Table 2 for metamorphic rocks. All sixteen representative grains show high CaO contents ranging from 53.153 to 55.796 wt.% while MgO contents ranging from 0.039 to 1.028 wt.% and Fe₂O₃ contents ranging from 0.003 to 1.362 wt.% respectively.

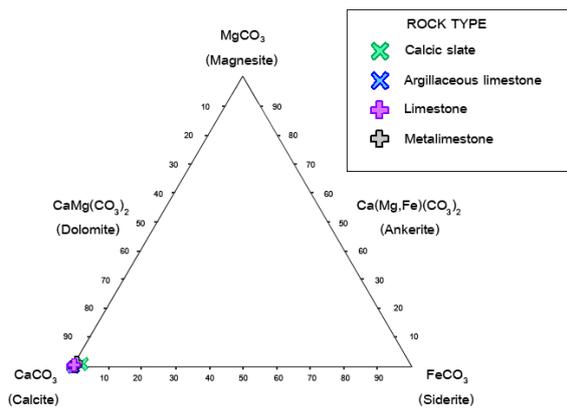


Figure 5 Ca-Fe-Mg triangular diagram showing the chemical compositions of sixteen representative carbonate mineral grains (Holland et al., 1998).

According to the results, the sixteen representative grains from four rock types are definitely calcite (Fig. 5), that is the calcium-rich mineral of the carbonate rocks, and none of representative mineral grains are classified as Ferro-Magnesian carbonate minerals.

4.4 Whole-rock geochemistry

The whole-rock geochemistry, including major and minor compositions of six representative rock samples from Ban Maepong limestone mine, were analyzed and

the results along with Loss on ignition (LOI) results are summarized in Table 3.

The metallimestone category comprises three calcic slate samples (CM1, CM2 and CM8), and unmetamorphosed limestone category includes two argillaceous limestone samples (CM4 and CM16_3) and single limestone sample (CM28).

The calcic slate samples (CM1 and CM2) are made up by 31.37 – 39.44 wt.% of SiO₂ and 22.89 – 30.87 wt.% of CaO.

The argillaceous limestone sample CM16_3 is made up by 42.79 wt.% of SiO₂ and 7.39 wt.% of CaO while CM4 is made up by 11.21 wt.% of SiO₂ and 48.25 wt.% of CaO. The percentage of Loss on ignition (LOI) of CM16_3 is 10.37 that is less than the rest of representative rock samples.

The limestone sample CM28 is made up by 7.64 wt.% of SiO₂ and 48.72 wt.% of CaO. The percentage of Loss on ignition (LOI) is 38.93 that is more than the rest of representative rock samples.

The argillaceous limestone sample CM4 shares similarities in composition to the calcic slate sample CM8. They are made up by 11.21 – 13.30 wt% of SiO₂, 42.31 – 48.25 wt% of CaO, and 35.07 – 36.17 wt% of Loss on ignition (LOI).

Table 3 The whole-rock geochemistry of six representative rock samples from Ban Maepong limestone mine (major and minor oxide in wt%).

Oxides	Metalimestone			Limestone		
	CM1	CM2	CM8	CM4	CM16_3	CM28
SiO ₂	39.44	31.37	13.3	11.21	42.79	7.64
TiO ₂	0.46	0.34	0.15	0.12	3.67	0.1
Al ₂ O ₃	10.12	6.34	3.68	2.15	13.61	1.81
Fe ₂ O ₃	3.94	2.99	1.33	0.82	13.9	0.64
MnO	0.07	0.06	0.02	0.02	0.06	0.01
MgO	1.82	1.29	1.37	1.12	3.12	1.27
CaO	22.89	30.87	42.31	48.25	7.39	48.72
Na ₂ O	0.93	0.97	0.26	0.3	0.09	0.11
K ₂ O	1.87	1.03	0.7	0.37	3.96	0.26
LOI	17.1	23.3	36.17	35.07	10.37	38.93
Total	99.83	99.79	99.78	99.77	99.84	99.83

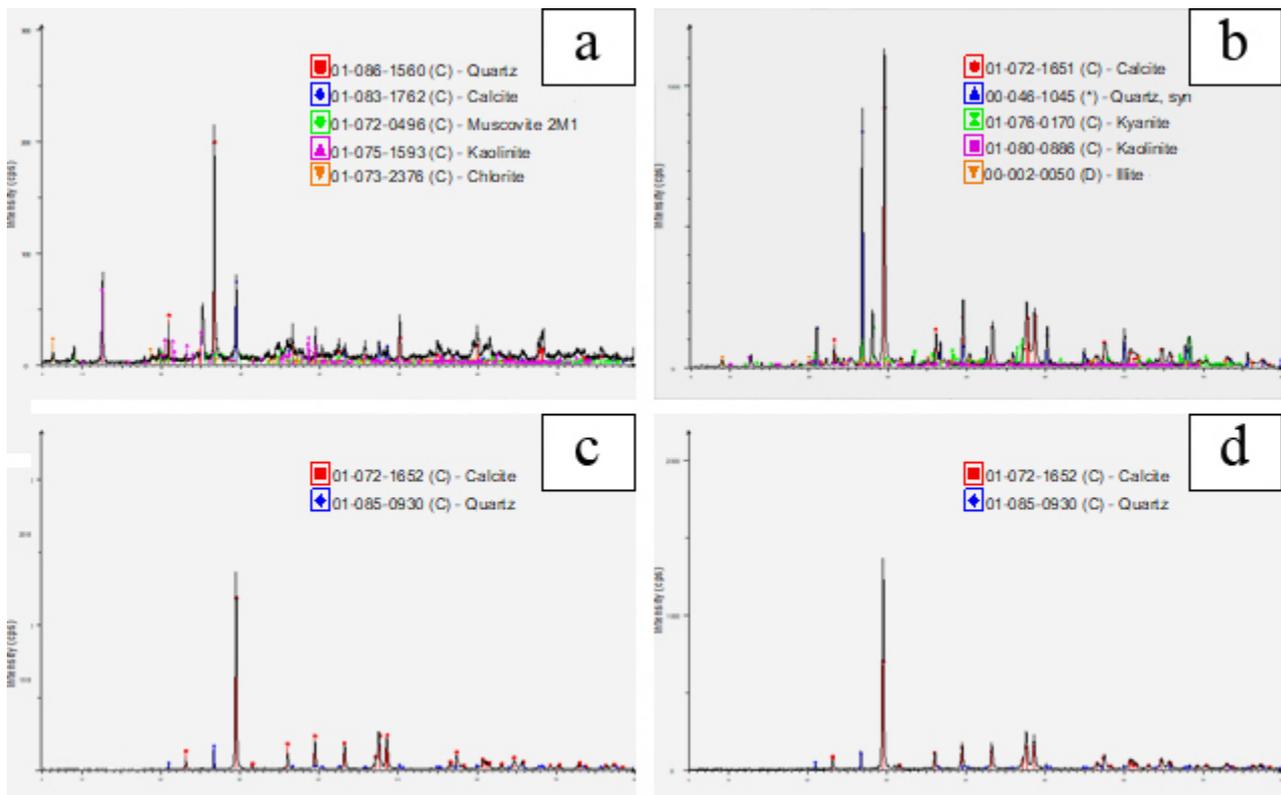


Figure 6 The mineral assemblages of four rock samples that were analyzed by X-ray diffraction (XRD): (a) argillaceous limestone (CM16_3), (b) calcic slate (CM2), (c) limestone (CM28), (d) metalimestone (CM21_1).

4.5. Mineralogy

The results from XRD show the mineral assemblage of the four representative rock samples, including argillaceous limestone (CM16_3), calcic slate (CM2), limestone (CM28), and metalimestone (CM21_1) (Fig. 6).

The most abundant rock forming mineral of argillaceous limestone (CM16_3) is mainly quartz followed by calcite and kaolinite, respectively. Chlorite and muscovite as the phyllosilicate minerals are also found.

The most abundant rock forming mineral of calcic slate (CM2) is calcite followed by quartz. The accessory minerals are kyanite, kaolinite, and illite.

The limestone (CM28) and metalimestone (CM21_1) share similarities in mutual mineral assemblages. The most abundant rock forming mineral of these rock samples is calcite, with quartz as an accessory mineral.

5. Discussion

According to the field investigation, Ban Maepong limestone mine locates on Permian sedimentary rocks that had been overlapped by the Permian Triassic volcanic rocks. The sedimentary rocks in Ban Maepong limestone mine consist of limestone and argillaceous limestone. The argillaceous limestone in the northern part of Ban Maepong limestone mine has the same color with calcic slate. The slaty cleavage is developed due to metamorphism (Fig. 3d – 3e). In addition, the limestone in the eastern part of Ban Maepong limestone mine is locally metamorphosed into metalimestone.

According to the previous studies (Mokhtari, 2012; Andrianarimanana et al., 2017) and exposure of calc-silicate rock within Ban Maepong limestone mine, the metamorphism of the calc-silicate rock usually caused by the nearby batholith of the plutonic rock. However, the plutonic rock is not presented within Ban Maepong limestone mine, but it locates in Triassic granite rock unit in the eastern mountainous area of Chiang Mai province, approximately five kilometers away from the eastern boundary of study area, and belongs to the Wiang Pa Pao-Khuntan batholiths (Charusiri et al., 1993). The geological setting of Ban Maepong limestone mine shares similarity with case of Selo Gajah Hill in Bojonegoro Regency, Eastern Java, Indonesia where the clastic limestone was metamorphosed due to the porphyritic andesite intrusion (Winarno et al., 2020).

According to the results through laboratory processes, the metalimestones from Ban Maepong limestone mine can be classified into two types. The first type is metalimestone that had been metamorphosed from limestone, and the second type is calcic slate that had been metamorphosed from argillaceous limestone.

The metalimestone metamorphosed from limestone protolith still retains its mineral assemblages in both petrographic and mineralogical results. The mineral chemistry results reveal that calcite is the sole carbonate rock forming mineral in all representative samples. The wollastonite that is sometimes occurs in the presence of silica-bearing fluids as in skarns (Whitley et al., 2020) is not presented in metalimestone from Ban Maepong limestone mine. In addition, the texture that

had been replaced by calcite were partly metamorphosed and recrystallized into almost equigranular calcite (Fig. 7f), and triple junctions are commonly observed between mineral grains such as quartz and calcite or calcite and calcite (Fig. 4c). However, specimen of metalimestone and limestone

cannot be distinguished from each other like marble and limestone. Quartz and calcite in the metalimestone can constrain the metamorphic condition of the metalimestone to be lower than 300 °C (Skippen, 1980) (Fig. 8a) due to the effect of the Permian-Triassic volcanic eruption.

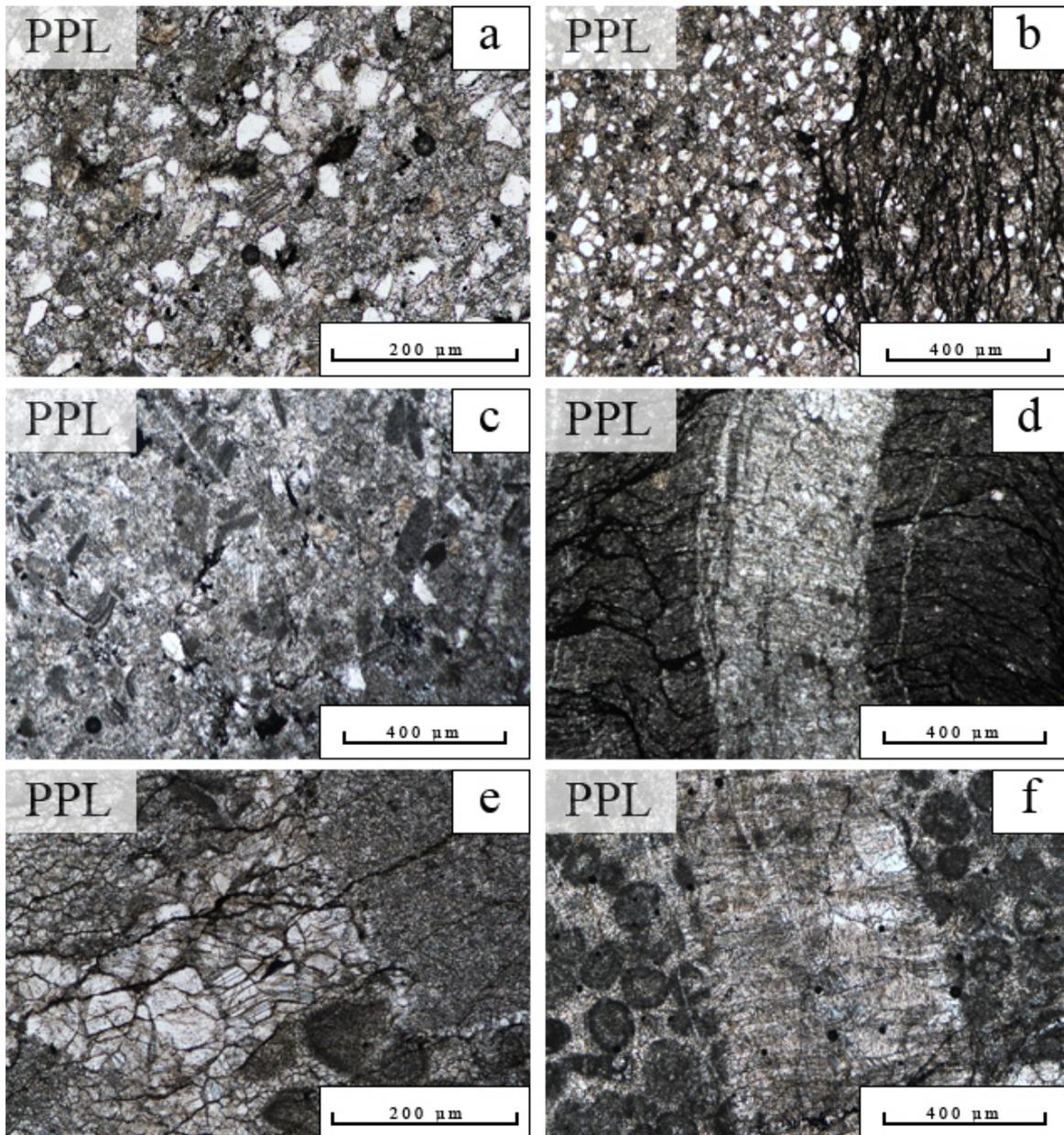


Figure 7 The photomicrographs under plane-polarized light (PPL) showing the rock texture before and after metamorphism: (a) non-metamorphic part of calcic slate (CM2), (b) metamorphic part of calcic slate (CM2), (c) argillaceous limestone (CM4), (d) calcic slate (CM8), (e) limestone (CM11), (f) metalimestone (CM21_1) with some relict texture of limestone.

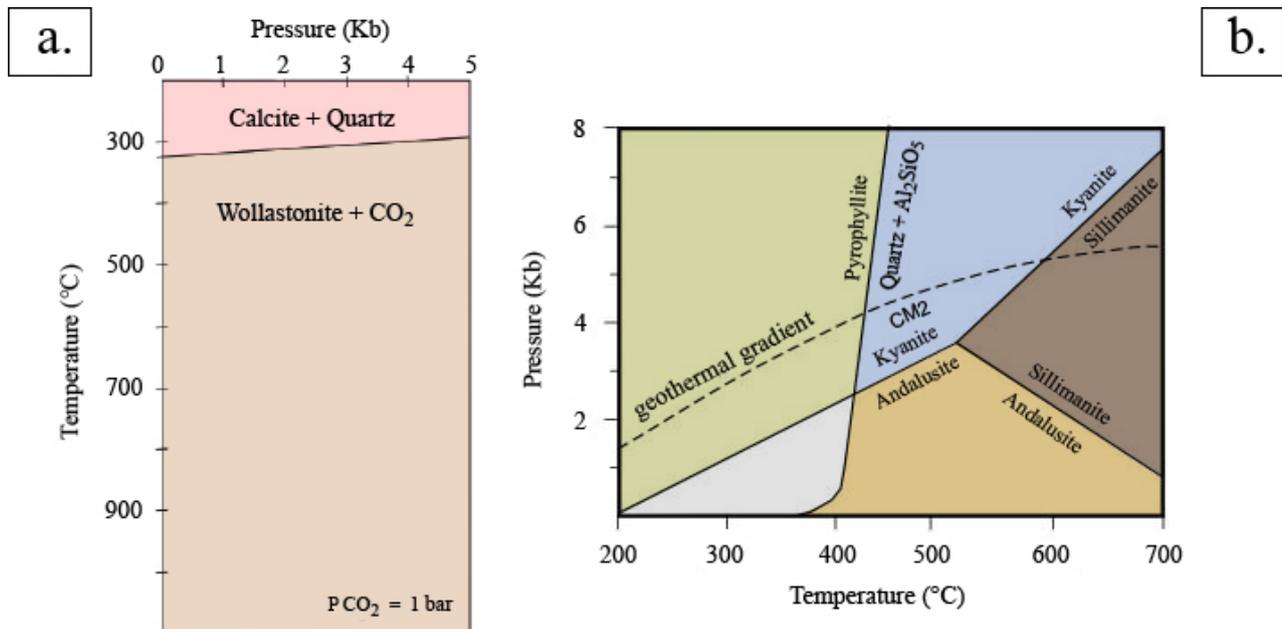


Figure 8 (a) The thermodynamic system of calcite and quartz (modified after Skippen, 1980), (b) The stability fields of metamorphic reaction of pyrophyllite, kyanite, andalusite, and sillimanite (modified after Nelson, 2011).

Moreover, the calcic slate of argillaceous limestone protolith produced kyanite as a new mineral from metamorphism. The kyanite can indicate high-pressure condition (Nelson, 2011). The presence of kyanite together with quartz in the calcic slate, that is clay-rich protolith can indicate that the temperature is higher than 400 °C and pressure is higher than 3 kilobars (Fig. 8b). In addition, the results of whole-rock geochemistry indicate that protolith of calcic slate of dark gray color with greasy surface in the northern part of Ban Maepong limestone mine is nearby argillaceous limestone. The early stages of metamorphism were observed through polarized-light microscope (Fig. 7a – 7b). The lepidoblastic texture was formed after clay minerals with flaky habit in the calcic slate were metamorphosed.

6. Conclusion

The metalimestone and related rocks from Ban Maepong limestone mine in Doi Saket district, Chiang Mai Province, northern Thailand, might be formed by marine sediments of the Paleo-Tethys Ocean during Carboniferous to Permian. The tectonic activity let the area was intruded and covered by andesitic rock of Chiang Rai-Chiang Mai volcanic belt. The heat from volcanic rock, andesite, intruded into the carbonate sedimentary rocks in the mine, causes argillaceous limestone metamorphosed into a calcic slate, and limestone metamorphosed into a metalimestone.

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