CHAPTER II

PHYSIOGRAPHY, GEOLOGY AND HYDROGEOLOGY OF THE CHIANG MAI BASIN

2.1 Geomorphology

The Chiang Mai Cenozoic intermontane basin is a kidney-shaped basin with an axis oriented in the northeast-southwest direction. The basin is bounded by the Khun Tan mountain range on the east and by the Inthanon mountain range on the west. The highest peaks on the two ranges are 1,685 meters above mean sea level (m msl) at Doi Pui in the west side and 1,025 m msl at Doi Lao Luang in the east side. The topography of the study area is shown by 1:50,000 scale topographic map sheets, Changwat Chiang Mai (4746 I), San Pa Tong (4746 II), Changwat Lamphun (4846 III) and San Sai (4846 IV).

Geomorphological features of the basin can be divided into three units (Tinnakorn Tatong, 2000). These are terraces, alluvial fans and flood plains.

Terraces are found on both at eastern rim and western rim of the study area. The ancient Ping River built up the terraces. The terraces are divided into high terraces and low terraces by its elevation. The high terraces occur at the outer rim of the basin and have an elevation between 330 and 450 m msl. The high terrace area in the western part is higher than in the eastern part. The low terraces are separated from the high terraces by their lower elevation (300-330 m msl).

Alluvial fans occupy the areas where the main rivers enter the basin. The stream velocity decreases and sediments are deposited at the foot of mountains with fan morphology. The biggest alluvial fan of the basin is the Mae Kuang alluvial fan located in the north-eastern part of the Chiang Mai Basin.

Flood plains are flat areas covering the central part of the basin. Flood plains occur along both sides of the main river, especially the Ping River. These areas show meandered scars and some oxbow lakes. They are the lowest areas and often flooded during monsoon seasons. The drainage system of the study area has a dendritic pattern of the Ping River, the biggest river of the basin. The Ping River flows from north to south in the center of the basin and divides the area into two parts, western part and eastern part. The river enters the basin at the elevation of around 320 m msl in the north and leaves the basin at around 280 m msl in the south.

The main western tributaries are Mae Rim, Mae Tha and Mae Khan/ Mae Ngan. These tributaries join the Ping River in the northern, middle and southern parts, respectively. The main eastern tributary is Kuang River entering the basin in the north-east. Mae Kuang Dam controls the flow of the Kuang River. The dam is located at the foot of the eastern mountain range. The main eastern tributaries of Kuang River are On, Thi and Tip Rivers.

2.2 Climate

Chiang Mai Basin is located in the Northern Thailand. Surrounded by mountains, the weather of Chiang Mai varies considerably in comparison with other parts of Thailand. The climate is characterized by the monsoon, which creates three distinct seasons.

The winter season occurs from November to February when the north east monsoon carrying cool and dry air masses move through the area and causes the cool and dry weather. The minimum of temperature are in range from 7 degree Celsius (°C) to 14 °C.

The summer season is influenced by south-east monsoon, which carry dry air masses from the South China Sea across the Gulf of Thailand to the basin. This occurs between February and April. During this period hot and drought condition prevail. The maximum temperatures generally range from 35 °C to 42 °C.

The rainy season appears when the south-west monsoon starts in May and ends in September. The monsoon moves the moist air masses from the Indian Ocean and passes through the basin with the highest precipitation rate in August. The average annual rainfalls in the basin are 1,159.67 mm/yr between 1967 and 2001.

2.3 Geology

The Chiang Mai intermontane basin was formed during late Cretaceous and early Tertiary. This was a period of trans–tensional faulting, caused by the collision of the Indian with the Eurasian Continent (Sangad Bunopas and Vella, 1983; Songpope Polachan and Nares Sattayarak, 1989). As a result of the collision, the Indian continental plate was rotated clockwise and created a trans-tensional dextral shear regime. Under this condition the basin was formed as pull-apart structure, graben and half-grabens, with a longitudinal axis in N-S direction. Striking faults in NW-SE and NE-SW direction can be interpreted as dextral shear faults and sinistral shear faults. While N-S striking faults is related to extensional faults. Interpretation from a Landsat TM Satellite image reflects the above-mentioned pattern of faults. Figure 2.1 shows the lineaments mapped from the satellite image and interpreted as faults. The shape of the basin is generated by intersection of a set of faults of the three major directions: NW-SE, NE–SW and N-S. Lineaments are inferred from the area of consolidated rocks into the basin area. They are clearly visible in the Quaternary area. This provides evidence of neotectonic activities in the basin. Drainage pattern of the basin is also governed by these faults. It is evidenced that the Mae Kuang River does not join the Ping River at the upstream (around San Sai District) but instead bends to the SE and flowing in parallel to the Ping River almost 40 kilometers before joining. This is probably dictated on a major fault zone in the NW-SE direction (Margane et al., 1998). The depth of basement is varied from place to place was studied by Kittichai Wattananikorn et al., 1995 the studied gravity data of the basin. This is the only available source of information about the deep structure. The Bouguer gravity anomaly map is shown in Figure 2.2. Normal block faulting configures the basin with the Tertiary and Quaternary sediments of more than 2,000 meters filling up (Kittichai Wattananikorn et al. 1995). These faults are believed to be less active during late Tertiary and Quaternary. Nevertheless the lineaments from the satellite image clearly show the extension of faults cutting through the Quaternary and resent sediments. For this reason, the tectonic movements might still occur until the recent.

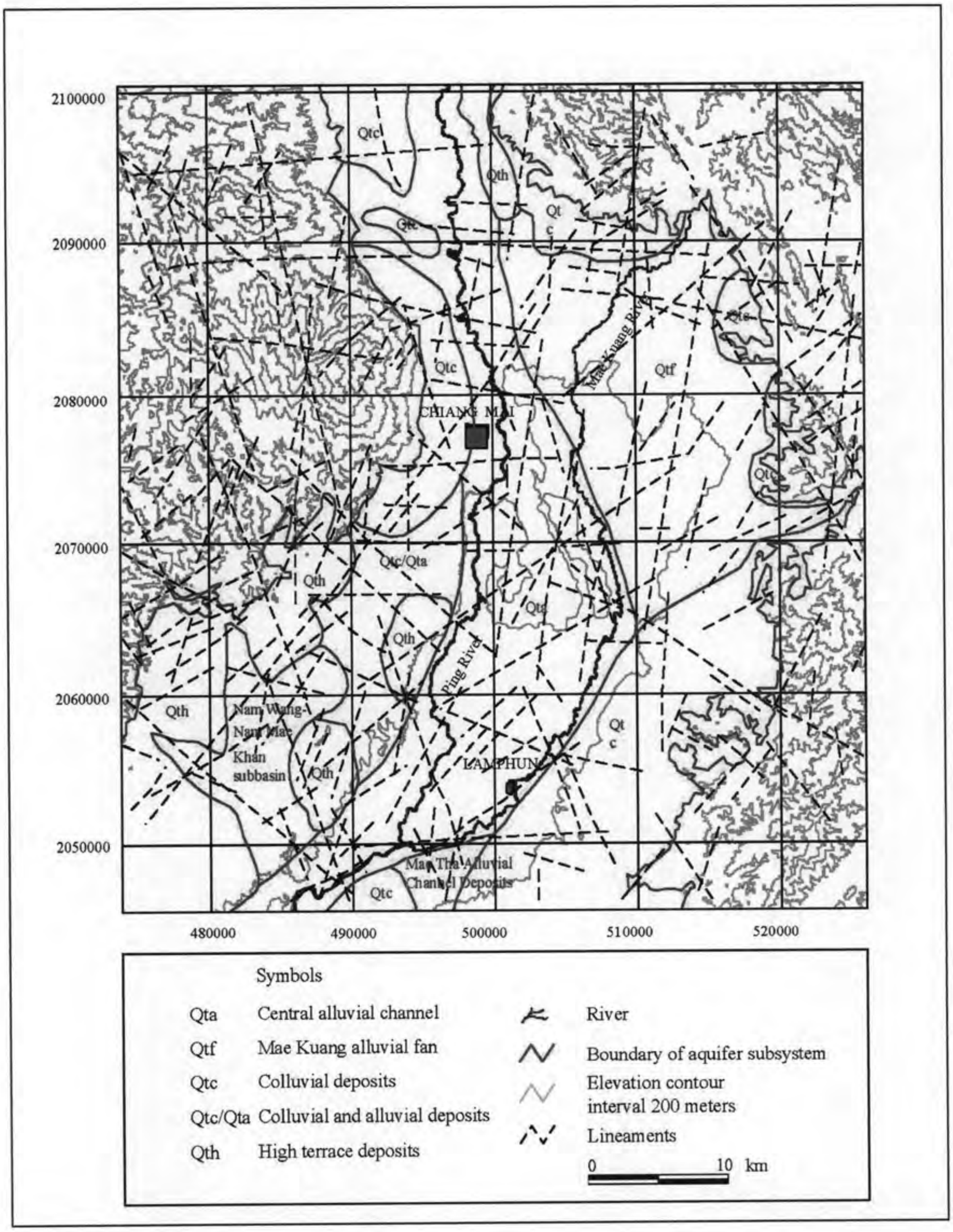

Figure 2.1 Lineament interpretation from Landsat TM satellite image (06/04/91) (modified from Tinnakorn Tatong, 2000 and Sirirat Uppasit, 2004)

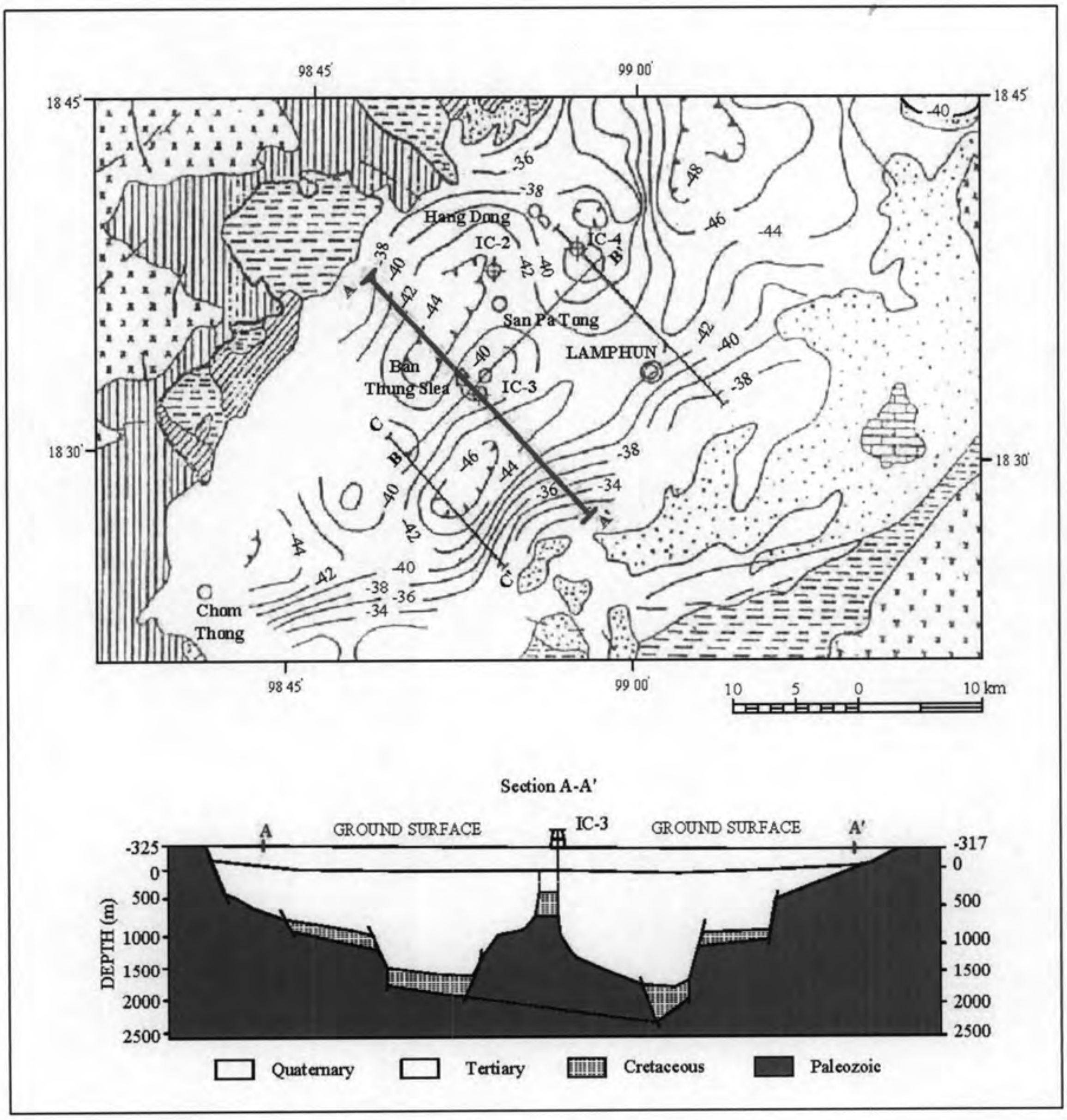

Figure 2.2 Bouguer gravity structural interpretation of the Chiang Mai Basin (modified from Kittichai Wattananikorn et al., 1995)

The geology of Chiang Mai basin and its surroundings can be described separated into two groups. These are well consolidated rocks of the Pre-Cambrian and Paleozoic age, and poorly consolidated to unconsolidated rocks of Tertiary and Quaternary age. The geological map of Chiang Mai Basin is shown in Figure 2.3.

2.3.1 Consolidated rocks

The well consolidated rocks underlie the western range, Doi Suthep, and eastern mountain range, which form great relief and steep slopes. Many types of metamorphic, sedimentary and igneous rocks are in this group of consolidated rocks. The well consolidated rocks in the study area and surrounding areas have been reported by Beshir (1993) and Tinnakorn Tatong (2000). Accordingly, classification of well consolidated rocks using their ages and lithologies are as follows:

1. Pre-Cambrian metamorphic complex, PC (570-4,600 million years): The rock unit is named Lang Sang Gneiss. They form Doi Suthep Mountain in the western part of the study area. The Lang Sang Gneiss group consists of para and ortho gneiss, which are very coarse-grained, black and white banded, good foliation and feldspar augens. They are interbedded with schist, migmatite, calc-silicate and marble lenses. The rocks were metamorphosed by high grade and regional metamorphism. They were in contact with Paleozoic rocks. The rock types are regarded as meta-sedimentary with wide range of compositions, affected to large degrees by anatexis and derivation of acidic to intermediate magma with tectonic and metamorphic modification taking place subsequently to emplacement.

2. Ordovician Hod limestone, O (435-500 million years): This Ordovician limestone is found only in the western mountain range. The rocks can be divided into three parts: lower, middle and upper parts. The lower part of this unit consists of beds of argillaceous limestone. The middle part consists of slaty shale, sandstone and interbedded limestone. The upper part is massive limestone, which is grey to dark grey in colour. It is interbedded with argillaceous.

3. Silurian-Devonian meta-sediments, SD (345-435 million years): these are named Don Chai Group or Silurian Don Chai Group. The rocks consist of slate, which is black to dark grey in colour, dense to thinly bedded and partly interbedded with greywacke and limestone lenses. The Don Chai Group is found on the western side of the mountainous area. Attempts have been made to divide into formation of non-metamorphosed and slightly metamorphosed character. Their distribution and stratigraphic relations are unsolved.

4. Carboniferous sedimentary rocks, C (280-345 million years): The rock unit is Mae Tha Group. They can be recognized into two parts: lower and upper parts. The lower part, which unconformable overlies the older rocks, consists of conglomerate, sandstone, siltstone, shale and mudstone. These were deposited in terrestrial environment. The upper part consists of slaty shale of blackish grey to greenish grey color. The shale contents decrease upward and are substituted by sandstone and greywacke. The uppermost part is units are composed of shale interbedded with limestone. The age is given as Upper Carboniferous due to its conformably overlain by the lower Permian limestone. Middle Carboniferous is a period of major tectonic accompanied by magmatic activity. The area shows clear separation of depositional environment into basin and ridge. Red beds and volcanic sequences are of uncertain age within the Carboniferous. There are fairly well developed foliated granite, locally associated with intrusion of diorite, gabbro and pyroxenite.

5. Permian sedimentary rocks, P (230-280 million years): The Permian rocks we found mainly in the eastern part of the Chiang Mai Basin. The rocks are divided into two formations: Pa Huat Formation (lower part) and Kiu Lom Formation (upper part). The lower part consists of sandstone and siltstone, which are partly tuffaceous sandstone contain fossils, tuff and agglomerate. The upper part is a thick bedded to massive limestone with dark grey to black colour and interbedded with shale. The Permian rocks show great variation in lithology and thickness. In many areas, they are overlain by Permo–Triassic volcanic sequence.

2.3.2 Igneous rocks

1. Triassic granite, Gr2: These are porphyritic biotite granite, equigranular porphyritic granite. They are in the same age. Porphyritic biotite granites are found in the south east of the mountainous area. It is white to light grey in colour, medium-grained with K-feldspar phenocrysts. Major minerals in the granites are quartz, feldspar and biotite. Minor minerals are hornblende, muscovite, zircon, apatite and fluorite. Equigranular porphyritic granite forms the high mountains in the north west of the basin. They are metamorphosed and gneissic in some parts, medium-to-coarse-grained with slightly foliation. There can also form are dykes and sills cutting through the rocks.

2. Triassic volcanic rocks, V: Volcanic rocks are found only in a small area in the north east of the basin. The volcanic rocks consist of basaltic/andesitic lava, tuff, lapilli and tuff breccia. There rocks are highly weathered and form lateritic and clay-rich soils throughout the area.

2.3.3 Unconsolidated rocks

The poorly consolidated rocks of the Tertiary age are found only in the western rim of the basin. The unconsolidated sediments of the Quaternary age cover most areas inside the basin.

1. Tertiary semiconsolidated sediments, T (1.8-65 million years): The Tertiary sediments were deposited in the lacustrine environment and tropical climate. The rock unit in the lower part is named Chaiprakarn Unit. The rocks comprise sandstones of single origins. Thickness of the rock is about 30 meters. The upper rock unit is Mae Sod Formation and transitional zone of Mae Sod Formation. Their thickness is about 180-210 meters and 90 meters, respectively. Mae Sod Formation consists of alternation of clay, clay stone, and brown compact. Transitional zone of Mae Sod Formation consists of clay, and sandy clay. The Tertiary rocks show definite tectonic displacement. The rocks are known in other isolated basins with similar lithology.

2. Quaternary sediments, Q (present-1.8 million years): The Quaternary sediments can be built up in the alluvial environment. In early period, these sediments were deposited in dry cool and wet warm climatic conditions. Then, they were deposited in wet and warm weathers later. The Quaternary sediments can be classified into 6 units, based on shallow borehole data with depth less than 6 meters and their different morphologies. These units are described as follows:

High terrace deposits (Qth): The high terrace deposits are found on both sides of the basin. They are distributed especially along the western rim over a large area. The sediments composed of sand, sandy clay, silty clay and gravel. The sand varies from fine to coarse grains with gravel mix. It is sub-angular and poorly sorted. Iron and manganeous are found abundantly in the sand layer. The hard layers of laterite (plinthite) are frequently found up to 1.5 meters thick. The clay layers are yellowish brown to reddish brown in color. The gravel layers consist of sandstone, quartzite, quartz and chert fragments, which are sub-rounded to rounded. Sandstone and quartzite boulders are found in many places. From the field observation, these sequences usually overlie erosional surface of Pre-Quaternary rock, Tertiary rocks in the west rim and the Carboniferous rocks in the east rim (Niran Chaimanee, 1997). Therefore the relative time of high terrace deposits is Pleistocene age.

Colluvial deposits (Qc): The colluvial deposits are found along the footslope of the mountain range at the eastern rim of the basin. Gravity and water transported the deposits with the short distance from the parent rocks. The extension of colluvial sediments depends on the degree of weathering of the parent rocks and the tectonic setting. The reflecting areas are in the eastern area such as San Sai, Doi Saket districts and Doi Ti near Lamphun province. The sediments consist of loosed sand with very fine grains, overlain by lateritic pan and mottled clay with rock fragments in angular shape. There is no sedimentary structure. The deposits directly overlie on the bedrock in the eastern rim of the basin, Lamphun area, and on the high terraces in the northern part of the basin (San Sai area). Therefore, the age of the colluvial deposits should be equivalent or slightly younger than the high terrace.

Alluvial complex (Qa): The alluvial complexes form broad plains of low relief on both sides of the basin. The alluvial plains were partly eroded by tectonic uplifting in combination with the recent Ping River activities. Therefore, the sedimentary development is in doubt. The alluvial complexes consist of clay, silt and sand. Loose silt or silty clay are light grey color, homogeneous without any sedimentary structure and compacted. Fine sand layers, which are slightly to very clayey in light grey to dark brown color, are found with abundant pisolites and/or lime nodules. Fine sand layers, which are slightly to very gravelly, can be found in some areas. These layers indicate the fluvial cycle of channel and over bank deposits. The thick and homogeneous silt and silty clay in this formation might reflect a low energy and continued deposition as lacustrine of lake environment.

Alluvial fans (Qfd): The alluvial fans are extensively distributed in the eastern part of the basin from San Sai toward San Kampaeng areas. Three alluvial fans are found in the east: Mae Kuang fan in the upper north, Mae Pong fan in the middle and San Kampaeng fan at the southernmost. Mae Kuang fan is the largest one. The sediments consist of coarse sand and gravel in the main channel zone, while fine to medium sands are found on both sides. Clay and/or silt layers alternate in the lower part. Sand layers of the middle alluvial fan usually contain some clays, probably due to the short distance of transportation from the source material. These sedimentary deposits of the southern alluvial fans overlie on compacted silty clay probably of alluvial complex. The formation of these fans is likely related to the climatic optimum during middle Holocene (present–0.01 million years) when precipitation increased and caused high sediments flux from the mountain area toward the lower alluvial plain. These sediments were transported by river system and eventually formed fans (Niran Chaimanee, 1997).

Flood plain deposit (Qff): The central flood plains or Mae Ping flood plains are found mainly along the present Ping River. There are some remaining of Mae Ping paleo-channels. The river is shifting from east to west. The central flood plains consist of silty clay of brown to dark grey color, alternating with loose fine to medium sands. Plant remains and mica can be observed in this unit. Silty clay with slightly sandy, light grey to light greenish grey, are found in lower part of this sequence. Pisolites and mottles are common in this unit. The sediments of central flood plain clearly show the depositional environment as over bank and swamp. The loose sand alternation in this unit contributes to the shifting of channel through time.

Mae Ping channel deposits (Qfl): The Mae Ping channel deposits consist of loose sand and silt layers. The sand is brown to light brown color with abundant mica. The sediments are well sorted. Interbedded clays are found in some parts of this unit. Generalized stratigraphy of the Chiang Mai Basin and surrounding areas, modified from Beshir (1993) and Tinnakorn Tatong (2000), is summarized in Table 2.1. Stratigraphic section of the study area is derived from the interpretation of the lithologic description. The Quaternary is designated relative age as there is no absolute age dating data available.

Table 2.1 General Stratigraphy of Chiang Mai basin and surrounding area (modified from Beshir, 1993, Tinnakorn Tatong, 2000 and Sirirat Uppasit, 2004)

Period	Epoch	Time (million years)	Geological Unit	Thickness (m)	Lithology	Remarks	Igneous Activity
		345					
Devonian to Siurian	-		Silurain-Don Chai Group	-	Thick series of shale, sandstone, graywacke and chert with minor limestone, locally phylite, slate, quartz-feldspathic schist, chert and tuffs.	Attempts have been made to divide into formations of non-metamorphosed and slightly metamorphosed characters. Their distribution and stratigraphic relations are unsolved.	-
		435					
Ordovician	-		Ordovician Hod limestone	-	Lower part consists of thin beds of argillaceous limestone, slaty shale, sandstone and interbedded limestone in middle part. Massive dark grey limestone and minor sandstone and claystone.	Occur only in the western mountain range.	-
		500					
Cambrian	-		-	-	Well bedded to massive, fine to coarse grained sandstone, increasingly argillaceous toward the top, locally quartz schist, quartz-mica schist.	The age is given by the stratigraphic position and similarity in lithology to rocks containing Saukid Trilobites and orthid brachiopods recognised in the Peninsular	-
		570					
Precambrian			Lang Sang Gneiss	-	Medium to high grade para and ortho gneisses, schist, marble and calc-silicate rock.	Rock types are regarded as meta-sedimentary rocks with wide range of composition, affected to large degree by anatexis and derivation of acid to intermediate magma with tectonic and metamorphic modification taking place subsequent to emplacement.	-
		4,600					

Table 2.1 General Stratigraphy of Chiang Mai basin and surrounding area (modified from Beshir, 1993, Tinnakorn Tatong, 2000 and Sirirat Uppasit, 2004)

Period	Epoch	Time (million years)	Geological Unit	Thickness (m)	Lithology	Remarks	Igneous Activity
Quaternary	Holocene or Recent	Present – 0.01	Flood Plain Deposits	10-60	Unconsolidated; well sorted sand and gravel overlain by clay and silt.	Thick layer of coarse grained gravel and pebble was deposited behind natural levee. This grades into coarse silt at the natural levee and fine silt and clay within the backswamp deposit.	-
	Middle to Upper Pleistocene	0.01 – ?	Low Terrace Deposits	> 150	Unconsolidated; gravel, sand and clay.	Mostly form high dissected surfaced terrace.	-
	Lower Pleistocene	? – 1.8	High Terrace Deposits (Mae Fang Formation) Unconformity	> 760	Semi to unconsolidated; sand, sandy clay, clay, minor gravel bed.	Partly formed dissected surfaced terrace but mostly concealed under sediments.	-
Tertiary	Miocene-Pliocene	1.8 – 65	Transitional zone of Mae Sod Formation	~ 90	Clay, sandy clay, brown with a few beds of thin bedded sand with appearance of oil show.	The rocks show definite tectonic displacement and are known in isolated basins with similar lithology.	-
			Mae Sod Formation	180-210	Alternation of clay, clay stone, brown compact, trace of oil show.		
			Chaiprakarn Unit Unconformity	~ 30	Sandstone of various origin.		
Cretaceous		65 – 141	Khorat Group	> 240	Pebble, cobble beds of rock derived from Doi Ti-Doi Saket Formation; compacted, overlying on alternated beds of sandstone and black shale.	-	-

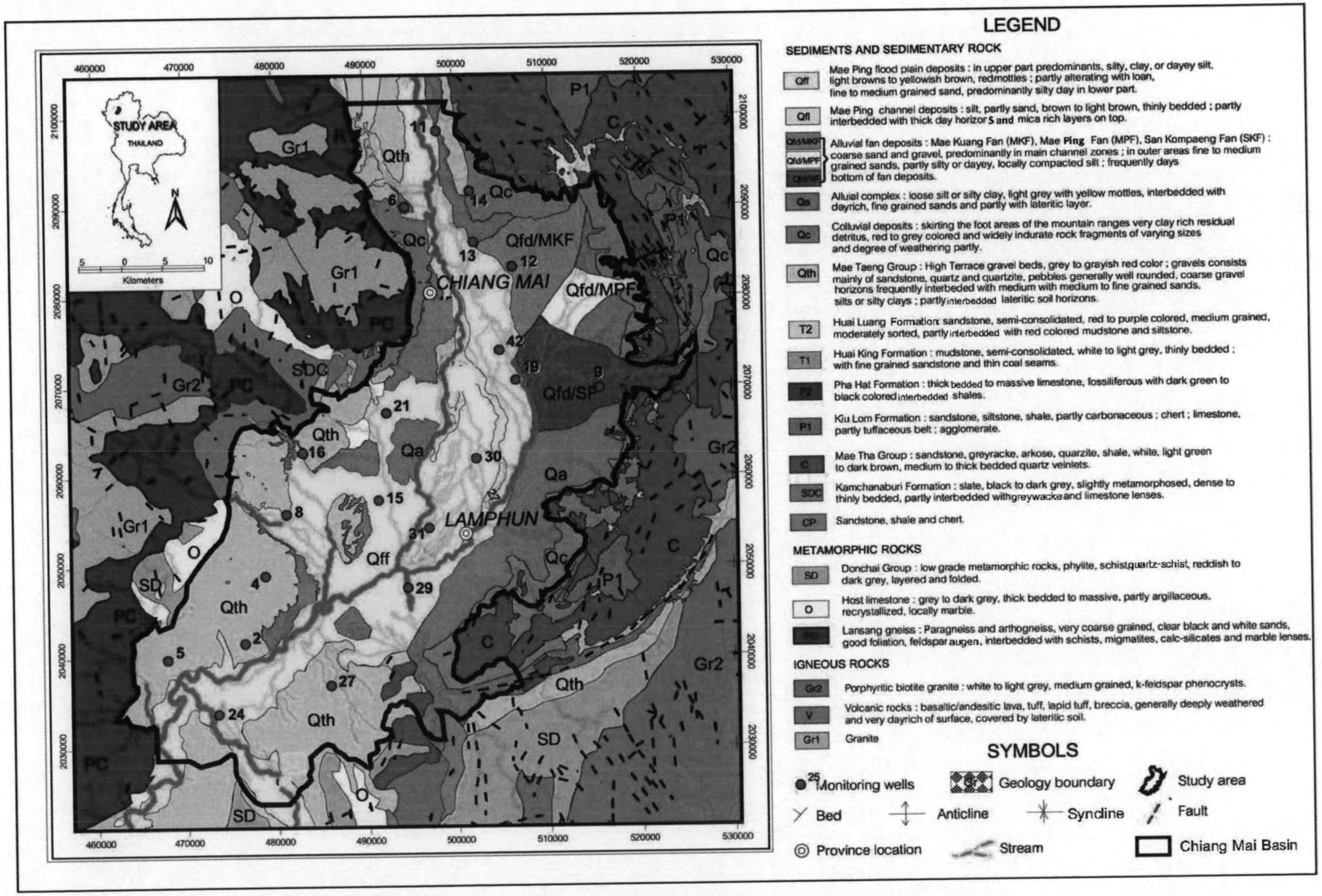

Figure 2.3 Geologic Map of Chiang Mai basin (modified from DMR, 2001)

2.4 Hydrogeology

The Chaing Mai geology comprises of various kinds of rocks of different ages. The variety of geological structures are favorable for groundwater storage such as faults, fractures, and folds. Rocks can be hydrogeologically classified into 3 main types (Figure 2.4) which are unconsolidated, semi-consolidated, and consolidated rocks. Following this classification, these three rock types are further subdivided into various hydrogeological units (Department of Mineral Resources, 2000a and 2000b).

2.4.1 Hydrogeological units in unconsolidated aquifers

The hydrogeological units in unconsolidated rocks consist of gravels, sands, silts, rock fragments and clays which are loosely cemented. Generally, groundwater is stored in intergranular voids of the sediment grains. The storage capacity of groundwater aquifers in the sediment deposits, particularly in those gravel and sand layers, depends on the following properties:

-Thickness of the sediment sedimentary unit. The thicker unit is the better storage capacity.

-Sorting of sediment grain. Well sorting provides better storage capacity.

-Roundness of sediment grain. The well rounded grain renders good storage capacity.

The unconsolidated aquifer of the Chiang Mai Basin can be divided into 3 hydrogeological units as follows;

1. Alluvial sediments aquifer (Qcp): consists of gravel, sand, silt, and clay. Groundwater is stored in intergranular voids of gravel and sand, deposited along the flood plain and meander belts of the Mae Ping River. The average depth to the aquifer is 20-40 m., and groundwater well can yield more than 20 cu.m/hr.

2. Low terrace sediments aquifer (Qcr): consists of gravel, sand, silt, clay deposited along narrow terrace next to the Mae Ping River's flood plain which consists mainly of thick clay with some gravel and sand pocket to thick gravel and sand bed. Groundwater is stored in intergranular voids of gravel and sand deposits. The average depth to the aquifer is 30-100 m., and groundwater well can yield 10-20 cu.m/hr except the area adjacent to alluvial sediment which may yield more than 20 cu.m/hr.

3. High terrace sediments aquifer (Qcm): consists of gravel, sand, silt, and clay deposited along area higher than young terrace deposit. Groundwater is stored in intergranular voids of gravel and sand deposits. The average depth to the aquifer is 50-250 m., and 300 m. in some area. Groundwater well can yield 2-10 cu.m/hr.

2.4.2 Hydrogeological units in semi-consolidated aquifers

The hydrogeological units in semi-unconsolidated rocks (Tsc) consist of various Tertiary rocks such as shale, oil shale, and lignite. Groundwater is stored in cracks, fractures, faults, and bedding planes. The average depth to the aquifer is 20-60 m., and groudwater well can yield less than 2 cu.m/hr.

2.4.3 Hydrogeological units in consolidated aquifers

Most groundwater is stored in spaces of various geological structures i.e. cracks, fractures, faults, and bedding planes, caves, and in weathering zone. The groundwater quantity depends upon size and continuity of these structures. The structures with large cavity and good continuity will store a great deal of groundwater.

The consolidated aquifers of the Chiang Mai basin can be classified into hydrogeological units as follows;

1. Triassic-Jurassic sedimentary rocks aquifer (Tri): consists of sandstone, siltstone and conglomerate. Groundwater is stored in cracks, fractures, faults, and bedding planes. The average depth to the aquifer is 10- 40 m., and 70 m in some area. Groundwater well generally yields less than 2 cu.m/hr.

2. Permian-Carboniferous limestone aquifer (PC): consists of gray to dark gray, massive to bedded limestone with chert nodule. In some part there is shale interbedded. Groundwater is stored in cracks, fractures, faults, caves and bedding planes. The average depth to the aquifer is 12-20 m., and groundwater well generally yields less than 2-10 cu.m/hr.

3. Permian-Carboniferous meta-sedimentary rocks aquifer (Pcms): consists of sandstone, shale, chert, limestone, slate, mudstone, quartzite, phyllite. Groundwater is stored in cracks, fractures, faults, and bedding planes. The average depth to the aquifer is 12-30 m, and groundwater well generally yields less than 2 cu.m/hr or nil.

4. Ordovician limestone aquifer (Ols): consists of gray to dark gray, recrystallized, laminated, argillaceous limestone with interbedded shale in the lower part. Groundwater is stored in cracks, fractures, faults, caves and bedding planes. The average depth to the aquifer is 30-70 m., and drilled well generally yields 2-10 cu.m/hr.

5. Cambrian-Devonian metamorphic rocks aquifer (DEmm): consists of quartzite, schist, phyllite, gneiss. Groundwater is stored in cracks, fractures, faults, and bedding planes. The average depth to the aquifer is 30- 40 m., and groundwater well generally yields less than 2 cu.m/hr.

6. Gneiss, schist, and migmatite (Gn): consists of gneiss, schist, and migmatite. Goundwater is stored in cracks, fractures, faults, and bedding planes. The average depth to the aquifer is 30-80 m., and groundwater well generally yields less than 2 cu.m/hr.

7. Volcanic rock aquifer (Vc): Groundwater is stored in cracks, fractures, faults, and weathering zone. The average depth to aquifer is 30-80 m., and groundwater well generally yields less than 2 cu.m/hr.

8. Granite aquifer (Gr): Groundwater is stored in cracks, fractures, faults, and weathering zone. The average depth to aquifer is 10-20 m., and groundwater well generally yields less than 2 cu.m/hr.

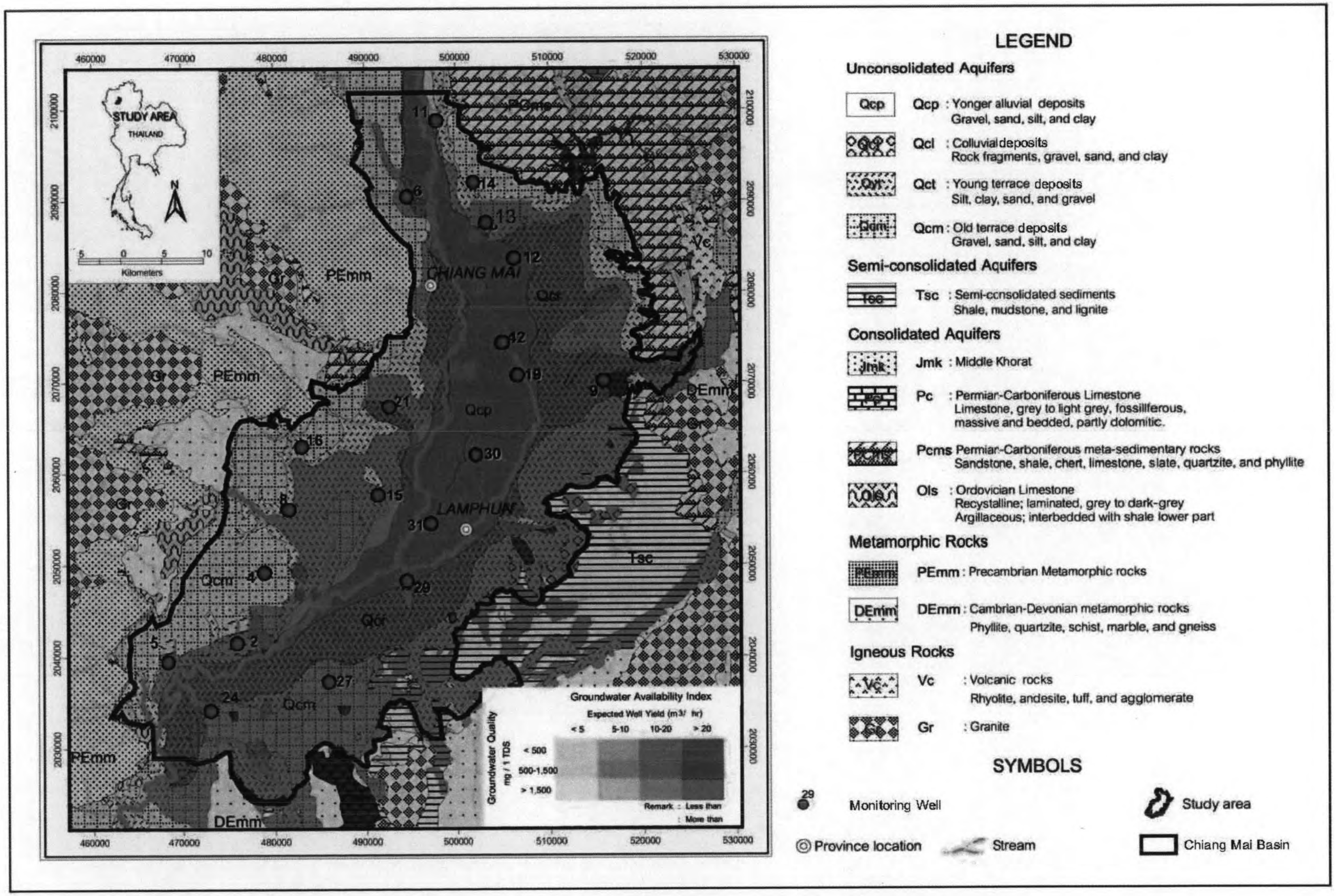

Figure 2.4 Aquifer systems of Chiang Mai basin (modified from DMR, 2001)

2.5 Previous studies on groundwater recharge in Chiang Mai Basin

1. Fongsaward Suvagondha (1979) studied the recharge patterns on the eastern part of Chaing Mai Basin covering about 200 sq.km. by using rainfall data during period from 1969 to 1976. It was found that the rate of excess rainfall to flow and fill to the aquifers was from July to October (total rainfall of 390 mm/yr) accounting for 70 percent of yearly rainfall or 273 mm/yr.

2. Fongsaward Suvagondha and Santichai Jitapunkul (1982) chose choride mass balance from the different volumes of chloride in rainfall and the groundwater to calculate the recharge rate added to aquifer. The area located on the east of basin and they used rainfall data during period from 1969-1974 and found the average of around 1,300 mm/yr. The amount of chloride in rain water was equal to 0.36 ppm on the average and the average in the aquifers were from 2.5 to 4.0 ppm and the recharge rates were from 0.9 to 14.4 or equal to 11.7 to 187.2 mm/yr.

3. Pisanu Wongpornchai (1990) calculated recharge rate by using the same technique employed by Fongsaward Suvagondha (1979), but the study area was on the western part of the basin covering 480 sq.km. based on meteorological data during 1958 - 1984 only in October to September (average rainfall of 91.14 mm/yr). He found that 71 percent of the rainfall percolated into the aquifer at the rate of 65 mm/yr.

4. Tinnakorn Tatong (2000) calculated recharge rate by using groundwater balance mathematical model technique during the period from July to October. He found that rainfall could refill aquifer directly in the basin at the rates from 25 to 293 mm/ yr.

5. Sirirat Uppasit (2004) calculated recharge rate by using water table fluctuation approach and the specific yield by using the average yearly rainfall data period from 1963 to 2001(1,116 mm). It was found that the volume of water flow was between 0.37 and 251.86 mm/yr, representing 6-21 percent of average rainfall all year.