CHAPTER 2

Geological Setting

The geological map of Nakhon Sawan area on a scale of 1: 250,000 was firstly compiled by Bunopas, and subsequently published by Department of Mineral Resources (1976). Department of Mineral Resources (2007) republished the geological maps of Changwat Nakhon Sawan and Uthai Thani on a scale 1:1,000,000. The report of geological survey was conducted by Bunopas (1980). Accordingly, the geological map of the study area and vicinity presented here (Figure 2.1) was modified from Department of Mineral Resources (1976) and Department of Mineral Resources (2007). The distribution of the rocks in the study area comprises sequence of sedimentary, metamorphic and igneous rocks, and has a long axis parallel/subparallel to a north – south direction. They can be separated into six major lithostratigraphic units of metamorphic and sedimentary rocks: Precambrian Rock unit, Silurian-Devonian Rock unit, Permian Rock unit, Triassic Rock unit, Jurassic Rock unit and Quaternary Sediments, and two major units of igneous rocks: Triassic Rock unit and Cretaceous Rock unit. The details of all the lithostratigraphic units in this region are separately summarized in the next section.

2.1 Metamorphic and Sedimentary Rocks

2.1.1 Precambrian rock unit

The rock unit occurs along the high mountain range in the southwestern part of the study area, and was named as Uthai Thani complex. This unit consists of metamorphic complex of amphibolite facies that includes augen gneiss, granite gneiss, biotite-microcline gneiss, quartz feldspathic gneiss, biotite schist, banded quartzite, calc-silicate rock and marble (Bunopas, 1976).

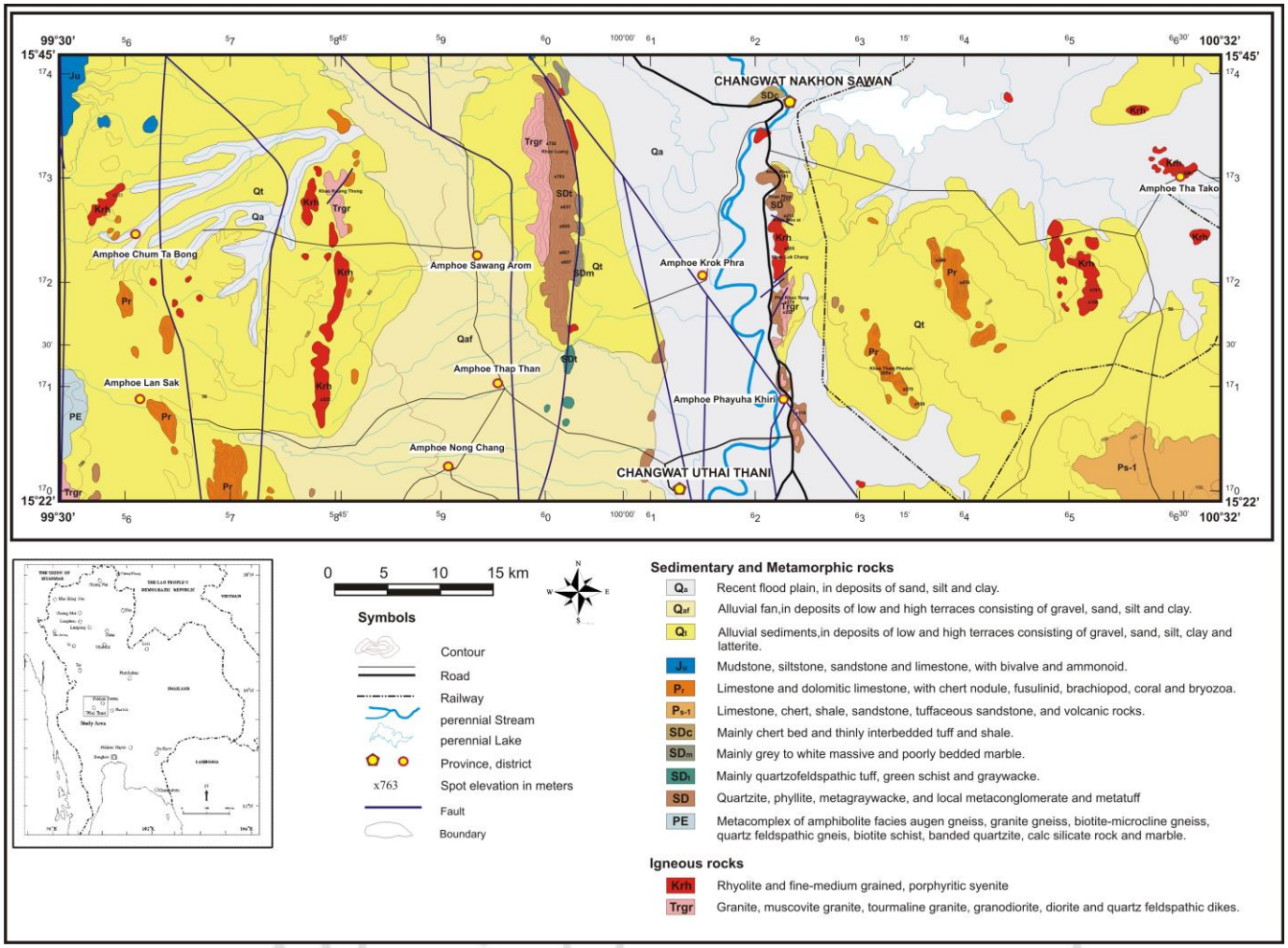

Figure 2.1 Geologic map of study area modified form Bunopas (1976); Department of Mineral Resources[a] (2007) and Department of Mineral Resources[b] (2007). The Mae Ping Fault Zone is taken from Morley, *et al.*, (2007).

2.1.2 Silurian-Devonian rock unit

The Silurian-Devonian Rocks occur in the central part of the study area. Their distribution is in north - south direction along a mountain range and small isolated hills. They were moderately to strongly folded, and partly emplaced and covered by post Permian diorite - granite plutons, and andesite – rhyolite lavas and tuff, respectively. They are classified as Tanao Sri Group (Bunopas, 1976; 1980) and are subdivided into four rock formations from older to younger as follows: Ban Rai Formation, Khao Luang Tuff, Khao Mano Marble and Khao Gob Chert.

The Ban Rai Formation consists of quartzite, phyllite, metagreywacke and metachert beds with local metaconglomerate. Their distribution is in north - south direction along Khao Khieo, Khao Pra, Khao Musi and Khao Khok Mai Den and a few small isolated hills, south of Nakhon Sawan Province.

The Khao Luang Tuff comprises massive to poorly bedded metaquartzofeldspathic tuff, green schist and metagreywacke. These rocks crop out along Khao Lung and west of Khao Khieo and Khao Khok Mai Den. They are flanked along the west by intrusive rocks and along the east by Khao Mano Marble and rhyolite.

The Khao Mano Marble includes marble that has gray to white colors and is massive to poorly bedded. Fossils of unidentified shells and coral were found in rock fragments. These rocks distribute along the eastern flank of Khao Lung range and underlain conformably by Khao Lung Tuff.

The Khao Gob Chert is the least common rock in Silurian-Devonian age in the study area. It consists mainly of thin bedded, white, gray, black and brown metacherts. Occasionally, metachert is interbedded with metaquartzofeldspathic tuff, slate, and phyllite. They crop out at Khao Gob, Muang District, Nakhon Sawan Province and Khao Phawaeng and Khao Sakae Krang, Uthai Thani Province.

2.1.3 Permian rock unit

The Permian rock occurs in western and eastern parts of the study area (Department of Mineral Resources, 2007) and was grouped into Ratburi Group (Bunopas, 1980). They are subdivided into two formations from older to younger: Permian limestone, dolomite and volcanic rock, and Permian limestone and clastic sedimentary rock.

The Permian limestone, dolomite and volcanic rock expose along the southeast of the study area in Ta Khli District, Nakhon Sawan Province with northwest - southeast trending. They consist of limestone, chert, shale, sandstone, tuffaceous sandstone and volcanic rock.

The Permian limestone and clastic sedimentary rocks distribute in the area of Prayuhakiri District, Nakhon Sawan Province, and Thap Than and Nong Chang Districts, Uthai Thani Province as isolated mountains with northwest - southeast trending. They are composed of limestone and dolomitic limestone, with chert nodule, fusulinid, brachiopod, coral and bryozoa. The limestone in Prayuhakiri is well bedded and crosscut by andesite dike at Khao Bo Kaew. The limestone in Thap Than and Nong Chang is poorly bedded, with gray to dark gray colors. Fossils are uncommon in this area.

The limestone in the study area is not in contact with older or younger sedimentary rocks. It was intruded by a small stock of granite and was in contacted with patches of rhyolitic rock at Khao Lo, Tha Tako District, Nakhon Sawan Province (Figure 2.2).

2.1.4 Triassic rock unit

The Triassic rocks occur in the central and western parts of the study area (Bunopas, 1980) and is classified as Huai Hin Lat Formation. The sedimentary and volcanic rocks distributed at Khao Kwang Thong, Khap Pha Lat, Khao Hin Thoen and Khao Khot Yang in the western part of Uthai Thani are believed to have developed during Triassic age. The sedimentary rock include conglomerate, calcareous shale interbedded with siltstone and sandstone. The volcanic rocks include andesite and rhyolitic tuff. The

Triassic rock unit unconformably overlies the Paleozoic rock unit (Boonsue, 1986). In addition, limestone monadnocks at Khao Pra, Khao Kachi, Khao Kwang Thong, Khao Thonglang, Khao Chong Lom, Khao Hin Thoen, and Khao Pathawi, northwest of Uthai Thani Province are generally gray, massive and poorly bedded with scleractinian coral, foraminifera (*duostominids, Aulotortus and Ophthalamidium*) indicating Late Triassic (Carnian or Norian) age (Ueno *et al.*, 2010).

Figure 2.2 Photograph of limestone that is in contact with rhyolitic rock at Khao Lo, Tha Tako District, Nakhon Sawan Province, grid reference 612318.

2.1.5 Jurassic rock unit

The Jurassic rocks occur in the northwestern part of the study area and vicinity (Department of Mineral Resources, 2007). They consist of mudstone, siltstone, sandstone and limestone with fossils of bivalve and ammonoid.

2.1.6 Quaternary Sediments

The Quaternary sediments in the study area occur along the Chao Praya River in a central floodplain. These sediments form as terrace deposits, alluvial fan deposits and alluvial deposits (Department of Mineral Resources, 2007). The terrace deposits are characterized by gravel, sand, silt, clay and laterite that occur as a low-level terrace (15 - 40 meters above the mean sea level). The alluvial fan deposits consist of gravel, sand, silt and clay that form as fluvial deposits and fans along basin margins. The alluvial deposits comprise gravel, sand, silt and clay that form as fluvial deposits, back swamps, recent flood plains and channel deposits. The thicknesses of alluvial deposits vary from 30 to 60 meters.

2.2 Igneous Rocks

2.2.1 Triassic rock unit

The Triassic rocks occur in the central and western parts of the study area (Department of Mineral Resources, 2007). This unit is composed of granite, muscovite granite, tourmaline granite, granodiorite, diorite and pegmatite dikes.

The felsic to mafic volcanic/ hypabyssal rocks in the area of Nakhon Sawan and Uthai Thani Provinces are the southern extension of any volcanic belt in the north. The igneous rocks in central plain Thailand distribute along a narrow hill with north – south trending. Igneous rocks, including plutonic, volcanic and volcaniclastic rocks, are widespread in several isolated N-S trending hills and mountains. They occur as lava flows, stocks, and dikes. They distribute in the western part of Uthai Thani Province and areas of Tha Tako and Krok Phra Districts, Nakhon Sawan Province. Intrusive rocks include granite, granodiorite and diorite that occur as stocks of various sizes; some may intrude the older sedimentary rocks of Permian and Silurian-Devonian ages. The volcanic and volcaniclastic rocks range in composition from andesite to dacite and rhyolite that form as lava flows and pyroclastic falls. The rocks overly Permian and pre-Permian rocks. Igneous rocks in the area are believed to have been formed during the period

between the post-Permian and the pre-Jurassic. The Permo - Triassic volcanic rocks (andesite, rhyolite, tuff, and agglomerate) also form a north – south trending low mountain range in the western part parallel to the Triassic limestone (Vimuktanandana, 2008).

Boonsue (1986) and Intasopa (1993) studied igneous rocks in the study area that were classified as extrusives and intrusives. They form north-south trending chains of small hills or mountains, and display outlines of stocks in sedimentary rocks. The compositions of these rocks range from intermediate to silicic. Evidences from fieldwork, petrography and geochemistry suggest that the intrusive rocks are shallow emplaced, and are related to the capped volcanic rocks. The pyroclastic rocks are generally late in the sequence of igneous activities. They are interbedded with sandstone, shale and carbonate rocks of the Middle Triassic age. The volcanic rocks are andesite and rhyolitic tuff. The andesite is in contact with the rhyolitic tuff at Khao Khot Yang. Rhyolitic tuff is interlayered with the sedimentary sequence. The Triassic rocks overly unconformably on the Paleozoic rocks. The stratigraphic succession and the paleontological evidence indicate that the activities took place between post-Permian and Middle Triassic. Geochemical data and their variation diagrams suggest that these plutonic and volcanic rocks belong to the same differentiation trend of calc-alkaline series from intermediate to silicic rocks; arcs of the continental margin type seem to be more favorable.

2.2.2 Cretaceous rock unit

The Cretaceous rocks occur in the northeastern, central, and western parts of the study area (Department of Mineral Resources, 2007). This unit consists predominantly of rhyolite and syenite.

2.3 Major Structure

Morley (2002) reported the Mae Ping fault zone that exposed around the Lan Sang national park, on the Tak-Mae Sot road. The trace of the faults is interrupted in central Thailand. The Pliocene-Recent thermal sag basin deposits associated with underlying Late Tertairy rift create a flat topography and covers the faults, whose outcrop traces are

apparent in the hilly regions to the west. In one part of the Central Plain, elongate Upper and Lower Paleozoic outlines trending N-S to NNW-SSE poke through thin Plio-Pleistocene sediments. These outliers are interpreted as representing a strike-slip duplex geometry. The duplex, known as a region of uplift called the Chai Nat ridge, lies between two major Tertiary sedimentary basins, the Phetchabun and Suphan Buri basins. The duplex formed at a major right-stepping bend in the Mae Ping fault zone and demonstrated that left-lateral fault displacement was not responsible for creating the Tertiary rift basins because the ridge developed at a restraining bend in the fault is consistent with left-lateral motion, and the right-lateral motion was relatively minor, because the right-stepping geometry is ideal for the creation of a pull-apart basin, yet the main Tertairy basins lie north and south of the Chai Nat ridge, not on the ridge. However, minor episodic right-lateral reactivation might have occurred numerous times during the Miocene-Pliocene, perhaps associated with phase of inversion (Morley, 2001). The trace of Mae Ping fault zone is thought to strike NW-SE, though Cambodia, in the vicinity of Ton Le Sap lake, and though the Mekong delta (Lacassin *et al.*, 1997), and is currently undergoing episodic, low-strain-rate-dextral motion.

The majority of the outcrops within the Chai Nat ridge are Lower to Upper Paleozoic slaty to phyllitic igneous, volcaniclastic, and metasedimentary rocks. The rocks have been through at least the Permo-Triassic Indosinian Orogeny, which itself has several deformation episodes (Charusiri *et al.*, 1993). Carbonates of Siluro-Devonian age and Permo-Triassic age have been mapped with in Chai Nat duplex. These rocks display a wide range of characteristics, and include recrystallized marbles with little remaining primary sedimentary fabric; massive carbonates, partially recrystallized and heavily veined; well-bedded massive carbonates that contain fossils of fusulinids, brachiopods and corals and well-bedded carbonates interbedded with shale. Granite is intruded by strongly altered mafic dikes, that in places have taken place on a subvertical, north-south-striking shear-zone-related foliation. Apatite fission-track dating of the granite outcrop shows rapid cooling in the Miocene, with a central age of 18 $\pm$ 1 Ma (Morley *et al.*, 2007).