Chapter 2

GENERAL GEOLOGY AND MAJOR GOLD PROVINCES IN SUKHOTHAI AND LOEI – PHETCHABUN FOLD BELTS

2.1 General geology

Mainland Southeast Asia is composed of the Shan-Thai Terrane (or Sibumasu) and Indochina terrane (e.g. Bunopas, 1981, Barr et al., 2000). The Shan-Thai Terrane is composed of the Shan States in Myanmar, part of Yunnan (China), western Thailand and western peninsular Malaysia. The Indochina Terrane is composed of Vietnam, Laos, east and northeast Thailand, Cambodia and the eastern Malay Peninsula (Fig. 2.1). These authors have argued that both the Shan-Thai and Indochina Terranes were rifted off and separately drifted away from Gondwana. Northward drift of the two microcontinents eventually ended up with a collision of Shan-Thai and Indochina plates in late Triassic to Jurassic. The collision along the Nan-Uttradit and Loei sutures resulted in the formation of the Loei-Phetchabun Fold Belt and the Sukhothai Fold Belt. These events also led to the development of the major metallogenic episodes in the country.

The northward movement, subduction and ultimate collision of the Indian Plate with the Eurasian plate in the Tertiary also played important roles in the formation of mainland Southeast Asia to the present day.

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Copyright© by Chiang Mai University
All rights reserved

2.2 Geology of the Sukhothai Fold Belt

The geological map of Thailand shows that the basement of the Sukhothai Fold Belt is composed of high grade metamorphic complexes (Fig. 2.2). The metamorphic complex is overlain by Lower Palaeozoic sequences and is, therefore, assigned to the Precambrian. However, this interpretation is contradicted with others, who have proposed that the formation of metamorphic complex was formed in Tertiary age as

Figure 2.1 Map of mainland Southeast Asia showing Shan-Thai and Indochina terranes and significant structural features (modified from Meffre, 2007).

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Copyright© by Chiang Mai University
All rights reserved

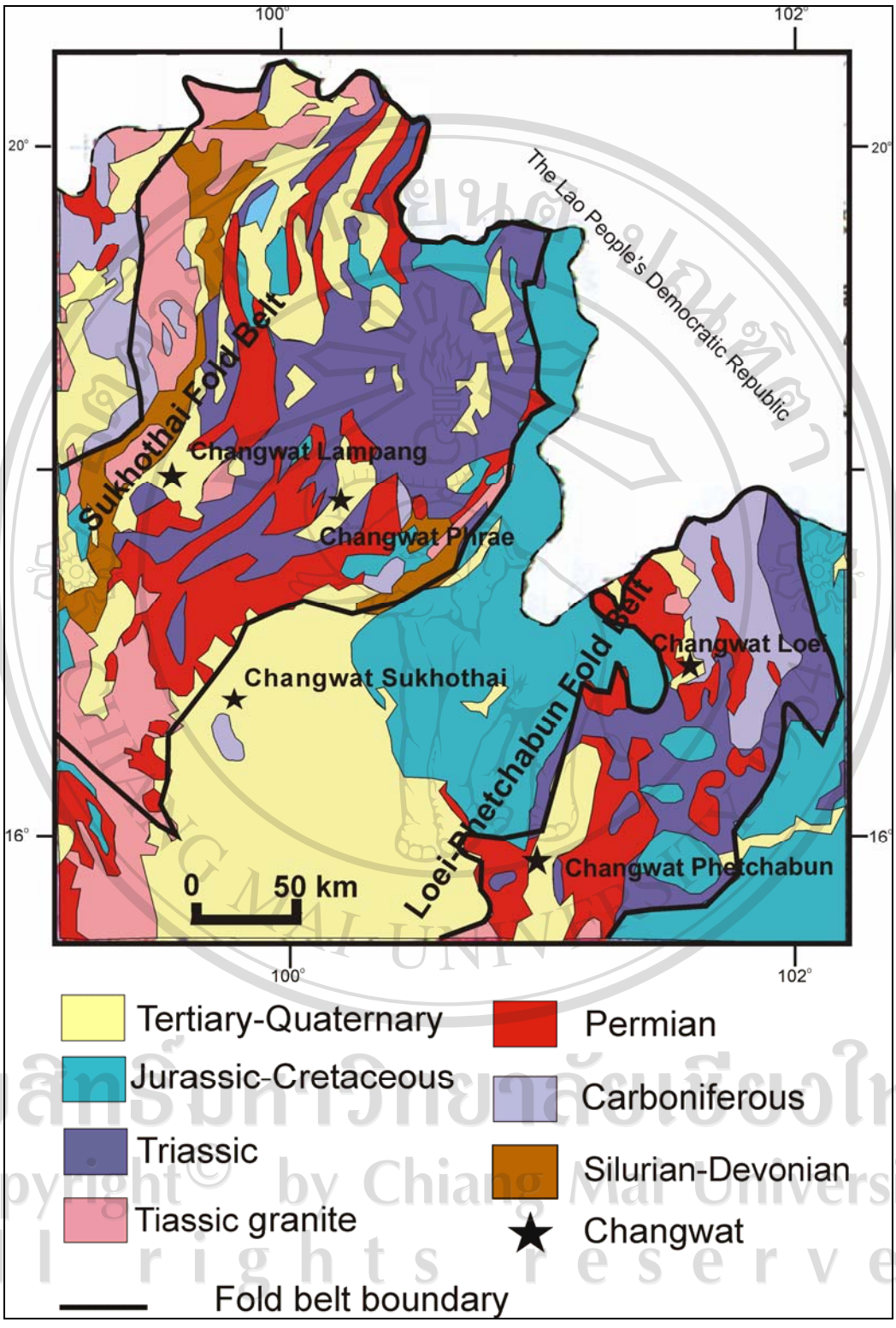

Figure 2.2 Geological map of northern and eastern Thailand showing distributions of major rocks units in Sukhothai and loei-Phetchabun Fold Belts (modified from Department of Mineral Resources, 1999).

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Copyright© by Chiang Mai University
All rights reserved

a result of detachment along NW-SE Mae Ping Fault, e.g. Rhodes (2008). The age of zircon from Lansang gneiss indicates the Triassic granite protolith of gneissic rocks with Tertiary age of metamorphisms (Meffre pers. Comm.).

From the geological map of Thailand, the metamorphic complex consists mainly of strongly deformed, highly metamorphosed paragneiss, orthogneiss, and schist, as well as marble and calc-silicate rocks. However, the age and nature of the underlying crystalline basement complex have not been well defined owing to the complexity of stratigraphic correlation and field relation with the overlying sequences. They have been considered by many researchers as remnants of Precambrian strata. The exposures of the underlying crystalline basement complexes in the Sukhothai Fold Belt are limited to NW-SE trending Mae Ping (Mae Moei) Fault at the southern end of Sukhothai Fold Belt and extend northward to the Chiang Mai metamorphic core complex.

The metamorphic complex is, in general, unconformably overlain by the N-S trending strata of the Palaeozoic. The Cambrian strata are composed mainly of highly metamorphosed quartzite and schist. The Ordovician strata are composed mainly of recrystallised limestone, which conformably overlies on the Cambrian sequence. The Silurian-Devonian strata are composed of siliciclastics and low grade metamorphic rocks, which conformably overlie the Ordovician strata. The Carboniferous strata are composed of siliciclastic rocks with subordinate intercalated carbonate strata. The Permian strata are composed mainly of limestone with subordinate clastic rocks. The aforementioned strata have been locally intruded by Triassic-Jurassic granite batholiths and are generally overlain by Triassic volcanic and volcaniclastic rocks. The formation of Mesozoic sequence in the Sukhothai Fold Belt has started by the Triassic strata, which comprise variable rock types from weakly deformed strata of Lampang Group in northwestern Thailand (Piyasin, 1974) as well as the Phrae Group in the eastern part (Chonglakmani, 1989). The occurrences of unconformably overlying Jurassic-Cretaceous strata, which are composed mainly of continental redbeds, are spatially limited to the eastern part of the Sukhothai Fold Belt, and are bounded by the Nan-Uttaradit suture.

Finally, the pull apart driving force causing by the northward movement and collision of the Indian and Eurasian Plates has caused the formation of small Tertiary coal, oil and gas-bearing basins, which are widely distributed in northern Thailand.

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Copyright© by Chiang Mai University
All rights reserved

Extensive deposition of alluvial sediments on the flood plains of the main rivers took place during the Quaternary.

2.3 Geology of Loei-Phetchabun Fold Belt

The geological map of Thailand (Fig. 2.2) also shows that the structurally lowest parts of the Loei-Phetchabun Fold Belt consist of thick sequences of Palaeozoic strata. The lowermost Palaeozoic sequences are composed of low grade metamorphic rocks as well as volcanic and volcaniclastic rocks of Silurian-Devonian age. The Silurian-Devonian strata are locally unconformably overlain by thick sequences of Carboniferous clastic and intercalated carbonate rocks as well as locally intruded by Carboniferous granite e.g. granite at Dong Khui District in Phetchabun Province (Meffre, pers. comm.). The uppermost Palaeozoic successions are represented by widely distributed N-S trending fossil-rich Permian limestone and subordinate fossiliferous clastic rocks. The overlying uppermost Permian strata are intruded by subordinate Permian granite e.g. granite at Nong Bua District in Nakorn Sawan Province (Meffre, pers. comm.).

The Mesozoic sequences in the Leoi-Phetchabun Fold Belt started by the occurrences of marine Triassic strata of Huai Hin Lat and Nam Pong Formations, which locally and spatially unconformably overlie the Upper Permian limestone sequences adjacent to the N-S arcuate shape of the margin of the Khorat Plateau. The transition of marine Triassic successions to continental Jurassic strata was locally marked by the intrusions of Late Triassic granite.

The occurrences of Jurassic-Cretaceous continental successions in the Loei-Phetchabun Fold Belt, which are known as the Khorat Group, are widely exposed throughout the belt. The majority of Jurassic-Cretaceous continental successions are composed of continental sedimentary deposits including redbed sandstone, siltstone and intercalated shale. The occurrences of Maha Sarakham Salt Formation in the Khorat Plateau mark the end of the continental deposit in the Loei-Phetchabun Fold Belt.

Finally, the Quaternary sedimentary deposits resulted in the formation of widely exposed terrace and flood plain deposits along major rivers in the Loei-Phetchabun Fold Belt.

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Copyright© by Chiang Mai University
All rights reserved

2.4 Major metallogenic provinces in Sukhothai and Loei-Phetchabun Fold Belts

This chapter will provide information on the gold and iron-copper-gold deposits, which have been investigated in the Sukhothai and Loei-Phetchabun Fold Belts.

The gold and iron-gold deposits in Thailand can be geographically classified into 6 provinces (Fig. 2.3). The Chiang Rai – Chiang Mai gold province (1) is located in the northern end of the country whereas the Lampang – Phrae gold province (2) is located in the southern part of the Chiang Rai – Chiang Mai gold province. Loei – Nong Kai – Udon Thani gold province (3) is located at the northern end of the northeastern Thailand, while Phetchabun – Lopburi gold province (4) is extended southward from the Loei – Nong Kai – Udon Thani gold province. Sra Kaew – Rayong gold province (5) is located in the east coast, whilst Prachuap Khirikhun – Chumporn gold province (6) is located in the southwestern part of Thailand.

2.4.1 Low sulphide system

Low sulphide system is applied for gold and iron-gold deposits that contain less abundant sulphide mineralisation. The gold mineralisation may occur as free gold or in other forms. These examples of the low sulphide system gold deposits in Thailand are listed below.

2.4.1.1 Phrae Province

Gold exploration has been carried out by Department of Mineral Resources in highly prospective areas of Phrae Province, using regional geochemical exploration techniques in order to complement the airborne geophysical survey, i.e. ground follow-up program.

Two major gold prospects have been investigated, i.e. Doi Kaew Noi, Ban Mae Chong Fai, of Long District and Huai Kham On of Wang Chin District. Both of them are located in the eastern flanks of Lampang-Phrae volcanic belt that formed an approximately N-S trending, arcuate S-like volcanic belt. It is composed mainly of andesite and andesitic volcaniclastic rocks with subordinate rhyolite, rhyolitic tuff and locally granite intrusions. Based on stratigraphic correlation, a Permo-Triassic age has been previously assigned to this volcanic belt.

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Copyright© by Chiang Mai University
All rights reserved

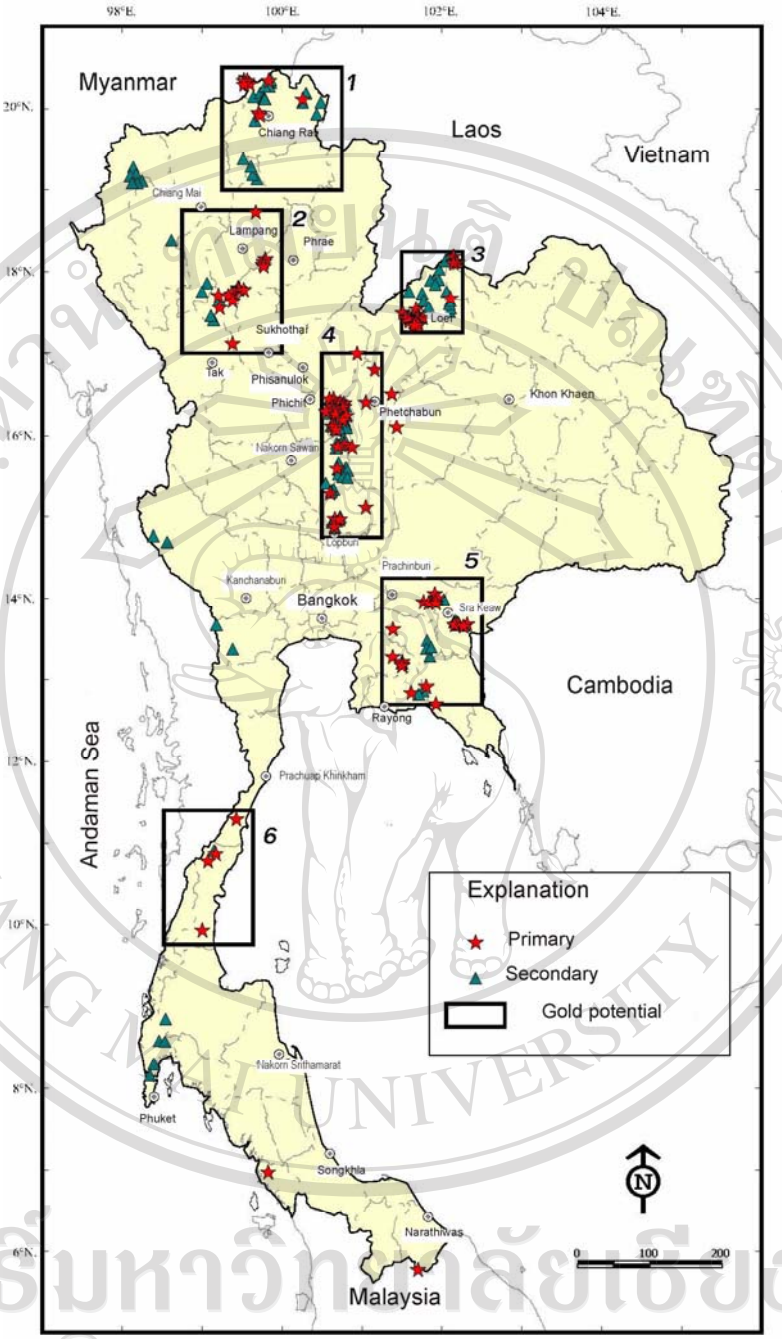

Fig 2.3 Gold provinces map of Thailand; 1 = Chiang Rai – Chiang Mai gold province, 2 = Lampang – Phrae – Sukhothai gold province, 3 = Loei – Nong Kai – Udon Thani gold province, 4 = Phetchabun – Lopburi gold province, 5 = Sra Kaew – Rayong gold province, and 6 = Prachuap Kirikhun – Chumporn gold province, red stars represent primary gold deposits, green triangles represent secondary gold deposits (Premmanee, 2003).

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Copyright© by Chiang Mai University
All rights reserved

In general, free gold has been found in volcanic hosted quartz-rich veins with small amounts of sulphide minerals including pyrite, pyrrhotite, chalcopyrite bournonite and galena. It is also noticeable that enclave chloritisation envelop has been recognised as the major alteration product at the vein margins.

2.4.1.2 Sukhothai Province

A similar method of gold exploration has also been carried out by the Department of Mineral Resources in two major gold prospects in Sukhothai Province i.e. Huai Pong Daeng prospect of Sri Sachanalai District as well as Mae Bo Thong prospect of Thung Saliam District. They are located in the eastern flank of Phrae-Sukhothai N-S trending arcuate S-like volcanic belt parallel to those of Phrae-Lampang volcanic belt. Free gold has been observed in volcanic hosted quartz-rich veins with hematite or iron oxide association. Regional investigation suggested that the volcanic host rocks at Mae Bo Thong prospect have been strongly sheared and severely altered, and have undergone chloritisation with clay alteration overprinting, whereas those of Huai Pong Daeng prospect show less shearing and wall rock alteration.

2.4.1.3 Lampang Province

Gold exploration in conjunction with regional geochemical program has also been carried out during an intensive mineral exploration program in the highly prospective areas program in Lampang Province i.e. Ban Mae Mok gold prospect of Thoen District. It is located in the central core of Sukhothai-Phrae volcanic belt. It is noticeable that the southern ends of Lampang-Phrae and Phrae Sukhothai volcanic belts are joined at Thoen and Mae Prik Districts. Free gold has been found in volcanic hosted quartz-rich veins with minor iron oxide association. The volcanic host rocks have been locally sheared, where extensive quartz veins are found. Strong chloritisation, in conjunction with clay mineral alteration are commonly observable along the vein margins.

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Copyright© by Chiang Mai University
All rights reserved

2.4.1.4 Phichit-Phitsanulok-Phetchabun Provinces

Geochemical exploration and intensive mineral exploration programs have been carried out in Phichit as well as Phitsanulok and Phetchabun Provinces i.e. Wang Sai Phun District of Phichit Province, Noen Maprang District of Phitsanulok Province, Wang Pong and Chon Daen Districts of Phetchabun Provinces. They are located in the centre of volcanic core complex consisting of andesite to rhyolite volcanic rocks with intensive andesitic volcaniclastic rocks, granite and granodiorite associations. Free gold and electrum have been found in quartz-carbonate and quartz-rich veins. It is also noticeable that subordinate pyrrhotite and chalcopyrite associations have been detected as minor components in the veins. The veins show strong relation with chloritisation alteration against the basaltic andesite host rocks.

2.4.2 Fe-Cu-Au Sulphide system

Iron and copper are the most common sulphide minerals associated with gold mineralisation in Thailand and have been reported elsewhere. Gold mineralisation can be found either in a free gold form or in a factory gold (dissolved) form. If the sulphide mineral components are greater than 5%, then it is considered to be sulphide – gold system.

2.4.2.1 Loei Province

Regional geochemical survey in conjunction with ground follow-up exploration program in Loei Province resulted in the discovery of intrusive related gold-bearing quartz and sulphide-rich ore bodies in Phu Tap Fah deposit of Wang Saphung District. High grade gold sulphide veins are hosted by andesitic volcaniclastic and low grade metamorphic host rocks in association with skarn alteration and granodioritic intrusives. A detailed study has been made from selective drill cores suggesting that the gold-forming fluids have been initiated by magmatic processes.

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Copyright© by Chiang Mai University
All rights reserved

2.4.2.2 Nong Kai Province

Regional geochemical exploration was carried by the ground followed up program in Nong Kai Province, i.e. Phu Lon Fe-Cu-Au prospect, Sang Kom District along Thai-Laos border. The Fe-Cu-Au ore bodies were found in a granite-related andesite hosted rock. A pervasive and intensive garnet skarn was especially observed in and nearby the Fe-Cu-Au ore bodies.

2.4.2.3 Udon Thani Province

Regional geochemical exploration, which was carried by the ground follow-up program in Udon Thani Province, shows that free gold are rich in stream sediments at the Ban Kham Charoen and adjacent areas of Na Yoong District. The follow-up, stream sediment geochemical exploration suggests that gold may have been extracted from intrusive related quartz-rich veins in rhyolite and rhyolitic volcaniclastic host rocks that are especially well exposed at the top of Phu Koh Hill. However, detailed exploration may not be allowed due to conflict of interest in the local community.

2.4.2.4 Nong Bua Lamphu Province

Results form regional geochemical exploration followed by an “intensive mineral exploration in high potential area program” in Nong Bua Lamphu Province indicate that high gold content was discovered in sulphide-rich quartz veins cutting across andesite and andesitic volcaniclastic host rocks at Suwan Kuha District.

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Copyright© by Chiang Mai University
All rights reserved

2.4.2.5 Phetchabun Province

Regional stream sediment geochemical exploration program has been carried out at Khao Lek or Khao Mae Kae of Bung Samphun District. As a result, the Fe-Cu-Au ore bodies have been discovered. The iron-sulphide-rich ore bodies are hosted by basaltic andesite, which has been locally intruded by granodiorite. Magnetite is the most abundant mineral found in the ore bodies, whereas chalcopyrite and secondary

copper ore were locally found in magnetite rich ore body. Pyrite and other sulphide minerals are rarely observed in the veins. A few gold nuggets were occasionally extracted from stream sediments during the stream sediment exploration program, which was carried out in flood plain basin inside the arcuate basaltic andesite host rock belt. Intensive garnet skarn development and the overprinting epidote skarn are obvious along the margin of the magnetite ore bodies.

2.4.2.6 Lop Buri Province

Fe-Cu-Au mineralisation in association with skarn alteration has been found in andesitic volcaniclastic host rocks at Ban Bo Thong of Nong Muang District. Fe-Cu-Au mineralisation was observed as massive hematite-magnetite rich veins with less abundant chalcopyrite in the volcanic hosted ore bodies. The occurrence of gold was reported in the skarn related gold-bearing quartz veins.

All of the above mentioned deposits suggest that gold mineralisation in the Sukhothai Fold Belt may be similar to the low sulphide style of mineralisation. On the other hand, the gold mineralisation in the Loei-Phetchabun Fold Belt may be classified as high sulphide style of mineralisation.

The distribution of gold and iron-gold provinces is specially associated with the exposures of volcanic and plutonic rocks. Therefore, it is essential to study the formation of volcanic and plutonic rocks in order to obtain the nature and evolution of the hosted volcano-plutonic rocks.

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Copyright© by Chiang Mai University
All rights reserved