CHAPTER 5

CONCLUSIONS

5.1 Chiang Rai-Chiang Mai Volcanic belt

The least-altered, mafic igneous rocks discussed in this study were from Mae Sai and Mae Chan areas, Chiang Rai Province. The study areas are parts of the Chiang Rai-Chiang Mai volcanic belt, which is one of the five belts pre-Cretaceous volcanic belts in Thailand. It extends southward from the Changning-Menglian suture in south China to Chiang Rai, Chiang Mai, Mae Hong Son, and Lamphun Provinces.

Petrochemically, the studied mafic igneous rocks can be separated into two magmatic groups as Group I and Group II. They diverse magmatic affinities from transitional to subalkalic magma series, respectively.

5.1.1 Group I Rocks

The group I rocks are distributed in the Mae Sai area and composed largely of gabbro, diorite, monzodiorite, microgabbro, microdiorite and minor andesite/basalt(dike). These rocks are associated with the Carboniferous-Devonian quartzite, quartz schist, phyllite and calc-silicate rock. Also, The group I rocks are associated with the Permian-Carboniferous rocks made up of gray to dark gray limestone and marble and the Carboniferous sedimentary rocks included dark gray shale interbedded with gray siltstone, fine grained sandstone and greywacke.

Gabbro is coarse grained and seriate texture. Its constituents are made up of amphibole and plagioclase. Secondary patches of chlorite/serpentine, titanite are present in the samples. Tiny veins (up to 0.6 mm across) and voids of epidote, chlorite/pumpellyite, titanite/leucoxene, quartz are filled in this sample.

Diorite is medium-coarse grained, seriate texture. It is made up mainly of plagiocalse, amphibole and small amounts of opaque minerals, unidentified mafic

minerals, quartz and apatite. The rocks may show interstitial quartz. Secondary patches of epidote, chlorite, titanite/leucoxene and tiny veins (sizes up to0.25 mm across) are infilled with titanite/leucoxene, chlorite/pumpellyite, epidote. Also, presents are locally aggregates of epidote, calcite and chlorite in some samples.

Monzodiorite is medium-coarse grained texture, consists mainly of amphibole and plagioclase and small amounts of opaque minerals and quartz. Secondary patches of titanite/leucoxene, epidote, chlorite are present in the rock. Tiny veins (sizes up to 1.0 mm across) are infilled with largely of titanite/leucoxene, chlorite/pumpellyite and minor quartz, epidote.

Microgabbro is fine-medium grained, seriate texture and composed largely of plagioclase, with subordinate amphibole and opaque minerals. Secondary patches of epidote, chlorite,pumpellyite and titanite. Tiny veins (up to 0.25 mm across) of chlorite/pumpellyite, epidote, quatrz are cut through amphibole, plagioclase, and opaque minerals. Secondary patches of epidote, chlorite and titanite are present in the rock samples.

Microdiorite is fine-medium grained texture, and made up principally of plagioclase, amphibole and small amounts of opaque minerals, unidentified mafic minerals and quartz. It may show interstitial quartz to amphibole. Secondary patches of chlorite, epidote, titanite/leucoxene are present in the rocks. Tiny veins (sizes up to 0.2 mm across) filled with epidote, chlorite/pumpellyite, and calcite are locally present in the rock.

Andesite/Basalt is very fine-grained, ophitic/subophitic and intergranular texture. Its constituents are plagioclase and amphibole, minor opaque minerals, and very small amount of apatite. Secondary patch of titanite, chlorite are commonly present in the rock. Tiny veins and fractures (sizes up to 0.2 mm across) mainly of calcite, with subordinate quartz, titanite, epidote, chlorite, and Fe-Ti oxide are filled in the samples.

Amphibole in group I rocks has been formed as metamorphosed after clinopyroxene in low-grad metamorphism. The igneous rocks of group I rocks are greenschist following the present of amphibole.

Chemically, the Group I rocks have Zr/TiO_2 and Nb/Y ratios in the ranges of 0.030-0.0349 and 0.1071-0.7191, respectively. The composition ranges correspond to transitional to subalkalic series. The chondrite-normalized REE patterns for the representatives of Group I rocks present a relatively flat REE pattern from Sm to Yb, with chondrite-normalized Sm/Yb [herein (Sm/Yb)cn] = 2.127-2.649, and slightly LREE enriched, with chondrite-normalized La/Sm [herein (La/Sm)cn=1.744-3.060]. These REE pattern are typical of tholeiitic series. In term of N-MORB normalized multi-element patterns, the Group I rocks generally show step-like patterns, characteristics of within-plate basalt. The chemical composition of representative for Group I rocks, especially trace elements and rare earth elements, are closely similar to tholeiitic basalt from western Samoa Seamount, which have been formed as a hotspot chain in southwest Pacific plate, north of Tonga Trench.

5.1.2 Group II Rocks

The Group II rocks are distributed in the Mae Chan area and made up largely of mainly gabbro, diorite, microgabbro, microdiorite/microgabbro, andesite/basalt and basalt. The studied mafic rocks of Group II rocks are associated with the Triassic-Permian rocks made up largely of maroon to light gray rhyolite/rhyolitic tuff and tuff, sandstone, siltstone, shale and gray limestone. Also, mafic igneous rocks are associated with porphyritic biotite granitic intrusion, with aplite and pegmatite dyke.

Gabbro is medium-grained, seriate texture. It is mainly of plagioclase, clinopyroxene, with a small amount of orthopyroxene and opaque minerals. Secondary patches of chlorite, titanite/leucoxene are present in small amount. Tiny vein (less than 0.5 mm thick) of epidote, chlorite/serpentine and titanite/leucoxene are locally present in a small amount.

Diorite has medium-coarse grained, seriate texture. It is made up largely of plagioclase, amphibole and minor quartz and opaque minerals. Tiny veins (up to 0.4

mm across) of chlorite/serpentine, quartz are locally present in the sample. Secondary patches of chlorite, titanite/leucoxene and epidote are present in the samples.

Microgabbro has fine-grained and seriate to equigranular textures. It is made up mainly of plagioclase, clinopyroxene and minor orthopyroxene, brown amphibole, olivine and opaque minerals. Tiny veins (size up to 0.2 mm across) of chlorite and calcite are locally present in the sample.

Microdiorite/microgabbro has fine-medium grained and seriate textures. Its constituents are largely of plagioclase, clinopyroxene, olivine and minor orthopyroxene, opaque minerals, brown amphibole and quartz. Secondary patches of chlorite, titanite/leucoxene and epidote are present in the samples. Tiny veins (up to 1.0 mm across) of chlorite and epidote are locally present in the samples.

Andesite/Basalt is very fine-grained and may has intergranular textures. It is composed mainly of plagioclase, amphibole and minor opaque minerals and quartz. Secondary path of chlorite is commonly present in the samples.

Basalt is fine-grained, ophitic/subophitic texture. It comprises plagioclase and clinopyroxene, with small amounts of opaque minerals and unidentified mafic minerals, and a very small amount of apatite. Secondary patch of chlorite and titanite are commonly present in the rocks.

Chemically, the Group II rocks have Zr/TiO_2 and Nb/Y ratios in the ranges of 0.0006-0.0396 and 0.0318-0.3235, respectively. These compositional ranges correspond to subalkalic series. The chondrite-normalized REE patterns for the Group II rocks are relatively flat REE pattern from Gd to Yb, with chondrite-normalized Sm/Yb [herein (Sm/Yb)cn] = 1.331-3.052, and flat to slightly LREE enrichment, with chondrite-normalized La/Sm [herein (La/Sm)cn] = 0.852-1.831 and have positive Eu anomaly, correspond to typical of tholeiitic series. N-MORB normalized multi-element patterns of the Group II rocks present flat pattern, negative niobium anomalies. The representatives are chemically similar to aphyric tholeiite resembling immature back arc basin, from the latest Jurassic greenstone belt in Hokkaido, northernmost island of Japan.

5.2 Tectonic Implications

Thailand is generally believed as being the product of the collision between several micro-continents, including two main micro-continents, i.e. Shan-Thai continent and the Indochina continent. The major ocean basin that separated the Shan-Thai and Indochina terranes may be interpreted by the Chiang Rai-Chiang Mai volcanic belt**,** Nan-Chanthaburi suture or Loei-Phetchabun-Nakhon Nayok volcanic belt.

Chiang Rai-Chiang mai volcanic belt is distributed associated with Silurian-Devonian to Permo-Triassic sedimentary rocks. Barr *et al*. (1990) interpreted that the Chiang Rai-Chiang Mai volcanic belt are related to a continental within-plate environment, while Panjasawatwong *et al.* (1995) and Panjasawatwong (1999) believed that the Chiang Rai-Chiang Mai volcanic belt formed in an oceanic within-plate environment as ocean islands and seamounts in either a major ocean basin or a mature back-arc basin. Phajuy *et al*. (2005) reported that there are mid-ocean ridge and ocean-island basalts in this region. After that, Phajuy (2008) analyzed that this belt formed in back-arc basin, ocean-island and mid-ocean ridge environment.

For this study, the studied mafic igneous rocks in the northern part of the Chiang Rai-Chiang Mai volcanic belt can be separated into ocean island basalts (Group I) and immature back-arc basin (Group II). Group I, the ocean island basalts might have located in a major ocean basin in the Silurian period (Fan *et al*., 2010; Wang *et al*., 2010). Group II, the immature back-arc basin might have started rifting in the upper Carboniferous period (Braun and Hahn, 1976). This conclusion is agreeable with the study of the mafic igneous rocks in the Chaing Rai-Chiang Mai volcanic belt by Phajuy (2008).

On the other hand, Paengkaew and Kitisarn (2000) reported that the studied mafic igneous rocks of the Group II occurred in the Permo-Triassic period, so the immature back-arc basin still active in this period. The conclusion of tectonic setting from this study that have been formed in this age is inconsistent with the most tectonic models of Thailand.

The mafic igneous rocks of the Mae Sai area have been formed as ocean-island basalt in the Silurian (Fig 5.1) and located in a major ocean basin. Whereas, mafic igneous rocks in the Mae Chan area have been formed as immature back-arc basin basalt in the Upper Carboniferous.

Furthermore, the mafic igneous rocks of the Mae Chan area should to be dated for the absolute ages to more clearly reconstruct a tectonic model of Chiang Rai-Chiang Mai volcanic belt in Thailand.

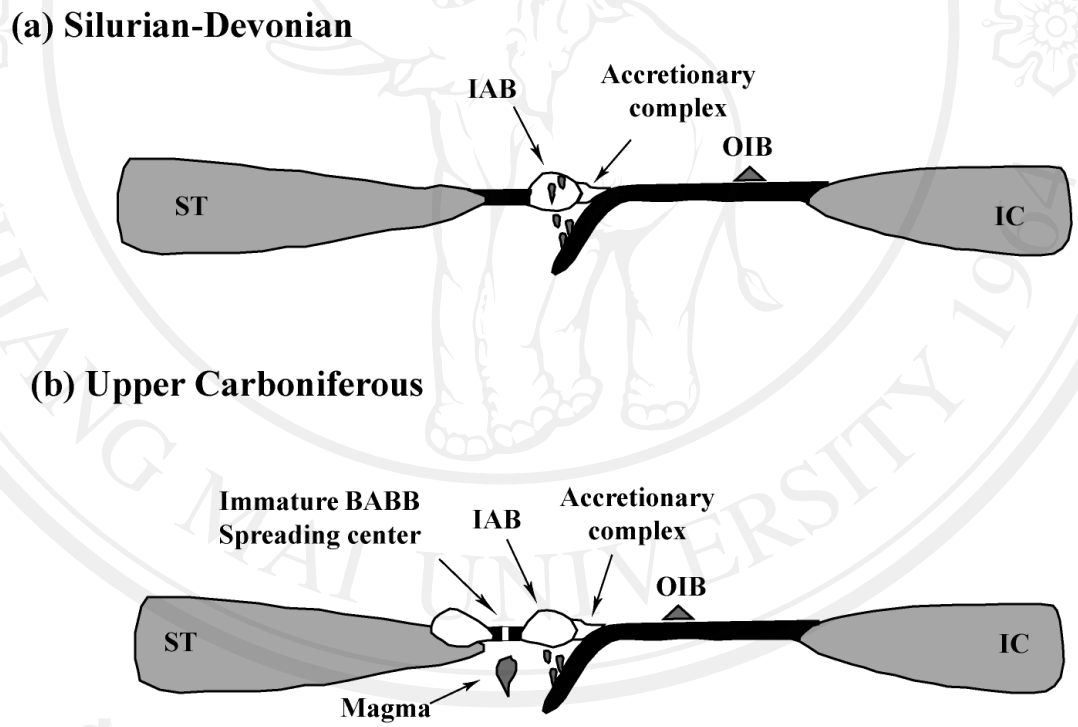

Figure 5.1 Schematic diagrams showing tectonic evolution of Shan-Thai and Indochina terranes. The abbreviations used are ST, Shan-Thai terrane; IC, Indochina terrane; IAB, isalnd-arc basalt; OIB-ocean-island basalt; and BABB, back-arc basin basalt.