# CHAPTER V

# DISCUSSION

## 5.1 Depositional environments and ages of the Mae Sariang Group

### 5.1.1 Depositional environments

Sediments of the Mae Sariang Group can be grouped into 3 formation (Table 5.1) as Kong Sum formation ($Tr_1$), Pra Trumuang formation ($Tr_2$), and Mae Leab formation ($Tr_3$)

The Kong Sum formation ($Tr_1$ unit) is further subdivided into 2 lithofacies viz. lower conglomerate (I) and lithic sandstone (II) The lower conglomerate (I) is characterised by of series thick-bedded, reddish brown siltstone interbedded with pebbly sandstone. The conglomerate is clast-supported and clasts are made up mainly of chert, limestone, and sandstone. This lithofacies lies unconformably over the Permian unit. The lithic sandstone (II) is characterised by thick-bedded, gray-colored, fine- to coarse-grained lithic sandstone with graded bedding. It is considered that sediments of the $Tr_1$ unit was deposited in deep marine environments, not close to the shelf.

The Pra Trumuang formation ($Tr_2$ unit) consist of 4 lithofacies including dark gray mudstone and sandstone (III), chert interbedded mudstone (IV), conglomerate interbedded sandstone (V), and sandstone and shale (VI). Generally, $Tr_2$ is characterized by thin-bedded mudstone intercalated with thin-bedded sandstone, thin-bedded chert intercalated with thin-bedded mudstone, conglomerate interbedded sandstone, and sandstone interbedded shale with common cross-bedding, graded bedding, and flute casts. These lithofacies indicate that sediments of the $Tr_2$ unit deposited as turbidities in deep-water submarine fan environment.

Results from Landsat and aerial photographic analysis reveal that lithofacies of the $Tr_1$ unit are different from those of $Tr_2$ unit based on topography and drainage patterns.

Table 5.1 Summary of the characteristics of the Mae Sariang Group

| Formation | Litho-Facies | Lithology | | Geometry | | Sediment structure | Fossils | Facies (atter Mutti and Ricchi-Lucchi, 1978) |
|---|---|---|---|---|---|---|---|---|
| | | Color | Lithological characteristics | Thickness (meters) | Distribution | | | |
| Mae Leab (80-120 m) | 9 | White | Medium-grained sandstone | 20-30 | Local | Fining upward sequence | | |
| | 8 | Dark gray | Siliceous shale interbedded mudstone | 80-90 | Cover the areas | Laminar | *Halobia* sp.* | C |
| | 7 | Dark gray | Calcareous mudstone interbedded with sandstone | 20-30 | Local | | | G |
| Pra Trumuang (200-770 m) | 6 | White to light gray | Sandstone interbedded shale | 480-510 | Cover the areas | Flute cast, graded-bedding, coss-bedded | *Halobia sp.* [1] | D, E |
| | 5 | Brown, reddish brown | Conglomerate and sandstone | 90-100 | Local | Graded-bedding | *Daonella* sp.[1] | A |
| | 4 | Dark gray | Chert interbedded with mudstone | 16-148 | Local | Limestone lens, laminar | Radiolarian[2] | G |
| | 3 | Dark gray | Mudstone interbedded sandstone | 60-70 | Local | | | D, E |
| Kong Sum (150-150 m) | 2 | Gray | Lithic sandstone | 50-100 | Cover the area | graded-bedding, cross-lamination, load casts | *Halobia* sp., *Daonella* sp.[3] | C |
| | 1 | Brown, reddish brown | Conglomerate and siltstone | 20-50 | Cover the area | | | A |

*= study area; 1 = Hahn and Siebenhüner, 1982; 2 = Kamata et al., 2002; 3 = Jindasuth et al., 1990

Field evidence supports that cherty rocks are present only in $Tr_2$ unit and disappear in the $Tr_1$ unit.

The Mae Leab formation ($Tr_3$ unit) comprises 3 lithofacies; i.e., calcareous mudstone and sandstone (VII), siliceous shale interbedded mudstone (VIII), and medium sandstone (IX). The characteristics of sedimentary assemblages points to the nature of sedimentary deposit in the deep marine environment.

Tofke et al. (1993) studied geology in the Mae Sariang area and found that the sedimentary sequences are mainly true ribbon-chert, true pelagic limestone, and a thick turbidite sequence of siliciclastics. Chonglakmani (1999) proposed the Triassic sedimentary belt is exposed in the Mae Sariang area as the Mae Sariang Group (Figure 5.1) and extends southward to Tak, Mae Sot, Kanchanaburi, and to Songkhla in peninsular Thailand, where is known as the Na Thawi Fomation. He considered that this belt facies is deep marine and oceanic facies. The belt can be correlated with the Semanggol Formation of the Kulim-Taiping zone in northwest Malaysia. An equivalent facies consisting of chert, meta-argillite, red shale, limestone, and deep water rhythmite occurs in central Sumatra (Eubank and Makki, 1981).

It is considered in this study that the sedimentary sequences of the Mae Sariang Group occurred in the outer shelf to slope of the deep marine environment. Comparison is made with the deep-water submarine fan settings proposed by Mutti and Ricchi-Lucchi (1978) and Lewis (1982) (see Figures 5.2 and 5.3, respectively). The $Tr_1$ unit can be compared with inner fan facies (Facies A) indicate by thick-bedded siltstone interbedded with pebbly sandstone, and middle fan facies (Facies C) indicate by thick-bedded, lithic sandstone. The $Tr_2$ unit is comparable with middle fan (Facies C, Facies D, and Facies E) indicate by thin-bedded mudstone intercalated with thin-bedded sandstone, thin-bedded chert intercalated with thin-bedded mudstone, conglomerate interbedded sandstone, and sandstone interbedded shale with common cross-bedding, graded bedding, and flute cast whereas the $Tr_3$ unit is similar to basin plain (Facies D and Facies G) indicate by medium-bedded mudstone intercalated with thin-bedded sandstone, black, thin-bedded, siliceous shale interbedded with black thin-bedded mudstone.

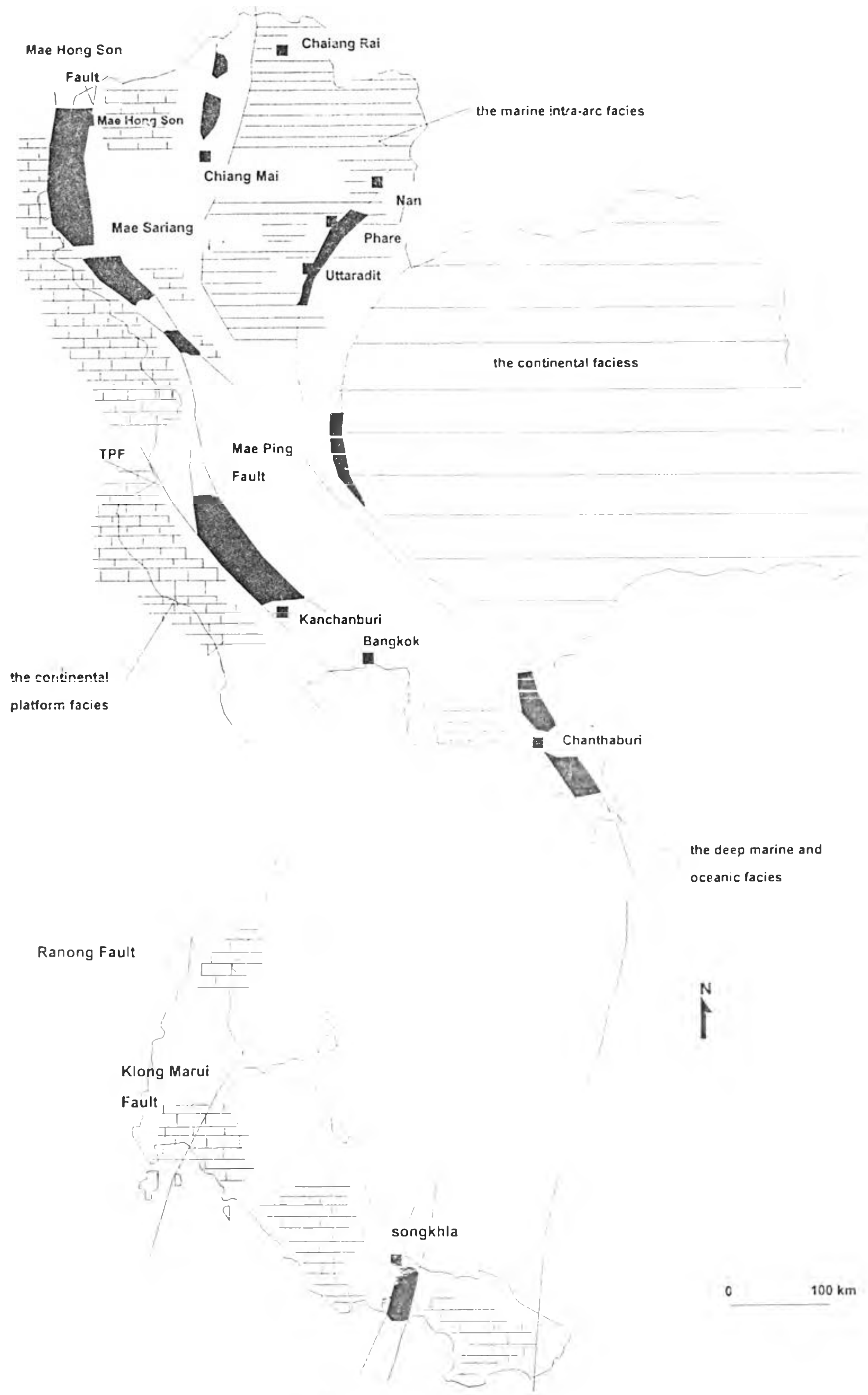


Figure 5.1 Triassic paleogeography (modified Chonglakmani, 1999).

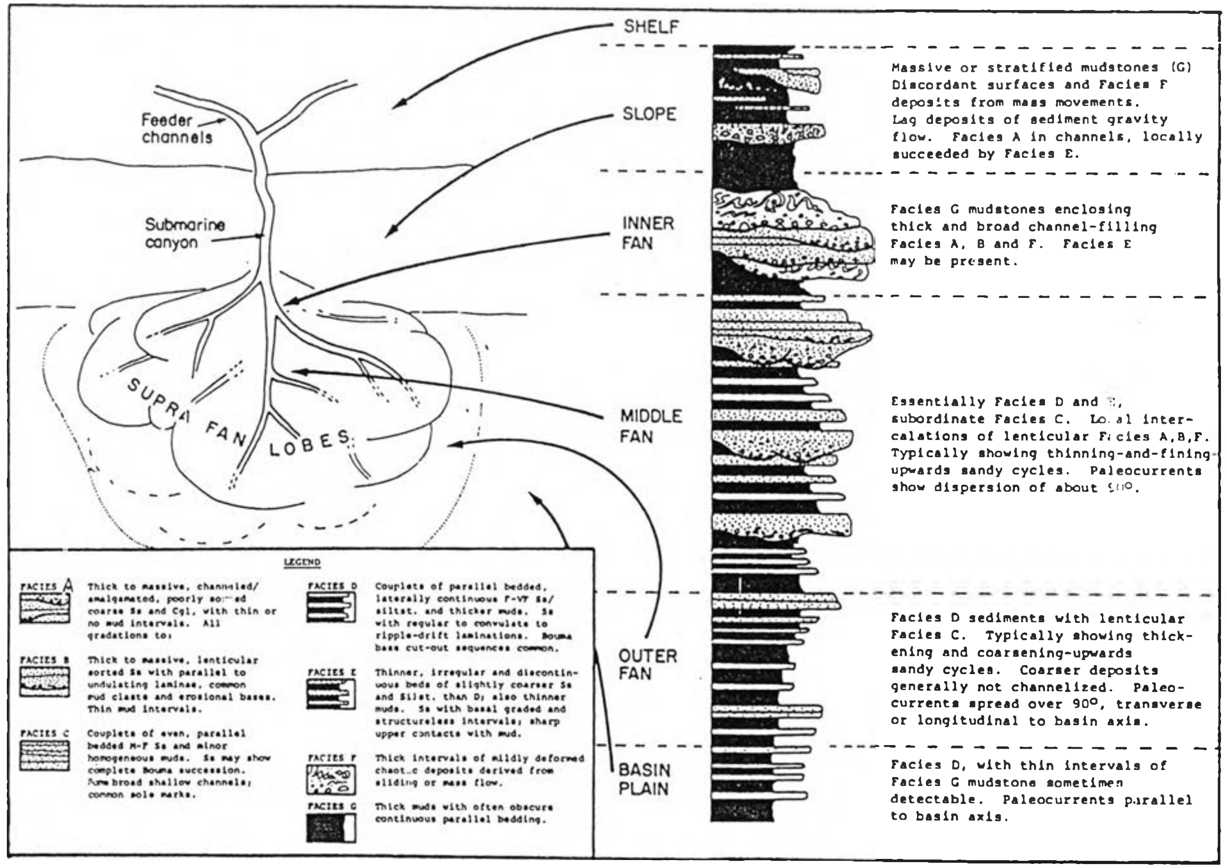


Figure 5.2 Vertical facies sequence in relation to plan-view morphology of an idealized deep-water submarine fan system (column after Mutti and Ricchi-Lucchi, 1978).

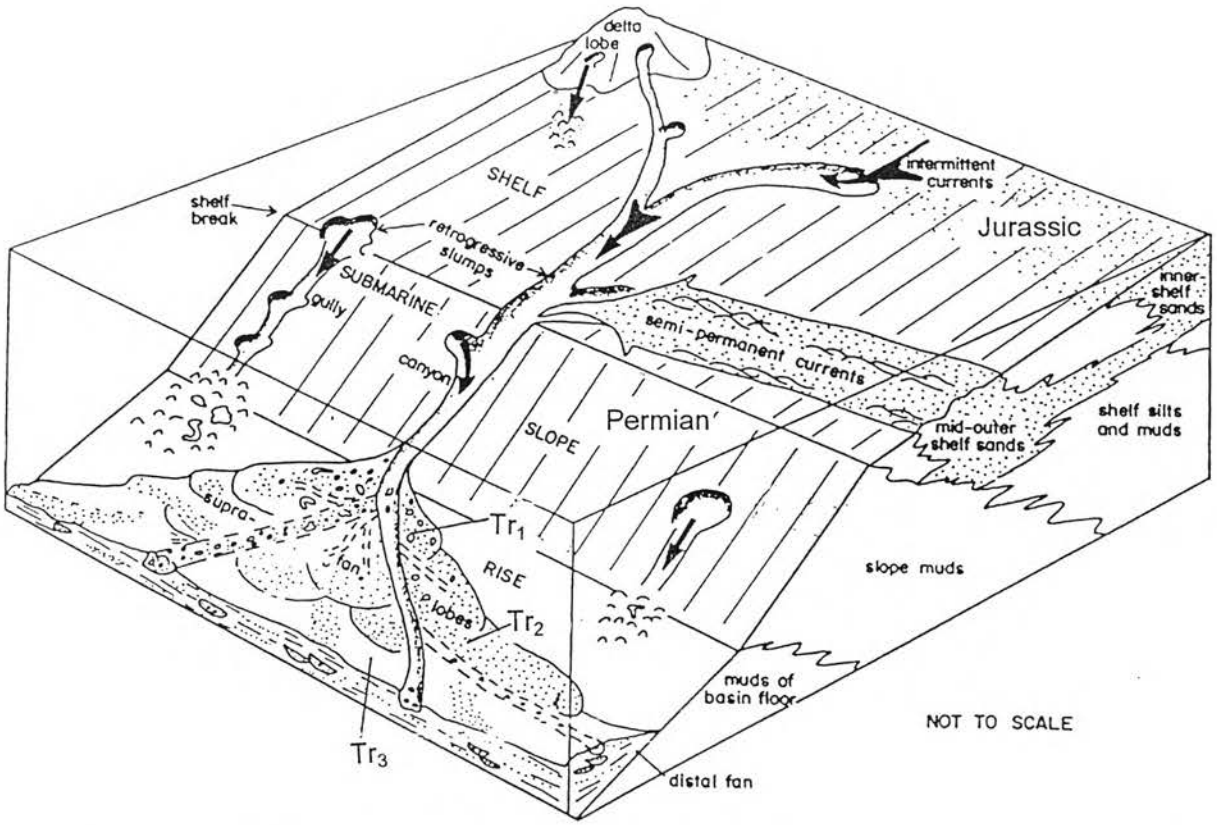


Figure 5.3 Schematic block diagram of a deep-water submarine fan setting and sediment supply system (from Lewis, 1982). In this diagram the Permian, Triassic, and Jurassic strata of the Mae Hong Son-Mae Sariang area are also assigned.

So it is quite likely that the Mae Sariang Group occurred in the deep-water submarine fan based the above-mentioned evidence.

As stated in Chapter II, the Permian sequence in the Mae Hong Son-Mae Sariang area consists of 2 major units-limestone with shale and chert interbeds in the lower part and clastics with chert and limestone interbeds in the upper part. This suggests that the environment as quite deep at that period. Such environments persisted to Triassic where the depositional environment was deep-water submarine fan. Shallow marine conditions (inner to middle shelf) existed over most of western and southern Thailand in the Jurassic (Toarcian-Bajocian). These conditions are indicated by abundance of faunas, the presence of oncolitic and oolitic limestone, and plant remains in sandstones.

### 5.1.2 Ages

Age of the Mae Sariang Group was first proposed as Middle Triassic by Buam et al. (1976). Reconfirmation of this age was done by Hahn and Siebenhüner (1982) who studied fossils of *Halobia* and *Posidonia* and the Anisian-Norian (Middle-Upper Triassic) age was suggested. Later Tofke et al. (1993) studied *Posidonia* and *Halobia* in shale belongings to turbidite in the Mae Sariang area and assigned Middle to Late Triassic for the age of the turbidite unit.

Caridroit et al. (1993) mapping a clastic sequence west of Amphoe Mae Sariang area, corresponding to the $Tr_1$ unit in this study. The paleontological data proved that this sequence is not of Middle Triassic age, but seen to be younger (Late Triassic to or younger). The result conclusion is based on radiolarians of Middle to Late Permian age and radiolarians of Triassic age found in pebbles contained in these clastics.

Kamata et al. (2002) found Early? to Late Triassic (Spathian? to Carnian) radiolarians were obtained from the bedded chert sequence of the Mae Sariang Group which is in the Pra Trumuang formation at Amphoe Mae Sariang area. Additionally, fossils of *Halobia* sp. was found in the shale belonging to Mae Leab formation at Ban Huai Pong.

So based upon paleontological point of view, it is considered that the age of the Mae Sariang Group is mainly Middle to Late Triassic.

## 5.2 Sandstone Provenance

Dickinson et al. (1983) had proposed the triangular QFL compositional diagram for sandstone suites derived from the different kinds of provenance terranes controlled by plate tectonics. Three main provenance are termed "continental blocks," "magmatic arc," and "recycled orogens."

In this study 35 Triassic sandstone samples of the Mae Hong Son-Mae Sariang area were plotted in this QFL triangular diagram of Dickinson et al. (1983) and showing in Figure 5.4. Based on the result from this triangular diagram plot, it is interpreted that sources of sandstone from the Mae Hong Son-Mae Sariang area are continental block and recycled orogen provenance.

## 5.3Tectonic setting using detrital chromian spinels

Compositional variation of chromian spinel is due to an apparent differentiation process of magma which may integrate crystallization differentiation, magma mixing (Sakuyama, 1978), inequilibrium crystallization of spinel (Thy, 1983), magma assimilation, etc. Therefore as stated by Arai (1992), the geochemical results obtained from chromian spinels can be applied to assessment of spinel-bearing igneous rocks and to estimate the provenance of detrital spinel particles, which are of igneous affinity. As described clearly in previous chapters, it is obvious that though the chemical result strongly indicate mafic source component for chromian spinel-bearing sandstone, the petrographic results point to the provenance of basaltic nature. Therefore, the geochemical data correspond fairly well with the petrographic results. Detrital spinels from the Mae Sariang Group are herein regarded as having the source potentially from ultramafic and basaltic environment.

In this study, results from EPMA analysis on chromian spinels and than of Sugiyama's data (Appendix I) are used for tectonic setting interpretion. Three main groups

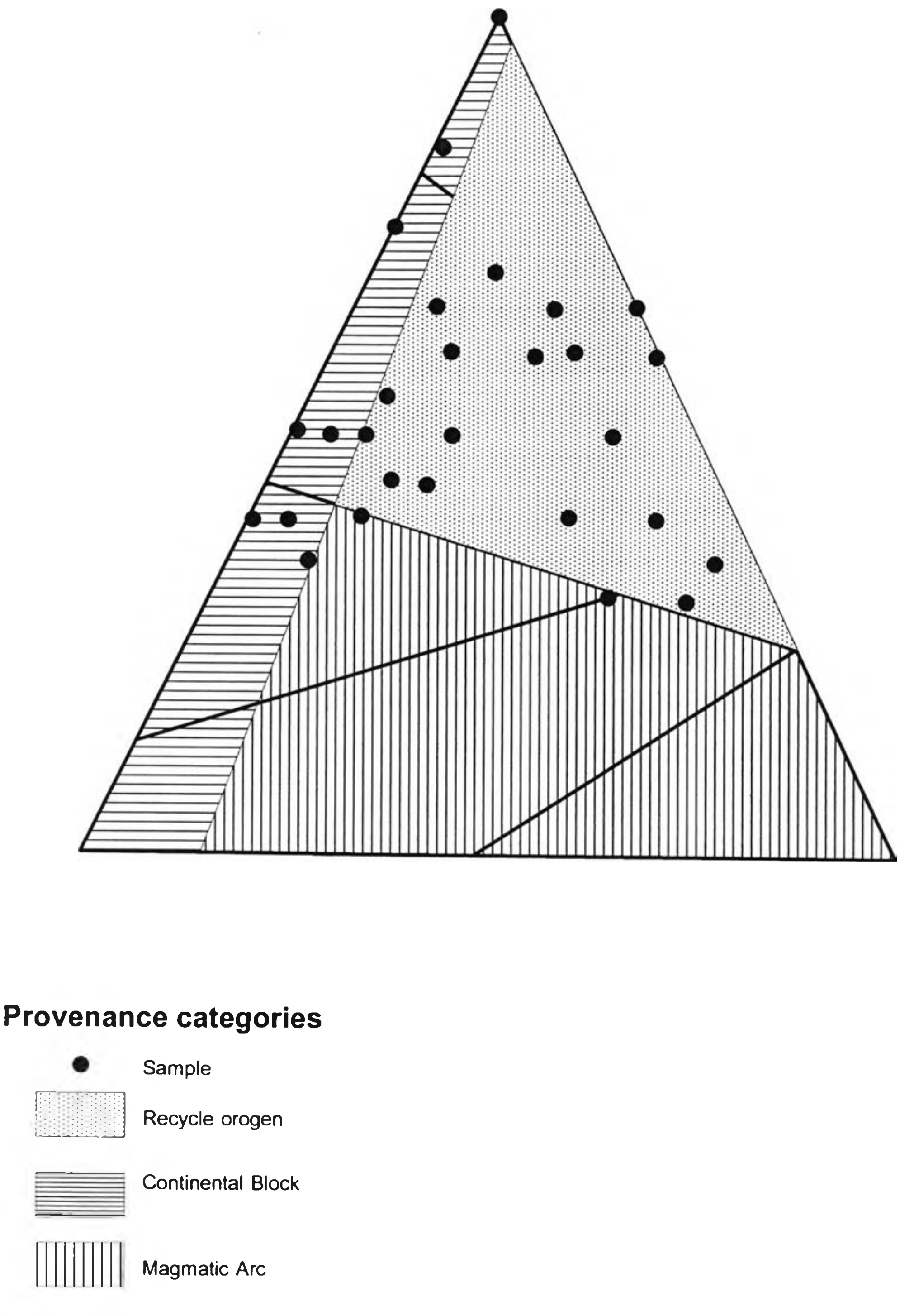


Figure 5.4 QFL diagram for Triassic sandstones in the Mae Hong Son area. Provenance fields are after Dickinson nad others (1983).

of magma are considerate arc magmas (basalts and andesite), ocean-floor basalts (MORB) and intraplate basalts (see Glassley, 1974; Arai, 1992). It is quite obvious that chromian spinels from are magma usually have a wide spread of Cr#. Chromian spinels in arc magmas show an inter-volcano variation of the Cr#, from 0.3 to 0.7 (Figure 5.5). Based upon the results proposed by Arai (1992), it is clear that the range of Cr# from the Mae Sariang detrital chromian spinels fill within those of the fore-arc and ocean floor basalts environments.

Wilson (1989) noted that $TiO_2$ contents can be used to distinguished different kinds of magmas. The $TiO_2$ contents frequently increase from island arc magma to intraplat basalts via MORB on a significant FeO/MgO ratio. This indicates a high usefulness of the $TiO_2$ contents of chromian spinels for distinguishing among those different magma origins (Arai, 1992). Spinels from the intraplate basalts are clearly discriminated from other ones by their high Ti contents. Spinels from boninites and high-Mg basalts/andesite are also characterized by quite higher Cr# and $TiO_2$ contents. The spinels of the MORB origin, are, however, undistinguished form those in the arc magmas and those in the back-arc basin basalts in term of the Cr#-$TiO_2$ relationships (see Figure 5.6). The relationship between Cr# and $TiO_2$ content of data plots of detrital chromian spinels from the Mae Sariang sandstones from this and Sugiyama's studies indicate the major trend of spinels corresponding to the MORB field of Arai (1992)'s diagram.

In addition, Arai (1992) also found that at a certain range of Cr between 0.3 and 0.6, there exists a relationship of $Fe^{3+}$#-$TiO_2$ for chromian spinels. He also recognized that $Fe^{3+}$# of the MORB spinel is very low which is partly due to the less fractionated character of the MORB relative to the other magmas. Spinels in an arc-related alkaline basalt occupy a high-Ti portion of the arc-magma region on the $Fe^{3+}$#-$TiO_2$ diagram (see Figure 5.7). The MORB spinels are intermediate, although not so clearly, between the arc-magma and intraplate-basalt spinels in their proportions between $TiO_2$ content and $Fe^{3+}$#. Low $Fe^{3+}$# is very characteristic for MORB spinels. Additionally, spinels in the back-arc basin basalt are intermediate in $TiO_2$. Content, they are similar to the MORB spinels in this sense but extend more towards a high $Fe^{3+}$# region. The relationship between $Fe^{3+}$# and $TiO_2$ of chromian spinels in three main magma groups was proposed by Arai (1992). Plots of the detrital

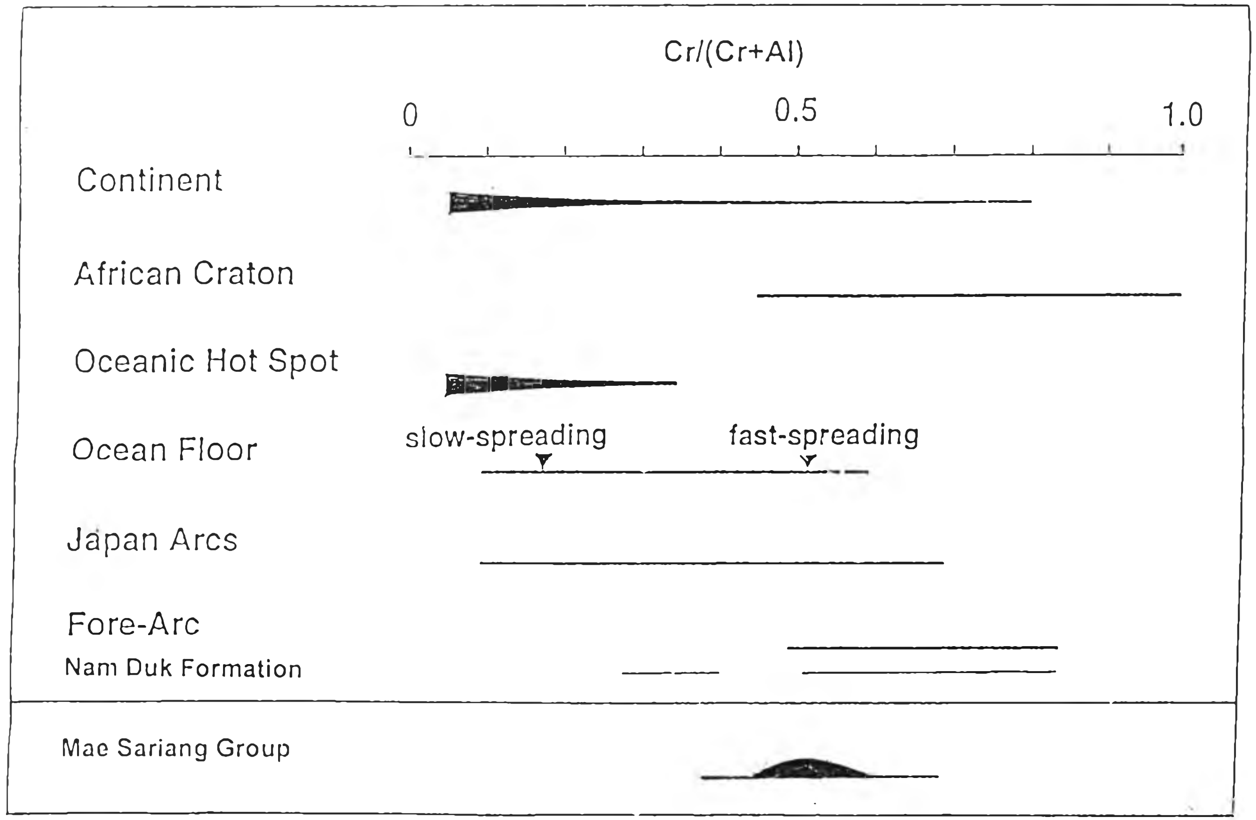


Figure 5.5 Bar graphs showing ranges of Cr/(Cr+Al) ratios (or Cr#) of chromian spinels in various provenance (modified form Arai, 1994) as compared with that Mae Sariang Group.

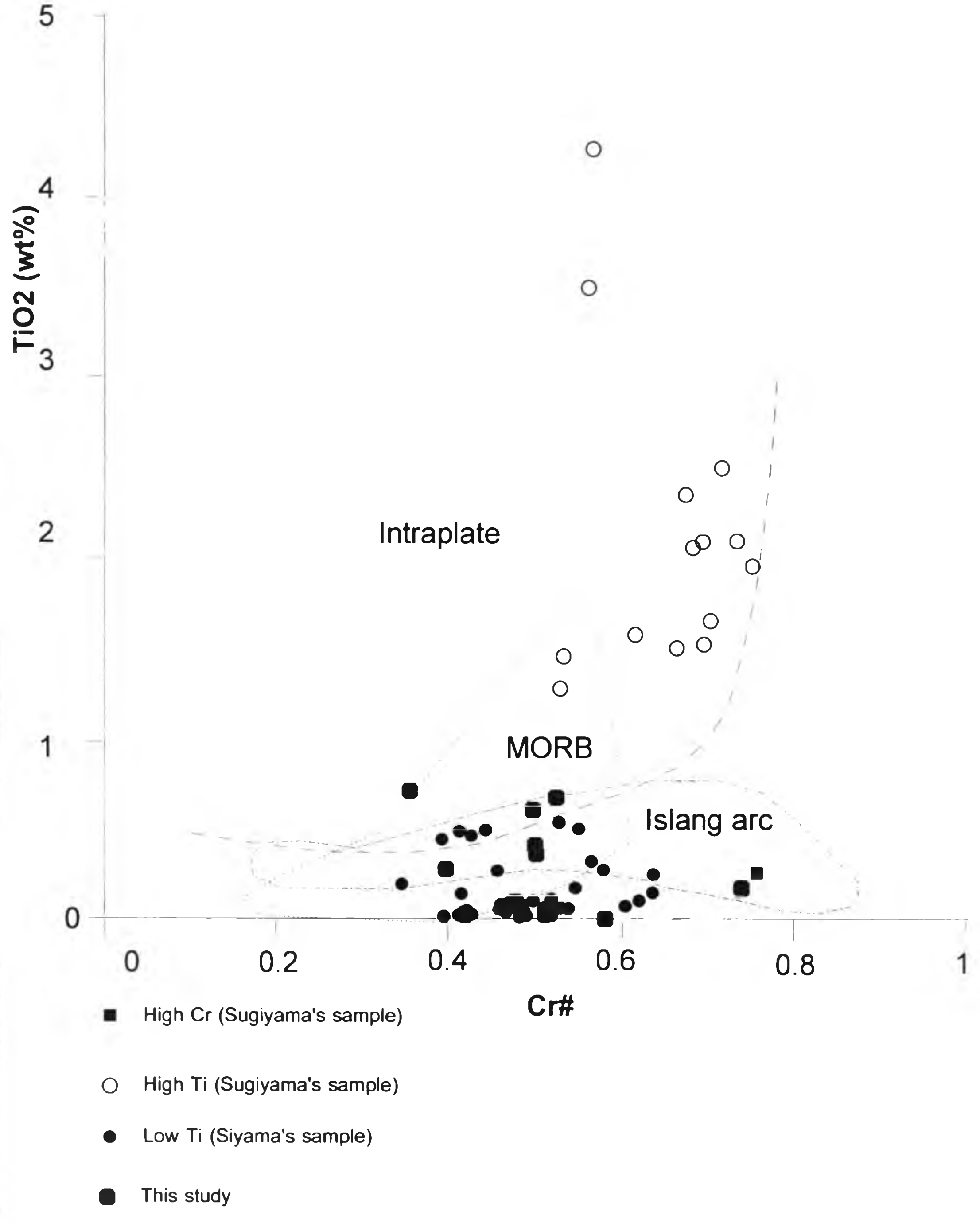


Figure 5.6 Relationships between Cr# and TiO2 content of chromian spinels of Mae Sariang sandstones in comparision with fields of intraplate basalts, MORB (Mid-oceanic ridge) and are magmas proposed by Arai (1992).

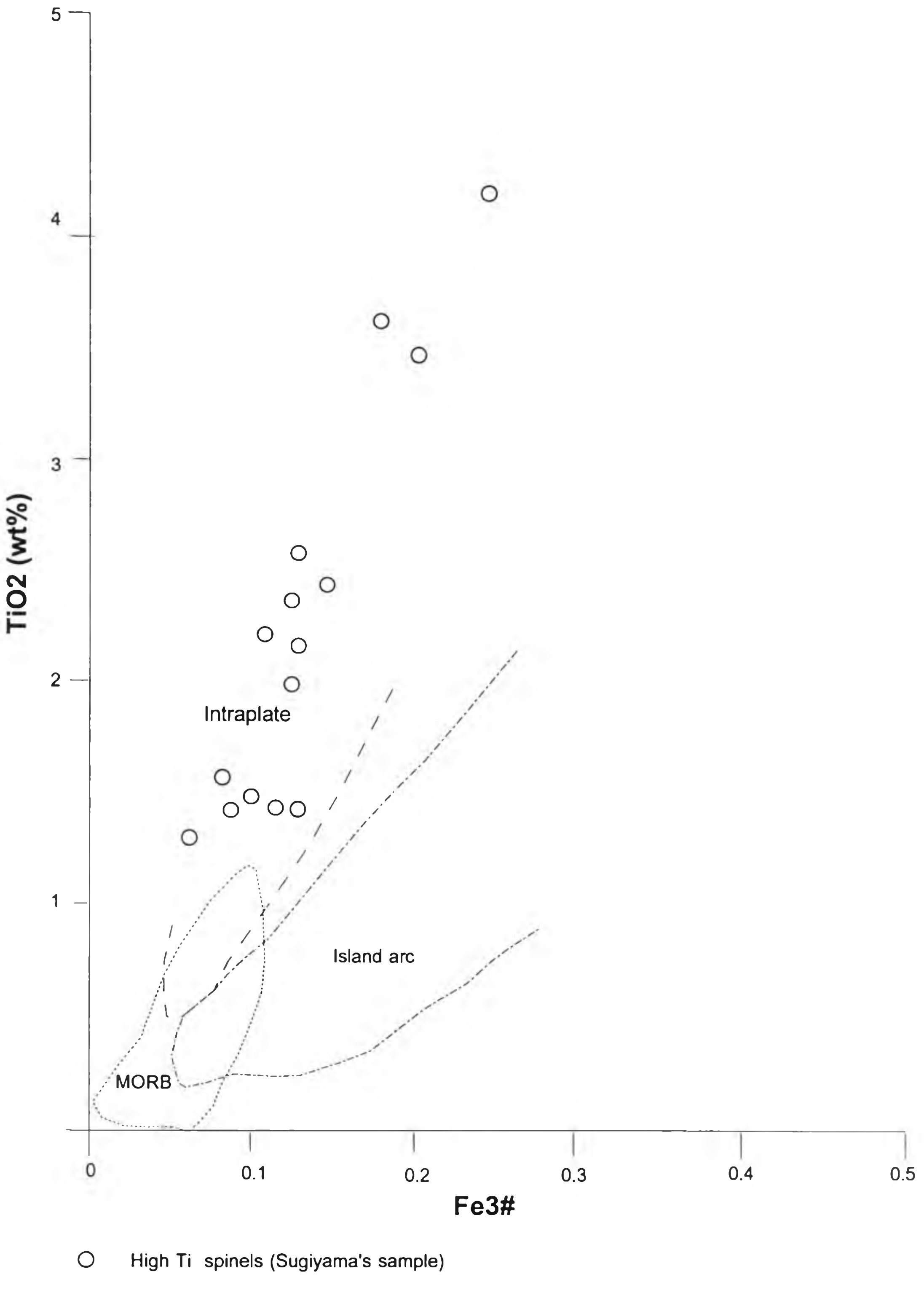


Figure 5.7 Relationships between Fe3+/(Cr+Al+Fe3+) and TiO2 content of chromian spinels of Mae Sariang sandstones in comparison with fields of intraplate basalt, MORB and are magmas proposed by Arai (1992).

chromian spinels in the Mae Sariang Group seems to correspond the MORB and intraplate-related trend of Arai (1992).

One may agree that coincidence of detrital spinels chemistry with any field does not necessarily imply a similar origin, because individual grains consider only selected aspects of the total chemical diversity of the spinels. Overlapping among fields on some plots is expected even though the geochemistry may be relatively distinct on other plots. Therefore, one may agree that the spinel grains may have been derived from ultramafic source region. A ternary plot of $Cr^{3+}$, $Al^{3+}$, and $Fe^{3+}$ (Figure 5.8) is herein considered useful for discriminating the ultramafic provenance of detrital chromian spinel-bearing sandstones. Based upon criteria proposed by Cookenboo et al. (1997), the ternary plot of the major cations in chromian spinels can be applied for such discrimination. The $Cr^{3+}$, $Al^{3+}$, and $Fe^{3+}$ data from the Mae Sariang spinel-bearing sandstone, from this study and Sugiyama's study, are plotted in the discrimination diagram, it is obvious that most values fall within the field of Alpine-type peridotite, although the former is more suitable. However, the Cr# and Mg# for the Mae Sariang spinels are plotted (Figure 5.9) compared with Alpine-type peridotite (field from Irvine, 1978). It is discovered that the Mae Sariang's values correspond very well with Alpine-type peridotite. According to Bloomer and Hawkins (1987) and Cookenboo et al. (1997), such the Alpine-type peridotite rocks are always common in the modern island-arc suite. Therefore, it is strongly believed that the Mae Sariang spinels may have derived from the provenance dominated by MORB and intraplate basalt tectonic setting.

To confirm the most probable tectonic setting of Mae Sariang Group using detrital chromian spinels data, the model based upon the work of Haggerty (1976) using Cr# and Mg# is also applied (Figure 5.10). It is visualized that the chromian spinel plots of the Mae Sariang Group correspond fairly well to the type ophiolites which is generated within the mid oceanic ridge (MOR) and ophiloite related regions. When comparing these $Mg/(Mg+Fe^{2+})$ and Cr/(Cr+Al) cationic ratios with those of Cookenboo et al (1997) in Figure 5.11, they are also similar to the ratios of spinels from marginal basin seafloor. Note that Cr# range of the Mae Sariang is higher than that of the Island arc of Cookenboo et al. (1997), although Mg# range an rather similar. The Cr# range of the Mae Sariang Group is also high than that of the mid-oceanic ridge of Cookenboo et al. (1997). Thus, it can be concluded from these

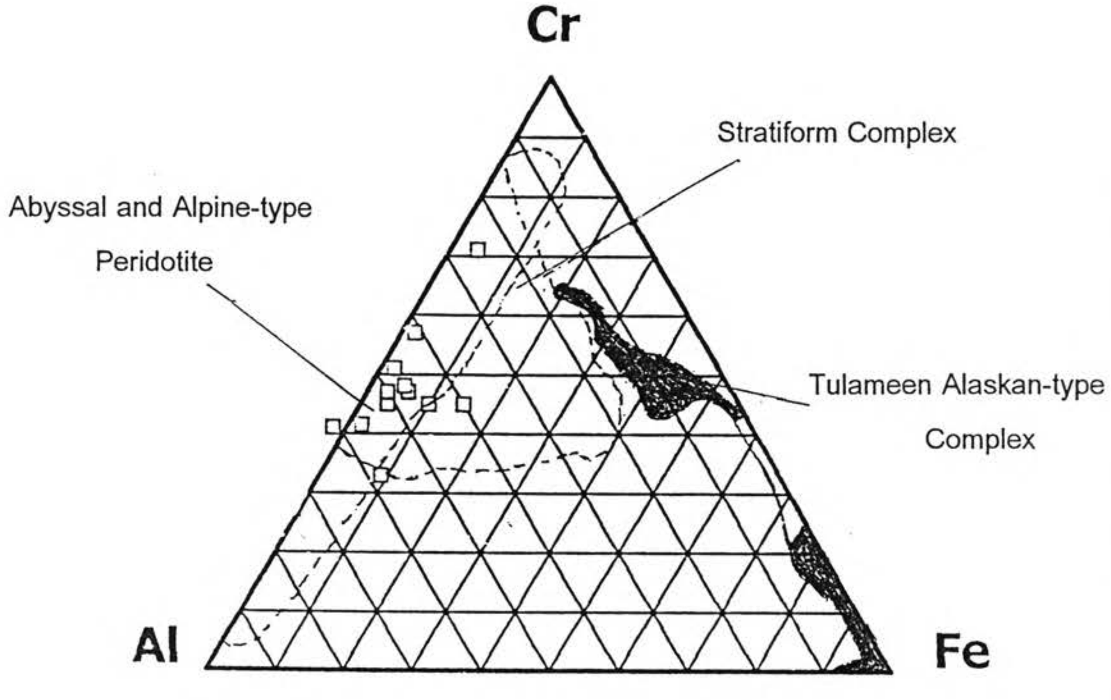


Figure 5.8 Ternary plot $Al^{3+}$, $Fe^{3+}$, and $Cr^{3+}$ values in chromian spinels in comparison with fields of stratiform mafic/ultra complexes, Alpine-type peridoties and Alaskan-type peridoties quoted by Cookenboo et al. (1987).

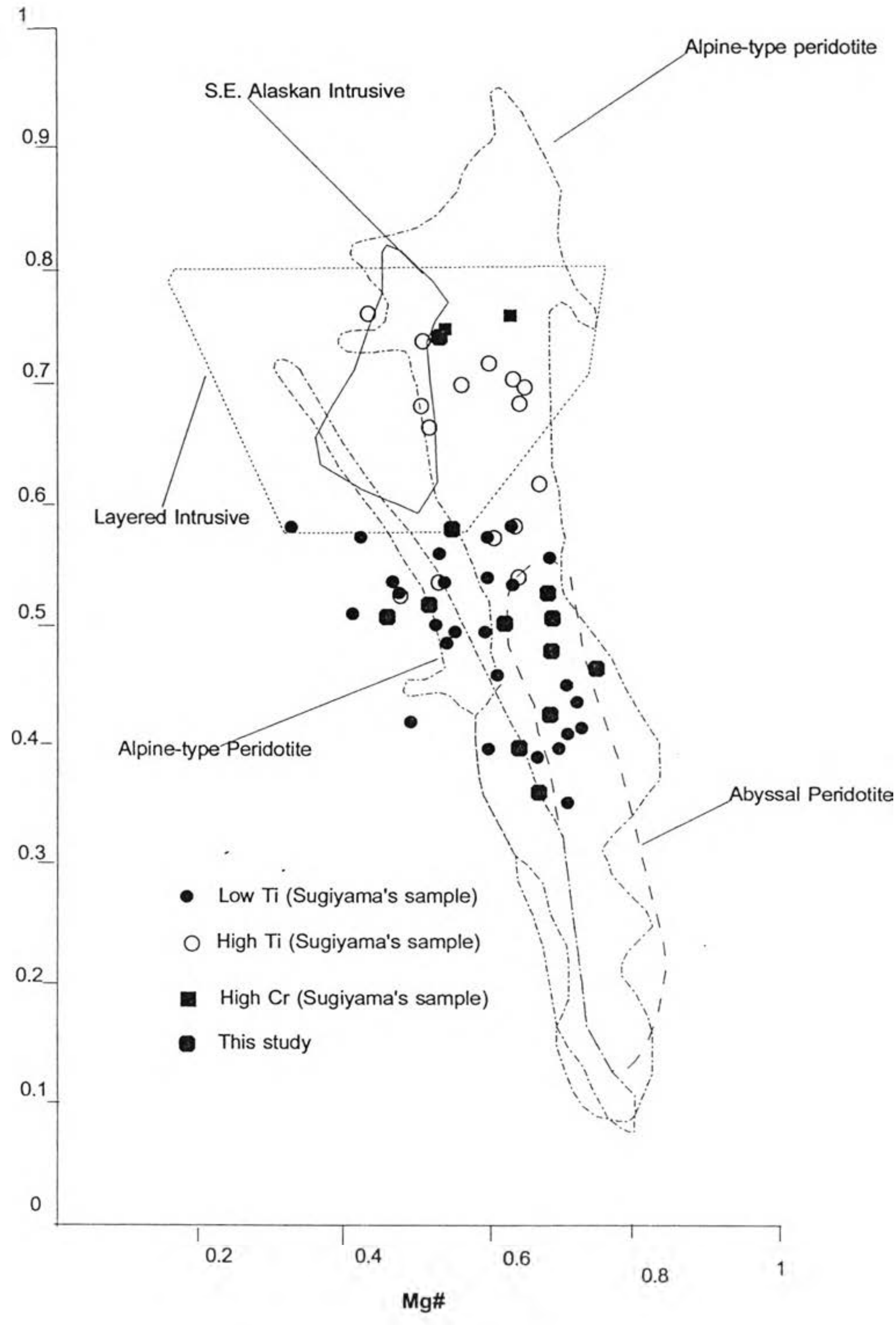


Figure 5.9 Plots of Cr# versus Mg# of detrital chromian spinels of Mae Sariang Group in comparison compositional field of Alpine-type peridotite and stratiform complexes proposed by Dick and Bullen (1984).

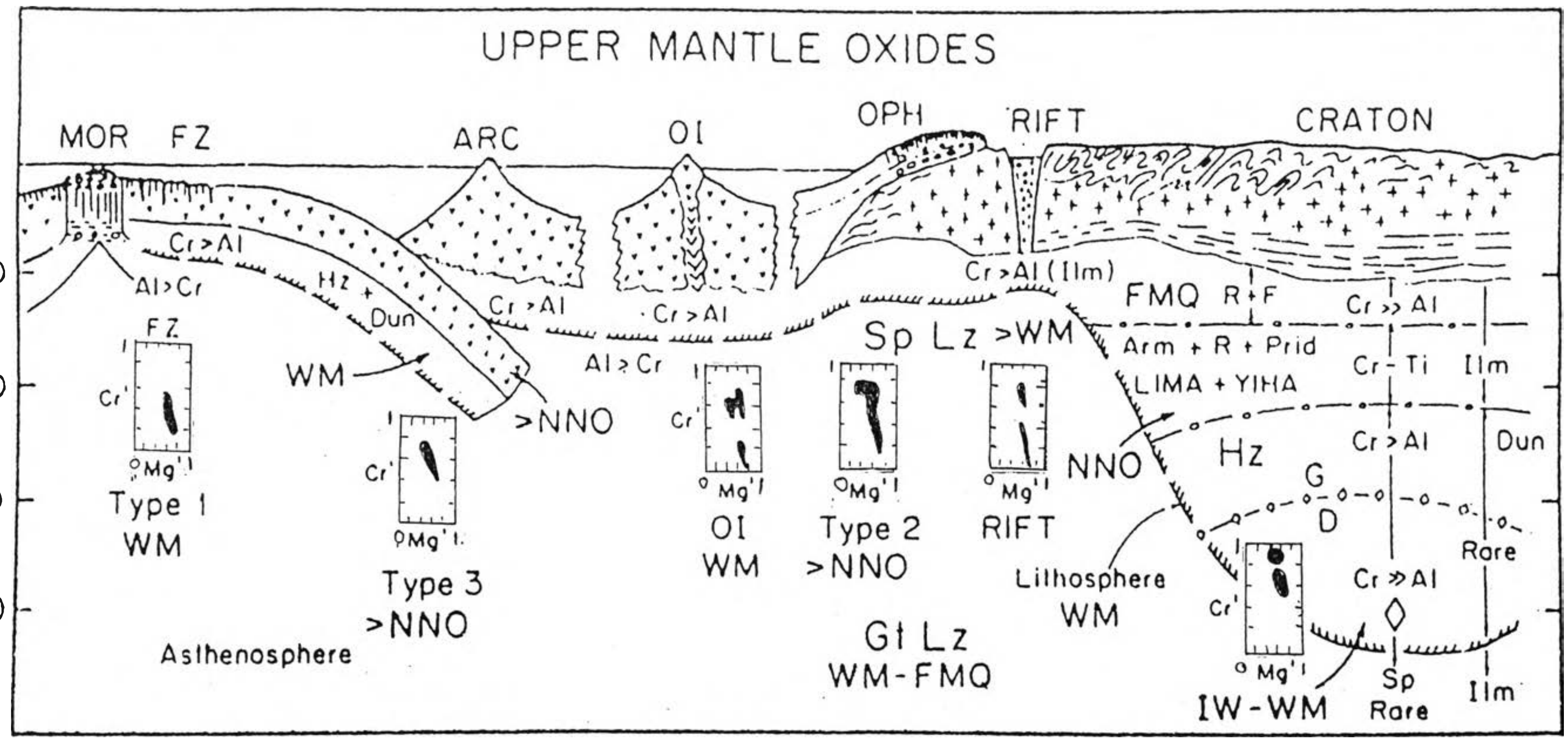


Figure 5.10 Simplified tectonic settings band upon Cr# and Mg# for mafic and ultramafic rocks from mid-ocean ridge (MOR) and fracture zone (FZ), to arc, ocean islands (OI), ophiolite (OPH) complexes, continental rifts and stable cratons (Haggerty, 1976).

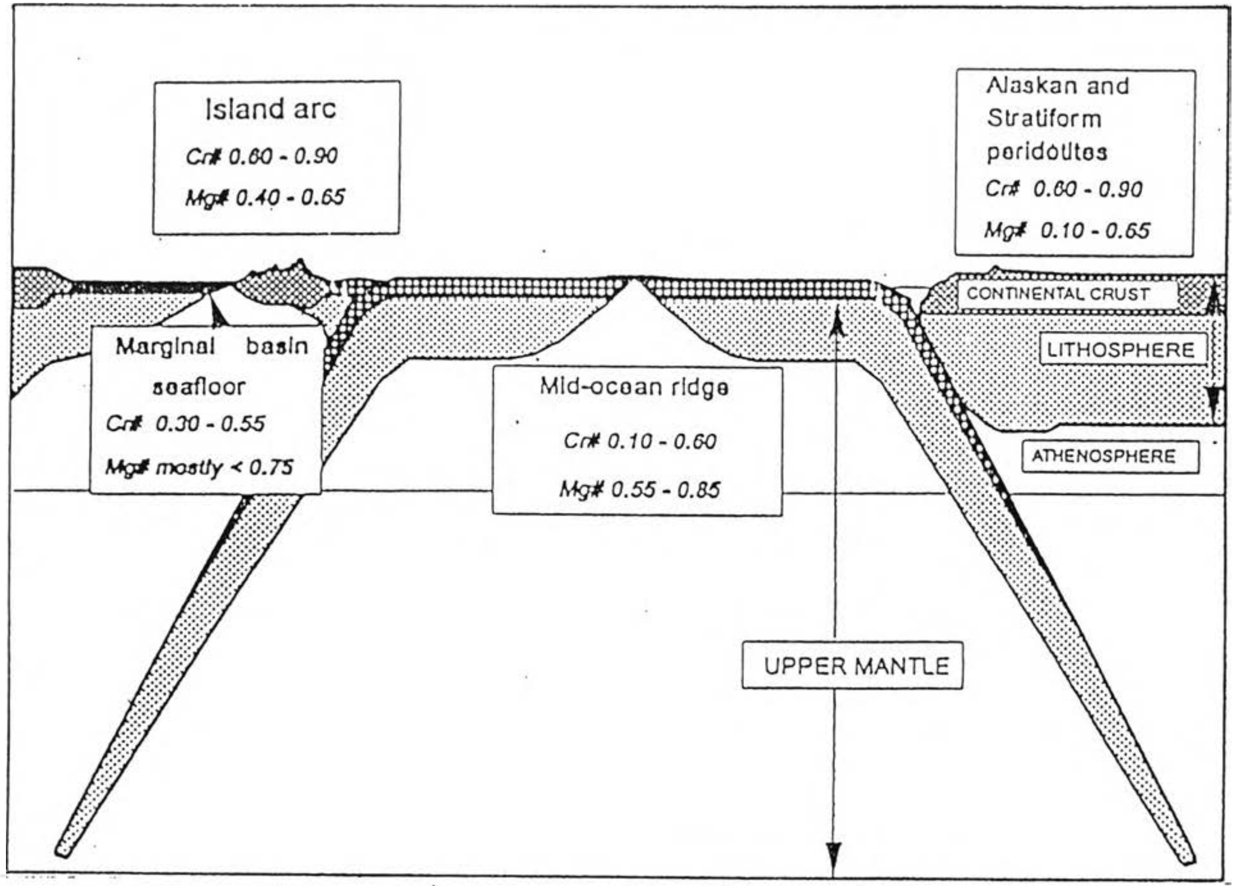


Figure 5.11 Typical spinel compositions from various sea-floor (potential Alpine-type ophiolite) and continental-crust origins (Cookenboo et al., 1997). No scale implied.

results that detrital chromian spinels from Triassic strata in the Mae Hong Son-Mae Sariang area were derived from Alpine-type peridotites below the mid-ocean ridge region.

**5.5 Tectonic senario of the Mae Hong Son Area**

As noted in earlier sections in this chapter, it is rather confirmed from petrochemical data of detrital chromian spinels that its provenance of the Mae Sariang sandstone is dominated by ocean floor and intraplate basalt tectonic setting. As mentioned previously in Chapter II and section 5.1 in this Chapter, that the Mae Sariang Group was formed during Middle to Late Triassic as recognized by Buam et al. (1970), Hahn and Siebenhüner (1982), Caridroit et al. (1993), Kamata et al. (2002).

Rocks of the Mae Sariang Group are located in the Shan-Thai (Bunopas, 1981) or the Sibumasu terranes (Metcalfe, 1988). The Shan-Thai block consists of portion of Myanmar, Thailand, northwestern Malaysia, and Sumatra. It is bounded to the west by the dextral Sagaing Fault, the Andaman Sea and the dextral Sumatran Fault Zone; to the east by the Bentong Raub line, the extension of the Bentong-Raub line into the Gulf of Thailand, and finally by the Nan-Uttaradit ophiolite line in northern Thailand; and to the north by the Red River Fault and the Himalayan Syntaxis (Metcalfe, 1988). It rifted from Gondwanaland in the Middle or Late Paleozoic and began travelling northward (Hutchison, 1989).

Prior to the deposited of the Mae Sariang Group, the paleogeography of the study area is denoted by deep-marine setting as evident by the occurrence of chert, fine-grained sandstone and shale without any volcanic association onto the passive continental margin. Later on in the Late Permian to early Triassic (Figure 5.12), rifting may have occurred in the study area, and as a result Sibumasu or Shan-Thai may have splitted or rifted off into "Western and Eastern Shan-Thai". The Mae Sariang Fault (or Mae Hong Son Fault) may serve as the supporting evidence for the weak zone of this scenario. Small ocean floor of Paleotethys may have happened in response to rifting, as supported by chemical data of detrital chromian spinel (see Figures 5.5 to 5.11).

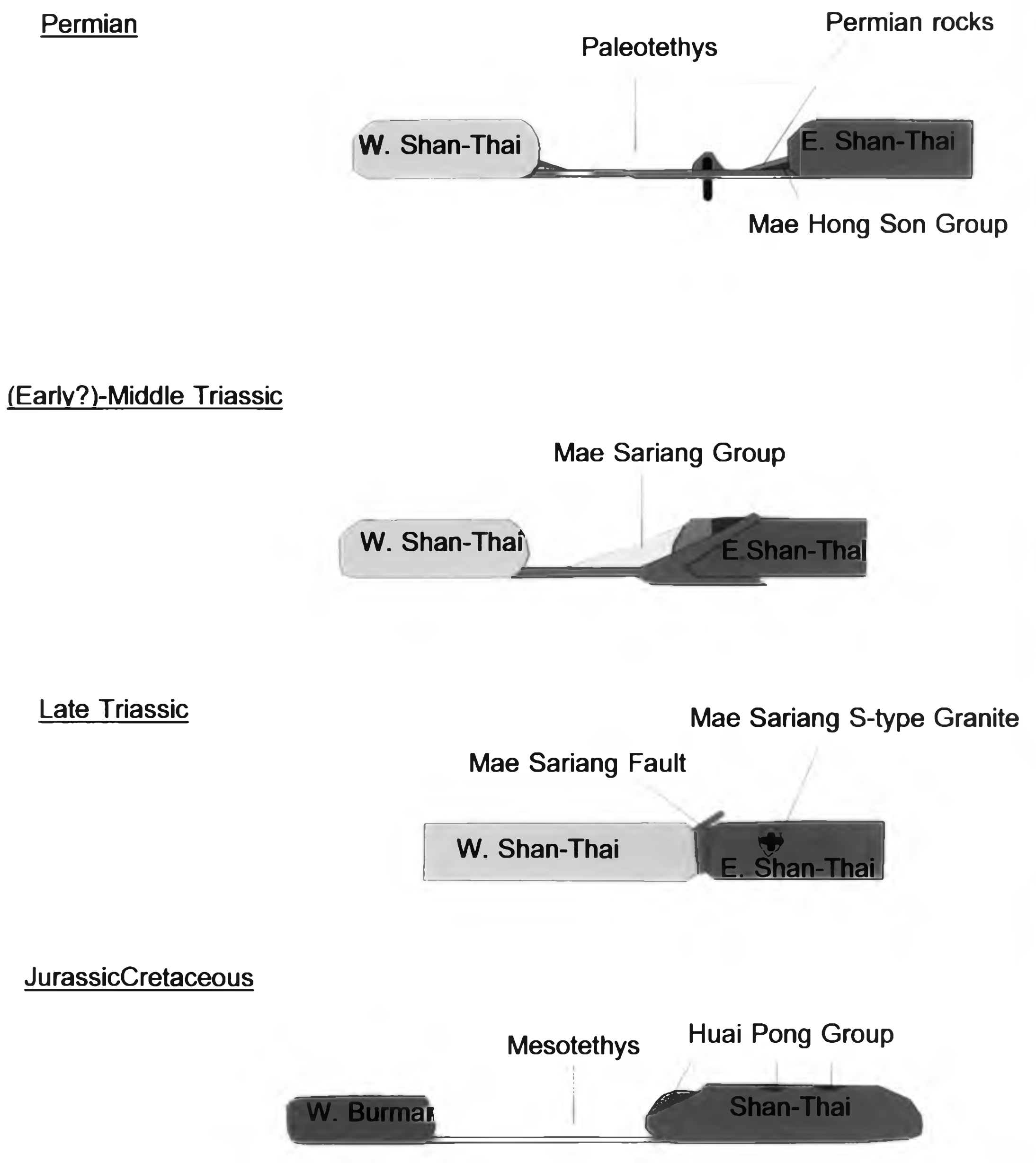


Figure 5.12 Tectonic reconstruction of Shan-Thai during Permian-Cretaceous, Mae Hong Son-Mae Sariang area.

During Middle to Late Triassic, marine sedimentation may have taken place in the deep-marine environment at the western margin of Eastern Shan-Thai. Modal compositional of sandstone of the Mae Sariang Group reveal that their provenance are recycle orogenys and continental block (Figure 5.4). Base on the paleocurrent pattern such as flute casts and cross-bedding, it is considered that there was a large landmass southeastward or eastward not far from the Mae Sariang-Mae Hong Son area. Recently, an area about 1x1 km size of a serpentinite body is exposed east of Tak (Panjasawatwong, 2003, per. com.). This perhaps serves as a good candidate for the spinel provenance. This area is very close to the Mae Sariang-Lansang metamorphic core complex, which is regarded herein as source rock of sandstone.

During Middle Triassic, Eastern and Western Shan-Thai may have caused the emplacement of the S-type granites, east of Mae Sariang area. The granites were dated at 212-240 Ma by von Braun and Jordan (1976) using Rb-Sr method and at 210-220 Ma by Charusiri (1989) using Ar-Ar method. Continental crystalline basement complex was then uplifted and become partial melted to generate the S-type granite.

During Jurassic, Eastern and Western Shan-Thai may have closed definitely causing almost all Shan-Thai emerged. Paleotethys become close and Mesotethys was transgressive over west of Shan-Thai. Sediments of the Huai Pong Group (Meesooka and Grant-Mackie, 1996) were deposited onto the shelves, and some parts became non-marine sediments similar to that of the Khorat Group.