

CHAPTER 5

TECTONIC SETTING OF SA KAEO-CHANTHABURI ACCRETIONARY COMPLEX – DISCUSSIONS

Based upon my field investigation and petrochemical studies on the detrital chromian spinels stated in previous chapters, a discussion on the depositional environment for the Pong Nam Ron Formation and its relevant tectonic settings could be made as below in details. Finally tectonic construction of the Sa Kaeo-Chanthaburi Accretionary Complex is proposed.

5.1 *Mélanges* in the Sa Kaeo-Chanthaburi Accretionary Complex

Although several authors had already been studied geology in this Sa Kaeo-Chanthaburi area (Salyapongse, 1992; Chaodumrong, 1992b; Jungyusuk and Khositanont, 1992; Fontaine and Salyapongse, 1997; Fontaine et al., 1997; Salyapongse et al., 1997), nobody had been recognized and paid much attentions to the chaotic structures in this region.

With another concept, Hada et al. (1997, 1999) had studied and classified the Sa Kaeo-Chanthaburi area as a southern segment of the Nan-Uttaradit Suture in eastern Thailand. The rock assemblages in the Sa Kaeo-Chanthaburi area were subdivided into two parallel belts; a western

belt of Chanthaburi chert-clastic sequence, and an eastern belt of serpentinite Thung Kabin *mélange*. The work of Hada et al. (1997, 1999) is the first published report about the appearance of *mélange* in eastern Thailand.

After the field investigation in the present study, the characteristics of chaotic structures of *mélanges* such as block-in-matrix and duplexs are well recognized in accordance with Hada et al. (1997, 1999)'s reports. Characteristics and distribution of *mélanges*, however, are better defined in the present study.

Based on Silver and Beutner (1980), *mélange* are mappable bodies of fragmented and mixed blocks in a matrix, and it is not dubious that the rock assemblage in the SKCB-AC is one of *mélange* in Thailand. The blocks in *mélanges* of the Khao Prik unit are generally characterized by large mountain-size limestones associated with basaltic rocks. *Mélanges* of the Khao Hleam unit contain a diverse assemblage of basaltic pillow lavas, volcanoclastic rocks, radiolarian cherts, fossiliferous limestones, clastic rocks and serpentinites. The tectonic blocks in *mélanges* of the Ban Nong Bon unit are characteristically sandstones and conglomerates. Cherts and limestones frequently occur as small tectonic blocks in shale matrix. The rocks in *mélanges* of the Soi Dao unit are similar with those of the Khao Hleam unit.

Rather than broadly applying the term “ophiolite” to all occurrences of structurally emplaced ultramafic rock, I prefer to follow the definition by Anonymous (1972), Coleman (1977) and Zen (1983) in restricting the terms to the obducted slabs of oceanic crust and upper

mantle (ophiolite *sensu stricto*). As mentioned by Metcalfe (1998, 1999), there is an occurrence of “ophiolitic rocks” in the SKCB-AC. However, from my field investigation, the Khao Hleam unit and the Soi Dao unit of the SKCB-AC are possibly the belts of dismembered ophiolitic mélanges of the oceanic plate materials that do not exhibit any stratigraphy implicit in the Coleman (1977)’s definition of “ophiolite”.

Generally rock assemblages in this area were classified as the Permian rocks (Chaodumrong, 1992b; Salyapongse et al., 1997) by using age of fossils found and identified by some authors (Sashida et al., 1997; Hada et al., 1997; Fontaine and Salyapongse, 1997; Fontaine et al., 1997; Salyapongse et al., 1997). One of the important paleontological papers is Hada et al. (1997, 1999) who discriminated the Early, Middle and Late Permian radiolarian faunas from chert blocks of the Khao Hleam unit. On the other hand, Chutakositkanon et al. (2003b) gave different ages for mélange of these rock assemblages somewhat younger than previous studies as the Late Paleozoic to Early Mesozoic.

Considering the current tectono-stratigraphy and paleontological data, the ages of mélange should be younger than those of fossils (Permian) from tectonic blocks, but still be older than ages of the Soi Dao Granite (Upper Triassic) that intruded in the SKCB-AC. The present interpretation is in a good agreement with earlier interpretation of Chutakositkanon et al. (2003b). New ages of mélanges are assigned now as the Uppermost Permian to Lower Triassic, while the ages of covering sediments of the Pong Nam Ron Formation are assigned to the Middle Triassic.

Recently, Chutakositkanon et al. (2003a, 2003b) explained the characteristics of mélanges in the SKCB-AC and their relationships with the adjacent Chanthaburi chert-clastic sequence of Hada et al. (1997, 1999). The SKCB-AC was interpreted as the older accretionary complex, and its trench will be shifted to the west and formed new accretionary complex of the Chanthaburi chert-clastic sequence. From the relationships of both accretionary complexes and their paleontological data, it can aid us explain clearly about the direction of subduction. The SKCB-AC and Chanthaburi chert-clastic sequence are the products of the east-dipping subduction of ancient oceanic plates underneath the western margin of the Indochina during the Late Permian to Triassic.

5.2 Sedimentological significance of the Pong Nam Ron Formation

The Pong Nam Ron Formation was named for the Triassic greywacke unit by Siwaboworn et al. (1976) and used later by some authors (Salyapongse, 1992; Chaodumrong, 1992b; Chutakositkanon et al., 2001, 2002, 2003a, 2003b). It is considered that these sandstones represent syn-collisional sediments along the remnants basin between the collision zone between the Sibumasu and Indochina (Salyapongse, 1992; Chaodumrong, 1992b).

In the aspect of sedimentology, the terrigenous clastic rocks of the Pong Nam Ron Formation were regarded as turbiditic deposits of a submarine fan (Chaodumrong, 1992b; Chutakositkanon, 2001a, 2002). The chemical compositions of the greywacke sandstones are mostly constant (Salyapongse, 1992). The plots of K_2O/Na_2O versus SiO_2 of the whole-rock composition of these greywacke sandstones according to

Roser and Korsch (1986)'s scheme suggested their parental source rocks were in the active continental margin as well as in the oceanic island arc margin (Salyapongse, 1992; Salyapongse et al., 1997)

The bulk composition of sandstones of the Pong Nam Ron Formation is analyzed by the point-count determination of modes for detrital framework grains. Compositional plots are filled in the dissected arc field of Dickinson (1985). Probably it indicates arc-derived debris, typically deposited in fore-arc or inter-arc basins (Dickinson, 1982). This provenance interpretation is in a good agreement with previous interpretations of Salyapongse (1992).

Focusing on the distribution of the Pong Nam Ron Formation in the previous studies (Siwaboworn et al., 1976; Salyapongse, 1992; Chaodumrong, 1992b; Hada et al., 1997, 1999), the Ban Nong Bon unit exposed between the Khao Hleam and Soi Dao units were recognized as a part of the Pong Nam Ron Formation. However, the *mélange* characteristics of the Ban Nong Bon unit discovered in the field investigation are strongly different from those of the Pong Nam Ron Formation around its type locality. *Mélange*, broken formation and coherent turbidite sequence of sandstones and shales are dominantly observed in the Ban Nong Bon unit. Chert and limestone also occur as small tectonic blocks in a shale matrix (Chutakositkanon et al., 2001a, 2002, 2003a, 2003b). It is significant to discriminate the Ban Nong Bon unit from the turbiditic sandstone and shale alternation of the Pong Nam Ron Formation.

5.3 Tectonic setting inferred by detrital chromian spinels

Since few rock sources can contain chromian spinels (Hiscott, 1984), the occurrences of detrital chromian spinels in the turbiditic sandstone, conglomerate and volcanoclastic rocks in the SKCB-AC indicate the subaerial and/or subaqueous exposures of mafic-ultramafic rocks during their sedimentation. As described clearly in the previous chapters, the rather small, euhedral to subhedral chromian spinels with the inclusion suggests strongly the provenance of basaltic origin (see Arai, 1992, 1994b).

Considering the geochemistry of chromian spinels, Scowen et al. (1991) demonstrated that chromian spinels even totally enclosed in olivine could change its solidus composition by the diffusion through olivine in slowly cooling magmas; and the chemistry of chromian spinels is also dependent on the cooling rate, even if the magma chemistry is the same. The Ti content of spinels, however, is a reliable indicator of magma chemistry because the diffusivity of Ti^{4+} in olivine is relatively low (Scowen et al., 1991; Arai, 1992). As stated by Arai (1992), the geochemistry obtained from the chromian spinels can be applied to an evaluation of the spinel-bearing igneous rocks and to estimate the precise provenance of detrital chromian spinel particles, which are of igneous affinity, especially from a volcanic origin.

According to Arai (1992), three main groups of magmas are considered in this study as arc magmas (basalt and andesite), ocean-floor basalts (MORB) and intraplate basalts (oceanic hot-spot basalts and flood basalts). The three groups can be distinguished to some extent from each

other by their Ti contents (Glassley, 1974; Wilson, 1989); the contents increase from island-arc magmas to intraplate basalts via MORB on a particular FeO/MgO ratio (Glassley, 1974). This indicates a potential usefulness of the TiO₂ content of chromian spinels for distinguishing among these different magma origins (Arai, 1992).

Considering the Cr#-TiO₂ relationships (see Arai, 1992), the chromian spinels from boninites and high-Mg tholeiites/andesites have quite high Cr# (> 0.8) with the low TiO₂ content. The arc magmas have spinels with a wide spread of Cr# about 0.2 to 0.9, while the intraplate alkali basalts have Cr# < 0.6 with the higher and more variable TiO₂ contents. The oceanic plateau basalts and back-arc basalts are very similar to intraplate basalts and to MORB, respectively. The most chromian spinels of MORB, however, are undistinguished from those of the arc magmas and those of the back-arc basalt in terms of the Cr#-TiO₂ relationship.

As the $\text{Fe}^{3+}/(\text{Cr}+\text{Al}+\text{Fe}^{3+})$ atomic or $\text{Fe}^{3+\#}$ of chromian spinel is strongly dependant on the degree of differentiation of host magma, the TiO₂ content should be compared for spinels with comparable $\text{Fe}^{3+\#}$. In this study, detrital chromian spinels with $\text{Fe}^{3+\#} < 0.2$ (Arai, 1992) are chosen for the comparison on the Cr#-TiO₂ relationship. The geochemical plots of detrital chromian spinels from the Pong Nam Ron Formation and from the sandstone and conglomerate blocks in mélanges are mostly corresponding to the island arc-related field of Arai (1992)'s Cr#-TiO₂ relationship diagram (Figs. 44 and 45). The plots of detrital chromian spinels from the volcanoclastic rocks in mélanges of the Khao Hleam unit are clearly filled in the intraplate basalt, while the plots of detrital

Pong Nam Ron Formation

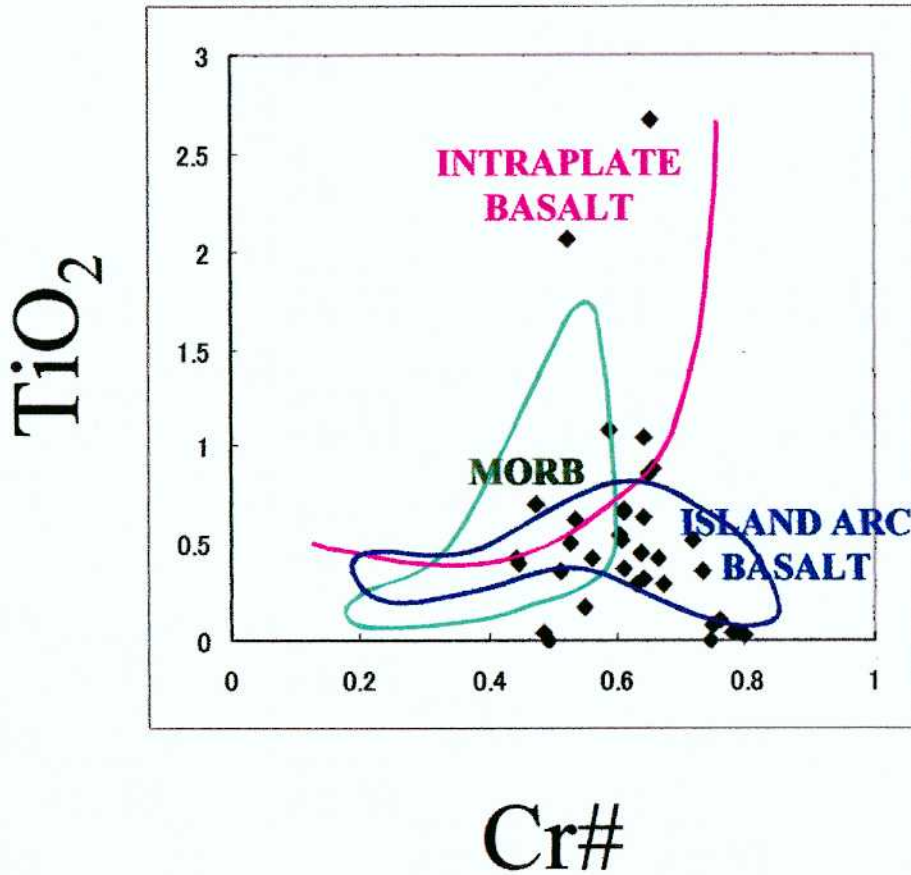


Fig. 44 Relationships between Cr# and TiO₂ content of detrital chromian spinels from the Pong Nam Ron Formation in comparison with fields of MORB, intraplate basalt and arc magmas proposed by Arai (1992).

Sandstone and Conglomerate blocks in Mélange

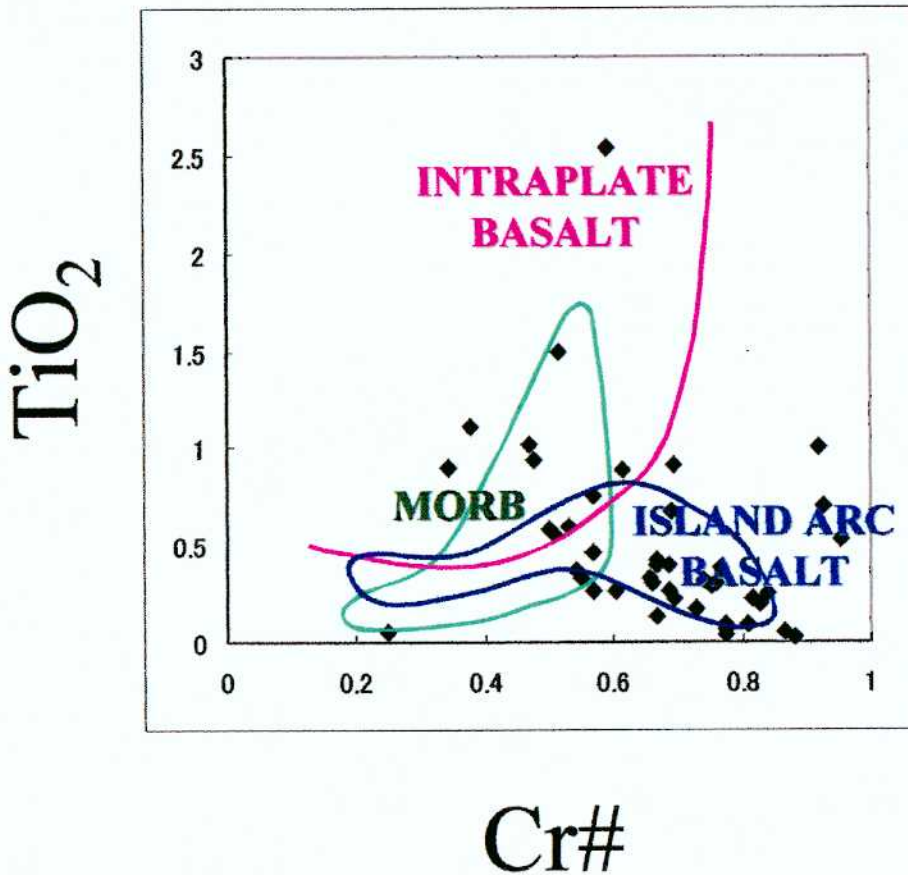


Fig. 45 Relationships between Cr# and TiO₂ content of detrital chromian spinels from the sandstone and conglomerate blocks in mélange in comparison with fields of MORB, intraplate basalt and arc magmas proposed by Arai (1992).

chromian spinels from volcanoclastic rocks of the Soi Dao unit are filled in three categories of the MORB, intraplate basalts and island arc basalts (Fig. 46).

In addition, Arai (1992) also reported that it is very useful to discriminate clearly the chromian spinels of the intraplate basalts from those of the arc magmas in terms of the $\text{Fe}^{3+\#}\text{-TiO}_2$ relationships for spinels with Cr# of 0.3 to 0.6. The MORB spinels are intermediate, although not so clearly, between the arc-magma and intraplate-basalt spinels. Low $\text{Fe}^{3+\#}$ is characteristic of MORB spinels. The results are successfully applied to estimate 1) parental magmas for dunite cumulates, 2) original magma chemistry of altered or metamorphosed volcanics, and 3) provenance of detrital chromian spinel particles (Arai, 1992).

To unravel the provenance of detrital chromian spinels in the Pong Nam Ron Formation and in sandstone blocks in mélangé, I plotted the geochemistry of detrital chromian spinels with Cr# of 0.3 to 0.6 in the Arai (1992)'s $\text{Fe}^{3+\#}\text{-TiO}_2$ relationship diagram. The plots of detrital chromian spinels in the Pong Nam Ron Formation and the sandstone and conglomerate blocks in mélangés seem to correspond to the arc-related trend (Figs. 47 and 48). The plots of detrital chromian spinels in the volcanoclastic rocks in the Khao Hleam unit are clearly filled in the intraplate basalt, while the plots of detrital chromian spinels from volcanoclastic rocks of the Soi Dao unit are distributed clearly in two trends of the intraplate basalts and island arc basalts (Fig. 49).

Considering Chutakositkanon (1999) and Chutakositkanon et al. (2001b), the characteristics of detrital chromian spinels from the Pong

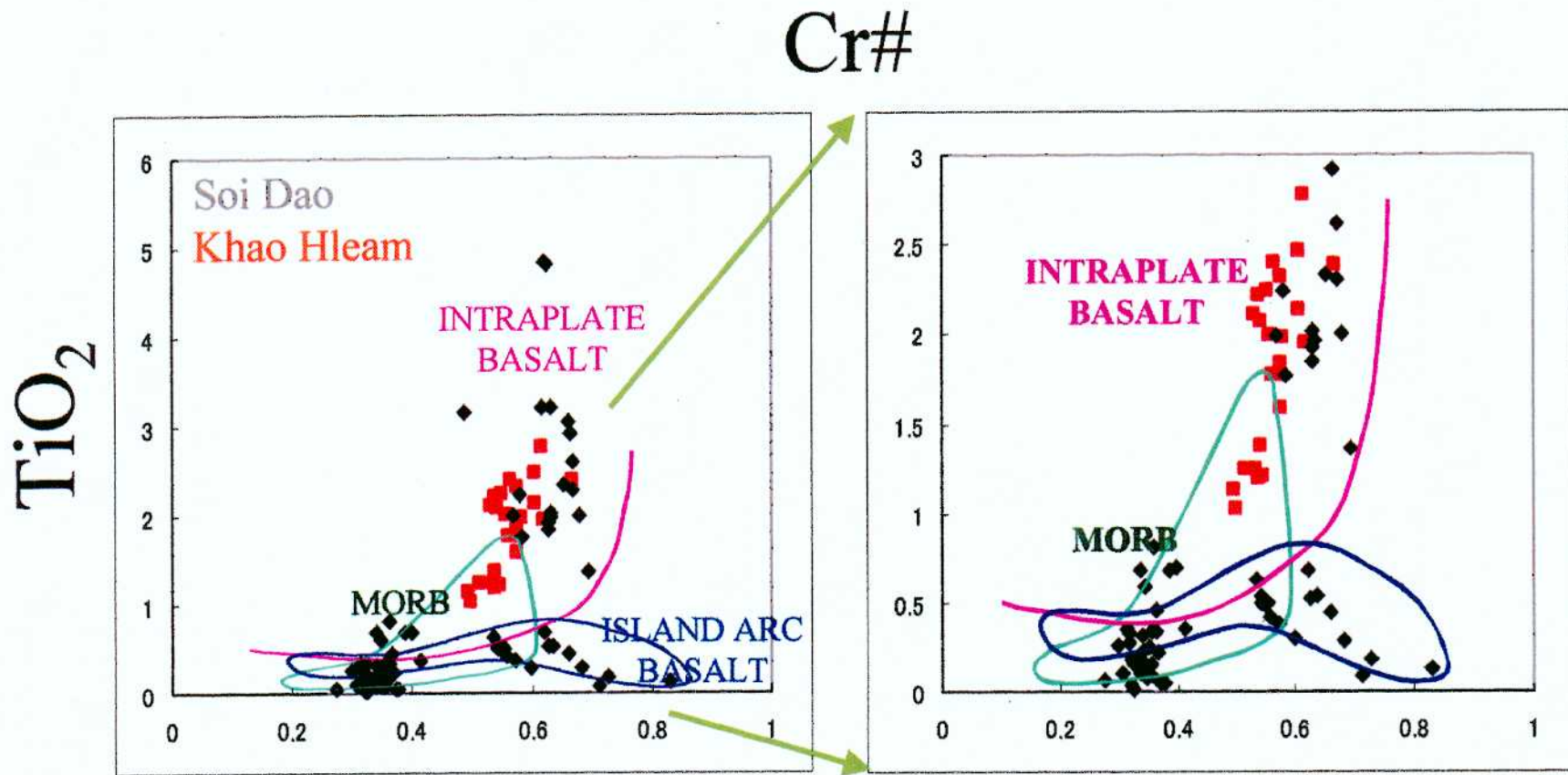


Fig. 46 Relationships between $Cr\#$ and TiO_2 content of detrital chromian spinels from the volcanoclastic rocks in comparison with fields of MORB, intraplate basalt and arc magmas proposed by Arai (1992).

Pong Nam Ron Formation

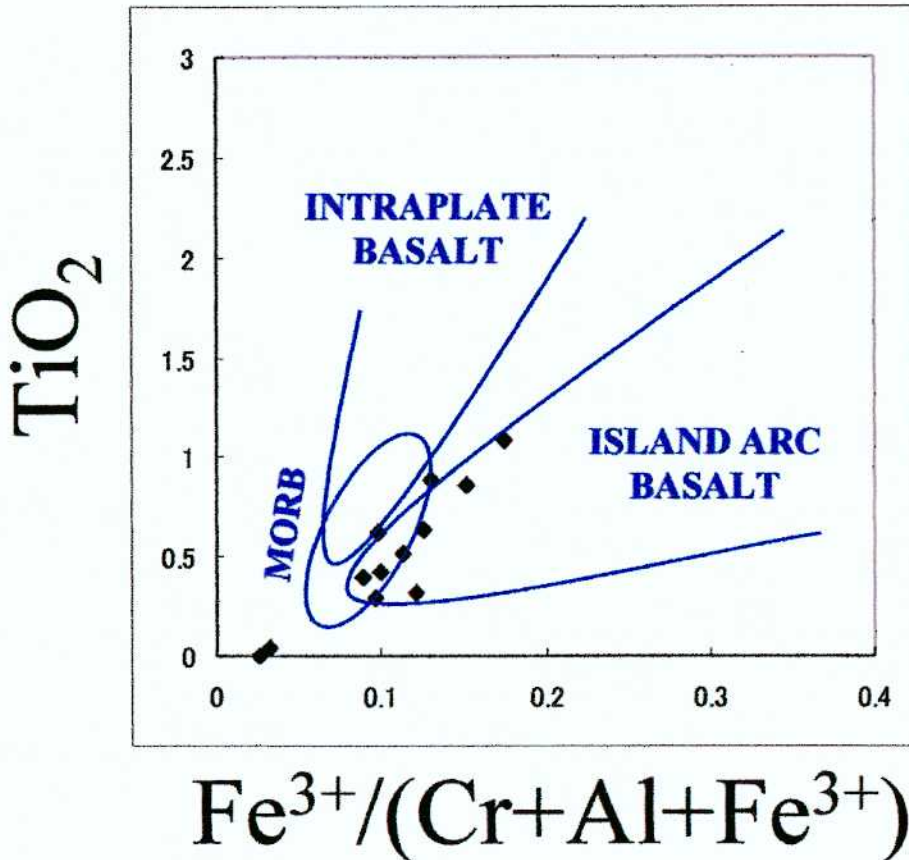


Fig. 47 Relationships between $\text{Fe}^{3+}/(\text{Cr}+\text{Al}+\text{Fe}^{3+})$ and TiO_2 content of detrital chromian spinels from the Pong Nam Ron Formation in comparison with fields of MORB, intraplate basalt and arc magmas proposed by Arai (1992).

Sandstone and Conglomerate blocks in Mélange

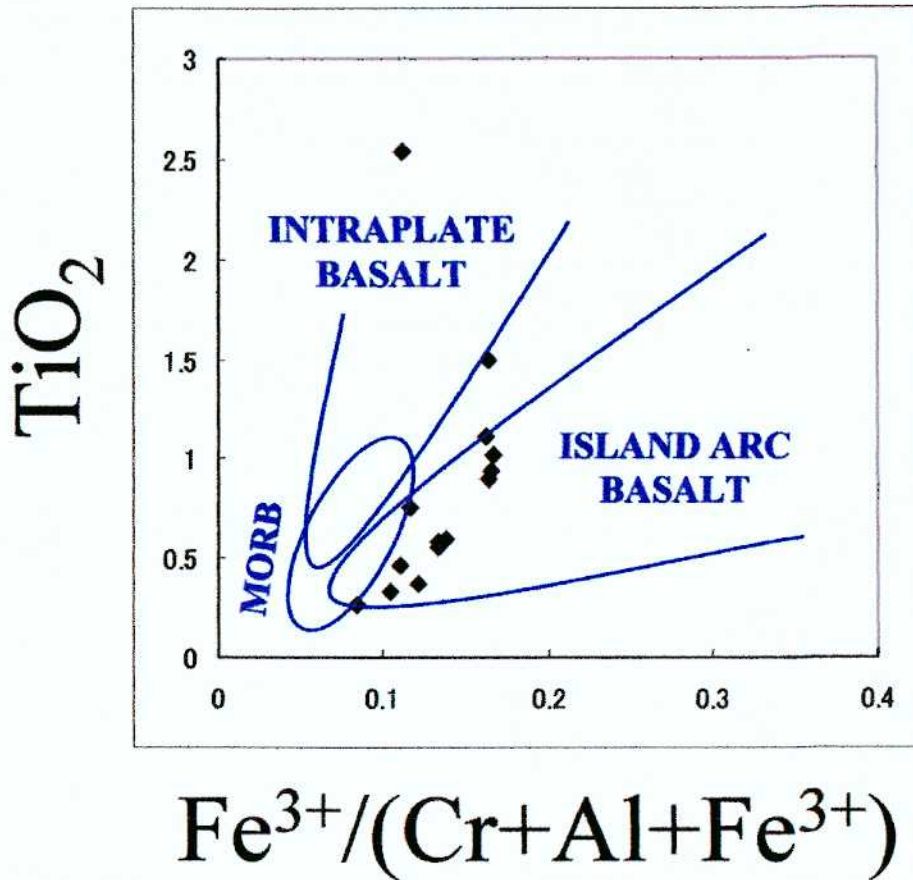


Fig. 48 Relationships between $\text{Fe}^{3+}/(\text{Cr}+\text{Al}+\text{Fe}^{3+})$ and TiO_2 content of detrital chromian spinels from the sandstone and conglomerate blocks in mélangé in comparison with fields of MORB, intraplate basalt and arc magmas proposed by Arai (1992).

$$\text{Fe}^{3+}/(\text{Cr}+\text{Al}+\text{Fe}^{3+})$$

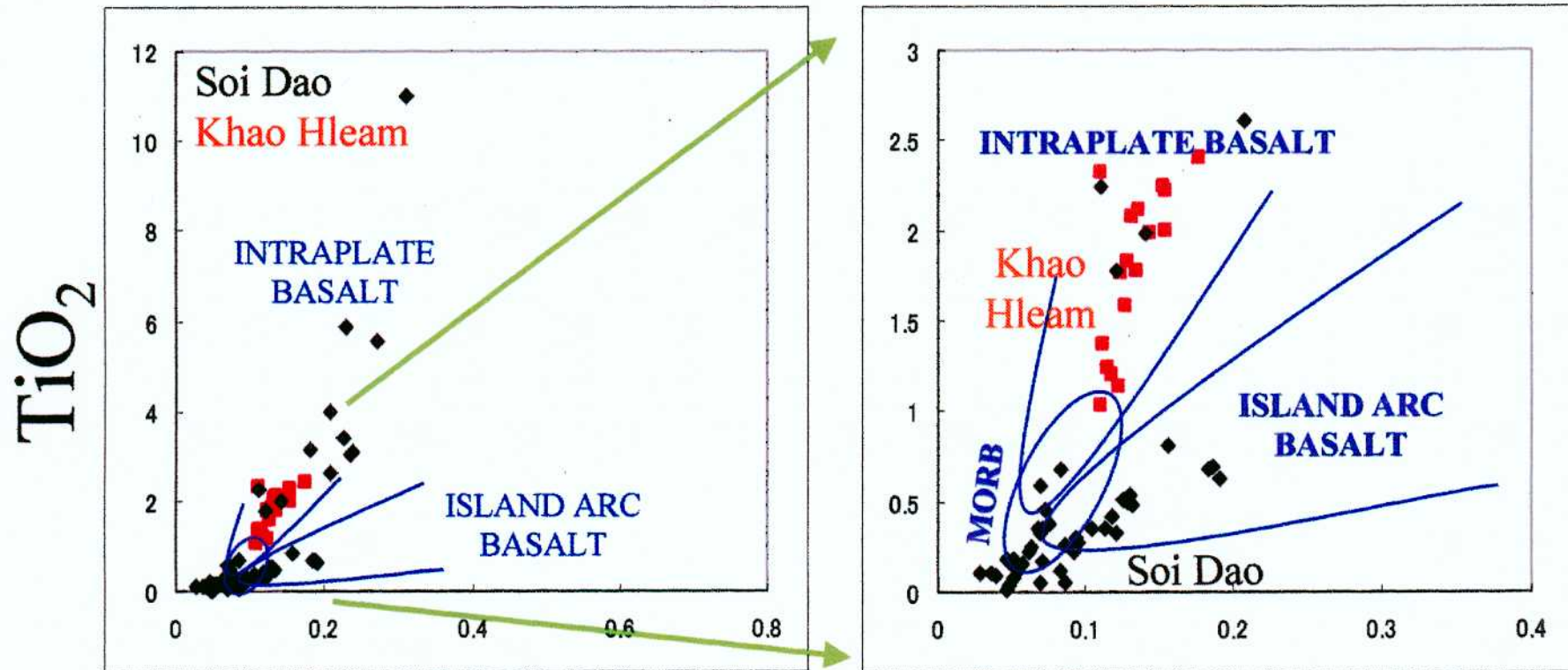


Fig. 49 Relationships between $\text{Fe}^{3+}/(\text{Cr}+\text{Al}+\text{Fe}^{3+})$ and TiO_2 content of detrital chromian spinels from the volcanoclastic rocks in comparison with fields of MORB, intraplate basalt and arc magmas proposed by Arai (1992).

Nam Ron Formation is very similar to those of detrital chromian spinels from the Nam Duk Formation in the Phetchabun area, north-central Thailand. Probably the detrital chromian spinels of the Pong Nam Ron Formation have the similar provenance and tectonic setting to those of the Nam Duk Formation. The Nam Duk Formation is located on the western margin of Indochina during the Middle Permian. Detrital chromian spinels are discovered from the sandstone beds of turbidite of the Nam Duk Formation. It has already reported that the detrital chromian spinels of the Nam Duk Formation were derived from the exposed basalt-serpentinite magmatic arc complex in the north-central Thailand during the deposition (Chutakositkanon, 1999; Chutakositkanon et al, 2001b).

5.4 Tectonic history of the western margin of Indochina

The Permian and Triassic marine successions along the western margin of the Khorat Plateau can be a key lithology to unravel the paleoenvironments and tectonic settings of the western margin of the Indochina before its complete collision with the Sibumasu in the Late Triassic (Bunopas, 1981; Bunopas and Vella, 1983; Metcalfe, 1988). The geology of these various successions is important for the discussions on the tectonic evolution of the western margin of the Indochina.

5.4.1 Saraburi, central Thailand

The Saraburi Group was first proposed by Bunopas (1981) and Bunopas et al. (1988) for the Permian successions that are distributed in the west margin of the Khorat Plateau. These carbonate successions

itself also represent one of western margins of the Indochina during the Permian. Wielchowsky and Young (1985) studied lithofacies in the Permian rocks of the Saraburi Group, and subdivided paleogeographically into three parts, the western Khao Khwang Platform, the central Nam Duk Basin, and the eastern Pha Nok Khao Platform. Dawson and Racey (1993) proposed the Permian strata of central Thailand as a sequence of supra-tidal to outer platform facies comprising a Lower to upper Middle Permian carbonate platform succession.

In the Khao Khwang carbonate platform, the Permian sedimentary facies of the Khao Pun area in the Saraburi Province, central Thailand are reported as the transgressive/regressive succession of shelf sea/platform environment to pelagic or abyssal environment below the carbonate compensation depth (Chutakositkanon, 1996; Chutakositkanon, et al., 2000). During the middle Middle to early Late Permian, the depositional basin of the Saraburi Group became deeper than the previous studies (Bunopas, 1981; Wielchowsky and Young, 1985) mentioned, as suggested by the prolonged occurrence of the laminated radiolarian (e.g. *Follicucullus* sp.) cherts. This cryptic evidence indicate the abyssal environment during the middle Middle to early Late Permian; whereas, the previous studies advocated shelf-facies environments. Following this, the age of radiolarians in chert indicates the closing of Paleo-Tethys around the Saraburi area, central Thailand.

It is concluded that the Permian successions in the Khao Pun area were deposited on the continental margin ranging from platform to abyssal environments during the Early Permian to early Late Permian. The western margin of the Indochina around the Saraburi area had

possibly been a passive margin during the Early Permian to early Late Permian (Fig. 50).

5.4.2 Phetchabun, north-central Thailand

The Nam Duk Formation (Chonglakmani and Sattayarak, 1978) in the Phetchabun Province, north-central Thailand itself is located in the Phetchabun fold and thrust belt (Wielchowsky and Young, 1985). Helmcke and his co-authors (Helmcke and Kraikhong, 1982; Helmcke and Lindenberg, 1983) described that the Nam Duk Formation is composed of Permian orogenic sequence of pelagic sediments, flysches, and molasses.

Recently, the stratigraphy of the Nam Duk Formation is studied in detail (Chutakositkanon, 1999; Chutakositkanon, et al. 2001b). The stratigraphical and sedimentological data indicate that the Nam Duk Formation is composed of a deep marine sequence comprising units of turbiditic limestone-shale alternation and turbiditic sandstone-shale alternation, and a shallower marine sequence comprising continental shelf limestone and shale. Since few rock sources contain chromian spinels (Hiscott, 1984), the occurrence of detrital chromian spinels in the turbiditic sandstone-shale sequence indicates the subaerial and/or subaqueous exposures of mafic-ultramafic rocks during the sedimentation of the Nam Duk Formation. The relatively small and subhedral to euhedral chromian spinel grains with some inclusions probably suggest their derivation from a volcanic origin.

The relationship between their Cr# and TiO₂ content

indicates their derivation mostly from the island arc-related volcanics (Arai, 1992a). Spinels from the island-arc basalt are clearly discriminated from the intraplate basalts by their low Ti contents. In addition, Arai (1992a) also found that there exists a relationship between the $Fe^{3+}/(Cr+Al+Fe^{3+})$ and TiO_2 content for chromian spinels of volcanic origin, and proposed the compositional fields of three main magma groups, island-arc, mid-ocean ridge and intraplate. Their Fe^{3+} - TiO_2 relationships also suggest the arc-related field of Arai (1992a). The Nam Duk spinels are mainly included in both MORB and island-arc basalt. However, if the Cr#- TiO_2 relationship is also considered, the Fe^{3+} - TiO_2 relationships for the Nam Duk spinels suggest strongly that the Nam Duk spinel is included only in the island-arc field.

There is however a possibility that some of them (below 0.05 in Fe^{3+} and below 0.2 wt% in TiO_2) were derived from peridotites or related serpentinites. Their high Cr#,s, mostly from 0.5 to 0.8, and low Fe^{3+} ratios, may indicate that their source is spinel-bearing harzburgite. Their low-Ti may suggest a sub-arc environment for the peridotite emplacement.

It is therefore reasonably concluded that the detrital chromian spinels in the Nam Duk Formation as a whole have been derived from mafic-ultramafic rocks of arc tectonic setting developed in this region during the Middle Permian. This is in accordance with the characteristics of chromian spinel-bearing turbidite sequences in the Nam Duk Formation, which suggest deeper marine sediments in arc region. The western margin of the Indochina around the Nam Duk basin had possibly been an active margin during the Middle Permian (Fig. 50).

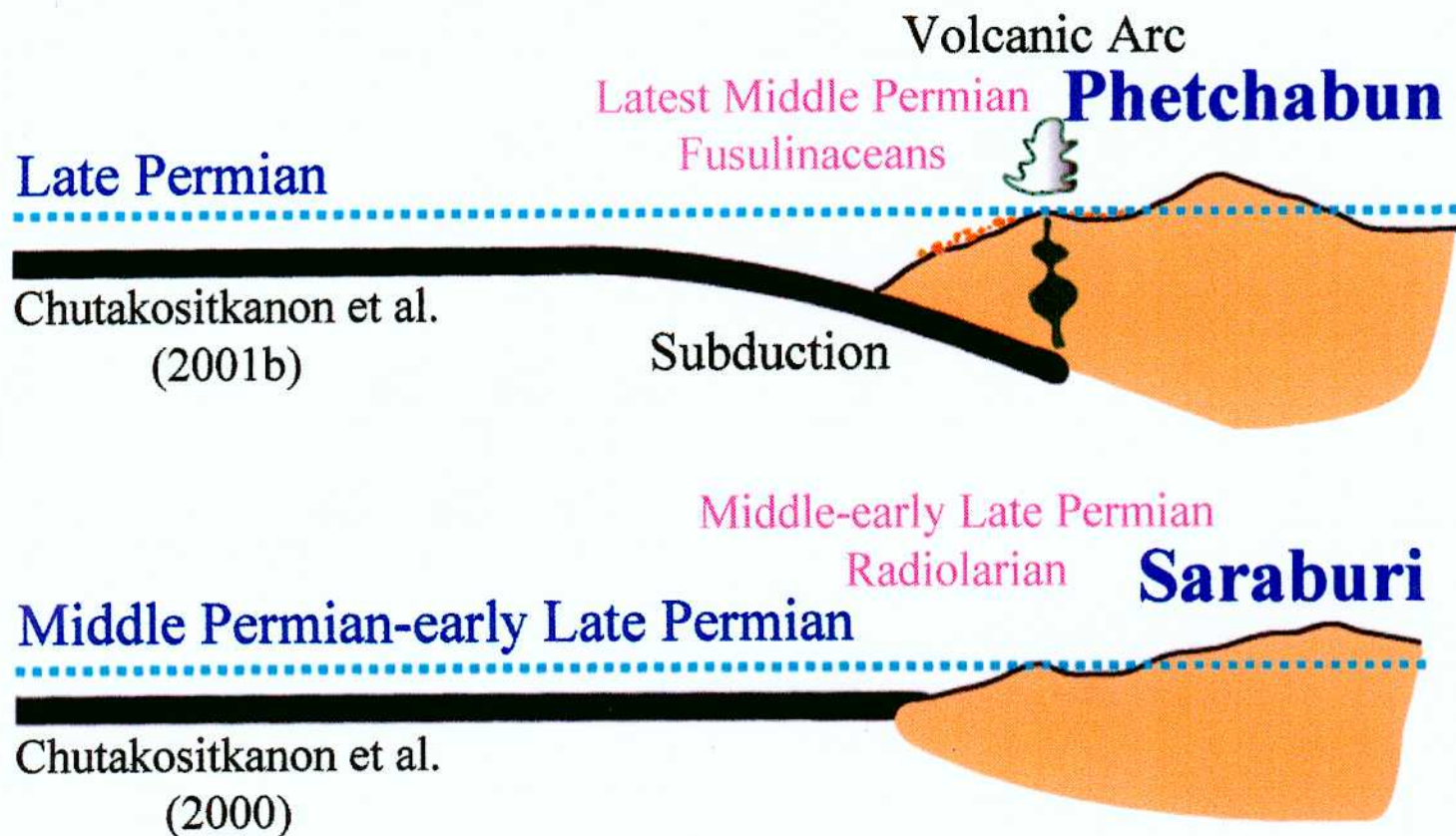


Fig. 50 Tectonic model of the western margin of the Indochina around the Saraburi and Phetchabun areas during the Middle Permian to Late Permian.

5.4.3 Sa Kaeo-Chanthaburi, eastern Thailand

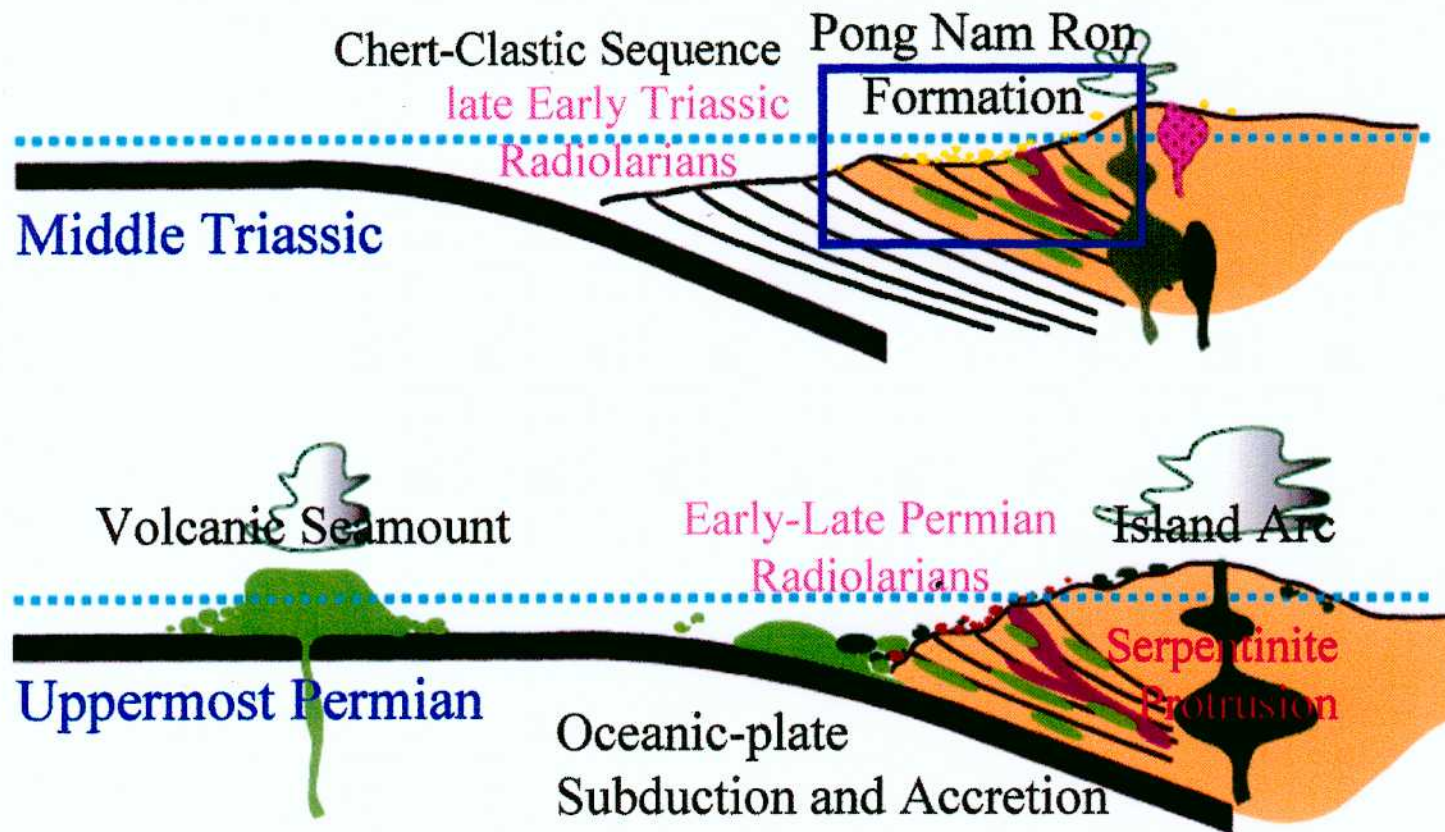
Considering the tectonic evolution of the SKCB-AC based on the previous discussion stated, the tectonic history of the western margin of the Indochina in eastern Thailand is comprehended more clearly. As noted in earlier sections in this chapter, it is rather confirmed from *mélange* characteristics, compositional mode of sandstones, and petrochemical data of detrital chromian spinels that the tectonic setting of the SKCB-AC is strongly related to accretions and subductions in the magmatic arc setting.

Although mentioned previously in earlier sections that the rock assemblages in this area were classified as the Permian rocks (Chaodumrong, 1992b; Salyapongse et al., 1997), the occurrence of the youngest Late Permian fossil faunas from tectonic blocks in *mélanges* can be regarded as the lower limit of the ages of *mélange* formation. This leads the present author to argue against the previous age interpretations for the *mélange* of the SKCB-AC. It is therefore considered that the formation of *mélange* units became younger, and the Latest Permian to Early Triassic are herein preferred. Furthermore, the arc-related Pong Nam Ron Formation, which was formed as the covering sediment of these *mélange* units, is probably the Middle Triassic. Therefore, it is quite possible to note that the SKCB-AC have been formed in the accretion- and subduction-related tectonic settings of an accretionary complex with magmatic arc on the western margin of the Indochina during the Late Permian to Middle Triassic.

Concerning the direction of accretion and subduction, the structural and paleontological features of the SKCB-AC and its adjacent area are required, especially from the Chanthaburi chert-clastic sequence of Hada et al. (1997, 1999). Since the older Permian radiolarian and fusulinacean faunas are discovered only in the SKCB-AC on the east, while younger Triassic radiolarians are found only in the Chanthaburi chert-clastic sequence on the west; the Paleo-Tethys or trench site should be shifted to the west from the Permian to Triassic. It is very strong evidence to conclude that the oceanic plate, carrying seamounts with reef atolls, was eastward subducted under the Indochina and left some parts of oceanic materials to accrete on the western margin of the Indochina (Fig. 51).

The compression style gave rise to the subduction, accretion and tectonic uplift in several regions of the western margin of Indochina. In the Sa Kaeo-Chanthaburi area, eastern Thailand, the occurrence of chert fragments and clasts in greywacke and conglomerate presumably indicate their reworks of earlier pelagic sediments that have been tentatively accreted and uplifted. In addition, well-preserved sub-hedral and euhedral chromian spinels have been transported probably in a short distance from their arc-related provenance. As a result of continuing subduction and accretion, the trench sites or subduction zone have shifted westward, and the new accretionary complex of the Chanthaburi chert-clastic sequence have been formed on the west of the SKCB-AC; while the Triassic terrigenous sediments of the Pong Nam Ron Formation are deposited in fore-arc basin on the older accretionary complex, SKCB-AC, as a submarine fan (Fig. 51).

Sa Kaeo-Chanthaburi



119

Fig. 51 Tectonic model of the western margin of the Indochina around the Sa Kaeo-Chanthaburi area during the Latest Permian to Middle Triassic.