WORKSHOP ON STRATIGRAPHIC CORRELATION OF
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TECTONIC AND GEOLOGIC EVOLUTION OF THAILAND

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ABSTRACT. *Thailand consists of Shan-Thai and Indochina Microcontinents.*

In the early stage of their evolution (Archeotectonics), *Shan-Thai and Indochina were cratonic fragments of Gondwana Australia in the Southern Hemisphere during the Precambrian to Lower Paleozoic.*

During Middle Paleozoic to Lower Triassic (Paleotectonics), *Shan-Thai and Indochina were rifted and drifting in the Paleotethys. Paleomagnetic and Paleontologic data suggest that Shan-Thai move from a low latitude Southern Hemisphere to a low latitude Northern Hemisphere position, while rotating nearly 180 degrees in the horizontal plane, in the time between early Carboniferous and early Triassic. During the Middle Triassic Shan-Thai sutured nearly simultaneously to Indochina and to South China, the continent-continent collision being a part of the Indosinian Orogeny and Indochina tended to underthrust Shan-Thai.*

After the collision (Mesotectonics), *mountains arose along the suture, particularly along the overthrusting Shan-Thai margin, and at the same time granites were intruded to high levels in the sediments, and extensive rhyolites were extruded on the land surface. Erosion of the mountains produced mollasse deposits (mostly alluvial plain red-beds)* which occur on both sides of the *suture, but are most fully developed in the Khorat Basin that formed on the underthrusting west side of the Indochina continent.*

Rifting of continental Southeast Asia and the opening of the Gulf of Thailand by tensional regime during late Cretaceous to Tertiary mark the Neotectonics stage *of Thailand with subsequent rapid uplift of the present mountains during the Quaternary.*

INTRODUCTION

Geologically Thailand is part of a linear entity extending from the Shan States of Burma, to possibly as far as the north-west part of the Malay Peninsula. There are also stratigraphic similarities to the eastern Himalaya, Yunnan, Laos and Kampuchea. These structurally complex belt of Precambrian and early Mesozoic rocks are conventionally known as "Yunnan-Burmese-Malayan geosyncline" (Kobayashi, 1964, 1972, 1973; Burton, 1967; Baum *et al.*, 1970; Bunopas 1976) and are confining on the west, contrasting with broad, concentric gentle folded structure of younger Mesozoic mollasse (Khorat Group) on the east.

An attempt by Kobayashi (1973) to analyse the pattern of major facies in the"Yunnan-Malayan geosyncline" from Yunnan to Malay Peninsula was inconclusive. A systematic configuration of facies belts over that distance has never been demonstrated. This is not surprising because it is now clear that Paleozoic to early Mesozoic strata in Yunnan and northern Laos belong to a different fold belt (geosyncline) from that in Thailand (fig.1).

Generalised plate tectonic interpretations of Southeast Asia geology (Hutchison, 1973; Mitchell, 1976, 1977) were followed by plate tectonics interpretations of specific aspects of Thailand geology (Asnachinda, 1978; Bunopas and Vella, 1978; Thanasuthipitak, 1978; Beckinsale *et al.*, 1979). A model involving continent-continent collision of Indochina with Burma, western Thailand and Malay Peninsula (Gatinsky *et al.*, 1978) is the most comprehensive plate tectonic interpretation yet published. The model described by Bunopas (1981) resembles that of Gatinsky *et al.*(1978) and Ridd (1980) in general aspects but differs in details, especially in the postulated time of collision and orogeny.

The principal tectonic and paleogeographic events that affected Thailand and adjacent regions are summarised by Bunopas (1981). Thailand extends over contiguous parts of two former microcontinents joined by continent-continnet collision in late Triassic time, namely Shan-Thai (western half of Thailand, eastern Burma and north-west Malay Peninsula) and Indochina (eastern half of Thailand, Laos, Kampuchea, south Vietnam and eastern Malay Peninsula). The two microcontinents ostensibly had independent histories prior to their collision and suturing, but similarities in their stratigraphic sequences and paleolatitudes determined from fossils suggest that they may have not been entirely independent and indeed may have had a common origin, possibly on the margin of Gondwana. Nevertheless, the position of the Shan-Thai tectonic block relative to Australia remains controversial (Stait and Burrett, 1983).

All the preliminary palaeomagnetic data from Thailand (Bunopas, 1981; Bunopas *et al.*,1978), Malaysia (Haile, 1980; McElhinny *et al.*, 1974) and China (McElhinny, *et al.*1981) appear to support plate tectonic interpretations of Asia as a composite continent (Argand, 1924; Burrett, 1974, 1981).

MAJOR GEOLOGICAL FEATURES

Several distinct geological provinces that extened into adjacent parts of Southeast| Asia can be distinguished within Thailand (fig.1). All of them except the Khorat Basin in the northeast are more or less linear and trend roughly north-south. Their northern ends abut against the west-north-west to north-west trending fold belt aligned along the Red River and lying more or less on the border of Laos and Yunnan and in North Vietnam. Their southern ends possibly reach Borneo, but are obscure, partly because the Sundaland continental crust is largely covered by sea, and probably partly because of a complex tectonic history, still scarcely known, associated with subduction of Tethyan and Indian Ocean floor during the Mesozoic and Cenozoic Eras. The magnitude and timing of known strike-slip faults are still unknown, and any number of strike-slip faults may still be undiscovered, especially on the submerged parts of the continent.

Three main geological provinces are immediately obvious. In the middle, separating the other two, is a north-south trending fold belt of middle Paleozoic to lower Mesozoic marine sediments. The other two are fragments of ancient continent with crystalline Precambrian basement rocks. The three may be designated Western Province, Central Province and Eastern Province. The central province can itself be divided into three parallel strips, a western fold belt, an eastern fold belt and a discontinuous ophiolite belt between the two fold belts, probably marking the Nan Geosuture (Bunopas and Vella, 1978). These provinces have been dislocated by sinistral strike-slip faults and their trends have been modified by sinistral oroclinal bending that appears to be associated with the strike-slip faulting (fig.1).

Throughout this paper, the Western Province and the western fold belt (Sukhothai Fold Belt) of western part of the Central Province are considered to constitute Shan-Thai Craton (Bunopas and Vella, 1978) or block; and the Eastern Province and the eastern fold belt (Loei Fold Belt) of eastern part of the Central Province constitute Indochina Craton (Bunopas, 1981) or block.

The Gulf of Thailand on the west of South China Sea is another geologic feature which reflects late largest change in the geography of Thailand and continental Southeast Asia. It is postulated by Bunopas and Vella, 1983) that the Gulf of Thailand was formed by rifting and a brief ocean-floor spreading during the late Cretaceous and/or Cenozoic. On land north of Bangkok, the rift is represented by a graben, the Chao Phraya depression, and narrowing and shallowing towards its head shortly north of Sukhothai.

STRATIGRAPHIC CORRELATION

Correlation of pre-late Triassic sequences across Shan-Thai and Indochina Cratons is still meagre, lithologically and plaeontologically. In Thailand Precambrian metasediments and early Paleozoic sandstone and limestone are exposed in the Western Province only (fig.1), and their general trends are mainly north-south. Thick Middle Paleozoic sediments and volcanic rocks are widespread to the east of the western mountains (in Sukhothai Fold Belt). In contrast, thinner Middle Paleozoic rocks of the west of the western mountains (in western part of the Western Province) and west of the Eastern Province (in Loei Fold Belt) contain no significant volcanic assemblage. Upper Paleozoic arenites, argillited and carbonates are found adjacent to Middle Paleozoic rocks but also spread farther to the east and the west, in all major geological provinces. The youngest thick marine strata are represented by long narrow troughs containing Triassic marine strata on the east and the west of the western mountains (e.g. east and west of the Western Province). The basal part of the eastern Triassic rocks (Lampang-Uttaradit) contains abundant volcanic rocks while the western Triassic rocks (Mae Sot-Mae Hong Son) contain no significant volcanic material. Marine Jurassic shale and limestone are only known to conformably overlie the marine Triassic rocks on the west of the western mountains. The young Mesozoic rocks are mostly Jurassic to Cretaceous non-marine red-beds of the Khorat Group covering the Khorat Plateau to the east, and preserved as isolated outlines west of the plateau and in peninsular Thailand. The top of the Khorat Group in the Khorat Plateau contains siltstone with rock salts and potash deposits. Cenozoic rocks are entirely terrestrial shale and sandstone with local lignites and oil shales evidently deposited in downfaulted depressions in western Thailand, and are mainly non-marine in the Gulf of Thailand (Bunopas, 1976,1981).

ARCHEOTECTONICS : *CRATONIC FRAGMENTS*

(*Precambrian-Lower Paleozoic*)

The Precambrian cratonic nucleus of Shan-Thai is likely to have been a marginal part of the Western Australian Precambrian shield. Its rocks are metasediments of amphibolite grade that originally included marine impure carbonates and probably terrigenous turbidites, were of considerable thickness, and evidently were continental margin (geosynclinal) deposits. They presumably were metamorphosed as a result of deep burial, were uplifted and deeply eroded to a peneplain before middle to upper Cambrian marine shelf strata were laid down on top of them.

The siliciclastic Tarutao Formation (Bunopas *et al.*, in press) and the comformably overlying Thung Song Formation (Bunopas, *et al.*, in press) carbonate units display a gradual deepening of the environment of deposition from peritidal in the Upper Tremadocian and Lower Arenigian to open subtidal in Middle Arenigian (Wongwanich *et al.*, 1983, this volume) Similar Cambrian and Ordovician sequences (Bunopas, 1981) may display the same environment of deposition on the Precambrian basement through the whole length of the Western Province.

The Precambrian rocks of Indochina are similar to those of Shan-Thai in metamorphic grade and lithologies, and could have originated from the same Precambrian shield margin.

Paleomagnetic of Carboniferous rocks shows that Shan-Thai was probably in the Southern Hemisphere, inverted more than 180° clockwise from its present orientation, and a part of Gondwana adjacent to northwest Australia (Bunopas *et al.*, 1978, Bunopas 1981). Paleomagnetism of Ordovician rocks of Langkawi Island, northwest Malay Peninsula (Haile, 1980) is consistent, but still at a distance with Australia. Stait and Burrett (1983) have the opinion that the similarity of the nautiloid faunas of Shan-Thai with Australia and North China suggests that reconstructions placing Shan-Thai at a great distance or in a widely different climatic belt are unlikely. Eihter juxtaposition or proximity of Shan-Thai Block and West and/or Northwest Australia is suggested by their data. Their conclusion contrasts with that of Haile (1980) based on paleomagnetic work from the cleaved and thermally metamorphosed (over 250°C) Ordovician Setul Limestone of the Langkawi Islands. There are no paleomagnetic data from the Paleozoic rocks of Indochina, and therefore no direct indications on origin in the Southern Hemisphere.

PALEOTECTONICS : *THE BIRTH AND NORTHWARD DRIFTING OF SHAN-THAI AND INDOCHTNA (Middle Paleozoic-Lower Mesozoic)*

Shan-Thai remained attached along its (on) western edge to its parent craton until early in the Carboniferous, then rifted away. Late in the Ordovician or early in the Silurian, Lower Paleozoic continental margin deposits that must have existed along its (now) eastern side, together with an unknown amount of the Precambrian cratonised crust, were separated and carried away either by rifting or by transform faulting.

The question arises as to whether the Lower Paleozoic rocks of the Malay Peninsula represent the separated marginal deposits, but cannot be solved at present. After the separation subduction commenced adjacent to the newly rifted (now eastern) margin of Shan-Thai, forming an island arc. Silurian to Lower Carboniferous rocks (fig.3) include shelf carbonates and clastics that were deposited on the Shan-Thai craton, and marginal (eugeosynclinal) deposits that were laid down in the back-arc basin and between the arc and the trench. The island arc extended to the (now) south, adjacent to the Lower Paleozoic terrain of the Malay Peninsula, where similar Silurian to Lower Carboniferous marginal deposits were deposited.

The west margin of Indochina, now contiguous with Shan-Thai, has thick marginal deposits ranging from Silurian to Triassic in age, and was a passive margin until late in the Permian. It evidently was a rifted margin in about middle Paleozoic time.

Early in the Carboniferous Period the Tethyan (and perhaps the entire worldwide) plate tectonic regime changed. Gondwana rapidly rotated clockwise, with the result that Australia shifted sharply southward. As Gondwana began to rotate a rift developed along its northern side from Shan-Thai to Turkey, and the long strip of continent on the north side of the rift was left behind. The rift opened to form a new ocean, the incipient Mesozoic Tethys. Subsequently the Paleozoic Tethys (Paleotethys) closed along consuming plate margins along its northern side. Closure was complete (and the Mesozoic Tethys opened to its full extent) by late in the Triassic. The continent-continent collisions resulting from the closure caused folding of continental margin deposits and widespread granite injection known as the Indosinian Orogeny (sometimes called Cimmerian Orogeny).

The change in the platetectonic regime was signalled by the end of subduction and volcanism along the Shan-Thai margin early in the Carboniferous. The end of subduction was accompanied by minor folding and minor granite injection (Lower Carboniferous Orogeny), attributed to collapse of the back-arc area and collision of the volcanic arc with cratonic Shan-Thai. Simultaneous rifting of Shan-Thai from Gondwana initiated deposition of the "pebbly mudstone" bearing Singa Formation, Phuket Group, Kaeng Krachan Group and Mergui Formation along the (now) western margin, and of Carboniferous clastics in presumed rift valleys of westernmost northern Thailand and adjacent Burma. From the middle of the Carboniferous to the middle of the Permian, Shan-Thai lay isolated between the Paleozoic Tethys and the Mesozoic Tethys, dismembered from its sister microcontinents (Tibet? Iran, Afghanistan and Turkey), detached from the north edge of Gondwana. It had passive margins on all sides, and during the Permian was carried northward with accelerating velocity and rotated slowly clockwise. Towards late Permian time Shan-Thai and Indochina were both rapidly approaching a convergent plate margin along the southern edge of South China. They must have been fairly close to each other, but how they became so cannot be determined. Late in the Permian a spreading ridge developed in the ocean floor between Shan-Thai and Indochina and a pair of subduction zones was formed, one dipping relatively westward beneath Shan-Thai, the other relatively eastward beneath Indochina (fig. 3). The result was rapid convergence of Shan-Thai and Indochina. Shan-Thai probably first contacted Indochina at its southern end, in the late Permian or early Triassic and then, according to the paleomagnetic model, rapidly swung around clockwise to unite with the whole western side of Indochina during the Triassic. Almost simultaneously the two microcontinents (Shan-Thai and Indochina) collided with South China (fig.2D). The intrusion of the long belt of tin-bearing granites of Triassic to early Jurassic age that extends through Burma, west Thailand, the Malay Peninsula and northwest Indonesia is associated with the collision of Shan-Thai and Indochina.

MESOTECTONICS : *THE REUNION OF SHAN-THAI AND INDOCHINA AS PART OF CONTINENTAL SOUTHEAST ASIA (Middle-Upper Mesozoic)*

The continent-continent collision (Indosinian Orogeny) terminated marine deposition on Thailand almost permanently. Small marine basins persisted at Mae Moei and in the Kwae Noi-Kwae Yai fault zone in the west until the Jurassic (fig.2C). The evaporites in the Khorat Plateau represent a brief marine incursion from the northeast in the Cretaceous (fig.2D). The most important post-Triassic rocks are the predominantly alluvial floodplain deposits of the Khorat Group, a molasse facies of substantial thickness that accumulated in a situation probably closely paralleled by the Khorat Plateau.

Jurassic and Cretaceous tectonism was mainly sinistral strain manifested by the Mae Ping and Kwae Noi strike-slip faults which are subparallel to the Red River strike-slip fault separating Southeast Asia from South China. The Mae Ping and Three Pagodas Faults ceased moving late in the Cretaceous or early in the Tertiary; the Red River Fault is still active and its present sense of displacement is dextral. but during the Mesozoic it was sinistral judging from the difference between Thailand and South China Jurassic and Cretaceous paleomagnetism (Bunopas, 1981; Maranate,1982). It is not clear when subduction commenced along the eastern margin of the present Bay of Bengal (west side of Shan-Thai) but it probably was when peninsular India commenced its rapid drift north to close the Mesozoic Tethys and open the Indian Ocean. Tin-bearing Cretaceous granites forming a belt subparallel to, and partly overlapping with the late Triassic-early Jurassic belt in Burma, Thailand and the Malay Peninsula, were emplaced probably as a result of this phase of subduction. The sinistral strain of Thailand can be attributed to clockwise rotation of South China tending to drive Southeast Asia against the converging plate margin on the east side of the closing Mesozoic Tethys (fig. 2D and 3).

NEOTECTONICS : *RIFTING OF CONTINENTAL SOUTHEAST ASIA, THE OPENING OF THE GULF OF THAILAND AND LATE CENOZOIC TECTONICS (Late Mesozoic-Cenozoic)*

Cenezoic continental deposits of substantial thickness, with local economically important lignite, oil shale and petroleum accumulated in structural basins that formed to the west of the Khorat Plateau either late in the Cretaceous or early in the Tertiary.

The change in tectonic regime that occurred in Thailand about the end of the Mesozoic, although poorly dated, is likely to have coincided with and to have been related to the collision of peninsular India with Asia. The Indian collision may have put a stop to the clockwise motion of South China (fig.4). Certainly the twisting stress disappeared, Southeast Asia relaxed, and on its western side gentle basins began to form in which were deposited fine-grained clastics derived from adjacent gentle swells, interbedded with organic deposits. During the Tertiary a tensional regime developed and a system of north-south trending normal faults appeared. The faults are nearly parallel to the present-day motion of ocean crust descending beneath Indonesia along the Java Trench. Tension probably started in the south with the opening of the Gulf of Thailand (Bunopas and Vella,1983) where many north-south trending normal faults have been revealed by seismic surveys and very large thicknesses of paralic Oligocene to Quaternary sediments have been proved by petroleum exploration drilling. The northwest trend of the Gulf shorelines is deceptive, having been inherited from the line of weakness along the Mesozoic Kwae Noi Fault, and the north-south trending faults indicate that the spreading motion in the Gulf was east-west. Northeast to east-northeast trending strike-slip faults in peninsular Thailand, formerly thought to be sinistral on fallacious geological evidence, are dextral and accommodate the northward narrowing of the Gulf to zero width at Bangkok. Their northeast trend, which theoretically should be at 45° to the inferred principal horizontal stress direction, is supporting evidence for an east-west spreading motion in the Gulf.

The time when tensional faulting commenced in Thailand to the north of the Gulf is uncertain. The climax of the tensional faulting is probably indicated by the small but widespread fields of late Tertiary and early Quaternary alkaline basalts in Thailand and Indochina. The climax probably coincided with the main phase of uplift of the present mountains of Thailand. The mountains have peneplained tops and youthful geomorphology on their margins, and contain infrequent but significant Quaternary deposits uplifted to great elevations. The Quternary deposits throughout Thailand are rudaceous, contrasting with the Tertiary deposits which are fine-grained. Marine terraces and raised shorelines adjacent to the Gulf, and alluvial terraces around the central plain of Thailand (fig.5), none of which has been studied, also indicate probably rapid uplift during the Quaternary (Bunopas,1981).

In a study of one of the Tertiary basins, Mae Moh Basin near Lampang in North Thailand, Vella (1983) found that Mae Moh Basin was formed by post-middle to late Miocene normal faulting. Other basins in North Thailand, were probably formed at the same time and in the same tensional tectonic regime. The regional structure of North Thailand seems to be like that of the northern half of the Gulf of Thailand.

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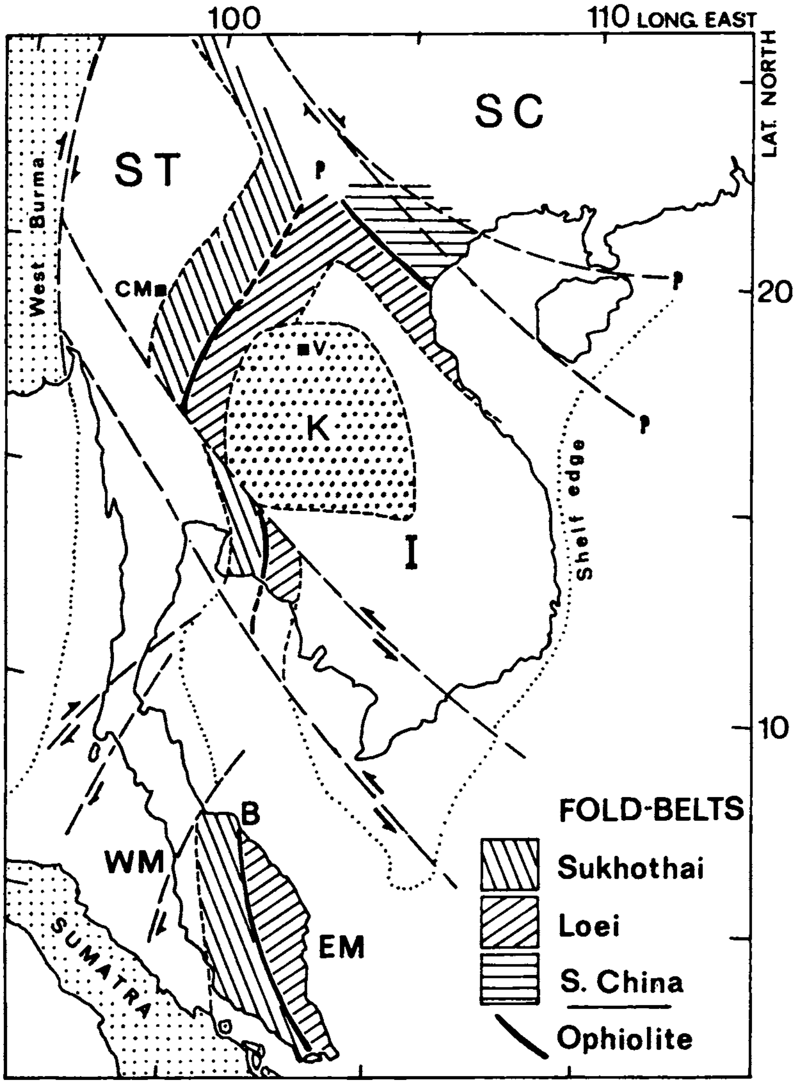

Figure 1 . Ancient cratonic areas; I, Indochina (including eastern Thailand); SC, South China and ST, Shan-Thai (eastern Burma, western Thailand and Northwestern Malay Peninsula). Adjacent fold-belts are formed of thick mainly marine Paleozoic to Triassic sediments and tholeitic volcanic rocks that accumulated along the margins of the cratons. Ophiolites lie between contiguous fold belts. Sinistral faulting and oroclinal bending occurred mainly during the Jurassic and Cretaceous. K, Khorat Basin; CM, Chiangmai; V, Vientiane; WM, West Malay Peninsula; EM, East Malay Peninsula; B, Bentong ophiolite line.

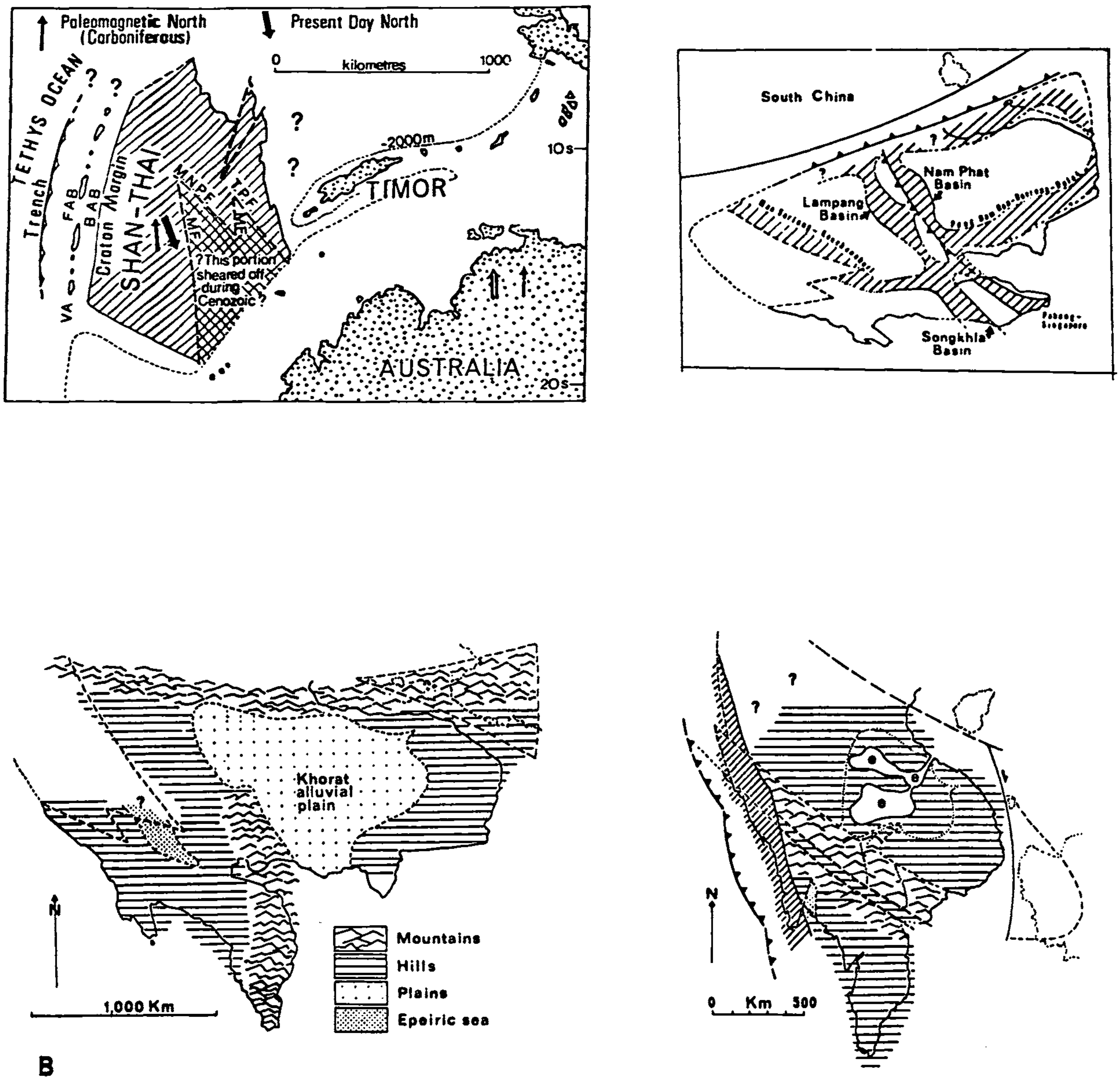

Fig. 2 Reconstruction of Thailand during: 2A, early Carboniferous; 2B, Middle to Upper Triassic; 2C, Jurassic; 2D, early to Middle Cretaceous paleogeographic sketch map, see Bunopas, 1981.

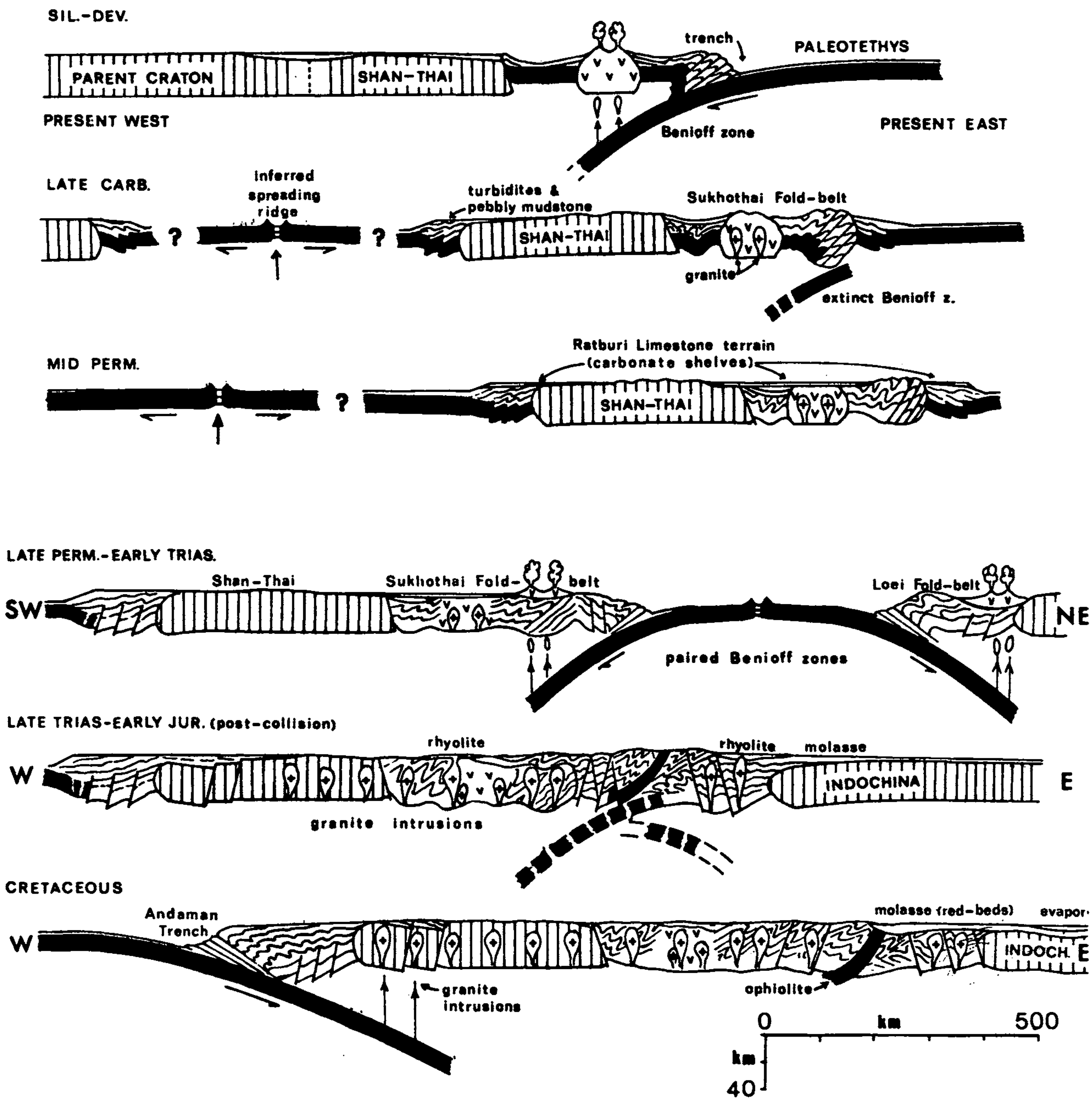

Fig. 3. Plate tectonic history of Thailand, consisting of Shan-Thai (west) and Indochina (east), (from Bunopas, 1981).

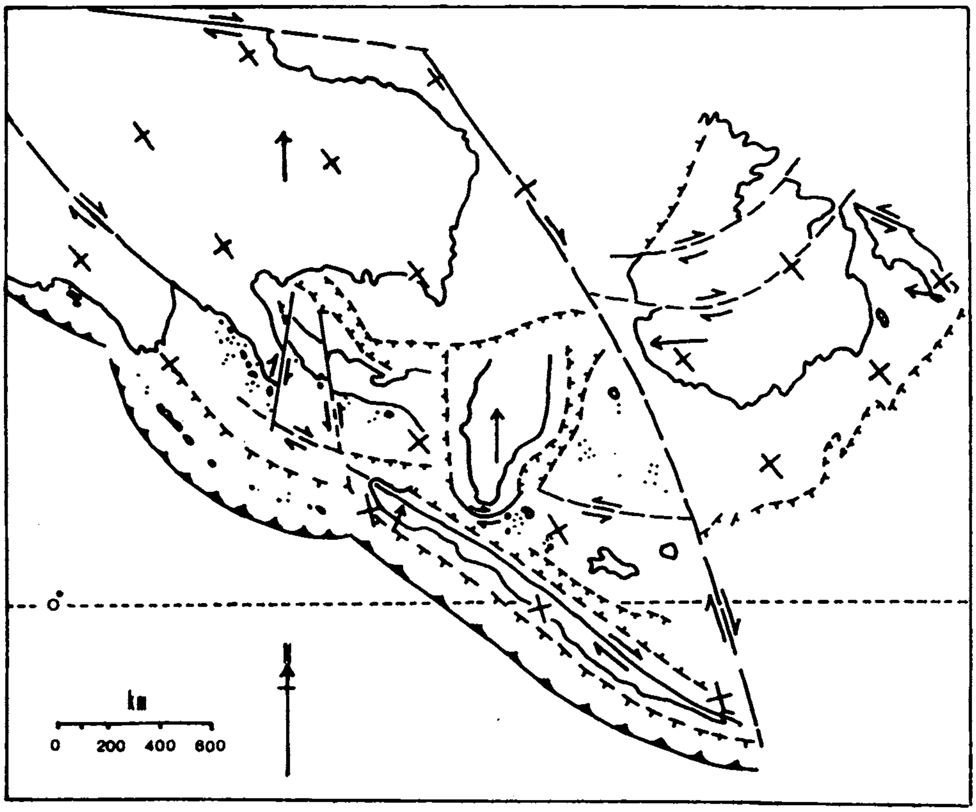

Fig. 4 Map showing possible configuration of continental Southeast Asia in late Cretaceous time. Arrows show Mesozoic magnetisation declinations, half arrows sense of strike-slip displacements.

Figure 1 - Geologic map and mineralization of southern Songkhla province

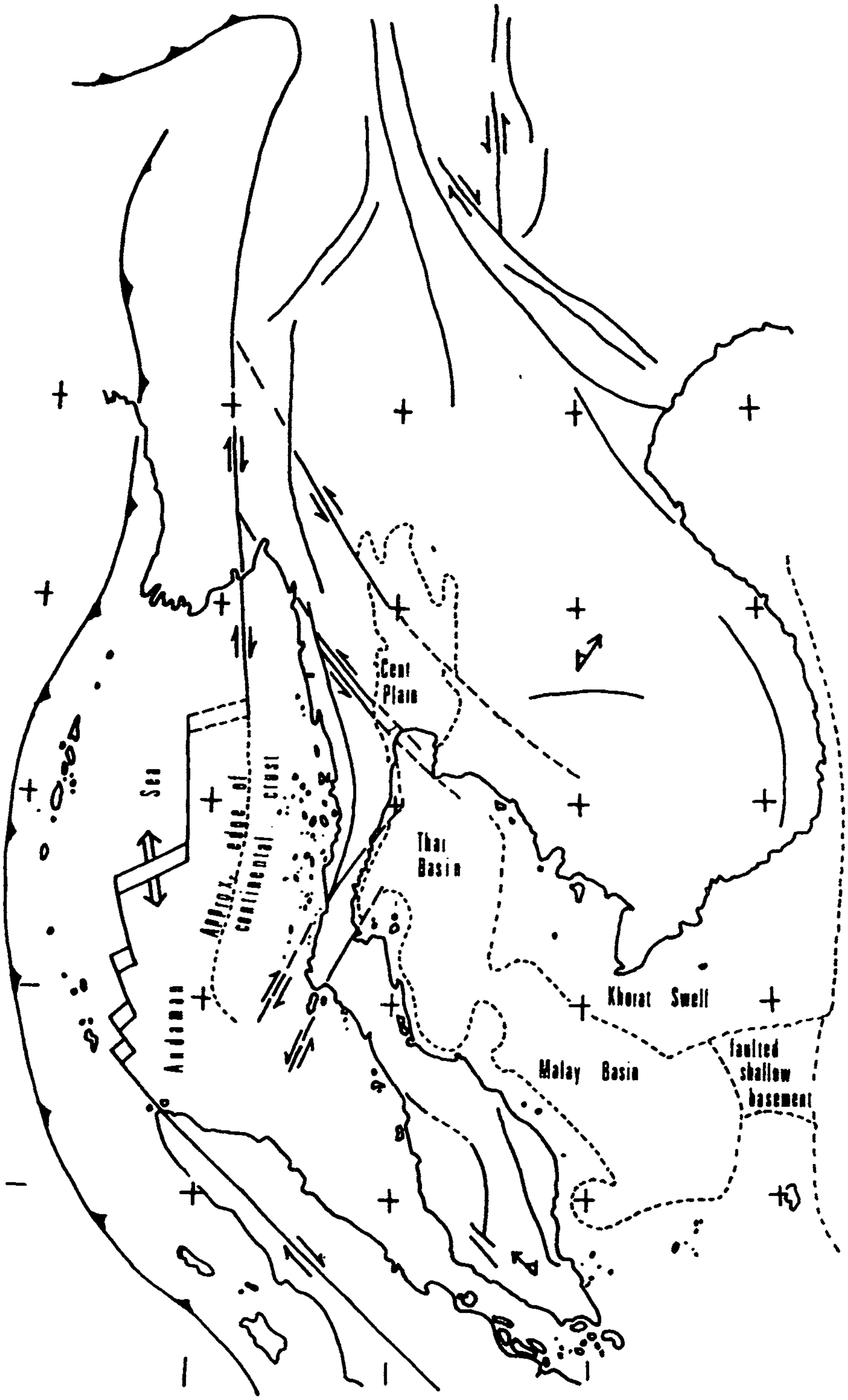

Fig. 5 Map showing major tectonic features of continental Southeast Asia (modified from map published by Circum-Pacific Council for Energy and Mineral Resources, 1981).