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With the compliments of the authors.
Dr. Punya Charusiri

MIOCENE (-OILGOCENTE) EVENTS IN THAILAND : EVIDENCES FROM $^{40}Ar/^{39}Ar$ and K-Ar GEOCHRONOLOGY

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ABSTRACT

New $^{40}Ar/^{39}Ar$ age determination, together with published K-Ar data, of granitoid and mineralized rocks from at least seven areas in Thailand, reveals that Miocene (-Oligocene) events are also represented. In the Mae Lama area, northern Thailand, the ca. 23 Ma (earliest Miocene) thermal event, recorded by the $^{40}Ar/^{39}Ar$ age spectra of alkali feldspar from Late Cretaceous granite, is interpreted to be related to activation of north-trending, Mae Hong Son fault and thrust system. In the Samoeng area, northern Thailand, a significant thermal overprint at ca. 23 Ma, recorded by the age spectra of biotite and hornblende from inferred Precambrian to a sinistral displacement along the north-trending Samoeng fault zone. Ceramic pegmatites (ca. 29 Ma) in the Tak area, northern Thailand, is possibly related to Mae Tun faulting. Published young K-Ar dates (19-30 Ma) of several Triassic granitoid and metamorphic rocks in northern Thailand may indicate the age of north-trending major fault displacement. In south-central Thailand, $^{40}Ar/^{39}Ar$ geochronology of mica from Early Eocene, Hub Kapong-Hua Hin mineralized granites and biotite from Early Oligocene Pranburi-Hua Hin cataclastic rocks, may indicate 17-19 Ma (Miocene) overprinting. Such tectonothermal event may be related to the reactivation of the north-trending Pranburi-Hua Hin fault zone. Biotite age spectra from Early Eocene granites in the Prachaub Khirikhan area, southern Thailand, is referred to indicate a very young, 7-8 Ma (Late Miocene), tectonothermal event. In the Yala area, southern Thailand, the $^{40}Ar/^{39}Ar$ age spectrum of hydrothermal K-feldspar from Triassic granites and K-Ar mica dates are interpreted to represent an age of displacement along the Yala fault zone. The Miocene-Oligocene events recorded by $^{40}Ar/^{39}Ar$ geochronology are considered to indicate the stages in the development of basins in northern Thailand and in the opening of the Gulf of Thailand.

INTRODUCTION

The $^{40}Ar/^{39}Ar$ dating technique is a modified version of the K/Ar method by converting the natural isotope ^{39}K in K-bearing rocks or minerals to ^{39}Ar using fast neutron irradiation. The ages of the rocks or minerals are determined from the measured $^{40}Ar/^{39}Ar$ isotope ratio. The $^{40}Ar/^{39}Ar$

method is divided into 2 types : the total-fusion and the step-heating technique. The first involves the release of all Ar gases by fusion of the irradiated sample, but the results yield far better precission than those of K-Ar method (Berger and York, 1981). The second involves the release of Ar gas by heating the sample at progressively increasing temperature and the gas released from each step is analyzed separately to provide a date, generating an age spectrum which consists of a series of dated. If the sample is undisturbed, the apparent dates (i.e., $^{40}Ar/^{39}Ar$ ratios) will be constant, thereby producing an age "plateau". If the sample is reheated by subsequent event, the age spectrum is more complex, comprising various distinct ages. Basically, the disturbed age spectrum is characterized by concave-downwards curve, rising form the time of outgassing (reheating) toward the age of sample formation. The loss of radiogenic ^{40}Ar is interpreted by Turner (1968) to be due to the effect of volume diffusion during reheating event.

This paper represents the first $^{40}Ar/^{39}Ar$ dating data to have been carried out in Thailand and deals with the analyses of the age spectra obtained from samples collecting from various parts of the country (Fig. 1) in an attempt to clarify the tectonothermal history during Miocene and Oligocene. The analytical procedure and results are described in detail by Charusiri (1989).

MAE LAMA - TAE SONG YANG MINING AREA

Geological Setting

The region is extensively underlain by Lower Paleozoic metasediments which are locally unconformably overlain by the Mesozoic clastic sediments (Fig. 2). The Late Cretaceous (ca. 70 Ma) and Tertiary (ca. 42 Ma) S-type granitoid suites (Charusiri, 1989) intrude only the Lower Paleozoic strata. The area displays two major fault - zones : the northwest-trending Mae Ping Fault (Bunopas, 1981) and the north-trending Mae Hong Son Fault (Charusiri, op. cit.).

Three deposits will be mentioned herein : the Mae Lama W(-Sn) and the Huai Luang Sn (-W) and the Huai Luang Sn(-W) deposits in the Mae Lama area (Changwat Mae Hong Son) and the Mae Surie deposits Sn(-W) in the Tae Song Yang area (Changwat Tak). All deposits occur at the apical parts of the granitoid stocks. Mineralization of all deposits is considered to be controlled by the movement of Mae Ping Fault (Charusiri et al., 1989).

Geochronological Studies

At the *Mae Lama* deposits, microcline from the biotite granite (MLM-9), has been dated using step-heating technique. The age spectrum displays a strongly disturbed profile, obviously reflecting a thermal disturbance at a minimum age of 23 Ma. The age minimum is considered to reflect the argon loss due to thermal diffusion (Turner, 1968) by tectonic effect. An Ar-loss age spectrum of the Mae Lama feldspar suggests an event of short duration (< 1 Ma) at low temperature (ca. 150° to 300°C). A biotite concentrate from the same granitoid sample (MLM-9) yielded a total-fusion age of 58 Ma, probably recording the same tectonothermal resetting event.

At the *Huai Luang* deposit, a muscovite from Sn-bearing quartz vein (HL-3) yields a very

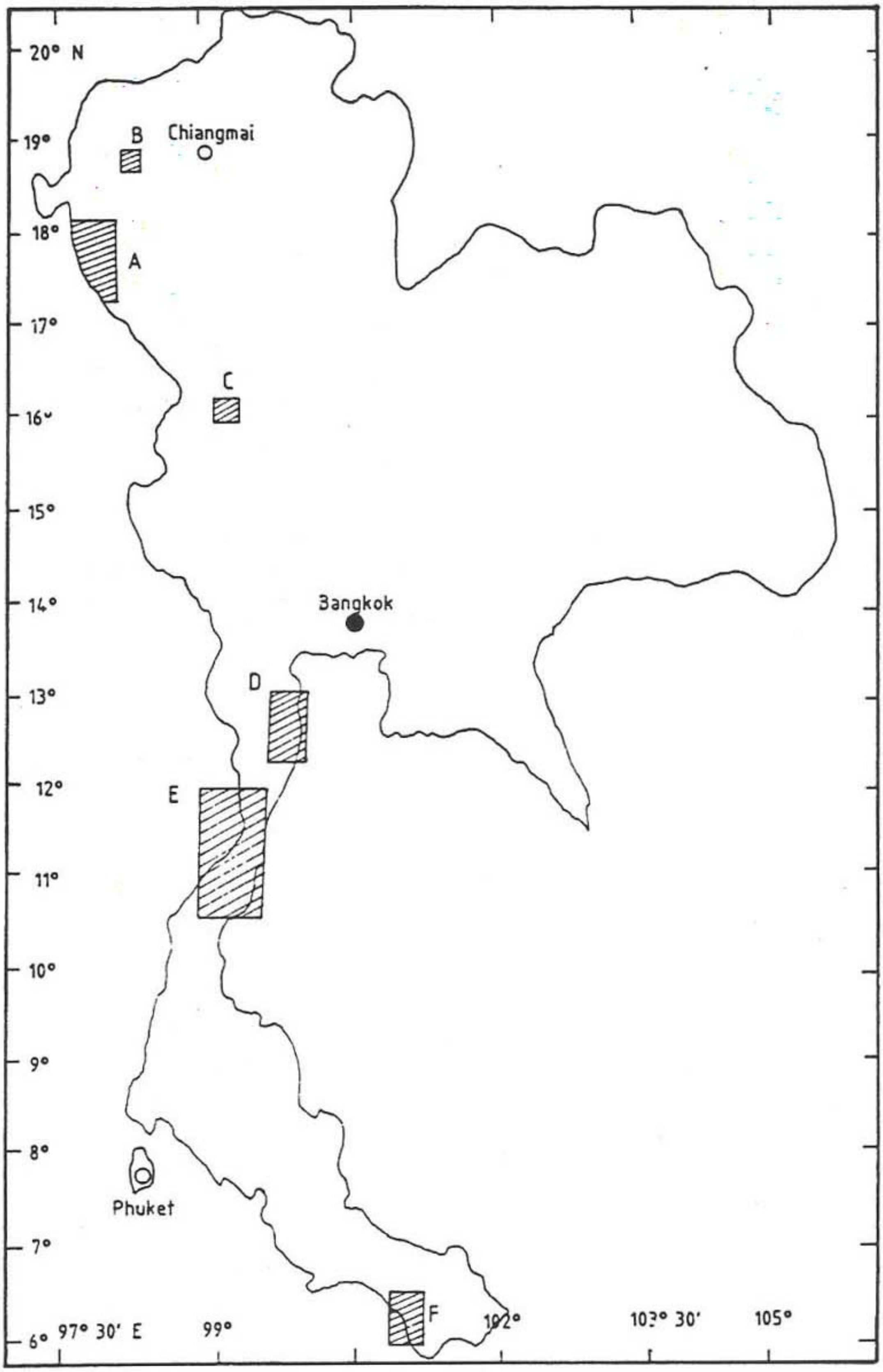


Figure 1. Index map of Thailand showing the locations of the study areas (▨) A = Mae Lama - Tae Song Yang. B = Samoeng. C = Tak. D = Hua Hin - Pranburi. E = Prachaub Khirikhan. F = Yala.

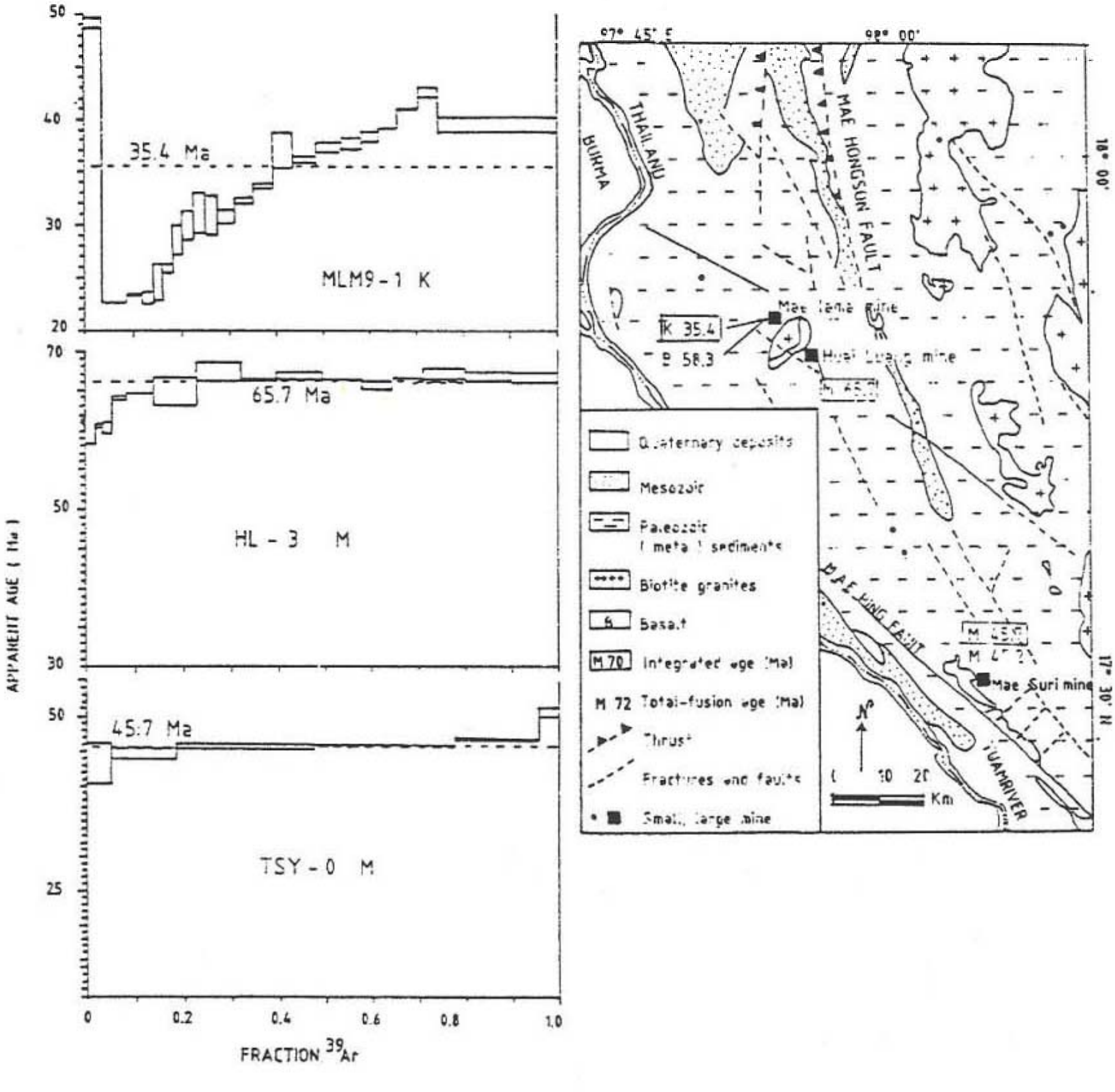


Figure 2. Geological sketch-map of the Mae Lama-Tae Song Yang mining area, after Charusiri (1989), and showing the locations of the studied mines and the distribution of Sn-W deposits, the $^{40}Ar/^{39}Ar$ dates, and the $^{40}Ar/^{39}Ar$ age spectra. (N. B. M = muscovite; K=potash feldspar).

slightly disturbed age spectrum with 13 % of the Ar loss and a 67-69 Ma age "plateau". Another muscovite from muscovite granitoid (HL-12) gave a total-fusion date of 66 Ma.

At the *Mae Surie* deposits, a muscovite from W-quartz vein (TSY-5) displays an age spectrum with a good plateau. The minimum at the first step, 21 Ma, may be a result of thermal resetting as such is inferred for the Mae Lama feldspar.

Several lines of evidences, including geological informations,geochronological results, and natures of ore deposits, strongly suggest that the northeast-trending Mae Ping and north-trending Mae Hong Son Faults controlled the intrusions. The relationship between ca. 23 Ma thermal event recorded by the Mae Lama microcline and the Huai Luang and Mae Surie muscovites and local tectonic activity is undefined. It is, however, possible that reactivation of the Mae Hong Son fault and thrust system occurred at the Oligocene-Miocene boundary, leading to partial de-gassing of the Mae Lama feldspar and Huai Luang muscovite. The age minimum of the Mae Surie muscovite age spectrum may possibly indicate the regional Mae Ping Fault at ca. 46 Ma and controlled the location of the ore-related intrusion (Charusiri, 1989), may have been reactivated at ca. 23 Ma.

SAMOENG MINING AREA

Geological Setting

The rocks exposed in the Samoeng district (Fig. 1) are predominantly (meta) sedimentary and granitoid rocks of Precambrian to Mesozoic (Fig. 3). The inferred of Precambrian rocks expose in the eastern part of the study area. The Paleozoic rocks occur as roof pendants of the main-phase, S-type, porpyritic, biotite monzogranite of either pre-Tertiary (Teggin, 1975; Punyaprasiddh, 1980) or Paleogene (Von Braun et al., 1976).

Fine-grained, biotite muscovite granites of Early Eocene age (Charusiri, 1989) are present as minor and later phase very close to the contacts between granitoids and Paleozoic country rocks. Sn-and W-mineralization, which also occurred in Early Eocene (Charusiri, op. cit.), is confined to the contact zone. Bed-rock cassiterite-scheelite deposit comprises both contact metasomatic and varied vein types. Large-scale, north-trending Somoeng Fault (and thrust) are considered to separate the Precambrian rocks from the granitoid bodies.

Geochronological Studies

A muscovite concentrate from a scheelite-bearing quartz-feldspathic vein (SM-20), 300 m north of the Sathit working, displays a highly disturbed age spectrum with an integrated age of 45.8 Ma (Fig. 3). The high-temperature step age of this spectrum is ca. 55 Ma, interpreted to be the age of mineralization (Charusiri, 1989). The minimum apparent age of this spectrum has been obscured by possible excess argon, but the general shape of the spectrum is consistent with the occurrence of a thermal overprint at 23 Ma. Hydrothermal microcline from the same vein (SM-20) gave a very young total-fusion date of 28.9 Ma. A biotite concentrate from scheelite-bearing pegmatite (SM-15) gave a total-fusion date of 46.2 Ma. A muscovite sample from tin-bearing pegmatite (SM-19), from the Huai Phra Chao workings, yielded a similar total-fusion date of 46.0 Ma. These two total-fusion dates and an age spectrum, are considered to indicate an argon loss by volume diffusion.

Biotite and homblende concentrates from schistose rocks (OSM-1 and OSM-2) of inferred Precambrian age from the southeastern part of the mapped area (Fig. 3) were selected for dating. The step-heating spectra of one biotite and two hornblendes record integrated ages at ca. 23, 59.5 and 65.8 Ma, respectively. The biotite (OSM-2) shows an internally concordant age spectrum with a well-defined plateau age of about 23.5 Ma. Another biotite (OSM-1) yielded a similar total-fusion age of ca. 22.2 Ma. The two homblende yielded similar, saddle-shaped.

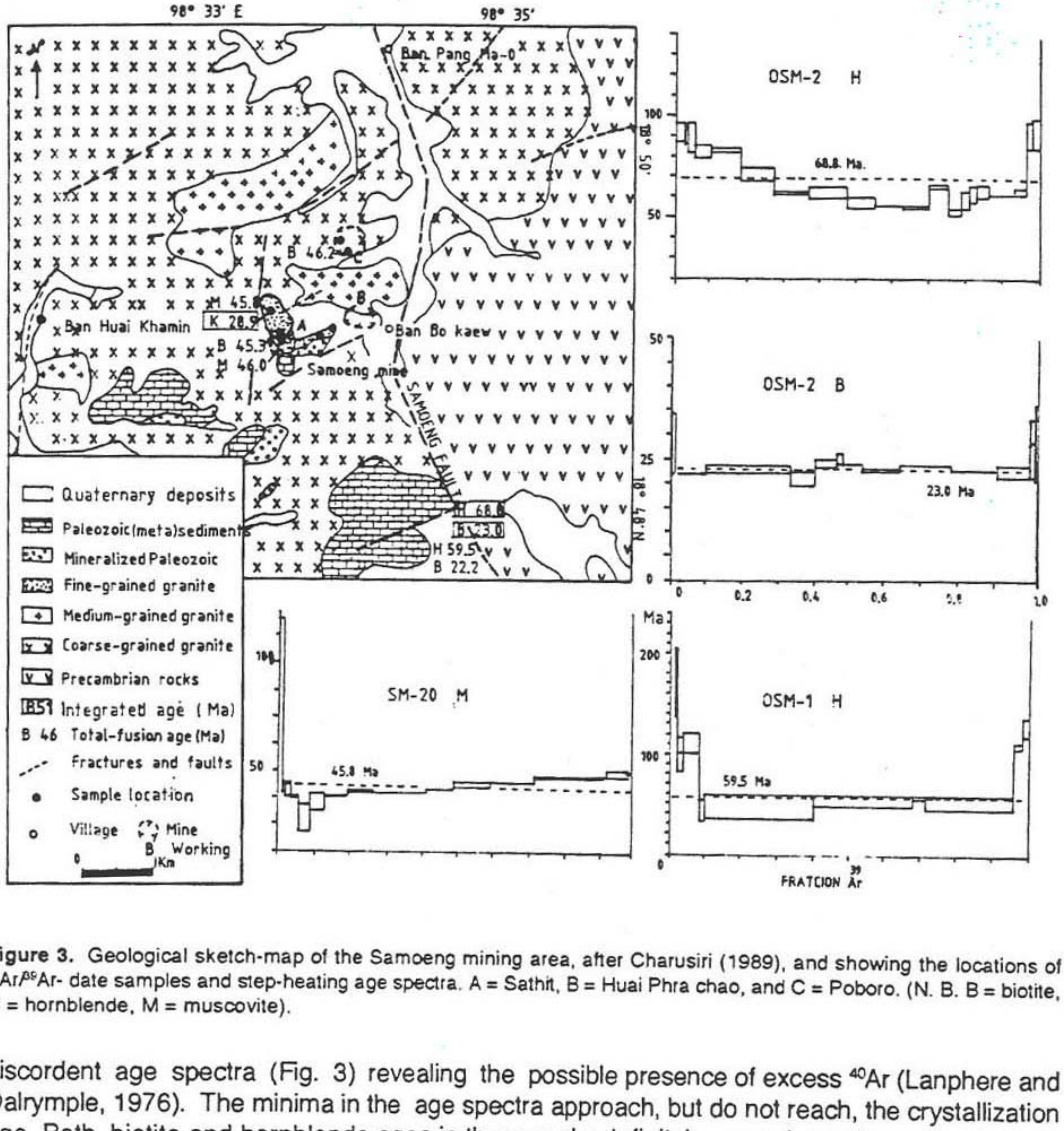


Figure 3. Geological sketch-map of the Samoeng mining area, after Charusiri (1989), and showing the locations of $^{40}Ar/^{39}Ar$- date samples and step-heating age spectra. A = Sathit, B = Huai Phra chao, and C = Poboro. (N. B. B = biotite, H = hornblende, M = muscovite).

discordent age spectra (Fig. 3) revealing the possible presence of excess ^{40}Ar (Lanphere and Dalrymple, 1976). The minima in the age spectra approach, but do not reach, the crystallization age. Both biotite and hornblende ages in these rocks definitely record a subsequent thermal event. The young ages are considered to reflect a tectonothermal overprint at ca. 23 Ma, at which time the temperature was high enough to reset totally the biotite dates and to reset partially the hornblende dates. The inferred age of this thermal event is in satisfactory agreement with that deduced form the minimum in the spectrum of the hydrothermal muscovite (SM-20) from the mine (see above).

The biotite date and the clearly disturbed hornblende dates of the inferred Precambrian rocks (OSM-1 and -2), in conjunction with the minimum in the muscovite age spectrum for the scheelite-bearing quartz vein (SM-20), are considered as strong evidence for a significant thermal event at ca. 23 Ma (earliest Miocene). This overprint is attributed to compressional tectonism at or immediately following the Oligocene-Miocene boundary. Evidence for significant late-tectonic, post-mineralization, disturbance includes the presence of gneissoid and cataclastic granite, the wolframite clasts in breccia sheets, and the thrust system in hornfels and skarn rocks, occurring in the mine area (Charusiri, 1989). It is noteworthy that the inferred age for this tectonothermal event is coeval with that inferred to have affected the Mae Lama - Tae Song Yang mining area (see previous section). Charusiri (1989) concluded that the occurrence of oblique reverse-sinistral displacement along the Samoeng fault is implied by the orientations of the thrusts in its inferred footwall plate in the mining area.

CHIANG MAI AREA : BASEMENT COMPLEX OF NORTHERN THAILAND

Geological Setting

The central crystalline complex of northern Thailand (Fig. 4), west of Chiang Mai, consists predominantly of gneiss of Precambrian to Paleozoic age (Von Braun et al., 1976) and of anatectic granite (Cobbing et al., 1986). The complex is crosscut by a large number of granitic dykes and veins.

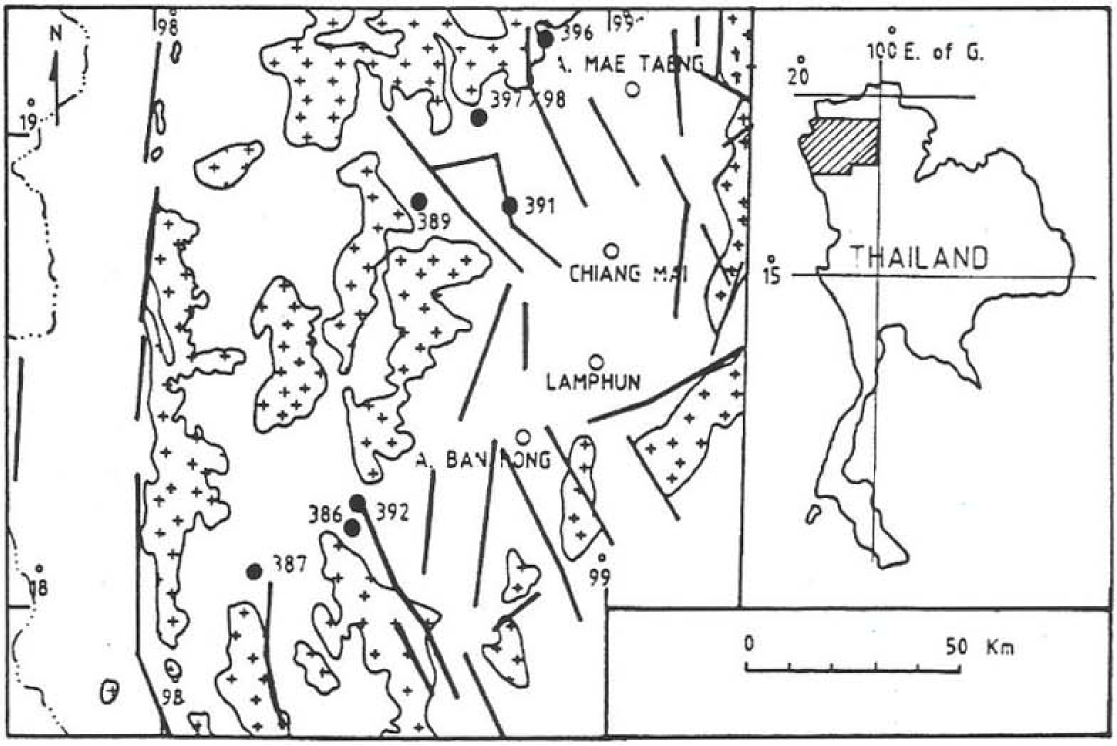


Figure 4. Distribution of granites and fault zones of central crystalline complex and localities of some dated samples (modified after von Braun et al., 1976).

Geochronological Studies

Von Braun et al. (1976) dated granitoid rocks from the central crystalline basement complex. Some of their analytical data are shown in Table 1. The dates can be obviously classified into 2 major groups : 20-23 Ma and 32-36 Ma. In Amphoe Omkoi, Chiang Mai, two biotites from granites yielded K-Ar dates of 29.3 and 46 Ma, respectively (JICA, 1986). It is of interest that these samples were collected from, or in the vicinities of, approximately north-trending fault system. The authors, therefore, consider that these considerably young dates may represent events of magmatism associated with tectonism.

Table 1. Selected K/Ar mica dates* from the central crystalline complex, northern Thailand.

No.**	Lithology	Mineral	wt%	K %	Ar cm^3STP/g 10^7	age Ma
386	Calc-silicate rocks	bi	7.79	72	62.8	20.1
		bi	7.81	71	60.9	19.5
389	Microgranite	ms	8.98	74	73.7	20.5
		ms	8.85	73	73.7	20.8
	Pegmatite	ms	8.93	65	80.8	22.6
		ms	8.94	64	79.5	22.2
391	Cataclastic granite	bi	7.55	72	107.3	35.3
		bi	7.72	78	106.6	34.3
392	Granodiorite dyke	bi	7.48	79	58.4	19.5
		bi	7.37	78	58.1	19.7
396	Fine-grained granite	bi	7.36	73	95.5	32.3
		bi	7.41	57	92.9	31.2
397	Fine-grained granite	bi	6.64	70	49.2	18.5
398	Fine-grained granite	bi	6.62	66	49.3	18.6

*Data from von Braun et al. (1976)

**see Figure 5 for location, bi = biotite, ms = muscovite.

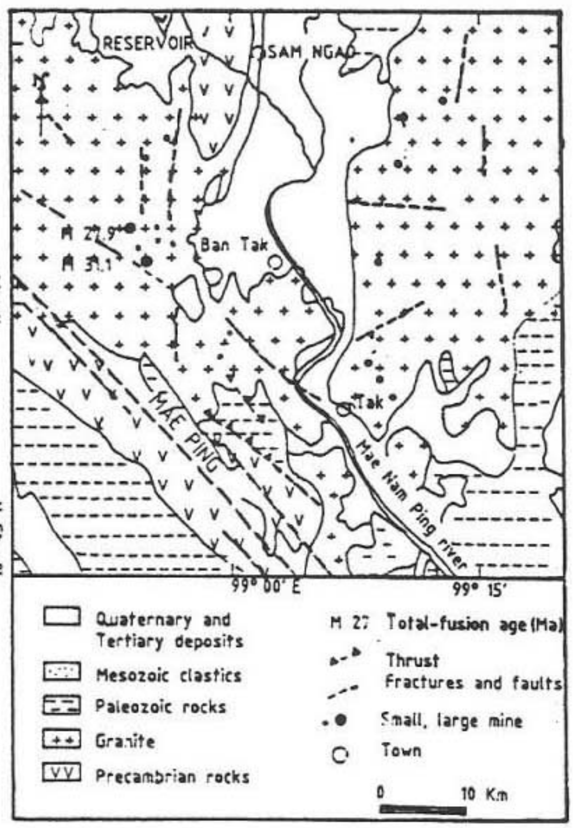
TAK MINING AREA

Geological Setting

The area is mainly underlain by rapidly-cooled, zoned, I-type granitoids (Mahawat, 1982; Charusiri, 1989) of ca. 220-225 Ma (Pitakpaiwan, 1969; Teggin, 1975). The Triassic Tak granitoids intrude inferred Precambrian to-Paleozoic meta-sediments. The Mesozoic sediments overlies unconformably the older strata and disconformably the batholith in several places

(Fig. 5). Pegmatites occur throughout the plutons, particularly in their peripheral parts. Feldspar has been quarried for ceramic industry for more than two decades.

Fractures and faults are common in the study area. Most are aligned north-south or northwest-southeast. The major, northwest-trending, Mae Ping Fault traverses the south-western part of the area. The north-trending fractures and faults (Mae Tun Fault) are considered to control the Mae Tun basin (Charusiri, 1989). Chaodamrong et al. (1983) suggest that the basin may have developed mainly in the Miocene.



Fugure 5. Geological sketch-map of Tak mining area, after Charusiri (1989) and showing the locations of the Ar^{40}/Ar^{39} dated samples, and the distribution of feldspar deposits (all indicated mines).

Geochronological Studies

Two pegmatites, from the Pong Erawan (PONG-1) and Tep Prathan (TEP-1) feldspar mines, were dated by total-fusion method. Hand-picked muscovites from these pegmatites gave similar dates of ca. 28 Ma (Pong Erawan) and 33 Ma (Tep Prathan). These geochronological data imply that the pegmatites hosted by the Tak batholiths were emplaced in the late Oligocene, and do not have a genetic relationship to the Tak I-type granitoids. The occurrence of such large volumes of north-trending pegmatites is inferred herein to be related to Tertiary faulting along the Mae Tun River. Although the Mae Ping Fault is more prominent, the authors suggest that the Mae Tun Fault may have played not only a significicant role in the generation of the pegmatites but also an onset of the Mae Tun basin development. The parallelism of the trends of the pegmatites and of the Mae Tun fault-block supports this possibility.

HUA HIN - PRANBURI AREA

Geological Setting

The area is mainly underlain by the low-pressure, amphibolite-facies, Hua Hin - Pranburi metamorphic comples (Pongsapich et al., 1983), including gneisses, schists, marbles, quartzites and calc-silicate rocks of Precambrian to Lower Paleozoic (Dheeradilok, 1985). The metamorphic complex, including Hubkapong, Hua Hin and Pranburi Gneisses (Pongsapich et al., op. cit), is presumed to be overlain unconformably by (meta-) sedimentary rocks of the Sukhothai, Kaeng Krachan and Ratburi Groups. The 52 Ma, non-foliated granites (Charusiri, 1989) exposed in the northern and central parts of the area. Sn-W mineralization occurs associated with the granites. Tertiary andesite and rhyolite dykes are common in the north and cross-cut the granites and gneisses. Major, north-trending dextral, Pranburi - Hua Hin Fault lies very close to the coast (Fig. 6), forming a large cataclastic zone.

Geochronological Studies

A biotite concentrate from a protomylinite sample (KT-1) of the I-type gneiss, fault-zone, was dated using the step-heating technique. It yielded an internally concordant age spectrum with an age of ca. 34-35 Ma. It is of interest that the first step of the Ar-release pattern gives an apparent age of about 20 Ma.

Three samples of the more intensely cataclasted, I-type Pranburi gneissic rocks yielded similar biotite $^{40}Ar/^{39}Ar$ dates two concentrates from a protomylonite sample (PB-12) and a mylonite sample (PB-49), yielded total-fusion dates of 34.0 and 34.6 Ma, respectively. A biotite concentrate from another protomylonite (PB-11) gave an undisturbed age spectrum, which displays a clear plateau, defined by more than 90 % of the ^{39}Ar released. Again, the first argon-release step yielded an apparent age of ca. 17 Ma. The minima in the first steps of both age spectra determined for cataclastic rocks are interpreted as indicating argon loss through volume diffusion and record a thermal event at ca. 17-20 Ma. Two white-mica concentrate and muscovite (Charusiri, 1989), from Eocene, non-foliated granite, collected from tin mines, yield remarkably total-fusion dates of ca. 19.0 and 23.3 Ma.

All radiometric data for cataclastic rocks from the Pranburi - Hua Hin fault-zone, i.e., Bignell's (1972) K-Ar analyses (see Fig. 6) and the author's $^{40}Ar/^{39}Ar$ dates,show very consistent ages, varying from 33.5 to 36 Ma. It is considered reasonable, therefore, to infer that the large-scale faulting took place in the Early Oligocene, possibly coincident with, or immediately preceding, the initial opening of the Gulf of Thailand, assigned by Bunopas and Vella (1983) to the Oligocene. Field evidence indicated clearly that the mylonitic foliation of the Pranburi gneiss overprinted the earlier gneissic fabrics. However, this inferred age of the faulting is totally at variance with those proposed by Putthapiban and Suensilpong (1978), who considered an Ecocene age; by Pongsapich et al. (1980), who suggested the faulting to be older than Permian Ratburi

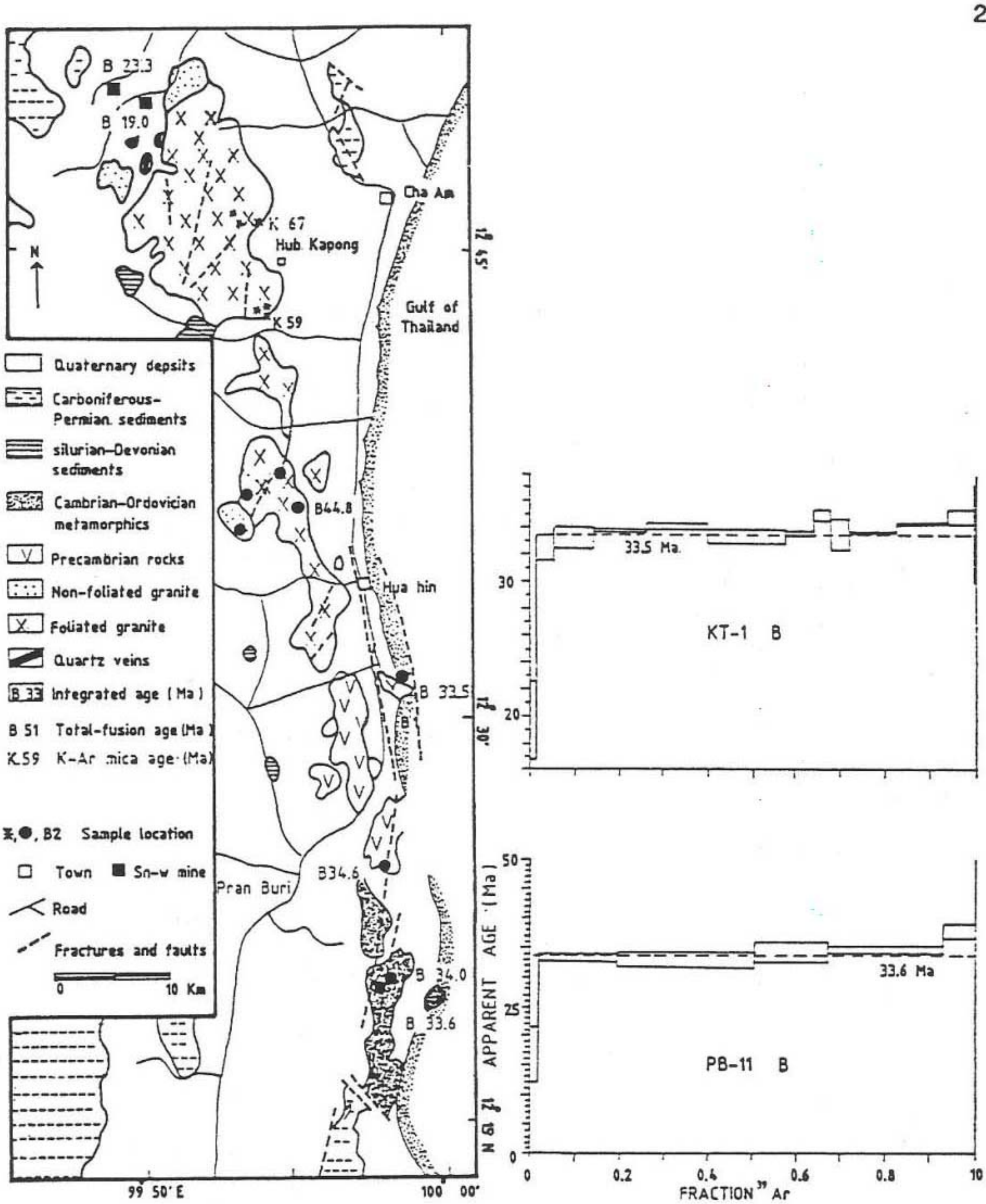


Figure 6. Geological sketch-map of Hua Hin-Pranburi area, after Charusiri (1989) and showing locations of Ar^{40}/Ar^{39} - dated samples and age spectra. X = K - Ar dated sample locations of Nakhapadungrat et al. (1984); B1, etc = dated sample locations of Bignell (1972). Note that Hua Hin-Pranburi metamorphic complex includes granitoid rocks in the western and southern parts of Hub Kapong, the Hua Hin gneissic rocks west and south of Hua Hin and the Pranburi gneissic rocks in the east and northeast of Pranburi.

carbonates; and by Dheeradilok et al (1976), who advocated a Carboniferous age.

The dates of non-foliated granites (ca. 19-23 Ma) from the area of the tin-tungsten deposits are much younger than those within the Hua Hin - Pranburi area. The authors do not consider the mineralization to be of Early Miocene. The age deduced can be regarded as a plausible indication of the timing of the clay and white mica develop-ment by renewed hydrothermal alteration postdating the emplacement of Eocene Sn-W mineralized granites. The argillic alteration may have also been associated with the large, barren quartz vein (Fig. 6) which occurs along a north-trending, major fracture zone in the area and may have been coeval with the emplacement of the local Tertiary volcanic dykes. This inferred Miocene event, which may be regarded as the youngest event affecting the area, may also be recorded distinctively by the apparent age minima, at ca. 17-19 Ma, in the two step-heated samples from the Pranburi -Hua Hin fault-zone. The postulated tectonothermal overprint is tentatively correlated with a stage in the opening of the Gulf of Thailand.

PRACHUAB KHIRIKHAN MINING AREA

Geological Setting

The area is underlain by Eocene, S-type granites (Charusiri, 1989) and by Upper Paleozoic and Mesozoic sediments. northeast-trending faults are inferred to represent the northward extension of the Ranong fault-zone. Sn-bearing pegmatite dykes, are surrounded by granitoid rocks, but the ore-bearing pegmatite swarms extend into the Upper Paleozoic rocks (Fig. 7). Volcanic rocks are also reported in the study area (Silapalit et al., 1975).

Geochronological Studies

A medium-grained, foliated, biotite (± muscovite) granite (HY-1), collected at Nam Tok Huai Yang, was investigated using the step-heating technique. A biotite concentrate yielded a well-defined plateau age of about 54 Ma. It is interesting that the first step of the the Ar-release pattern gives an apparent age of about 7-8 Ma. This apparent age minimum is tentatively interpreted as recording argon-loss by volume diffusion in the Late Miocene.

The apparent-age minimum in the age spectrum of the granite is considered as evidence for a considerably young, Late Miocene, tectonothermal event within the Ranong fault-zone. This overprint may have been related to tectonism, possibly associated with extrusion of felsic volcanics, although the latter have not be directly dated.

YALA MINING AREA

Geological Setting

The study area is underlained by Late Triassic, S-type granite (Charusiri, 1989), and more extensively, by Paleozoic sedimentary strata (Fig. 8). Middle Jurassic Sn mineralization

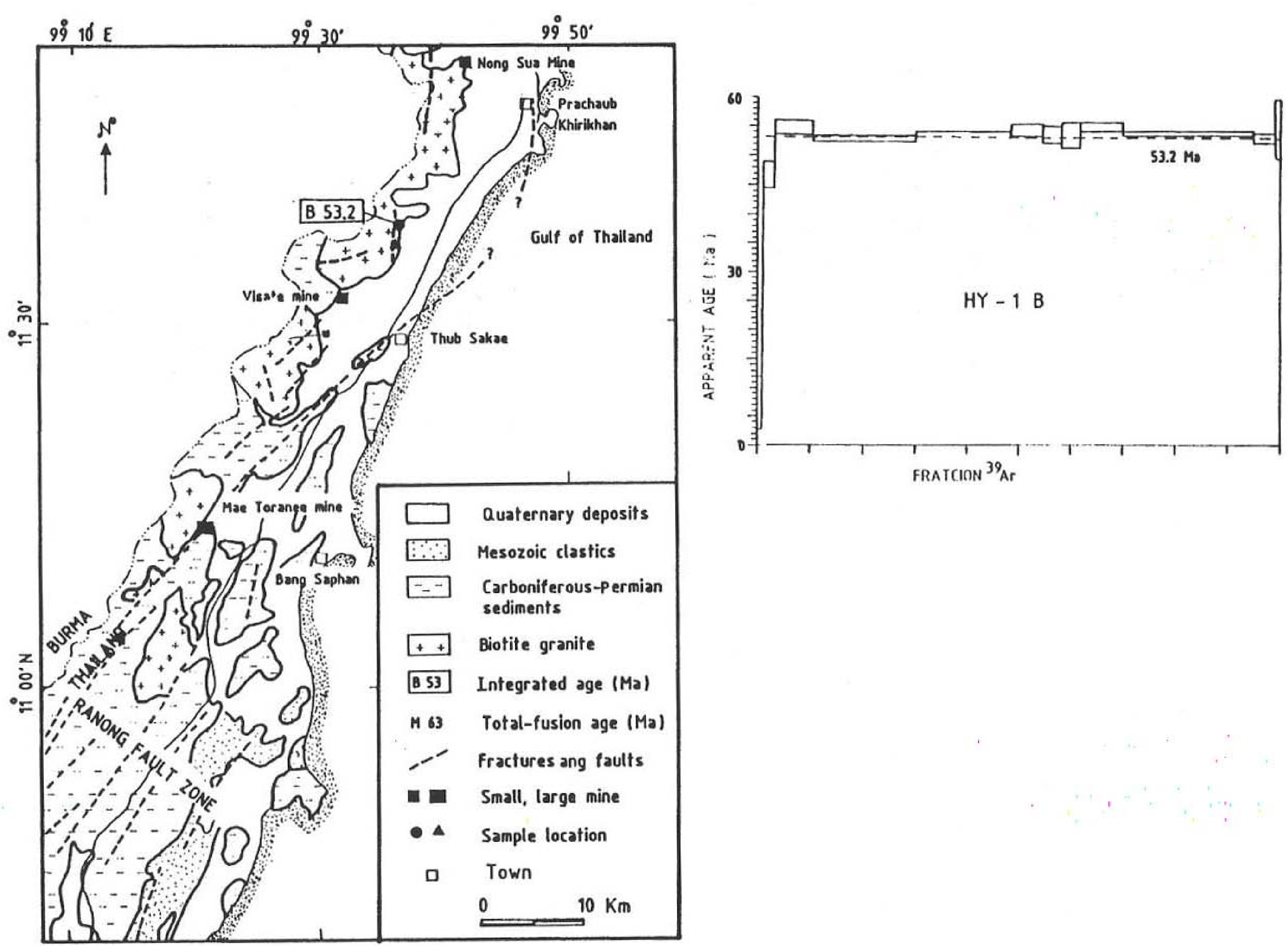


Figure 7. Geological sketch-map of the Prachaub Khirikhan mining area, modified after Silpalit et al. (1975) and showing locations of the $^{40}Ar/^{39}Ar$ daled samples, step-heated age spectra, and the distribution of Sn(-W-Ta-Nb) mines.

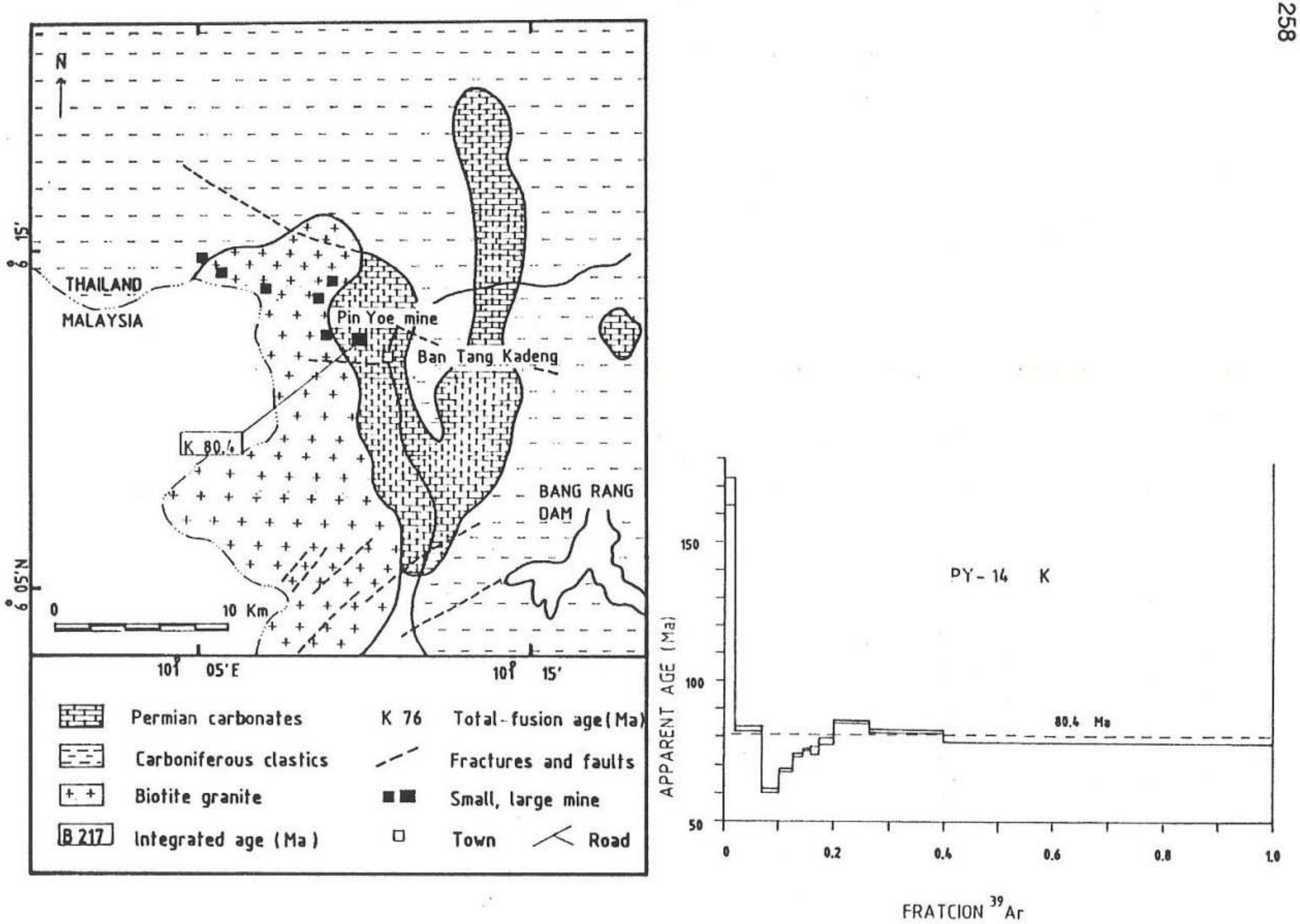


Figure 8. Geological sketch - map of the Yala mining area, modified after Charusiri et al. (1975), Muenlek et al. (1980) and Chongllakmani et al. (1983), showing locations of the $^{40}Ar/^{39}Ar$ dated samples, the distribution of tin-tungsten deposits, and a $^{40}Ar/^{39}Ar$ age spectrum.

(Charusiri, 1989) occurs at the granite-carbonate contact, forming a large, cassiterite-malayaite, skarn deposit. Minor fractures are mainly oriented northeast-southwest (Charusiri et al., 1975).

Geochronological Studies

A concentrate of a Ba-bearing K-feldspar (Charusiri, 1989) from malayaite-bearing skarn from the Pin Yoe mine was dated using step-heating technique. The old apparent age (ca. 170 Ma) of the lowest-temperature step is interpreted to reflect the age of white mica which constitutes about 5 % of feldspar sample. This age approaches the age of mineralization supported by the total-fusion muscovite date. The subsequent monotonic increase in apparent age could imply either argon-loss by volume diffusion or, less probably, slow cooling (Harrison and McDougall, 1982). The ca. 60 Ma minimum in the age pattern, the plausible minimum age would be at about 30 to 35 Ma, which is very close to the very young K-Ar biotite dates (35 Ma and 34.7 Ma : Pitakpaiwan, 1969 and Bignell, 1972; respectively) for granites about 40 km east of the Pin Yoe mine. The K-Ar dated and the $^{40}Ar/^{39}Ar$ age minimum may support the occurrence of a thermal event in the mid-Tertiary. The authors suggest that the north-trending Yala fault-zone, which is about 45 km east of the Pin Yoe mine and is knowto extend northeastwards to the Gulf of Thailand, may have been responsible for this inferred thermal event.

CONCLUSION

The above $^{40}Ar/^{39}Ar$ dating results, together with the published K-Ar data, indicate clearly that Miocene-Oligocene events also exists in Thailand. The authors consider that the major, northwest, northeast and north-trending faults may have been responsible for the inferred thermal events. In this study, at least 3 stages of Miocene-Oligocene events are recognized. i.e., 7-8 Ma, 17-23 Ma and 29-33 Ma. The youngest 7-8 Ma (Late Miocene) stage occurs mainly in the south-central (Prachaub Khirikhan) and northeastern (Phetchabu) (Charusiri et al., in prep.) parts of Thailand, both of which are supported by the dates of volcanic eruptions. The extrusions may have occurred along the large-scale, northeast-trending Ranong Fault and north-trending Phetchabun Fault, respectively. The second stage, 17-23 Ma (Early-to-Middle Miocene) occurs widely in northern Thailand and locally in the south-central part. Not only the northwest-trending Mae Ping fault but also the north-trending fault, e.g. Samoeng, and Mae Hong Son are considered to have been active during this event. The earliest, 29-33 Ma (Early Oligocene) are inferred from the minor intrusions in the north (e.g. Tak and Chiang Mai), the Pranburi - Hua Hin cataclastic zone in the south-central, and the inferred Yala faulting in the southern most part of the country.

The infilled intermontane basins with Tertiary and Quaternary sedimentary strata of the north and northwestern Thailand are referred herein to be the depression-basins controlled and bounded by north-trending faults and fractures, which Bunopas (1981) considered to be associated with Cenozoic basaltic eruption (Fig. 9). The Chao Phraya Plain, north of Bangkok, is regarded as the largest complex down-faulted structural depression, consisting of a number of basement highs protruding through alluvium and appears to have a horst-graben structure like that of the Gulf of Thailand (Bunopas, op. cit.). The authors also considered that the possible

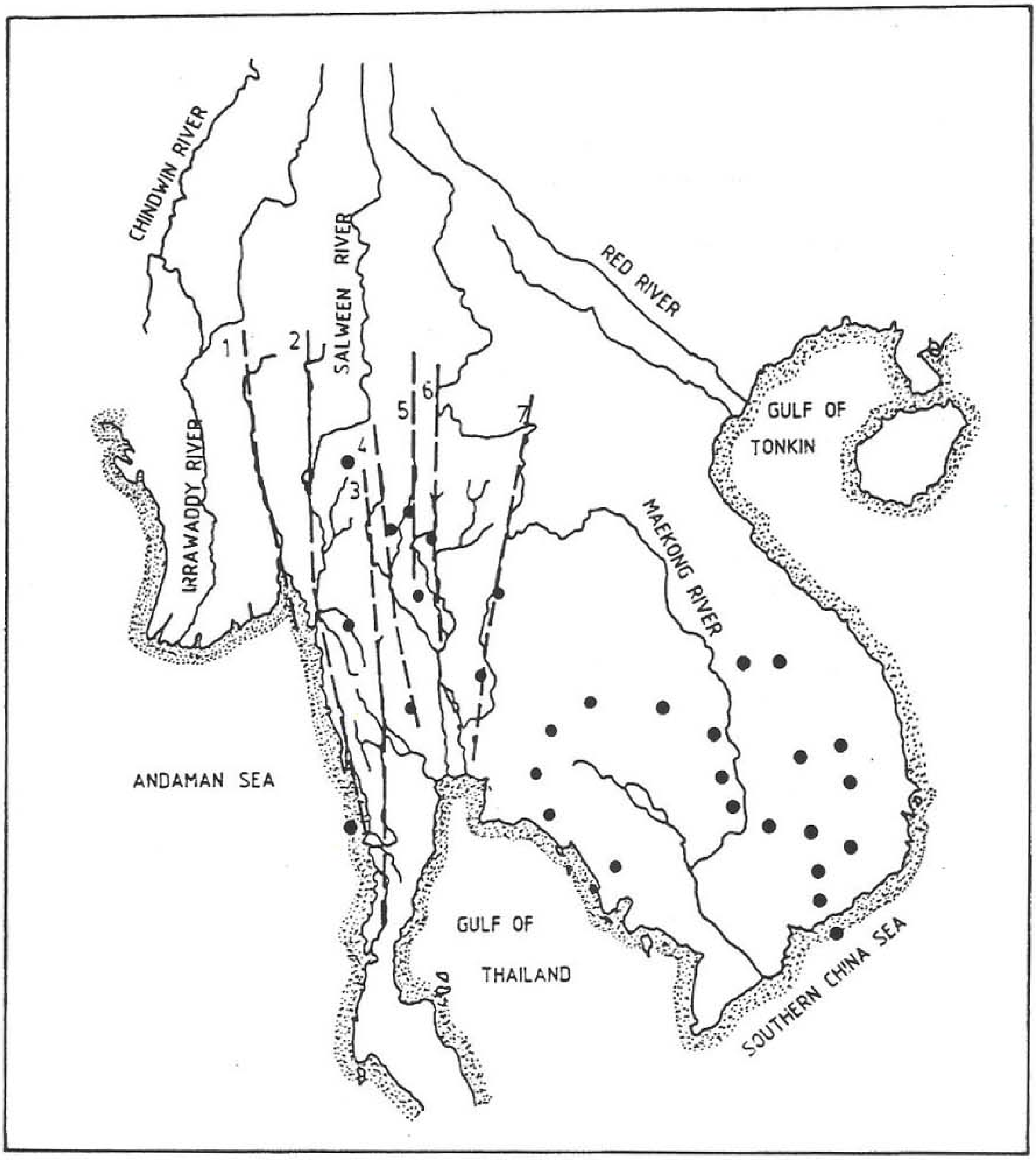


Figure 9. Diagramatic map showing distribution of Quaternary-Tertiary basalt centres (black circles) and presumed major north-trending Faults and fractures in part of Southeast Asia (modified after Bunopas, 1981). (1) Madalay Fault (Shan scarp). (2) Tavoy Fault. (3) Tenasserim Fault. (4) Salween Fault. (5) Chiangrai Fault (6) Uttaradit-Pisanulok Fault. (7) Phetchabun Fault.

age of the development of these structure-controlled basins and the opening of the Gulf of Thailand, as inferred from the $^{40}Ar/^{39}Ar$ dates, would be Early Oligocene.

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