WORKSHOP ON STRATIGRAPHIC CORRELATION OF
THAILAND AND MALAYSIA

Haad Yai, Thailand
8-10 September, 1983

SIR-A
A SHUTTLE IMAGING RADAR STRIP OVER SOUTH THAILAND AND NORTHEAST PENINSULAR MALAYSIA

B.N. Koopmans
ITC. P.O. Box 6
Enschede, Netherlands

S. Muenlek
Economic Geology Division
Department of Mineral Resources
Bangkok 10400, Thailand

Abstract

A study was undertaken to evaluate a visual geological interpretation of side-looking radar images of the second Space Shuttle mission. The images were obtained by synthetic aperture radar in the L-band, over a strip 50 km wide between Takua Pa (Thailand) and Dungun (W. Malaysia). The interpreted radar geological map was compared with available Landsat MSS. It was attempted to correlate the structural features in the sedimentary rocks from both sides of the border. A lineament analysis was made from the radar images. Some differentiation could be made between different igneous intrusive bodies on the basis of their joint and fault patterns.

The SIR-A mission

In November 1981, the SIR-A project was flown during the second Space Shuttle flight by the United States National Aeronautics and Space Administration (NASA) during a 2½ day mission. The SIR-A project hardware consisted of an L-band synthetic aperture side-looking radar. The coverage was along strips with a ground swath approximately 50 km wide. The shuttle trajectories vary from 41° north to 36° south of the equator. As the project was on an experimental basis, there was no continuous coverage. One of the strips covers a zone at the border area of Thailand and Malaysia. It enters south peninsular Thailand along the west coast near Takua Pa district and runs in a southeast direction along Songkhla Lake over Yala in south Thailand towards Kuala Dungun along the east coast of peninsular Malaysia (Fig. 1).

The nearly circular shuttle orbit had a mean altitude of 259 km. The radar depression angle was 43° ± 3° which provided an incidence angle of 50° ± 3° for near and far range of the swath. The radar frequency was 1278.3 MHz, which gave a wavelength of 23.5 cm.

The great advantage of radar satellite data compared with MSS or RBV satellite data over a tropical rainforest zone is that the radar beam penetrates the cloud cover. The long wavelength of the L-band radar energy shows little attenuation in the atmosphere and continuous ground cover was obtained over the terrain. A disadvantage is the smaller spectral sensitivity of radar in comparison with MSS or RBV data and a restricted dynamic range. The spatial resolution of the SIR-A imagery is in the order of 40 m. The synthetic aperture data were optically correlated on board. No digital data are available from the SIR-A mission.

Radar image interpretation

The radar strip between Takua Pa (Thailand) and Kuala Dungun (Malaysia) has been visually interpreted. The original imagery available at 1:500,000 was enlarged to 1:250,000. On the radar imagery, as on aerial photographs, lithologies can be recognised with respect to tone, textural patterns, drainage patterns and geomorphological expression (Fig. 2).

The flat alluvial areas are reasonably discernible on the radar imagery. This is based principally on the distinction between flat areas and areas with relief. The pattern of beach ridges, swales and backswamps in the coastal zone is visible on the basis of tone, but even more on pattern. The sandy beach ridges, well known from their light tone on aerial photographs, appear in dark tones on the radar imagery because of the specular reflection of the incoming radar beam away from the receiver. The backswamp areas with a dense, rather irregular vegetation appear light-toned on the radar as a result of the scattering in all directions of the radar energy. This contrasts strongly with aerial photographs, on which the backswamps appear dark in tone.

The inland alluvial areas consisting of fluvial overflow plains, river terraces and swampy areas are difficult to differentiate on this scale unless textural patterns such as old river oxbows or point bars can be discerned.

Well-stratified sedimentary sequences can be recognised on the basis of their typical pattern of strike ridges. In many cases the dip direction can be determined from dipslope development, flat irons or 'V'-shapes in cross-cutting valleys or consequent drainage channels. Differentiation can be made between the well-bedded sedimentary sequences of Triassic-Jurassic age consisting of quartzites, sandstones and conglomerates, forming well-defined strike ridges, alternating with shaly layers, and the Palaeozoic sedimentary sequences which develop far less clearly discernible strike ridges. In the Mesozoic red beds of Thailand and in the Saoing (Ong, 1969), Tembeling (Koopmans, 1968) and Gagau (Alexander, 1959) formations and group, the structures developed are relatively simple. This is an additional criterion on which these rock outcrops can be differentiated from the Palaeozoic outcrops, which are multiple deformed and in most cases have developed one or more cleavages and have a low- to medium-grade metamorphism.

The limestones have developed the typical advanced tropical karst morphology of steep isolated inselbergs or mountain ridges with deep karstic depressions. The presence of shear vertical cliff sides causes an accentuation of the limestone cliffs by radar shadowing on the imagery. Most topographic slopes on other rock sequences are shallower than the depression angle of the SIR-A radar and consequently have developed no radar shadow. This criterion can be successfully used to differentiate the limestone outcrops by their morphological expression.

Most of the granites are discernible in the first place by the presence of an extensive joint and fault pattern, although these patterns may vary for the different batholitic ridges. These areas are in general high-relief areas with well-developed dendritic or subparallel drainage. In the coastal areas the boundaries of the granites are sometimes difficult to recognise as the relief is eroded to a flat denudation plain, not distinguishable from the alluvial coastal plain on the radar, although granite outcrops may still be encountered in the field. Granites with different compositions may appear with different textures, for example, lower relief and more finely dissected; others are more identical in morphology to sedimentary areas with well-developed strike ridges without a strong joint or fault pattern developed. From these latter ones the granite composition was established only on the basis of information from the existing geological maps (sheets Narathiwas and Betong, southern Thailand, and geological map of W. Malaysia).

The Khao Bu Yo granite, a small outcrop SE of Yala, is known to have a gneissic texture. On the radar imagery the granite was not distinguishable from the sedimentary surroundings. Several similar areas are indicated on the interpretation map with a separate signature. The development of linear directions, parallel with strike ridges in the surrounding sedimentary rock sequences, and the absence of a well-developed pattern of joint or fault lineaments suggests a tectonic or pretectonic origin. The Khao Bu Yo granite-gneiss is from structural and metamorphic field evidence of a syntectonic origin, related to an early Carboniferous Orogeny (Muenlek et al, 1982). Muenlek further noted that the Silurian-Devonian rocks suffered at least three successive deformation phases in the early Hercynian period and that the younger Carboniferous and Permo-Carboniferous rocks showed quite different tectonic textures. Similar evidence has been described by Koopmans (1965) for the Langkawi Islands, where an orogenic event was postulated in the time lapse between deposition of the Lower Palaeozoic Setul Formation and the Upper Palaeozoic Singa Formation. A closer study in the field of the nature of these granites with distinctive linear morphology is necessary to derive well-founded conclusions.

The entire radar strip between Takua Pa (Thailand) and Kuala Dungun has been interpreted. In this publication only the part relevant to the Thai-Malaysian border area will be treated (Figs. 3a, b & c). For the Takua Pa-Thung Song area we refer the interested reader to Muenlek and Koopmans (1983).

Geological setting and correlation

Peninsular Thailand is underlain by low-grade metamorphic and sedimentary rocks which range in age from Cambrian to Quaternary and igneous rocks of predominantly granitic composition. The area southeast of Thung Song, including the Banthat Mountain ranges, consists mainly of Lower Palaeozoic rocks and granites. The oldest rocks are quartzites and phyllites which are overlain by the Ordovician Thung Song Limestone. The Thung Song Limestone consists mainly of argillaceous and dolomitic limestone and crops out especially in the east and southeast of Thung Song district, Nakornsrithammarat Province and in the west of Patthalung Province. The outcrops of the Thung Song Limestone can be traced southwards on Landsat into the Setul Limestone of Perlis (peninsular Malaysia). A continuous sequence of Silurian-Devonian rocks which are of miogeosynclinal facies, the Tanaosri Group, has been subdivided into the Kanchanaburi Formation for their lower part and the Khaeng Krachan Formation for the upper part (Javanaphet, 1969; Bunopas, 1976).

The Tanaosri Group consists of tentaculite-graptolite shale, sandstone with locally phyllite, quartzite and chert beds. Lithologically it can be correlated with the Mahang Formation (Burton, 1967) from Kedah (Malaysia). Muenlek et al. (1981) described the Silurian-Devonian strata of Narathiwas and Betong quadrangle as the Ban To Formation overlain by the Betong Formation. The first consists mainly of mica-schist, phyllite, quartzite, meta tuffs and an alternating sequence of bedded limestone, phyllite and quartzitic sandstone; the second formation consists predominantly of shale and sandstone with two lenses of limestones with tentaculites. On lithological grounds a reasonable correlation seems warranted with the Baling Group of peninsular Malaysia.

The Carboniferous, which crops out in Songkhla Province, is made up of sandstone, red argillite, siliceous shale, bedded chert with locally quartzite and slaty shale. Some *Posidonomya* sp. were found in this sequence. It forms a very subdued relief of isolated hills or low undulating terrain with little drainage developed on it. Correlating the radar interpretation with the Landsat interpretation to the south, this zone of subdued relief can be extended southwards in the Malaysian state of Perlis in the area where the Kubang Pasu Formation is cropping out, consisting of grey, red to purple feldspatic sandstones and varicoloured mudstones. The Carboniferous age of the Kubang Pasu Formation is in accordance with the Thai observations. The overlying Permian Chuping Limestone is in a similar stratigraphic position as the Ratburi Limestone on the Thai side of the border.

In the south of Songkhla Province, the sequence of Middle to Upper Triassic rocks which consists of basal conglomerate, sandstone, shale and limestone is found unconformably overlying older rocks (Muenlek et al, 1982). The basal Mi Kiat Conglomerate consists of poorly sorted clasts of subrounded chert, quartzite and sandstone with a sandy matrix. The conglomerates are partly interbedded with reddish-brown feldspatic sandstones. This is followed by the Na Thawi Formation, the Wong Yai Siltstone and the Lam Long Sandstone. This Triassic sequence often forms a number of well-developed strike ridges as a result of the competence differences of the rock composition of the different formations. The combination of SIR-A and Landsat imagery made it possible to trace the Triassic sequence to the Malaysian part of the peninsula, where they occur as strike ridges and parallel zones with a clear drainage differentiation of the Malaysian Pedu Formation. On the Thai side the sedimentary characteristics of the sequence are well visible on the radar strip west of the Na Thawi Fault, but east of this fault strike ridges are absent, although the area is mapped as Triassic. The presence of a number of NW-SE running lineaments and a subdendritic drainage pattern, somewhat controlled by the lineaments present, suggested an interpretation as a granite pluton.

The Bang Lang and Khao Boodo granites of Thailand find their continuation in the Malaysian main boundary granite. East of the granite an important structural contact occurs: the north-south oriented Tomo Fault. This fault separates the Carboniferous to the west from the Silurian/Devonian in the east. Strike ridges on both sides of the fault are roughly parallel. No Landsat frame was available to the authors to enable a southwards interpretation of the fault into Malaysia. Its situation and orientation in line with the Bentong-Raub ophiolite line, however, are striking.

East and south of the Kemahang granite the structural trend lines are distinguishable in the Malaysian Taku Schists. They are clearly separable on the basis of morphological pattern from the younger Upper Palaeozoic sediments and volcanics outcropping between the Kelantan River and the Eastern Granite Belt. Particularly the ignimbrite dike (Aw, 1967), running as a positive terrain lineament in the extension of the Lebir Fault, clearly demarcates the eastern extension of the Taku Schists at this scale of image interpretation. In the field an unconformity was observed between the Upper Palaeozoic tuff-shale sequence and the Taku Schists near the old Temangan iron mine. Along the eastern limit of the Temiang granite, sediments of Jurassic-Cretaceous age form extensive dipslopes with a gentle eastern dip. They are partially in fault contact with the granite body and partially seem to be overlying the granite with an unconformable contact. The strike of these rocks is parallel with the faulted eastern limit of the Temiang granite.

Between the Temiang granite and the Lawit-Tebu granite range a number of oblique-oriented rather open structures are visible in the Triassic-Jurassic rocks of the Besut River valley. The axial trend of these structures makes an approximately 45° angle with the grain of the granite batholiths and the strike of the Jurassic-Cretaceous. A similar direction is observable in the sedimentary roof pendant of G. Lawit.

Lineament patterns in granite

Linear features caused by faulting and jointing are well displayed on radar imagery. These patterns are particularly strongly developed in some of the granite batholiths. A lineament analysis has been performed for the various granite bodies to see if differences occur between the joint and fault patterns. For this purpose the granites have been subdivided in 7 different units, of which 3 are in Malaysia and 4 in Thailand (Fig. 4). Rose diagrams for lineament length and frequency distribution have been compiled in 5° interval classes.

In the following description reference will be made to the midmark of the interval classes in 360°. Some granite areas are excluded from the sub-units and from the lineament analysis on the basis of an entirely different morphology, as they could be clearly differentiated from the strongly fractured batholith bodies.

The 7 sub-units vary slightly in lineament density (Table 1) from a minimum of 0.24 length km/km^2 to a maximum of 0.37 length km/km^2.

The Temiang granite has a strong peak in cumulative length (35.5 km) and frequency (12) in the direction 300°, and a slightly smaller peak in direction 275°. Directions 65°-85° are also reasonably represented, whereas a small peak occurs in the direction 0°-10° (Fig. 5). The longest lineament (7.9 km) actually runs in direction 5°. Comparing the lineament distribution of the Temiang granite with the Lawit-Tebu granite (sub-unit 2), some differences can be noted. Both batholith intrusions have a clearly developed length direction which is oblique to the structural trend lines present in the sediments between and east of the granite plutons. This length direction of the granite intrusions is controlled by deep-seated faulting in a roughly north-south direction which is afterwards rejuvenated and is expressed by the long lineaments forming the eastern boundary of the Temiang granite and the lineament directions within the granites in direction 350°-5°. These directions are independent of the fold structures in the superficial sedimentary cover of Triassic-Jurassic age, which run in a direction of approximately 320°.

Fig. 6 shows the rose diagram for the Lawit-Tebu granite. The peak in direction 350° represents the length direction of the pluton. The longest lineament (6.6 km) and highest cumulative length direction of lineaments occur in this direction. Perpendicular to it, lineaments in direction 85°-90° are also strongly developed. The 60°-65° peak direction seems to be developed later than the N-S and E-W sets and represents a shear direction, as does the direction 310°.

The Kemahang granite, situated at the boundary between Malaysia and Thailand, is the smallest of the granite sub-units treated here, but with the highest lineament density (Table 1). The Kemahang granite, similar to the eastern granite belt of peninsular Malaysia, shows a clear intrusive character on the SIR-A imagery. The granite boundary is discordant with the structural trend lines in the surrounding sedimentary and metamorphic rocks. The granite pluton has no obvious length direction. Nevertheless, the longest lineament and longest cumulative length direction run approximately N-S, identical to the eastern belt granites.

Table 1 Lineament data for 7 granite batholiths.

Granite Sub-unit:	I Temiang	II Lawit-Tebu	III Kemahang	IV Waeng	V Khao Boodo	VI Bang Lang	VII Karakiri
Area extension km^2	1399	495	187	524	645	580	234
Σ Lineament length km^2	344.7	162.6	69.1	174.5	186.9	191.0	71.0
Lineament density km/km^2	0.25	0.33	0.37	0.33	0.29	0.33	0.30
Σ Lineament frequency	95	59	16	35	38	56	13
Length/frequency	3.6	2.8	4.3	5.0	4.9	3.4	5.5
Longest lineament*	7.9(5)	6.6(350)	10.8(355)	21.7(320)	16.4(280)	4.6(340)	10.7(10)
Max. Σ length* per interval class	35.3(300)	19.9(350)	11.4(5)	21.2(320)	22.1(55)	27.8(80)	19.4(305)
Max. Σ frequency* per interval class	12(300)	7(80/85)	4(65)	4(75/80)	4(55/60)	8(75)	3(305)

* Direction between brackets, 5^{o} interval classes.

The entire lineament distribution within the Kemahang granite is very similar to that of the Lawit-Tebu granite, clearly representing fractures developing as a result of the cooling process within granite and subsequent uplift.
These observations are in agreement with McDonald (1968), who considered the Kemahang granite as intrusive, and Khoo (1980), who described it as a high-level emplacement granite.

The Waeng Aris granite (sub-unit 4) has again a clear length direction of the batholith, with lineaments parallel to this roughly north-south direction and short lineaments perpendicular to it (Fig. 8). The two peaks in directions 80° and 60° do not represent two separate directions. Considering their distribution within the batholith, they only seem to represent local variations. An oblique lineament direction is present in direction 320°, being the maximum cumulative length direction, representing a shear direction.
The trend lines in the surrounding low metamorphic sedimentary rocks are parallel with the length boundaries of the granitic body.

The distribution of lineaments of the Khao Boodo-Khao Riya granite is more comparable to that of the Temiang granite (Fig. 9). A clear length direction occurs in the granite batholith; no lineaments parallel with this direction are found, however. The maximum cumulative length direction is 55°, having only a slightly higher value than the peak of cumulative length in direction 85°. The latter 85°-100° direction belongs to the short lineaments developed perpendicular to the length direction of the pluton. Directions 60° and 305° seem to form two shear sets oblique to the main batholith direction.

The Bang Lang granite is an adamellite biotite granite. It curves northwards in its length direction of the batholith in direction 340°. This trend line follows the structures of the sedimentary sequence to the west of it. In the southern part of the granite, as depicted on the radar imagery, some short lineaments in directions 0° and 340° occur, representing the length direction. A large number of relatively short lineaments occur (the longest lineament in this sub-unit present is only 4.6 km long) in directions varying between 80° and 100°. Although represented as two peaks in the rose diagram (Fig. 10), they appear to be related if we consider their spatial distribution over the area. The peak in direction 65° is clearly cross-cutting the previous directions and forms a separate lineament direction.

The Khao Karakiri granite is a small batholith of 234 km^2. It has developed no clear length direction and is very discordant with the general structural grain of the zone. The morphological expression is distinct from the previously described granitic sub-units. This granite is also distinguished in composition from the Khao Boodo and Bang Lang granites (Muenlek et al, 1982). It is a coarse porphyritic tin-bearing granite with main constituents being quartz, microcline, plagioclase and biotite. Lineament direction 305°-315° is strongly present in this granite body (Fig. 11), a direction not found in the Bang Lang granite but present as an oblique wrench direction in the Lawit-Tebu granite. This lineament direction is also found in a zone east of the Nathawi fault. This latter zone was initially interpreted as granite on the basis of the occurrence of this lineament direction. Field evidence and information of the geological map indicate this area as belonging to the Triassic with only two small granite outcrops occurring.

It is suggested here that this zone is underlain at shallow depth by a high-level pluton. The stoping of the magmatic intrusion and the vertical uplift during subsequent pulses of intrusive activity, following the cooling process of the outer shell of the magmatic body, affects the solidified part and its nearby sedimentary fringe and roof. This causes a joint and fault pattern to develop in the sedimentary roof very similar to the pattern developed in the Karakiri pluton. Dixon (1975) pointed out in model studies of progressive intrusions that particularly the sedimentary cover of a pluton is the most affected by faulting and jointing, more than the surrounding fringe. The presence of small granite outcrops in that area gives additional credence to the presence of a larger pluton just below the surface. Additional fieldwork in the area may prove this interpretation.

Fig. 12 shows a rose diagram for faulting and jointing in the sedimentary region of Songkhla to Sungei•Kolok area. The peak in direction 355° represents the long fault directions principally in the eastern part of the area (among others Tomo fault), whereas the direction 10° is more representative for the western part (among others Nathawi fault). Direction 305°-315° is restricted to the small area east of Nathawi fault, mentioned above as underlain by granite. Direction 290° is present in the east and probably related to wrench movements.

For the area between Thung Song and Songkhla (Fig. 3a) a lineament rose diagram was compiled over the entire area (Fig. 13). The general fold trend varies between north-south for the large synclinal structure SW of Thung Song to NW-SE for the eastern structures related to the Banthat Mountain range. The latter direction is represented by the 315° peak for SIR-A lineaments. Perpendicular to the length direction of the Banthat granite, a large number of relatively short lineaments occur in directions 55°-85°. The 30°-50° and 90°-115° directions form a complementary set in the Banthat range. To the SW of Thung Song the lineaments in directions 70° and 35° are the more prominent ones, of which the earlier direction is a normal faulting, principally developed perpendicular to the fold structures, and the latter one a wrench direction. This direction is also the most prominent fault direction occurring on the existing geological map.

Conclusions

The satellite radar imagery provides a good synoptic view of the structures present in the area. The acquiring scale of the imagery (1:500,000) does not provide sufficient detail to extract small structures or tight folding, but the general trend line can be recognised and more open structures can be mapped when strike ridges are well developed as in the Permo-Triassic and younger Mesozoic rock sequences. Differentiation in lithological units, without prior knowledge of the geology of the area, is difficult because of the restricted dynamic range of the sensing system which results in a small range of tonal variations. Intrusive granites are clearly recognisable on the bases of texture, morphological expression and lineament development. Granites without clearly developed lineament pattern and with a texture very similar to that of sedimentary or metamorphic rock sequences are tentatively interpreted here as being of a synorogenic nature with a possible gneissic or migmatitic texture. An area with a clear granitic lineament pattern, but mapped as Triassic sedimentary rock, is interpreted here as being underlain by a near-surface pluton. On the basis of structural trend lines a correlation could be made between the formations mapped in southern Thailand and northern Malaysia where Landsat cover of sufficient quality was available. A continuous cover of overlapping radar strips, allowing stereo-viewing, would have been very helpful for cross-border correlation. The experimental nature of the SIR-A flight did not allow for such a continuous cover.

From lineament analysis it was found that the granite batholiths have a length direction roughly north-south, parallel to the major lineament direction. They probably follow deep-seated faults which were rejuvenated after partial solidification in the granite plutons. The Lebir, Tomo and Nathawi faults are also representative for this direction. Lineaments perpendicular to this direction are extensively developed in the granite bodies. Towards the west the structural grain swings round in a more NW-SE direction. In the Bang Lang granite direction 340° is represented, and in the Banthat Mountain range direction 315°. With this change the perpendicular faulting also changes in direction from roughly 90° to direction 55°-85°.

In the eastern part later shear directions are represented by directions 310°-320° and 60°-65°; some lateral displacements are apparent. In the western part, in the Banthat range, these directions have also changed orientation towards 30°-50° and 90°-115°.

Although the granite bodies in several cases follow the strike ridges and structural trends of the surrounding sediments, their discordant character is obvious. Other plutons make a clear angle with the sedimentary structures, as, for example, the Temiang and Lawit-Tebu granites. The older structural grain present in the Carboniferous and older Taku schists is N-S and parallel with the length directions of the granite plutons, whereas the Triassic-Jurassic sediments are folded in a NW-SE axial direction oblique to the eastern granite belt.

The SIR-A imagery is useful for synoptic structural outline. Detail should be obtained from aerial photographs and fieldwork.

References

ALEXANDER, J.B. (1959)
Pre-Tertiary stratigraphic succession in Malaysia. Nature, Land 183, p.230-231.

AW, P.C. (1967)
Ignimbrite in Central Kelantan, Malaya. Geol.Mag. 104, p.13-17.

BUNOPAS, S. (1976)
On the stratigraphic successions in Thailand - A preliminary survey summary. Journ.Geol.Soc. Thailand Vol.2, no.1-2, p.31-58.

BURTON, C.K. (1967)
The Mahang Formation: A Mid-Palaeozoic euxinic facies from Malaya. Geol. en Mijnbouw 46, p.167-187.

DIXON, J.M. (1975)
Finite strain and progressive deformation in models of diapiric structures. Tectonophysics 28, p.89-94.

GEOLOGICAL MAP OF WEST MALAYSIA, 7th edition (1973)
Geological Survey, Malaysia.

JAVANAPHET, J.C. (1969)
Geological map of Thailand scale 1:1,000,000. Dept.Min.Res., Thailand.

KHOO, T.T. (1980)
Some comments on the emplacement level of the Kemahang granite, Kelantan. Bull. Persatuan Geologi Malaysia No.13, p.93-101.

KOOPMANS, B.N. (1965)
Structural evidence for a Palaeozoic orogeny in Northwest Malaya. Geol.Mag. V.102.6, p.501-520.

KOOPMANS, B.N. (1968)
The Tembeling Formation - A lithostratigraphic description (W. Malaysia). Bull.Geol.Soc. Malaysia 1, p.23-43.

McDONALD, S. (1968)
The geology and mineral resources of North Kelantan and North Trengganu. Mem.Geol. Survey Dept. W. Malaysia 10, pp.202.

MUENLEK, S; A. MEESOK & P. THONGCHIT (1982)
Geology and mineral resources of Sheet Narathiwas and Betong, Southern Peninsular Thailand. GSSR Paper No.3, pp.59.

MUENLEK, S. & B.N. KOOPMANS (1983)
The Shuttle Imaging Radar-A over South Peninsular Thailand. ITC-Journal 1983-3 (in press).

ONG, S.S. (1969)
Geology of the Muda Dam area, Kedah, W. Malaysia. B.Sc. honours thesis. Dept. of Geology, Univ. of Malaya (MS).

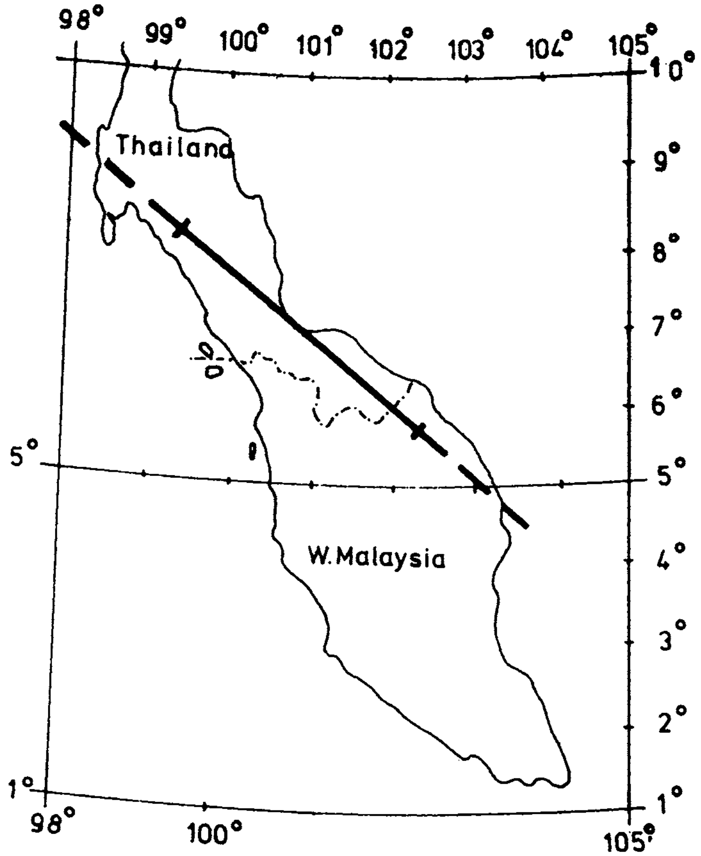


Fig. 1 - Location map SIR-A strip Thailand-Malaysia

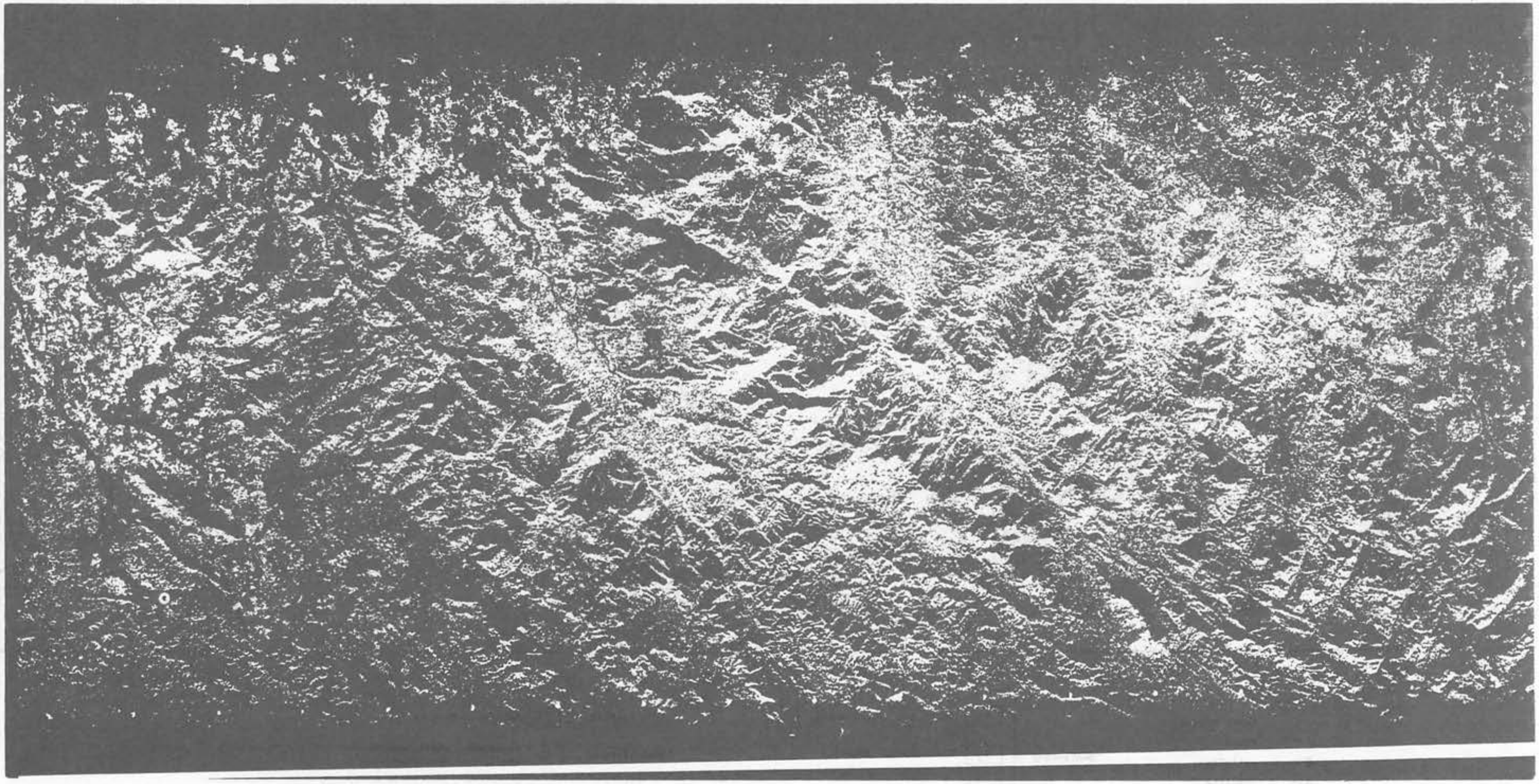


Fig. 2 - SIR-A radar image of Khao Boodo-G. Sarut

Fig. 3a . RADAR GEOLOGICAL MAP THUNG SONG _ SONGKHLA AREA

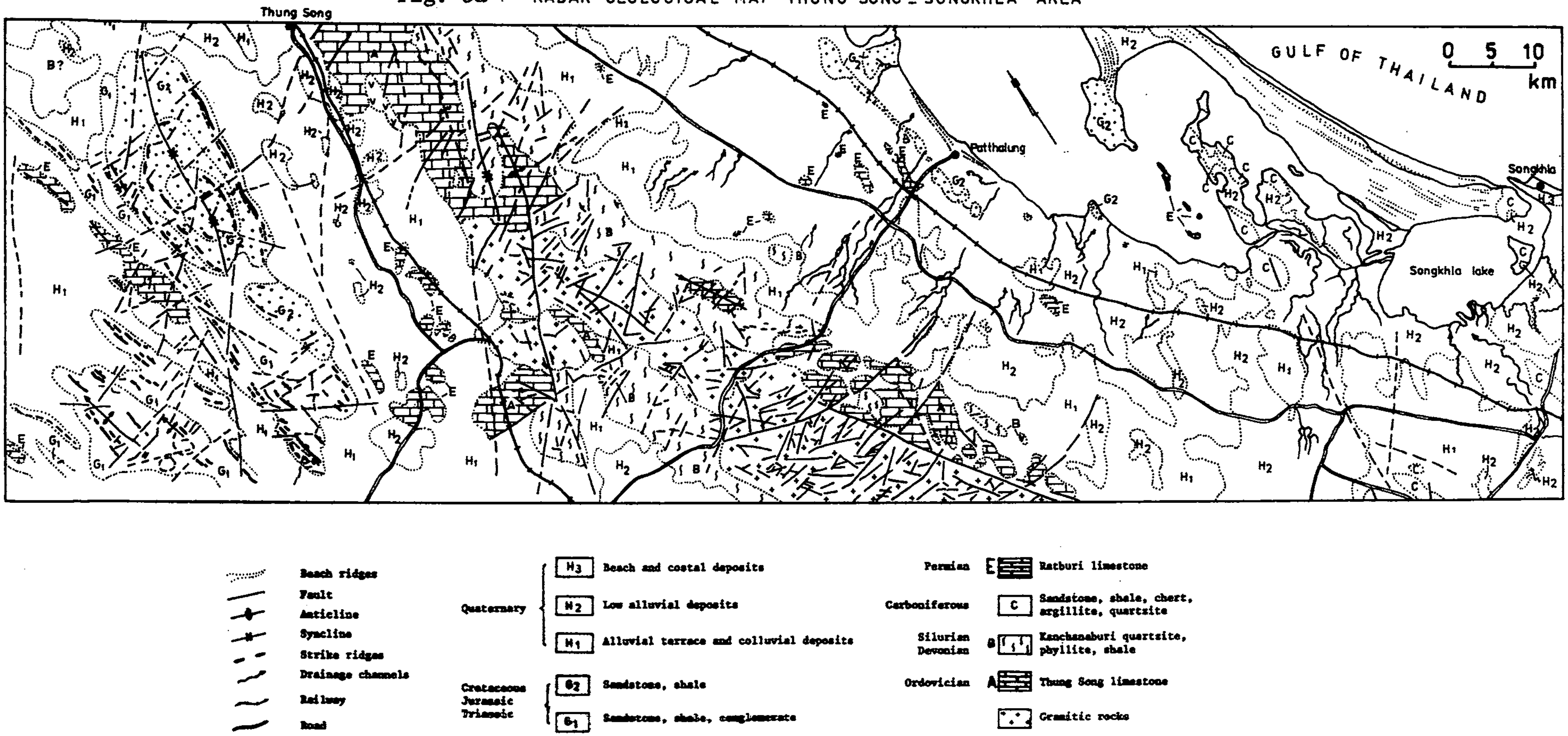


Fig. 3b RADAR GEOLOGICAL MAP KHAO_BOODO_ SONGKHLA AREA

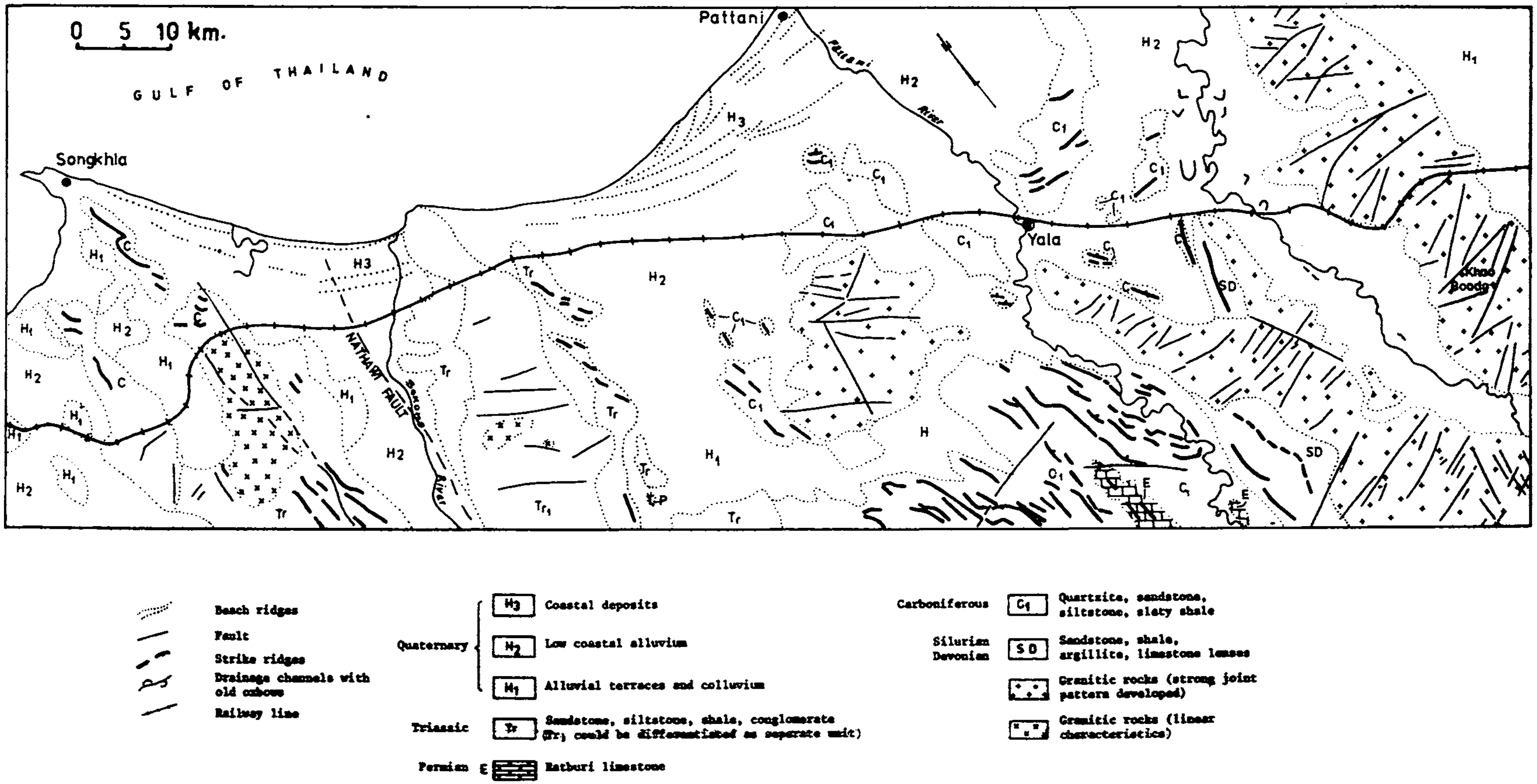
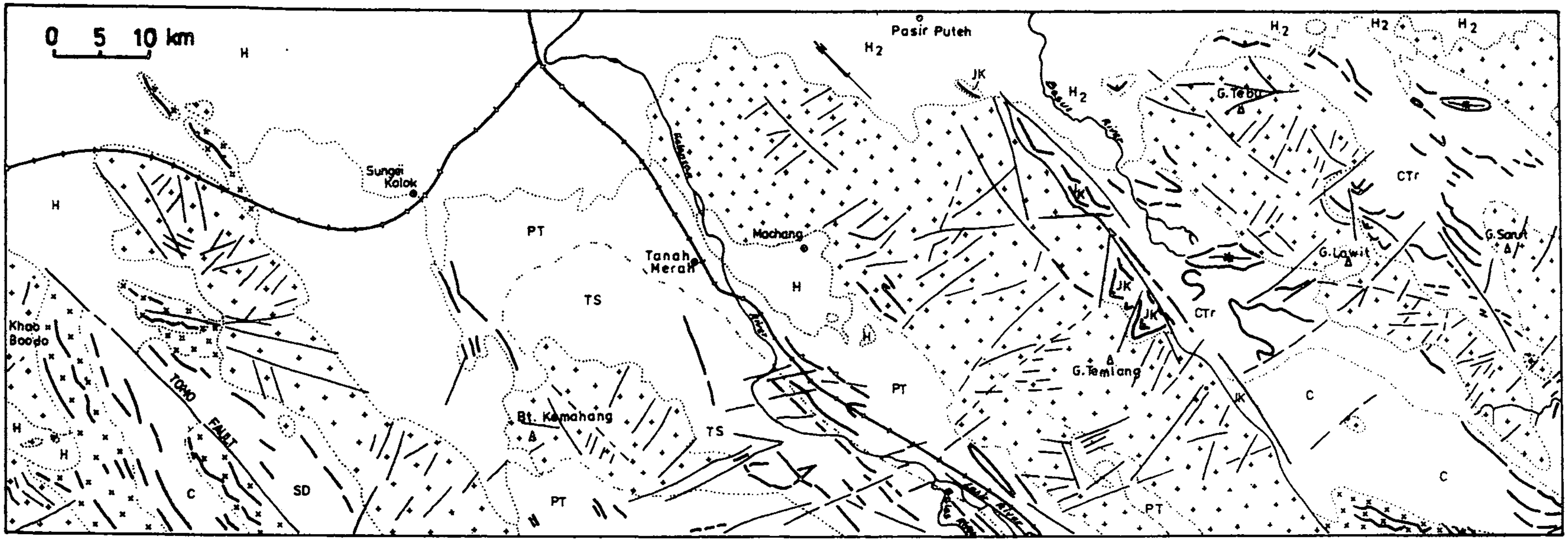


Fig. 3c

Fig. 3c RADAR GEOLOGICAL MAP KHAO BOODO _ G.SARUT AREA



Fault	
Syncline	
Strike ridges (bedding plane dip indicated)	
Drainage	
Railway line	

Quaternary	H2	Low coastal alluvial
Quaternary	H	Undifferentiated alluvial
Cretaceous Jurassic	JK	Gagau group, sandstone, conglomerate
Triassic Carboniferous	CTr	Sandstone (Triassic) Slate-graywacke (Carboniferous)
Permian Triassic	PT	Sedimentary - volcanic sequence
Carboniferous	C	Shale-slate, graywacke, quartzite
Silurian Devonian	SD	Sandstone, shale, argillite, limestone lenses
	TS	Taku schists, mica-amphibolite schists
		Granitic rocks (strong joint pattern developed)
		Granitic rocks (linear characteristics)

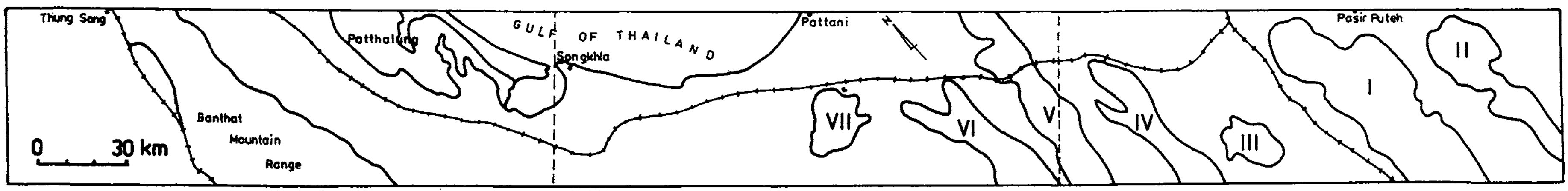


Fig. 4 - Granitic sub-units for lineament analysis

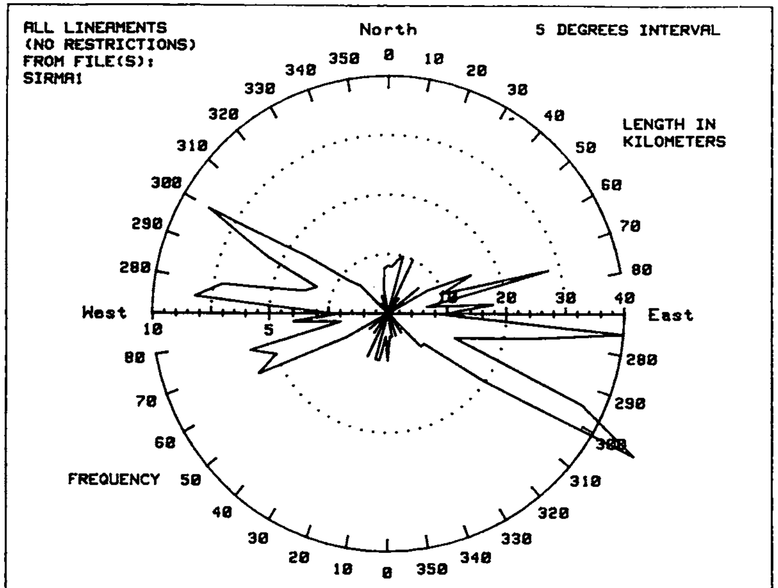


FIG.5 LINEAMENT ROSE DIAGRAM TEMIANG GRANITE-MALAYSIA

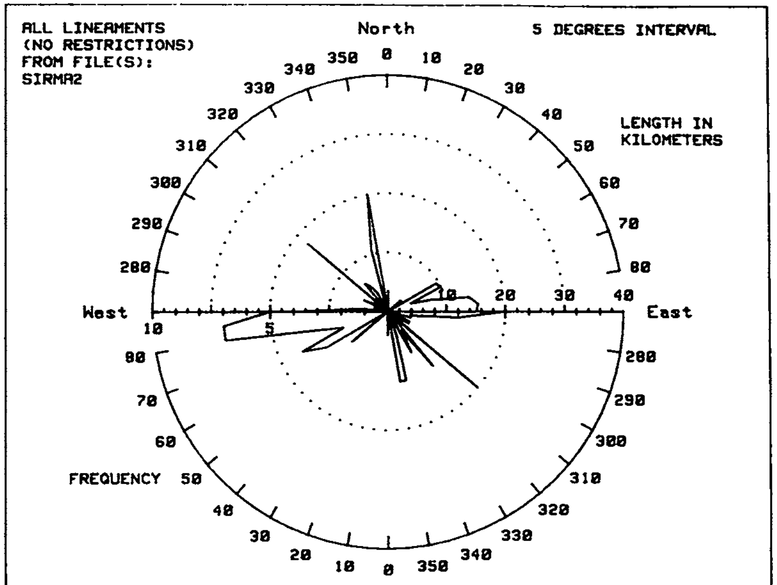


FIG.6 LINEAMENT ROSE DIAGRAM LAWIT-TEBU GRANITE-MALAYSIA

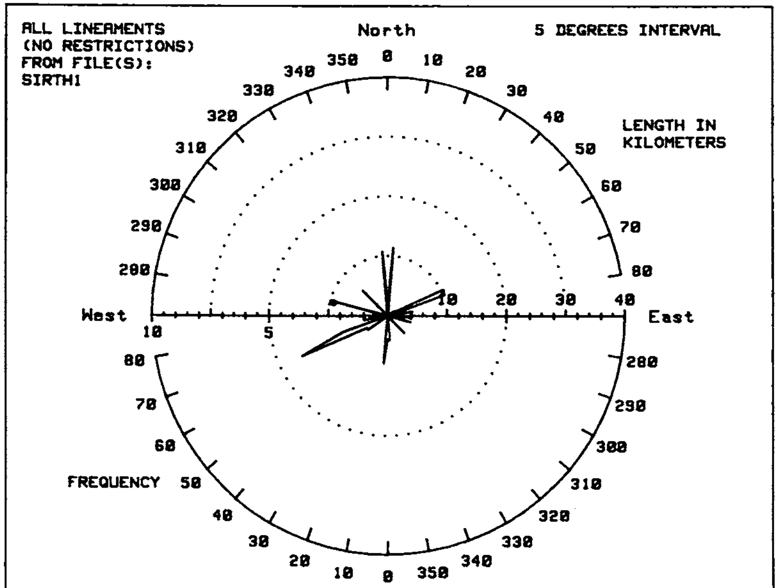


FIG.7 LINEAMENT ROSE DIAGRAM KEMAHANG GRANITE-MALAYSIA

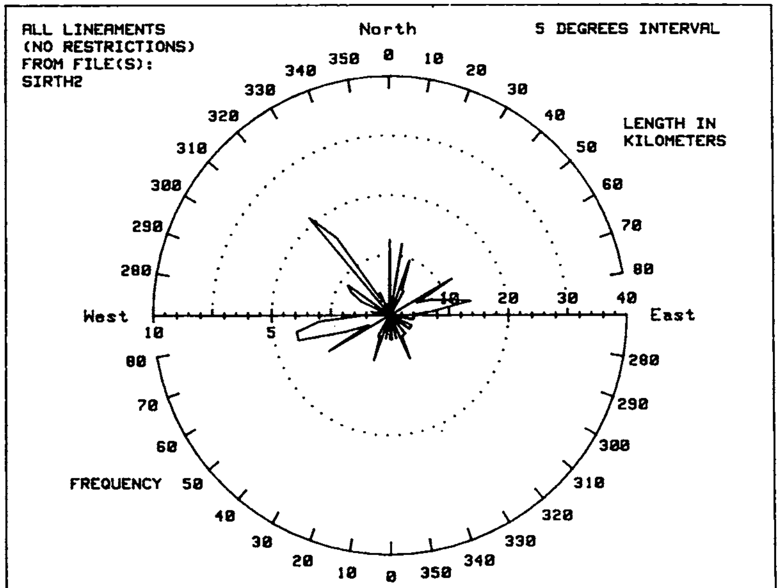


FIG.8 LINEAMENT ROSE DIAGRAM WAENG ARIS GRANITE-THAILAND

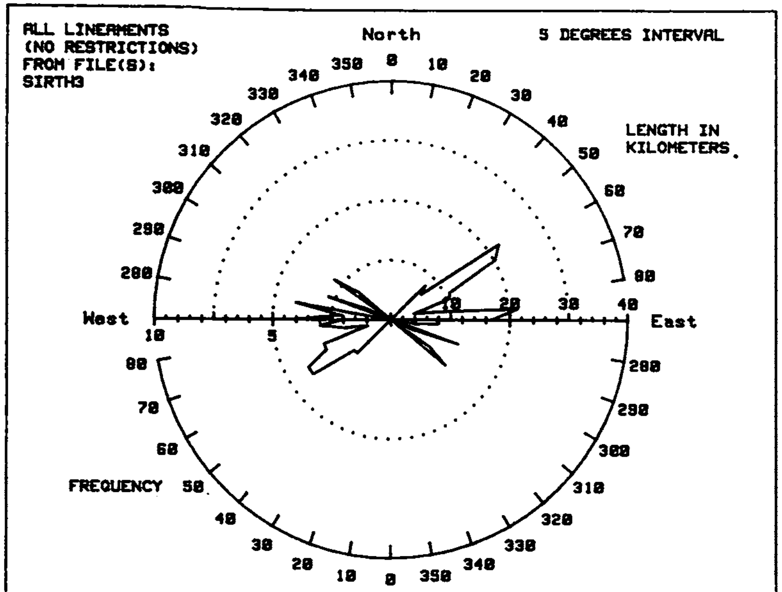


FIG.9 LINEAMENT ROSE DIAGRAM KHAO BOODO GRANITE-THAILAND

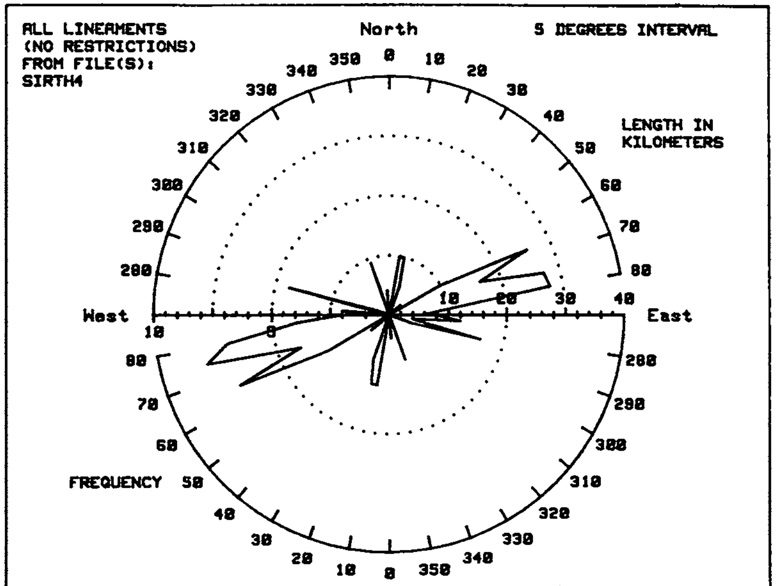


FIG.10 LINEAMENT ROSE DIAGRAM BANG LANG GRANITE-THAILAND

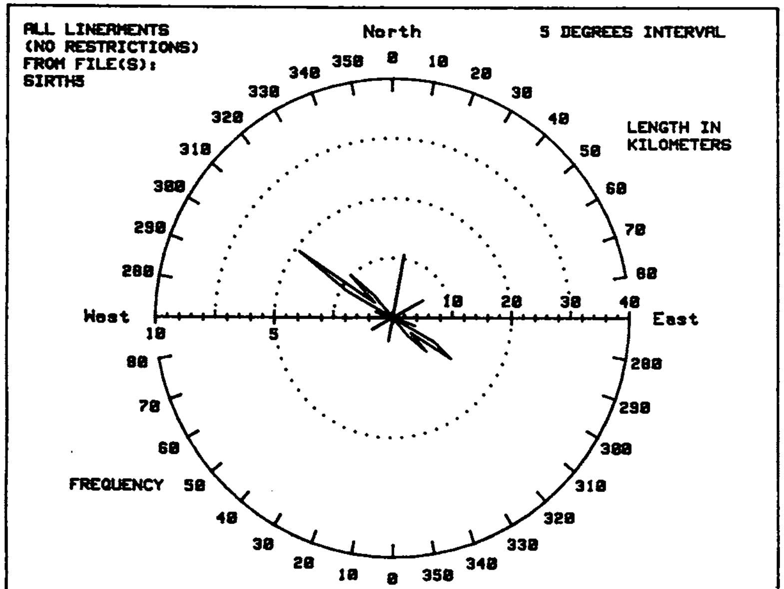


FIG.11 LINEAMENT ROSE DIAGRAM KHAO KARAKIRI GRANITE-THAILAND

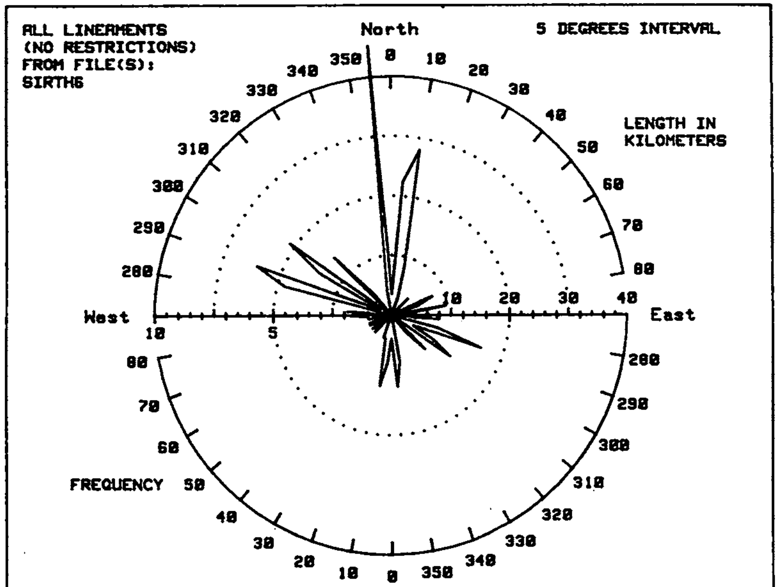


FIG.12 LINEAMENTS IN SEDIMENTS:SONGKHLA-S.KOLOK,THAILAND

364

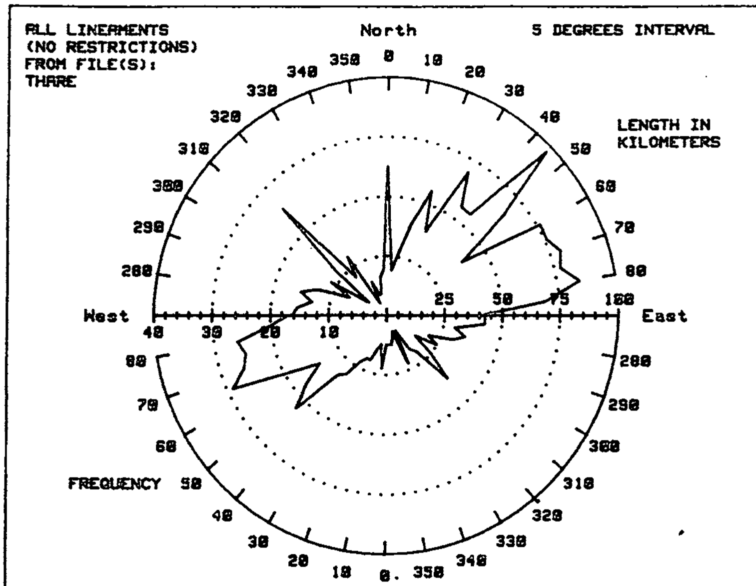


FIG.13 LINEAMENT ROSE DIAGRAM THUNG SONG-SONGKHLA, THAILAND