



Implications of the Bok Bak Fault movements on the structure and lithostratigraphy of the Pokok Sena area

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Abstract: Exposures of the Lower and the Upper Paleozoic sediments in the Pokok Sena area were recognised as equivalent to the Mahang and the Kubang Pasu Formation respectively. The Mahang Formation consists of mainly weathered slate, and minor siliceous mudstone and chert. The lower part of the exposed Kubang Pasu Formation comprises dark laminated mudstone and dark grey chert. The sequence is overlain by interbedded mudstone and sandstone. Thick sandstone interbedded with thin shale represents the upper part of the formation. The area has topographically asymmetric NNW ridges with W-vergent thrust faults and oblique lateral faults. Exposures at several localities display the slate of the Mahang Formation overlies the younger Kubang Pasu Formation. The formations are separated by moderately steep reverse faults. Merging and combination of lateral slips and reverse movements reflects a transpressional deformation within the Paleozoic sediments. A flower geometry is defined by vertical to steeply dipping lateral faults which have shallow plunging slickensides and moderately steep dipping reverse faults.

INTRODUCTION

The presence of major strike slip fault in Peninsular Malaysia was identified for the first time by Burton (1965) in Baling Kedah. He recognised the northwest striking fault as the Bok Bak fault. The fault was shifted approximately 5 miles to the east along northeast dextral fault. He postulated the fault trace continuity from Jeneri, Kedah to Surat Thani, Thailand. The fault trace is about 4 miles west of Pokok Sena. He also proposed the extension of the fault towards Pulau Tinggi, Mersing.

Raj (1982) agreed the southward extension only up to central Perak and southwest Kelantan on the basis of lineaments study in granite that was mapped from LANDSAT imagery. The fault existence was proven in north Perak with the discovery of mylonite and cataclastic zones in Sungai Kawan, Sungai Rengkih and Sungai Perlus in north of Sungai Siput (Abdul Majid Sahat, 1987).

The northwestern extension of the fault from Pokok Sena to Wang Kelian was proposed on the basis of dragged strike ridges, deflected rivers and offset of the Paleozoic formations (Syed Sheikh Almashoor, 1996). On the map, there is a transfer

zone between the fault trace of Burton (1965) and the fault trace of Syed Sheikh Almashoor (1996) in the Pokok Sena area (Fig. 1).

The effect of the Bok Bak faulting on morphology and distribution of the geological units have been noticed and reported by several workers (Burton, 1965; Courtier, 1974; Raj, 1982; Syed Sheikh Almashoor, 1996). However field evidence of structures and stratigraphy of sedimentary units affected by the fault has never been discussed.

This report summarises the field investigations observed in the Pokok Sena area and to document the stratigraphy, structural style and geometry of the Paleozoic sediments within the transfer zone of the Bok Bak fault.

GEOLOGICAL SETTING AND STRATIGRAPHY

The Mahang Formation

The Mahang Formation covers central and south of Kedah. Burton (1967) has recognised four facies within the lithostratigraphic unit, viz.

- a dominant argillaceous facies,
- a subsidiary arenaceous facies,

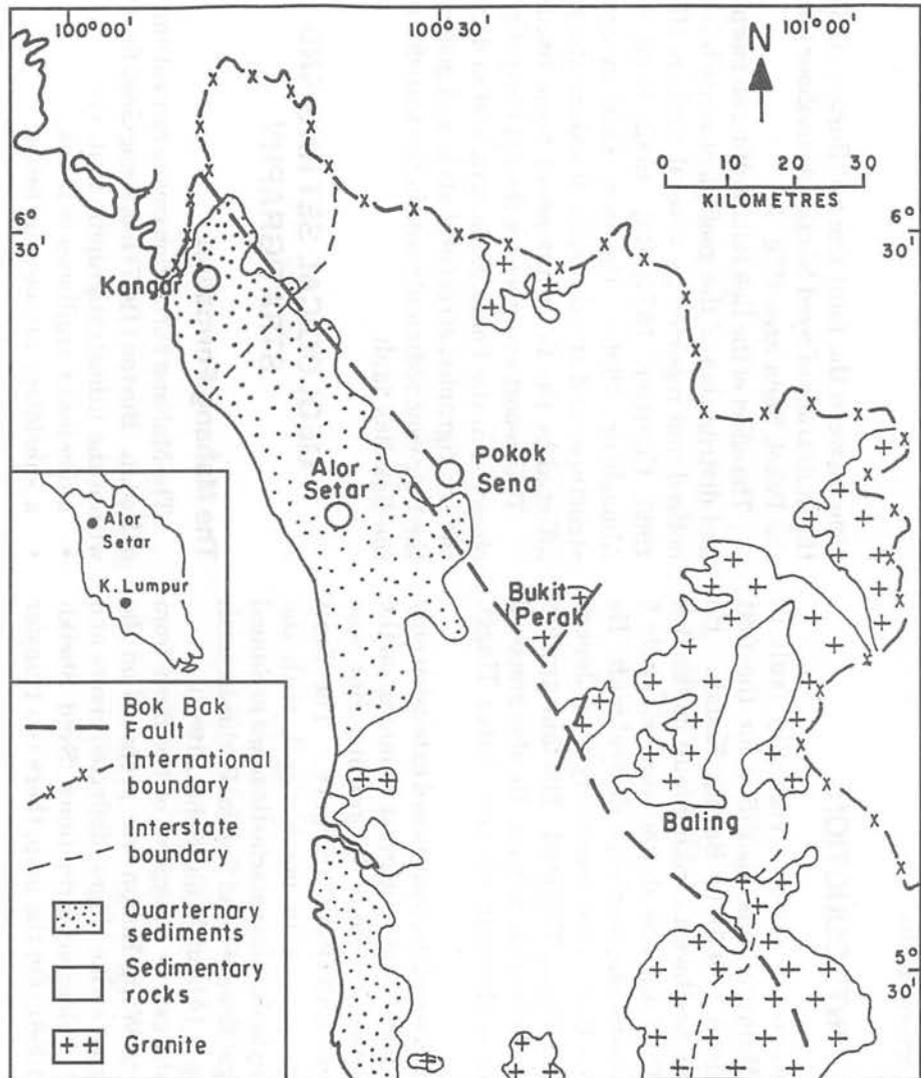


Figure 1. A map showing the Bok Bak fault trace from Wang Kelian to north of Perak. The map is modified from Syed Sheikh Almashoor (1996).

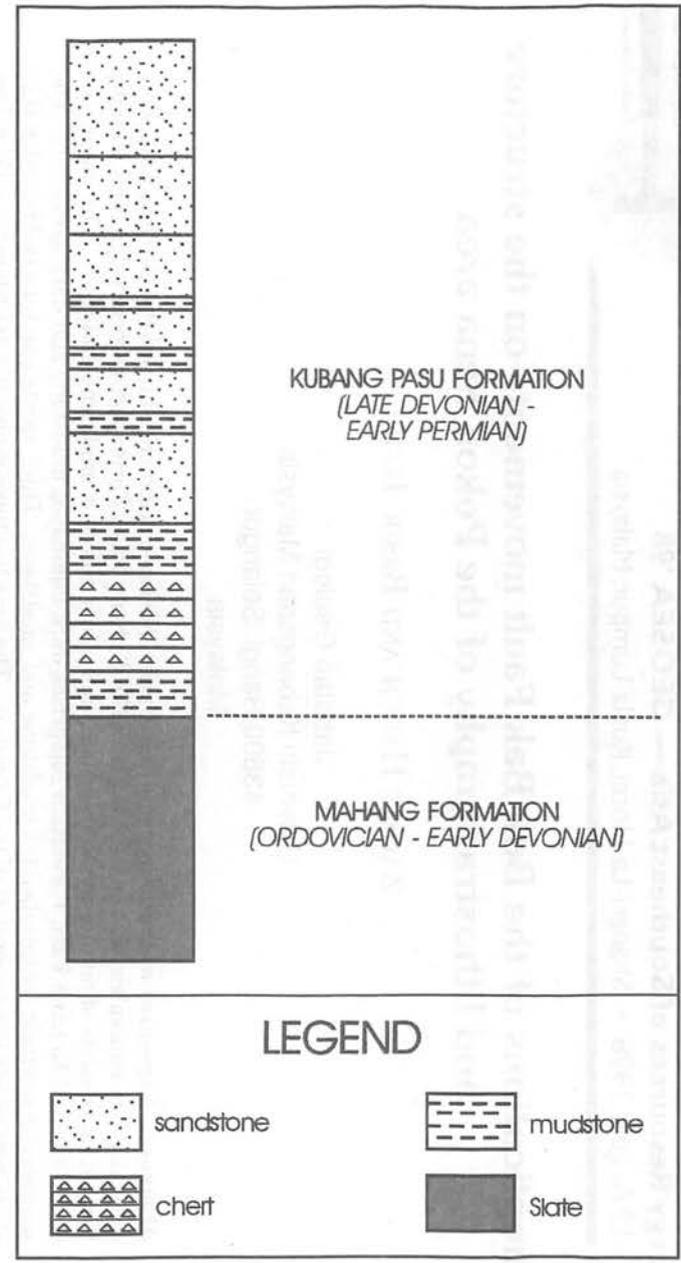


Figure 2. Lithostratigraphy of the Mahang Formation and the Kubang Pasu Formation in the Pokok Sena area.

- a minor siliceous facies which grades imperceptibly into the argillaceous ,
- a very restricted calcareous facies.

Burton (1967) recognised sharp borders of the Mahang Formation as wrench fault, the northern boundary is an exceptional where the Mahang is probably underlying the Kampong Sena Formation (This formation was later included in the Kubang Pasu Formation). The Mahang Formation was slightly metamorphosed and the argillaceous rocks turned to slate. Most of the slate is weathered and red in colour. The Mahang Formation contains Silurian graptolites and early Devonian graptolite-tentaculite fossils (Burton, 1988).

The Mahang Formation is well-exposed near Bandar Aman Jaya, a new township situated at the south of Bedong. The area is partly mapped by Burton (1988). Only three facies were recognised in central Kedah i.e. argillaceous facies, arenaceous facies and siliceous facies (Burton, 1988). The dark grey slate contains several species of graptolites which is comparable to the graptolites of the Mahang Formation in the Bedong area (Burton, 1988). Development of slaty cleavage in the dark grey slate and red slate are pronounced under the microscope. The slates from the Pokok Sena and Bandar Aman Jaya areas exhibit similar characteristics. Therefore, they belong to the Mahang Formation.

In the Pokok Sena area, the weathered slate is exposed extensively at several earth quarries at Bukit Jabi, Bukit Kerangan, Cheong Chong Kaw Estate and south of Kampong Panchor. The formation consists of mainly weathered slate of various colours, greyish green, purple, bright red, and minor siliceous mudstone and chert. The weathered siliceous mudstone and chert are greyish white. The slate is very fine grained and exhibits well developed slaty cleavage.

The Kubang Pasu Formation

The Kubang Pasu Formation is also exposed at Bukit Jabi, Cheong Chong Kaw Estate, south of Kampong Panchor, Bukit Kamelong, Kampung Belukar and Bukit Telaga Jatuh. The lowest part of the Kubang Pasu Formation comprises sequence of dark laminated mudstone and dark grey chert. The lower sequence is overlain by interbedded thin sandstone with thick mudstone, followed by sequence of interbedded mudstone and sandstone. The sandstone within the latter sequence contains cross and parallel lamination. Thick sandstone interbedded with thin shale represents the uppermost part of the formation (Fig. 2).

Radiolaria from the chert of the Kubang Pasu Formation was dated as Tournaisian-Visean, Lower

Carboniferous (Basir Jasin, 1995). The upper part of this formation is thought to be an Early Permian based on the discovery of Early Permian Radiolaria from the base of the Semanggol Formation (Basir Jasin, 1997).

GEOLOGICAL STRUCTURES OF THE AREA

The rocks in the Pokok Sena area are extensively exposed at several earth quarries. These outcrops exhibit more structural information which was not exposed before. Several good exposures are available at Bukit Jabi, Bukit Kerangan, Cheong Chong Kaw Estate, and south of Kampung Panchor.

Bukit Jabi

Bukit Jabi is a NNW trending strike-ridge. The Mahang Formation crops out on the east side of the ridge and the Kubang Pasu Formation is exposed on the west (Fig. 3). The Mahang Formation consists of green to red coloured slate. The slate of the Mahang Formation strikes NNW to north and dip moderately steep to steep (50° – 70°) to east. The red slate of the Mahang Formation is underlain by unmetamorphosed thick sandstone interbedded with mudstone. Initially, it was thought to be a top part of the Jerai Formation. A detailed study shows that it is a top part of the Kubang Pasu Formation. Both formations are separated by a mylonite zone. Steeply dipping beds are younging towards east with general strike NNW to NNE.

Strike slip faults cut and shifted the slate of the Mahang Formation (Fig. 3). Dextral faults strike ranging from NNE to NE and vertical to moderately steep dipping to the east. Slickensides on the fault surfaces plunge shallow (22°) to SW and horizontal in the NE-SW direction. Some segments of the faults indicate pure strike slip and the other segments indicate oblique strike slip.

Vertical to moderately steep (43°) dipping sinistral faults strike ranging from WNW to NNW exhibit slickensides shallowly (04° – 010°) plunging to the west, to NNW and to the SE. The fault zone is highly fractured. The dextral faults are cut by the sinistral faults.

Relationship between strike slip and reverse faults was observed within the Kubang Pasu Formation. The strike slip and reverse faults cut the bedding and after some distance the faults are disappeared into the bedding planes. Movements were also taken place within thin shales. These shales exhibit foliated black shiny rocks that are easily break and weathered.

Dextral faults strike NNE and ENE, dip ranging from 70° to 90° . These faults do not keep the

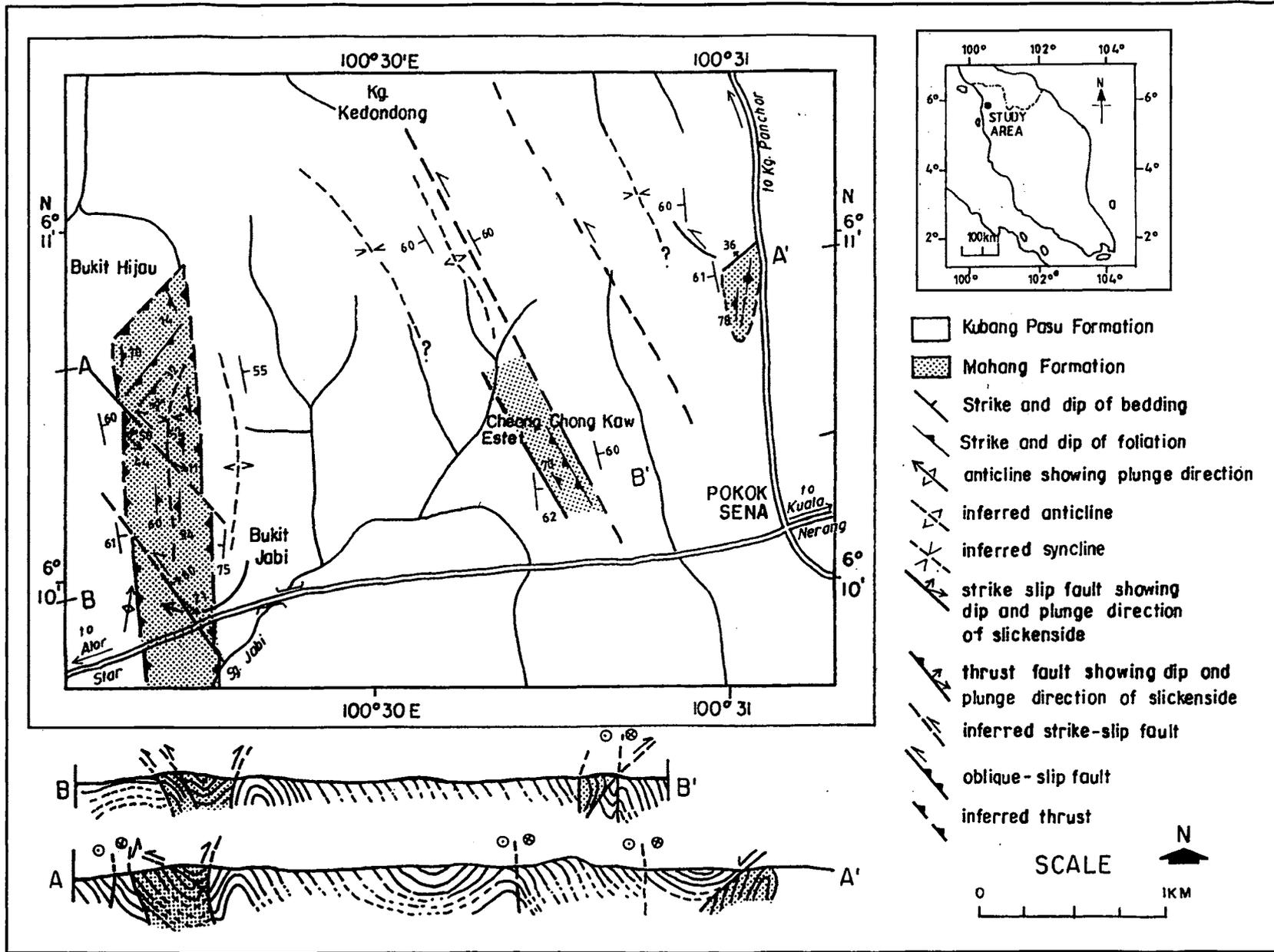


Figure 3. Geological map and the cross section of the Pokok Sena area.

attitude, several display changes of strike to SSW and dip 60° to 90°. Vertical to steeply dipping faults normally exhibit slickensides plunging 10° to 37° either to NNE or to SSW. There are also moderately steep dipping faults exhibit slickensides plunging 21°–44° to SE or to WNW. These are oblique dextral faults

Gentle to steeply (24°–70°) dipping sinistral faults strike NW to N cut and shifted the dextral faults within the Kubang Pasu Formation. Slickensides on several fault surfaces plunge less than 10° to NW and to SE, and an almost pure strike slip is suggested. Oblique slip could also be suggested from the evidence of gentle to moderately (24°–45°) plunging slickensides either to SE or to WNW. Merging of low angle faults with steeply dipping faults and combination movements along the thrust and strike slip faults form flower structure in transpressional zone (Fig. 4, 5).

There is also an exposure of an open fold plunging to NNE with in the Kubang Pasu Formation.

The Mahang Formation seems to be thrustured onto the top of the Kubang Pasu Formation. The boundary is gentle to moderately dipping oblique sinistral fault with strike ranging from NW to N.

Bukit Kerangan

This is the northern extension of Bukit Jabi (Fig. 3). The Mahang Formation consists of slate from various colours; greyish green, purple and red, and thin layers of chert. The Mahang Formation overlies the Kubang Pasu Formation and the boundary is a reverse fault (Fig. 6). The reverse fault strike 31°, and dip 32° to the southeast. The foliations from other parts of Bukit Kerangan strike either NNW to NNE or SSE to south and dip 50° to 75°. Underneath the red slate of Mahang Formation and the reverse fault is faulted the middle sequence of the Kubang Pasu Formation. The bedding is steeply dipping to the east and strikes NNW. The NNW to NNE faults that dip moderately steep to vertical (36° to 90°) to the east are of reverse to sinistral movement. The faults cut and shifted the bedding, and continued the movement along the bedding plane. The fault movement is easily detected with the presence of thin mylonites along the fault planes and deflected thin beds adjacent to the faults.

50 m wide of fault zone was exposed at the southeast of Bukit Kerangan. Moderately steep (55°–62°) dipping faults strike NNW, moderate to steeply plunging slickensides on the fault surfaces suggest an oblique sinistral slip. Brecciated fault surfaces with vertical to steeply plunging slickensides were also observed on vertically NW sinistral faults.

The sequence, orientation of beddings and faults, type of faults and style of fault movements within the Kubang Pasu Formation were observed very much like the exposure of the Kubang Pasu sequence at Bukit Jabi.

Cheong Chong Kaw Estate

A complete sequence of the Kubang Pasu Formation was observed here. Steeply dipping beds strike NNW and ripple cross bedding within the sandstones suggest younging towards east. *Posidonomya cf. becheri* (Bronn) was found in the grey mudstone of the middle sequence of the formation. The fossil is believed to be the Carboniferous age. The red slate with good foliation was found on top of the NNW ridge. A vertical sinistral fault with mylonites strikes 130°, forms a western border between the red slate and thick sandstone of the Kubang Pasu. Another fault strikes 136° and 62° dipping to the west, forms an eastern border between the same slate and slump chert unit of the Kubang Pasu Formation underneath (Fig. 7).

The Kubang Pasu sequence is cut by vertically to steeply dipping sinistral faults strike WNW to NW, with moderate to very low plunging slickensides either to WNW or ESE. A half flower geometry is defined by vertically to steeply dipping sinistral faults which have moderate to shallow plunging slickensides and moderately steep dipping reverse faults

South of Kampong Panchor

The stratigraphic boundary between the Mahang and the Kubang Pasu formations is exposed at south of Kampong Panchor. The Mahang Formation is overlain by a slump unit of grey chert interbedded with grey mudstone which represents the base of the Kubang Pasu Formation (Fig. 8). The unit is almost parallel to the boundary. The boundary is sharp and marked by an iron pan. The slate which represents the top part of the Mahang Formation has also undergone some degree of weathering processes that its relationship with the above boundary is vague. The foliation of the slate strikes 185° and dip steeply (78°) to the west. The boundary dips 36° to NW and strikes 235°. The strike of lower part of the chert unit varies from 225° to 240° and the dip is ranging from 16° to 43°. The mudstone on top of the chert unit strikes 174° and dips 61°. The orientation of the mudstone is the same as the other sequence of the Kubang Pasu Formation at this locality. The bed strike is ranging between 170° to 180° and the dip is ranging between 55° to 61°. Ripple Cross laminations within the sandstone indicate that the sequence is in normal position. Even though the sequence is in normal

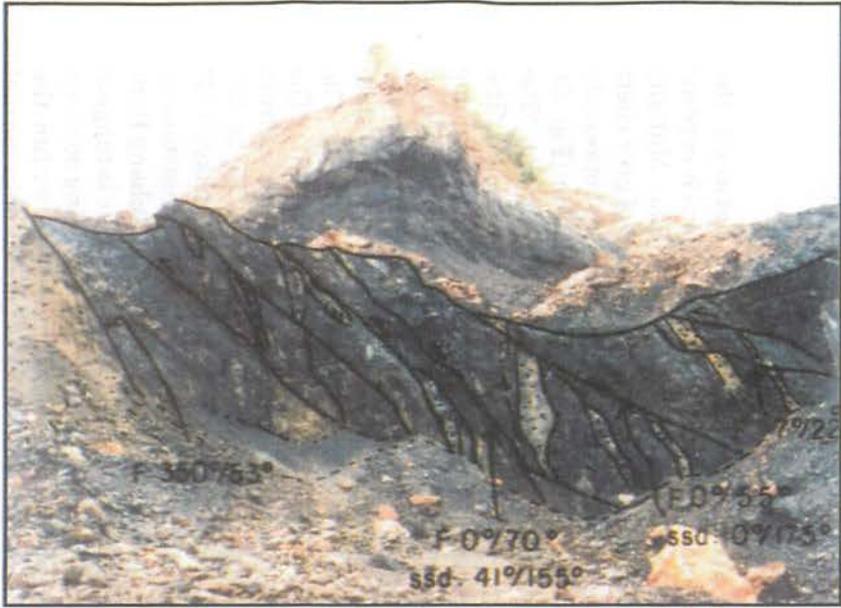


Figure 4. Fault zone forming part of the flower structure in the Kubang Pasu Formation at Bukit Jabu. Fault (F 0°/70°) contains slickensides (ssd. 41°/155°) plunging 41° towards 155°E.

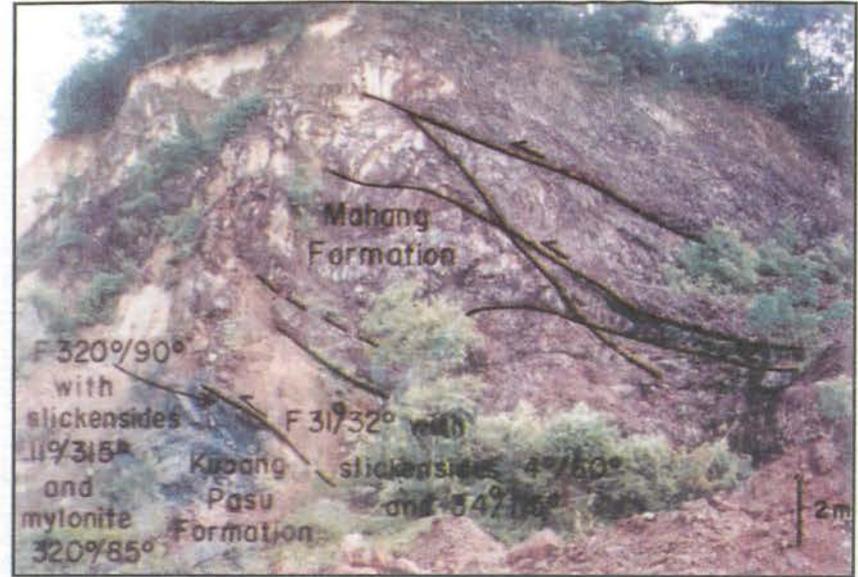


Figure 6. Slate of the Mahang Formation is on top of the Kubang Pasu Formation at Bukit Kerangan.

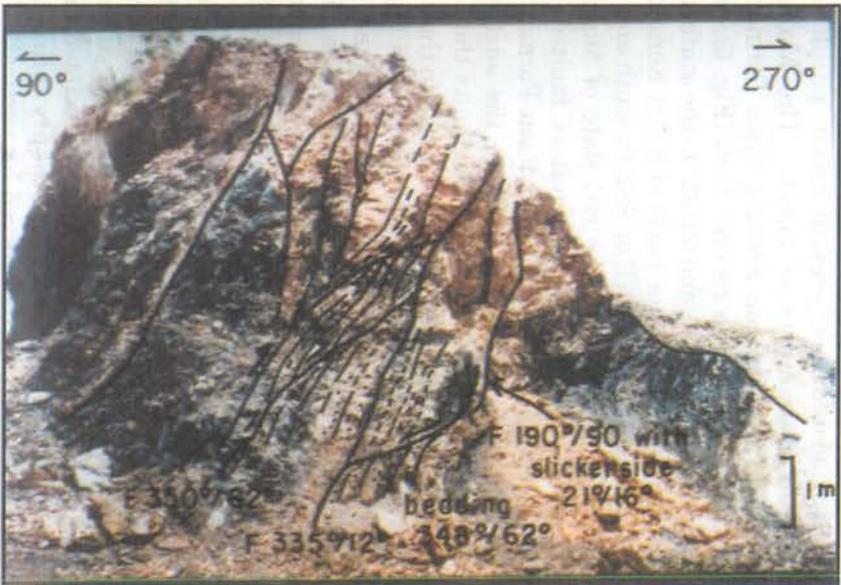


Figure 5. Flower structure in the Kubang Pasu Formation.



Figure 7. Contact between the lower part of the Kubang Pasu Formation and the slate of the Mahang Formation at Cheong Chong Kaw Estate.

position, we found that lithology is changing along the strike. The changes is due to the NW faults that cut and shifted the sequences sinistrally.

DISCUSSION AND CONCLUSION

Structural style within the Mahang Formation is not much different from the structural style of the Kubang Pasu Formation (Fig. 9, 10). The strike of the foliation of the Mahang Formation is ranging from NW to NNE with gently to steeply dipping either to the east or to the west. Bedding of the Kubang Pasu Formation moderately to steeply dips either to the west or to the east and the strike ranges from NNW to NNE. Based on the cross-section of the area, it can be deduced that there are big gentle open folds to asymmetrical folds and some parts are perhaps to be tightly folded. The big gentle open folds and small scale tight fold were observed in the Kubang Pasu Formation. These folds are interpreted to be fault related because they were normally found adjacent to the faults.

Both formations were affected by the sinistral and dextral faults movements. The NW to N and WNW sinistral faults often contain low angle plunging ($< 10^\circ$) slickensides and an almost pure strike-slip movement is suggested. However oblique-slip is also indicated by gently to moderately plunging slickensides on the sinistral fault surfaces as well as on the dextral fault surfaces. Dextral faults were often found to be shifted sinistrally by the NW lateral faults.

Strikes of reversal movement in the Mahang Formation are concentrated in two sectors; i.e. the

NNW to N and the NE sectors (Fig. 9, 10). The fault planes of NNW to N sectors are gently to steeply dipping towards the east and the west. The fault planes of the NE sector dip either to NW or to SE. The slickensides is plunging gently to steeply towards ESE to SE. The strike of the reverse faults in the Kubang Pasu Formation seems to be concentrated within a NW to NNE sector and dip towards the east. The slickensides gently (10°) to moderately (about 55°) plunge towards east and SE to SSW.

Both analyses from the Mahang Formation and the Kubang Pasu Formation show that parts of the reverse fault sectors are overlapping with the strike-slip fault (sinistral and dextral) sector. These analyses indicate the oblique lateral faults movements with reversal components.

The NW to N striking faults exhibit combination of movements of sinistral slip and thrusting. The evidence of combination merging movements along the sinistral and the low thrust fault planes are indicated by the shallow and moderately plunging slickensides on these surfaces. Vertical cross section shows that the pattern of the faults diverges from steeply dipping fault to low angle faults where reverse-oblique movements are dominated. The pattern is known as a positive flower structure (Fig. 3) which is commonly found in transpressional zone of the strike-slip region (Naylor *et al.*, 1986; Sylvester, 1988). The combination of these movements in the transpression zone has brought up the slate of the Mahang Formation thrusting onto the younger Kubang Pasu Formation in the Pokok Sena area (Fig. 3).

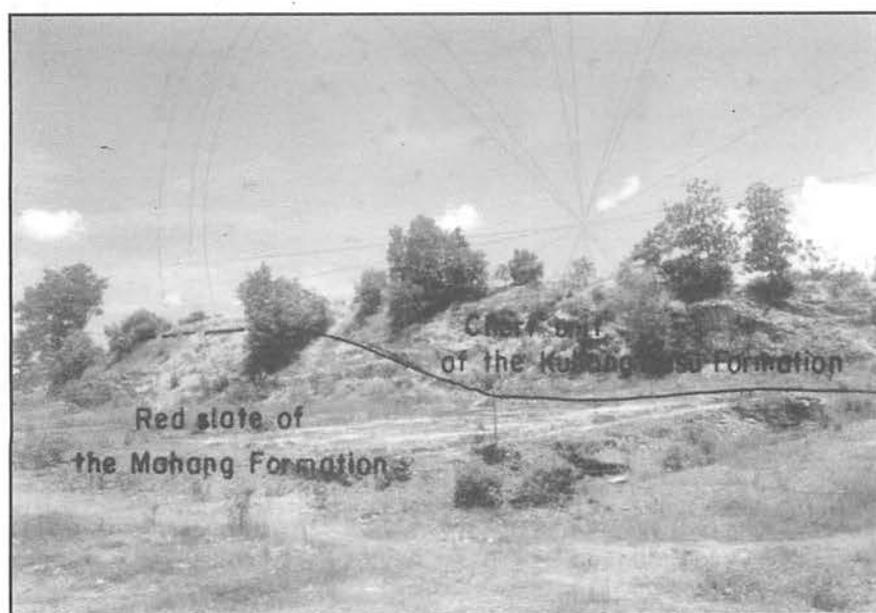


Figure 8. The chert of the Kubang Pasu Formation overlying the slate of the Mahang Formation.

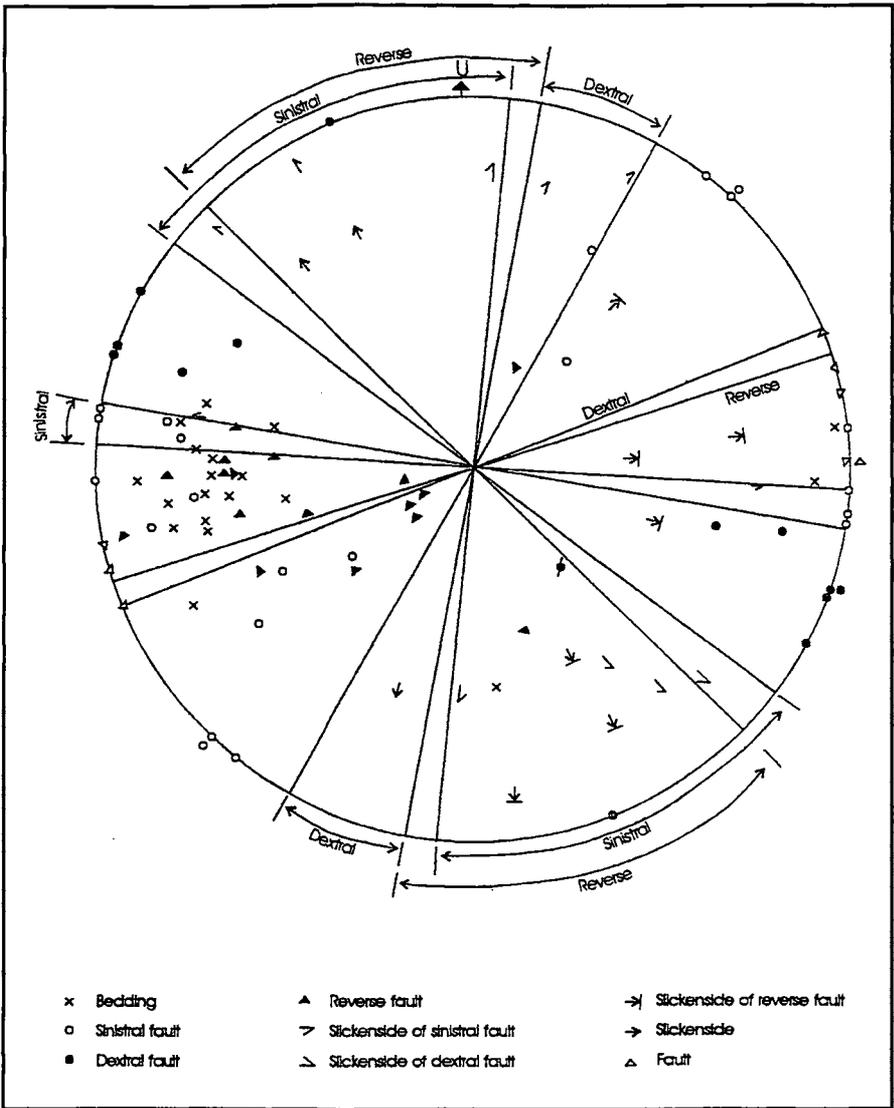


Figure 9. Equal-area stereographic plot of poles to structural planes (bedding, fault) and slickensides of the Kubang Pasu Formation. Number of readings is 102.

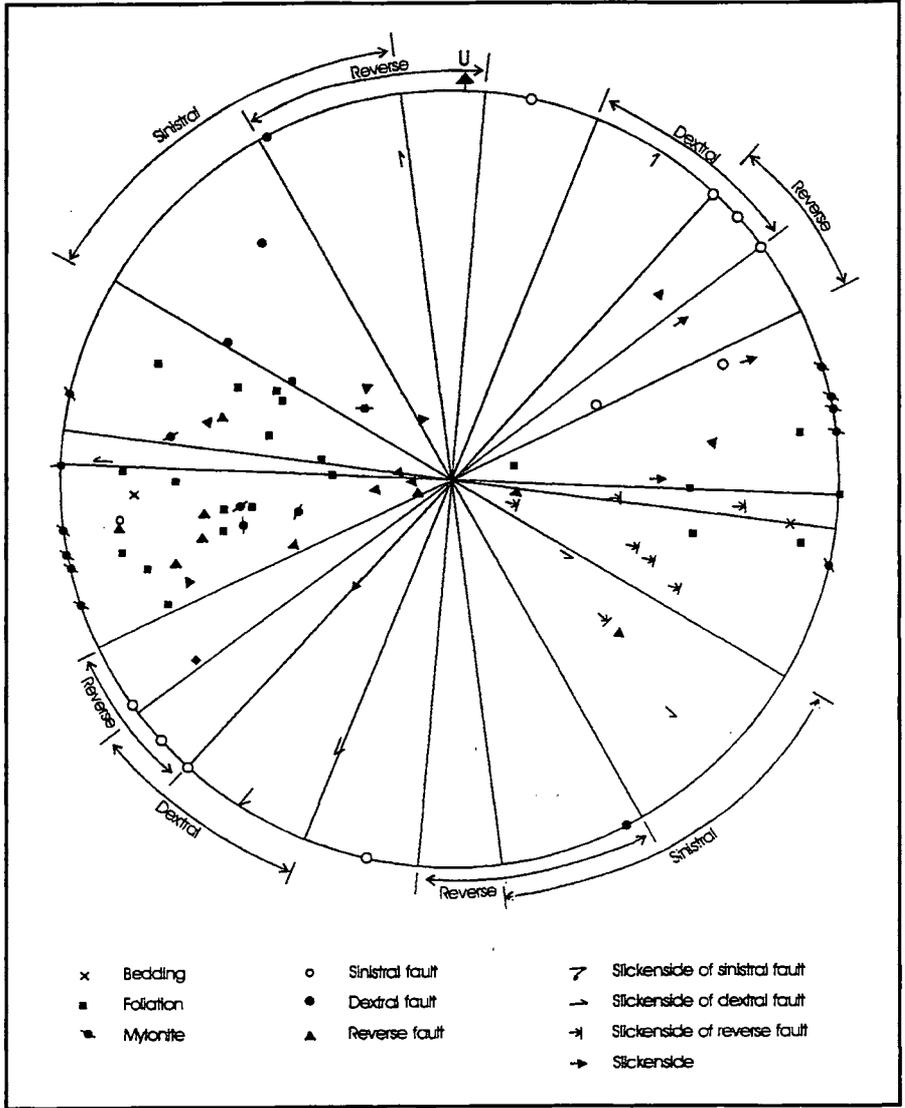


Figure 10. Equal-area stereographic plot of poles to structural planes (bedding, foliation, mylonite, fault) and slickensides of the Mahang Formation. Number of readings is 90.

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