Geol. Soc. Malaysia, Bulletin 28, November 1991; pp. 165 - 194

Palaeoenvironments of the Lower Miocene to Pliocene sediments in offshore NW Sabah Area

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Abstract: A biostratigraphic reinvestigation of 108 SSPC and competitor wells was undertaken in order to review the palaeoenvironments of the Lower Miocene to Pliocene deposits in the offshore NW Sabah area.

The study was integrated with seismostratigraphic data, which defined the positions of the palaeoshelf edge/palaeocoastline, and allowed for more detailed palaeoenvironmental reconstructions. For each stratigraphic interval, palaeoenvironment maps showing the areal distribution of depositional environments were constructed. In addition, detailed biostratigraphic/seismostratigraphic correlation enabled the recognition of four "seismic facies" (base of slope, slope, shelf and coastal plain). Integration with sand distribution data allows the characterisation of the palaeoenvironments/seismic facies in terms of their reservoir potential.

INTRODUCTION

The palaeoenvironmental study encompassed the area offshore of the NW Sabah coast (Fig. 1) and included data from some 108 wells.

The study was carried out to revise the biostratigraphy and thereby gain a better understanding of the palaeoenvironmental development of the NW Sabah offshore. It also aimed at demonstrating the relationship between palaeoenvironments and their associated seismofacies in assessing the distribution of reservoir-seal pairs.

The stratigraphic framework and depositional model on which this study was based on are shown in figures 2 and 3, respectively. Biostratigraphic revision was carried out on all 108 wells. An additional check for consistency of the palaeoenvironmental interpretation was provided by BULKMAT, a computer programme designed for the probabilistic interpretation of depositional environments based on foraminiferal content.

Chronostratigraphic control was derived mainly from palynological data. Seismic data of superior quality acquired over the past decade add to the refinement of the palaeoenvironmental maps and demarcate the extent of the palaeoshelf edge and palaeocoastline.

The integration of biostratigraphic and seismostratigraphic data enabled the construction of 19 palaeoenvironmental maps. These maps, which show the lateral distribution of palaeoenvironments, are based on the dominant palaeoenvironment (i.e., thickest) penetrated within well sections for each time interval. The stratigraphic intervals were defined primarily on

Presented at GSM Petroleum Geology Seminar 1989

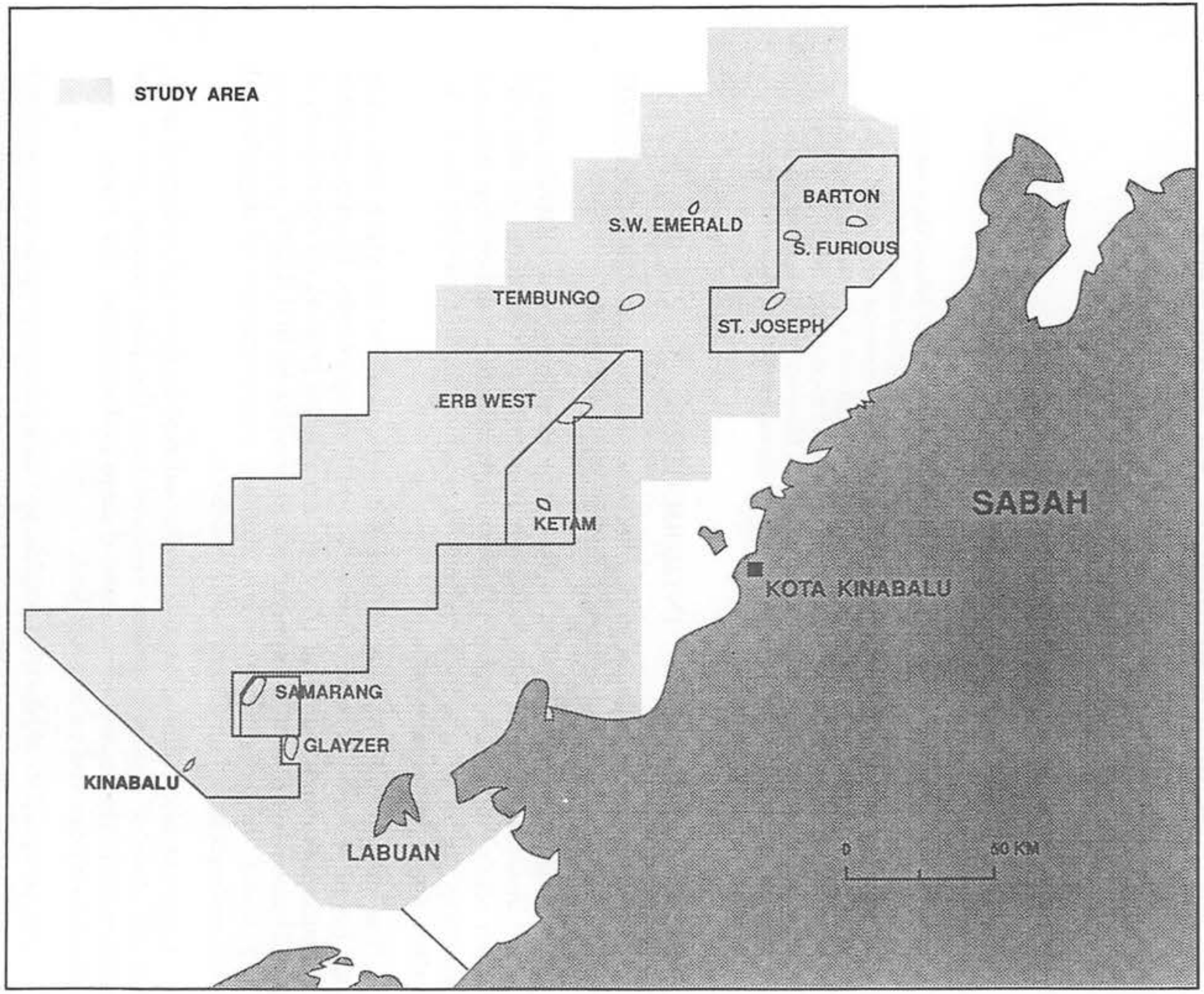

Figure 1: Map of study area

palynological zonations. In the absence of palynological data, planktonic foraminiferal and calcareous nannoplankton data were used. Further subdivision within palynological zones was carried out to provide more refined stratigraphic control.

The net thickness of potential reservoir sand within each stratigraphic interval was calculated using a petrophysical evaluation method which applied lithological cut offs.

GEOLOGICAL FRAMEWORK

The Tertiary sediments of NW Sabah are divided into four main sedimentary units designated Stages I-IV. In the study area, only 2 of the 4 sedimentary stages are of concern, namely, Stages III and IV (Fig. 2). NW Sabah, in general, is an extensive post-collisional outbuilding continental margin (Bol and Van Hoorn, 1980). Deposition of Stage III sediments, prior to early Middle Miocene, was in deep marine environments. Subduction processes along the continental margin ceased in the early Middle Miocene and were followed by rapid and massive north-westerly progradation of a marine slope and shelf assemblage across the old collision zone. The thick Stage IV sequence, with high sedimentation rates, reflected the strong hinterland uplift and erosion that prevailed throughout the Late Miocene-Recent.

The early Middle Miocene and younger sediments of Stage IV are characterised by syn-depositional tectonic deformation. Tectonic pulses, which followed quieter periods of coastal/coastal plain sedimentation, gave rise to a series of unconformities: the Lower Intermediate Unconformity (LIU) in the late Middle Miocene, the Upper Intermediate Unconformity (UIU), Shallow Regional Unconformity (SRU) and Horizon III in the Late Miocene and Horizons II and I in the Pliocene and Pleistocene, respectively. These unconformities define a series of substages (IVA-IVG) and pass from an erosional surface in the southeast to an onlap surface or conformable horizon towards the northwest.

Based on the differences in structural style and sedimentation history, NW Sabah has been divided into 6 tectonostratigraphic units (Fig. 4). Five of the six units are of concern in the study area and will be discussed very briefly.

Inboard Belt

The Inboard Beld occupies the long stretch of area to the west of and parallels the present coastline with its seaward margin defined, in the south, by the Morris Fault and in the north by a line passing slightly landward of the Hankin, Erb West, SW Emerald and Bonanza areas. It is characterised by intense compressional wrench features separated by deep, wide synclines. The Inboard Belt can be further subdivided into three subprovinces, viz., southern, central and northern Inboard Belts.

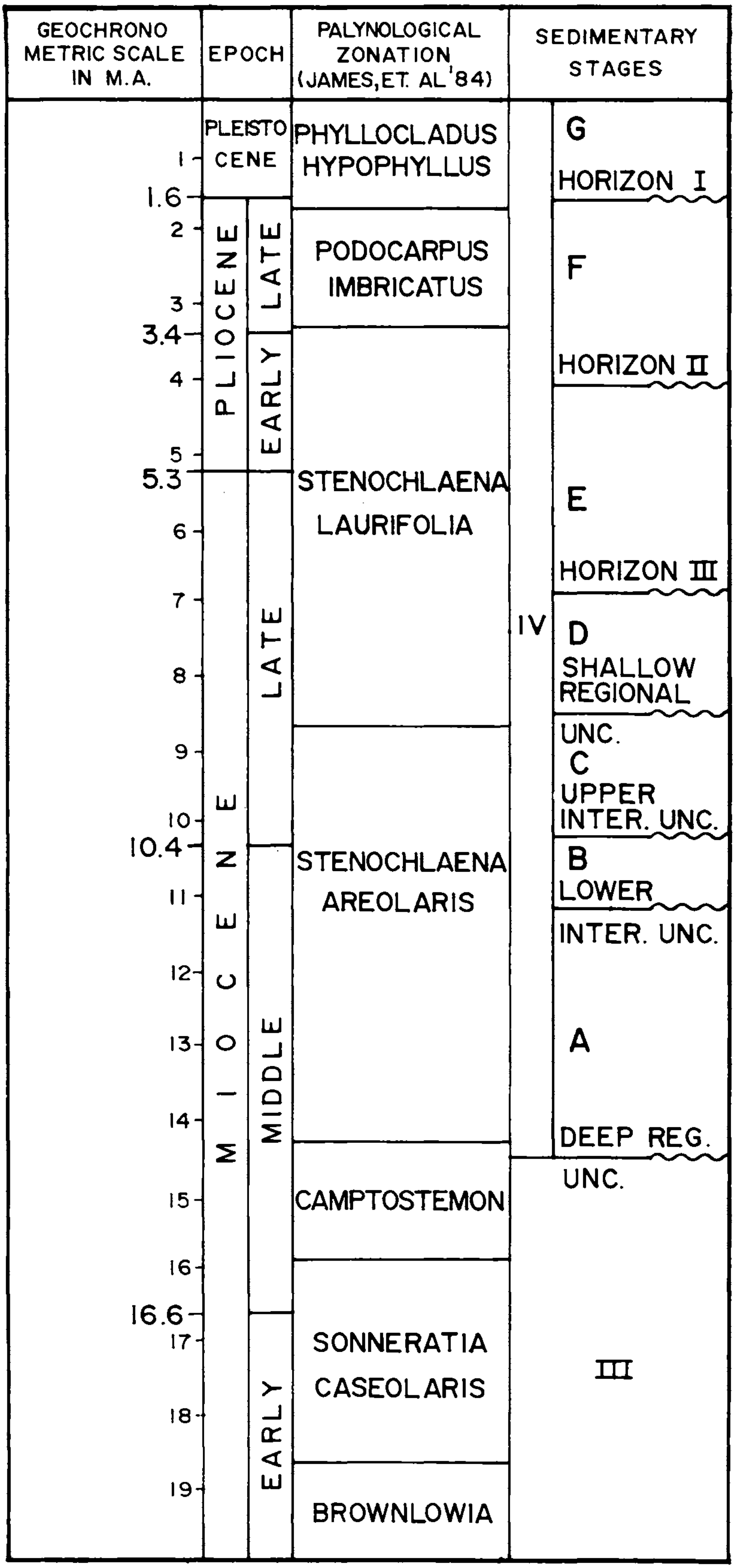

Figure 2: Generalised stratigraphic scheme of NW Sabah

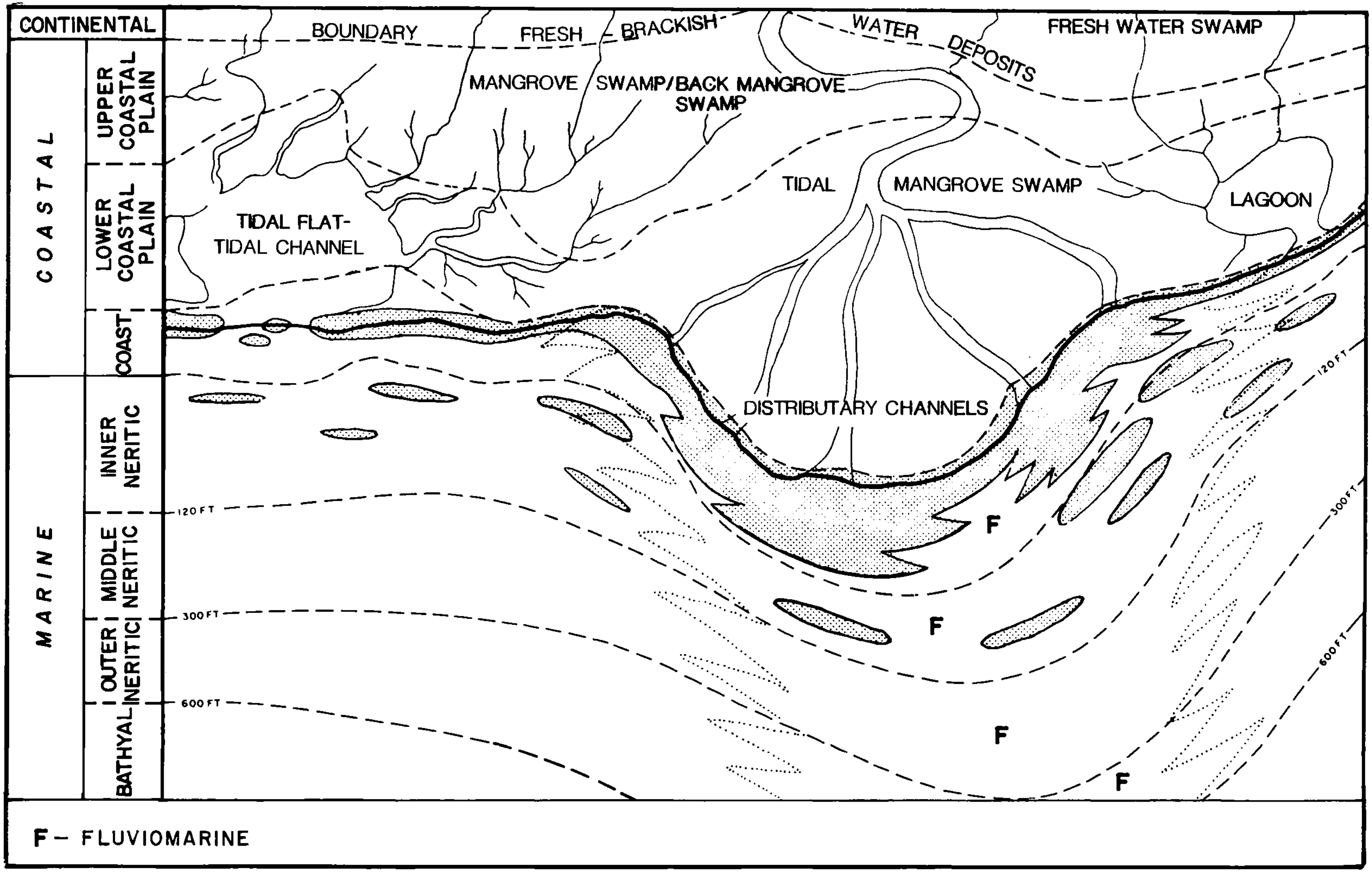

Figure 3: Schematic outline of NW Borneo environmental units

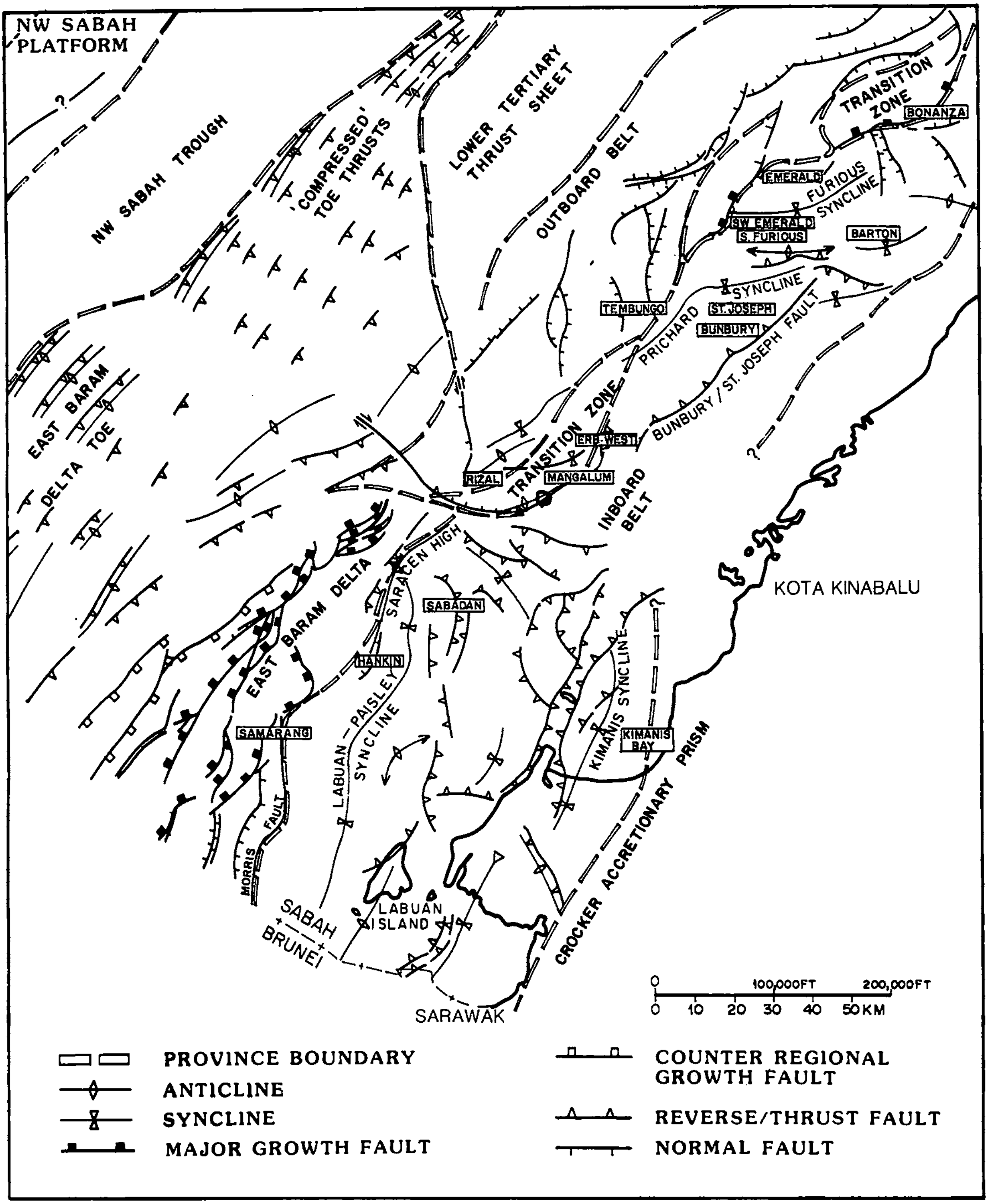

Figure 4: Simplified structural map

The southern Inboard Belt covers the area south of Sabadan and Kimanis Bay with the main tectonic lineaments trending N-S about 5-20 km apart. In the eastern part of the sub-province they form a series of parallel, narrow wrench-related uplifts with steep flanks and strongly faulted crests that were active during the Middle and Late Miocene and were finally uplifted in the Pliocene. The Morris Fault, which bounds the Inboard Belt to the west, is an en-echelon system of normal faults.

The central Inboard Belt covers the area between Sabadan and Kimanis Bay, in the south and Tembungo and Bunbury in the north. This sub-province is tectonically more complex than the southern area due to the interaction of both WNW-ESE and N-S trending tectonic lineaments. Compressional wrenching across both lineaments occurred principally in three phases in the Middle to Late Miocene. The net result was the formation of domal, faulted fold interference patterns.

The northern Inboard Belt covers the area north of the Central Inboard Belt. It is characterised by intersecting lineaments, in this case, NE-SW and E-W. In contrast with the central Inboard Belt, the lineaments are more widely spaced.

Outboard Belt

This belt extends from the latitude of Mangalum to Philippines waters and is a structurally complex area characterised by compressional folding and strike-slip faulting associated with mobile clay movements.

Transition Zone

The Transition Zone lies between the Inboard and Outboard Belts and is an area of deltaic sedimentation affectedby both compressional and extensional tectonics.

Eastern Baram Delta

The Eastern Baram Delta, which is well developed in the eastern part of offshore Brunei (James, 1984), extends into southern Sabah in the area west of the Morris Fault system and on strike with the Outboard Belt in the north. This region his characterised by typical delta tectonics, in places modified by deep-seated wrenching.

NW Sabah Margin (Fold Belt)

Beyond the Eastern Baram Delta and the outer region of the Outboard Belt, a series of large, assymetrical, over-thrusted anticlines and ridges occur, possibly associated with deep-seated shale ridges.

SEISMOSTRATIGRAPHY

Seismic facies recognition and interpretations were carried out by J-M. Lamy who had earlier done the seismostratigraphic evaluation of Block SB-1. A large amount of seismic data were evaluated, although these were restricted mainly to Block SB-1.

High confidence seismic facies interpretation is more or less confined to substage IVC and younger sediments due to lack of seismic definition with depth. This is due, in part, to the fact that the older sediments are strongly tectonised.

Four basic seismofacies are recognised (Figs. 5 and 6):

1. Discontinuous parallel topsets of variable amplitude (high-low) and relatively high frequency. These facies are representative of sediments deposited in the coastal plain and are usually sand-prone.
2. Continuous to semi-continuous parallel topsets of relatively high to moderate amplitude and frequency. These facies are representative of sediments deposited on a shelf and may range from sand-prone to shale-prone facies.
3. Clinoforms (foresets) represented by sigmoid and oblique seismic reflection patterns in association with reflection free seismic facies, with generally low amplitude. These represent desiments deposited on a gently sloping depositional surface beyond the shelf edge. Differences in prograding clinoform patterns result largely from variations in rate of deposition and water depth. These sediments are generally shale-prone. However, clinoforms may be associated with high amplitude and high frequency events interpreted as turbiditic sediments, which are often sand-prone.
4. Continuous parallel bottomsets of variable amplitude and frequency and associated with shale/silt-prone sediments deposited at the base of the slope under low energy conditions. Locally, these may be associated with distal turbidites.

All four facies are represented on a seismic section (Fig. 5) which crosses the Labuan Syncline. Well data shows that the first seismic facies corresponds to the lower coastal plain environments (Fig. 6). The discontinuous, hummocky reflectors may well represent channeling within the lower coastal plain environment. This discountinuous seismic facies is distinguishable from the second seismic facies-continuous topset facies, which is usually associated with coastal or shallow marine deposits. Well data show that the continuous topset facies represent sediments deposited on the coast.

Seismic facies 3 and 4 correspond to holomarine outer neritic-bathyal sediments (Fig. 6). Deep marine sands or tubidites, as interpreted from faunal

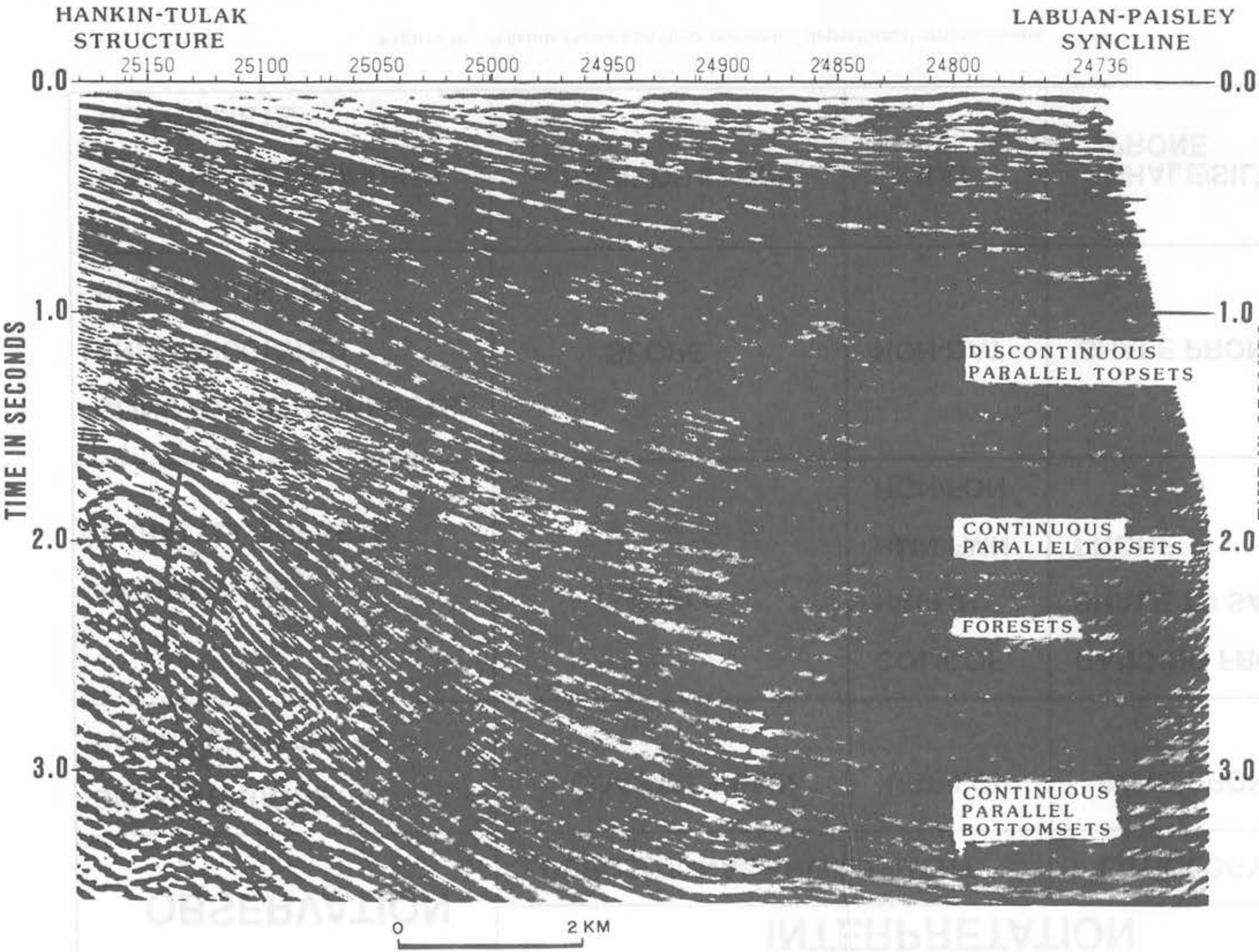

Figure 5: Seismic line across the Labuan Syncline showing the four basic seismic facies recognised in the study area.

OBSERVATION	INTERPRETATION		
	DEPOSITIONAL ENVIRONMENT		LITHOLOGY
DISCONTINUOUS PARALLEL TOPSETS	COASTAL PLAIN	UCP/LCP	SAND PRONE
CONTINUOUS PARALLEL TOPSETS	SHELF	COL/COF HIN/FIN HMN/FMN HON/FON	RANGING FROM SHALE TO SAND PRONE
CLINOFORMS (FORESETS) AND ASSOCIATED REFLECTION FREE	SLOPE	HON-BAT	SHALE PRONE
CONTINUOUS PARALLEL BOTTOMSETS	BASE OF SLOPE	BAT	SHALE/SILT PRONE

Figure 6: Seismic facies and their correlated depositional environments

content, may be seen within these sediments as high amplitude, high frequency events.

Fluvial and non-fluvial deposits cannot be differentiated on seismostratigraphic criteria (Vail *et al.*, 1987). Variations within the seismic packages are too subtle for interpretation. Differentiation of shelf sediments into inner, middle and outer neritic, based on reflection configuration is also not possible for the same reason, as all shelf sediments are represented by continuous topsets. These distinctions can only be made through analysis of foraminiferal assemblages.

The maximum shelf progradation based on the seismofacies study, from substages IVA-IVF, was mapped. The palaeoshelf edge serves as a guide for "dividing" the shelf into inner, middle and outer neritic environments in areas where well control is scarce. The palaeoshelf edge also gives a rough indication of the strike of the palaeocoastline, which is usually parallel to it. Identification of the palaeocoastline by seismostratigraphy is restricted to substages IVC and younger sediments in Block SB-1.

PALAEOENVIRONMENTAL EVOLUTION

Nineteen stratigraphically arranged palaeoenvironmental maps were constructed from the biostratigraphic and seismostratigraphic data. Figure 7 shows the time intervals (indicated in grey strips) which represent ten of the total palaeofacies maps (Figs. 8-17) presented in this report. These ten maps were selected to show the most palaeoenvironmental change. A generalised palaeobathymetry curve is plotted against the stratigraphic scheme (Fig. 7).

Early Miocene-early Middle Miocene
Stage III (Fig. 8)

The whole of offshore NW Sabah was a realm of deep marine shale deposition during the Early Miocene-early Middle Miocene (Fig. 8). In southern and central Inboard Belt, faunal and sedimentological data from a number of wells show that these deep marine shales alternate locally with turbiditic sand intervals. The presence of these turbiditic intervals may be attributed to the unstable slope conditions and high sediment supply which resulted from the uplift and erosion of the older sediments to the east and south of the Inboard Belt. On the mainland, the coast was prograding in a northwesterly direction, as seen from outcrop data. The extent of this coastal progradation is not known in the adjacent offshore areas due to the scarcity of well data.

Towards the end of Stage III, prior to the deposition of Stage IV, tectonic activity related to subduction processes led to a period of regional uplift and erosion of the older deep marine sediments. This period of uplift/erosion was marked by the Deep Regional Unconformity (DRU), a major unconformity

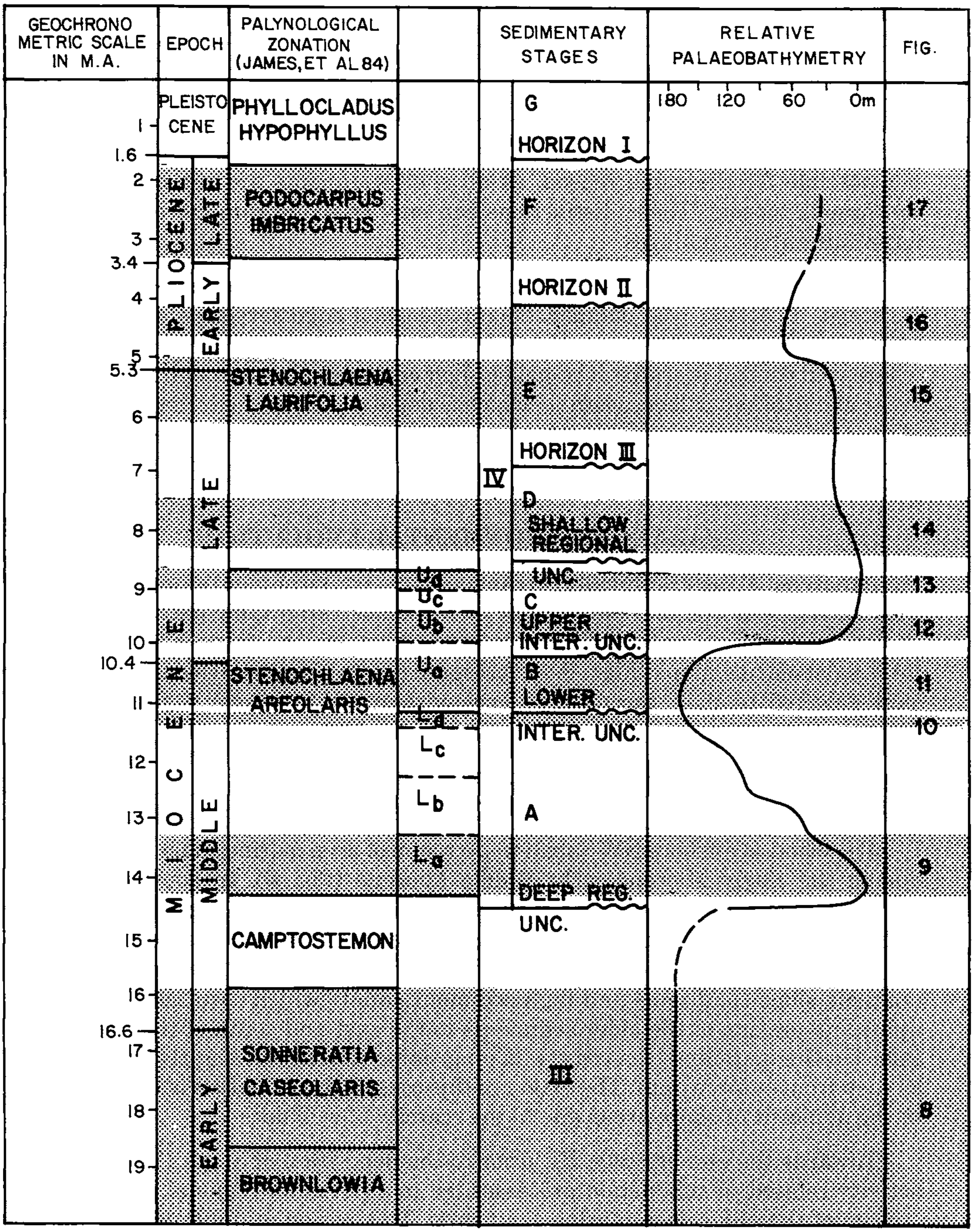

Figure 7: Time interval of selected palaeoenvironmental maps

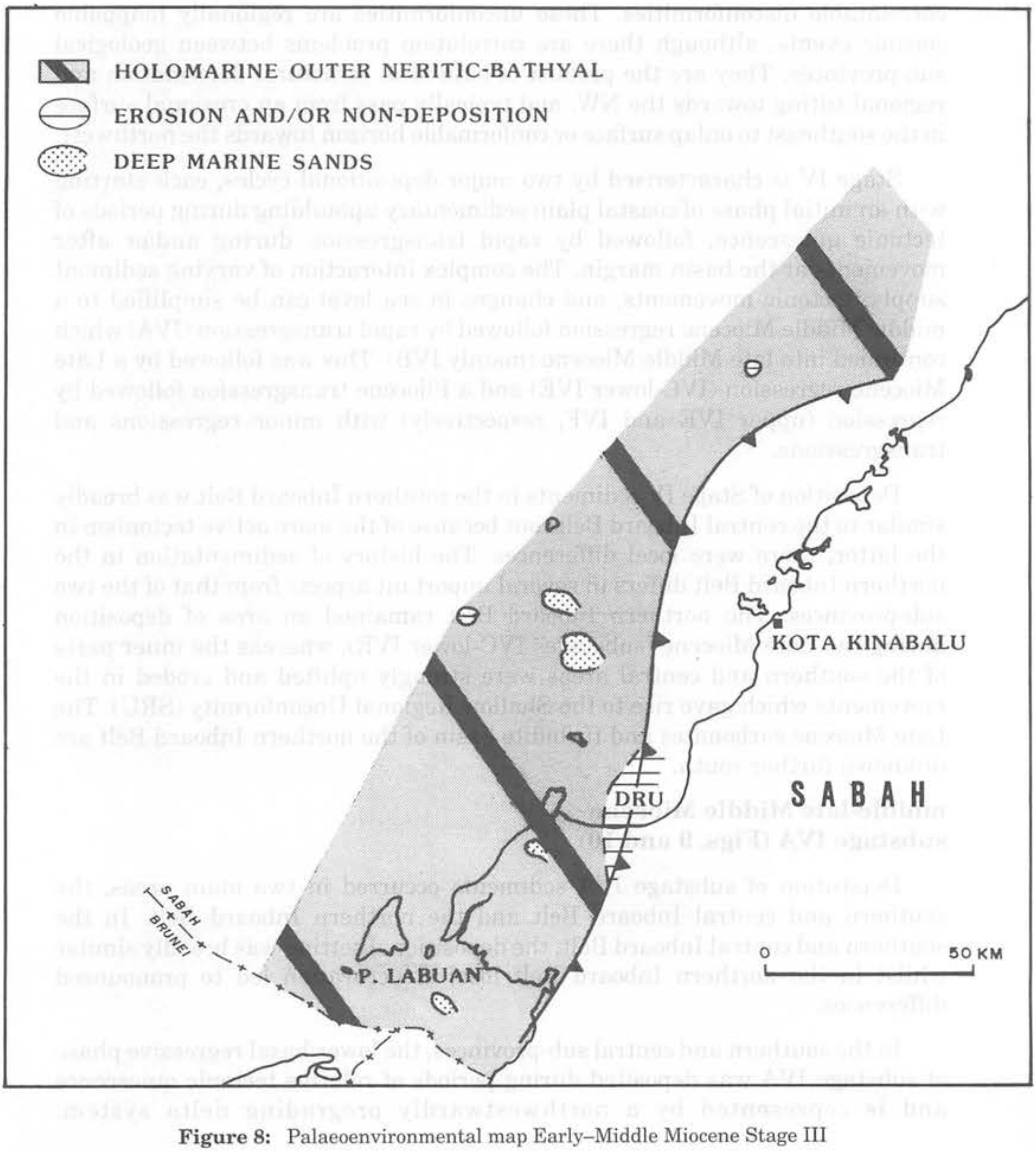

Figure 8: Palaeoenvironmental map Early–Middle Miocene Stage III

which separated Stage III sediments from the younger Stage IV sediments.

middle Middle Miocene-Pliocene
Stage IV (Figs. 9 - 17)

The middle Middle Miocene to Pliocene Stage IV sediments are divided into 6 substages, lettered A-F, each separated by unconformities or their correlatable disconformities. These unconformities are regionally mappable seismic events, although there are correlation problems between geological sub-provinces. They are the product of both local structural deformation and regional tilting towards the NW, and typically pass from an erosional surface in the southeast to onlap surface or conformable horizon towards the northwest.

Stage IV is characterised by two major depositional cycles, each starting with an initial phase of coastal plain sedimentary upbuilding during periods of tectonic quiescence, followed by rapid transgression during and/or after movements at the basin margin. The complex interaction of varying sediment supply, tectonic movements, and changes in sea level can be simplified to a middle Middle Miocene regression followed by rapid transgression (IVA) which continued into late Middle Miocene (mainly IVB). This was followed by a Late Miocene regression (IVC-lower IVE) and a Pliocene transgression followed by regression (upper IVE and IVF, respectively) with minor regressions and transgressions.

Deposition of Stage IV sediments in the southern Inboard Belt was broadly similar to the central Inboard Belt, but because of the more active tectonism in the latter, there were local differences. The history of sedimentation in the northern Inboard Belt differs in several important aspects from that of the two sub-provinces. The northern Inboard Belt ramained an area of deposition during the Late Miocene (substages IVC-lower IVE), whereas the inner parts of the southern and central areas were strongly uplifted and eroded in the movements which gave rise to the Shallow Regional Unconformity (SRU). The Late Miocene carbonates and turbidite basin of the northern Inboard Belt are unknown further south.

middle-late Middle Miocene
substage IVA (Figs. 9 and 10)

Deposition of substage IVA sediments occurred in two main areas, the southern and central Inboard Belt and the northern Inboard Belt. In the southern and central Inboard Belt, the depositional setting was broadly similar whilst in the northern Inboard Belt local structuration led to pronounced differences.

In the southern and central sub-provinces, the lower/basal regressive phase of substage IVA was deposited during periods of relative tectonic quiescence and is represented by a northwestwardly prograding delta system.

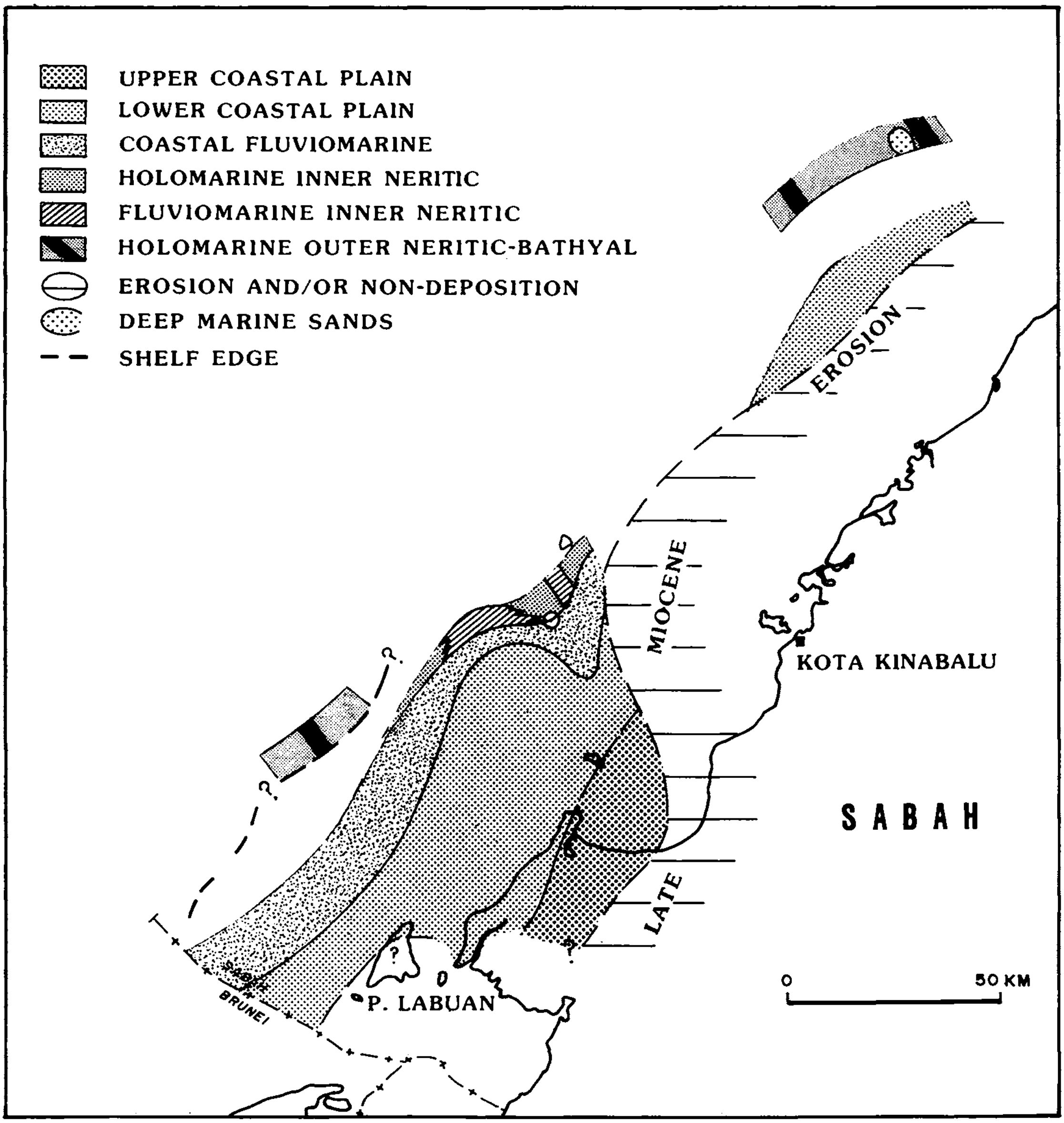

Figure 9: Palaeoenvironmental map Middle Miocene substage IVA

Figure 10: Palaeoenvironmental map Middle Miocene substage IVA/B

Sedimentation occurred in a coastal-coastal plain setting.

The remaining sediments of substage IVA comprise a thick interval with facies representing a variety of palaeoenviroments. Further subdivision within the lower part of the *Stenochlaena areolaris* (palynological) Zone was attempted to enable a finer and more meaningful stratigraphic breakdown of depositional environments within the thick substage IVA sequence. This palynological subdivision was done on the basis of correlatable palynological data and resulted in a four-fold subdivision (noted as L_a-L_d).

In the southern and central Inboard area (Fig. 9), deposition initially took place in a coastal-coastal plain environment (within subzone L_a). Faunal data show that a small delta developed in the central Inboard Belt. This was followed (Fig. 10) by rapid, southwestward transgression over the whole Inboard are (subzones L_b-L_d). This transgression was related to subsidence in the basin area and continued deepening resulted in the landward shift of the palaeoshelf edge.

In the northern Inboard Belt, the transgressive phase of substage IVA is not apparent (Figs. 9 and 10). Instead, about 6000 ft of continuous lower coastal plain sediments were deposited on an apparently stable but rapidly subsiding shelf, where the rate of subsidence and sedimentation were balanced. The vertical continuity of these thick coastal plain sediments can be recognised seismostratigraphically. At the northern Outboard/Inboard boundary, about 14 km away from the lower coastal plain, sedimentation took place in a deep marine setting. This rapid change of palaeobathymetry suggests a narrow, shallow shelf. Movements along fault zones were responsible for the oversteepening of the shelf. Deposition of the coastal-coastal plain sediments over active fault zones (e.g. Bunbury-St. Joseph) resulted in the formation of tectonically unstable marine slopes which slumped and caused deposition in a deep marine environment.

late Middle Miocene-early Late Miocene substage IVB (Fig. 11)

The relatively thin substage IVB interval is a marine transgressive sequence characterised by syn-sedimentary tectonic movements. In most wells substage IVB were eroded (Upper Intermediate Unconformity-UIU).

The deep marine sedimentation of substage IVB sediments occurred at the peak of a marine transgression which initiated in the middle Middle Miocene, during deposition of substage IVA sediments. These deep marine shales were deposited over an extensive area in the Inboard Belt and alternate locally with turbidites (Fig. 10). As indicated from well and seismostratigraphic data, these turbidites resulted from slope instability (high rate of sedimentation in an actively subsiding basin) (Levell & Kasumajaya, 1985).

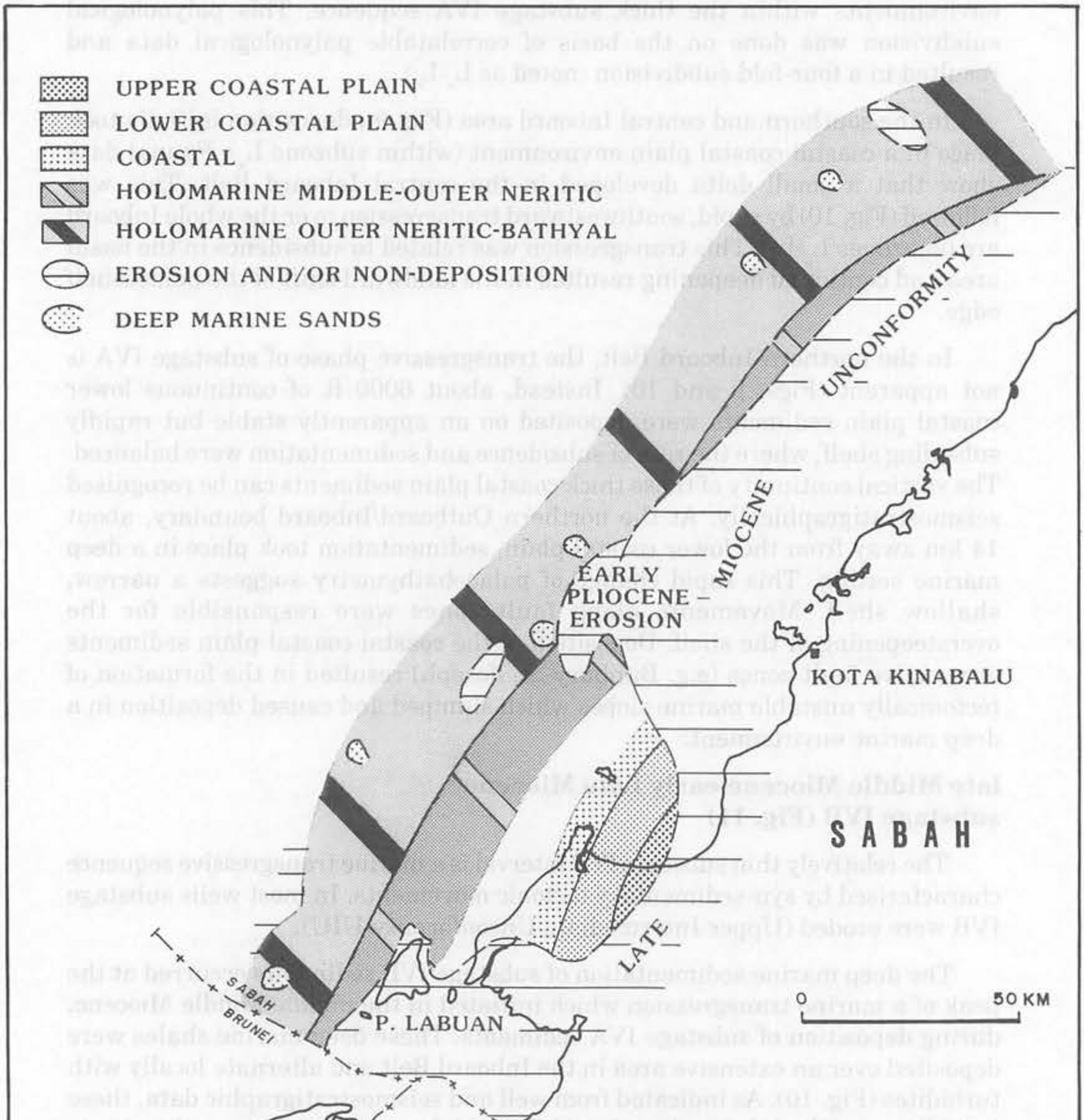

Figure 11: Palaeoenvironmental map Late Miocene substage IVB

An important tectonic event followed the end of the Middle Miocene. This event, initiated in the southwestern Sabah mainland, resulted in the deformation of sediments into tight, partly reverse faulted anticlines (Sabah Ridges). This event is denoted the Upper Intermediate Unconformity (UIU) and marks the beginning of an active regressive period in the southern and central Inboard Belt.

early Late Miocene
substage IVC (Figs. 12 and 13)

Further subdivision of the upper part of the *Stenochlaena areolaris* Zone (upper part) was carried out to enable finer breakdown of substage IVC sediments. The subdivision resulted in four subzones, noted U_a-U_d.

Substage IVC was deposited during a time of active regression. Sedimentation of deep marine shales continued from preious substage into the earlier part of this substage (subzone U_a). In the southern and central Inboard Belt, the palaeoshelf edge moved basinwards. This was followed by a phase of rapid regression (subzones U_b-U_d). This regressive phase is characterised by a large, northwesterly prograding delta system, developed initially in the south (Fig. 12).

The well developed deltaic progradation in the southern Inboard Belt can be traced from the southeastern areas into the Labuan Syncline and is particularly well illustrated on seismic where a topset sequence prograding over clinoforms can be interpreted. The accreting foresets show that the rate of subsidence initially balanced sedimentation. Subsequently, a decrease in subsidence led to rapid northwestwards progradation of a major delta system towards the Samarang area. This outbuilding is maintained by uplift of the hinterland and erosion of older foresets.

The uplifting of the hinterland is related to an important tectonic phase initiated on the southwestern Sabah mainland in the Inboard Belt at the beginning of the Late Miocene (UIU). The northern Inboard Belt remained largely unaffected by these tectonic movements, which are seen to be restricted to a zone east of the St. Joseph-Bunbury trend.

By the end of substage IVC, the palaeoshelf edge had shifted further basinward. The palaeoshelf edge, as defined on well and seismostratigraphic data, lay NE-SW with a marked incurvation along the trend of the Rizal-Mangalum fault zone which coincides with an important NNW-SSE shear zone. To the west of the palaeoshelf edge, substage IVC sediments are represented by deeper marine to bathyal facies.

The regressive nature of substage IVC is not apparent in the northern Inboard Belt (Figs. 12 and 13). A small delta developed in the Bunbury-St. Joseph area during lower substage IVC deposition (subzones L_a-L_d) but was

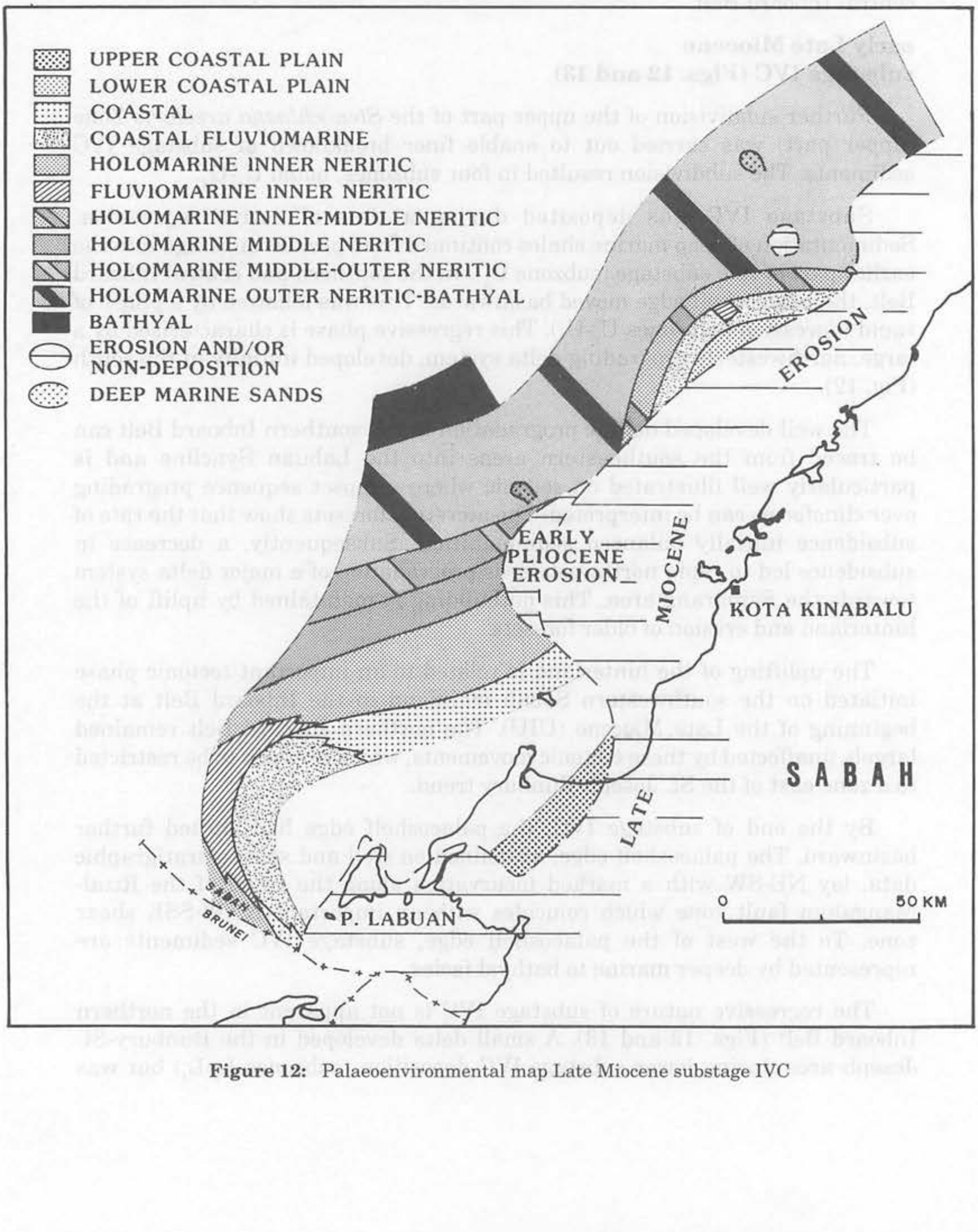

Figure 12: Palaeoenvironmental map Late Miocene substage IVC

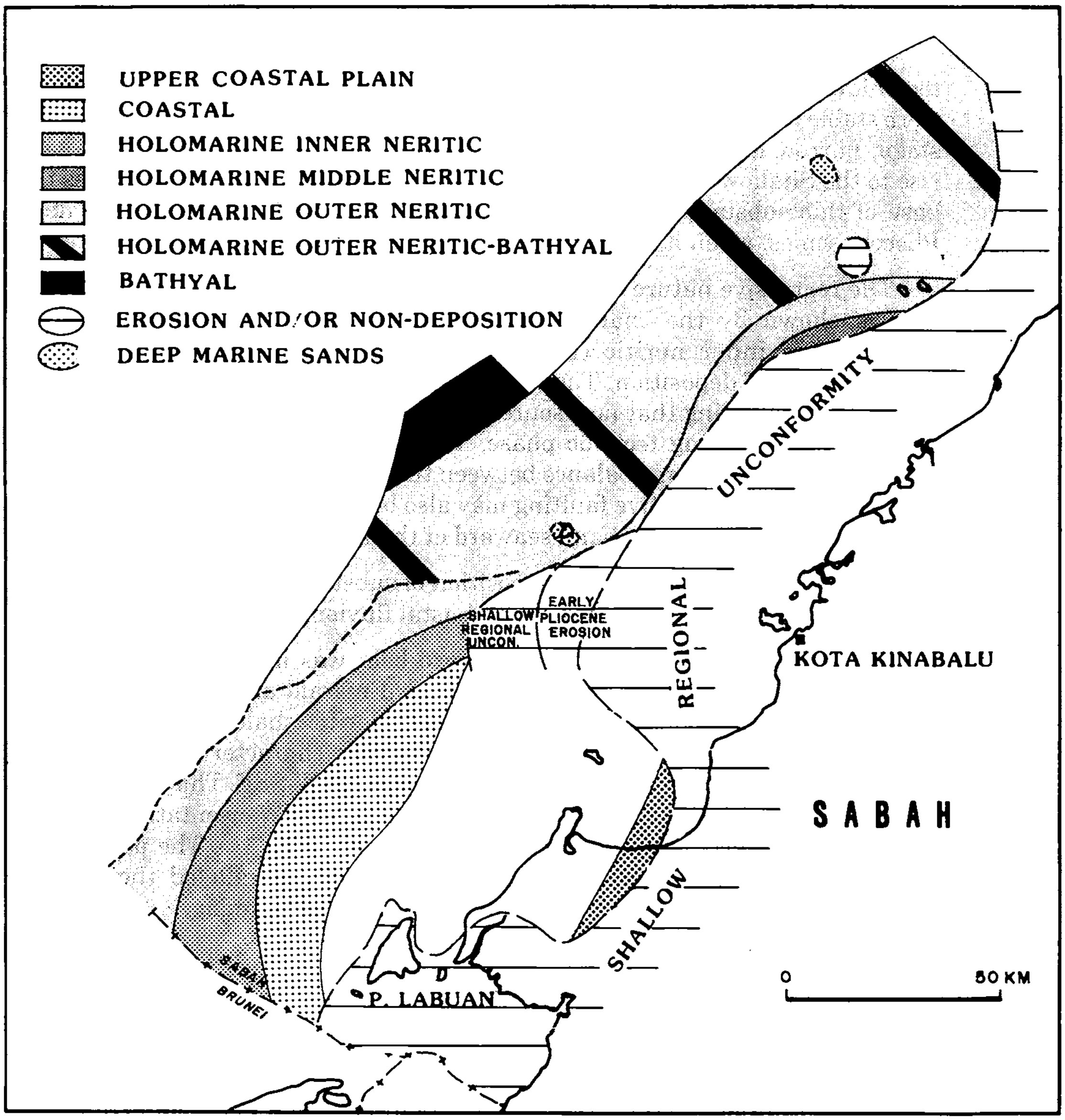

Figure 13: Palaeoenvironmental map Late Miocene substage IVC

later inundated towards the end (subzone L_d). The area east of S. Furious and Barton was flooded initially by a shallow sea in which reefoid limestones formed, apparently unhindered by the run-off from the nearby hinterland. Subsequently, the area deepened, terminating reef growth.

middle Late Miocene substage IVD (Figs. 14 and 15)

Substage IVD is another regressive phase during a period of relative tectonic quiescence. The areas south and east of Mangalum and east of Bunbury were stable areas of non-deposition and active erosion. Subsequent uplift of the steep, narrow anticlines formed during the deposition of substage IVC gave rise to the Shallow Regional Unconformity, an unconformity which defines the base of this substage. This erosional surface remained above sea level until Pliocene times, when it was overstepped by substage IVF sediments.

The regressive nature of substage IVD sediments in the southern Inboard Belt is shown by the change, laterally and vertically, from holomarine/fluviomarine inner neritic (Fig. 14) into coastal fluviomarine (Fig. 15) environments of deposition. The progradation of the shelf sediments was not extensive considering that new source areas for sediment supply were created during the preceeding tectonic phase. The lack of pronounced progradation may have resulted from a balance between the rate of sediment supply and the rate of sea level rise. Active faulting may also be responsible since it restricted sedimentation to a narrow band seaward of the Inboard/Outboard boundary.

In the central Inboard area, deposition of substage IVD sediments formed a southeasterly onlapping sequence of coastal fluviomarine sediments.

Substage IVD, in the northern Inboard belt, was initially deposited in a deep marine environment. In the Tembungo, Emerald and W Emerald area, the base of IVD consists of middle to outer neritic shales and deep water sandstones, some of them with excellent reservoir characteristics. Well data suggest that the strike of the palaeocoastline was NNW-SSE. This was followed by a clock-wise rotation of the palaeocoastline to a NE-SW orientation with the rapid northwesterly progradation of a delta system (Fig. 14). The palaeoshelf edge at the end of substage IVD (Fig. 15) roughly paralleled the present coastline along the area west of the Inboard/Outboard boundary.

middle Late Miocene-Early Pliocene Substage IVE (Figs. 15 and 16)

Substage IVE is a transgressive sequence. The sediments of substage IVE are poorly represented in the Inboard area.

In the southern and central Inboard Belt, substage IVE sediments were deposited in a coastal to shallow marine environment (Fig. 15).

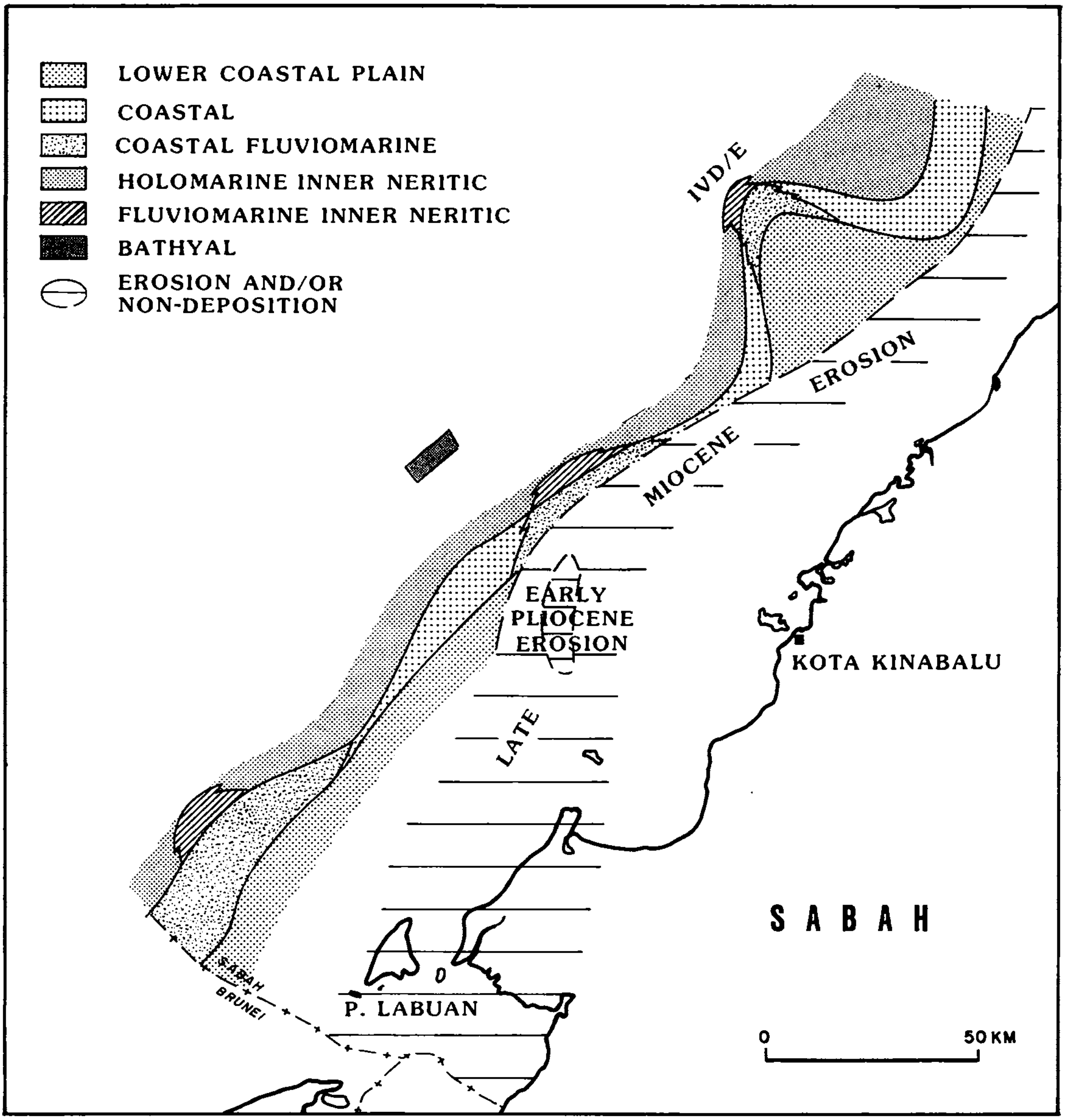

Figure 14: Palaeoenvironmental map Late Miocene substage IVD

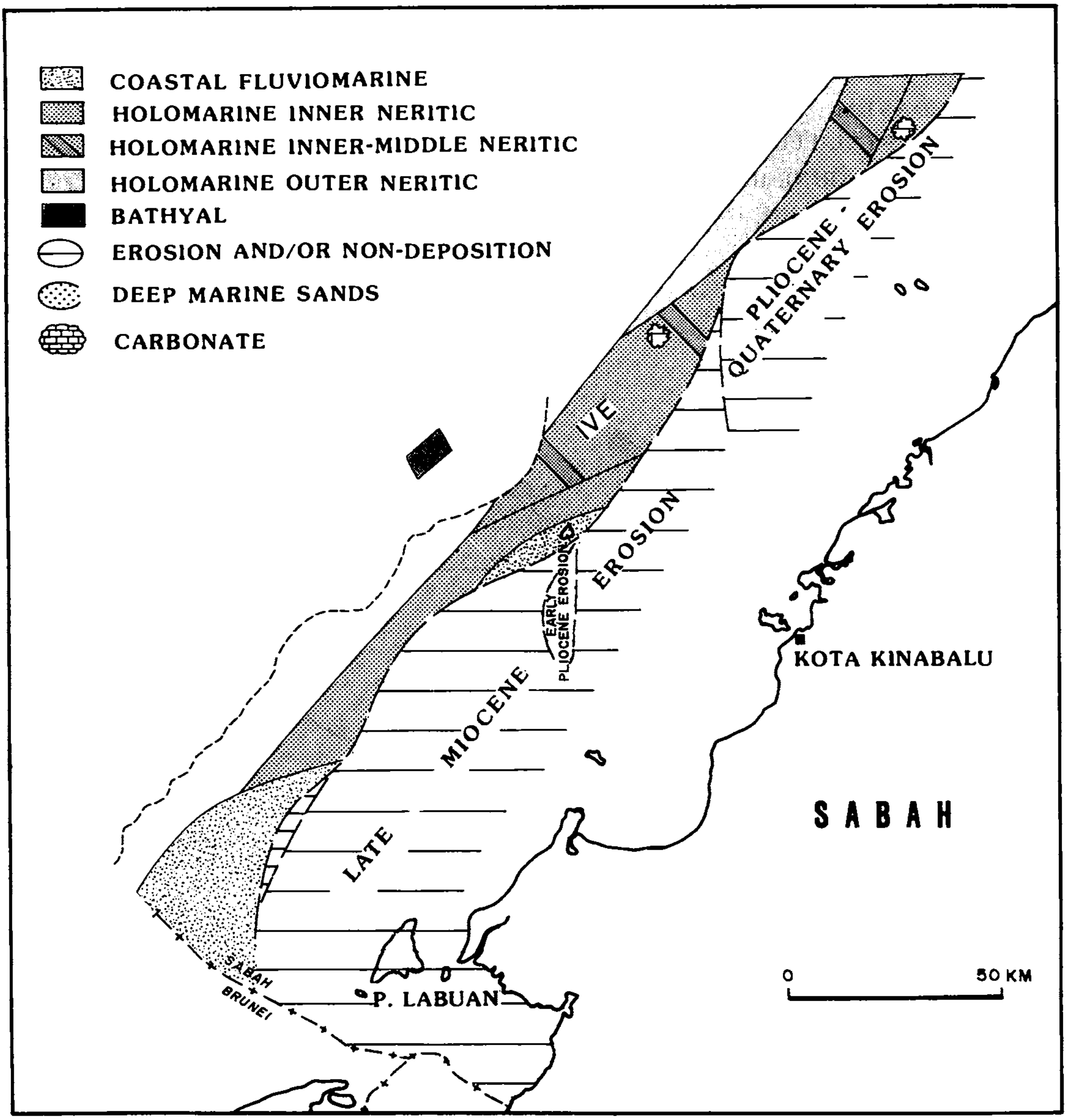

Figure 15: Palaeoenvironmental map Late Miocene substage IVD/E

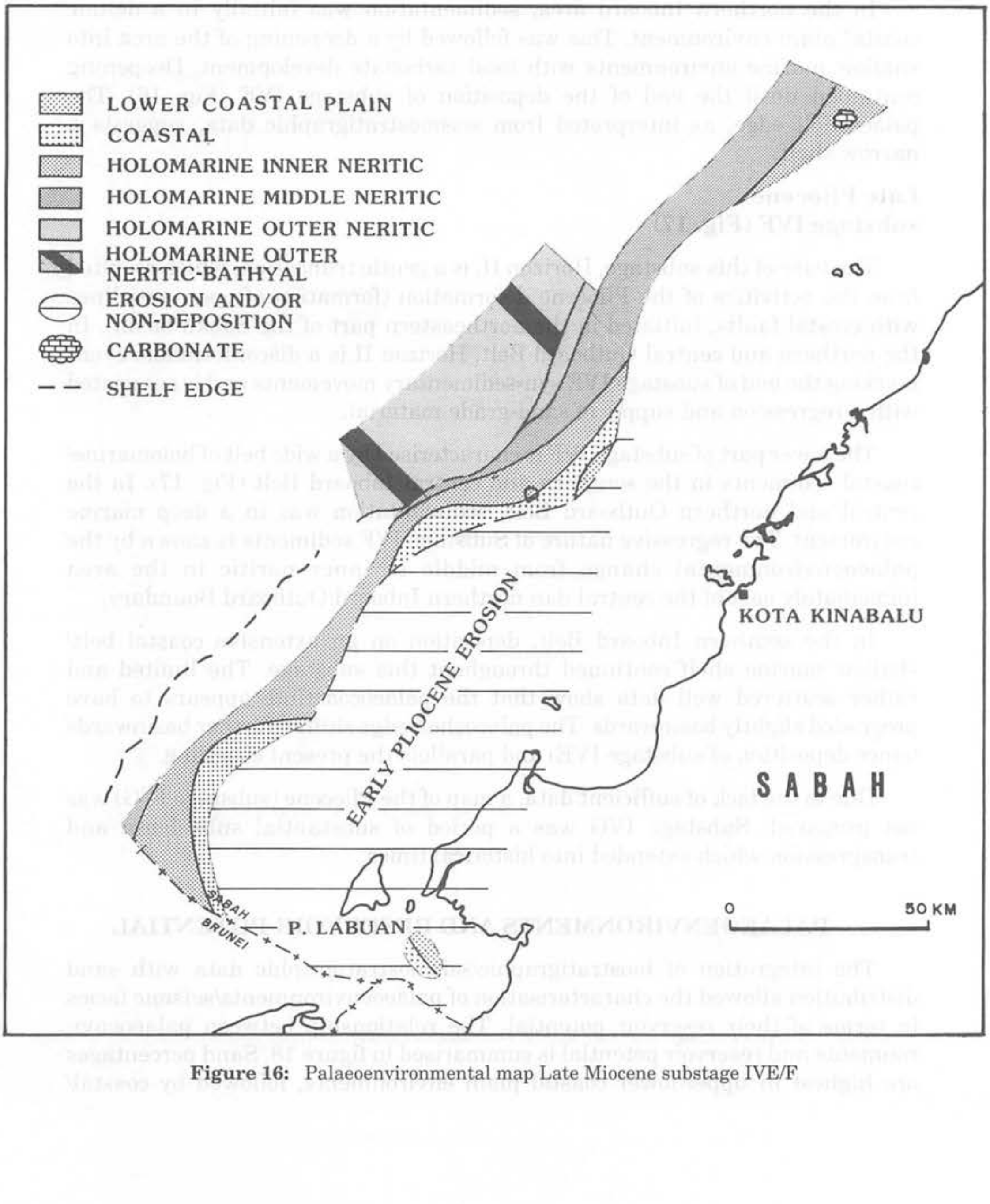

Figure 16: Palaeoenvironmental map Late Miocene substage IVE/F

The transgressive nature of substage IVE is marked by a change from stable coastal upbuilding (IVD) to unstable shoreline conditions with alternating small regressions and transgressions. Well data indicate varying environments of deposition within this substage, from coastal to holomarine, inner to middle neritic.

In the northern Inboard area, sedimentation was initially in a deltaic coastal plain environment. This was followed by a deepening of the area into shallow marine environments with local carbonate development. Deepening continued until the end of the deposition of substage IVE (Fig. 16). The palaeoshelf edge, as interpreted from seismostratigraphic data, suggests a narrow shelf.

Late Pliocene
substage IVF (Fig. 17)

The base of this substage, Horizon II, is a gentle truncation, which resulted from the activities of the Pliocene deformation (formation of open anticlines with crestal faults, initiated in the northeastern part of the Sabah basin). In the northern and central Outboard Belt, Horizon II is a disconformable event marking the end of substage IVE syn-sedimentary movements and is associated with a regression and supply of sand-grade material.

The lower part of substage IVF is characterised by a wide belt of holomarine/ coastal sediments in the southern and central Inboard Belt (Fig. 17). In the central and northern Outboard Belt, sedimentation was in a deep marine enviroment. The regressive nature of Substage IVF sediments is shown by the palaeoenvironmental change from middle to inner neritic in the area immediately east of the central dan northern Inboard/Outboard Boundary.

In the southern Inboard Belt, deposition on an extensive coastal belt/ shallow marine shelf continued throughout this substage. The limited and rather scattered well data show that the palaeocoastline appears to have prograded slightly basinwards. The palaeoshelf edge shifted further basinwards (since deposition of substage IVE) and parallels the present coastline.

Due to the lack of sufficient data, a map of the Pliocene (substage IVG) was not prepared. Substage IVG was a period of substantial subsidence and transgression which extended into historical times.

PALAEOENVIRONMENTS AND RESERVOIR POTENTIAL

The integration of biostratigraphic/seismostratigraphic data with sand distribution allowed the characterisation of palaeoenvironments/seismic facies in terms of their reservoir potential. The relationship between palaeoenvironments and reservoir potential is summarised in figure 18. Sand percentages are highest in upper/lower coastal plain environments, followed by coastal/

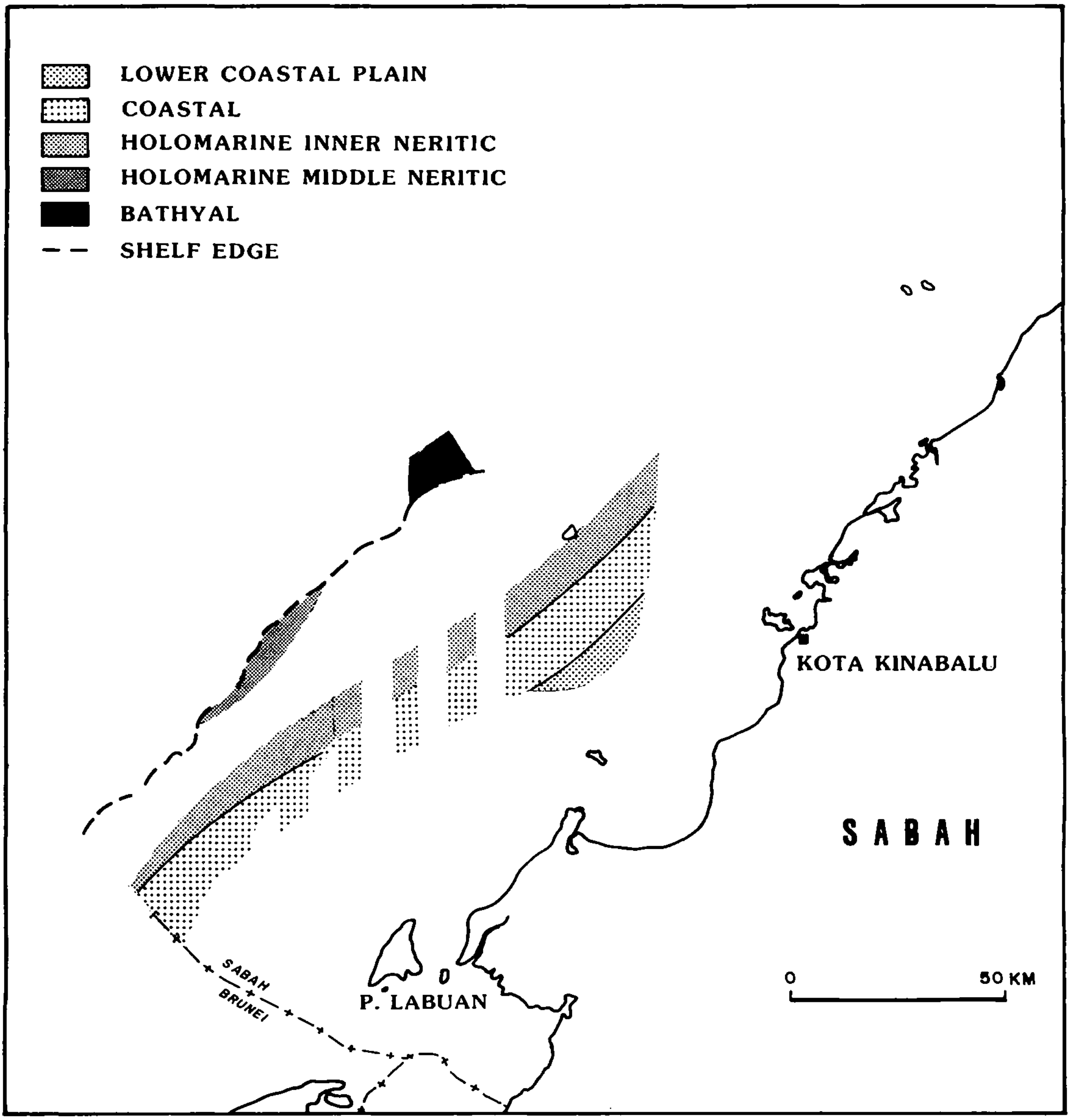

Figure 17: Palaeoenvironmental map Late Miocene substage IVA

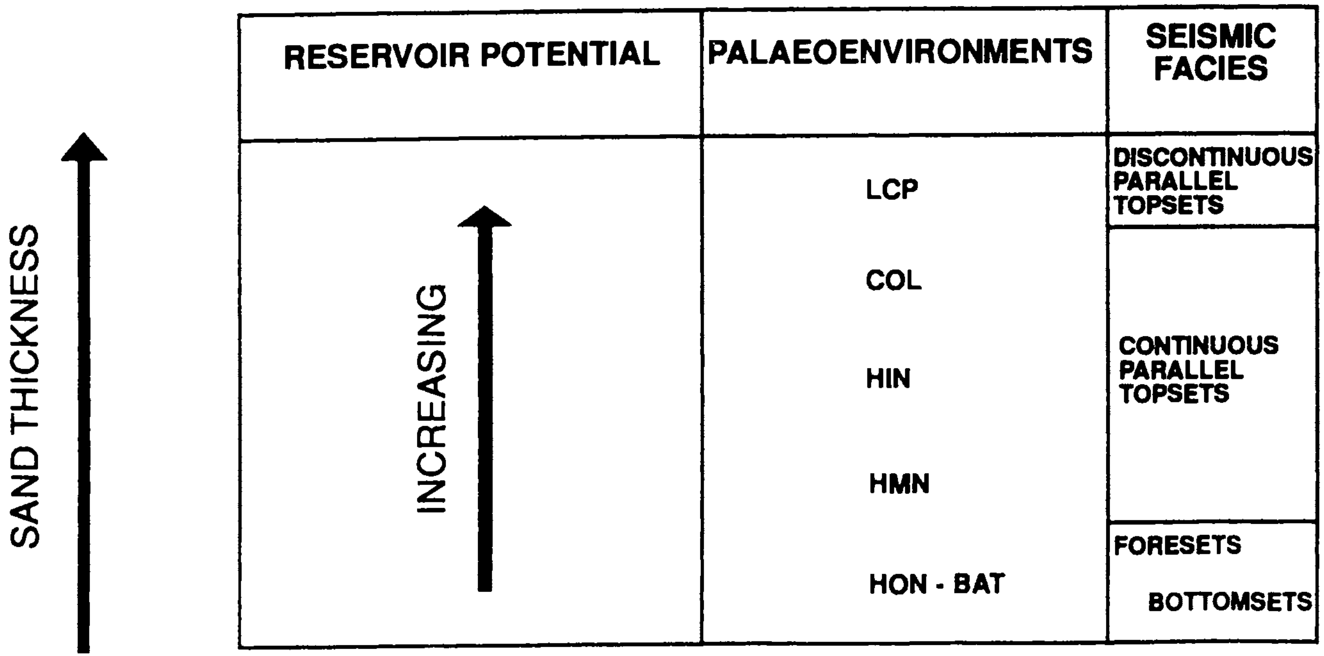

Figure 18: Summary of the relationship between palaeoevironments and reservoir potential

coastal fluviomarine environments. In deep marine environments the sand percentage is very low. High sand percentages are occasionally observed, due to the presence of turbidites or slumps. Palaeodepth is not the only controlling factor. Fluvial influence also effect the distribution and quality of the sand occurrence.

CONCLUSIONS

1. Briefly stated, the palaeoenvironmental evolution of offshore NW Sabah comprised pre-early Middle Miocene deposition of deep marine sediments of stage III and post-early Middle Miocene deposition of shelf/slope deposits of stage IV. Sedimentation in the latter phase was punctuated by major erosional events which resulted from periods of tectonism. These erosional events gave rise to 7 regional unconformities which divide Stage IV into 6 substages.
2. Stage IV sediments were deposited during two major depositional cycles, each starting with an initial phase of coastal plain outbuilding followed by rapid transgression. The interaction of variable sediment supply, tectonic movements and changes in sea level during the deposition of these sediments can be summarised as a middle Middle Miocene regression followed by rapid transgression (IVA) which continued into the late Middle Miocene (mainly IVB). This was followed by a Late Miocene regression (IVC-lower IVE) and a Pliocene transgression followed by regression (upper IVE and IVF) with small regressions and transgressions.
3. From middle Middle Miocene onwards, the palaeoshelf edge and palaeocoastline (defined to a large extent on seismostratigraphic data) paralleled the present coastline, with slight incurvations in certain area, and shifted progressively basinwards. In the Inboard Belt, the morphology of the palaeocoastline shows local variations due to the local development of prograding delta complexes.
4. Sand development is best in the lower coastal plain/coastal environments and poorer in the seaward direction. Fluvial conditions also favoured sand development.

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Manuscripts received on 5th October 1991