CHAPTER 5:PALEOENVIRONMENTAL CHANGES IN SARAWAK

5.1 INTRODUCTION AND GEOLOGICAL MAP

The geological map (Fig. 1, enclosed in the back folder) of the study area was drawn according the provisions as stipulated by the International Subcommission on Stratigraphic Classification (ISSC), 1994. The present study, is therefore describing a lithostratigraphic unit based on totally the lithology, physical characters and the stratigraphic positions of the sediments. In this present investigation, the lithostratigraphic units established are: the Suai, Sibuti, Lambir and Miri Formations. The geological boundaries between the Suai and Sibuti Formations is fault contact, the Sibuti and Lambir Formations is a disconformably contact whereas the contact between the Lambir and Miri Formations is also interpreted as a fault contact. The Suai Formation comprises mainly regionally metamorphosed bounded shale and shaly alternation; the Sibuti Formation comprises mainly mudstone and shaly alternations; the Lambir Formations comprises mainly sandy alternation and Miri Formation comprises of sandy alternation. The Suai Formation occurs at the lowest stratigraphic level and being successively overlied by the Sibuti, Lambir and Miri Formations.

5.2 PALEOENVIRONMENT

The paleoenvironment study of the Northwest Borneo Basin was interpreted by Liechti et al (1960), and Haile (1962). Both Liechti and Haile indicated the deposition during Early Miocene occurred in a deep, open marine sea whereas during Mid Miocene the deposition occurred in a delta and shallow sea areas. The paleogeography of the small area, the Subis Limestone area was described by Kandau (1988) whereas the Suai area was described by Ngap Dollah (1987), and they respectively interpreted the areas as formerly a reef and a lagoonal environment.

In the offshore of Northwest Sarawak, the paleogeography was described by Agostinelli et al (1990) and Hagemen (1985). Agostinelli described the source of the sediment was changed in anticlockwise direction; in Early Miocene, the source was from SW whereas in Mid Miocene, the source was from East. Hageman (1985) described sea level in the offshore regions of Northwest Sarawak changes; with a lower level in Early Miocene and getting higher, estimated 60 m above the average during late Mid Miocene-early Late Miocene (Fig. 79). However, Ho (1978) proposed the schematic model for the environment of deposition for NW Sarawak such as; a delta, lagoon, tidal channel and delta propogading front (Fig. 80).

In the present investigation, the description of the paleoenvironment is based

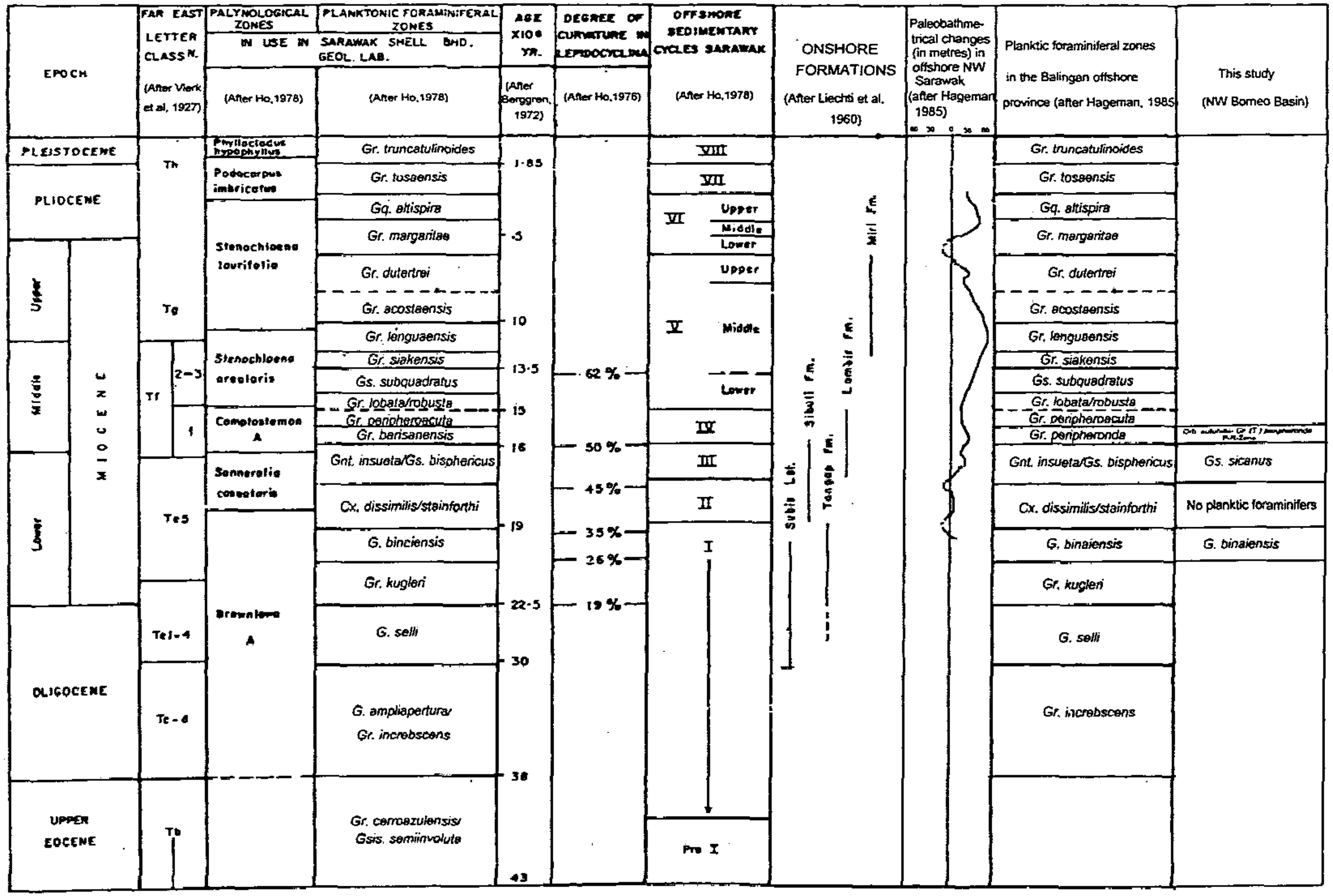


Figure 79. Correlation of planktic foraminiferal zonation with those of others in the region, and also the paleobathymetric changes in the Northwest Borneo Basin

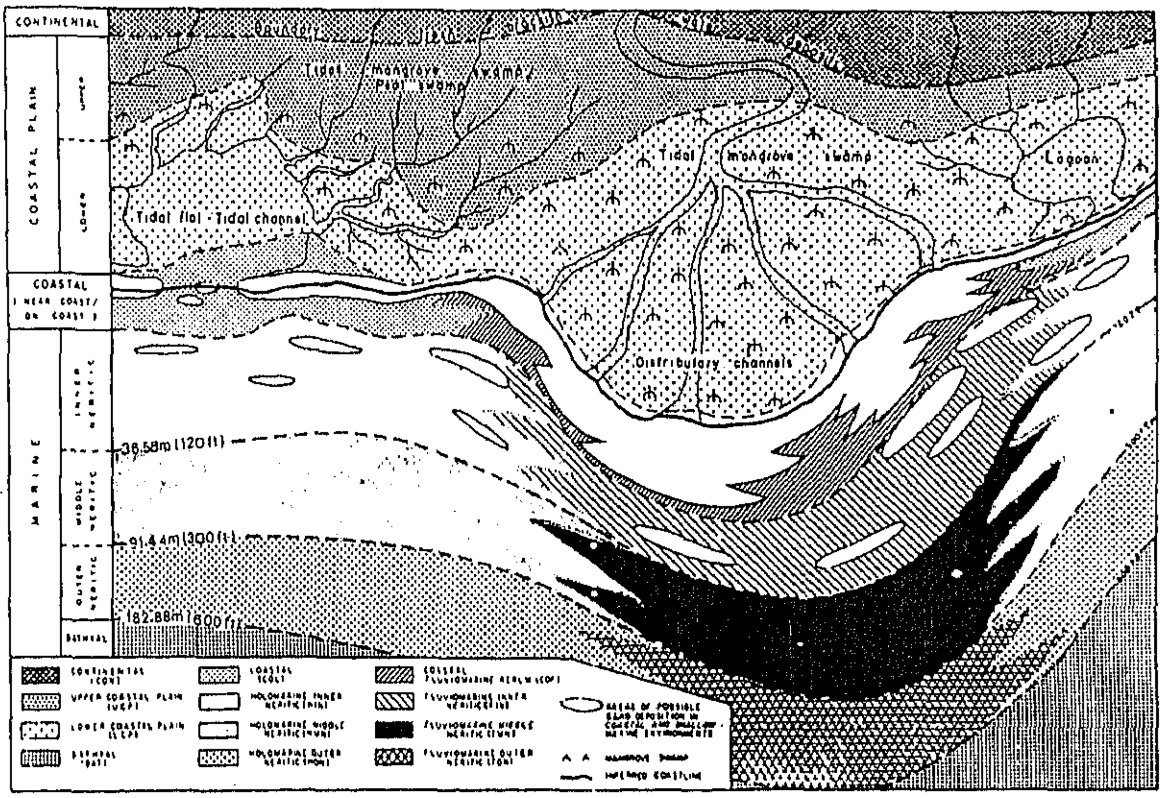


Figure 80. Schematic outline of the NW Borneo environment units (after Ho, 1978)

on the lithology, planktic foraminiferal biostratigraphy and also the consideration previous works in the offshore regions of Sarawak by few oil exploration companies such as Sarawak Shell Oil Company (Ho, 1978; Hageman, 1985) and AGIP Malaysia (Agostinelli, 1990).

5.2a Sedimentary Structures:

Sedimentary structures is one of the most important indicators of the sedimentary paleoenvironment and therefore their occurrence in each lithostratigraphic is being studied in detailed as shown in Figure 81. The following is the brief description of the sedimentary structures in each lithostratigraphic unit in the Northwest Borneo Basin.

i) The Suai Formation: Basically the Suai Formation is consisting of shaly alternations and bounded shale, in places, they are thick sandstone bed were located. The sedimentary structures are readily observed in the shaly alternation and thick sandstone beds such as cross laminations, cross-bedding, parallel lamination and ripple marks (Fig. 82-86). Ngap Dollah (1987), studied the geology and the sedimentary structures in the Suai area, described the sediments in the area were deposited in a shallow and low energy water environment, probably a lagoonal environment.

ii) The Sibuti Formation: this unit is consisting mainly bounded shale, mudstone and shaly alternation and limestone. The limestone is described as the Subis Limestone Member consisting of mainly coral alga and foraminiferal bioclasts in mainly micritic groundmass. Based on correlation, the total column of the Sibuti Formation is made up mainly shaly alternation in the lower sequence and mainly bounded shale in the top sequence, with the Subis Limestone Member interfingers at the base of the sequence. The limestone member is interpreted to have been deposited in a shallow and reef environment (Kandau, 1989), whereas the area underlain by the shaly alternation and bounded shale were deposited in a shallow and open marine sea environment (Haile, 1962; Kandau, 1988; Azhar et al, 1992).

The sedimentary structures of the Sibuti Formation observed during the present investigation are described in Figures 87-92. These structures indicated the environment of deposition of the formation was shallow to open marine.

iii) The Lambir Formation: this unit is consisting mainly sandy alternations, however in places they are beds of shale are located. This unit was interpreted by Mutalif (1990) as a deltaic to fluvial environments. The sedimentary structures observed in this unit are described as in Figures 93-99; they are; soft sediment deformation, trough cross bedding, bioturbation, channeling, cross bedding, cut and fill structures and herring bone cross beds, which indicates a deltaic to fluvial environment.

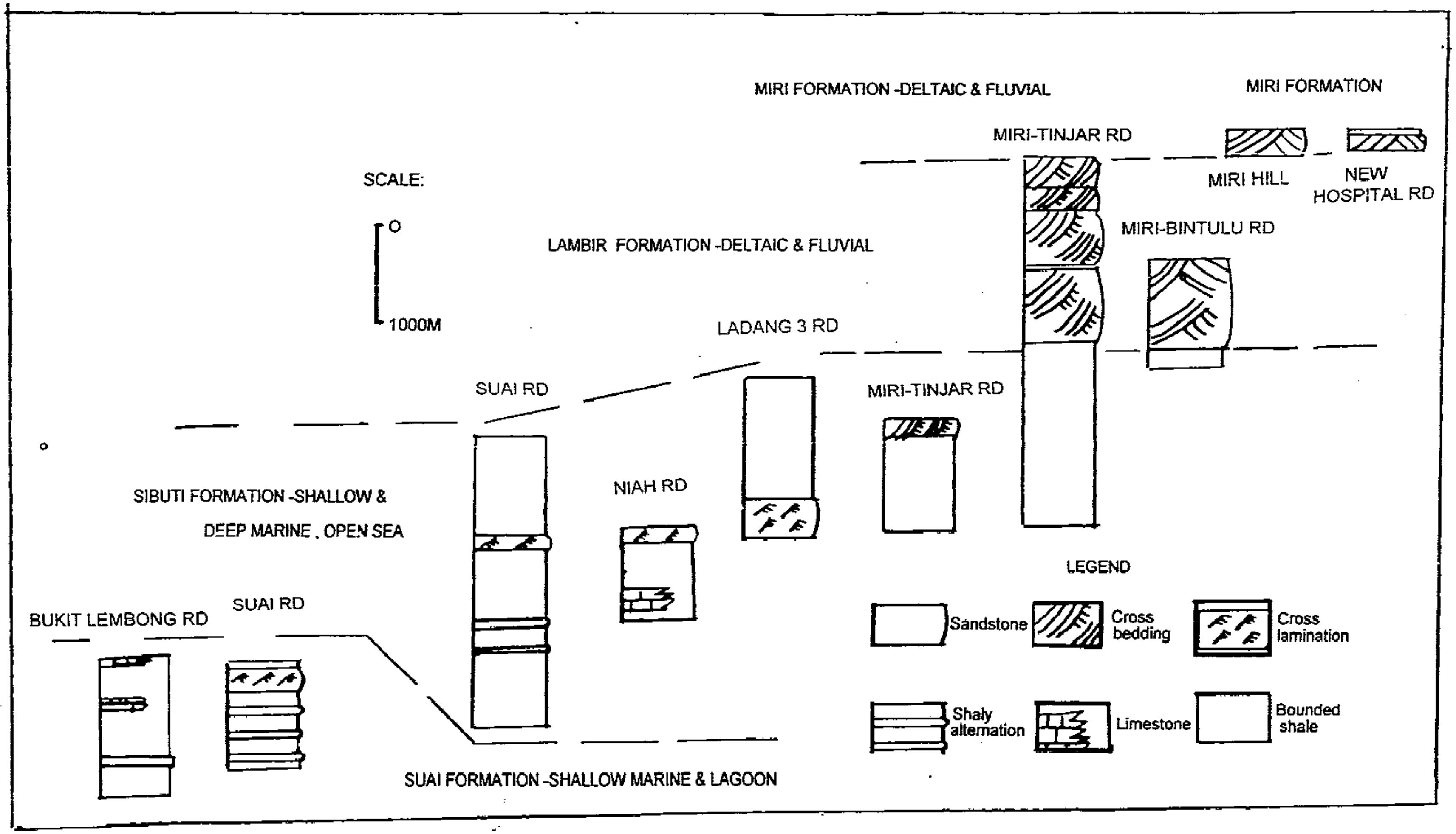


Figure 81. Distribution of sedimentary structures in the total column of the formations in Northwest Borneo Basin

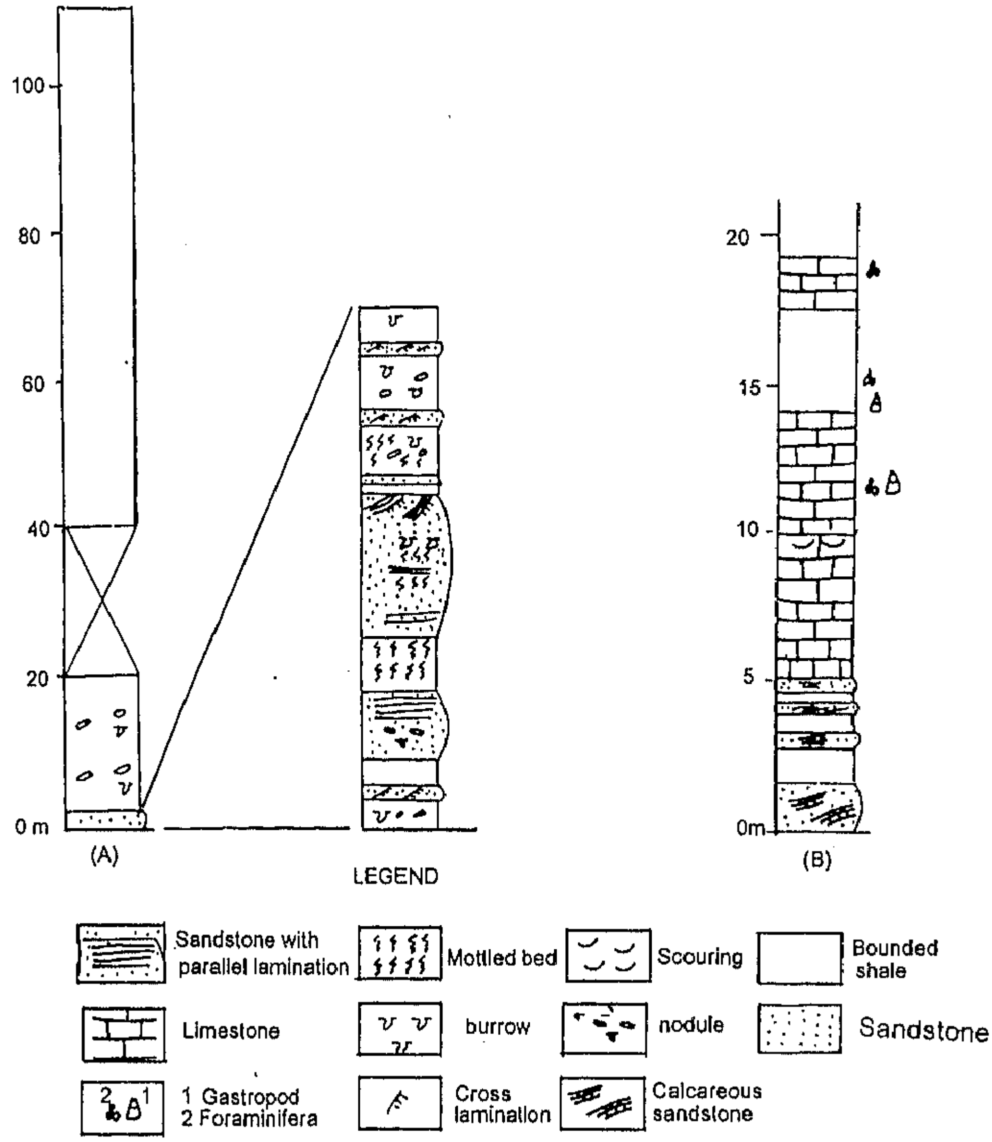


Figure 82. Log section of the Suai Formation at the North Suai Road Junction, Bintulu-Miri Road (A) and at BLD Quarry (B)

Figure 83. Cross lamination in thick sandstone bed of the Suai Formation.
Locality: Km 103, Bintulu-Miri Road

Figure 84. Parallel bedding in thick sandstone bed of the Suai Formation.
Locality: North Suai Road

Figure 85. Cross bedding in thick sandstone bed of the Suai Formation.
Locality: Km 103, Bintulu-Miri Road

Figure 86. Ripple marks in sandstone bed of the Suai Formation.
Locality: Km 103, Bintulu-Miri Road

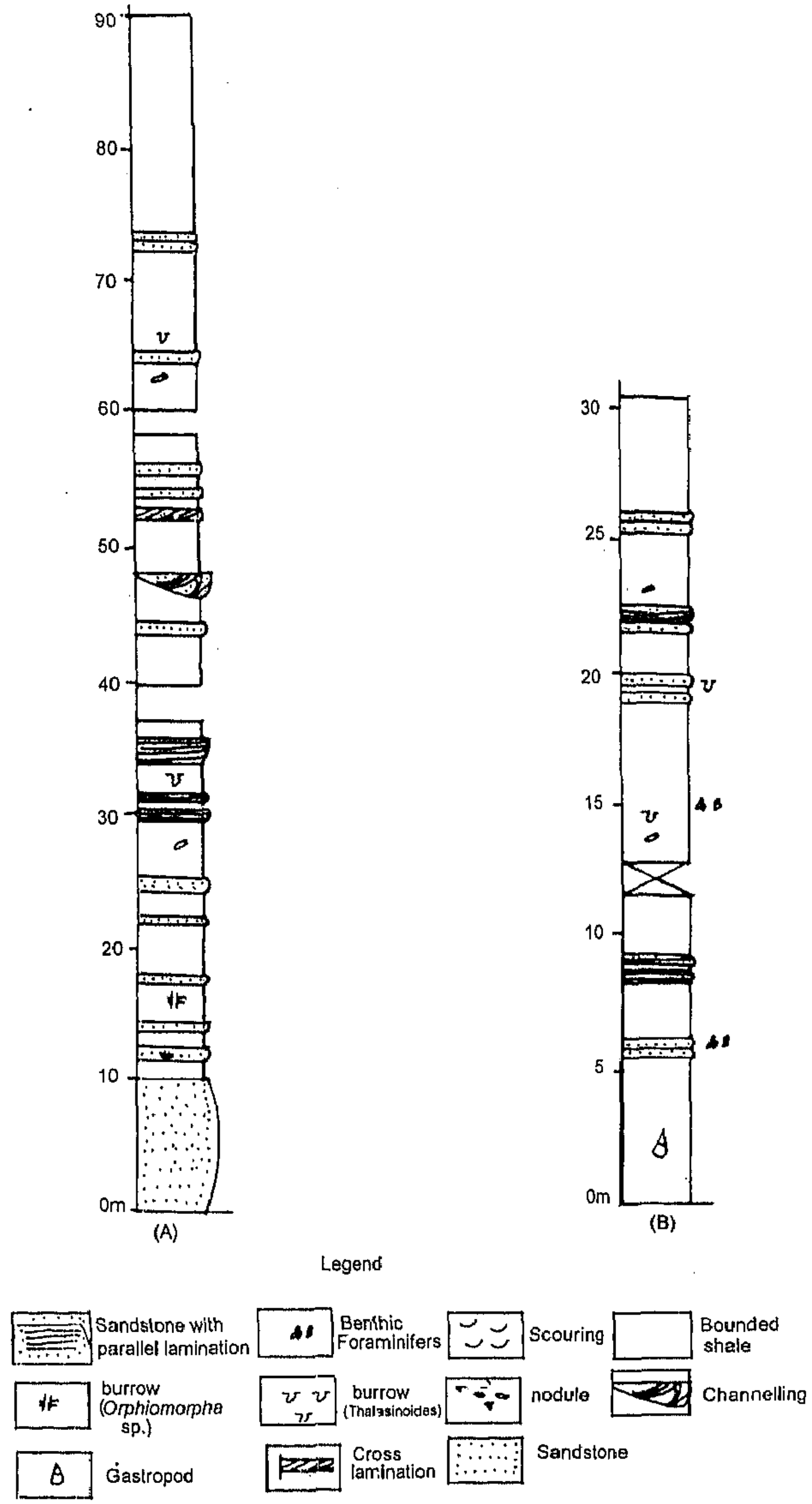


Figure 87. Log section of the Sibuti Formation at Km 2, Lamaus Road (A) and at Km 1st, Niah Road (B)

Figure 88. Mudstone interbedded with limestone in the Suai Formation.
Locality: BLD Quarry, North Suai Road

Figure 89. Slump structures in the bounded shale sequences in the Sibuti Formation. Locality: Km 2, Batu Niah Road

Figure 90. Ichnogenus *Orphiomorpha* sp. in the bioturbated sandstone of the Sibuti Formation. Locality: Km 106, Bintulu-Miri

Figure 91. Cut and fill structures (channeling) in the alternation of shale and sandstone of the Sibuti Formation. Locality: About 2 Km from the junction of Fung Tai Quarry Road, Bintulu-Miri Road

Figure 92. Bounded shale in the upper part of the Sibuti Formation, Locality: Km 70.5 Bintulu-Miri Road.

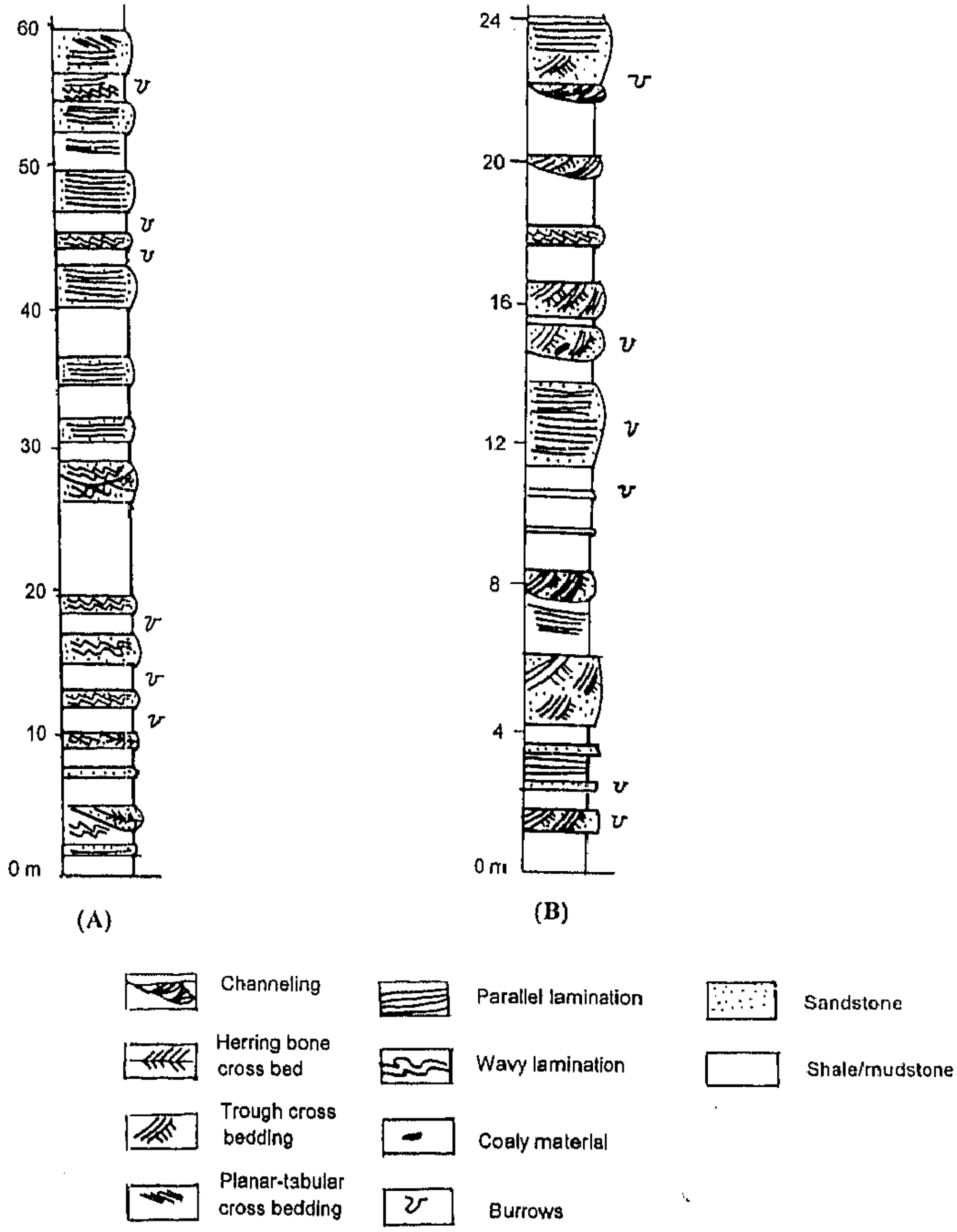


Figure 93. Log section of the deltaic sediments at Bukit Song, the Lambir Formation (A) and at Miri Hill, the Miri Formation (B)

Figure 94. Cross bedded sandstone beds of the Lambir Formation overlying the bounded shale of the Sibuti Formation. Locality: Entulang outcrop section, Km 37, Bintulu-Miri Road

Figure 95. Soft sediment deformation in cross bedded sandstone of the Lambir Formation. Locality: Entulang outcrop section, Km 37, Bintulu-Miri Road

Figure 96. Trough cross bedding sandstone of the Lambir Formation. Locality: Entulang outcrop section, Km 37, Bintulu-Miri Road

Figure 97. Bioturbated, laminated sandstone of the Lambir Formation.
Locality: Km 22, Bintulu-Miri Road

Figure 98. Gravel deposit in a channelised sandstone of the Lambir Formation. Locality: Km 22, Bintulu-Miri Road

Figure 99. Large scale cut and fill structure (truncation) in the sandstone of the Lambir Formation. Locality: Bukit Song, Bintulu-Miri Road

Figure 100. Trough cross bedding sandstone of the Miri Formation. Locality: Miri Hill, Bintulu-Miri Road

iv) The Miri Formation: this unit is consisting mainly sandy alternations, however, in places beds they are beds of shale are also located. This unit is previously interpreted by Belayong (1997) as a deltaic to fluvial environment. During the present investigation, the sedimentary structures observed are described in Figure 92 and Figures 100, 102; they are: trough cross bedding, cut and fill structures and herring bone cross beds which indicate a deltaic to fluvial environment.

5.3 GEOLOGICAL HISTORY

The geological development of the area is postulated based on the data made available during the present investigation such as geotectonics, lithology, fauna (planktic foraminiferal biostratigraphy) and the published data made available by the petroleum companies engaged with the oil exploration in the offshore NW Sarawak; such as; the data on the paleogeography and sea level changes in the offshore area of Sarawak.

Before the model of a geological evolution of the study area described, the following points have to be considered:

a) the opening of the South China Sea was started during Mid Oligocene and ended probably during the Mid Miocene, which caused faulting and subduction in the NW of Borneo region (Holloway, 1981),
b) the Island of Borneo was rotated since late Paleogene to Mid Miocene, approximately 20-10Ma (Hall et al, 1995).
c) Borneo or Southeast Asia as a whole is an active tectonic zone, with the Indian Australian Plate is still pushing from the south and the Pacific Plate is pushing from the east to form the rings of fire surrounding the regions, and this makes this region still tectonically active during the present time.
d) Major fault or lineament in the area are Tinjar Fault and West Balingan Line (Ismail Che Mat Zin, 1997), which are interpreted as major unconformity or steep slope.

The model of geological development of the area is described in Figures 103-109.

5.3a **Early Early Miocene, N . 5, Early Burdgalian (Figs. 103, 107)**

The basement of the basin for the deposition of the Suai Formation was tightly folded Belaga Formation with ridges striking NNW-SSE, parallel with West Balingan Line and the Late Eocene fold. Thus the basin was probably lagoon protected by the submerged ridge, with a slope located in the SW and a

Figure 101. Cut and fill structures (channeling) in mudstone of the Miri Formation. Locality: Miri New Hospital Road

Figure 102. Herring bone cross bedding sandstone of the Miri Formation. Locality: Miri Hill, Bintulu-Miri Road

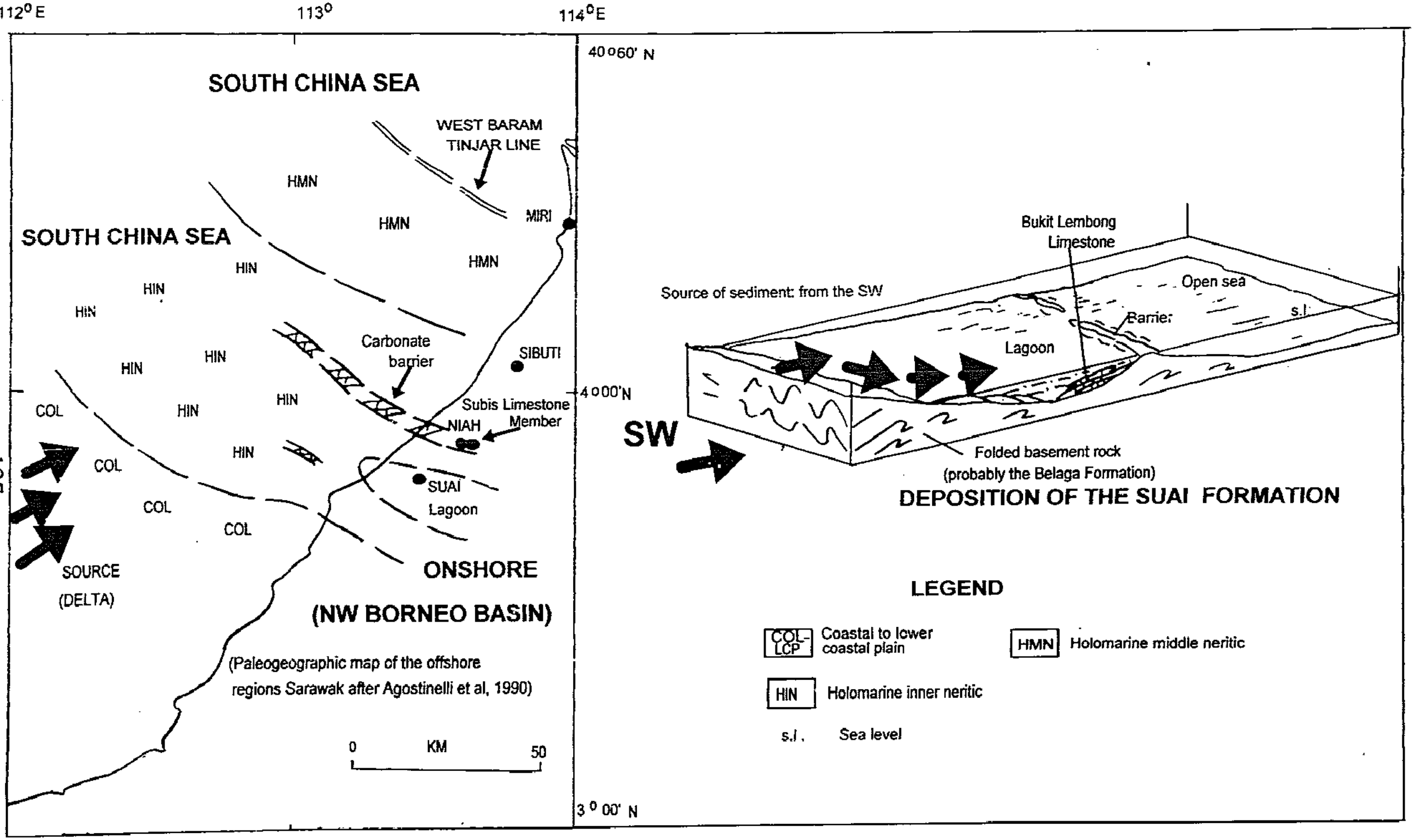


Figure 103. Depositional environment during the early Early Miocene (Top of Cycle I) in Northwest Borneo Basin

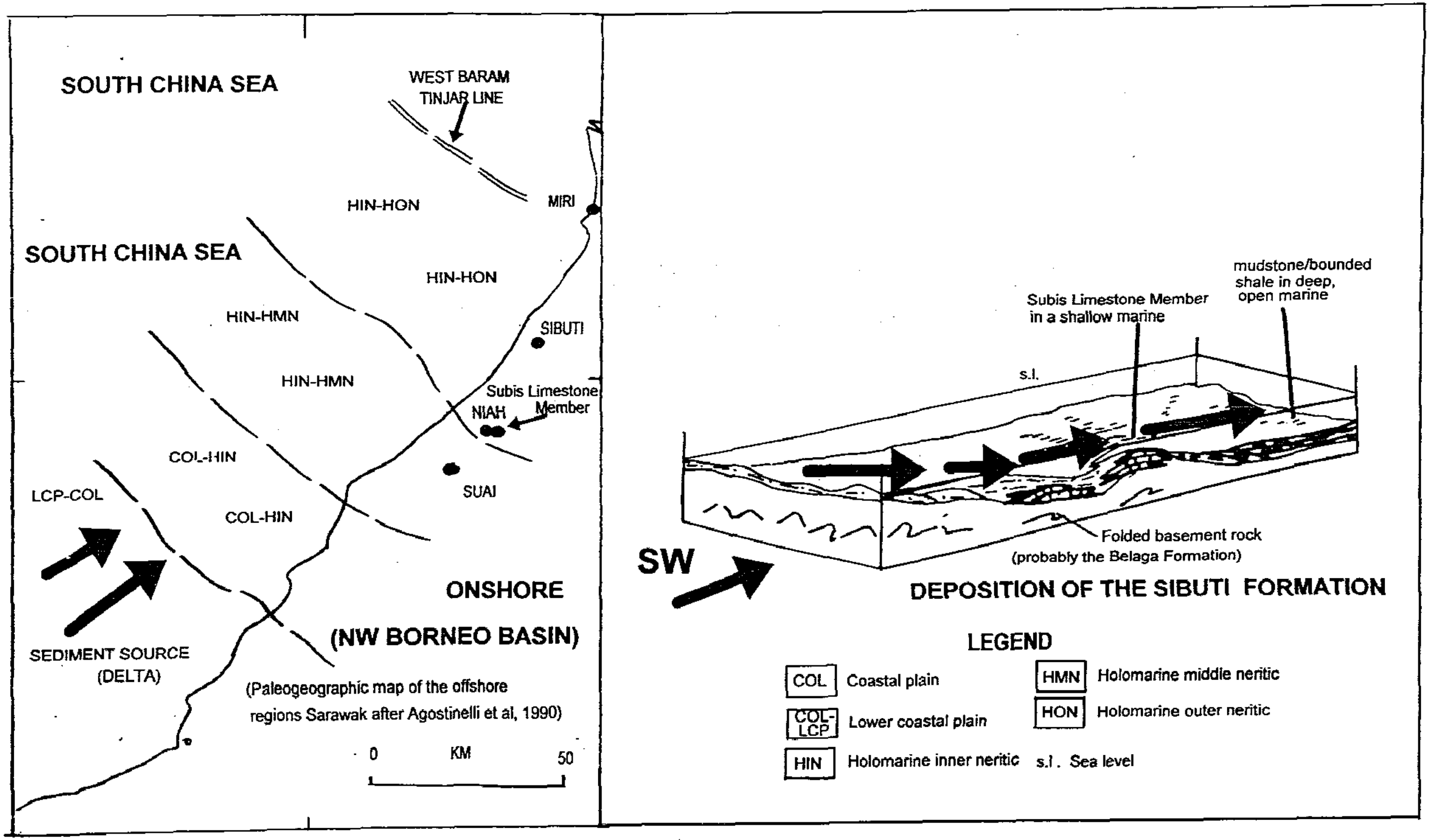


Figure 104. Depositional environment during the mid Early Miocene (Top of Cycle II) in Northwest Borneo Basin

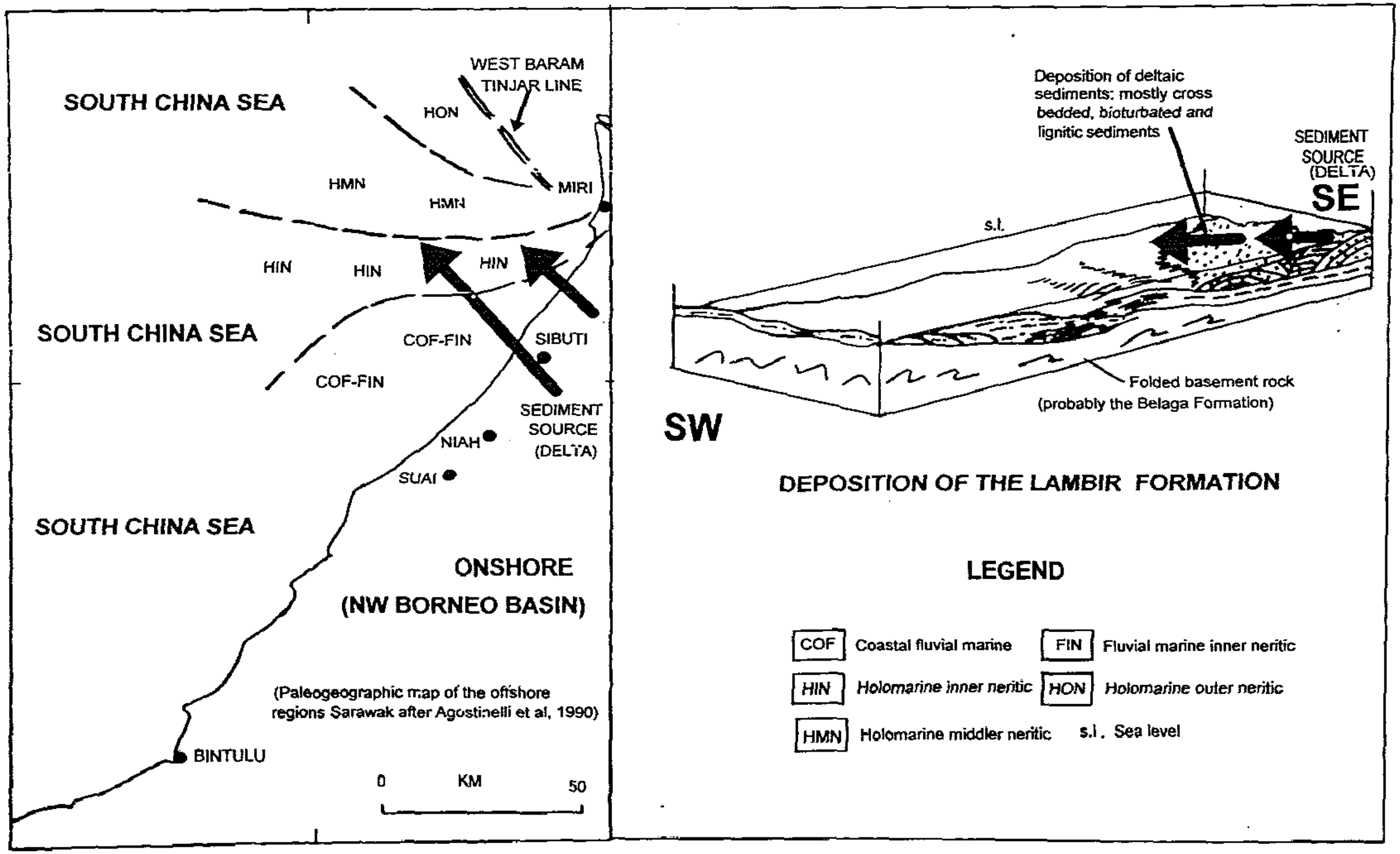


Figure 105. Depositional environment during the early Mid Miocene (Top of Cycle III) in Northwest Borneo Basin

barrier was located in the NE towards the open sea. The source of sediment was derived from southwest, mostly probably the eroded part of the Belaga Formation located in the southwest. The sedimentation took place on the slope with tidal influence as indicated respectively by the cross bedding, and as shown ripple marks. Also, the sediments were bioturbated by the burrowers such Ichnogenus *Orphiomorpha* sp. The presence of bounded shale indicates a quite environment which also signifies a lagoon. However, limestone mount was developed further on the ridges in the open sea.

The sea level was low at this period (Fig. 79) and therefore the sediment was not extensive and mainly made up of shaly alternations.

5.3b **Mid Early Miocene, Late N.7 - N.8, late Burdigalian-Early Langhian (Figs. 104, 107)**

In the study area, the record of geological event in the later part of early Early Miocene was (N.6) missing but recorded by Ho (1978) and Hageman (1985) in the offshore regions. The sediment could have been eroded or consumed during the tectonic disturbance or movement particularly during the rotation of the Island of Borneo. Major faults such as the Suai or Tinjar Fault were developed at this time. The underlying ridges of the Belaga Formation were striking NNW-SSE, parallel to the general strike of the Late Eocene folds (Fig. 109).

The basin during this period was a quite shallow sea, but clean especially towards the open sea. The source of sediment was still from the southwest. The slump structures, cross bedding and some channeling indicated the area was developed in a shallow marine environment with a rapid deposition occurred during the early phase of deposition. The clean and shallow sea was represented by the development of the reefal limestone, the Subis Limestone Member of the Sibuti Formation. However, later on as the basin was getting deeper as the result of sea level rise (Fig. 79); depositing a deep sea marine sediment mainly bounded shale, contained quite abundant of the planktic foraminifers, such as in the upper part of the Sibuti Formation. The sedimentary structures are quite few except for parallel lamination in some siltstone.

5.3c **Middle Miocene, N.9, early Langhian (Figs. 105, 108)**

The deposition was continued with the source the sediment were then derived the southeast. The anticlockwise rotation of the source materials was probably related to the anticlockwise rotation of the Borneo as a whole as the result of the opening of the South China Sea (Agostinelli, 1985). Towards the open sea, there was a great basin, formed by the Baram-Tinjar Line (Hutchison,

1989) where a rapid deposition of the deltaic sediment transported from the southeast took place; formed a big propograding delta was formed sedimentary structures such as trough cross-beddings and channeling in sandy alternations of the Lambir Formation. Also observed is the disconformable contact of the sandy alternation of the Lambir overlying the mudstone sequences of the Sibuti Formation in the Entulang outcrop section, Bintulu-Miri Road (Figs. 67, 94).

5.3d. **Middle Miocene (Figs. 106, 108)**

The fluvial and deltaic deposition was continued into this period. The delta is propogading towards the open sea continued to fill the great depression of the Baram-Tinjar Line. The source was still from the southeast. The delta formation is indicated by the sedimentary structures such as trough and herring bone cross beds and channeling in sandy alternations of the Miri Formation. The contact between the Lambir and Miri Formations however interpreted as a fault contact.

The presence of tuffaceous sand in the sandy alternation along the New Miri Hospital Road indicated that the age of this unit is probably Miocene, which is about 11 million years ago based on the age dating (Banda & Kim, 1992) of the volcanic rock in the area.

5.3e **Late Miocene-Pliocene Foldings (Fig. 109)**

The deposition in the Northwest Borneo Basin was ceased in Late Miocene, which was later was followed by folding in Pliocene resulted from the continuos pushing from the Pacific Plate in the east. The general trend of the folds in the Suai, Sibuti and Lambir Formations is NE-SW, parallel to general strike of the late Miocene-Pliocene folds in the north Sarawak. Soon after the folding, major faulting occurred with lateral displacement of about 3 km as shown in the Tangap Fault. The second phase of faulting is transacted the sediments in the NNW-SSE direction. The second phase faults are named Terusan Fault in Subis Limestone Member and Miri Fault in the north. After these major faultings the area was quite stable.

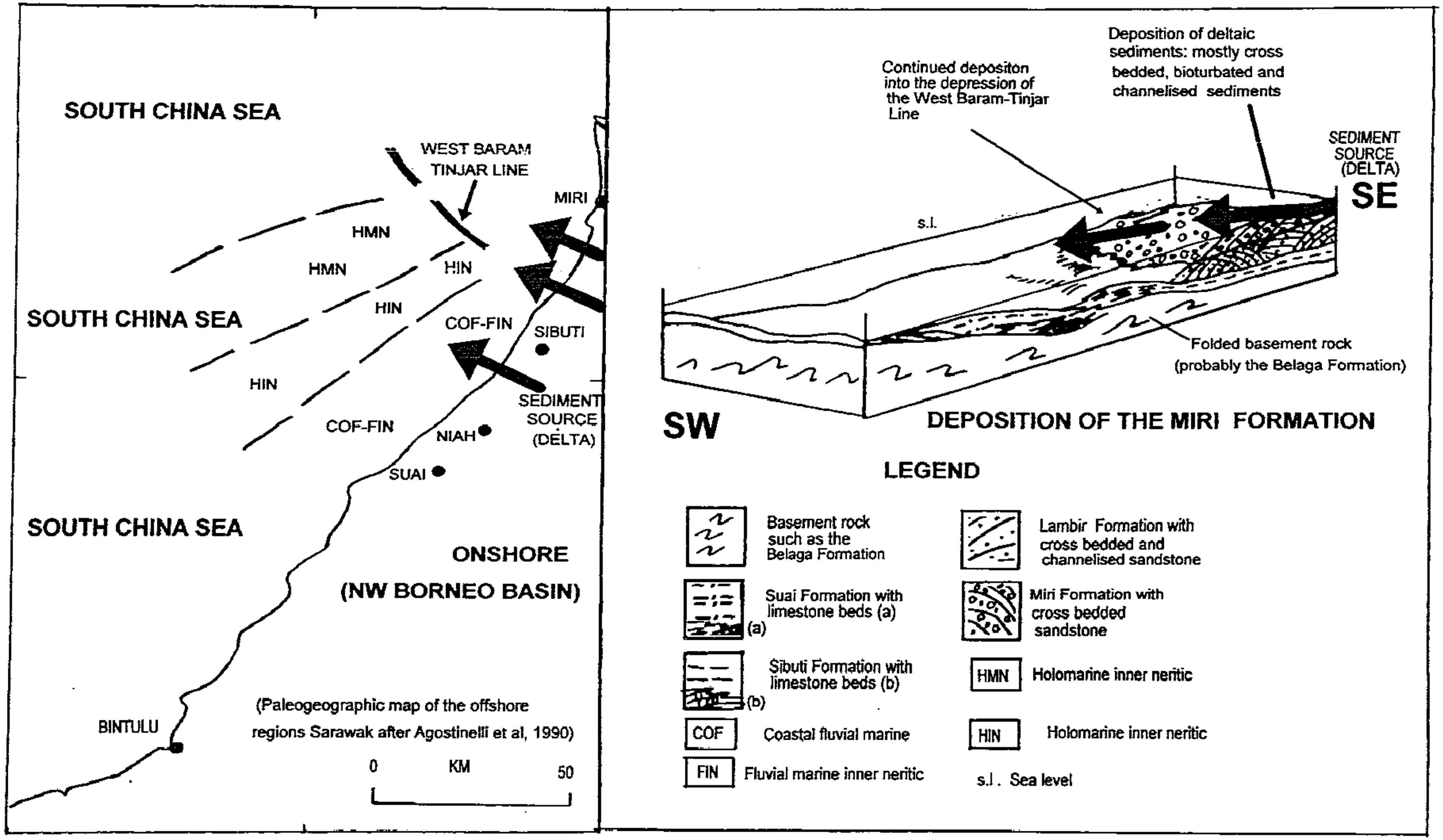
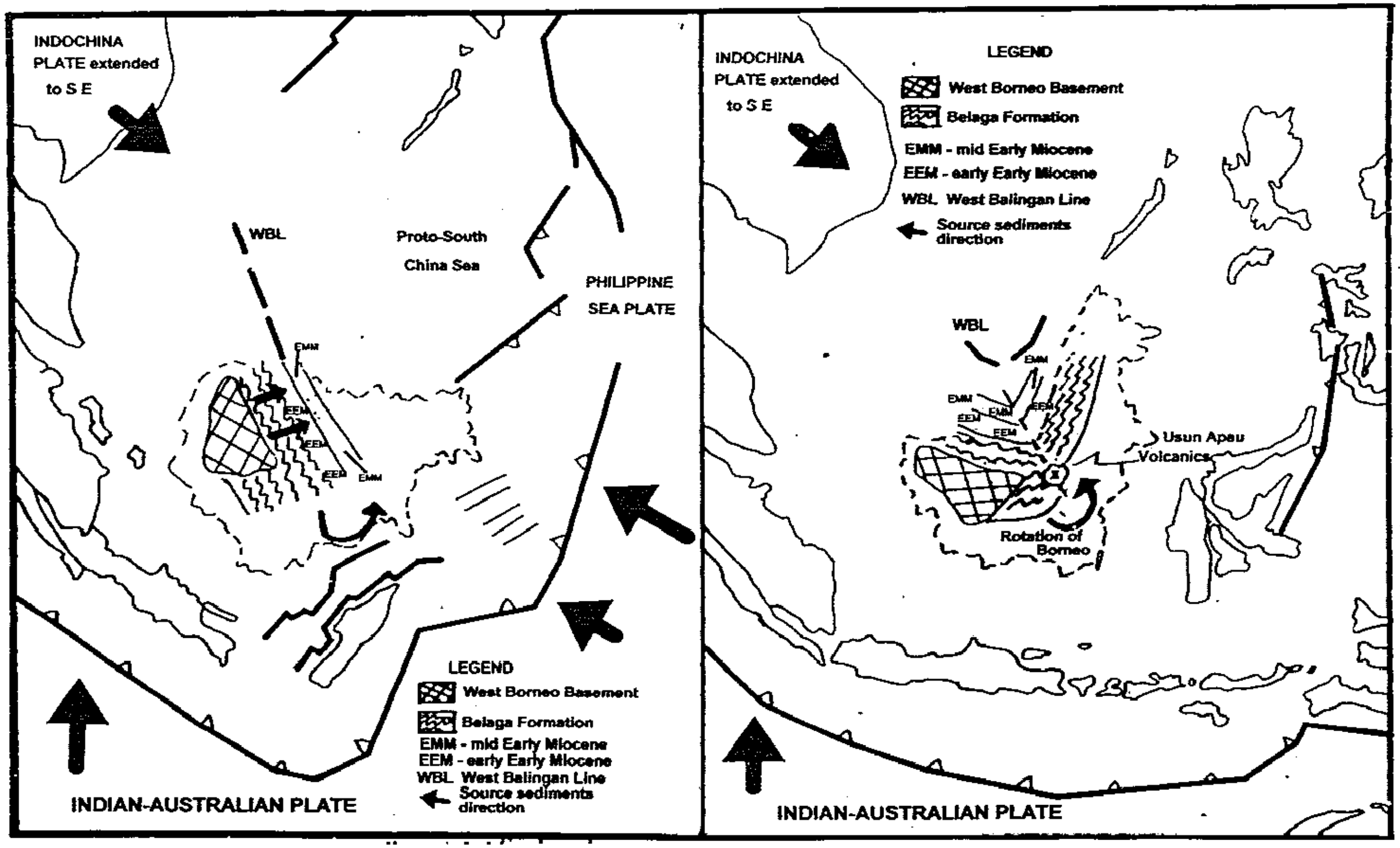


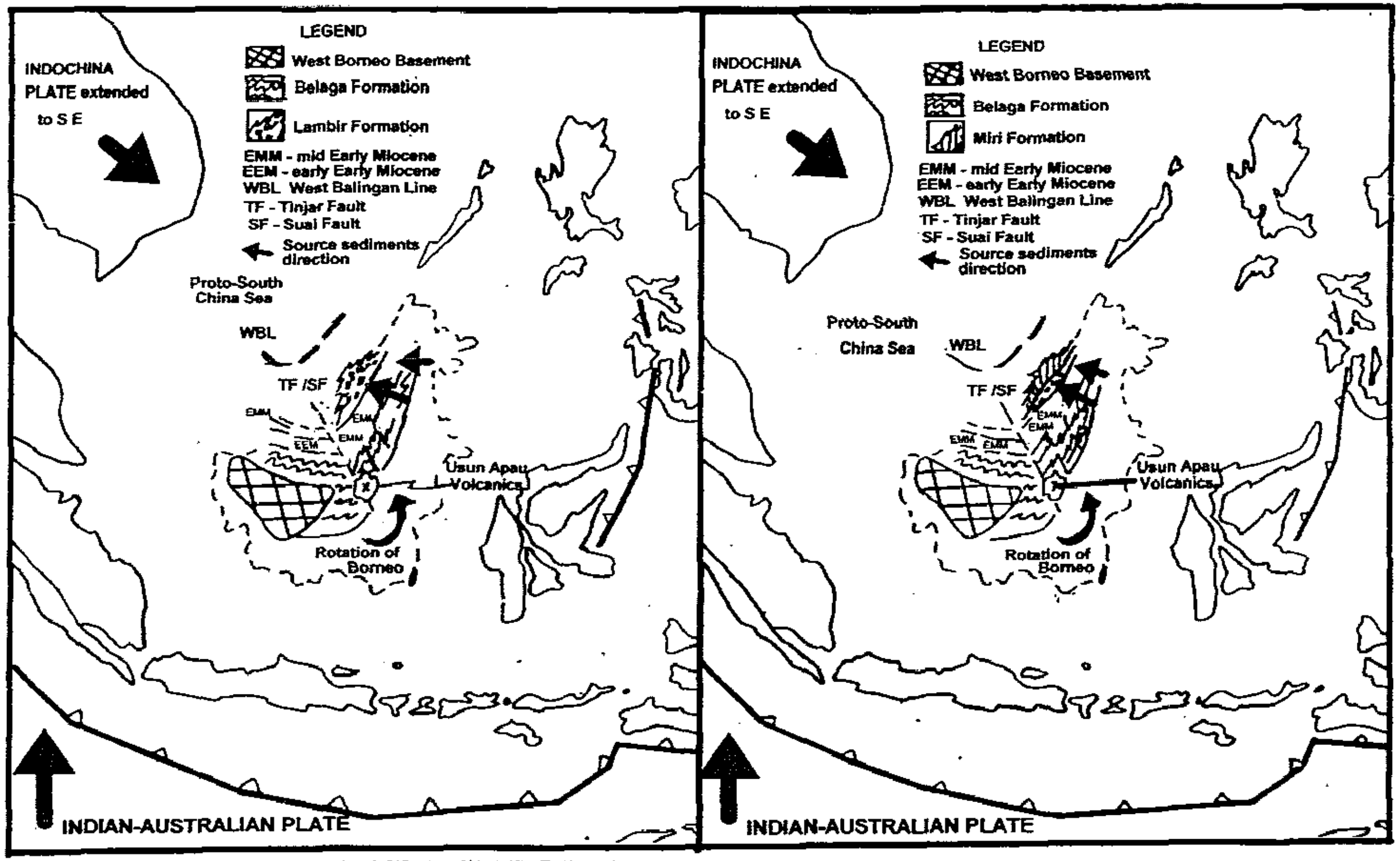
Figure 106. Depositional environment during the Mid Miocene (Top of Cycle IV) in Northwest Borneo Basin



Early Miocene (N.5-N.8): Deposition of the Early Miocene sediments; such as the Suai and Sibuti Formations. The sediments source was the Belaga Formation in the southwest.

Early Miocene-Late Miocene: Rotation of Borneo began; lineament and major fault, such as Tinjar Fault and Balingan West Line were developed at the knee point, and also the extrusion of Usun Apau Volcanics.

Figure 107. Geotectonic map of Borneo and the surrounding region of Southeast Asia during Early Miocene



Mid Miocene (N.9): Deposition of the fluvial and deltaic sediments; such as the Lambir Formation. The sediments source was the Belaga Formation in the east-southeast (ESE). Rotation of Borneo continued had developed the lateral fault in the region, such as Niah and Suai Faults

Mid Miocene –Pliocene : Deposition of the fluvial and deltaic sediments; such as the Miri Formation. The sediments source was the Belaga Formation in the east-southeast (ESE). Rotation of Borneo continued .

Figure 108. Geotectonic map of Borneo and the surrounding region of Southeast Asia during Middle Miocene

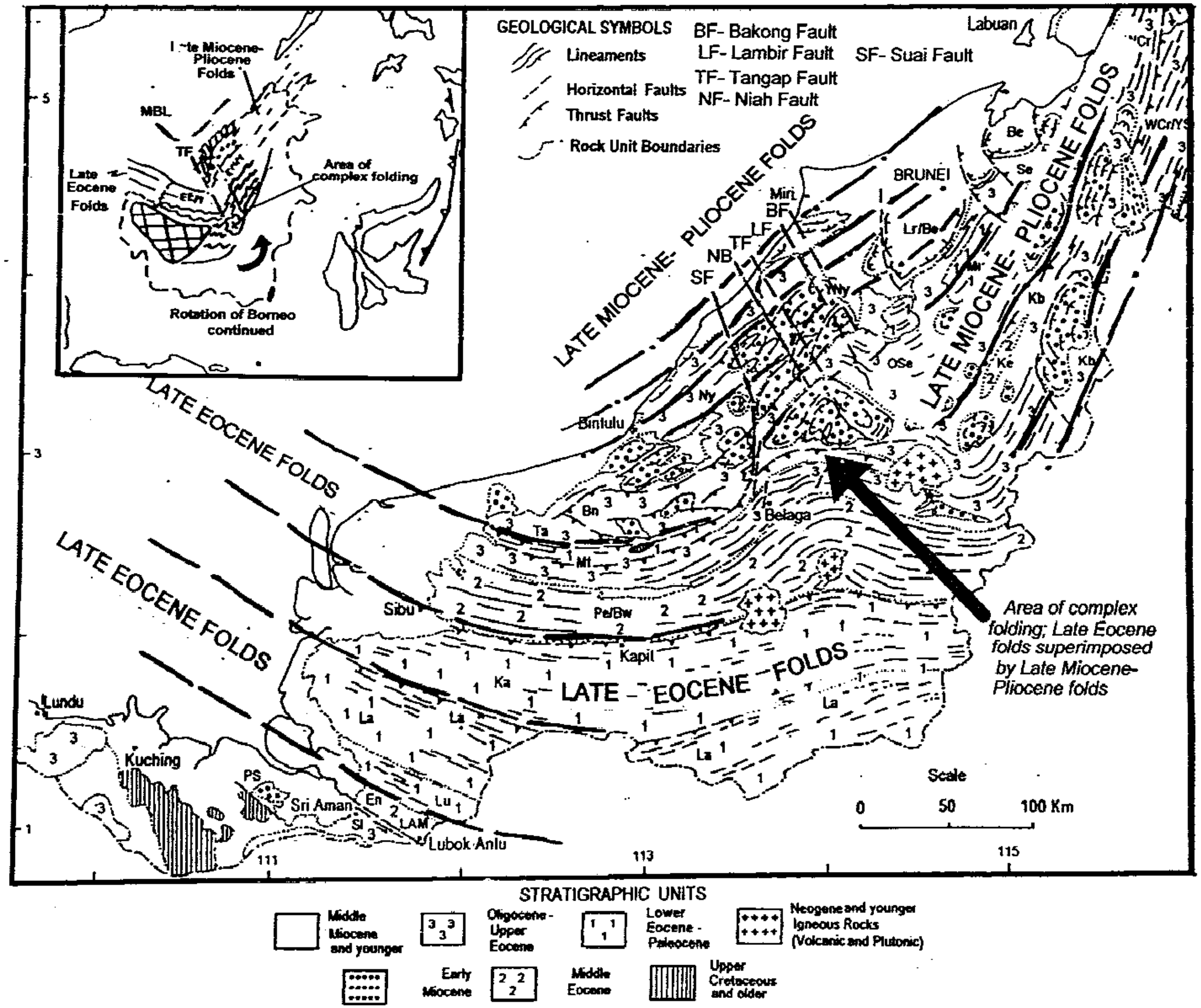


Figure 109. Regional folding during Late Eocene and Late Miocene- Pliocene in Sarawak

5.4 CONCLUSION

The present investigation which studied the geology, tectonic and the planktic foraminiferal biostratigraphy has come out with the up-to-date discussion on tectonics, lithology, planktic foraminiferal biostratigraphy and sedimentary structures of the area. As the result, a comprehensive model of geological evolution is postulated (Fig. 103-109) and the following concluding remarks are:

1) The output of the present investigation on the aspect of tectonics are: a) the tectonic and geological history of Borneo concur with the model of continent-continent collision which dominated the geological evolution of Borneo in the Cretaceous and Cenozoic times, b) based on the structural styles and sedimentation histories, the geological framework of Sarawak and its adjoining areas is consisting of 6 main tectonic provinces namely: i) Pre-Cretaceous Borneo Basement, ii) Early Cretaceous Melange, iii) Folded Rajang Group iv) Isolated Basin, (v) Peripheral Neogene Basin and vi) Luconia Block and c) the term Northwest Borneo Basin which is introduced in this work is to replace the obsolete term Northwest Borneo Geosyncline which was introduced by Liechti et al (1960), to describe Folded Rajang Group and Peripheral Neogene Basin

2) The deposition of the sediments in the area was initiated after the Late Eocene Orogeny in Sarawak, with the Belaga Formation as the source of the sedimentation.

3) The Suai Formation which was deposited in a shallow to lagoonal environment is belong to *Globigerina binaiensis* Zone, is early Miocene in age and also equivalent to the sediments in the top layer of the Cycle I (Ho, 1978) in the offshore region.

The Sibuti Formation which was deposited in a shallow to open sea environment is belong to *Globigerinoides sicanus Zone*, is mid early Miocene in age and also equivalent to the sediments of the top layer of the Cycle III in the offshore region.

The Lambir which was deposited in a fluvial-deltaic environment is belong to *Orbulina suturalis-Globorotalia (Turborotalia) peripheronda* Partial-range Zone *Globigerinoides sicanus Zone*, is early Middle Miocene in age and also equivalent to the sediments of the top layer of the Cycle IV.

No age determination by means of planktic foraminifers undertaken for the Miri Formation. However, based on benthic foraminiferal content, Liechti et al, (1960) described this unit is belonged to *Nonion* and *Loxostoma* Zones and the age assigned to Mid Miocene-Late Miocene.

4) The main structural elements described in the area are Subis Anticlinorium, and the major faults such as Miri, Bakong, Lapok, Tangap, Subis, Niah and Suai Faults. The anticlines and synclines existing in the area are given correlated number (1,2,3; Fig. 1), are striking NE-SW direction, which is parallel to the strikes of the sediments of the Sibuti and Lambir Formations. However is not really possible to correlate accurately the folds in the Sibuti and Lambir Formations with the folds that occur in the Suai and Miri Formations because of the fault contacts. These folds were being displaced by the major faults both laterally and vertically.