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Miocene stratigraphy of northwest Borneo Basin

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Abstract: The Regional Mapping Programme of Geological Survey of Malaysia, Kuching, Sarawak undertook the detailed mapping at scale 1:50,000 of Miocene sediments in northwest Sarawak. The results presented here are based on the sedimentological, structural and biostratigraphic analyses. Four formations could be defined in this area. They are the Miri Formation in the Mid to Late Miocene, the Lambir Formation in the early Mid Miocene, the Sibuti Formation in the mid Early Miocene and the Suai Formation from early Early Miocene. Additional member is the Subis Limestone Member in the lower part of the Sibuti Formation which is located along the central anticlinorium of the Sibuti Formation. The former Belait Formation in the south wing of the Subis Anticlinorium is correlated to the same horizon as the Lambir Formation. The Suai Formation is newly proposed here instead of the former Setap Formation. Setap Village locates within the Sibuti Formation in our compiled geological map. Therefore, we cannot use that name for the older formation than the Sibuti Formation. The major trend of the Miocene formations is the NNE-SSW anticlinorium associated with minor foldings within them. They are blocked by the faults trending NNW-SSE. Several faults could be defined blocking approximately perpendicular to the trend of the formations. Displacement of most faulted blocks is not so prominent that we can correlate sedimentary units to the next block. However, there are two faults which have vertical and horizontal displacement components more than several kilometers. The southern Suai Fault trending approximately N-S associated with the secondary fault has great displacement to form formation boundary between the Suai and the Sibuti Formations. Some sediments supply directions are also discussed on the basis of paleocurrent analysis of turbidites within these formations.

INTRODUCTION

The Northwest Borneo Basin (formerly known as Northwest Borneo Geosyncline) is located in the area of triple junction of the Eurasian, Philippine Sea and Indo-Australian plates, developing in northwestern Borneo (Fig. 1). The basin consists of sediments from Upper Cretaceous in the southern area to Pliocene in the northwestern area. The Miocene sediments occurs in the Subis, Sibuti, Bakong and Miri areas in Sarawak, the Temburong area in Brunei and in eastern Sabah along the northwestern part of the basin.

Most previous works in this area suggested many formations with interfingering relationships through Miocene such as the Setap, Tangap, Sibuti, Subis, Lambir, Belait, Tukau and Miri Formations (Liechti *et al.*, 1960; Wilford, 1961; Haile, 1962). A recent drilling work for groundwater suggested different geological columns on the thick sandstones in the northern parts of the area (Rosland, 1995).

As part of the geological mapping programme of the Geological Survey of Malaysia, we have surveyed the Miocene sediments in the Sibuti and Miri areas. The results of geological mapping presented here are based on the sedimentological, structural and biostratigraphic analyses of the Miocene sediments in the Subis, Sibuti, Bakong and Miri areas.

FORMATIONS AND THEIR DISTRIBUTIONS

Miocene sediments consists of shale, shaly alternation and sandy alternation throughout the surveyed area (Fig. 2). From sedimentological, structural and biostratigraphical analyses the sediments can be divided into four formations namely; the Miri, Lambir, Sibuti and Suai Formations. A limestone body, having interfingering relationships with the lower Sibuti Formation, is named the Subis Member.

The uppermost Miri Formation consists mainly of sandy alternations. Thin shale occurs in the uppermost part of the formation. The Lambir Formation consists of sandy alternations and occurs in the Lambir area and Bakong in the southern

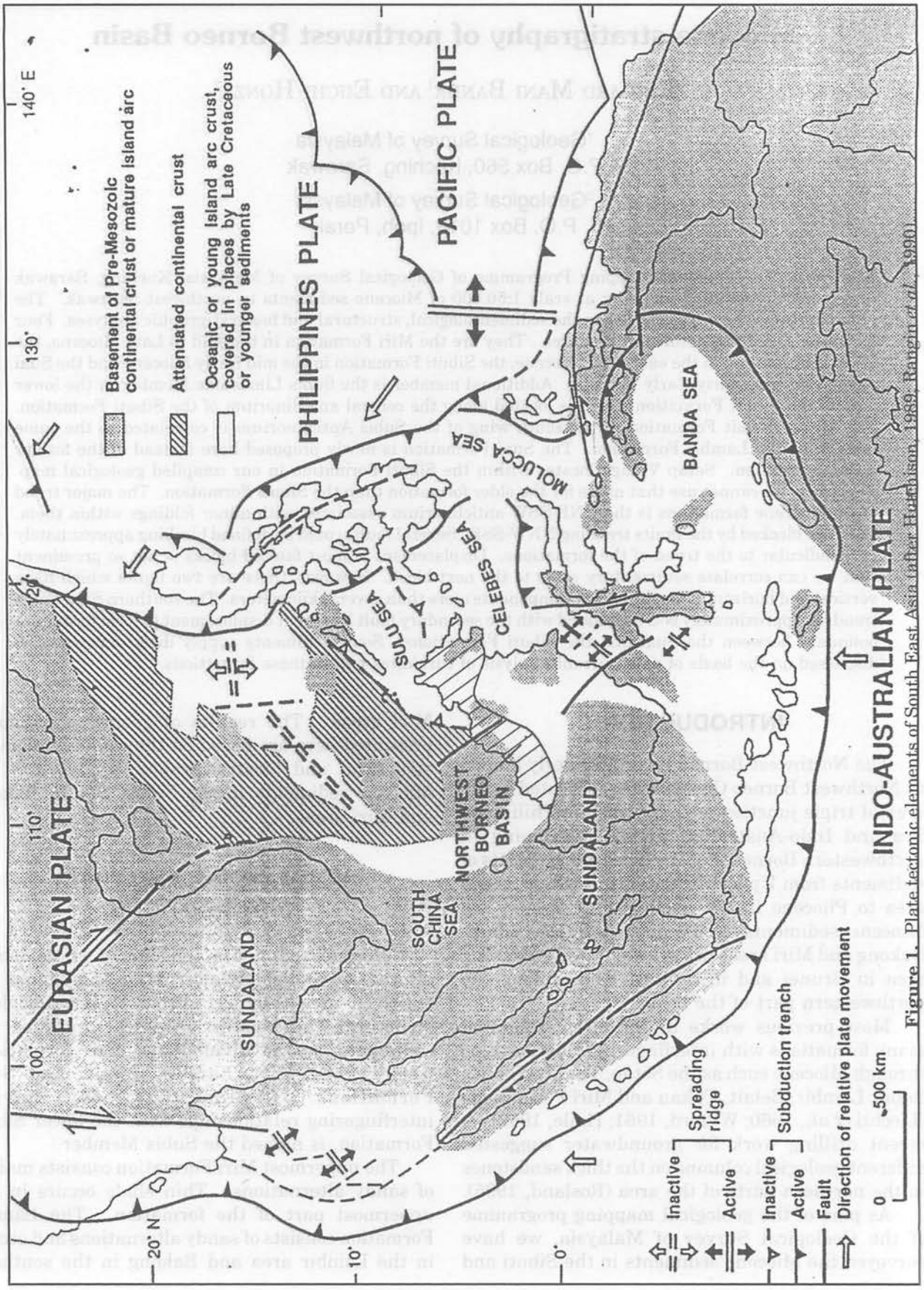

Figure 1. Plate tectonic elements of South East Asia (after Hutchison, 1989; Rangin *et al.*, 1990).

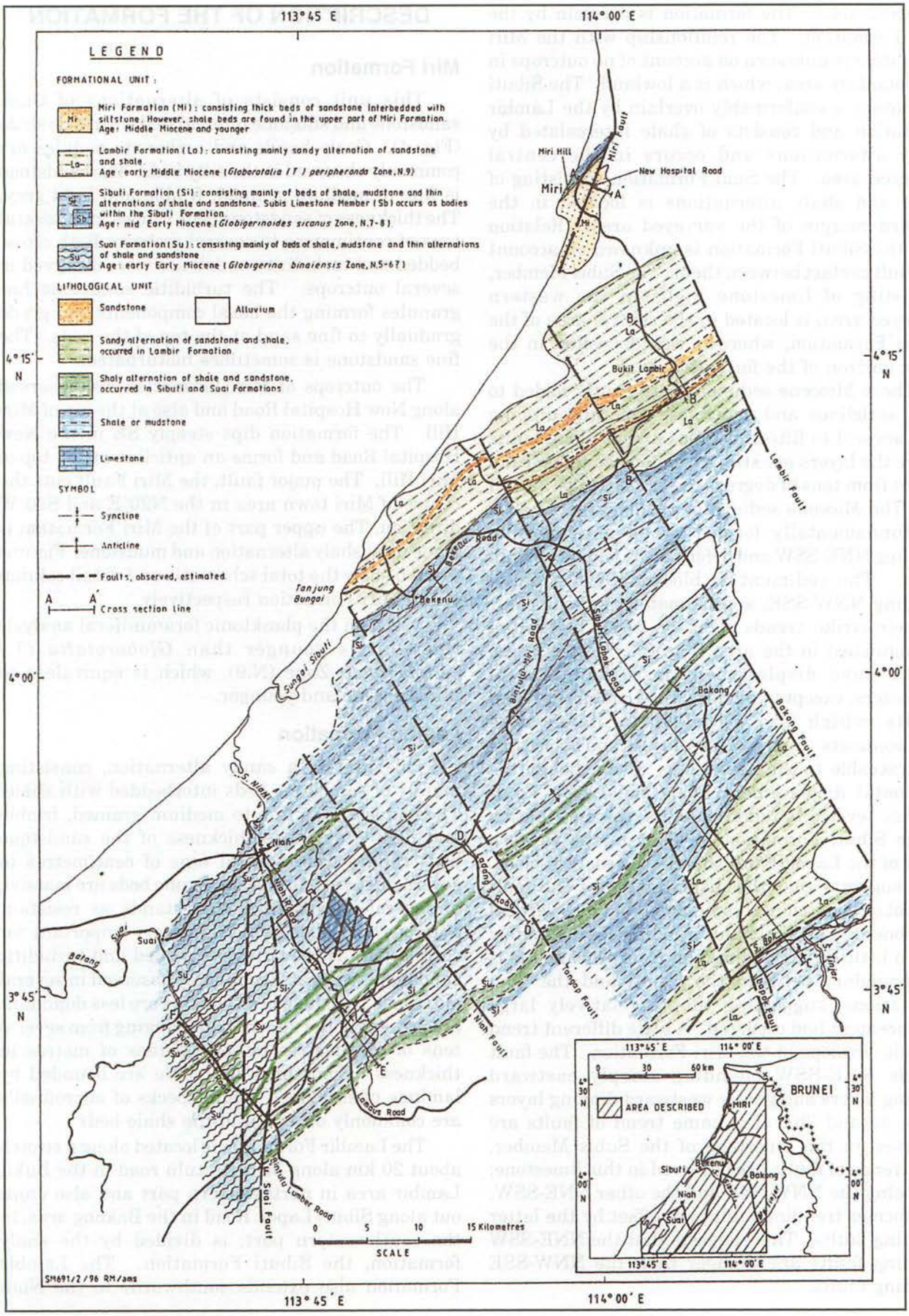

Figure 2. Geological map of Northwest Borneo Basin, Sarawak.

surveyed area. The formation is overlain by the Miri Formation. The relationship with the Miri Formation is unknown on account of no outcrops in the boundary area, which is a lowland. The Sibuti Formation is conformably overlain by the Lambir Formation and consists of shale intercalated by shaly alternations and occurs in the central surveyed area. The Suai Formation consisting of shale and shaly alternations is located in the western margin of the surveyed area. Relation with the Sibuti Formation is unknown on account of a fault contact between them. The Subis Member, consisting of limestone highs in the western surveyed area, is located in the central area of the Sibuti Formation, where it was deposited in the lower horizon of the formation.

These Miocene sediments are gently folded to form anticlines and synclines, generally dipping from several to fifteen degrees except along faults where the layers are strongly deformed to have dip angles from tens of degrees to vertical (Figs. 3a and 3b). The Miocene sediments in the surveyed area are fundamentally formed by an anticlinorium trending NNE-SSW and deformed by foldings within them. The sediment is blocked by the faults trending NNW-SSE, approximately perpendicular to their strike trends. Six or seven blocks are distinguished in the area (Fig. 2). Most of these blocks have displacement less than tens of kilometers, except two faults, the Lambir and Suai Faults which are believed to have more displacements. In most cases, layers and structures are traceable to the next block. Even though the horizontal displacement along the Lapok Fault reaches several to ten kilometers, the distribution of the Sibuti Formation is wider in the western block of the Lapok Fault than in the eastern block. This suggests that the displacement of the fault has not only horizontal component, but also vertical component. The Suai Fault trending approximately N-S, a little different direction from other faults is the boundary between the Sibuti and the Suai Formations, suggesting that a relatively large displacement had occurred. A little different trend of fault develops in the Miri Formation. The fault trends NNE-SSW bounding steeply eastward dipping layers and gently westward dipping layers (Figs. 3a and 3b). The same trend of faults are observed in the limestone of the Subis Member. Two trends of faults are observed in this limestone; one being the NNW-SSE and the other NNE-SSW. The former trending faults are offset by the latter trending faults. This suggests that the NNE-SSW trending faults are younger than the NNW-SSE trending faults.

DESCRIPTION OF THE FORMATION

Miri Formation

This unit consists of alternations of thick sandstone and siltstone intercalated with little shale (Fig. 4). Coaly bands and carbonate nodules are commonly observed in the silty beds. The sandstone is fine to medium grained, friable and light grey. The thickness of sandstone beds ranges from several tens of centimetres to several metres. Both cross-bedded and turbiditic sandstones were observed in several outcrops. The turbiditic sandstone has granules forming the basal components and grade gradually to fine sand at the top of the beds. The fine sandstone is sometimes bioturbated.

The outcrops of Miri Formation are observed along New Hospital Road and also at the top of Miri Hill. The formation dips steeply SE in the New Hospital Road and forms an anticline at the top of Miri Hill. The major fault, the Miri Fault cuts the centre of Miri town area in the N20°E and S20°W direction. The upper part of the Miri Formation is made up of shaly alternation and mudstone. Figures 4 and 5 show the total schematic and detail column of the Miri Formation respectively.

Based on the planktonic foraminiferal analysis this unit is younger than *Globorotalia (T.) peripheronda* Zone (N.9), which is equivalent to Mid Miocene and younger.

Lambir Formation

This unit is a sandy alternation, consisting mainly of sandstone beds interbedded with shale. The sandstone is fine to medium grained, friable and light grey. The thickness of the sandstone beds ranges from several tens of centimetres to several metres. Most of sandstone beds are massive of several metres thick and stands as resistant outcrops and beds, which are very important for correlation. However, cross-bedded and turbiditic sandstones were also commonly observed in several outcrops. The shale beds which were less dominant are present in the alternations ranging from several tens of centimetres to several tens of metres in thickness. Sometimes the shale are bounded by laminae of siltstone. White specks of microfossils are commonly observed in the shale beds.

The Lambir Formation is located along a stretch about 20 km along Miri-Bintulu road in the Bukit Lambir area in northwestern part and also crops out along Sibuti Lapok Road in the Bakong area, in the southwestern part; is divided by the shaly formation, the Sibuti Formation. The Lambir Formation also extends southwards to the Niah

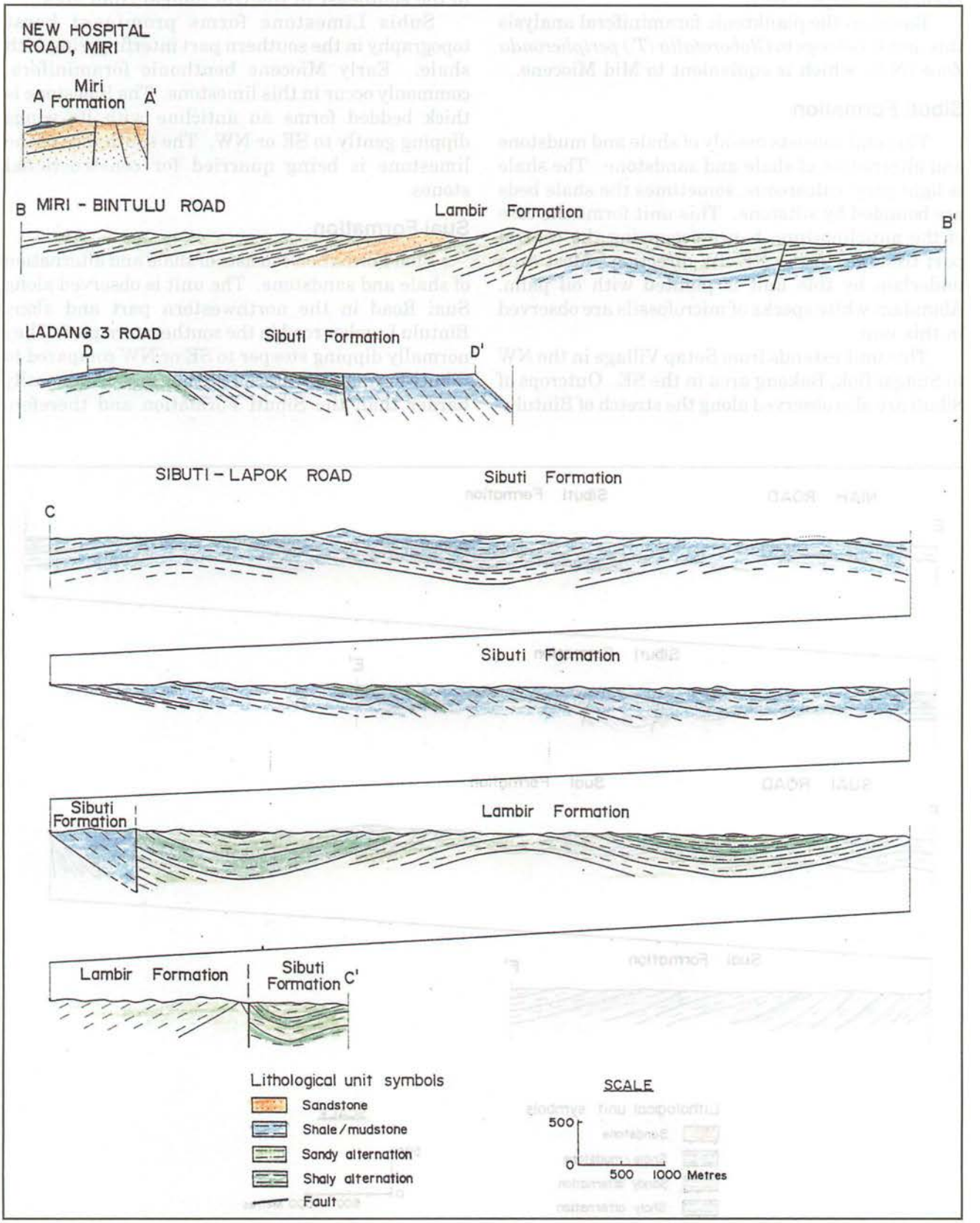

Figure 3a. Cross section of the Miocene sediments.

area in the western part. Figures 4 and 5 show the total schematic and detail column of the Lambir Formation respectively.

Based on the planktonic foraminiferal analysis this unit is belongs to *Globorotalia (T.) peripheronda* Zone (N.9), which is equivalent to Mid Miocene.

Sibuti Formation

This unit consists mainly of shale and mudstone and alternation of shale and sandstone. The shale is light grey, calcareous, sometimes the shale beds are bounded by siltstone. This unit forms the core of the anticlinorium, hence occupying the central part trending in the NE-SW direction. Most area underlain by this unit is planted with oil palm. Abundant white specks of microfossils are observed in this unit.

This unit extends from Setap Village in the NW to Sungai Bok, Bakong area in the SE. Outcrops of Sibuti are also observed along the stretch of Bintulu-Miri main road from Sibuti area to Niah area. The area underlain by this unit is undulating. It extends to the southeast in the Ulu Sungai Niah area.

Subis Limestone forms prominent karst topography in the southern part interfingering with shale. Early Miocene benthonic foraminifera, commonly occur in this limestone. The limestone is thick bedded forms an anticline with its wings dipping gently to SE or NW. The south face of the limestone is being quarried for constructional stones.

Suai Formation

Suai Formation consists of shale and alternation of shale and sandstone. The unit is observed along Suai Road in the northwestern part and along Bintulu Lumber road in the southeastern part. They normally dipping steeper to SE or NW compared to Sibuti Formation. Rocks of this unit is generally harder than the Sibuti Formation and therefore

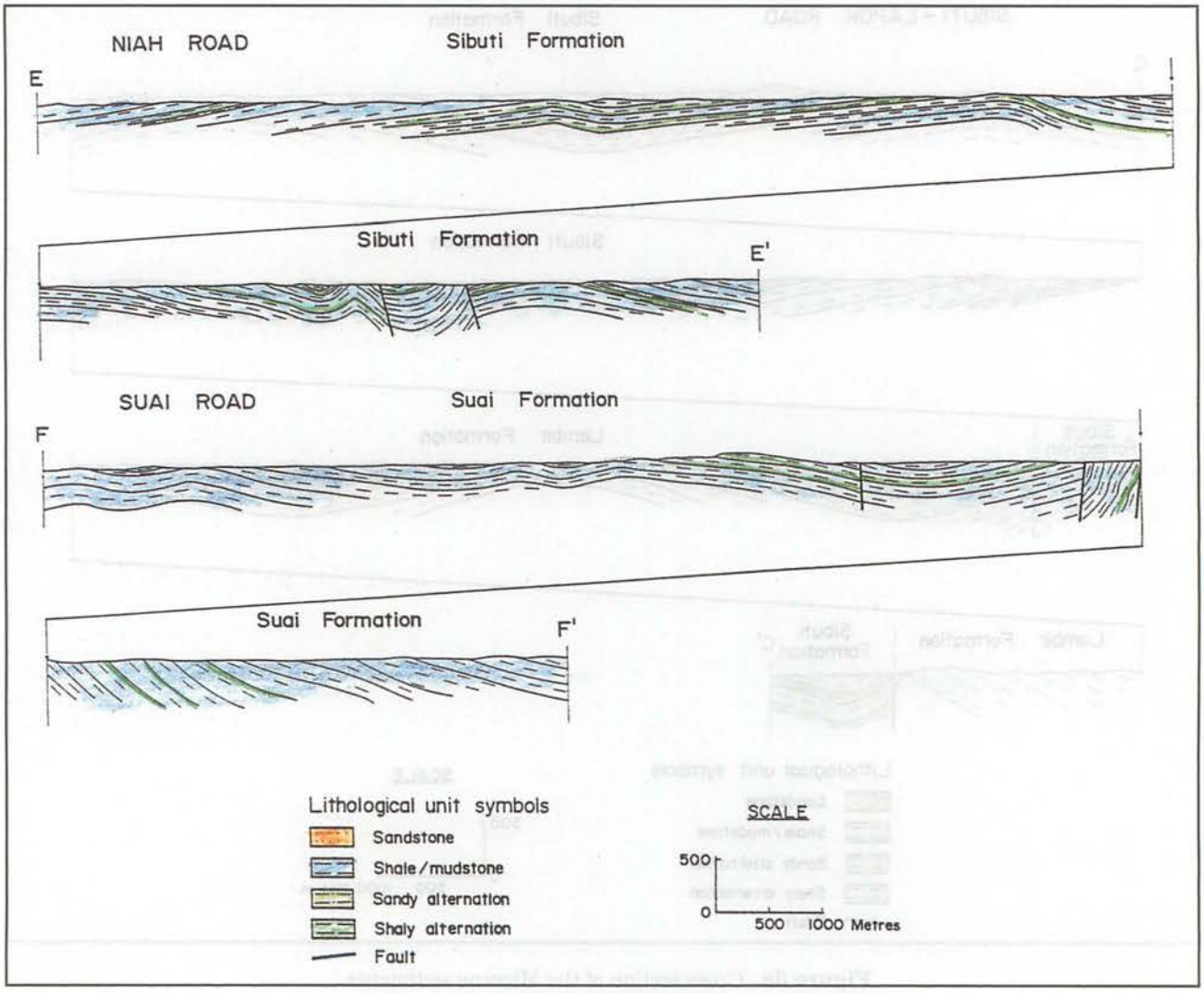

Figure 3b. Cross section of the Miocene sediments.

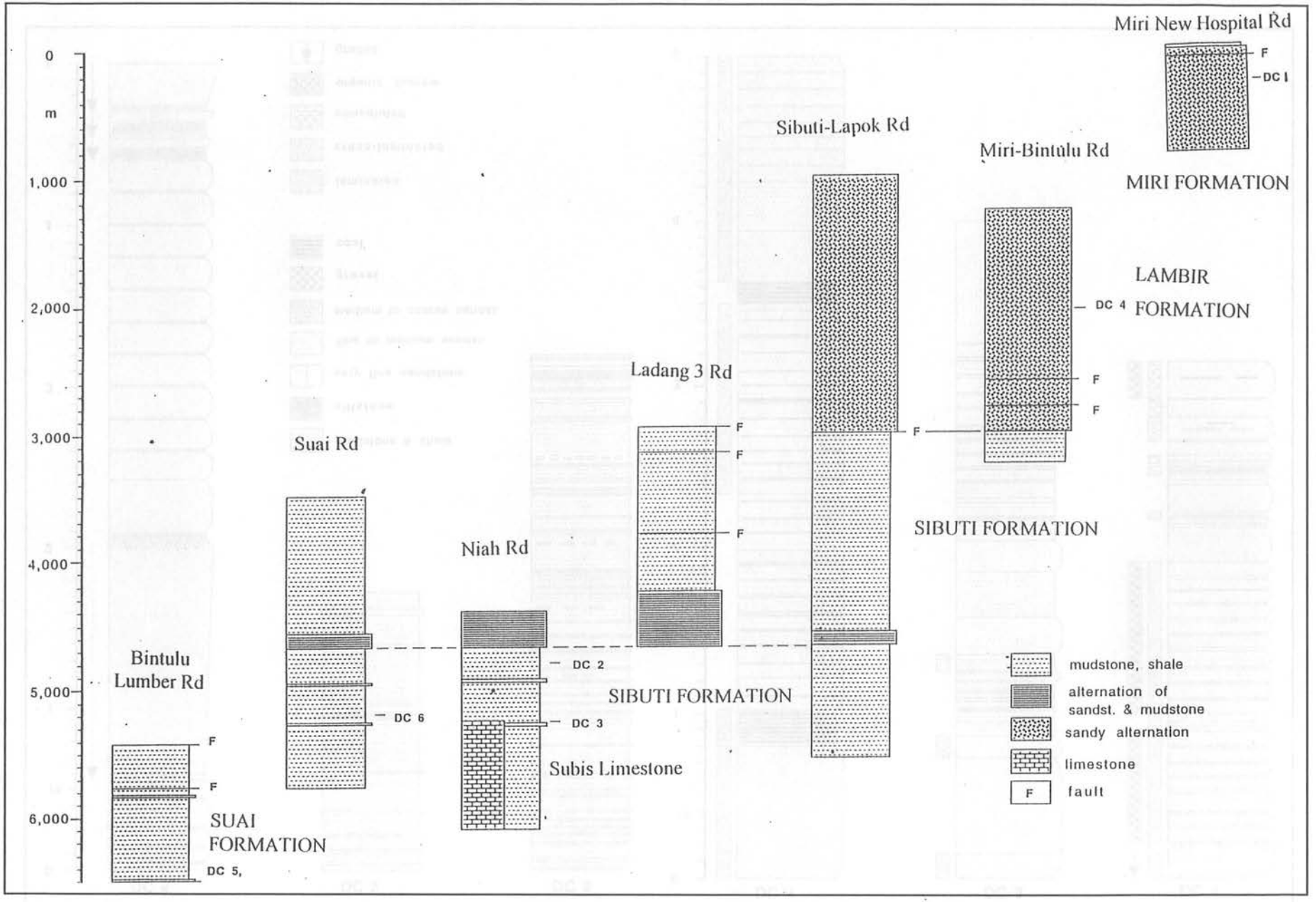

Figure 4. Schematic total column of the Miocene sediments.

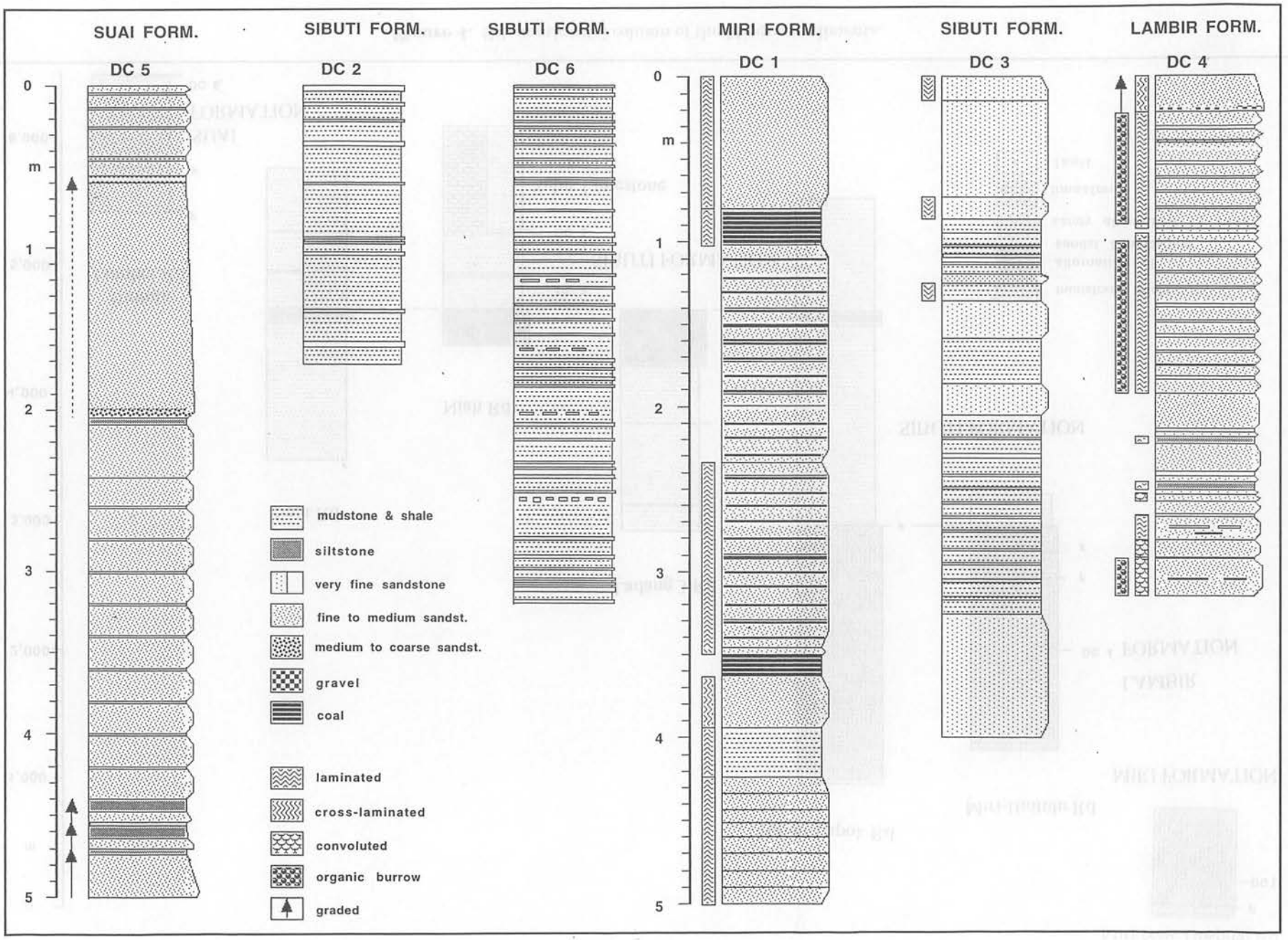

Figure 5. Detail column of the Miocene sediments.

believed to have undergone greater degree of weak regional metamorphism.

AGE ASSIGNMENT AND CORRELATION OF THE LITHOLOGICAL UNITS

Based on the planktonic foraminifera assignments, the Miocene formations are correlated to the Early to Late Miocene (Banda, 1994, 1995). Oldest is the Suai Formation which is within the range of *Globigerina binaiensis* Zone, equivalent to N.5–N.6 of Blow's 1969 zonation, is in the early Early Miocene. The Sibuti Formation is within the range of *Globigerinoides sicanus* Zone, equivalent to N.7–N.8, is in the mid Early Miocene in age. The Lambir Formation is within the range of the *Globorotalia (T.) peripheronda* Zone is equivalent to N.9, is in the Mid Miocene. The Miri Formation is within the range of *Globorotalia (T.) peripheronda* Zone and younger which is equivalent to N.9 and younger.

Stratigraphic relation between the Miri and the Lambir Formations is not clear on account that there are no outcrops, forming a lowland in the boundary area. This may suggest that mudstone sequences may been developed in the boundary area. The Lambir Formation conformably overlay the Sibuti Formation, consists dominantly of alternations of sandstone. Several alternation units of sandstone and shale are intercalated in the shale of the Sibuti Formation. Among them, a relatively thicker unit of alternations is observed approximately in the middle horizon of the formation, despite the thickness of the unit is variable, once thickening toward the northeast and thinning again in the northeastern margin. This alternation unit can be a marker for lithological correlation within the Sibuti Formation (Figs. 2 and 4).

Limestone of the Subis Member which is located in the central anticline of the anticlinorium in the surveyed area is correlated to the lowest horizon of the Sibuti Formation.

The southern Lambir Formation which occurs in the south wing of the anticlinorium is called the Belait Formation (Liechti, 1960; Wilford, 1961; Haile, 1962). However, as is illustrated in the cross section (Figs. 3a and 3b), this sandy alternations unit is assigned as an upper horizon of the overlying the Sibuti Formation and therefore is considered as the Lambir Formation of the north wing of the anticlinorium.

Therefore, we can distinguish only two formations of the Lambir Formation in the upper horizon and the Sibuti Formation in the lower horizon in the central and eastern areas. There is the same lithological unit as the Sibuti Formation in the west of the Suai Formation, having shale intercalated by the alternations units of sandstone and shale. However this unit is assigned to be in the lower horizon by means of planktonic foraminifera. This is called here the Suai instead of the Setap Formation. Setap Village is located in the Sibuti Formation in our compiled map.

SEDIMENT SUPPLY DIRECTION

Sediment supply directions of turbidites which is recorded in the sole marks at the bottom of the graded sandstone are from 230° in the Miri Formation, from NE or SW in the northern Lambir Formation, from SE in the southern Lambir Formation, from E or W in the upper and in the middle Sibuti Formation. This suggests that the direction of sediment supply varies, having shifted accordingly to age and to have omni-directional supplies of the shallow water sediments. Sediment supply directions of the northern Lambir Formation and of the Sibuti Formation are based on the observations of groove casts. We could not find out any float cast in these formations.

CONCLUDING REMARK

From the recent geological study of the Miocene sediments of the Northwest Sarawak Basin the following conclusions could be drawn:

i) Lithostratigraphic unit:

We have assigned the Miocene sediments in the area as the Sibuti Formation for the lower unit and the Lambir Formation for the upper unit. The uppermost sandy alternation unit is the Miri Formation. The southwestern margin where the sediment is older, with age of early Early Miocene is termed as Suai Formation. We have reported detail facies of these sedimentary rocks which is considered to be a typical unit of the formation.

The Belait Formation in the southern wing of the anticlinorium is corresponding to the same horizon as the Lambir Formation, and here we decided to abandon the term Belait Formation and named it as Lambir Formation. Based on accurate and systematic correlation we placed each formation in proper stratigraphic position. From this correlation we conclude that the Subis Limestone is located along the axis of the anticlinorium, occupying the lowest part of the Sibuti Formation.

ii) Planktonic foraminiferal assignment:

From the biostratigraphical analysis the Miri Formation is Mid to Late Miocene, Lambir

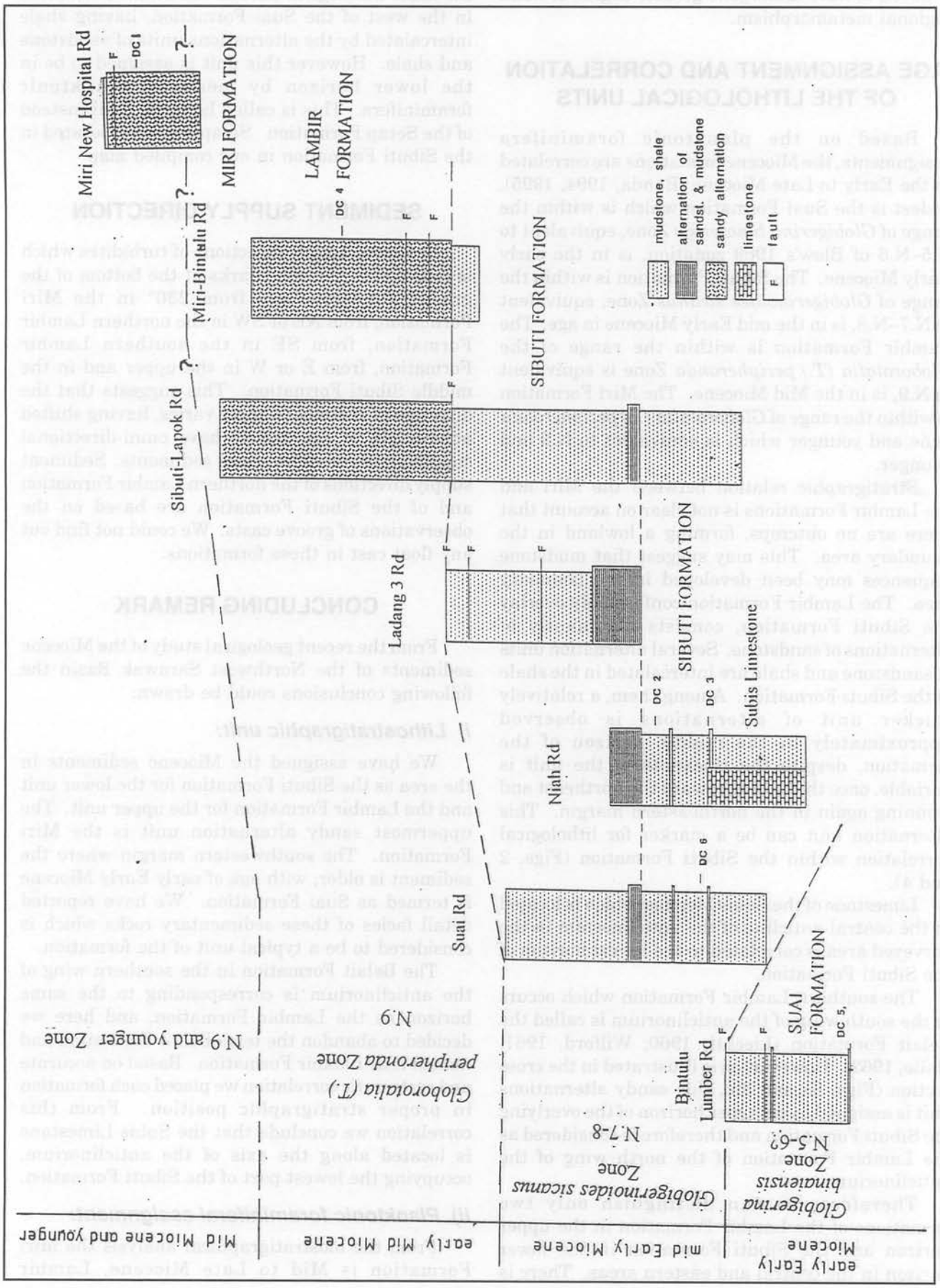

Figure 6. Biostratigraphic correlation of the Miocene sediments.

Formation is early Mid Miocene, Sibuti Formation is mid Early Miocene and the Suai Formation is early Early Miocene. Here we propose a new name the Suai Formation for the former Setap Formation. Setap Village is located within the Sibuti Formation, therefore it is not appropriate in the stratigraphic nomenclature.

iii) Structural assignment:

We could observe structures such as the NNW-SSE trending blocks bounded by NNW-SSE faults namely from the northeastern part to the southwestern part as the Lambir, Bakong, Lapok, Tangap, Niah and Suai Faults. The displacement of the block through major faulting is not prominent which makes it possible to correlate each layer in the next block. Even though the horizontal displacement along the Lapok Faults reaches several to ten kilometers, the distribution of the Sibuti Formation is wider in the western block of the Lapok Fault than in the eastern block. This suggests that the displacement of the fault has not only horizontal component, but also vertical component. The Suai Fault trending approximately N-S, a little different direction from other faults is the boundary between the Sibuti and the Suai Formations, suggesting relatively large displacement.

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