

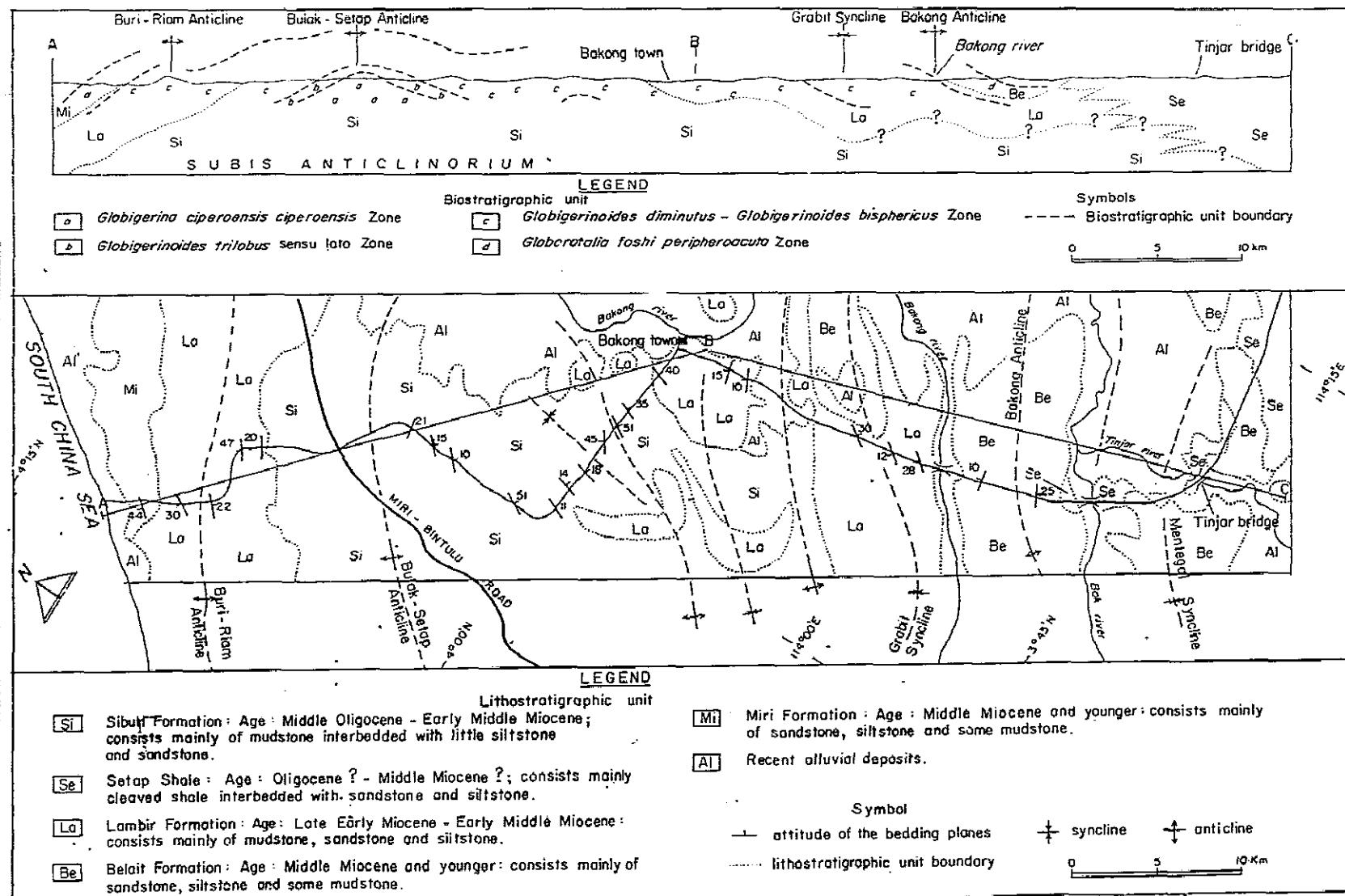
## CHAPTER 4: PLANKTIC FORAMINIFERAL BIOSTRATIGRAPHY

### 4.1 PREVIOUS INVESTIGATION

Liechti et al (1960) and Sarawak Shell Oil Company (cited by Ho, 1978, p. 3), respectively have described the occurrences of planktic foraminifers in a few places in the central Sarawak and also in the offshore provinces of the northwest Sarawak. In onshore areas, the planktic foraminifers occurred only very limited amount, in mainly the Sibuti and Suai Formations, and thereby no planktic foraminiferal zonation and the age was established in this region. The age of the sediments was then established based mainly from the analysis on benthos and big foraminifera, ranging from Early Miocene to Mid Miocene. However, in the extensive offshore provinces of the northwest Sarawak, there were many drilled holes contained planktic foraminifers that enabled the establishment of a complete planktic foraminiferal zonations based on Postuma (1971) with age ranging from early Paleogene to Pleistocene (Fig. 7)

Banda (1994, 1995a) initiated the study of the planktic foraminifers respectively in Miri-Tinjar Road and the Sibuti areas; attempted to establish planktic foraminiferal zonation and age of the sediments in these areas based the established planktic foraminiferal biostratigraphy of Blow's (1969). From the study of Miri-Tinjar Road section by Banda in 1994 (Fig. 55), there are 28 species of planktic foraminifers were recovered, commonly are: *Globigerina praebulloides praebulloides*, *Globigerinoides quadrilobatus quadrilobatus*, *Globigerinoides quadrilobatus sacculifer*, *Globigerinoides trilobus trilobus*, *Globigerinoides trilobus immaturus* and *Globoquadrina dehiscens dehiscens*. Based on the analysis of the first and the last appearance of the species, they are 4 biostratigraphic zones established namely: i) *Globigerina ciperoensis ciperoensis*, ii) *Globigerinoides trilobus sensu lato*, iii) *Globigerinoides diminutus-Globigerinoides bisphericus* and iv) *Globorotalia foshi peripheroacuta Zone*. These zones are correlatable to Blow's (1969) Zones P 20/N.1-N.11 with age ranging from Middle Oligocene to Middle Miocene. The oldest zone is *Globigerina ciperoensis ciperoensis* Zone formed the core of the Subis Anticlinorium, whereas the younger zones are located towards the periphery of the anticlinorium.

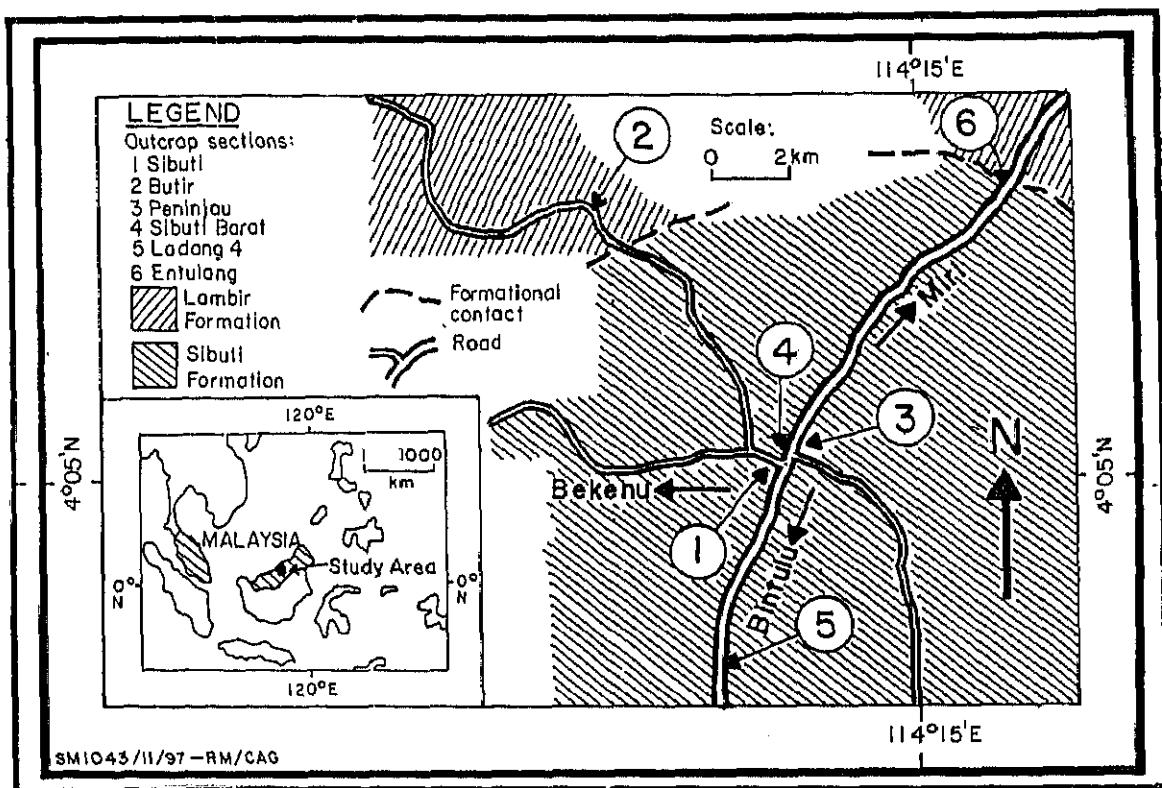
Banda (1995a) also conducted a study on the planktic foraminifers in the Sibuti area. Samples of mudstone were collected from six outcrops (Fig. 30) and they were 40 species recovered, with the most common species are *Globigerina praebulloides praebulloides*, *Globigerinoides quadrilobatus quadrilobatus*, *Globigerinoides trilobus trilobus*, *Globigerinoides trilobus immaturus*, *Globoquadrina dehiscens dehiscens* and *Praeorbulina transitoria*.



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Figure 55. Geological map of Miri-Tinjar Road, North Sarawak  
(after Banda, 1994)

These species implied the age of the sediments is early Mid Miocene, deposited in the open marine sedimentary environment.



**Figure 56. Sample locality for the planktic foraminiferal analysis in the Sibuti area**

#### 4.2 OBJECTIVE OF THE PRESENT INVESTIGATION

As stated in Chapter 1, the main objective of the present investigation is to study the geology and planktic foraminiferal biostratigraphy of the Northwest Borneo Basin. The account on the geology and tectonic framework of the area have been discussed in Chapter 2 and 3, and this Chapter 4, is discussing the planktic foraminiferal biostratigraphy of the Northwest Borneo Basin; attempting to establish the planktic foraminiferal zonation and age of the lithostratigraphic unit of the Suai, Sibuti, Lambir and Miri Formations established during the recent geological mapping. The mudstone collected during the geological mapping are processed in the laboratory for the extraction of the foraminifers and then analysed for the biostratigraphic zonation. With the combination of the data from geology, tectonics and biostratigraphy, a comprehensive stratigraphic framework of the area can be established in order to enhance the development of the economic potential of the whole region of the Northwest Borneo Basin.

#### **4.3 METHODOLOGY AND MATERIALS FOR THE PLANKTIC FORAMINIFERAL ANALYSIS**

In order to obtain planktic foraminifers for the analysis, mainly the mudstone samples were collected in the field during the detailed geological mapping at the scale of 1: 10,000. They are 214 samples of mudstone and shale were collected; each sample weighs approximately 150g, collected at approximately of 1 km distance interval (Fig. 57), however, in some localities, a very detailed sampling at 2 m interval was also conducted such as in the Entulang outcrop section. The total 214 samples are made up of 22 samples collected from the Suai Formation, 144 from the Sibuti Formation and 47 from the Lambir Formation and 1 from the Miri Formation.

They are 22 samples from the Suai Formation; were collected along Suai Road (Figs. 58, 59) and Bukit Lembong Road (Fig. 60). The samples collected were mainly mudstone, shale and some siltstone (Table 1).

They are 144 samples were collected over the extensive area of the Sibuti Formation; 32 samples of mainly mudstone and shale were collected from the type section, Miri-Tinjar Road section (Figs. 60-62, Table 2) and the rest were collected from the reference sections such as: along Niah Road (Figs. 63, 64, Table 3), Ladang 3 Road ( Fig. 65, Table 3) and Lamaus and Kuala Sibuti Roads ( Fig. 57, Table 3). The samples collected from these reference sections are mainly mudstone. Samples of mainly mudstone were also collected from the outcrop sections of Sibuti (Fig. 66, Table 4), Peninjau (Table 2), Ladang 4, Entulang (Fig 67, Table 4), Sekaloh (Fig 68, Table 4), Subis (Fig 69, Table 4).

From the Lambir Formation a total of 47 samples of mainly siltstone were collected; obtained from the type section, the Bintulu-Miri Road (Table 5, Figs. 70, 71) and the reference section, along Miri-Tinjar Road (Table 5, Figs. 72, 73). The samples collected were mainly siltstone and mudstone.

From the Miri Formation, only one mudstone sample was collected along Miri Hospital Road (Fig. 74, Table 5).

The samples when they are brought to the laboratory, were broken into a size of 2-3 cm and then dried in the oven at the temperature of 60°C for 3 days. The samples were then boiled in saturated anhydrous sodium sulphate solution to dissolve the mudstone. The sample is sieved through 200 mesh sieve leaving behind fragments of resistant rock and fossil tests, is later on dried so to pick the foraminifers from the rest of the fragments.

However, if the mudstone is not easily dissolved by boiling with sodium sulphate solution, is left to cool overnight so that when the solution crystallised within the intergranular spaces, it will help to disintegrate the rock further.

Planktic foraminifers were observed and identified under binocular microscope (Tables 1-6). The species with a good preservation and important for

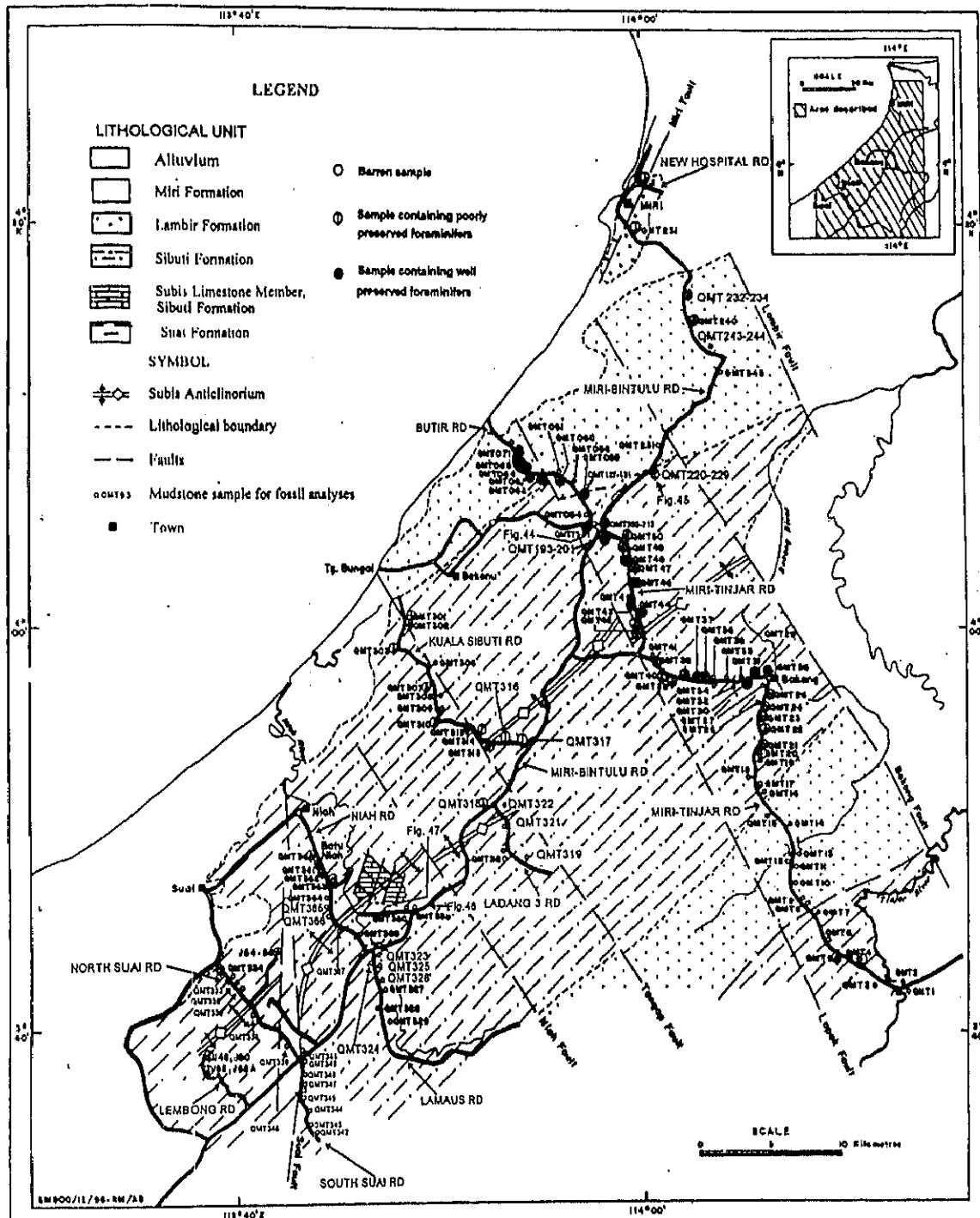


Figure 57. Sample localities of the planktic foraminiferal analysis in NW Sarawak

Table 1. Occurrence of the planktic and benthic foraminifers in the Suai Formation along Suai and Lembong Road

**NOTE:**

Abundance: / = Barren, R = Rare (less than 5), A = Abundant (more than 5)

Preservation: G = Good, M = Moderate, P = Poor

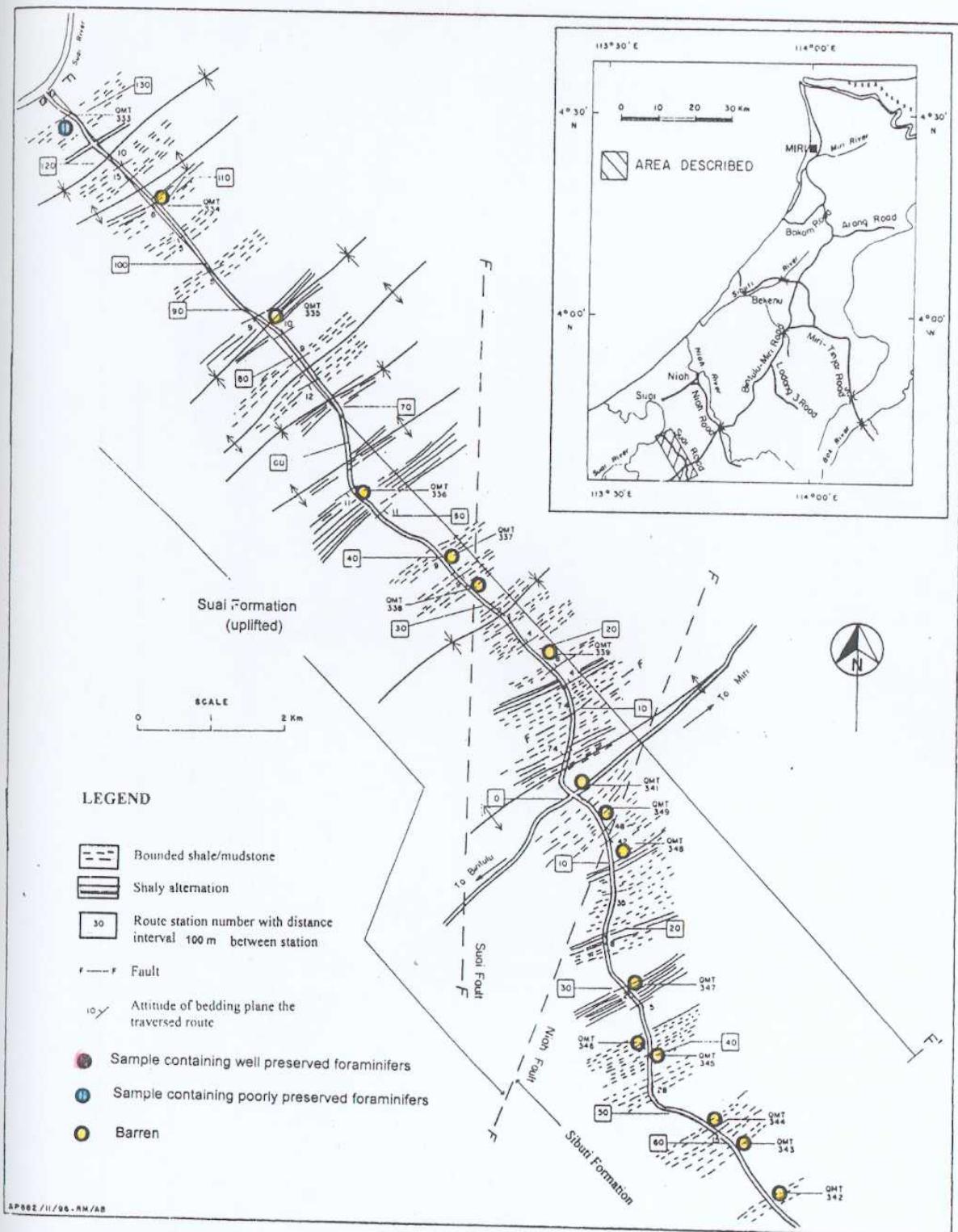


Figure 58. Sample localities of the planktic foraminiferal analysis in the Suai and Sibuti Formations, along Suai Road

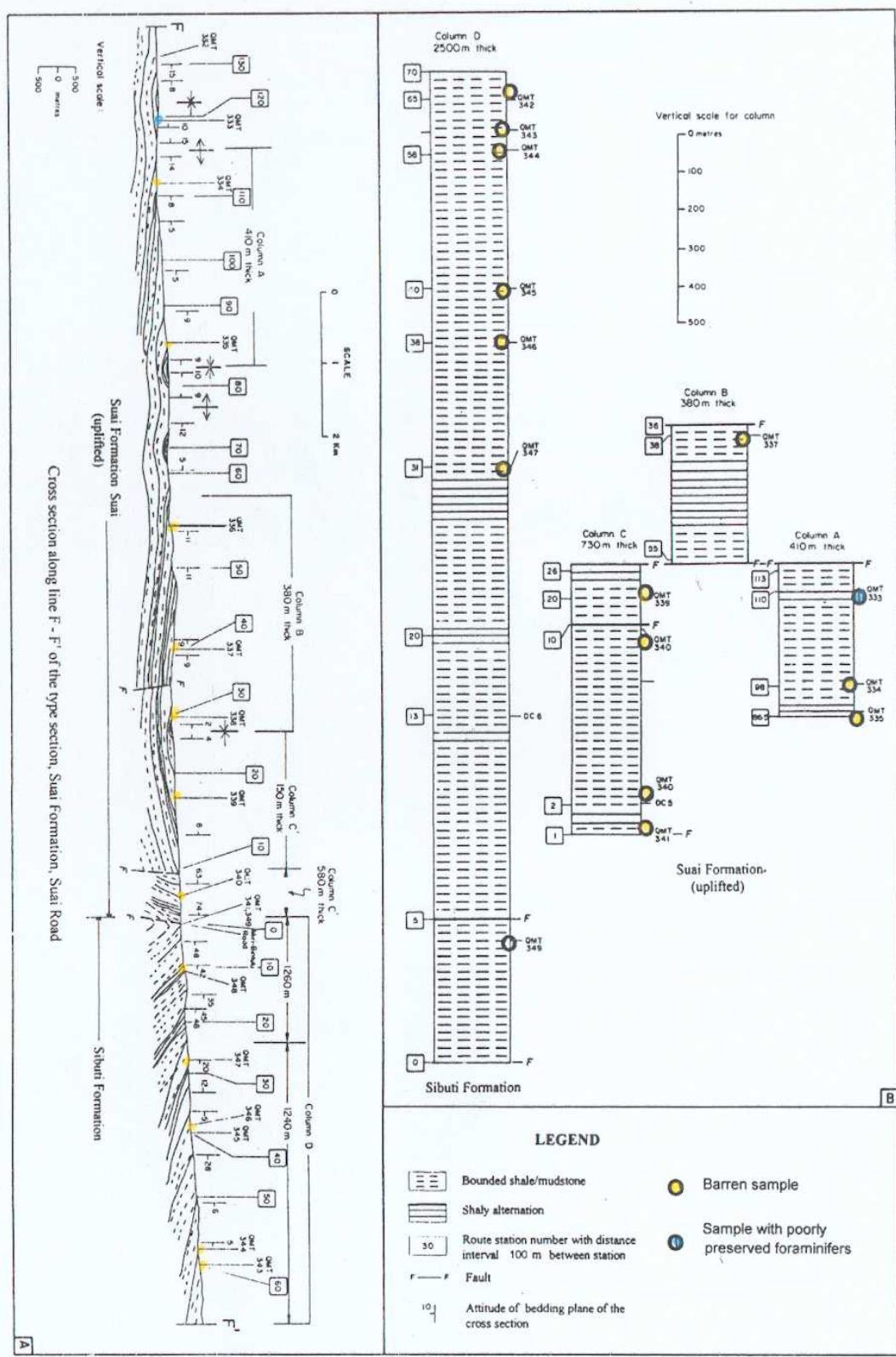


Figure 59. Sample localities of the planktic foraminiferal analysis in the cross and columnar sections of the Suai and Sibuti Formations, along Suai Road

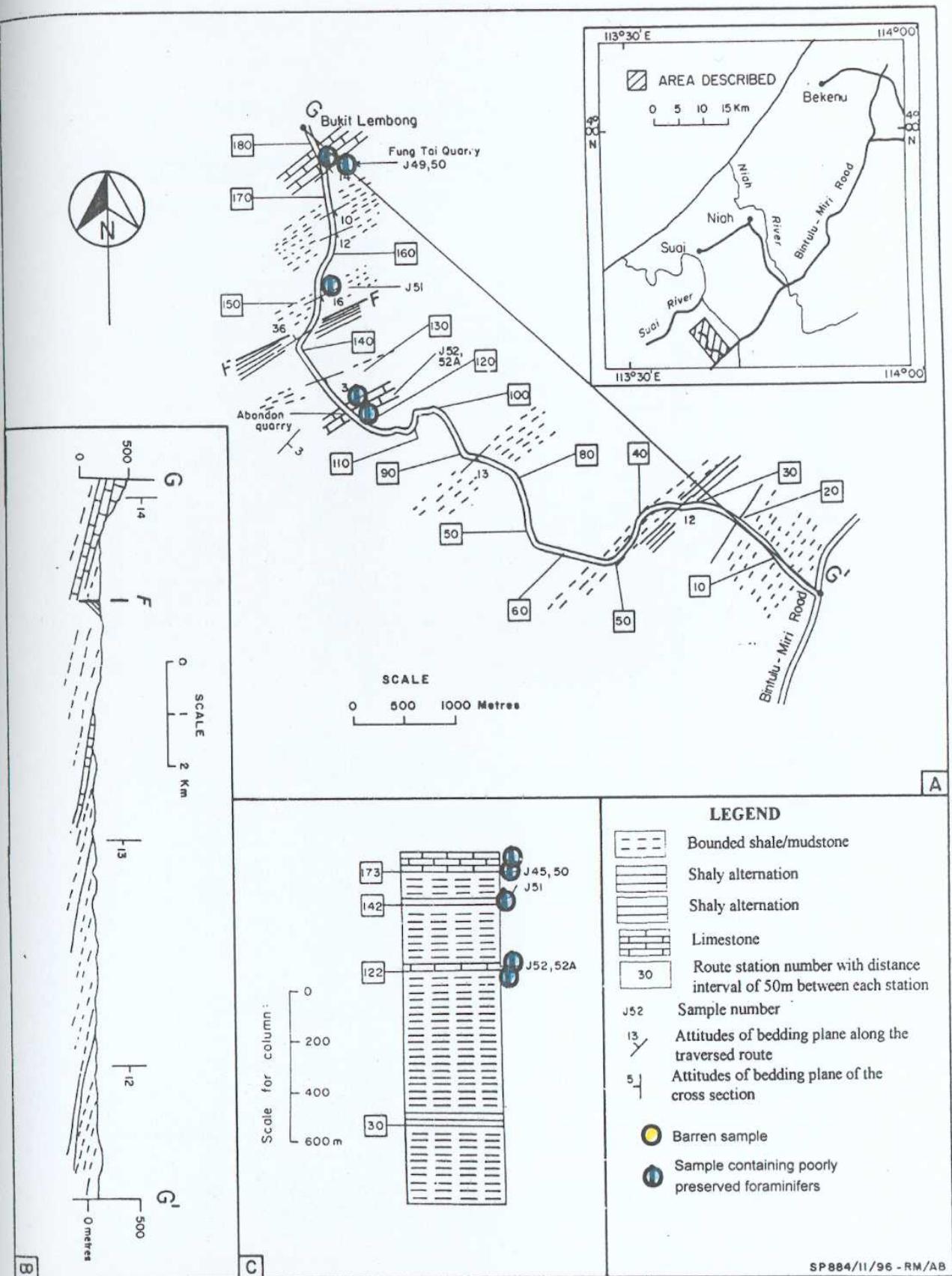


Figure 60. Sample localities of the planktic foraminiferal analysis in the Suai Formation, along Bukit Lembong Road

Table 2. Occurrence of the planktic and benthic foraminifers in the Sibut Formation along Miri-Tinhar Road

Age	Formation	Locality	Sample	Planktic Foram	Benthic Foram	Preservation	Abundance	Other remark
	SIBUTI FORMATION	MIRITINJAR ROAD	QMT019	/	/	/	/	Mudstone
			QMT020	R	R	P	R	Mudstone
			QMT021	A	A	P	A	Mudstone
			QMT022	/	R	M	R	Mudstone
			QMT023	R	A	G	A	Mudstone
			QMT024	R	A	G	A	Mudstone
			QMT025	R	A	G	R	Mudstone
			QMT026	R	R	G	A	Mudstone
			QMT027	A	A	G	A	Mudstone
			QMT028	A	A	G	A	Mudstone
			QMT029	A	A	M	A	Mudstone
			QMT030	A	A	G	A	Mudstone
			QMT031	R	R	G	R	Mudstone
			QMT032	A	A	G	A	Mudstone
			QMT033	A	A	G	A	Mudstone
			QMT034	/	/	/	/	Mudstone
			QMT035	/	/	/	/	Mudstone
			QMT036	/	/	/	/	Mudstone
			QMT037	R	R	M	R	Mudstone
			QMT038	R	R	M	R	Mudstone
			QMT039	R	R	M	R	Mudstone
			QMT040	A	A	P	A	Mudstone
			QMT041	A	A	M	A	Mudstone
			QMT042	A	A	G	A	Mudstone
			QMT043	A	A	P	A	Mudstone
			QMT044	R	R	G	R	Mudstone
			QMT045	A	A	G	A	Mudstone
			QMT046	A	A	G	A	Mudstone
			QMT047	A	A	M	A	Mudstone
			QMT048	R	R	P	R	Mudstone
			QMT049	R	R	P	R	Mudstone
			QMT050	A	A	M	A	Mudstone
			QMT202	A	A	G	A	Mudstone
			QMT203	A	A	G	A	Mudstone
			QMT204	A	A	G	A	Mudstone
			QMT205	A	A	G	A	Mudstone
			QMT206	A	A	G	A	Mudstone
			QMT207	A	A	G	A	Mudstone
			QMT208	A	A	G	A	Mudstone
			QMT209	A	A	G	A	Mudstone
			QMT210	/	/	/	/	Mudstone
			QMT211	A	A	G	A	Mudstone

SIBUTIFORMATION

**NOTE:**

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Preservation: G = Good, M = Moderate, P = Poor

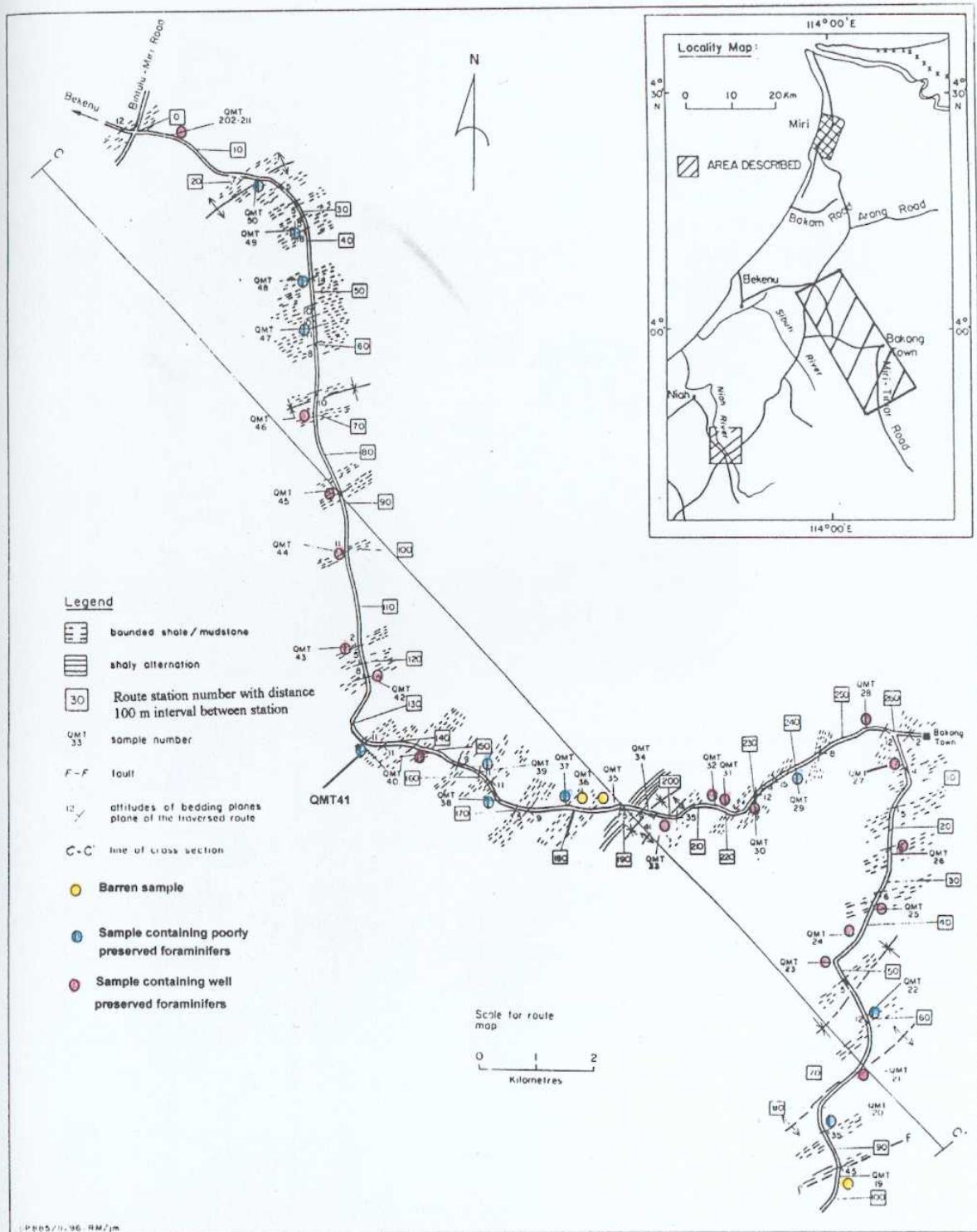


Figure 61. Sample localities in the Sibuti Formation, along Miri-Tinjar Road

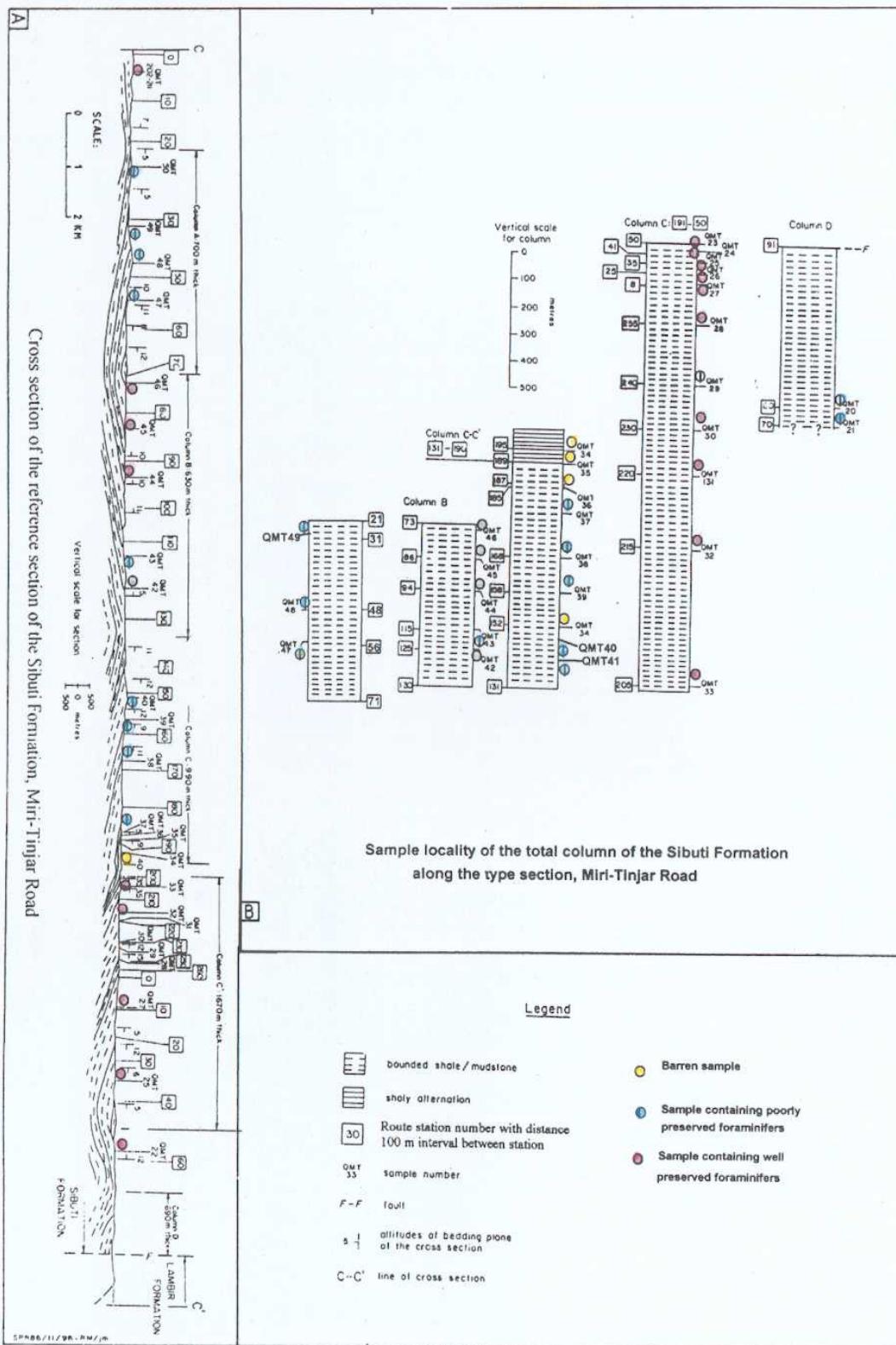


Figure 62. Sample localities in the cross section and total column of the Sibuti Formation, along Miri-Tinjar Road

Table 3. Occurrence of the planktic and benthic foraminifers in the Sibuti Formation along Suai, Niah, Ladang 3 and Kuala Sibuti Road

Age	Formation	Locality	Sample	Planktic Foram	Benthic Foram	Preservation	Abundance	Other remark
S I B U T I   F O R M A T I O N		(Figs. 57, 58)						
K U A L A   S I B U T I		(Figs. 62, 63)						
L A D A N G   3		(Fig. 64)						
L A M A U S   N I A H   R O A D		(Figs. 62, 63)						
R O A D		(Figs. 62, 63)						
S U A   R O A D		(Figs. 57, 58)						
			QMT348	/	/	/	/	Mudstone
			QMT347	/	/	/	/	Mudstone
			QMT346	/	/	/	/	Mudstone
			QMT345	/	/	/	/	Mudstone
			QMT344	/	/	/	/	Mudstone
			QMT343	/	/	/	/	Mudstone
			QMT342	/	/	/	/	Mudstone
			QMT357	/	/	/	/	Mudstone
			QMT358	/	/	/	/	Mudstone
			QMT359	R	R	/	R	Mudstone
			QMT360	/	/	/	/	Mudstone
			QMT361	A	A	P	A	Mudstone
			QMT362	A	A	P	A	Mudstone
			QMT363	A	A	G	A	Mudstone
			QMT364	/	/	/	/	Mudstone
			QMT365	/	/	/	/	Mudstone
			QMT366	/	/	/	/	Weathered mudstone
			QMT367	/	/	/	/	Siltstone
			QMT368	/	/	/	/	Siltstone
			QMT369	A	R	M	R	Siltstone
			QMT323	/	/	/	/	Mudstone
			QMT324	/	/	/	/	Mudstone
			QMT325	/	/	/	/	Mudstone
			QMT326	/	/	/	/	Mudstone
			QMT327	/	/	/	/	Mudstone
			QMT328	/	/	/	/	Siltstone
			QMT329	/	/	/	/	Mudstone
			QMT330	/	/	/	/	Mudstone
			QMT321	/	/	/	/	Mudstone
			QMT320	/	/	/	/	Mudstone
			QMT319	/	/	/	/	Shale
			QMT318	R	A	P	A	Siltstone
			QMT300	/	/	/	/	Mudstone
			QMT301	/	/	/	/	Weathered mudstone
			QMT302	R	A	P	A	Mudstone
			QMT303	R	R	P	R	Mudstone
			QMT304	/	/	/	/	Siltstone
			QMT305	R	R	P	R	Siltstone
			QMT306	/	/	/	/	Siltstone
			QMT307	A	A	M	A	Mudstone
			QMT308	R	/	/	R	Mudstone
			QMT309	R	/	/	R	Mudstone

NOTE:

Abundance: / = Barren, R = Rare (less than 5), A = Abundant (more than 5)

Preservation: G = Good, M = Moderate, P = Poor

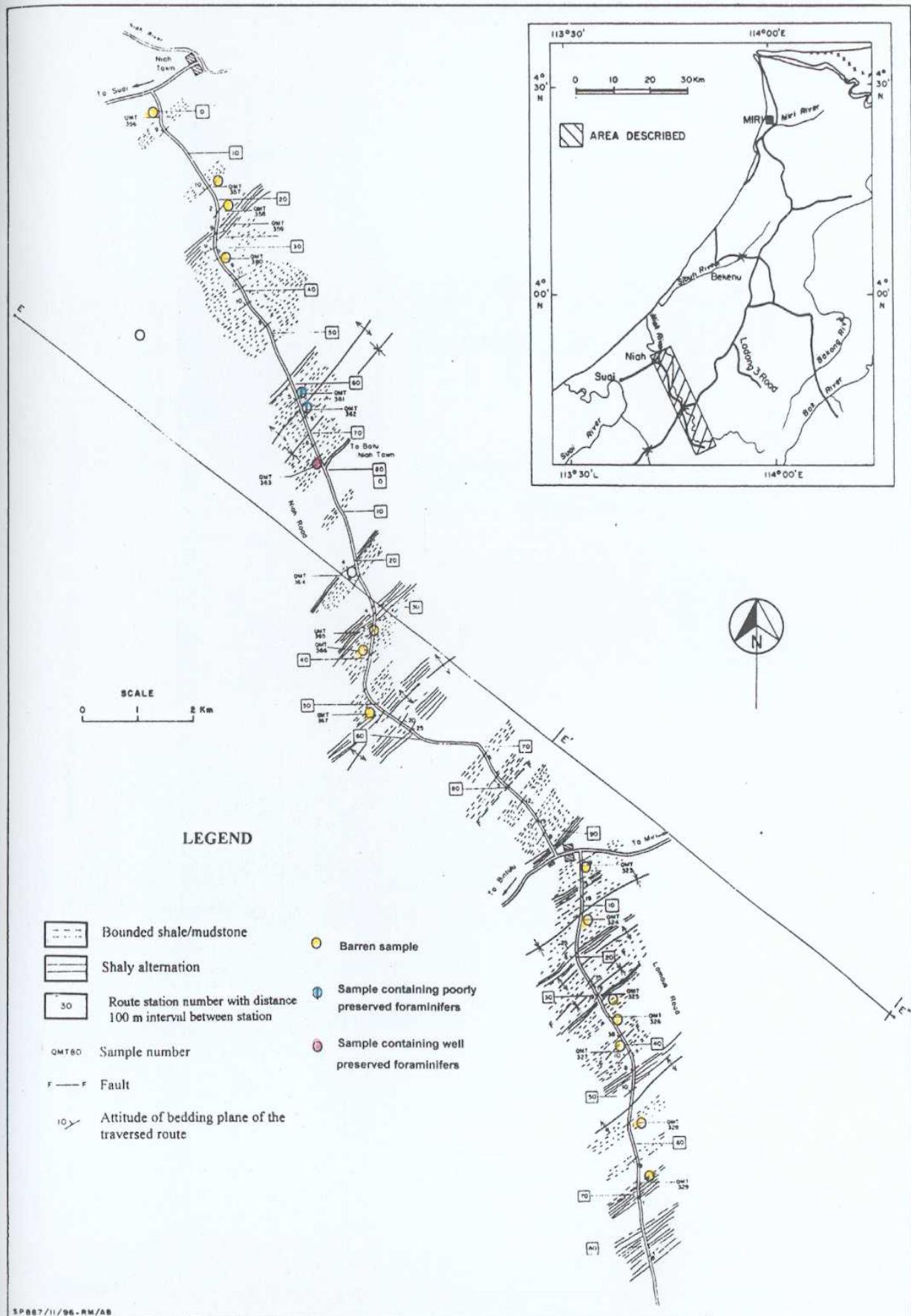


Figure 63. Sample localities in the Sibuti Formation, along Niah Road

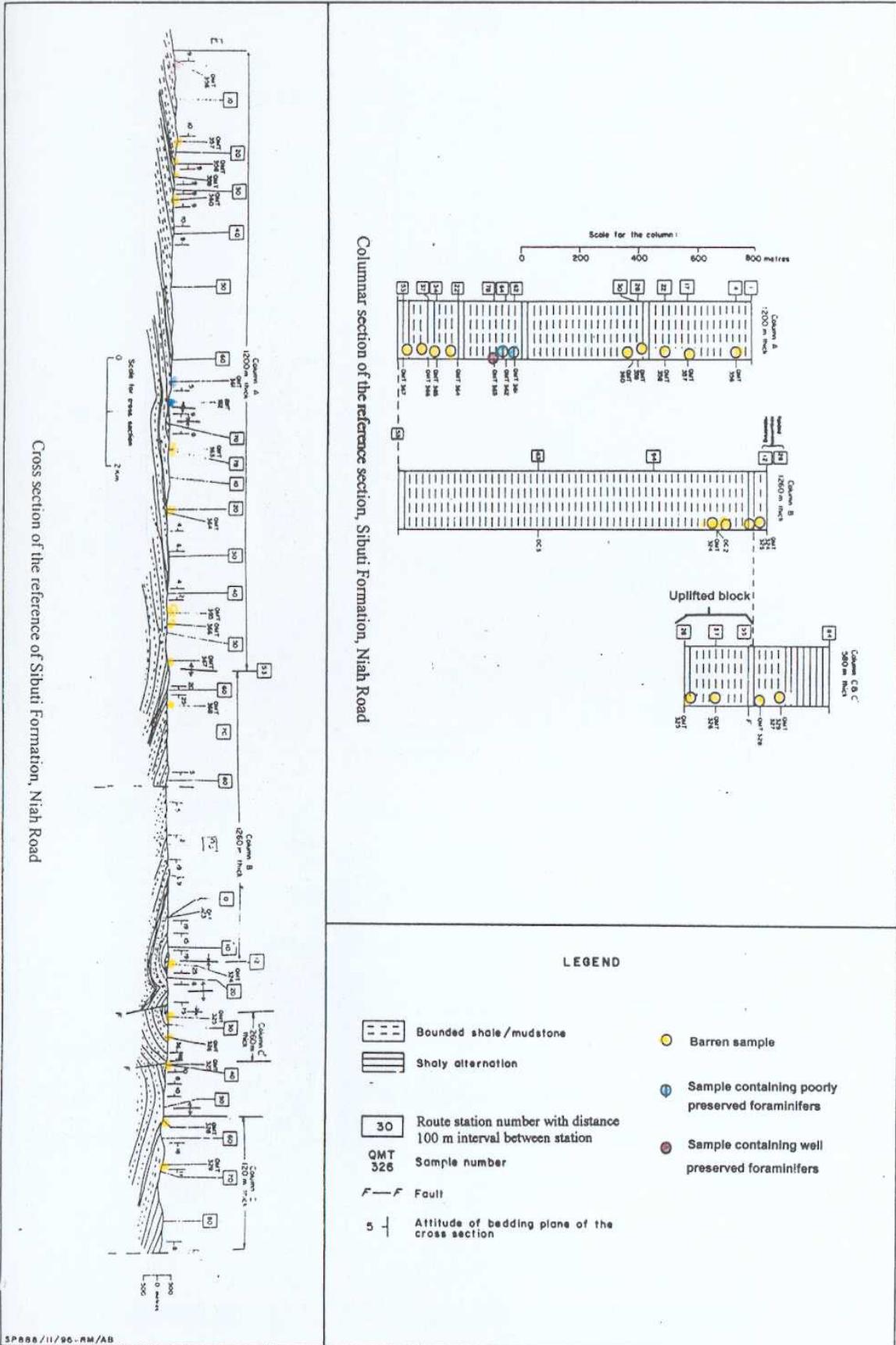


Figure 64. Sample localities in the cross section and total column of the Sibuti Formation, along Niah Road

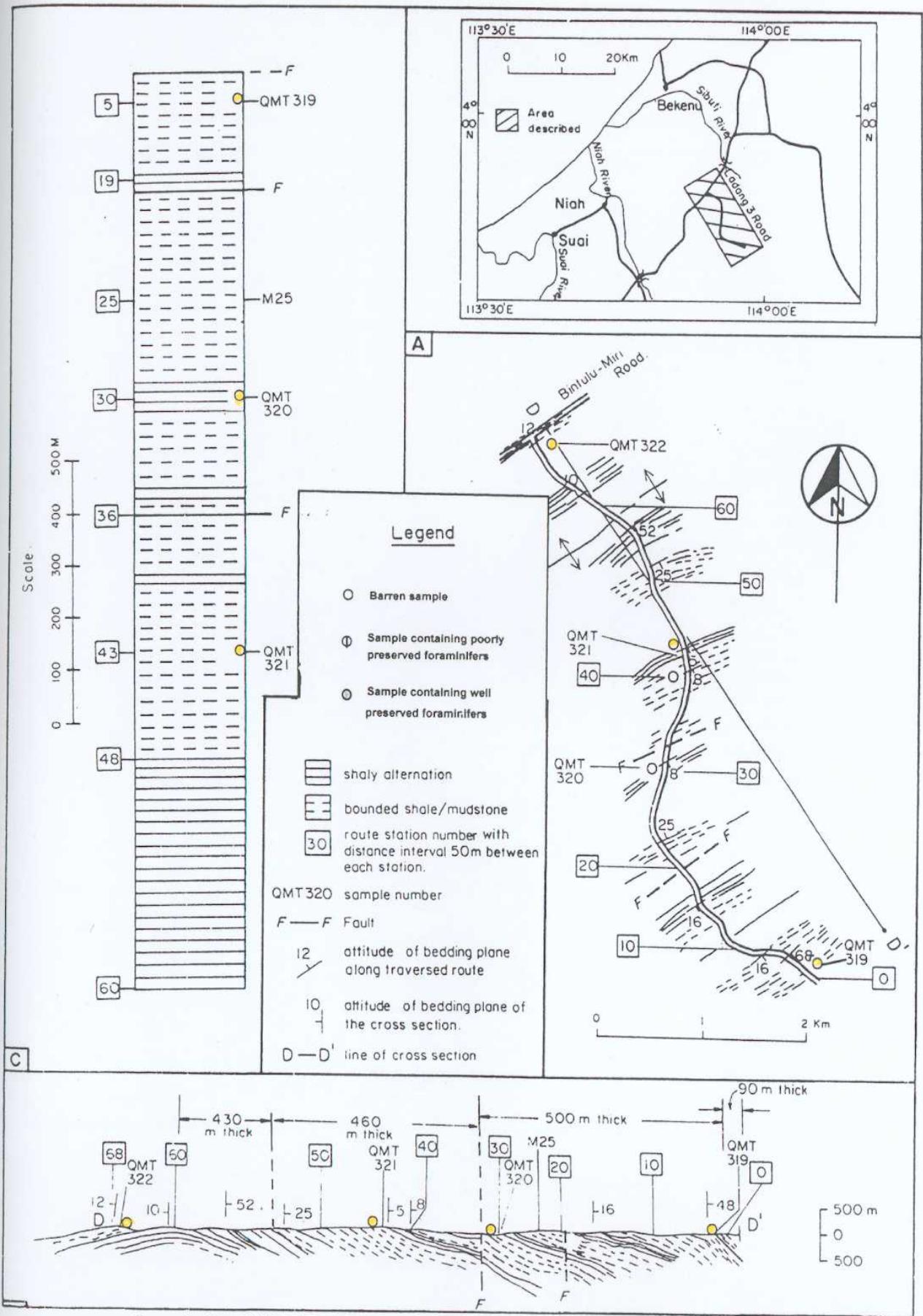


Figure 65. Sample localities in the cross section and total column of the Sibuti Formation, along Ladang 3 Road

Table 4. Occurrence of the planktic and benthic foraminifers in the Sibuti Formation along Kuala Sibuti, Bekenu, Miri-Bintulu and Miri-Tinjar Road

Age	Formation	Locality	Sample	Planktic Foram	Benthic Foram	Preservation	Abundance	Other remark
SIBUTI FORMATION BUTIR SIBUTI OUTCROP SECTION, BEKENU JUNCTION (Fig. 58)	KUALA SIBUTI MIRI - TINJAR RD (Fig. 56)	(Fig. 56)	QMT310	R	I	P	R	Mudstone
			QMT311	A	R	M	A	Mudstone
			QMT312	R	R	P	R	Mudstone
			QMT313	R	R	P	A	Mudstone
			QMT314	A	R	P	A	Mudstone
			QMT315	A	R	P	A	Mudstone
			QMT316	R	R	P	A	Mudstone
			QMT317	R	R	P	R	Mudstone
			QMT001	/	/	/	/	Mudstone
			QMT002	/	/	/	/	Mudstone
			QMT003	R	R	M	R	Mudstone
			QMT004	/	A	M	A	Mudstone
			QMT005	/	R	/	G	Mudstone
SIBUTI FORMATION OUTCROP SECTION, BEKENU JUNCTION (Fig. 65)	MIRI - TINJAR RD (Fig. 56)	(Fig. 56)	QMT073	A	A	G	A	Mudstone
			QMT074	A	A	G	A	Mudstone
			QMT075	R	R	M	A	Mudstone
			QMT076	R	R	M	R	Mudstone
			QMT077	R	R	M	R	Mudstone
			QMT078	A	A	G	R	Mudstone
			QMT079	A	A	G	A	Mudstone
			QMT080	R	R	G	R	Mudstone
			QMT081	A	A	G	A	Mudstone
			QMT082	A	A	G	A	Mudstone
			QMT083	A	A	G	A	Mudstone
			QMT084	A	A	G	A	Mudstone
			QMT085	A	A	G	A	Mudstone
			QMT086	A	A	G	A	Mudstone
			QMT087	A	A	G	A	Mudstone
			QMT088	A	A	G	A	Mudstone
			QMT089	A	A	G	A	Mudstone
			QMT090	A	A	G	A	Mudstone
			QMT091	A	A	G	A	Mudstone
SIBUTI FORMATION OUTCROP SECTION, BEKENU JUNCTION (Fig. 58)	MIRI - TINJAR RD (Fig. 56)	(Fig. 56)	QMT127	A	A	G	A	Mudstone
			QMT128	A	A	G	A	Mudstone
			QMT129	A	A	G	A	Mudstone
			QMT130	A	A	G	A	Mudstone
			QMT131	A	A	G	A	Mudstone

NOTE:

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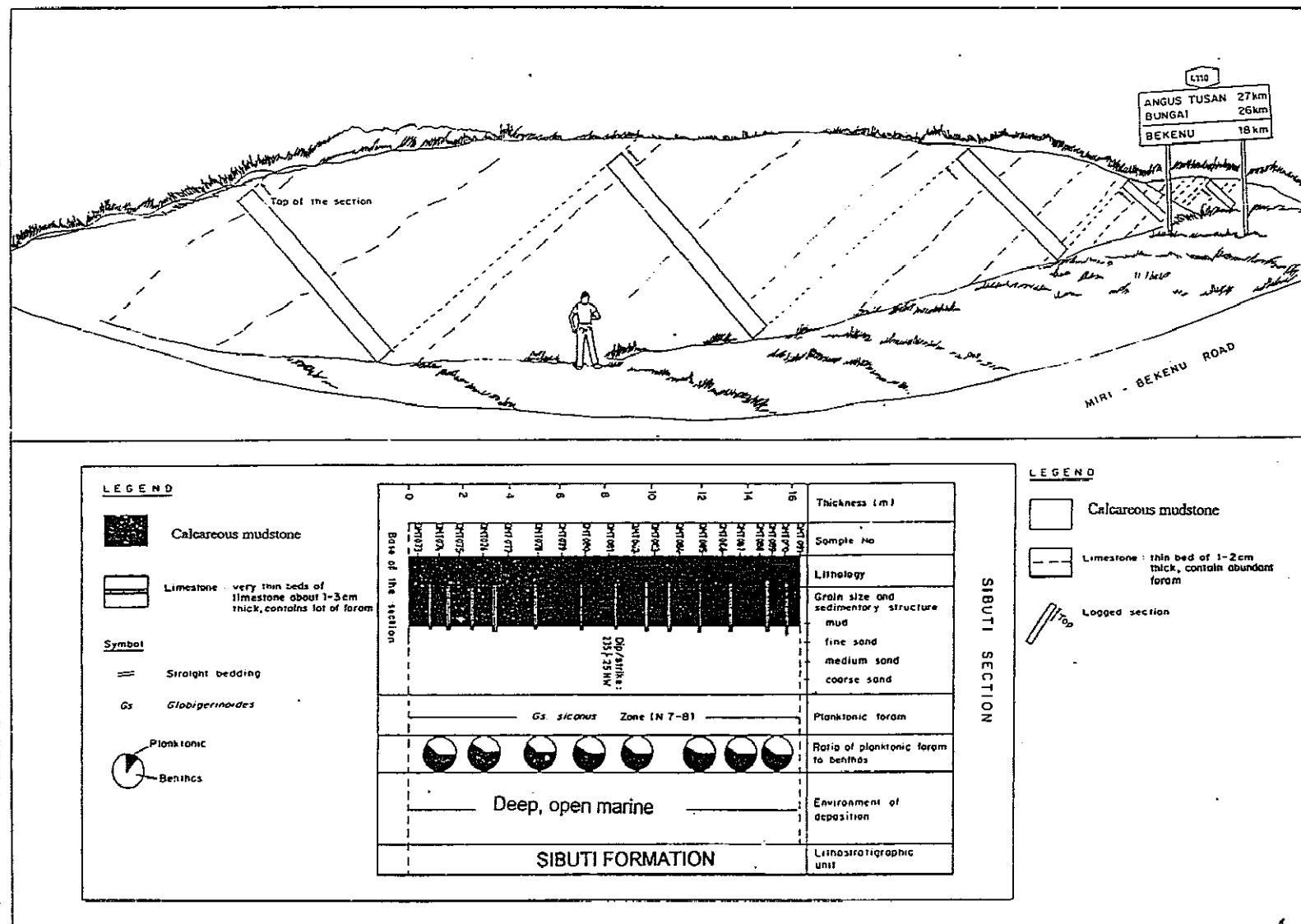
Table 4 (continued)

Age	Formation	Locality	Sample	Planktic Foram	Benthic Foram	Preservation	Abundance	Other remark
SUBI S OUTCRO P SECTION			SE KALO H TANGAP ROAD			ENTULANG OUTCROP SECTION		
(Fig. 66)			(Fig. 66)			(Fig. 66)		
S I B U I F O R M A T I O N			L A D A N G 4			O U T C R O P S E C T I O N		

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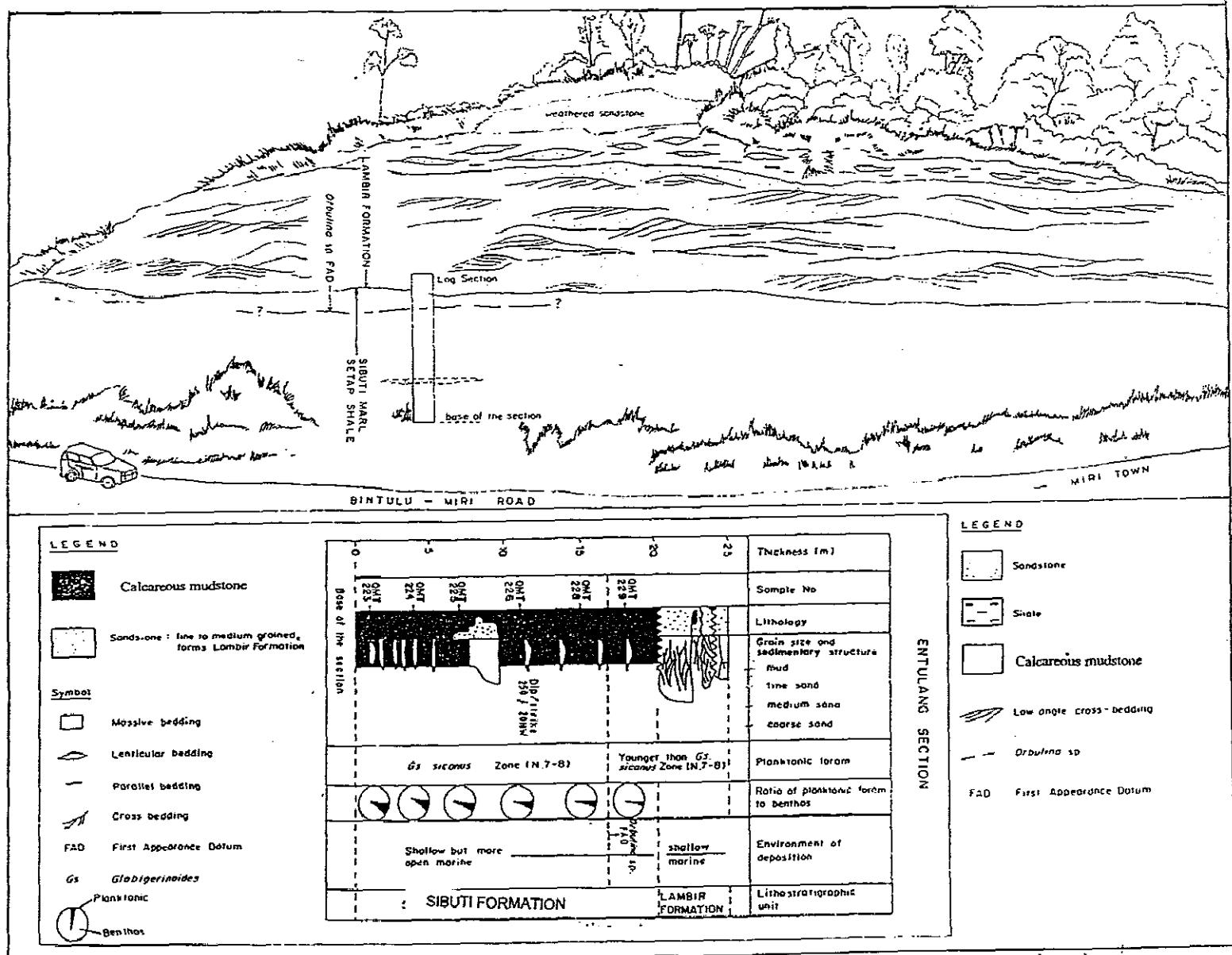


Figure 67. Sample localities in the Entulang outcrop section, Km 37th, Miri-Bintulu Road

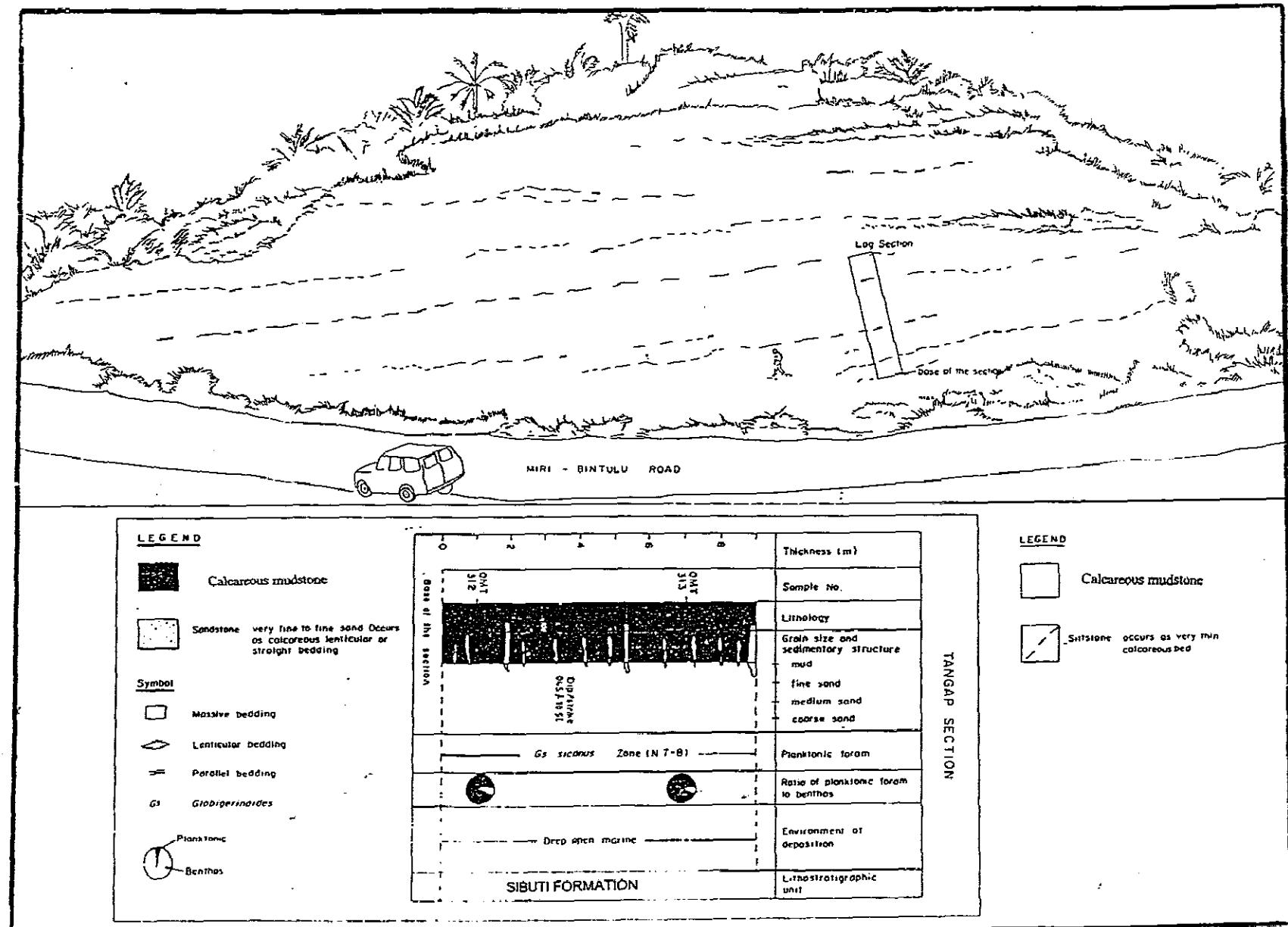


Figure 68. Sample localities in the Sekaloh outcrop section, Km 68th, Miri-Bintulu Road

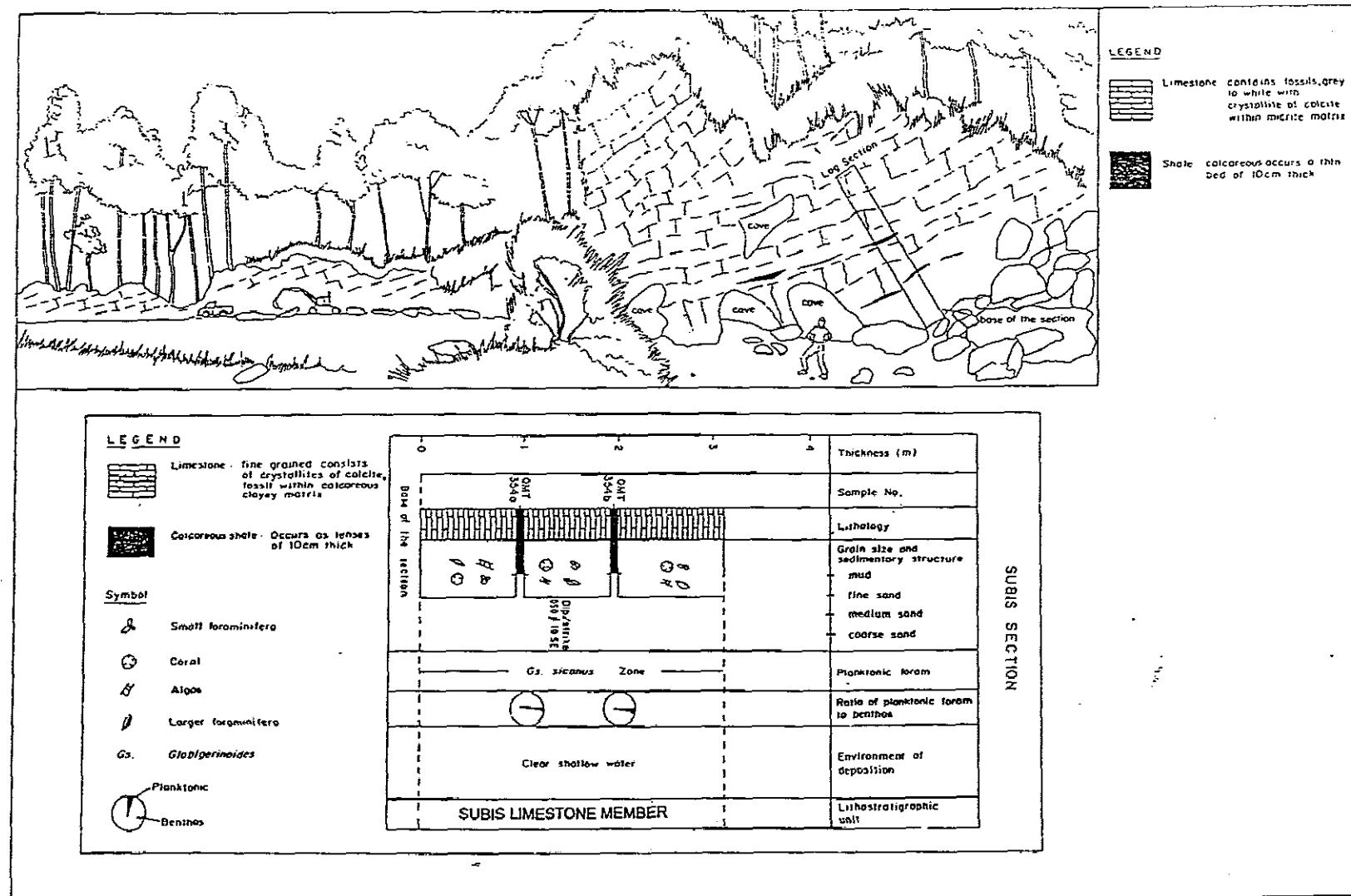


Figure 69. Sample localities in the Subis outcrop section, Geragok Quarry

**Table 5. Occurrence of the planktic and benthic foraminifers in the Lambir Formation along Miri-Bintulu and Miri-Tinjar Road and In the Miri Formation along the Hospital Road**

**NOTE:**

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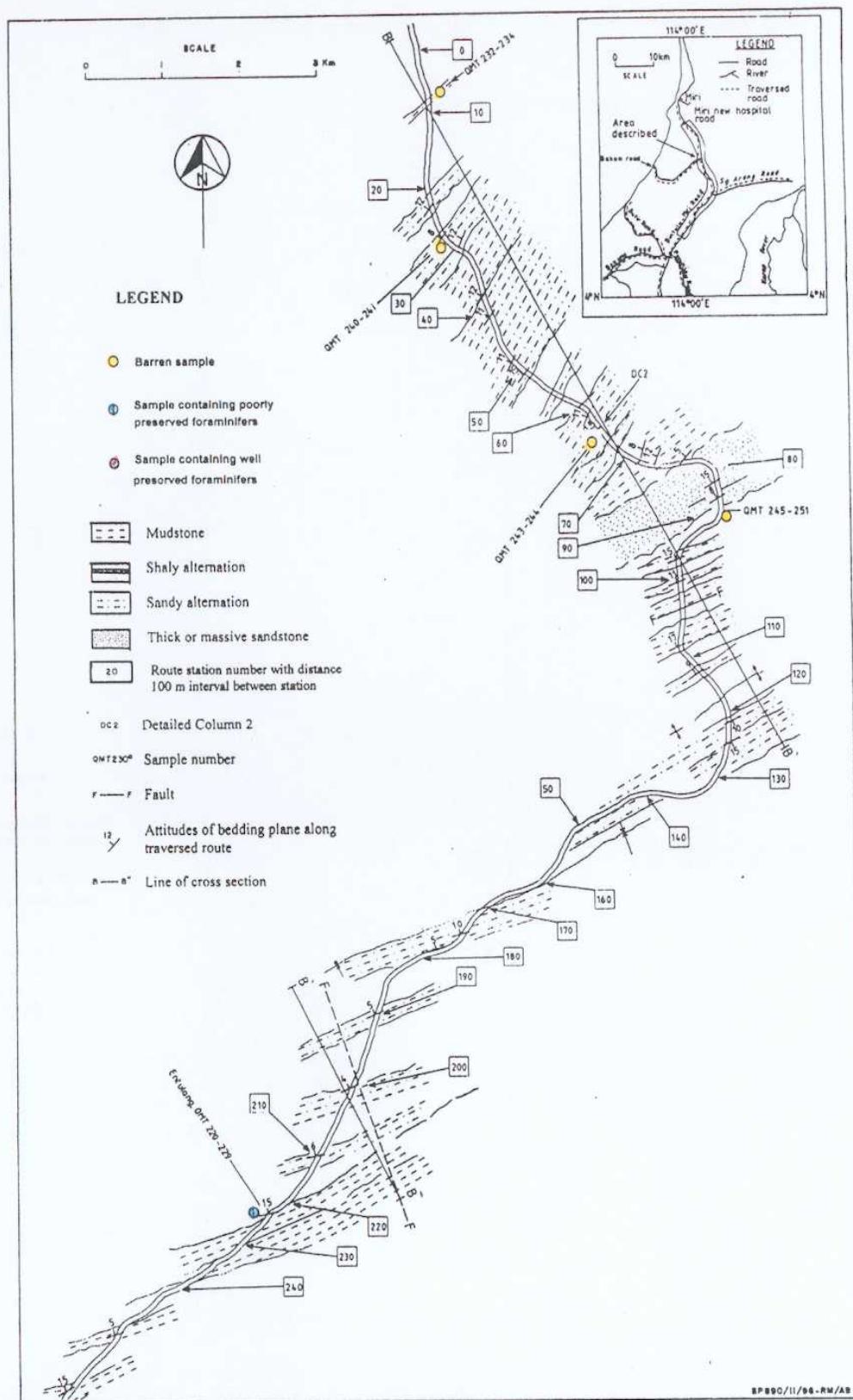


Figure 70. Sample localities in the Lambir Formation, along Miri-Bintulu Road

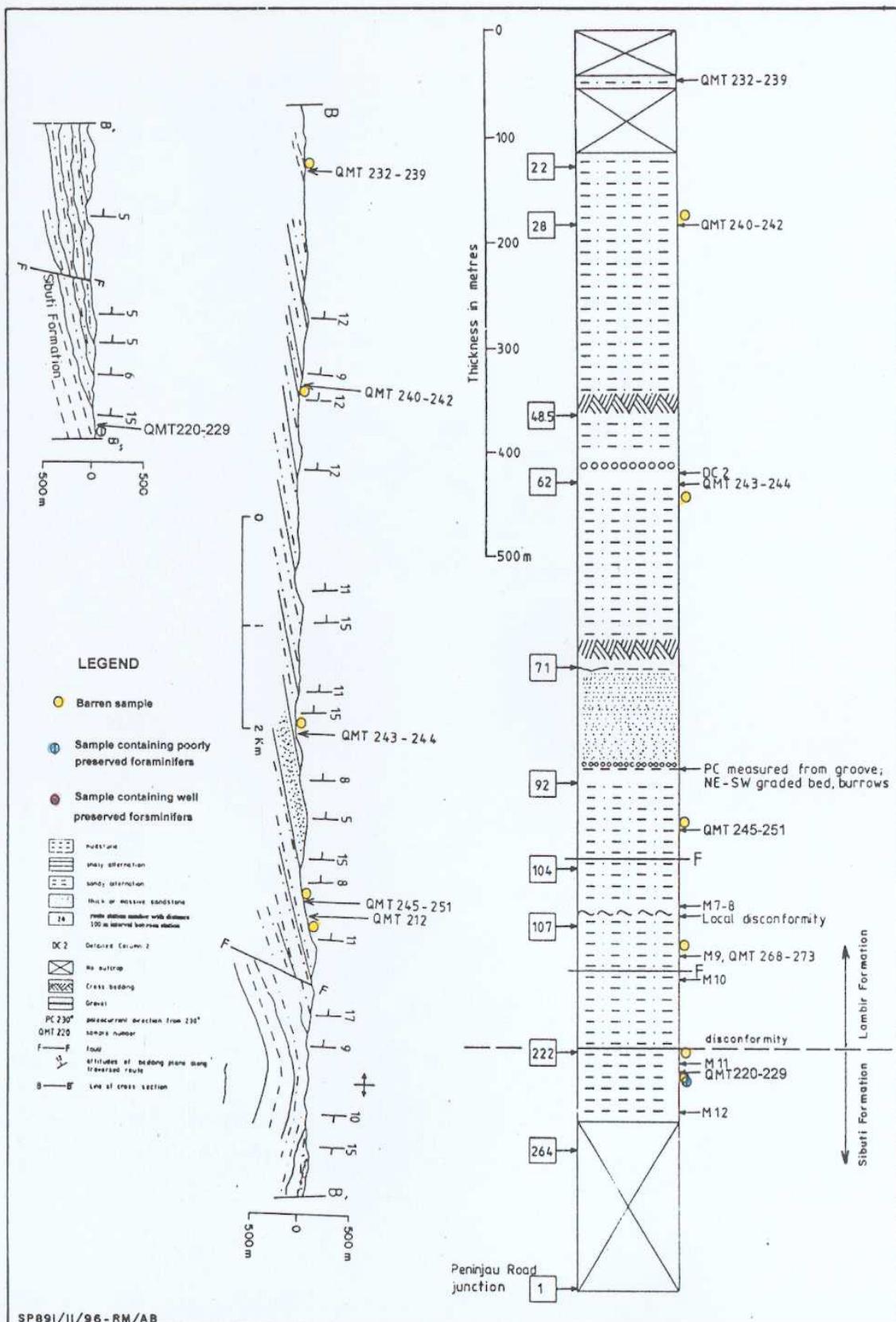


Figure 71. Sample localities in the cross section and total column of the Lambir Formation, along Bintulu-Miri Road

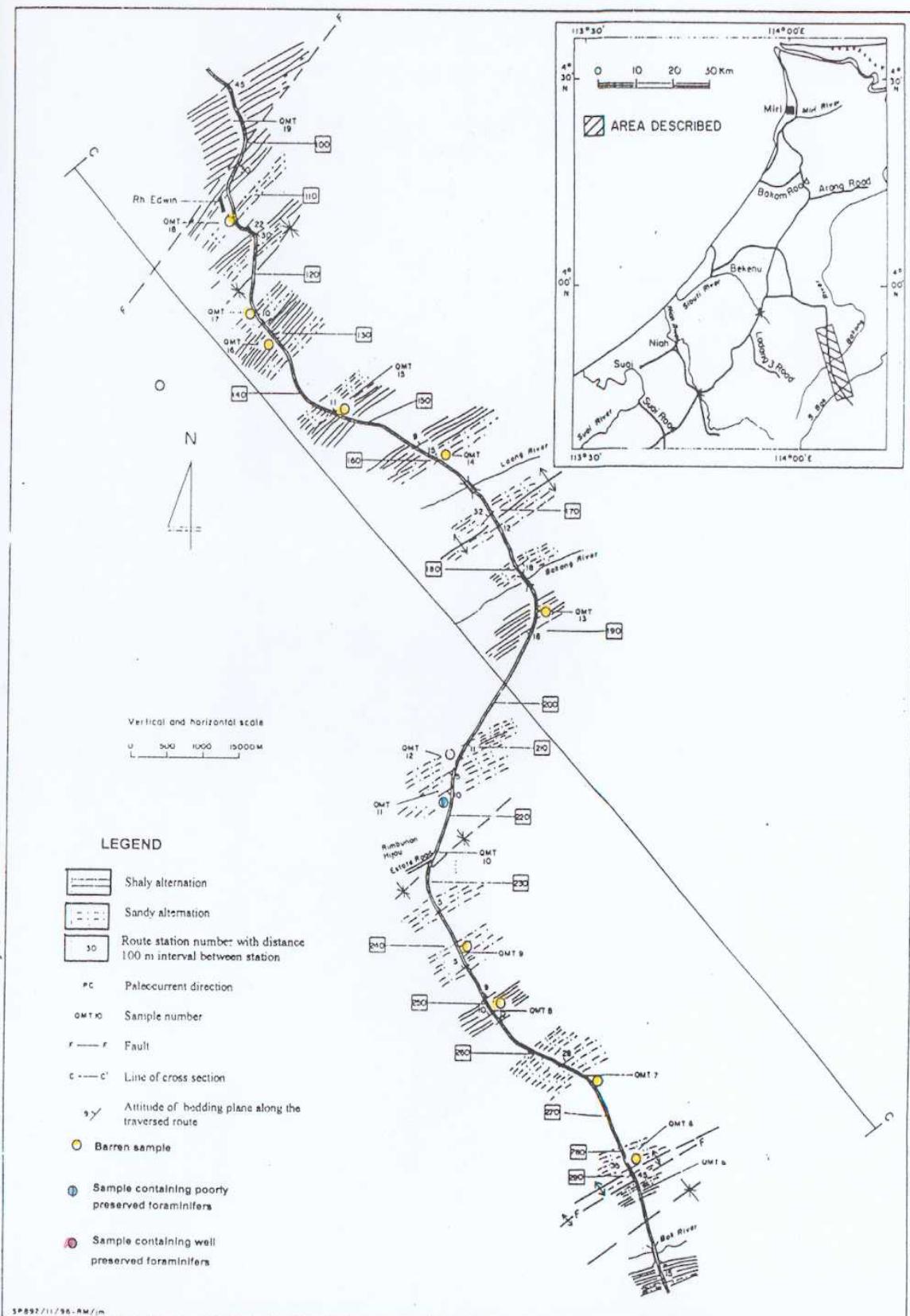


Figure 72. Sample localities in the Lambir Formation, along Miri-Tinjar Road

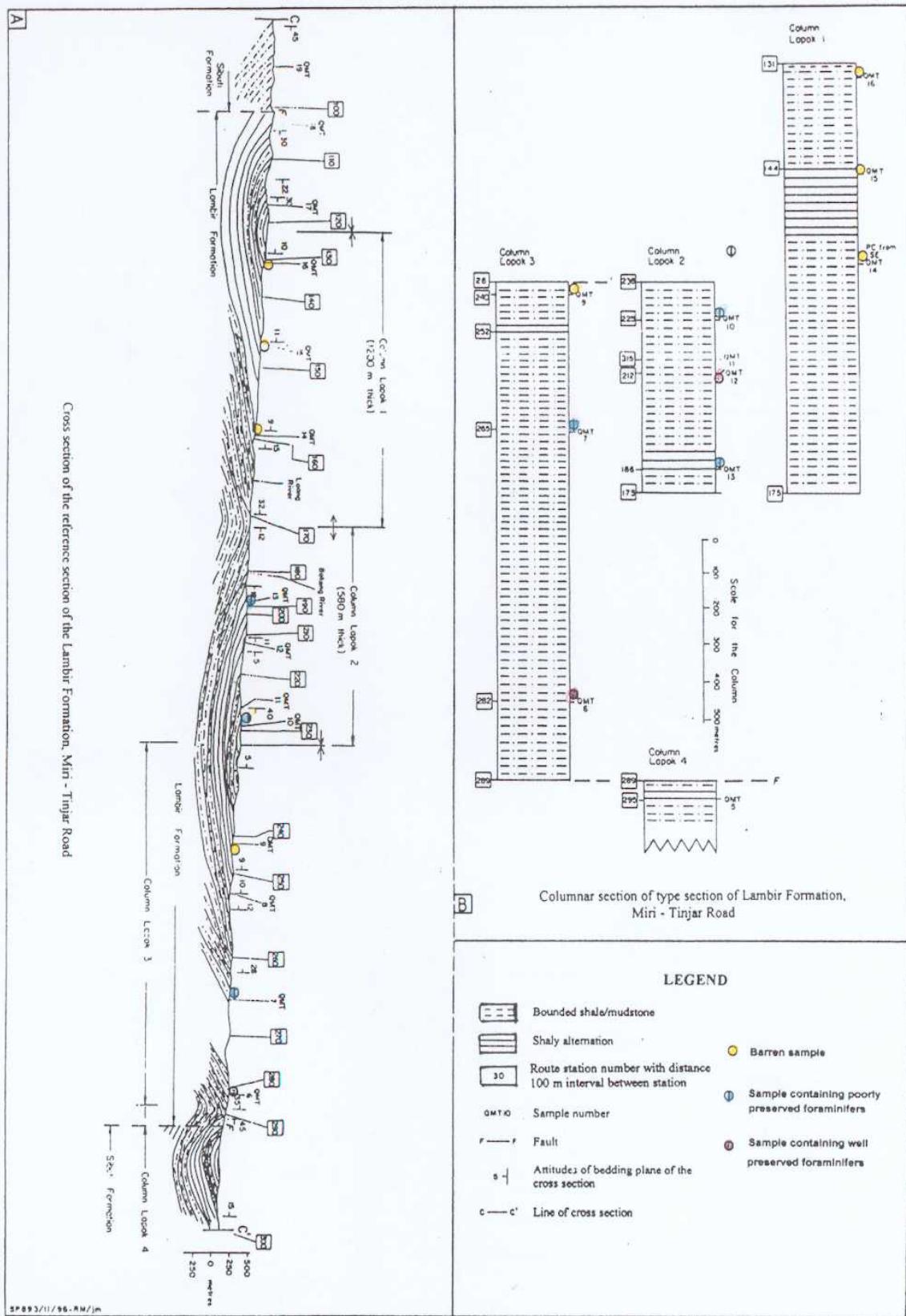
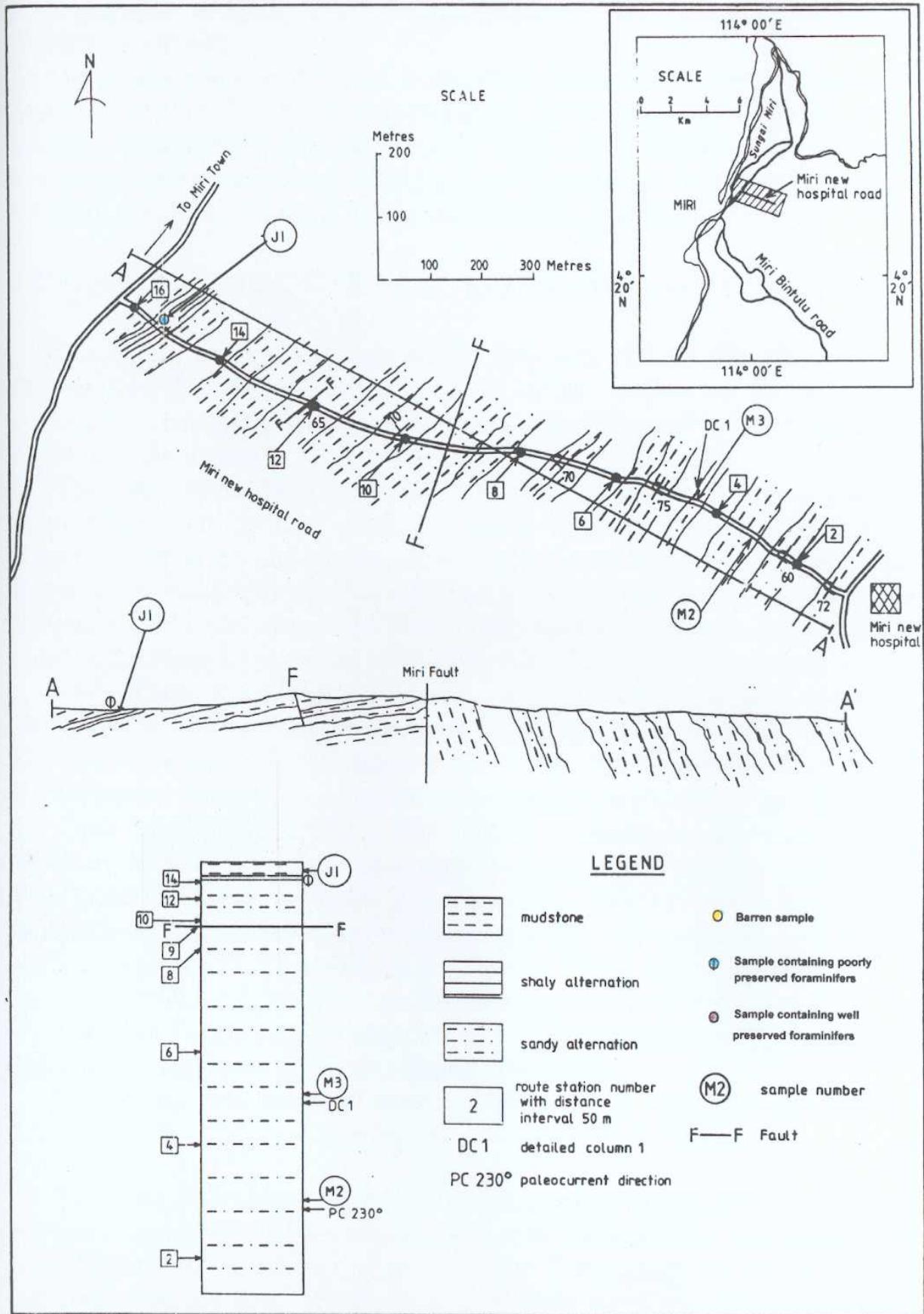


Figure 73. Sample localities in the cross section and total column of the Lambir Formation, along Miri-Tinjar Road



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Figure 74. Sample localities in the cross section and total column of the Miri Formation, along New Hospital Road

biostratigraphic analysis were photographed (Plates 1-3) using scanning electron microscope (SEM).

The generic classification used in this study were mainly of Blow (1969) and Stainforth et al (1975). For the identification and stratigraphic correlation of the planktic foraminiferal species, a wide range of literatures was used, but description of particular value were those of Blow (1969), Bolli (1957a, 1957b), Postuma (1971), Stainforth (1975) and Kenneth et al (1983).

#### 4.4 PLANKTIC FORAMINIFERAL BIOSTRATIGRAPHY

Out of 214 samples collected in the field only 120 samples yielded some foraminifers. The rest of the samples are barren. A total of 42 species or subspecies belonging to 10 genera were identified and their stratigraphic distribution are shown in Tables 1- 6, Figs. 75, 76, Plates 1-3).

**The Suai Formation:** produced very few and poorly preserved planktic foraminifers. The top layer of the formation is calcareous, contained some planktic foraminifers whereas the bottom layer is not calcareous, contained rare foraminifers which indicates the environment was not favorable or other possible reason for the rare occurrence the fossil could have been probably crushed as the result of the tectonic movement such as the Suai Fault is located nearby.

**The Sibuti Formation:** produced quite abundant and well preserved planktic foraminifers, however the South Suai Road section is barren. The Niah Road section which is interpreted to occur in the middle of the total column of the formation, contained some planktic foraminifers especially in the vicinity of the Subis Limestone Member. The Ladang 3 section is also fossil barren, however, the Miri-Tinjar Road section produced abundant planktic foraminifers. **The Lambir Formation:** most part is barren, however at the base of the formation such at the Entulang outcrop section (Fig. 69) contained abundant of benthic foraminifers. This formation is mainly deltaic sediments and for that reason it contains very rare planktic but abundant benthic foraminifers.

**The Miri Formation:** is barren of planktic foraminifers. This formation was deposited in shallow to deltaic and fluvial environment.

One of the most common species obtained from the study area namely: *Globigerinoides*, *Globigerina*, *Globoquadrina* and *Globorotalia*.

The Sibuti Formation contained abundant planktic foraminifers and the most common species is *Globigerinoides sicanus* is mid Early Miocene in age. The Suai Formation, even though they are few foraminifers in the formation, contained short range age species such as *Globigerina binaiensis* which is early Early Miocene in age. The Lambir Formation also contained few foraminifers, limited to the bottom horizon. Planktic foraminifers species such as *Orbulina*

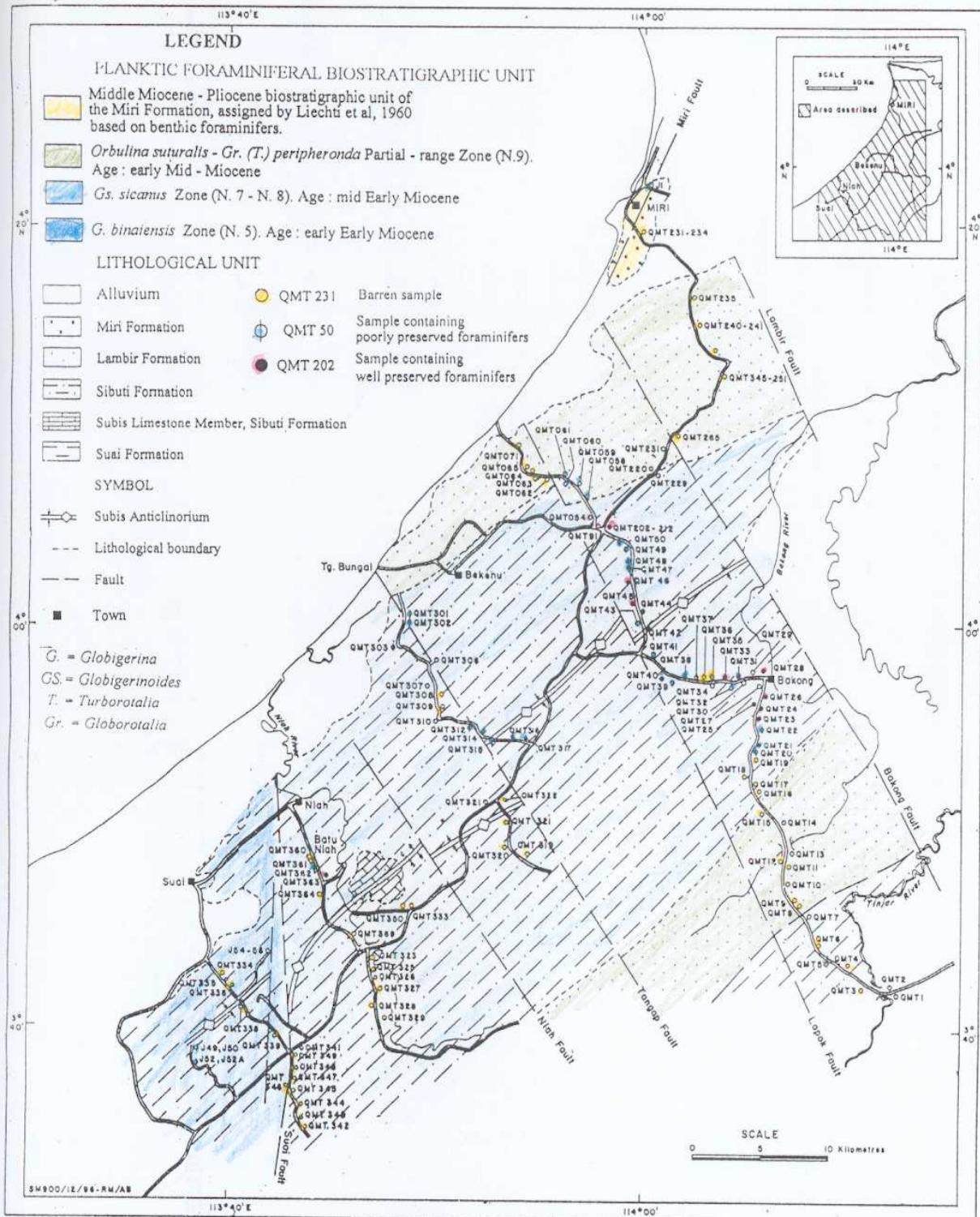


Figure 75. Occurrences of the planktic foraminifers in the samples from the Northwest Borneo Basin

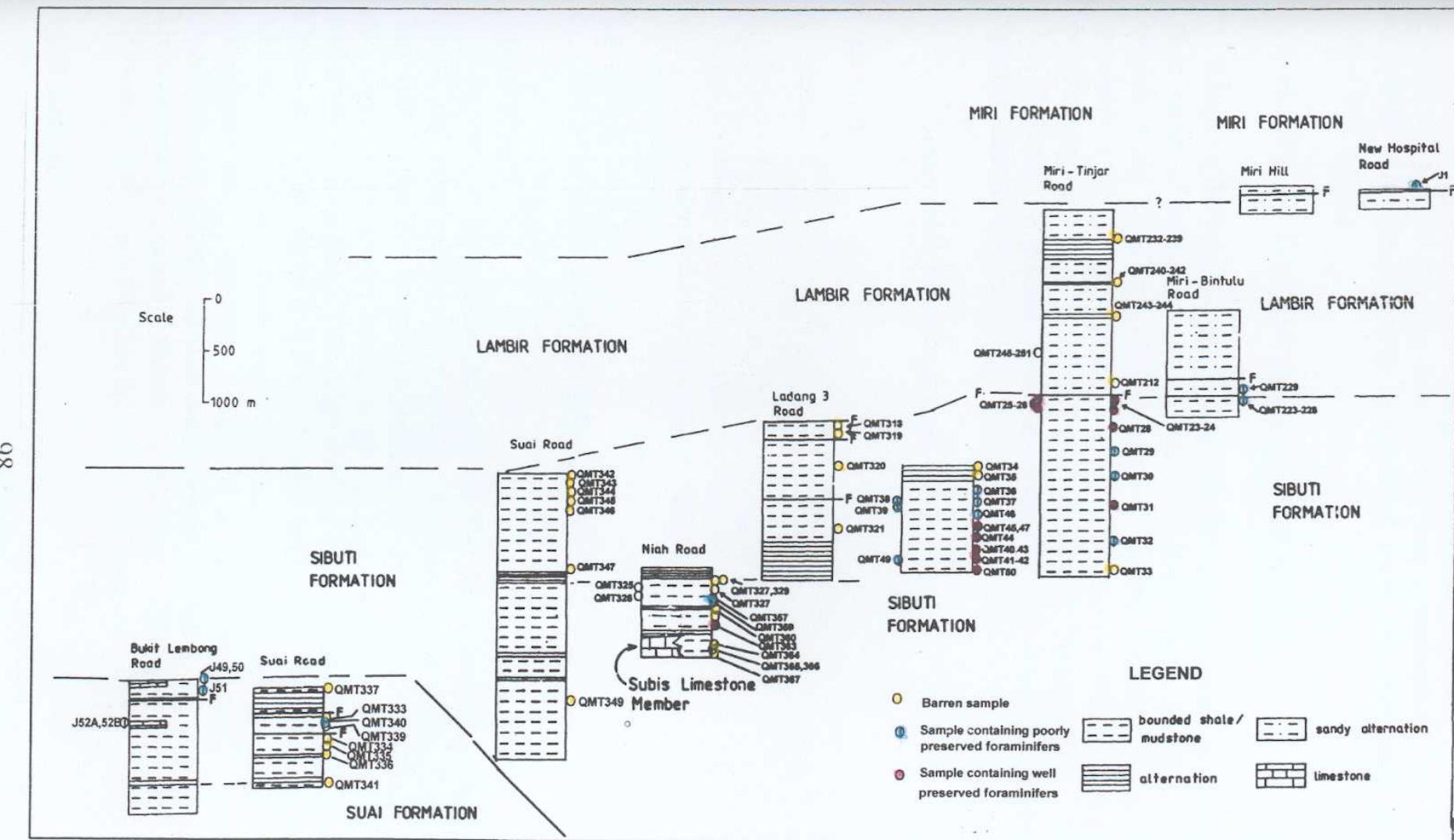


Figure 76. Occurrences of the planktic foraminifers in the samples in the total column of lithostratigraphic units of Northwest Borneo Basin

*suturalis* is observed at the base of this formation; indicated the sediment is early Middle Miocene in age. The datum of the first appearance of *Orbulina suturalis* is world wide phenomena, is therefore good time indicator of early Mid Miocene.

#### 4.5 PLANKTIC FORAMINIFERAL ZONATION

Based on the analysis of the first and the last appearance of species and also their range of occurrence in the lithostratigraphic unit, particularly the index species such as *Globigerina binaiensis*, *Globigerinoides sicanus*, *Orbulina suturalis* and *Globorotalia (Turborotalia) peripheronda*; they are three biostratigraphic zones established in the Northwest Borneo Basin (Table 6, Figs. 77, 78) during the present investigation which are discussed accordingly in their stratigraphic order.

##### 4.5a *Globigerina binaiensis* Zone (N. 5)

###### Synonymy

- Catapsydrax dissimilis* Zone (Bolli, 1957)
- Globigerinita dissimilis* Zone (Blow and Banner, 1962)
- Globigerina trilobus* Zone (Postuma, 1971)
- Globigerina binaiensis* Zone (Ho, 1978)
- Globigerina binaiensis* Zone (Hagemen, 1985)

###### Definition:

This zone is defined by the presence *Globigerina binaiensis*.

###### Characteristic:

This zone is represented by sample J54, J52A located in the North Suai Road, and sample J52 located at Bukit Lembong Road of the Suai Formation. They are 12 planktic foraminifers species identified from this zone. *Globigerina binaiensis* is the most distinctive species and only confined to this zone. The preservation is not good. Two other species; *Globorotalia (T.) opima opima* and *Globigerinita dissimilis dissimilis* are also confined to this zone, whereas 8 other species are: *Globigerina venezuelana*, *Globoquadrina dehiscens dehiscens*, *Globoquadrina altispira altispira*, *Globigerinoides quadrilobatus quadrilobatus*, *Globigerinoides quadrilobatus trilobus*, *Globigerinoides ruber*, *Globigerinoides quadrilobatus immaturus*, *Globorotalia (T.) mayeri*, *Globorotalia (T.) obesa* range up to the next zone.

###### Other Remark:

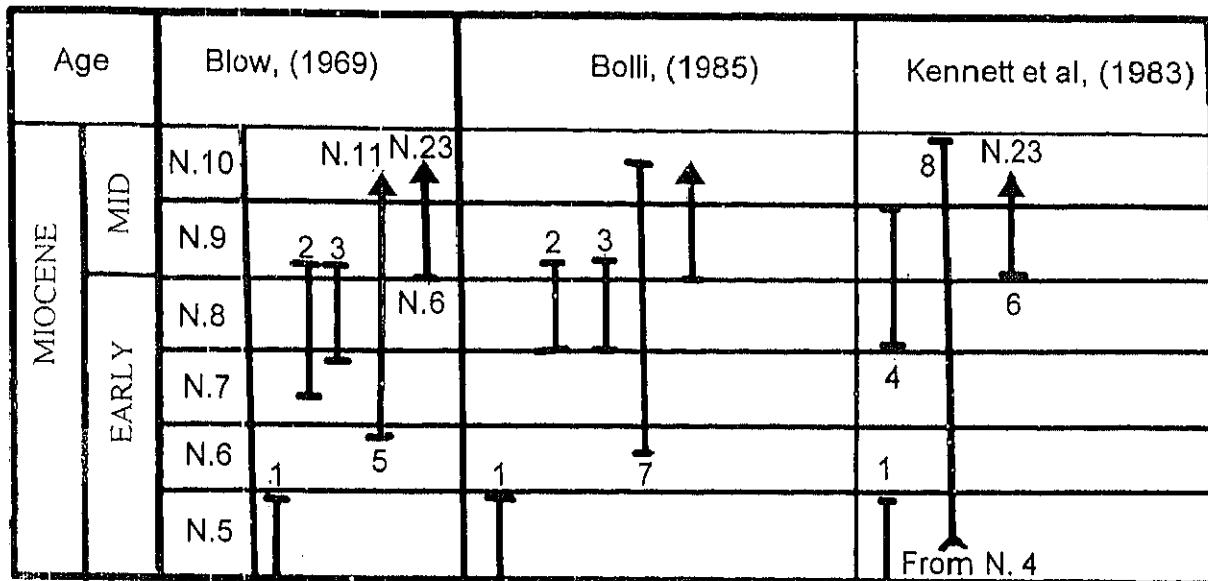
Table 6. Distribution of planktic foraminifers from Northwest Borneo Basin

## Symbol

Gs. *Globigerinoides* Orb. *Orbulina* Tr. *Turborotalia* Gr. *Globorotalia*

Species used for correlation

AGE		Early Middle Miocene			
LITHOSTRATIGRAPHIC UNIT (FORMATION)		Lambir		MIRI	
PLANKTIC FORAMINIFERAL ZONATION		Orb suturalis- Gr. (T) peripheronda Zone		Barren - no age assignment	
LOCALITY		Bintulu-Miri Rd.	Miri-Tinjar Rd.	Miri Hill	
GENUS	SPECIES	QMT229	QMT332 QMT240 QMT242 QMT245 QMT265 QMT231 QMT230 QMT220 QMT127 QMT121	QMT065 QMT064 QMT013 QMT011 QMT010 QMT006 QMT071	J1
<i>Globigerina</i>	<i>binalensis</i>				
<i>Globigerina</i>	<i>ciperoensis angustumbilicata</i>				
<i>Globigerina</i>	<i>cf. ciperoensis ciperoensis</i>				
<i>Globigerina</i>	<i>praebulloidies leroyi</i>	x			
<i>Globigerina</i>	<i>aff. praebulloidies praebulloidies</i>				
<i>Globigerina</i>	<i>praebulloidies occlusa</i>				
<i>Globigerina</i>	<i>praebulloidies praebulloidies</i>				
<i>Globigerina</i>	<i>sp.</i>	x			
<i>Globigerina</i>	<i>venezuelana</i>	x	x x	x	
<i>Globoquadrina</i>	<i>dehiscens dehiscens</i>			x	
<i>Globoquadrina</i>	<i>altispira altispira</i>	x	x	x	
<i>Globoquadrina</i>	<i>sp.</i>				
<i>Globigerinoides</i>	<i>diminutus</i>				
<i>Globigerinoides</i>	<i>obliquus obliquus</i>				
<i>Globigerinoides</i>	<i>quadrilobatus quadrilobatus</i>	x	x x	x x x x	
<i>Globigerinoides</i>	<i>quadrilobatus sacculifer</i>			x	
<i>Globigerinoides</i>	<i>ruber</i>			x x	
<i>Globigerinoides</i>	<i>subquadrateus</i>			x x x	
<i>Globigerinoides</i>	<i>sicanus</i>				
<i>Globigerinoides</i>	<i>quadrilobatus immaturus</i>	x x	x x x	x x	
<i>Globigerinoides</i>	<i>quadrilobatus trilobus</i>			x x x	
<i>Globigerinoides</i>	<i>sp.</i>				
<i>Globorotalia</i> (T.)	<i>peripheronda</i>		x		
<i>Globorotalia</i> (T.)	<i>cf. peripheronda</i>	x			
<i>Globorotalia</i> (T.)	<i>cf. mayeri</i>		x x		
<i>Globorotalia</i> (T.)	<i>mayeri</i>			x x	
<i>Globorotalia</i> (T.)	<i>cf. obesa</i>				
<i>Globorotalia</i> (T.)	<i>obesa</i>				
<i>Globorotalia</i> (T.)	<i>opima continuosa</i>				
<i>Globorotalia</i> (T.)	<i>cf. opima continuosa</i>				
<i>Globorotalia</i> (T.)	<i>opima nana-opima opima transition</i>				
<i>Globorotalia</i> (T.)	<i>opima opima</i>				
<i>Orbulina</i>	<i>suturalis</i>	x	x	x	
<i>Orbulina</i>	<i>universa</i>				
<i>Preeorbolina</i>	<i>glomerosa glomerosa</i>				
<i>Praeorbulina</i>	<i>transitoria</i>				
<i>Cassigennella</i>	<i>cniopensis</i>				
<i>Globigennita</i>	<i>dissimilis dissimilis</i>				
<i>Globigerina</i>	<i>unicava unicava</i>				
<i>Globigerinatelia</i>	<i>insueta</i>				
<i>Sphaeroidellopsis</i>	<i>seminula seminula</i>		x		
<i>Sphaeroidellopsis</i>	<i>disjuncta</i>			x	



1 *Globinerina binaiensis*, 2 *Globigerinoides bisphericus*, 3 *Praeorbulina sicana*, 4 *Praeorbulina sicamis*,  
 5 *Globorotalia (Turborotalia) peripheronda*, 6 *Orbulina suturalis*, 7 *Globorotalia foshi peripheronda*,  
 8 *Globorotalia (Fosshella) peripheronda*

Figure 77. Index species range chart after Blow (1969) and Bolli (1957, 1966) and Kenneth et al (1988)

Age		Blow (1969)	Bolli, (1957, 1966, 1970, Bolli & Premoli Silva, 1973)	This study
MIOCENE	MID	N.10      Gr.(T.) peripheronda Cons. -R-Z		Orb. suturalis- Gr. (T.) peripheronda P-R-Z
		N.9      Orb. suturalis- Gr. (T.) peripheronda P-R-Z	Gr. foshi peripheronda	
	EARLY	N.8      Gs. sicanus - Gnt. insueta	Praeorbulina	Gs. sicanus
		N.7      Gnt. insueta - Gs. quadrilobatus P-R-Z	Gnt. insueta	
		N.6      Gnt. insueta - Gnt. dissimilis Cons. -R-Z	Catapsydrax stainforthi	Zone of fossil barren
		N.5	Catapsydrax dissimilis	<i>G. binaiensis</i>

Gr. *Globo**rota**lia*, T. *Turbo**rota**lia*, Gn. *Globigerinatella*, O. *Orbulina*, Gs. *Globigerinoides*,  
 Gnt. *Globigerinata*, Cons. Consecutive, Con. Concurrent, P-R-Z. Partial Range Zone,

Figure 78. Correlation of planktic foraminiferal zonation of Northwest Borneo Basin with those of Bolli (1957, 1966) and Blow (1969)

*Globigerina binaiensis* Zone is equivalent to the *Globoquadrina praedehisca* *dehiscens-Globoquadrina dehiscens dehiscens* Partial-range Zone of Blow's (1969) which is early Early Miocene in age. This zone is reported in Balingan offshore province (Hageman, 1985) and in Luconia province (Ho, 1987), both in the offshore areas of Northwest Borneo Basin.

Other nearby region where the equivalent zone have been described such as in Bogor Jawa, Indonesia (Natori et al, 1978, Fig. 3.2, p. 83) where the fossiliferous mudstone sample JW.19b contained an assemblage of planktic foraminifers belongs to *Globoquadrina praedehisca* *dehiscens-Globoquadrina dehiscens dehiscens* Partial-range Zone of Blow's (1969) which is early Early Miocene in age. In the Philippines, the planktic foraminifers recovered from the fossiliferous mudstone samples of the Upper Malulog Formation, Cebu and Escalate Formation, Negros, were also correlatable to this zone (Porth et al, 1989, p. 97).

#### 4.5b *Globigerinoides sicanus* Zone (late N. 7-N. 8)

Synonymy:      *Globigerinatella insueta/Globigerinoides bisphericus*  
                        Subzone (Blow, 1959)  
                        *Globigerinatella insueta* Zone (Bolli, 1957)  
                        *Globigerinatella insueta* Zone (Postuma, 1971).  
                        *Praeorbulina glomerosa* Zone (Bolli, 1966)  
                        *Praeorbulina glomerosa curva* Zone (Jenkins, 1966)  
                        *Globigerinatella insueta/Globigerinoides bisphericus*  
                        Zone (Sarawak Shell Company, cited by Ho, 1978)

Definition:

This zone is represented by the presence *Globigerinoides sicanus*.

Characteristic:

This zone is represented by a total of 93 samples both from the Sibuti Formation (90 samples) and the lower part of the Lambir Formation (3 samples: QMT 060-062). They are abundant planktic foraminifers in this zone, and the most numerous and distinctive species identified is *Globigerinoides sicanus* which is confined to this zone only. The fossils are well preserved in the upper layer compared to poorly preserved in the lower layer of the zone. A total of 10 other species; *Globigerina* cf. *ciperoensis ciperoensis*, *Globigerina praebulloides occlusa*, *Globigerinoides diminutus*, *Globigerinoides obliquus obliquus*, *Globorotalia* (T.) cf. *obesa*, *Globorotalia* (T.) *obesa*, *Globorotalia* (T.) *opima opima-opima nana transition*, *Praeorbulina glomerosa glomerosa*, *Praeorbulina transitoria*, *Globigerinita unicava unicava* and *Globigerinatella*

*insueta* are restricted to this zone, whereas other species; *Globigerina praebulloides leroyi*, *Globigerina aff. praebulloides praebulloides*, *Globigerina praebulloide praebulloides*, *Globigerina venezuelana*, *Globoquadrina dehiscens dehiscens*, *Globoquadrina altispira altispira*, *Globigerinoides quadrilobatus quadrilobatus*, *Globigerinoides quadrilobatus sacculifer*, *Globigerinoides ruber*, *Globigerinoides quadrilobatus trilobus*, *Globigerinoides quadrilobatus immaturus*, *Globorotalia (T.) peripheronda*, *Globorotalia (T.) mayeri*, *Orbulina suturalis* and *Cassigerinella chipoloensis* range into the next zone.

Other Remark:

The *Globigerinoides sicanus* Zone is equivalent to the *Globigerinoides sicanus-Globigerinatella insueta* Partial-range Zone of Blow (1969). The latter zone is having its holotype locality sample RM.19285, from Pozon Formation, Venezuela (Blow, 1959, map 4); characterized by the plexus of *Globigerinoides sicanus* and *Globigerinatella insueta* and placed immediately below the appearance level of *Orbulina suturalis*. This zone is reported in Balingan offshore province (Hageman, 1985) and in Luconia province (Ho, 1987), both in the offshore areas of Northwest Borneo Basin.

Other nearby region such as Madura, Indonesia, the assemblage of the planktic foraminifers recovered from the fossiliferous mudstone samples at Locality 320, Madura, is corelatable to *Globigerinoides sicanus-Globigerinatella insueta* Partial-range Zone (Natori and Kadar, 1978, Fig. 3.12, p. 117). Also the foraminifers assemblage from the Ilihan Shale and the Wahig Limestone, Bohol, the Philippines (Porth et al., 1989, p. 101), is corelatable to this zone.

**4.5c *Orbulina suturalis-Globorotalia (Turborotalia) peripheronda* Partial-range Zone (N.9).**

Synonymy: *Globorotalia foshi barisanensis* Zone (Bolli, 1966)  
*Globorotalia peripheronda* Zone (Postuma, 1971).

Definition:

This base of this zone is placed at the horizon marking the first evolutionary appearance of *Orbulina suturalis* and the presence *Globorotalia (T.) peripheronda*.

Characteristic:

This zone is represented by the samples collected from the Lambir Formation: QMT229, 071, 127. *Globorotalia (T.) peripheronda* is quite common in this zone, and the fossils are quite well preserved. *Sphaeroidellopsis seminula*

*seminula* and *Sphaeroidellopsis disjuncta* are confined to this zone, whereas *Globigerina praebulloides leroyi*, *Globigerina aff. praebulloides praebulloides*, *Globigerina praebulloides praebulloides*, *Globigerina venezuelana*, *Globoquadrina dehiscens dehiscens*, *Globoquadrina altispira altispira*, *Globigerinoides quadrilobatus quadrilobatus*, *Globigerinoides quadrilobatus sacculifer*, *Globigerinoides ruber*, *Globigerina subquadratus*, *Globigerinoides quadrilobatus immaturus*, *Globigerinoides quadrilobatus trilobus*; *Globorotalia (T.) cf. peripheronda*, *Globorotalia (T.) mayeri*, *Globorotalia (T.) cf. mayeri*, *Cassigerinella chipoloensis* are in this zone also.

Other Remark:

The *Orbulina suturalis-Globorotalia (Turborotalia) peripheronda* Zone was defined by Blow (1969) with its holotype locality sample BO.202 of Bolli (1957); characterized by the first appearance of *Orbulina suturalis*. This zone is reported in Balingan offshore province as *Globorotalia peripheronda* Zone (Hageman, 1985) and *Globorotalia barisanensis* Zone in Luconia province (Ho, 1987), both in the offshore areas of Northwest Borneo Basin. Other nearby region such as in Northwest Masbate, the Philippines; the assemblage of the planktic foraminifers recovered from the fossiliferous mudstone samples of the Lanang Conglomerate and the Lower Buyang Formation are correlatable to zone (Porth et al, 1989, p.106-108).

## **4.6 AGE AND CORRELATION**

### **4.6a SUAI FORMATION**

A total of 32 samples were collected from the Suai Formation, only 6 samples produced some foraminifers with moderate preservation. Based on analysis of the first and last appearance and also the range of occurrence of the planktic foraminifers, this formation, is belong to *Globigerina binaiensis* Zone which is early Early Miocene age and therefore the Suai Formation is early Early Miocene age.

### **4.6b SIBUTI FORMATION**

A total of 144 samples were collected from the extensive area of the Sibuti Formation, only 101 samples produced some foraminifers with quite good preservation. Based on analysis of the first and last appearance and also the range of occurrence of the planktic foraminifers, this formation is belong to *Globigerinoides sicanus* Zone which is mid Early Miocene age, except for 5 metres top layer in the Entulang outcrop section (Fig. 67) which is belong to *Orbulina suturalis-Globorotalia (Turborotalia) peripheronda* Partial-range Zone which is early Mid Miocene. Therefore the Sibuti Formation is assigned to early Early Miocene to early Mid Miocene age.

### **4.6c LAMBIR FORMATION**

They are 23 samples collected from the Lambir Formation, however only 19 samples contained some foraminifers of mainly benthic but little planktic foraminifers; with poor preservation. Based on analysis of the first and last appearance and also the range of occurrence of the planktic foraminifers, this formation is belong to *Orbulina suturalis-Globorotalia (Turborotalia) peripheronda* Partial-range Zone is early Mid Miocene age. Therefore the Lambir Formation is assigned to early Mid Miocene age.

### **4.6d MIRI FORMATION**

No planktic foraminifers is retrieved from this unit and therefore no age assignment based on planktic foraminifers is undertaken. However, Liechti et al, (1960) assigned this formation Mid Miocene-Late Miocene in age based on benthic foraminiferal content belongs to *Nonion* and *Loxostoma* Zones. Therefore, the age of this unit is Mid Miocene-Late Miocene, is being retained in this report.

#### 4.7 CORRELATION BETWEEN THE ESTABLISHED ZONE HEREIN AND THOSE OF OTHERS

The planktic foraminiferal zones established in Northwest Borneo Basin during the present investigation, is correlated with local zone established in Luconia provinces by Ho (1978) and the Balingan offshore province by Hageman (1985), both in the offshore regions of NW Sarawak (Fig. 79). The correlation shows that the proposed planktic foraminiferal zones of the present investigation shows a close resemblance with the local zones.

The *Globigerina binaensis* Zone, is the assemblage of the planktic foraminifers in the Suai Formation erected during the present investigation, was also described in Balingan offshore province by Hageman (1985) and Luconia province by Ho (1978). Immediately above the *Globigerina binaensis* Zone is the *Catapsydrax dissimilis* Zone in the Balingan offshore province and *Catapsydrax dissimilis/stainforthi* Zone in the Luconia province. These zones is equivalent to N.5-6 of Blow's (1969) zones, is however missing in the study area, the Northwest Borneo Basin; was probably because there was a period non deposition (Ho, 1978, Fig. 6) or possibly the environment of deposition was not suitable for the planktic foraminifers or and lastly, the tectonic activity such as faulting that had destroyed these fossils.

*Globigerinoides sicanus* Zone is the next overlying zone which is also described by Hageman (1985) in the Balingan province and described as *Globigerinatella insueta/Globigerinoides bisphericus* Zone in the Luconia province (Ho, 1978), and therefore they are equivalent. The stratigraphic ranges of *Globigerinatella insueta* is the first appeared at N.6 and the last appeared at the base of N.9 (Blow, 1969, p. 269). Also, *Globigerinoides sicanus* is a prior synonym of *Globigerinoides bisphericus* (Blow, 1969, p. 327).

The *Orbulina suturalis-Globorotalia (Turborotalia) peripheronda* Partial-range Zone is the next younger zone, was described as *Globorotalia peripheronda* Zone in the Balingan offshore province (Hageman, 1985) and *Globorotalia barisanensis* Zone in the Luconia province (Ho, 1978), and therefore they are equivalent. *Globorotalia (Turborotalia) peripheronda* was widely recorded under the name of *Globorotalia barisanensis* (quoted by Bolli, 1983, p. 213).

The zone proposed of the present investigation is also correlated with other type of zonation such as palynological, sedimentary cycles and sea level changes zone as shown in Figure 78; *Globigerina binaensis* Zone is early Early Miocene, 20-22.5 millions years, *Brownlawa A* Zone, and Upper Sedimentary Cycle I; *Globigerinoides sicanus* Zone is late early Miocene, estimated 17 millions years, *Sonneratia caseotaris* Zone and Sedimentary Cycle III and *Orbulina suturalis-Globorotalia (Turborotalia) peripheronda* Partial-range

Zone early Mid Miocene, estimated 15.5 millions years, *Complastemon* A Zone and Sedimentary Cycle IV.

Correlation of the proposed zone in the study area with those of Bolli (1957, 1966) and Blow (1969) is shown in Figure 78.