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GEOLOGY OF THE SINDA-MOHARI REGION, HAUT-ZAIRE PROVINCE, EASTERN ZAIRE

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ABSTRACT The Sinda-Mohari region is topographically divided into the Mutimba plateau, hilly land and Semliki Plain. The hilly land is underlain by Precambrian basement rocks, Sinda Beds, Higher Terrace Deposits, Middle Terrace Deposits, Lower Terrace Deposits, and Alluvium (Recent river floor deposits).

The Sinda Beds are subdivided into the lower, middle and upper members. The lower member consists of clayey white coarse sand and yields such mammal fossils as Bovidae, etc. from the upper part. The middle member is characterized by alternating sand and mud beds. The upper member is composed of alternating thicker beds of sand and mud and contains such mammal fossils as *Prodeinotherium*, etc.

Generally, the Sinda Beds gently dip south to southeast. Folds parallel the northern boundary faults. An inferred fault is drawn parallel just north of these folds.

The context of geological phenomena from the older to the younger in this region is as follows. 1) formation of an extensive sedimentary basin by downwarping, 2) deposition of the Sinda Beds, 3) long-term denudation and peneplanation, 4) intense activity of the northern boundary faults and formation of the Higher Terrace Deposits, 5) activity of the southeastern boundary fault, 6) formation of the present Semliki Plain as the floor of the rift valley, 7) completion of the present drainage system, and 8) formation of the Middle and Lower Terrace Deposits within the deep valleys.

RESUME La région de Sinda-Mohari est divisée topographiquement en plateau de Mutimba, en terrain montueux et en plaine de la Semliki. Le terrain montueux est en dessous près de 1) sous-sol rocheux du précambrien, 2) couches de Sinda (Sinda Beds), 3) hautes terrasses sédimentaires, 4) moyennes terrasses sédimentaires, 5) basses terrasses sédimentaires, et 6) récents sédiments de fond de rivière.

Les couches de Sinda sont subdivisées en zones inférieure, moyenne, et supérieure. La zone inférieure consiste en une argile blanche brute sabloneuse, et renferme les fossiles mammaliens tels que le Bovidae etc. à partir de la partie supérieure. La zone moyenne est caractérisée par une alternance des couches sabloneuse et boueuse. La zone supérieure est composée de l'alternance des couches épaisses de sable et de boue, et contient les fossiles mammaliens comme le *Prodeinotherium* etc.

Généralement, les couches de Sinda inclinent graduellement du sud au sud-est. Les replis sont parallèles à la limite des failles du nord. Une supposée faille est dressée juste au nord parallèlement à ces replis.

Le contexte des phénomènes géologiques à partir de l'ancien au jeune dans cette région se présente comme suit; 1) formation d'un vaste bassin sédimentaire par une déformation en profondeur, 2) dépôt des couches de Sinda, 3) dénudation et pénéplanation à long-terme, 4) intense activité de la limite des failles du nord et formation de hautes terrasses sédimentaires, 5) activité de la limite de faille du sud-est, 6) formation de la présente plaine de la Semliki comme fond du Rift, 7) achèvement du présent système de draînage, et formation de moyennes et de basses terrasses sédimentaires dans les vallées profondes.

Key Words: Geology; Zaire; Rift valley; Sinda-Mohari; Sinda Beds.

INTRODUCTION

The East African Rift System is one of the topographic and geologic features in the African continent and shows an early phase of separation of the eastern block from the continent. The Rift System is divided into two parts, the Eastern and Western Rifts, and is formed by huge graben zones limited by normal faults from Ethiopia to Mozanbique. The graben is called the *rift valley* (Fig. 1).

It is also well-known that sediments in and around the rift valleys, especially in the Eastern Rift, yield hominoid fossils. The purpose of our research in eastern Zaire, in cooperation with *Centre de Recherche en Sciences Naturelles* (C.R.S.N.), Zaire, is to collect fossils of hominoids, mammals, molluscs, etc., and to analyze their geological age and the evolution of hominoids as well as the palaeoenvironment in the Western Rift.

The Western Rift is composed of a chain of narrow lakes arranged *en échelon* from Lake Mobutu Sese Seko in the north through Lake Tanganyika in the middle to Lake Nyasa in the south. Between Lakes Mobutu and Rutanzige (Edward), Mt. Ruwenzori soars to form an enormous horst block composed of Precambrian rocks. Lake Tanganyika is the deepest, with its bottom below sea level.

The investigated area is a hilly land of the Sinda-Mohari region, Haut-Zaire Province, which is located on the western escarpment of the Western Rift (Fig. 1). Based on the fossils obtained, the strata which form the hilly land were studied stratigraphically by Leriche (1938), Lepersonne (1949), Hopwood & Lepersonne (1953), de Heinzelin (1955), Adam (1959), Hooijer (1963), Gautier (1970), Hooijer (1970), Lepersonne (1970), Pickford & Senut (in press), etc.

The mammal fauna of the lower half in these strata indicates early Miocene in age

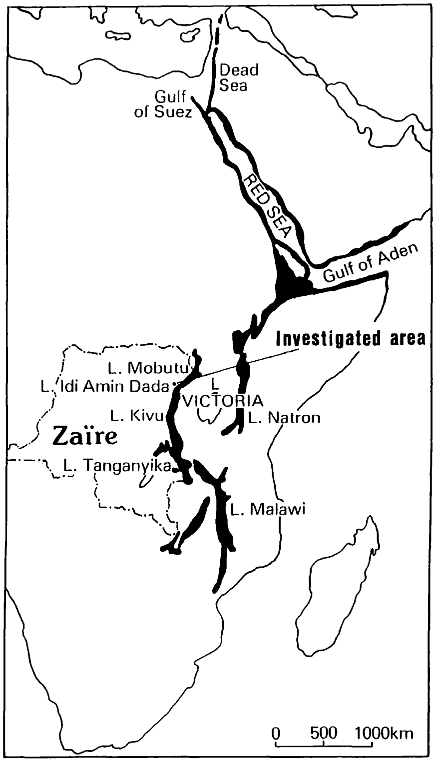

Fig. 1. Sketch map of the east African rift valleys and the investigated area (Holmes and Holmes, 1978; slightly modified).

(Hooijer, 1963). On the other hand, molluscan fauna of the upper half indicates late Pliocene or early Pleistocene time (Gautier, 1970). Pickford & Senut (in press) have considered it to be of Pliocene age, based on the molluscan fauna. We have obtained late Neogene mammal fossils (Yasui et al., this volume).

The geological surveys were performed from August to September in 1989 and 1990. We set up a base camp at Mutimba village, about 60 kilometers southwest to Bunia. We also made an attack camp on the left bank of the Sinda River, about 8 kilometers south by east to the base camp.

OUTLINE OF TOPOGRAPHY AND GEOLOGY

The Sinda-Mohari region is topographically divided into three parts, the Mutimba Plateau, hilly land, and Semliki Plain, from north to south (Fig. 2).

The Mutimba Plateau, which we provisionally call the plateau around Mutimba for convenience in the following descriptions and discussions, is underlain by Precambrian basement rocks, 1,300-1,400 meters in altitude.

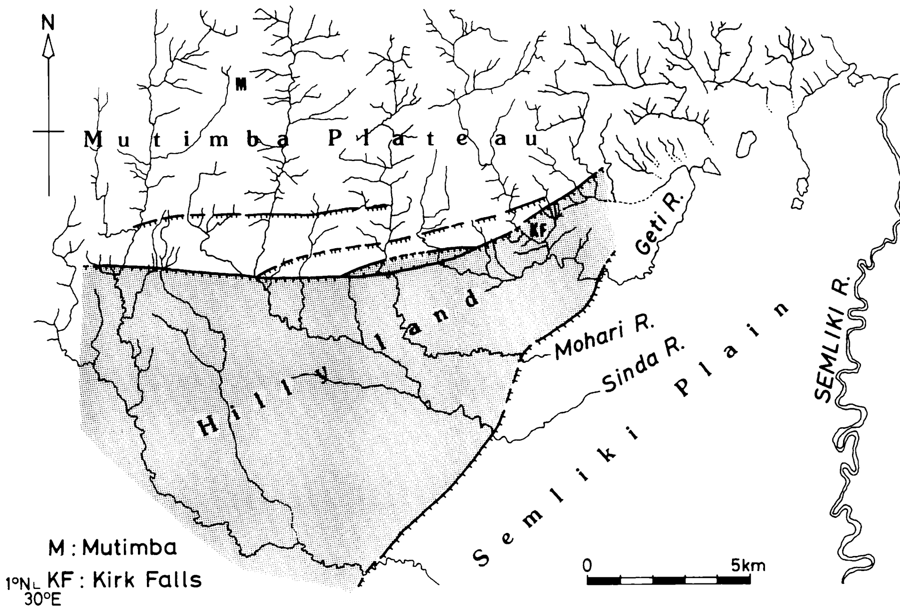

Fig. 2. Topography of the Sinda-Mohari region, Haut-Zaire Province, Eastern Zaire.

The hilly land is spread between the Mutimba Plateau and Semliki Plain and is composed of fluviolacustrine sand and mud beds. The strata gently dip southeast toward the Semliki Plain. Cobble to boulder gravels (Higher Terrace Deposits) cover the hilly land with accordance of summitlevel (about 800 meters in altitude). Terrace deposits are distributed along the river courses sculptured in the hilly land.

The Semliki Plain, about 650 meters in altitude, is the floor of the rift, in which the Semliki River flows northeastwards from Lake Rutanzige to Lake Mobutu.

Main boundary faults of the rift run along these topographical divisions (Fig. 2). The faults between the Mutimba Plateau and the downthrown hilly land (northern boundary faults) strike nearly E-W and have a throw of several hundreds meters, forming the western escarpment of the rift. The fault between the hilly land and Semliki Plain (southeastern boundary fault) strikes about N 45° E.

The Sinda and Mohari Rivers, tributaries of the Semliki River, flow southwards in the Mutimba Plateau and then go through the hilly land toward the southeast, sculpturing deep valleys. Finally, they turn northeastwards and pour into the Semliki Plain.

The investigated area is situated in river basins of the Sinda and Mohari within the hilly land.

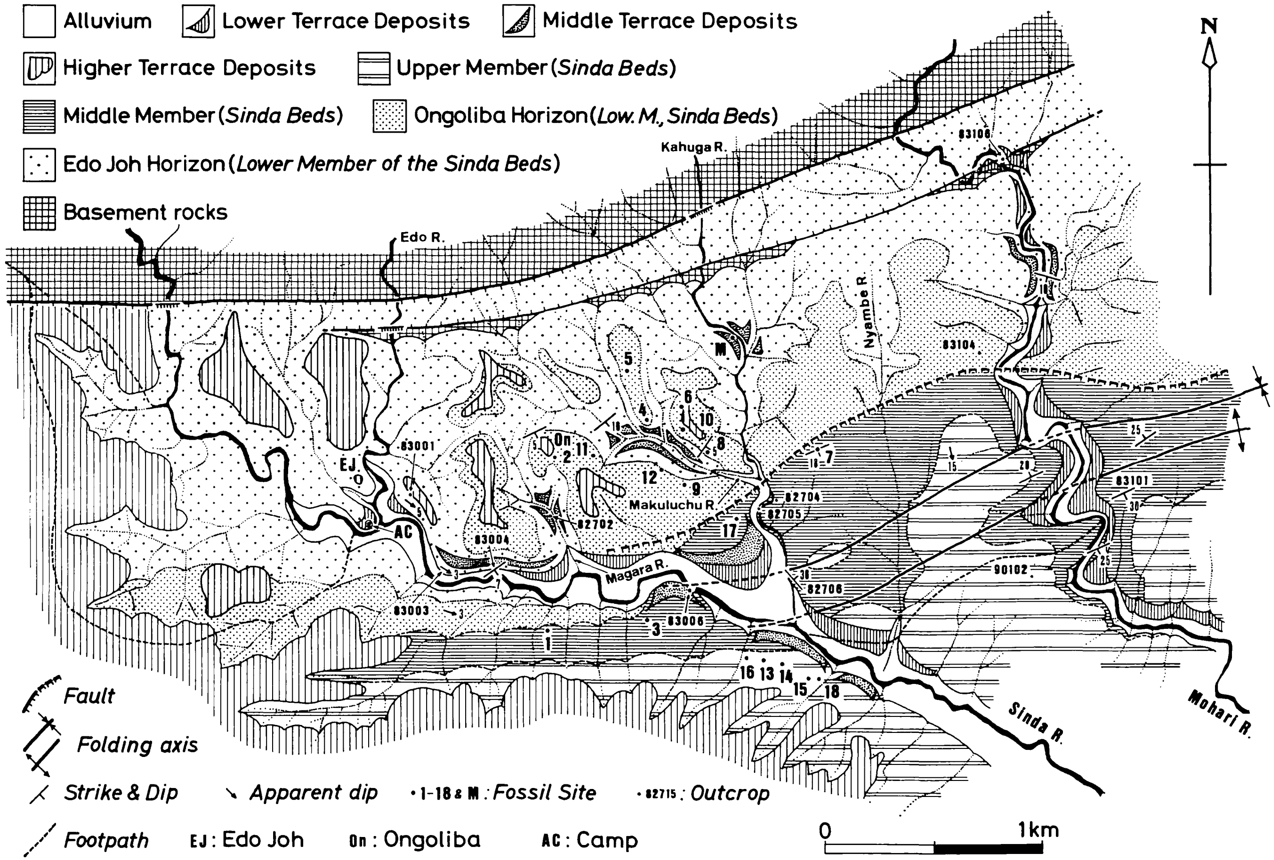

Fig. 3. Geologic map of the Sinda-Mohari region, Haut-Zaire Province, Eastern Zaire.

LITHOSTRATIGRAPHY

In the investigated area, the following lithostratigraphic units are identified. (1) Precambrian basement rocks, (2) Sinda Beds, (3) Higher Terrace Deposits, (4) Middle Terrace Deposits, (5) Lower Terrace Deposits, and (6) Alluvium (Recent river floor deposits) (Fig. 3 & Tab. 1). Among these units, the Sinda Beds form the main part of hilly land. The Semliki Series (Lepersonne, 1949; Hooijer, 1963), which constitutes the southeastern part of the hilly land, does not crop out in this area.

I. Precambrian Basement Rocks

The Precambrian basement rocks (granite gneiss, etc., which belong to the Ubendian metamorphic zone) sporadically crop out under the Sinda Beds along the main boundary faults between the Mutimba Plateau and downthrown hilly land. The basement rocks are weathered in general and have suffered minor faultings.

II. Sinda Beds

Hooijer (1963) has divided strata, which form the hilly land, into three units, the Mohari (Leriche, 1938), Kahuga and Sinda Beds, in ascending order. However, the Mohari and Kahuga Beds are not clearly distinguished from the Sinda Beds, because

Table 1. Stratigraphy and geohistory of the Sinda-Mohari region, Haut-Zaire Province, Eastern Zaire.

GEOLOGICAL AGE			STRATIGRAPHY (thickness in meter)		SEDIMENTATION & TECTONIC MOVEMENT
QUATERNARY	Holocene		Alluvium		
	Pleistocene	Late	Lower Terrace Deposits (5 ±)		Lower Terrace formation along the Sinda and Mohari Rivers
			Middle Terrace Deposits (10 −)		Middle Terrace formation during a stage when Lake Mobutu had a higher water level
		Mid. - Early			Completion of the present Semliki Plain & drainage system Activity of the southern boundary fault
			Higher Terrace Deposits (5 ±)		Formation of the Higher Terrace Cobble to boulder gravals covered the peneplain.
					Distinct relief between the downthrown hilly land and the Mutimba plateau Intense activity of the northen boundary faults
NEOGENE	Pliocene				Denudation and peneplanation
					Completion of the Sinda Beds deposition
			Sinda Beds	Upper Mem. (20 +)	Deposition of the alternating thicker beds of sand and mud during the basin had a tendency to retreat northeastwards
				Middle Mem. (30)	Deposition of the alternating sand and mud beds in the maximum subsidence
	Miocene			Lower Mem. (100 +)	Finer sediments deposition due to successive subsidence Immature coarse sand deposition, forming a delta
					Beginning of the Sinda Beds deposition
					Gentle downwarping formed an extensive sedimentary basin, covering the present Lake Mobutu and Semliki Plain.
PRE-NEOGENE			Precambrian basement rocks		

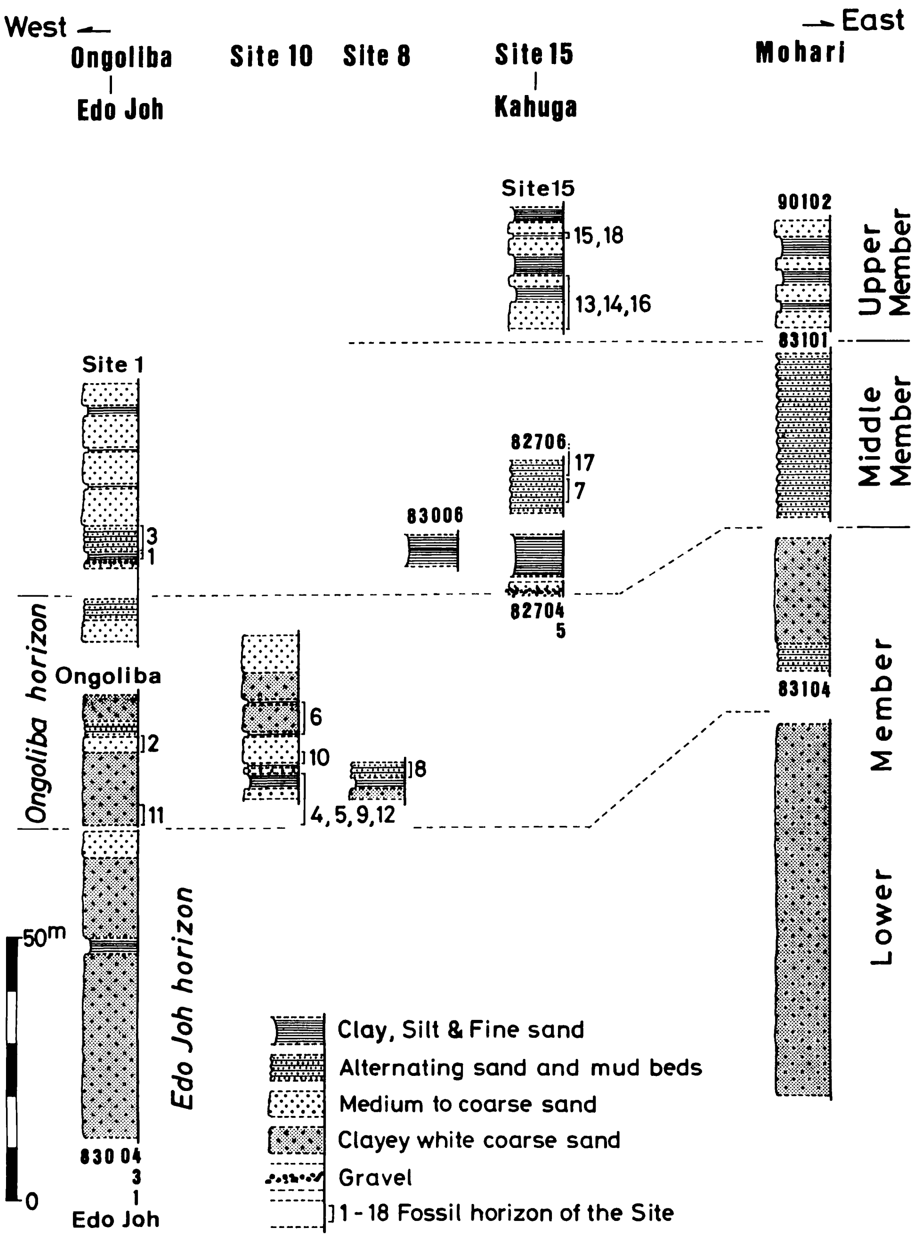

Fig. 4. Columnar sections of the Sinda Beds.

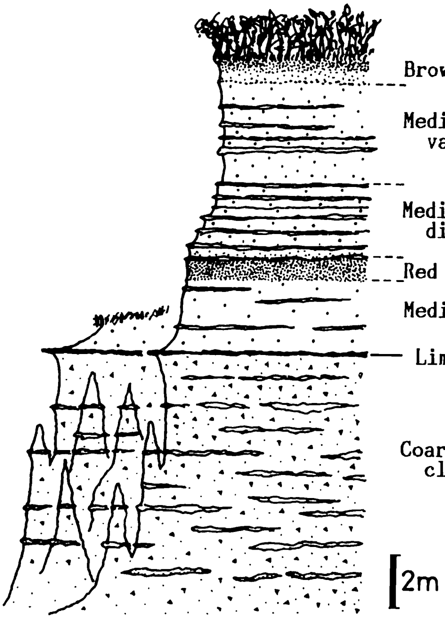

Fig. 5a. Sketch of the Ongoliba butte, the upper part (Ongoliba horizon) of the lower member of Sinda Beds.

we have not observed any lithologically sharp boundaries adequate to classify the strata into several formations. As Lepersonne (1949) has once stated, no important break can be placed. Thus, we use the term Sinda Beds for the strata which form the hilly land in this area.

The Sinda Beds are lithologically subdivided into three, the lower, middle, and upper members. The total thickness exceeds 150 meters (Fig. 4).

1. Lower member

The lower member is widely exposed in the northern part of the hilly land. The lower member is observed in detail in the upper reaches of the Sinda and Mohari Rivers as well as in that of the Edo River, a tributary of the Sinda River (Fig. 3). The thickness is more than 100 meters.

This member is mainly composed of clayey white coarse sand with much granule gravel and quartz grain, showing lower maturity (Fig. 4). Many intercalations of discontinuous mud seam are also contained. It is a characteristic feature that this member forms many earth pyramids on high cliffs facing deep valleys.

The upper part of this member, 30 to 40 meters thick, becomes finer with intercalations of thicker mud seam and limonitic bed. Granule gravel and quartz grain are scarcely contained. This horizon is observed in detail in the Ongoliba butte (Fig. 5a), which is situated in the upper reaches of the Magara River, a tributary of the Sinda River. So we call this horizon the *Ongoliba horizon*. This horizon yields such mammal fossils as Bovidae, etc. (Fig. 5b,c).

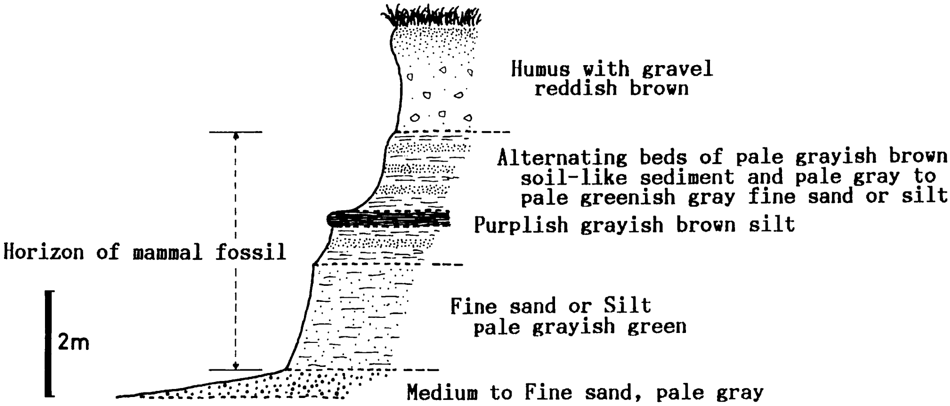

Fig. 5b. Sketch of Site 8, Ongoliba horizon.

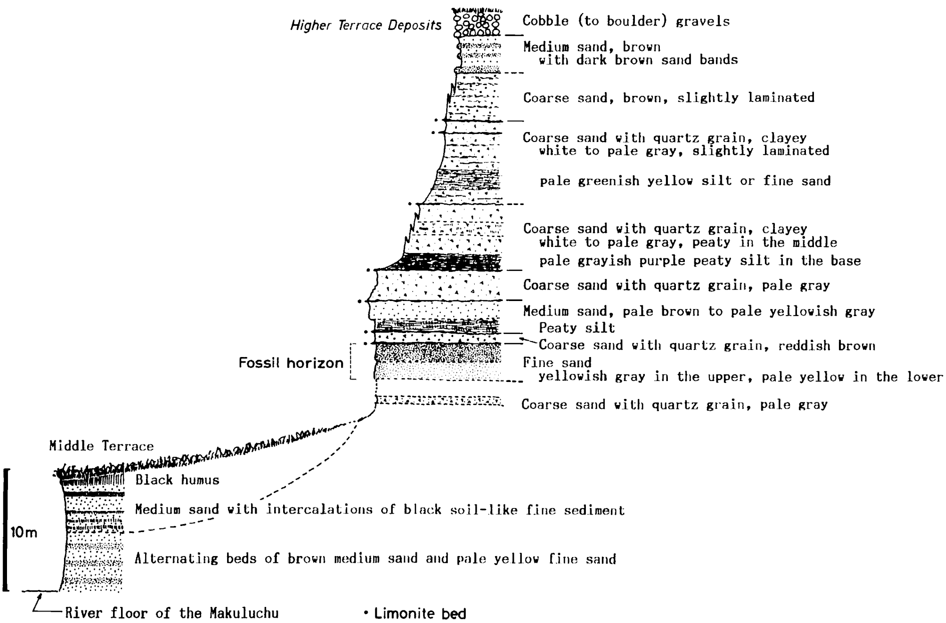

Fig. 5c. Sketch of Site 10, Ongoliba horizon.

The middle and lower parts of this member is called the *Edo Joh horizon.* The term, Edo Joh (means the Edo Castle, Edo is the former name for Tokyo, Japan), is a field name given for the large-scale earth pyramid (50-60 meters high) at the junction of Rivers Sinda and Edo. The pyramid shows a typical lithology of the lower and middle parts of this member, and its shape somewhat resembles the Japanese castle of prominence in the Edo era (1603-1867). The Edo Joh horizon is likely to be identical to the Mohari Beds of Hooijer (1963).

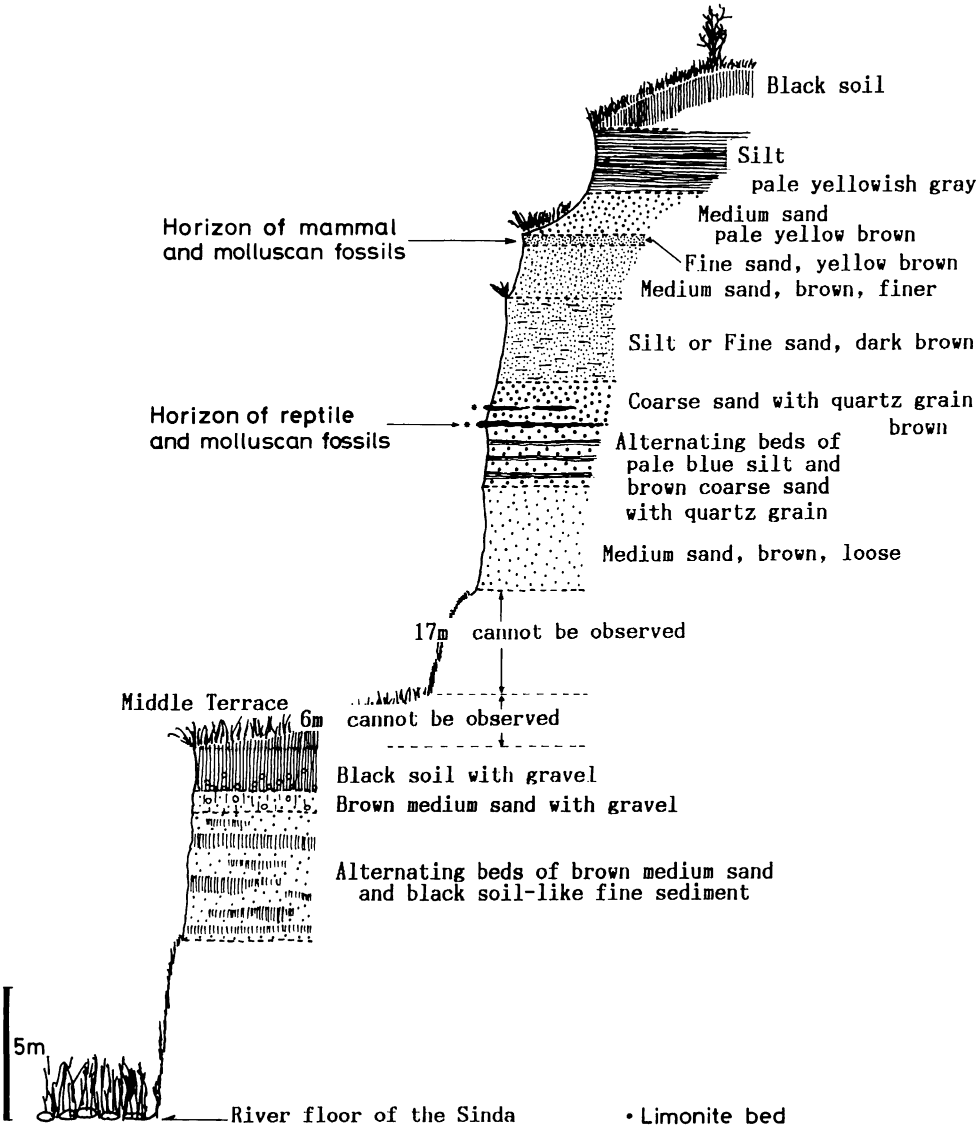

Fig. 6. Sketch of Site 15, the upper member of the Sinda Beds.

2. Middle member

The middle member crops out in the lower reaches of the Kahuga River, a tributary of the Sinda River, and in the middle reaches of the Mohari River. This member is also exposed in the southern bank of the Sinda River (Fig. 3). The thickness is about 30 meters.

This member is characterized by alternating sand and mud beds (Fig. 4).

In the Mohari River, the sand beds, 50 to 100 centimeters thick, are composed of pale yellow massive medium sand and are not so compact in general, though partly well-consolidated. The mud beds, 30 to 100 centimeters thick, are pale mauve gray silt and crumble easily in the desiccated parts on outcrops. From the monotonous sand of the lower member to the alternating beds of this member, the lithology changes so abruptly without a transitional facies that this member should be in fault contact with the lower member, although the contact cannot be observed because of vegetation cover.

In the Kahuga River, the sand beds are brown-colored, fine to medium sand showing fine lamination. The thickness is several tens centimeters to one meter. The mud beds are blueish gray silt and are thinner than the sand beds. This member has intercalations of thick (more than 8 meters) mud beds in the lower part and well-consolidated gravel bed in the basal part. The thick mud beds are dark brown to pale greenish gray fine sand and silt. The gravel bed, probably a few meters thick, is mainly composed of small pebble to granule of angular to subangular quartz fragments with brown medium sand matrix. The gravel bed shows limonitic brown color.

In the southern bank of the Sinda River, the alternating beds have sand as the dominant constituent. Namely, each of sand beds becomes thicker (several meters), whereas the intercalations of mud beds decrease.

3. Upper member

The upper member is exposed in the lower reaches of the Sinda and Mohari Rivers, and in the southern bank of the middle reaches of the Sinda River (Fig. 3). The thickness is more than 20 meters.

This member is characterized by alternating thicker beds of sand and mud (Fig. 4). Each of sand and mud beds becomes thicker (a few to several meters) than that of the middle member. The sand beds are composed of brown-colored, medium to coarse sand and are weakly consolidated. The mud beds consist of pale yellow to pale gray silt and fine sand. This member yields such mammal fossils as *Prodeinotherium*, etc. (Fig.6).

III. Higher Terrace Deposits

The Higher Terrace Deposits consist of cobble to boulder gravels and cover unconformably the Sinda Beds of the hilly land with accordance of summitlevel. The deposits, several meters thick, are weathered into reddish brown. The Higher Terrace surface shows a slightly convex topography.

IV. Middle Terrace Deposits

The Middle Terrace Deposits are distributed along river courses of the Sinda, Mohari, and their tributaries. The terrace surface is about 10 meters above the present river floor. The deposits, less than 10 meters thick, consist of brown sand (coarse- through medium- to fine-grained) and scarcely contain gravel.

Along the Sinda River, the terrace topography is fragmentarily found on both banks. The deposits show a parallel lamination and contain intercalated black soil seams (Fig. 7a).

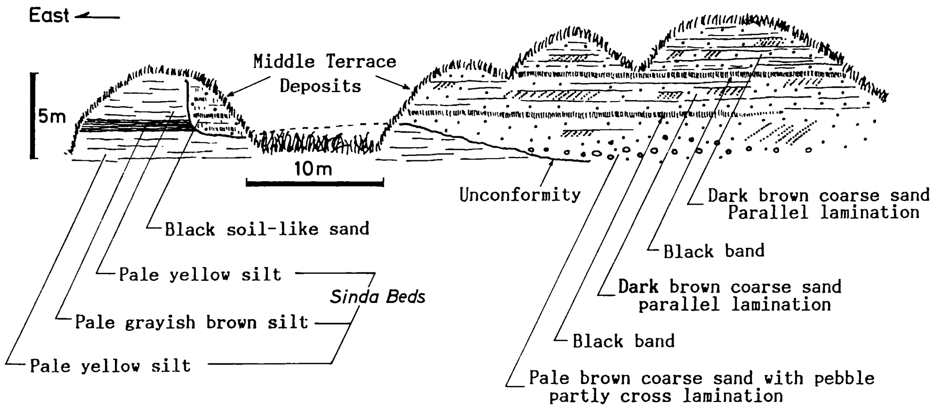

Fig. 7a. Sketch of an outcrop (83006) of the Middle Terrace Deposits.

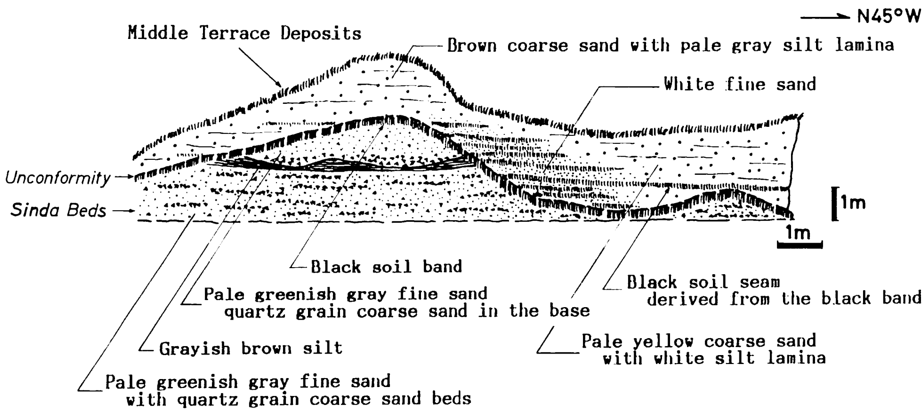

Fig. 7b. Sketch of the basal part of Middle Terrace Deposits (82702).

Within valleys of the tributaries, the Middle Terrace surface is fragmentarily recognized. The deposits have filled valleys up to the level of about 10 meters above the present river floor and consist mainly of brown to pale yellow sand with intercalations of mud and lenticular black soil seams. Stratigraphic horizon of the site where only molluscan fossils occur belongs to the Middle Terrace Deposits.

The unconformity between the Sinda Beds and Middle Terrace Deposits is observable at some outcrops along the tributaries (Fig. 7b). The unconformity surface is uneven and is accompanied by a zone of black paleosol.

V. Lower Terrace Deposits

The distribution of the Lower Terrace Deposits is restricted to courses of the Sinda and Mohari Rivers. The terrace surface is a few meters above the present river floor. The deposits, a few meters thick, are composed of sand and gravel.

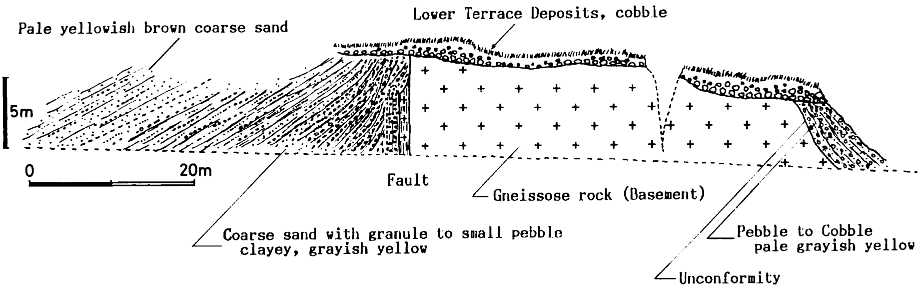

Fig. 8. Sketch of a fault accompanying the northern boundary faults (83106).

VI. Alluvium (Recent River Floor Deposits)

Recent river floor deposits consist of sand and gravel. Along main rivers such as the Sinda and Mohari which spring from the Mutimba plateau, the deposits contain cobble gravel of Precambrian basement rocks. On the other hand, the deposits along the tributaries are mainly composed of coarse to medium sand and scarcely contain gravel, because some of the tributaries spring from the hilly land which is mainly made of sand and mud of the Sinda Beds.

GEOLOGIC STRUCTURES

As already stated, the hilly land is bounded on the northern and southeastern sides by large-scale normal faults.

The faults of the northern boundary (northern boundary faults) strike N 70°-90° E and steeply dip south. Based on the altitude difference of basement rocks, 1,300-1,400 meters in the plateau and about 700 meters in the hilly land, the total throw is estimated to be 600-700 meters.

Another fault runs just south parallel with the boundary faults. This fault dips steeply north (Fig. 8). This is a fault associated with open tensional fissure. The narrow block bounded by both faults have been depressed.

Generally speaking, the Sinda Beds in the hilly land strike N 40°-80° E and gently dip (5°-10°) south to southeast.

An anticline with a trend of ENE, parallel with the northern boundary faults, is recognized in the middle course of the Mohari River. The south wing dips 25°-30° SSE, and about 25° NNW in the north wing. A syncline accompanies the anticline just north, and runs parallel with the anticline. The north wing dips 10°-20° SSE. An inferred fault is drawn just north parallel with the syncline. The southern block has been moved down.

The folding structures and a fault can be traced further west, as far as the lower reaches of the Kahuga River.

Many minor faults are observed at various outcrops.

DISCUSSION

I. Stratigraphic Horizon of a Few Remarkable Beds

In the Kahuga River, well-consolidated gravel bed is interbedded at the base of the middle member of Sinda Beds. Although it may be due to limonite formation, the lithification of this bed has been considerably advanced in comparison with that of sediments above and below this horizon (Sediments below this bed are not observable in this site). Accordingly, this bed appears to be older than any other bed. It is also noteworthy that most of the gravel are fragments of durable quartz, and less durable gravel, such as Precambrian gneissose rock, is scarcely included. There is a possibility that this bed is of older sediments made of reworked gravel.

In the Mohari River, the middle member of the Sinda Beds, comprised of alternating sand and mud beds, slightly differs from the other members of the Sinda River basin in lithofacies. The accurate horizon of this member should be further examined.

II. Geological Age

Except for the collected fossils, we have no effective data for geological age dating. Dating with the mammal fauna is discussed by Yasui et al., in this volume. Our goal here is to infer the geological ages from the mode of deposition, relative grade of compaction, and so on.

The **Lower Terrace Deposits** are inferred to be of Holocene or late Pleistocene age from the relative height of the terrace surface being a few meters above the present river floor.

The **Middle Terrace Deposits** are distributed within valleys of the tributaries and consist of such finer sediments as sand and mud. Accordingly, they date later than the completion of the present drainage system and coincide with the stage when Lake Mobutu had a higher water level. Stages of higher lake level of the Mobutu have been known to be at 28,000-25,000 B.P. and 12,500 B.P. to the present (Harvey, 1976). However, the deposits seem to be slightly older than the former stage from the viewpoint of the grade of compaction. We regard their geologic age as to be early stage of Late Pleistocene age or late stage of Middle Pleistocene age. The Rwebishengo Beds (Pickford et al., 1989), which exist on the opposite side of the Semliki Plain (Uganda side) and have filled valleys, are similar to the deposits in mode of deposition.

The lithology of the **Higher Terrace Deposits** shows that there existed a distinct topographic relief in the formational stage between the hinterland (Mutimba plateau) and depositional site (downthrown hilly land). The formational stage corresponds to the intense activity of the northern boundary faults. Compiling previous works, Ebinger (1989) has stated that the uplift along the northeastern flanks of this rift system changed the drainage patterns of several rivers during late Pliocene or Pleistocene time. Thus, the intense activity of the northern boundary faults is considered to be of early to middle Pleistocene age, and also the age of Higher Terrace Deposits.

A consensus has not been reached yet on the age determination of the **Sinda Beds** with faunal remains. Hooijer (1963) has considered it to be of early Miocene age based on the mammalian fauna, while Pickford & Senut (in press) have judged it to be of Pliocene age based on the molluscan fauna. In view of the grade of compaction, we estimate the age to be younger than early Miocene time.

III. Geohistory

We present a geohistory of this area as a compilation of our research (Tab. 1).

In late Neogene time, an extensive sedimentary basin, covering the present Lake Mobutu and Semliki Plain, was formed by gentle downwarping. In this area, situated in the southwestern marginal zone of the sedimentary basin, deposition of immature coarse sand (Edo Joh horizon of the Sinda Beds) took place, forming a delta. This area submerged due to successive subsidence of the basin, and the finer sediments (Ongoliba horizon of the Sinda Beds) were also deposited. Thereafter, this area reached the maximum subsidence, and the alternating sand and mud beds (middle member of the Sinda Beds) were formed. Finally, the basin had a tendency to retreat from this area toward the center, and the upper member of the Sinda Beds was deposited. Thus, the basin completed the deposition of Sinda Beds in this area.

Thereafter, long-term denudation and peneplanation prevailed in this area.

In early to middle Pleistocene time, the intense activity of the northern boundary faults formed the distinct relief between the downthrown hilly land and the Mutimba plateau, as already discussed, and then cobble to boulder gravel of the Higher Terrace Deposits were supplied on the peneplain.

Activity of the southeastern boundary fault, which runs between the hilly land and Semliki Plain, is considered to date later than that of the northern boundary faults. The present Semliki Plain was made clear its outline as the floor of rift valley by the activity of the southeastern boundary fault.

Formation of the present Semliki Plain has confirmed the present drainage system, and then the deep valleys have been sculptured in and around the hilly land.

During late Quaternary time, the Middle Terrace Deposits were formed within the deep valleys.

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