ENVIRONMENTAL IMPLICATIONS OF SLOPE DEPOSITS IN HUMID TROPICAL AFRICA: EVIDENCE FROM SOUTHERN CAMEROON AND WESTERN KENYA

Hiroshi KADOMURA and Nobuyuki HORI*

Abstract Radiocarbon-dated stratigraphic sequence of slope deposits in the humid, now and formerly forested areas of Southern Cameroon and similar stratigraphy in Western Kenya suggest following environmental history: 1) widespread savannization or steppization of closed forests during the Last Glacial Maximum arid phase in the low latitudes; 2) return of humid climates followed by forest reestablishment in the early to middle Holocene (>8,500-3,000 yr B.P.), and 3) anthropogenic transformation of upper part of the profile due to slash-and-burn agriculture facilitated by climate aridification from 3,000-1,000 yr B.P. onward. Because of low-resolution of both ages and environmental conditions inherent in slope deposits, this interpretation must be reassessed by well-dated palaeo-geoecological studies.

Key words: slope deposits, humid tropical Africa, environmental history, Southern Cameroon, Western Kenya

1. Introduction

In tropical Africa, most slopes of now and formerly forested, undulating to rolling hilly terrain are covered with superficial deposits which are collectively called as hillslope deposits (*e.g.*, Thomas, 1974; Faniran and Jeje, 1983). The deposits are usually composed of two distinct stratigraphic units overlying deeply weathered bedrocks: 1) a fine-grained colluvial sediment and 2) a gravelly layer. The latter generally occurs beneath the fine-grained colluvial sediment and has often been called as "stone line". Many have been written about the origin of these deposits, particularly of stone line (*e.g.*, Segalen, 1969; Thomas, 1974; Tamura, 1975; Young, 1976; Faniran and Jeje, 1983; Alexandre et Symoens, 1989). Major views which have been proposed by various authors to explain the origin of tropical slope deposits since mid-1950s can be summarized as shown in Table 1.

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* Department of Environmental Sciences, Faculty of Integrated Arts and Sciences, Hiroshima University.

Table 1 Various views of the origin and age of gravelly layer or stone line (*Mg*) and fine colluvial layer (*Mc*) in the humid tropics

	Gravelly Layer Stone Line (*Mg*)	Fine Colluvial Layer Hillwash Sediment (*Mc*)
Processes	a) Residual weathering (*e.g.* Young, 1976) b) Faunal pedoturbation by termites and worms (*e.g.* Nye, 1955; Soyer, 1989) c) Surface proceeses; wash, rilling, gullying, & mass movement (*e.g.* Fölster, 1969; De Ploey & Poesen, 1989) d) Winnowing by water & wind (Lag deposit) (*e.g.* Brückner, 1955; Fairbridge & Finkl, 1984) e) Seepage erosion and creep (Lag deposit) (Moeyersons, 1989) f) Multiple processes (*e.g.* Vogt et Vincent, 1966) g) Repeated lateral reworking along with relief evolution associated with climate change from tropical to equatorial conditions (Segalen, 1967, 1969)	a) Colluvial-alluvial (Thomas & Thorp, 1980) b) Derived from breakdown of worm casts & termitaria (Nye, 1955; Williams, 1968) c) Mass wasting, in patricular creep (Moss, 1965) d) Colluvial & termite-built (De Ploey, 1965) e) Unconcentrated wash (Fölster, 1969; Rohdenburg, 1969) f) Joint action of termites, worm & wash (Burke & Durotoye, 1971) g) Mixed with eolian dust deposit (Fried, 1983)
Ages and Environments	a) Past desertic environment (*e.g.* Bückner, 1955) b) Last Glacial 38-12 KBP, under semiarid, steppe-like vegetation(De Ploey, 1965) c) Glacial-postglacial switchover 12-9 KBP,under increased precipitation before reforestation (Thomas & Thorp, 1980) d) Last Glacial Maximum 18 KBP, by torrential rains within an arid or semiarid phase (Fairbridge & Finkl,1984) e) Last grand arid period *c.* 20 KBP; mid-Holocence dry episode *c.* 6.5 KBP (Roche, 1989; Alexandre & Soyer, 1989)	a) From late-Glacial, after reforestation (De Ploey, 1965) b) From early Holocene after reforestation (Thomas & Thorp, 1980) c) Holocene humid phase 8-4 KBP (Alexandre & Soyer, 1989)

During our field work on the geomorphology and late-Quaternary environmental history in the forest and savanna areas of Cameroon and Kenya, we have been attracted by the strikingly widespread occurrence of these deposits and their environmental implications (Hori, 1977a, 1977b, 1977c, 1982, 1986a, 1986b; Kadomura, 1977, 1982, 1984, 1986a; Kadomura *et al.*, 1986b, 1986c; Kadomura and Haruki, 1988; Kadomura and Hori, 1978, 1984a, 1984b; Kadomura and Imagawa, 1989). This paper summarizes our previous findings obtained from the humid, now and formerly forested areas of Southern Cameroon and Western Kenya (Fig. 1). Discussion on environmental implications of these deposits will be made in relation to an environmental history of tropical Africa established on the basis of lake-level changes, pollen diagrams, and oxygen-isotope profiles of deep-sea cores.

2. Classification of Regolith Profile and Stratigraphic Units

Based on our outcrop observations at more than 300 localities in Southern Cameroon and at about 100 localities in Western Kenya, regolith profile of these areas can be classified into following stratigraphic units in descending order according to the terminology proposed by Tamura (1982, 1984, 1986) (Fig. 2). The word "regolith" used here includes both materials transported and deposited by various processes and those derived from *in situ* weathering.

Migratory layer (Slope deposits)

Mh

Uppermost humic layer composed of loose, friable, sandy to silty soils; occasionally scattered by gravels or pebbles and potsherds, ceramics and other human artifacts. In Western Kenya admixed with volcanic ash.

Mc

Reddish to yellowish, thick, friable, sandy to clayey soil layer composing the main part of ferrallitic soils or Ferralsols; with ferric concretions and quartz granules and occasionally scattered by gravels, pebbles, and fragment of indurated cuirass. Subangular polyedic to blocky structure is well developed, particularly in the upper part of the layer. Ceramics and potsherds are occasionally contained in the upper part, and stone implements at various depths. The total thickness is ranging from 0.5 to 10 m or more. From the depositional structure and inclusions sometimes divided into upper (*Mcu*) and lower (*Mcl*) sublayers.

Mg

Gravelly layer including stone line; irregularly undulating, continuous or discontinuous layer, sometimes casting up and down, of coarser sediment composed of ferric concretions or pitholites, gravels and pebbles of quartz and weathered bedrock, and indurated cuirass boulders. Often contains rolled stone implements, particularly in Southern Cameroon. The thickness ranges from 0.1 to 2 m. In general only one continuous, well-defined layer occurs but two or more discontinuous layers are occasionally found within *Mc* layer. The former usually lies on the surface of *in situ* weathered zone. On steep

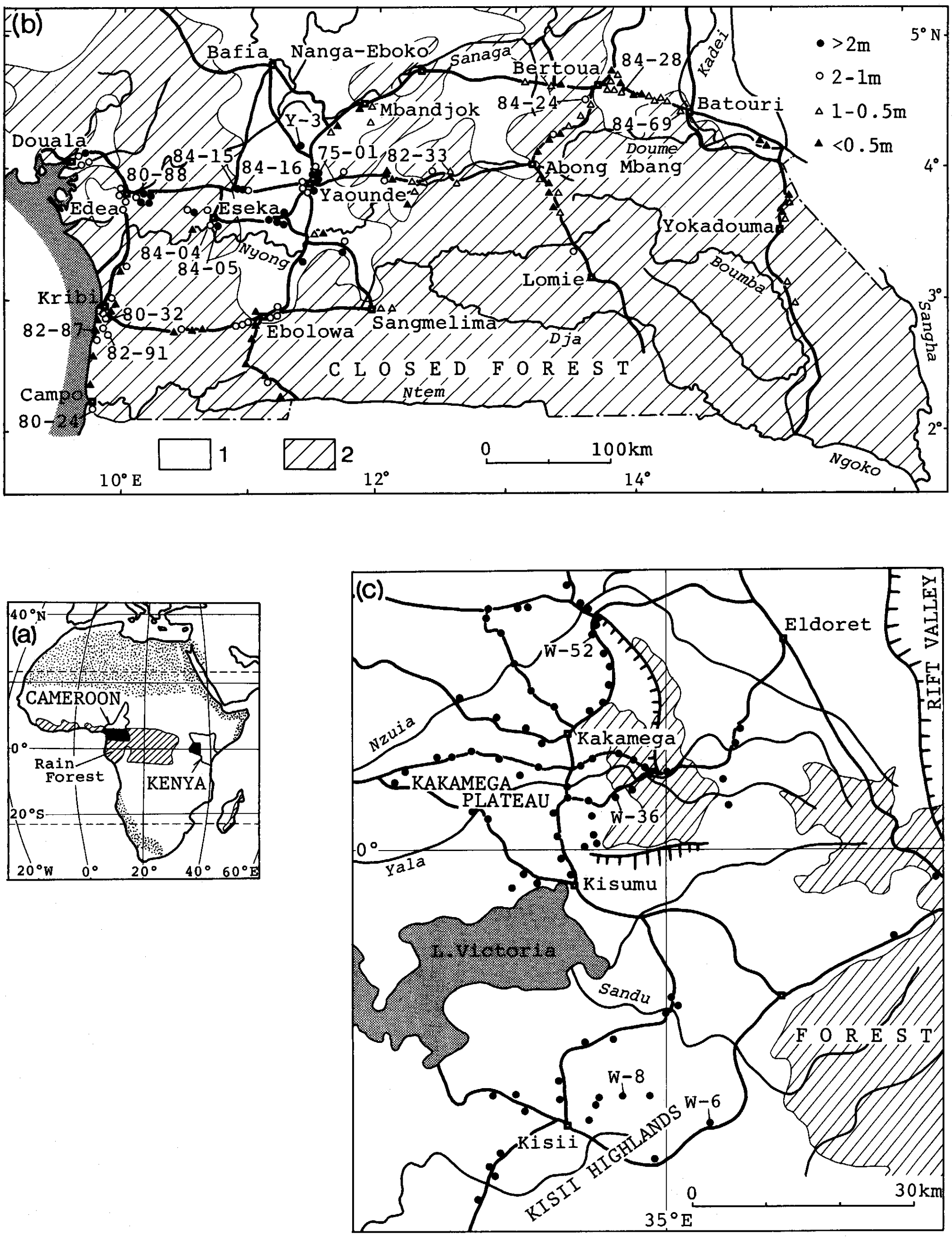

Fig. 1 Location of studied areas (a), and observed localities in Southern Cameroon with thickness of fine colluvial layer (b) and in Western Kenya (c)
1: degraded forest, savanna, and cultivated land for (b) and cultivated land for (c); 2: closed forest.

sloping terrain and hill-foot slopes as well as sites near dyke rocks resistant to weathering such as vein quartz, dolerite, *etc.* and indurated cuirass, *Mg* is mainly composed of coarse debris and boulders derived from these rocks and should better be described by *Mb* as a subtype of *Mg* (Kadomura, 1986a).

Mi

Indurated gravelly layer or stone-line; in general older than *Mg*. Sometimes called as gravelly or pitholitic cuirass.

Sedentary weathered zone

Wi

Indurated zone of *in situ* weathered bedrock; duricrust or indurated cuirass showing various degrees of induration.

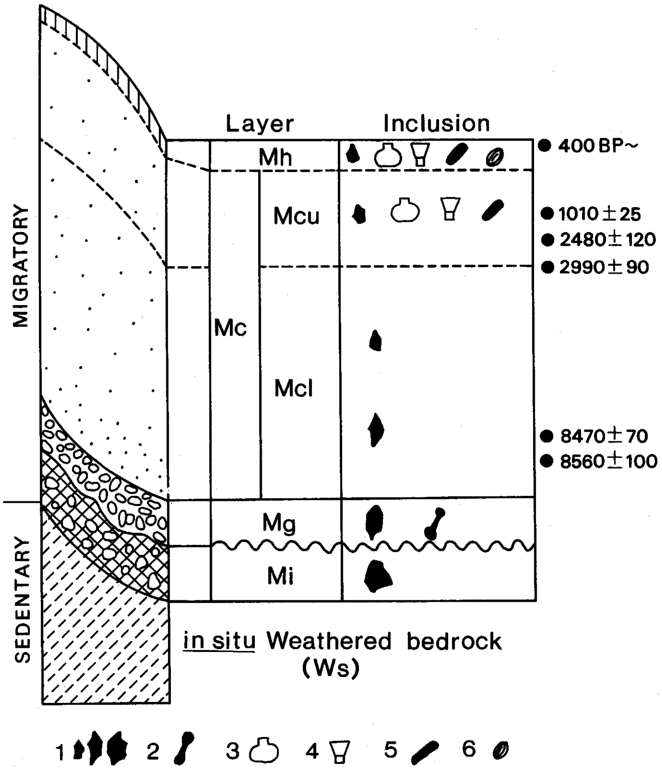

Fig. 2 Standard regolith stratigraphy for the forested areas of Southern Cameroon (modified from Hori, 1982)
Stratigraphy—*Mh*: humic topsoil; *Mc*: fine colluvial layer; *Mcu*: upper part of *Mc*; *Mcl*: lower part of *Mc*; *Mg*: gravelly layer and stone line; *Mi*: indurated gravelly layer. For details see the text.
Inclusion—1: light to heavy duty stone tools; 2: animal bone; 3: potsherds; 4: ceramics; 5: charcoal; 6: charred palm nuts. Radiocarbon dates from Hori *et al.* (1986)

Ws

in situ weathered bedrock; subdivided into *Ws1* (strongly weathered, red-colored or mottled zone; occasionally accompanied by vein quartz and corestones) and *Ws2* (original rock structure preserving, pale-colored zone; frequently accompanied by vein quartz and corestones).

R

Unweathered, fresh bedrock, more or less jointed; the surface of which is known as the weathering front. Sheeting parallel to the weathering front is common to crystalline rocks.

In humid tropical Africa, regolith stratigraphic units have been variously defined and classified by different authors. The correlation of our classification to other authors is shown in Table 2. Although the above regolith stratigraphic framework is mainly based on apparent sedimentological aspects of the subsurface profile, it can be used for examining major climatic/environmental changes by correlating nature and stratigra-

Table 2 Correlation of regolith stratigraphic units in humid tropical Africa used by various authors

This paper* S. Cameroon W. Kenya	Segalen (1967) Tropical Africa	Stoops (1967)** Central Africa	Burke & Durotoye (1971) + S. W. Nigeria	Bilong *et al.* (1982) S. Cameroon
Migratory				
Mh		Humiferous horizon	Humic top horizon	Niveau humifêre
Mc	Niveau I sable + argile	α-layer: cover layer	Termite-worm & wash (TTW) unit	Niveau IV: argileux et meuble
Mg	Niveau II (stone line)	β_1-layer: stone layer	Pediment gravel (stone layer)	Niveau III: dêtritique â blocs de cuirrase, gravillions, ferrugineux et fragments de quartz
Sedentary		(β_2-layer)		
Ws1		γ_1-layer		
	Niveau III: zone d'altêration		*in situ* weathered zone	Niveau II: vermiculiforme tachetê
Ws2		γ_2-layer		Niveau I: artêrite, conservant la structure de la roche sous-jacente

*For abbreviation see the text. **cited in Stoops (1989). +pediment deposits; others for hillslope deposits.

phic sequence of regolith profiles observed in different areas. According to the above classification, *Mh/Mc/Mg/Mi/Wi/Ws/R* series may be a complete, standard profile. However, all these units are not necessarily observed at every locality and one or two units may be absent at many localities. Nature and presence or absence of the units have environmental implications as discussed later. In the following chapters, description and discussion will be centered on migratory layer, *i.e.* *Mh/Mc/Mg* series slope deposits.

3. Southern Cameroon

Physical setting

Equatorial closed forests of the Congolian zone occupy the southern part of Cameroon as far north as approximately 5° N (Fig. 1b). The annual rainfall over the closed forests is in excess of 1,500 mm and dry month in which monthly rainfall is less than 50 mm does not exceed 2 months. In the northern periphery of the forested zone dry season occurs in July and January-February. Geomorphologically, the landscape of Southern Cameroon is divided into two regions: the Coastal Lowland below 300 m in altitude and the inland plateau (South Cameroon Plateau) ranging from 500-800 m in altitude.

Although the landsurface of the South Cameroon Plateau has been defined as a "peneplain" by some writers (*e.g.*, Segalen, 1967; Vallerie, 1973), it is not an unbroken, bevelled surface but an undulating terrain consisting essentially of an assemblage of immumerable small-size hills of 40-100 m high (Kadomura, 1977). Hillslopes are dominated by the convexity and the typical "demi-orange" hills are found everywhere throughout the plateau (*e.g.*, Segalen, 1967; Kadomura, 1977; Hori, 1982). The summit levels of the hilly lands of the plateau are grouped into several erosion surfaces (*e.g.*, Kuete, 1982, 1984, 1986, 1989). Besides a narrow belt of stepped coastal terraces, the topography of the Coastal Lowland is also characterized by undulating low-relief hilly lands (Hori, 1977a).

The principal geology of Southern Cameroon is the Basement Complex consisting of Precambrian crystalline rocks such as gneisses, schsits, migmatites, granites and quartzites. In general, these rocks have been deeply weathered to form thick regolith mantle, except those forming hills and inselbergs towering over the plateau level. Over the hill-tops at various levels, indurated cuirass frequently occurs in the uppermost part of *in situ*, deeply weathered zone even under the now and formerly forested areas. Under the natural conditions, however, it rarely crops out to form ledges and cornices unlike in the savanna environment.

Slope deposits

The undulating, now and formerly forested terrain of both the Coastal Lowland and the South Cameroon Plateau is almost evenly mantled with the *Mh/Mc/Mg* series slope deposits: a thin humic topsoil (*Mh*), a reddish to yellowish, sandy to clayey layer (*Mc*), and a thinly bedded gravelly layer (*Mg*) (Figs. 2 and 3). Among the three elements *Mc* layer can be found at almost all outcrops observed with varying thickness, except on rocky domes and steep hillside slopes. The thickness of *Mc* layer ranges from 0.5 to 10 m or more and is generally larger in the western part than in the eastern part (Hori, 1986a). In addition, in the eastern part, materials composing *Mc* layer is mostly sandy. This is mainly due to the fact that the materials composing *Mc* layer have been mainly derived from weathering of weakly metamorphosed rocks such as schists which tend to produce sandy fractions (Kuete, 1984, 1989). *Mc* layer is somtimes lacking due to recent truncation (Fig. 3d). In contrast, in the area of migmatic rocks around Yaounde, *Mc* layer occurs with an exceptional thickness, 10 m or more, as observed at the outcrops along the TRANSCAM railways (Fig. 3a).

The facies of *Mc* layer is massive as a whole but lenticular bedding structure indicating micro-depositional units is occasionally discernible in case of fresh outcrops (Fig. 3b). While the basal surface of *Mc* layer is characterized by the concavity, particularly on the lower part of hillside slopes, its depositional surface exhibits convex longitudinal profile

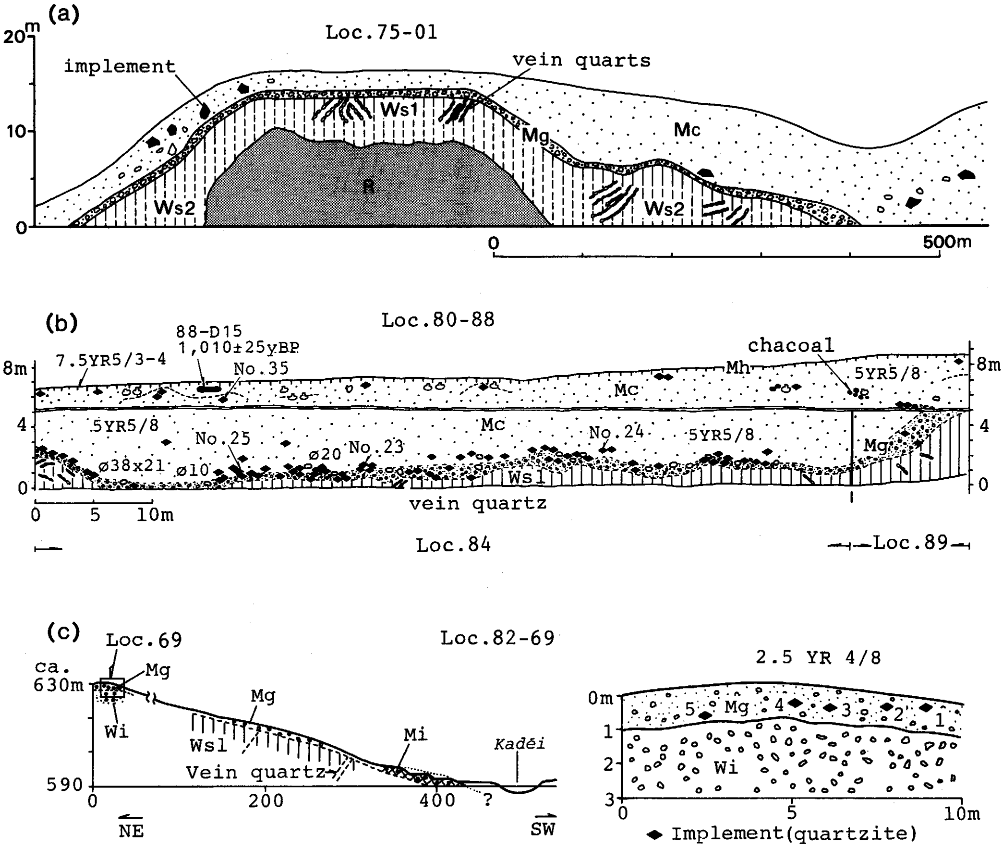

Fig. 3 Selected sections from Southern Cameroon
For locations see Fig. 1b. *Mh*: humic topsoil; *Mc*: fine colluvial layer; *Mg*: gravelly layer; *Mi*: indurated gravelly layer; *Wi*: indurated zone of *in situ* weathered bedrock; *Ws1*: upper part of *in situ* weathered zone (mottled zone); *Ws2*: lower part of *in situ* weathered zone (pallid zone); *R*: fresh bedrock. For details see the text.

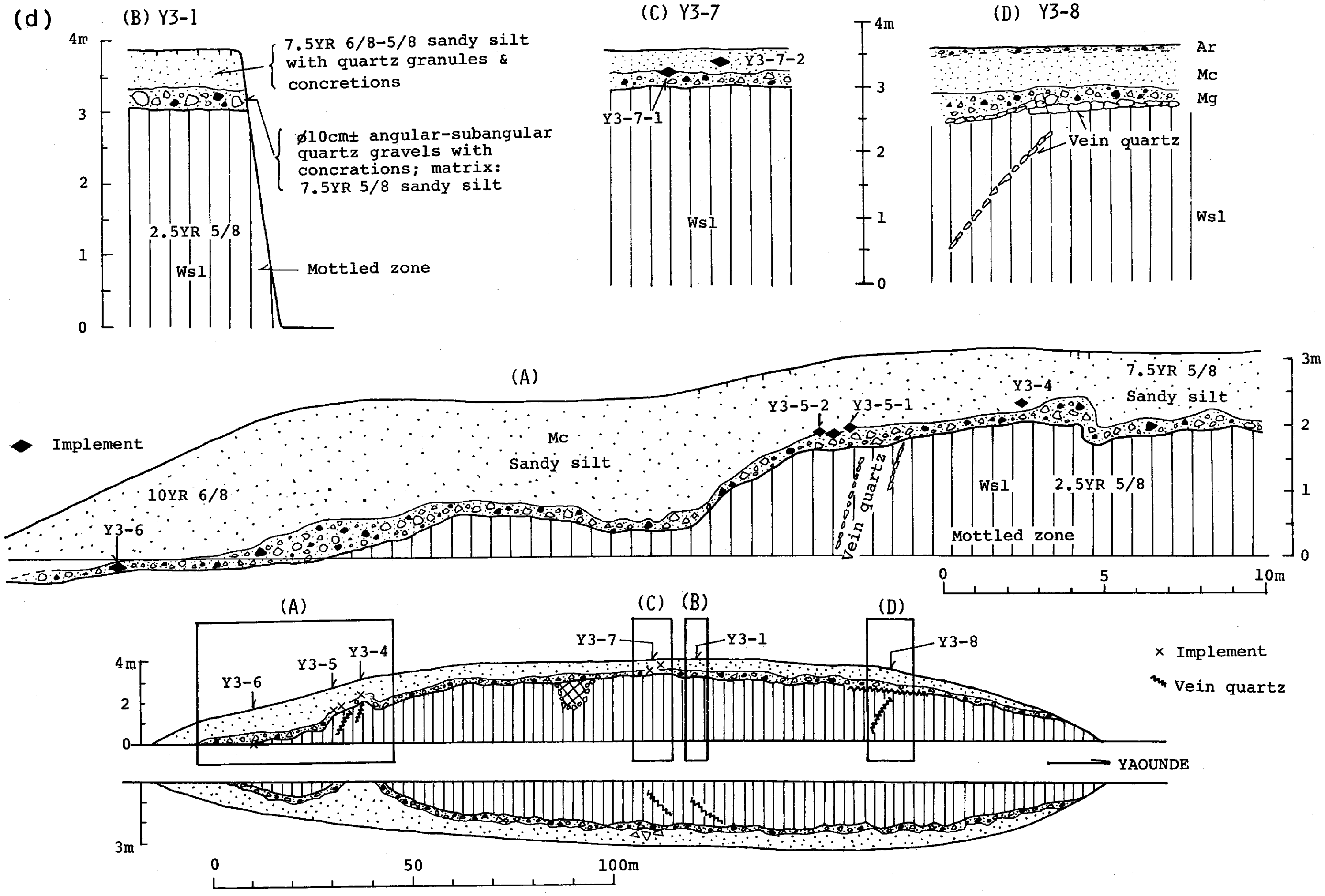

Fig. 3 (cont.)
Legend same as (a)-(c), except *Ar*: artificial fill-in soil.

and controls the convexity of the present landsurface.

The upper part of *Mc* layer often contains potsherds, ceramics, charred palm nuts, and charcoal. Implements of Lupemban and later ages are included at various depths but are usually concentrated near its basal surface (Fig. 3b). Dotted stone lines are occasionally intercalated at various depths.

Under the closed forest there is a distinct humic topsoil (*Mh*) of 10-30 cm thick, but in the case of artificial outcrops this layer was largely stripped.

Mg layer, with a thickness of 0.1 to 1 m, sometimes reaching 2 m, is commonly found below *Mc* layer at most outcrops throughout the forested undulating terrain. Its constituent materials differ form place to place according to the nature of underlying bedrock geology and the occurrence of indurated cuirasses on adjacent upslope areas. Pitholitic gravels, ferric concretions and nodules with lustrous surface, cuirass fragments, and angular to subangular quartz gravels and pebbles are the major materials composing *Mg* layer. Gravels and pebbles derived from metamorphosed rocks are always strongly weathered. Stone implements of Sangoan and Lupemban industries, most of which are made of quartzites and are heavily rolled, are rather abundantly included in *Mg* layer at many localities (Fig. 3a-d). Lenticular, micro-depositional structure is often observed (Fig. 3c), suggesting repeated reworking and resettlement. Depositional feature as a whole is usually wavy and sometimes shows festoon structure. Well-defined, long-continued *Mg* layer always truncates *in situ* weathered zone or indurated older deposits and shows the concavity at its lower slope section.

4. Western Kenya

Physical setting

The highlands and plateaux of Western Kenya around Kisii and Kakamega, located to the immediate east of Lake Victoria (Fig. 1c), are under the humid high-altitude tropical climate with annual rainfall of 1,500-2,000 mm and without distinct dry months. The lands of Western Kenya are known as one of the most densely populated and intensively cultivated areas in tropical Africa. Forest vegetation now only remains in the areas protected as forest reserve like Kakamega Forest. Kakamega Forest, which is evaluated as one of the most impoverished forest of Guineo-Congolian type of rainforest (Hamilton, 1982), and other forest reserves indicate that most wetter areas of Western Kenya were formerly covered with rainforest composed mainly of semideciduous species.

The geology of Western Kenya highlands and plateaux consists mainly of Precambrian metamorphosed sedimentary and volcanic rocks with granite intrusions. Dykes of quartzite, chert and dolerite frequently occur, forming prominent ridges and scarps within gently rolling to undulating terrain. As exemplified by the Maragoli granite hills in the southern part of the Kakamega Plateau, disintegrated granites tend to form a remarkable outcrop landform dominated by tor groups and boulder-covered hillslopes (Kadomura, 1986a).

Slope deposits

As in Southern Cameroon, the landsurface of Western Kenya highlands and plateaux is also extensively covered with *Mh/Mc/Mg* series superficial deposits which are underlain by *in situ* weathered zone or indurated older sediment (Fig. 4). The complete profile dominantly occurs on the gently sloping convex-type hillslopes.

Mc layer is composed of reddish, friable, clayey to silty soils and is occasionally scattered by gravels and pebbles. Its thickness is 0.5 to 3 m and sometimes reaches 4-5 m over the flat to very gently sloping landsurface. On the contrary, *Mc* layer is thin or almost lacking on steep hillside slopes, and in the vicinity of dyke rocks and large-scale quartz veins. In these cases the horizon of *Mc* is replaced by coarse debris and boulders which even occur on the ground surface (Fig. 4d).

Throughout the flat to gently sloping landsurface, dark-colored, thickly bedded, humus-rich *Mh* layer is developed very well and its thickness sometimes attains 1 m.

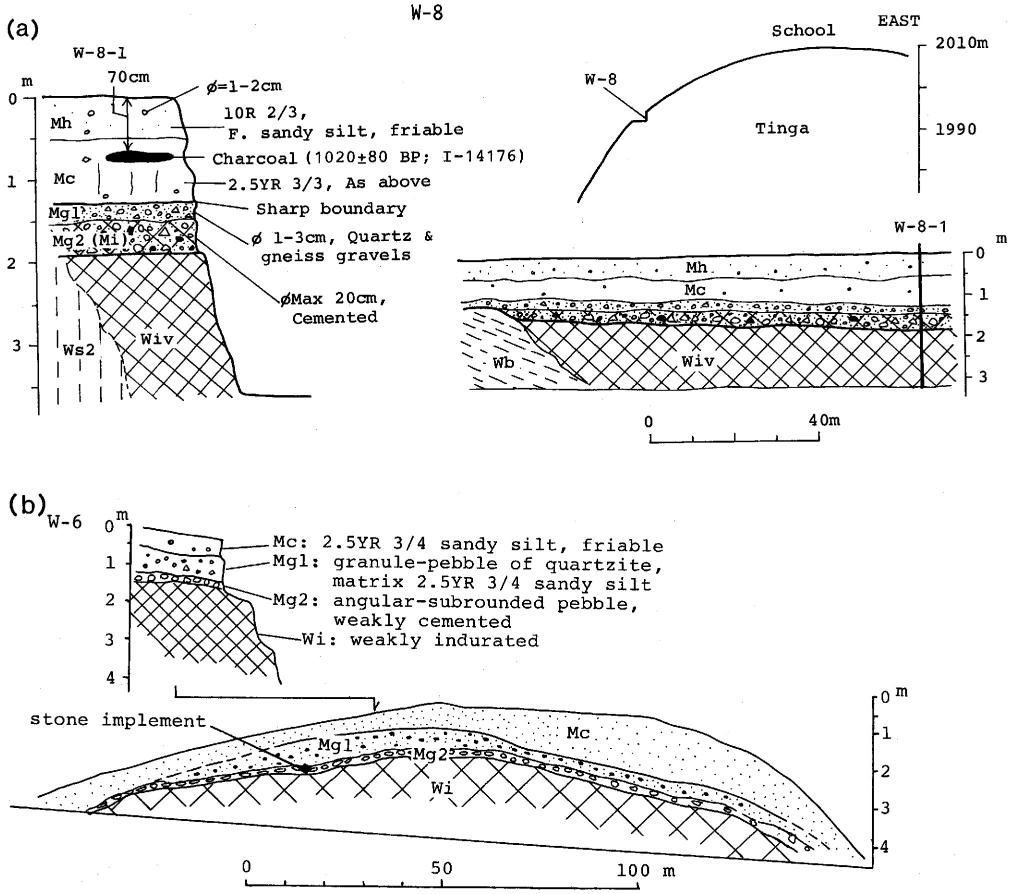

Fig. 4 Selected sections from Western Kenya
For locations see Fig. 1c. Legend same as Fig. 3, except *Wiv*: indurated vesicular cuirass; *Wb*; replace by *R*: jointed fresh bedrock

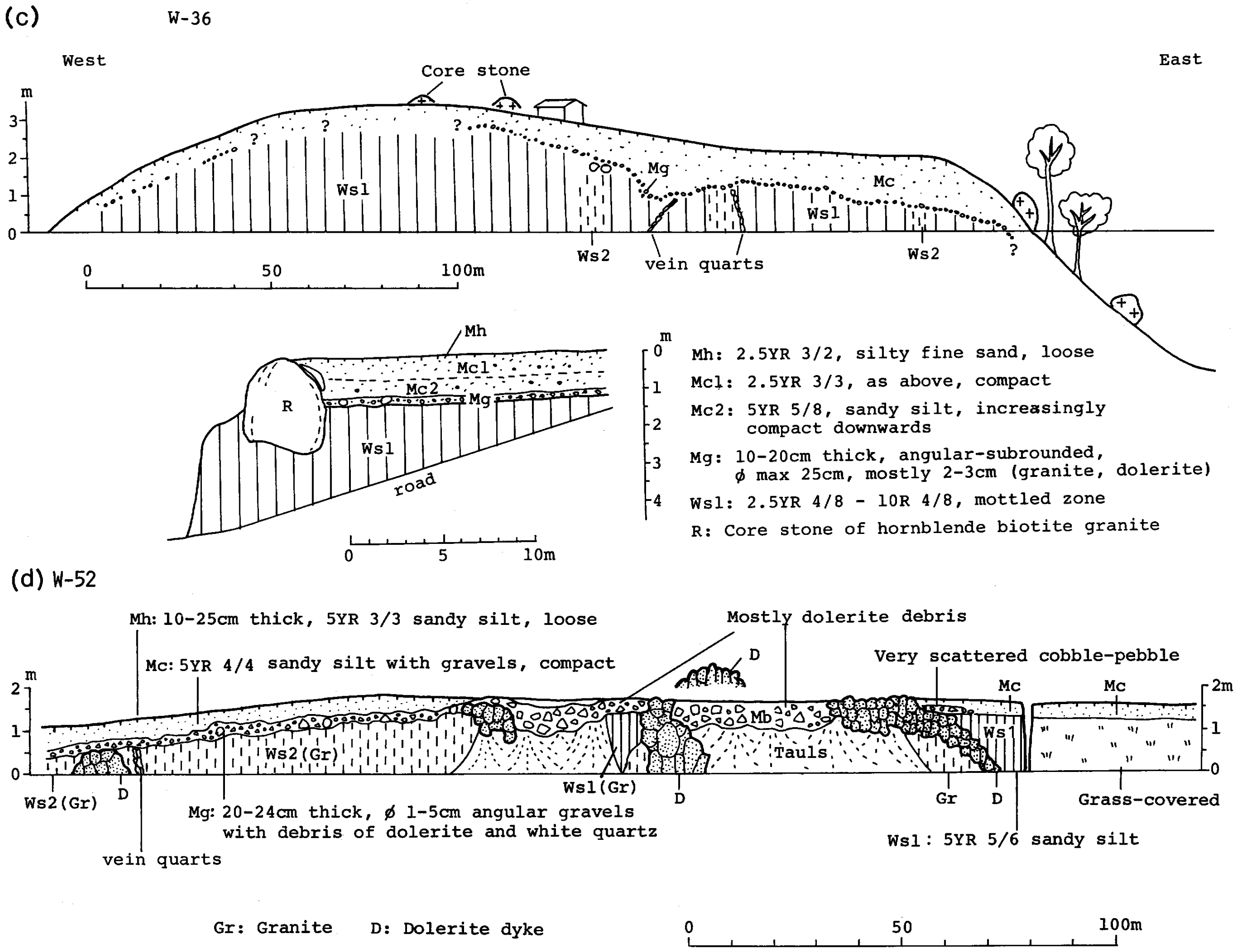

Fig. 4 (cont.)
Legend same as (a) and (b), except for *Mb*: *Mg* layer consisting of coarse debris and boulders.

Where a thick *Mh* layer is observed, it usually overlies underlying layer with a sharp boundary (Fig. 4a). This humic topsoil is composed of the admixture of reworked colluvial sediment and ash derived from Rift Valley volcanoes, as suggested by Wielemaker and van Djik (1981).

Although stone line-type, thinly bedded *Mg* layer is widespread throughout Western Kenya, it does not continuously occur but is lacking in many places, regardless to the bedrock geology. The areas underlain by deeply weathered granitic rocks with infrequent vein quartz are characterized by a thin, discontinuous stony deposit intercalating at the boundary between the migratory layer and the *in situ* weathered zone. In contrast, frequent vein quartz tends to contribute to the formation of a long-continued stone line and two or more sets of gravelly layer in some outcrops. However, the occurrence of the latter is always sporadic and discontinuous.

Over the flat to gently sloping landsurface, *Mb* layer which is composed of coarse debris and boulders only occurs in the vicinity of dyke rocks (Fig. 4d). Steep sloping lands and hill-foot slopes are dominantly covered with *Mb* layer.

In Western Kenya, as long as we observed, inclusion of stone implements within both *Mg* and *Mc* layers is less frequent compared with Southern Cameroon. Artifacts of more recent years such as potsherds and ceramic fragments, and charcoal are often contained in *Mh* layer and in the upper part of *Mc* layer (*Mcu*). A charcoal sample collected from the upper part of *Mcu* near Kisii town was dated at 1,020±80 yr B.P. (Fig. 4a). This date suggests that the forest of this area was already affected by human activities like slash-and-burn agriculture and that *Mh* layer which is admixed with volcanic ash is the product within the last 1,000 years.

5. Chronological Data

Palaeolithic implements

Although no systematic excavations were conducted, we unearthed more than 200 Palaeolithic implements from slope deposits at over 100 localities in the forested areas of Southern Cameroon. The localities from which stone implements were collected are widespread throughout the studied areas. Typological studies of collected implements were made by Prof. G. Omi, Department of Anthropology, Shinshu University and his colleagues (Omi *et al*., 1977, 1982, 1984, 1986). The stone implements unearthed from superficial deposits can be classified into three industry groups:

A) heavy-duty tools such as handaxes, picks, choppers, and core-scrapers of Final Acheulian to Sangoan/Lower Lupemban industries,

B) light-duty tools such as flake scrapers, discoidal scrapers, pointed tools, and points of Upper to Final Lupemban industries, and

C) small-sized tools such as points, scrapers, discs and flakes of Lupembo-Tshitolian industry.

According to the radiocarbon chronology of Palaeolithic industries in the Congo Basin (*e.g*., Van Noten *et al*., 1982; Lanfranchi, 1984), the three groups may be roughly correlated with following dates: A) 40,000 yr B.P. or older, B) 25,000-12,000 yr B.P., and C) 10,000-7,000 yr B.P.

In the closed forests of Southern Cameroon, the implements classified were unearthed both from *Mc* and *Mg* layers, and at many localities they were concentrated on the basal surface of *Mc* layer and within *Mg* layer (Fig. 3). Because the implements of the three groups are almost evenly occur both in *Mc* and *Mg* layers, direct correlation of an industry group with a certain stratigraphic unit is difficult. However, following general tendency is found in the occurrence of implements.

Although light-duty tools of B) and C) groups occur in *Mg* layer, they are dominantly found in the upper part of it. In contrast, heavy-duty tools occur in every part of *Mg* layer. These evidence suggests that the formation of *Mg* layer may date back at least to the Final to Upper Lupemban industry times. This also means that the deposition of *Mg* layer ended during the latter half of the Upper to Final Lupemban industry times. On the other hand, wide distribution of heavy-duty tools from the basal surface of *Mg* layer to the upper part of *Mc* layer indicates repeated reworking of these older tools as well as sediments composing both *Mg* and *Mc* layers.

For the concentration of implements on the basal surface of *Mc* layer, there are two possible interpretations: 1) implements first scattered within the overlying main body of fine-grained layer and then subsided due to the combined effect of pedological and biological processes, and 2) they were originally supplied on the palaeo-landsurface at the time of or immediately after the switchover from the deposition of gravelly layer to colluviation of fine-grained sediment.

In Western Kenya, as long as we observed at outcrops along the main roads, the inclusion of Palaeolithic implements within the slope deposits was very limited, and we could find such artifacts at only two localities.

Radiocarbon dates

Radiocarbon dates hitherto obtained from organic samples collected from colluvial and alluvial deposits in Southern Cameroon and Western Kenya are listed in Hori (1982, 1986a) and Hori *et al.* (1986). In Southern Cameroon, available dates, 15 out of 19 dates, for making up of chronological arrangement of slope deposits, can be classified into four age classes: A) *c.* 8,500 yr B.P. (2), B) 3,000-2,500 yr B.P. (3), C) *c.* 1,000 yr B.P. (5), and D) 400 yr B.P. or younger (5). Class A ages came from peat and wood collected from the lower part of *Mcl* layer near Kribi in the Coastal Lowland (Hori, 1982). Class B ages are from the lower part of *Mcu* layer and Class C and D ages from the upper part of *Mcu* layer, respectively (Fig. 2). In spite of our effort to find datable material from *Mg* layer in the past years, we could not collect any samples which were reasonably dated. However, the above dates from the lower part of *Mcl* layer indicate that the age of *Mg* layer is older than the early Holocene time at *c.* 8,500 yr B.P.

In Western Kenya, only one date is available for slope deposits; *i.e.* 1,020±80 yr B.P. that was derived from charcoal collected from the upper part of *Mc* layer (Fig. 4a). For reference, the radiocarbon dates we obtained from *Mc* layer overlying a low-relief hill at the south foot of the Taita Hills, which are located in a subhumid area of southeastern Kenya ranges from 4,200 to 2,800 yr B.P. (Kadomura *et al.*, 1986a).

6. Environmental Implications

As summarized in Table 1, in the last some forty years, many different views have been presented to explain the origin of both the fine (*Mc*) and coarse components (*Mg*) of slope deposits in the humid tropics. There is, however, as yet no general agreement about the origin of these deposits. On the other hand, in the last twenty years, reconstructed water-level changes of closed lakes such as Lake Chad (Servant et Servant-Vildary, 1980; Maley, 1981; Servant, 1983), Lake Bosumwti (Talbot *et al.*, 1984), and East African Rift Valley lakes (*e.g.*, Butzer *et al.*, 1972; Gasse, 1980), pollen diagrams from the equatorial areas (*e.g.*, Maley, 1981, 1987; Sowunmi, 1981; Hamilton, 1976, 1982), and oxygen-isotope profiles of deep-sea cores off Niger delta (Pastouret *et al.*, 1978), off Congo estuary (Giresse et Lanfranchi, 1984), and from the East Mediterranean Sea (Rossignol-Strick *et al.*, 1982) have offered high-resolution data for the making up of late-Quaternary environmental history of tropical Africa (*e.g.*, Maley, 1981, 1987; Street-Perrott and Roberts, 1983; Kadomura, 1986b). These data have lead to well-established following environmental history:

1) Last Glacial Maximum great aridity during 20,000-12,000 yr B.P.,
2) return of humid conditions associated with increased rainfall from *c*. 12,000 yr B.P.,
3) early Holocene humid period between 10,000 and 8,000 yr B.P. preceded by a short dry episode corresponding to the Younger Dryas cold event,
4) brief but severe arid episode at *c*. 7,500 yr B.P.,
5) mid-Holocene wet period between 7,000 and 5,000 yr B.P.,
6) onset of late Holocene aridification at 4,500-4,000 yr B.P.,
7) return of slightly humid climate during 3,500-3,000 yr B.P., and
8) increased aridification from *c*. 3,000 yr B.P. onward.

This well-established environmental history of tropical Africa enables us to examine the ages of slope deposits and environments under which they were formed in detail.

Mg layer

In a tropical rainforest zone of Sierra Leone, Thomas and Thorp (1980, 1985), by referring to the environmental history like above and their own abundant radiocarbon dates form alluvial and colluvial deposits, have reached following conclusion on the origin of gravelly deposits and stone-lines:

"The coarse gravels, alluvium and interfluve stone lines formed during the early Holocene 'pluvial' period under conditions of increased precipitation and enhanced flood discharge before reforestation". "Several sedimentary-morphological features, traditionally regarded as indicating semi-arid climates, were, in fact formed during the early Holocene pluvial" (Thomas and Thorp, 1980, p. 141).

On the contrary, Fairbridge and Finkl (1984), based on the widespread evidence from humid low-latitude areas of Africa, South America, and Australia, have speculated as follows:

"Tropical stone lines may be interpreted as winnowed mudflows or lag deposits that reflect morphoclimatic events of brief duration (torrential rains) within a arid or semi-arid phase of pronounced global cooling" (p. 41). As for the age they have described: "The principal stone line, commonly truncates saprolites, appear to be late Wisconsinan (Würmian) in age coinciding more or less the pleniglacial phase about 18,000 yr B.P. when extreme aridity affected most of low-latitude tropical lands." (pp. 41, 65).

We also interprete *Mg* layer observed in Southern Cameroon and Western Kenya as the product of enhanced surface processes such as slopewash, gullying, and mudflows under semi-arid climates with periodic heavy showers during the period from the maximum of the last glaciation to late glacial/postglacial switchover, on the basis of following evidence:

1) The principal *Mg* layer, which is the basal layer of a single cycle of slope deposits, commonly truncates *in situ* weathered bedrocks or indurated older deposits;
2) The depositional feature of *Mg* layer as a whole exhibits slightly concave upward;
3) Although both heavy and light duty stone implements occur in *Mg* layer, most light duty tools of Final Lupemban to Tshitolian industries were unearthed not from the lower part of *Mg* layer but from the upper part of it and overlying *Mc* layer; and
4) Although no available radiocarbon dates to know the absolute age of *Mg* layer were obtained, the dates from the lower part of *Mc* layer suggest that the formation of the principal *Mg* layer already ended before 8,500 yr B.P.

Our interpretation is that under the environment of open savanna or steppic vegetation, removal of *in situ* weathered profile and reworking of older deposits by active surface processes occurred repeatedly until the onset of early Holocene reforestation. This interpretation is supported by the fact that these processes are actively operating upon the landsurface of now dry savanna and steppe environments (*e.g.*, Kadomura, 1977, 1982; Kadomura and Hori, 1984a; Kadomura *et al.*, 1986b). As commonly observed at soil pits within the forested areas, processes of slopewash, rilling, and gullying are drastically enhanced by deforestation and surface disturbance, resulting in rapid removal of *Mh*/*Mc* layer followed by periodic reworking of stones during heavy showers. Recent field experiments in the Belgian loam region by De Ploey and Poesen (1989) have confirmed that rill and/or (ephemeral) gully flows are the main processes responsible for the evacuation of rock fragments in colluvial deposits.

As interpreted by Thomas and Thorp (1980, 1985), there is no doubt that alluviation and colluviation of coarser depoists were strongly activated by increased rainfall just before the early Holocene forest reestablishment. In addition, we incline to speculate that deposition and removal of the coarse sediment composing *Mg* layer already started during the maximum of the last glaciation when the now humid tropics affected extreme aridity. Inclusion of heavy-duty tools of Sangoan to Lower Lupemban industries, which are more or less rolled, and the presence of lenticular beds observed in *Mg* layer indicate the evidence of repeated, short distance reworking of its constituent materials since older times.

Mc layer

Mc layer, which commonly occurs throughout the studied areas, postdates the principal *Mg* layer and began to be formed in the early Holocene corresponding to the return of humid climates followed by reforestation. In Southern Cameroon, radiocarbon-dated chronology indicates that its formation started shortly before *c.* 8,500 yr B.P. and has continued until now (Fig. 2). From inclusions and depositional structure, this fine-grained colluvial layer is divided into two sublayers: the lower layer (*Mcl*) which is older than *c.* 3,000 yr B.P. and the upper layer (*Mcu*) younger than *c.* 3,000 yr B.P.

In Southern Cameroon, *Mc* layer is often scattered by Palaeolithic implements including those even date back to Acheulian to Sangoan industries. Together with its lenticular micro-depositional features, this implies that *Mc* layer is also admixed with older, repeatedly reworked sediments.

The depositional surface of *Mc* layer under the forest cover is characterized by the convexity, particularly on the upper to middle part of a hillslide slope, suggesting that its dominant formative process is not slopewash but creep-type mass wasting. However, slopewash associated with gullying may be important where there are canopy gaps due to tree-fall, forest fire, and landslide, even on the convex hillslopes. Dotted stone lines and thinly bedded coarser elements probably deposited corresponding to these events. In the lower part of a hillslope, which often exhibits the slight concavity, slopewash and gullying may play an important role in redistribution of reworked sediment from the middle to upper segments (*e.g.*, Kadomura and Imagawa, 1989).

Biological processes such as those by termites seem to contribute to the formation of *Mc* layer by casting up fine-grained soils and by the breakdown of termitaria. But this does not mean that the biological processes are the most prevailing agent in the formation of *Mc* layer. We, therefore, attribute here the formation of *Mc* layer to 'repeated joint work of creep, slopewash, and termites'.

Human interference

Frequent inclusion of charcoal fragment accompanied with potsherds and other artifacts in *Mcu* layer from *c.* 3,000 yr B.P. may be interpreted as the evidence showing the beginning of human interference with the forest vegetation due mainly to slash-and-burn cultivation. This date is expected to correspond with the early migration of Bantu speaking peoples into the Congolian forest block (Kadomura *et al.*, 1986b) from the supposed homeland in the highlands at the Cameroon/Nigeria border (Phillipson, 1977). As suggested by recent works such as by Thomas and Thorp (1980, 1985), Talbot *et al.* (1984), and Schwartz (1988), in the Guineo-Congolian forest zone slight aridification of climate began at *c.* 3,000 yr B.P. This aridification may contribute to the occurrence of both natural and man-made fires in the closed forests and facilitate the human occupation of the forested areas, resulting in anthropogenic deforestation and savannization from that time onward (Kadomura, 1989).

Coupled with climatic aridification, increased human impact on the landsurface has invited accelerated stripping of fine members of slope deposits, *Mh* and *Mc* layers in many places and sometimes has lead to denuded hillslopes studded by stones, as evidenced in the present-day savanna areas of Central, North and West Cameroon (*e.g.*, Kadomura, 1982; Kadomura and Imagawa, 1989; Tamura, 1984, 1986). Increase of charcoal fragments in *Mh* layer and the upper part of *Mcl* layer from 350-300 yr B.P. in

Table 3 Correlation of regolith stratigraphic units with late-Quaternary environmental history of tropical humid Africa

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1) Widespread savannization or steppization
    during the Last Glacial Maximum dry period
    at c. 20–12 KBP (*Ws* truncation, *Mg*)
2) Reforestation
    at late Glacial-early Holocene return
    of humid conditions
    at 12–9 KBP (*Mg/Mcl*)
3) Closed forests
    during early to mid-Holocene humid period
    at 9–3 KBP (*Mcl*)
4) Forest Degrdation
    since later Holocene due both to
    climate aridification and human impact
    from 3 KBP (*Mcu*)
5) Accelerated Degradation
    due mainky to human impact
    from 1 KBP (*Mcu/Mh*)
6) More Accelerated Degradation
    due mainly to human impact
    from 350–300 BP
    (stripping of *Mh/Mc*)

Southern Cameroon can be attributed to the massive migrations of agrarian populations into the closed forests from the savanna areas (Kadomura, 1984; Kadomura and Haruki, 1988).

8. Conclusion

From the foregoing, radiocarbon-dated stratigraphic sequence of slope deposits in the forested areas of Southern Cameroon (Fig. 2) can be correlated with a late-Quaternary environmental history based on other available data as summarized in Table 3. This correlation may be extended without hesitation to Western Kenya highlands and plateaux where the *Mh/Mc/Mg* series slope deposits occur over the undulating to gently rolling hilly terrain, with a striking similarity to those found in Southern Cameroon.

Similar slope deposits are widespread throughout humid to subhumid tropics not only in Africa (*e.g.*, Segalen, 1969; Thomas, 1974; Faniran and Jeje, 1983; Alexandre et Symoens, 1989) but also in South America (*e.g.*, Journaux, 1975) and Australia (*e.g.*, Fairbridge and Finkl, 1984). This means that chronological and environmental make up of those deposits may provide relevant data for continental- and global-scale comparative studies of late-Quaternary environmental history. However, well-dated data for slope deposits are still fragmentary and the resolution of both ages and environmental conditions inferred from those deposits is generally low. The promotion of better reconstruction of environmental history still needs more well-dated and well-documented data provided by palynology, geomorphology, pedology, archaeology and ecology. Our interpretation presented in this paper also requires reassessment by further research.

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