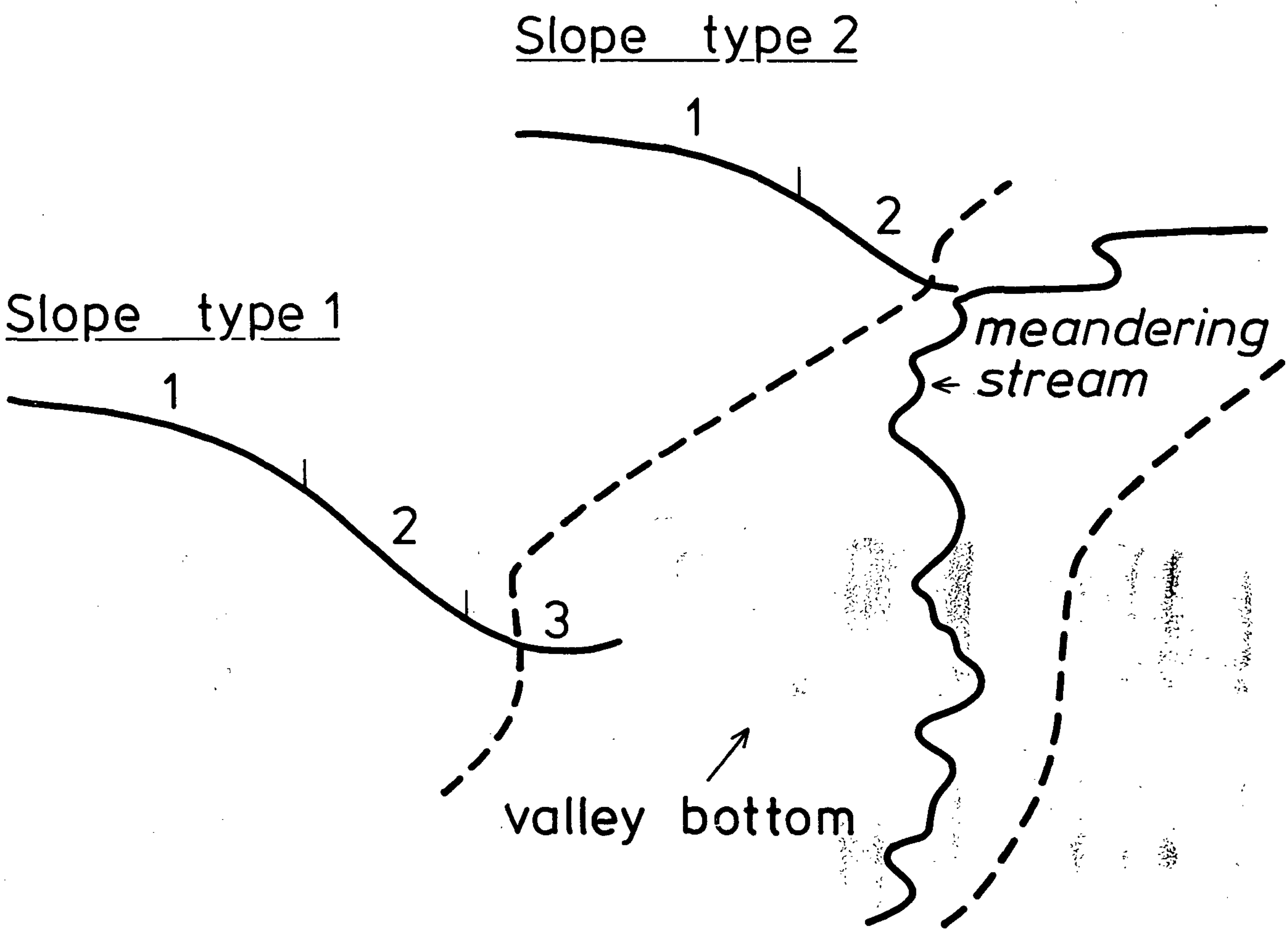
TRAINING PROJECT IN PEDOLOGY

KISII KENYA



Valley and hillside slopes in the Gucha river basin in South Western Kenya

PRELIMINARY REPORT NO 14

AGRICULTURAL UNIVERSITY
WAGENINGEN - THE NETHERLANDS

VALLEY AND HILL - SIDE SLOPES

IN THE

GUCHA RIVER BASIN AREA IN

SOUTH WESTERN KENYA.

by

G.R. Hennemann

Preliminary report no. 14

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TRAINING PROJECT IN PEDOLOGY, KISII - KENYA

Agricultural University, Wageningen - The Netherlands.

Contents

Preface

This report of the Training Project in Pedology at Kisii, Kenya, of the Section of Tropical Soil Science of the Agriculture University at Wageningen, the Netherlands, is the fourteenth of a series to be presented to Kenyan officials.

The project started in November 1973 after assent had been granted by the Office of the President of Kenya. It is meant for training of postgraduate students of the Agricultural University at Wageningen and for furnishing research opportunities to the staff. The activities of students and staff are directed to obtaining a better knowledge of the soils and the agricultural conditions of the project area to provide a basis for the further agricultural development of the area.

The project in Kisii is conducted by:
Ir. W.G. Wielemaker, teaching and research
Ing. H.W. Boxem, management.
Visiting specialists from the Agricultural University at Wageningen help to resolve special problems.

This report has been written by Mr. G.R. Hennemann, who was a participating student from October 1973 up to July 1974. The fieldwork was carried out during June and July 1974 by the author. Ing. H.W. Boxem compiled the report into this presentation.
We hope to pay back with these reports a small part of the great debt we owe to Kenya in general and to many Kenyan in particular for their valueble contributions to the good functioning of the project.

The supervisor of the project
J. Bennema, Professor of Tropical Soil Sience

1. Introduction

1.1. General

The aim of this survey is to make an inventory and to describe the different hill-side and valley-side slopes, which are present in the Gucha river drainage area.
By comparison of the basic slope forms one is able to obtain a better insight into their morpho-genesis and also into the development of the landscape as a whole.

The Gucha river has been selected for the study as much field-work has been done in this area previously (soil-surveys of Marongo and Kisii West, studies of sealing and erosion phenomena).

An advantage of the Gucha River drainage area for field-study is, that in all likelihood no great changes of drainage pattern has taken place since Early Tertiary times (Oyany - 1971).
Due to this, valley-side and hill-side development has continued more or less undisturbed for along time, thus creating favourable conditions for slope investigations.

1.2 The Gucha River

The total length of the Gucha River is approximately 89 km., while the drainage area covers about 5200 km^2 (see fig. 1).
Together with the Mara River in the South (7770 km^2) and the Sondu River in the north (5200 km^2) it drains the major part of SW-Kenya.

Its proper catchment area comprises the Kisii Highlands.

Main tributaries are according to size (see fig. 1).

1) Migori River
2) Riana River
3) Ongeche River
4) Sare River
5) Osani River
6) Nyangweta River

The Gucha River originates in the eastern part of the Kisii Highlands near the flanks of the Kijaur Plateau, which forms the divide between the Sondu (= Kipsonoi) River and the Gucha River.
In the upper stream area, valleys are broad, flat and swampy due to the low stream-gradients (Gekano Market - part I/ fig. 2).

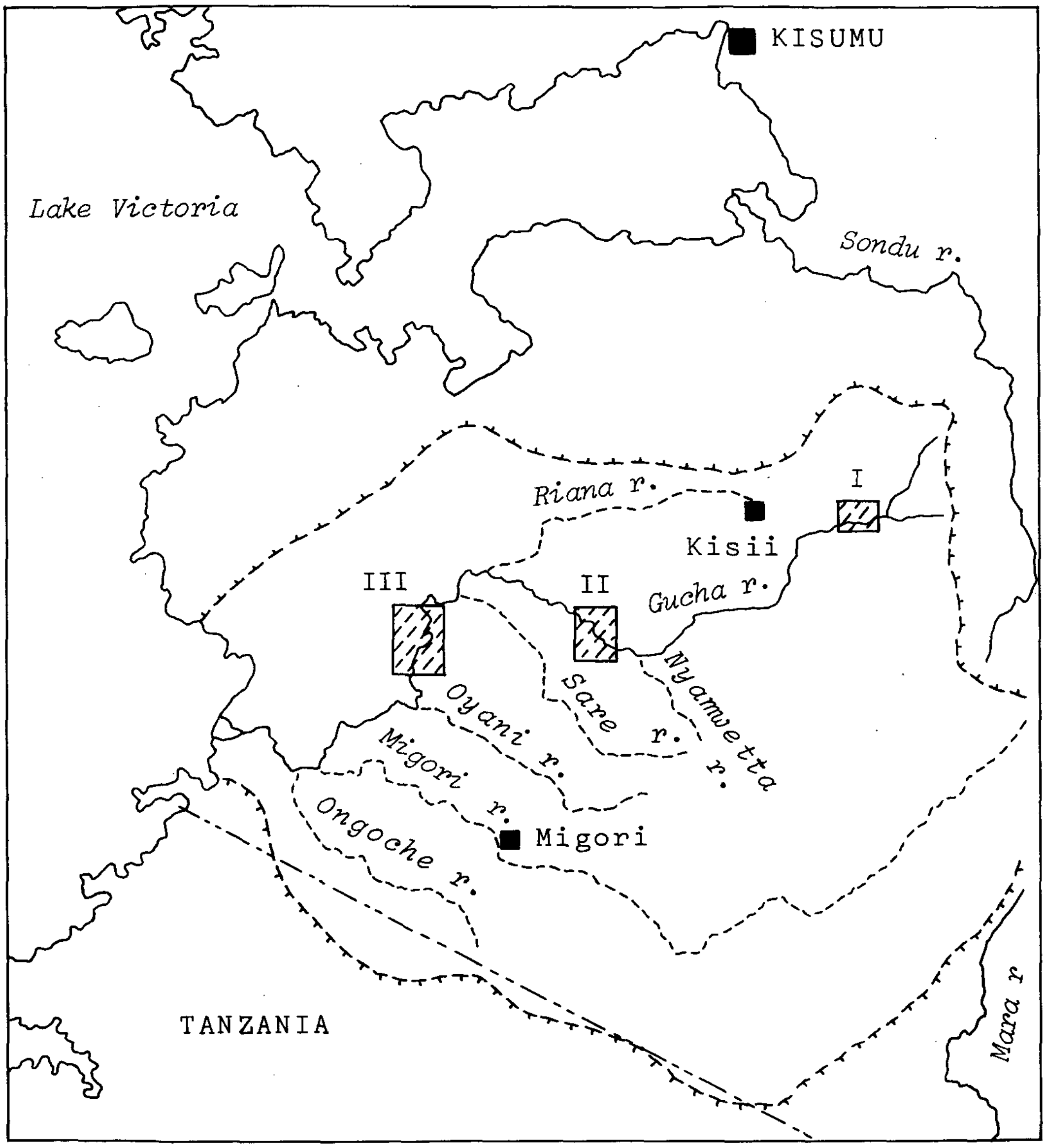

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Fig. 9 Gucha river drainage basin

main river

tributary

boundary Gucha river basin

sample area (Miriri/Kitere /Otange)

Thence the river runs through the western part of the Kisii Highlands with gradually increasing stream-gradients, while cutting through the two prominent quartzites ridges of Sameta and Venjo, where steep gorges have been formed. (see fig. 2/ part II).

West of these gorges, the river becomes gradually less incised, debouching in the Otange Plain, where swampy conditions prevail; here, the Gucha River has returned into a sluggishly meadering river with frequent floodings (fig. 2/ part III).

At Macalder Mine gradients are increasing and the Gucha valley is here more incised (fig. 2/ part IV).

Near Lake Victoria the valley passes into abroad alluvial plain again; the meadering river has formed a well-developed delta (fig.2/ part V).

From the longitudinal stream-profile it is evident, that the Gucha does not posses the properties of a graded river.
No smooth gradually decreasing stream-profile, but an irregular alternation of high and low gradients, resulting into rapids, gorges and swampy plains at some places.
All these phenomena are bearing witness of the recent rejuvenation of the Gucha River.

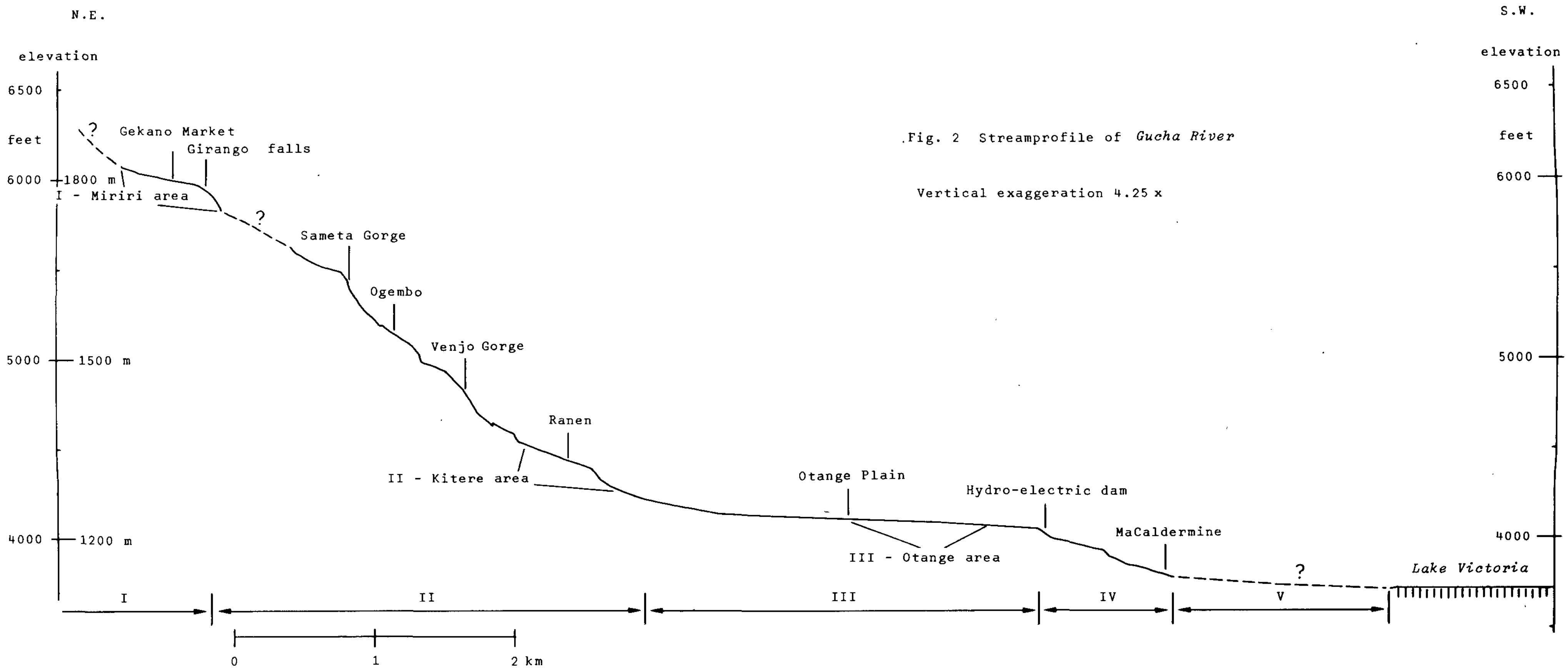

Fig. 2 Streamprofile of *Gucha River*

Vertical exaggeration 4.25 x

2. Environment

2.1. General

Three sample areas for field survey have been selected, occuring in the upper, middle and lower drainage basin of the Gucha (fig. 1). Representing three main landscapes, they have been described shortly as below:

Miriri area (I) is located in the Kisii Highlands and forms part of the old Kisii Highlands planation surface.
In includes convex plateax with an even summit level, slightly tilted in ESE - WNW direction (1: 150), steep straight to slightly concave slopes and flat floored swampy valleys (locally incised).
The area is comprisng approximately 9500 ha and is located between 1 latitudes of $0^{o}40$ - $0^{o}44'$S and longitutes of $34^{o}50'$ - $34^{o}55'$E in the Kisii District (sheet 130/2 - Kisii).
In includes parts of the Sub-districts of Nyaribari and East-Kitutu.
Important towns are Tombe, Magombo, Nyambaria and Rigoma.
Murram roads are running from Tombe to Gekano; from Musa Nyandisâ-Rigoma up to Magombo across the Gucha River, and from Tombe to Miriri (not visible on the map).
The major part of the area is only accessible by foot as slopes are generally steep and tracks are too narrow for landrovers.

The Kitere area (II) is located in the strongly dissected hills of the middle stream course of the Gucha River.
These hills range from Gucha Town in the west up to Sameta Hill in the east and are strongly influenced by the rejuvenated Gucha River and its tributaries.
The area, comrising approximately 8000 ha, is located between latitudes of $0^{o}46'$ - $0^{o}52'$S. and longitudes of $34^{o}33'$ - $34^{o}36'$E. in the South Nyanza District (Sub-location of East-Nyokal - sheet 130/3 - Kitere).
It comprises the above mentioned, dissected hills in the south and in the centre of the area, while in the north rolling, laterite-capped parallel ridges occur; they are likely to be remnants of a former plantion surface.
The main villages are Ranen (south), Gucha Town (centre) and Rakwaro (north).

Kitere has been a gold mining centre before worldwar II, but now only the ruins of the abandoned mine are visible.
The area is reasonably accessible by car and by foot, except for the Gucha valley and some tributarian valleys, which are often very rocky, steep and impenetrable due to the dense shrub-vegetation.

The Otange area (III): comprises a gently undulating plain, west of the dissected hills of the Kitere area.
The landscape, which covers a large area between Macalder Mine (south-west) and Gucha town (east), consists of an undulating plain with broad nearly level ridges (outcropping laterite-crusts) and wide concave valleys. The Otange area, comprising roughtly 9600 ha, is located between latitudes of $0^{o}47'$ - $0^{o}52'$S. longitudes of $34^{o}21'$ $34^{o}25'$E. It partly covers the sub-districts of East-Konyango, West - Nyokal and Kanyamkago in the South Nyanza District (sheet 129/4, - Gucha River). The main villages are Kagaga, Koguta and Otange, which are all located in the centre of the area. The only murram-road is the Rapogi-Rapedhi road (South-east -north-west direction), which is dependant of the Gucha Ferry. The area is reasonably accessible as the terrain is never steep or densely vegetated by shrubs. In valleys, where swampy conditions prevail, roads are only passable in the dry season.

2.2. Climate

The different climate conditions in the three areas are largely defined by their range in elevation.
There is a gradual transition from the rather hot and dry climate in the west (Otange) near Lake Victoria ($\pm$ 3700 ft) to a cool and permanently wet climate in the Kisii Highlands (6000-7000 ft.)

The Miriri area (I)

Due to the high altitudes, ranging from 6000 to 7000 feet (1800-2100 meter), the climate has a montane character with rather low annual temperatures and a high, well distributed rainfall. Mean annual temperatures are approximately 18-20^{o}C with mean maximum of 26 ^{o}C and mean minimum of 11^{o}C.

The annual precipitation is high (1800 - 2000 mm.) and evenly distributed through the year; only one short dry period is present in January and February. The other dry period is less pronounced with rather frequent rain-showers (July - August).
Evaporation and solar radiation are greatly reduced by clouds during most of the year. In the wetter months morning haze and mist occur in the valleys, thus reducing radiation and evaporation.

The Kitere area (II).

With altitudes ranging from 4300 to 5000 ft (1300 - 1500 meter) the climate is considerably drier, and hotter as compared to the Miriri conditions. The pronounced dry season area present (Dec. - February/ July - Aug.). Mean annual temperatures are about 22°C with maximum of 28°C and maximum 17°C.
The mean annual precipitation is about 1700 mm. with two pronouced dry seasons; severe droughts sometimes occur.
Rainshowers usually have a high intensity and erosivity as compared with the Miriri climate, where intensities are lower and the duration of the showers is longer.

The Otange area (III).

Altitudes are ranging from 4100 to 4300 ft. (1230 - 1300 meter). Climate conditions are not very much different from Kitere conditions except for the precipitation.
The mean annual rainfall (recorded during 7 years in Migori, which may be considered as fairly representative for the area) is only 1130 mm., which is considerably less than annual precipitation in Kitere. Mean annual temperatures are somewhat higher, but do not differ much from Kitere temperatures.

2.3. Geology

A large part of southwest-Kenya exposure is covered by Pre-Cambrian rocks, presumably the oldest exposure in the whole of Kenya. Two systems have been distinguished: the older, called Nyanzian and the younger Kavirondian (both of early Pre-Cambrian age), which are predominant in the western part of the Gucha drainage basin.

East of Kitere these systems are discordantly overlain by rocks of the younger Bukoban System (late Pre-Cambrian).

The Bukoban rocks cover the eastern part of the Gucha drainage basin. The Nyanzian System in the area comprises lavas of acid, intermediate and basic character. The Nyanzian rocks are folded along NW-SE lines and dips are steep almost everywhere. Locally granites have intruded the folded rocks (Kitere granites of Post-Nyanzian age).

Kavirondian deposits are laid down discordantly over the Nyanzian rocks; they include mainly conglomerates, grits and mudstones. In the area they have been infolded with Nyanzian rocks during a period of intense deformation.

The rocks of the Bukoban System (Kisii Series) form a nearly flat cake of basaltic, andesitic and rhyolitic lavas with a conspicuously outcropping hard quartzite bed in the middle of the succession. They are overlying discordantly the Nyanzian and Kavirondian system forming the Kisii Highlands (eastern part of the Gucha drainage basin.) The rocks of the Bukoban System lie more or less flatly, with only gently folding. Rocks of younger age are not present in the area, except for the Tertiary lavas (Kanyamkago lavas - Otange area.), the lateritic duricrusts and the valley sediments (Quarternary). Since a gently orogeny in Post-Bukoban times, movement has been confined until Tertiary times to general uplift and periods of denudation, culminating in the formation of large planation surfaces (Late Jurassic/Gondwana-Cretaceous/ Post-Gondwana - Sub-Miocene/ African).

In Miocene times movement has been confined to moderate vertical uplift and tilting, thus disturbing the latest mature erosion cycle (Sub-Miocene/African cycle) and and rejuvenating of the rivers.

This resulted into increasing dissection of the older planation surfaces and into a fresh dissection of the Sub-Miocene level. The planation surfaces all show the same westward tilt of approximately of 1:150 (ESE-WNW direction).

The Miriri area (I)

The rocks, present in the area, are part of a succession of rhyolitic and andesitic composition with associated pyroclasts. The higher parts of the Tombe Plataeu in the north and the crests in the south-east consist of rhyolitic rock, while hillslopes and valleys are mostly carved out in andesites. A thick soil-cover and deep rock-weathering of both rhyolites and andesites has resulted in the absence of natural surface exposures; only along road-cuts and river incisions (near cataracts) fresh rock outcrops are visible. So accurate limits of the different rock-types are uncertain.

The Kitere area (II).

The southern part of the area consists of Nyanzian rocks, mainly rhyolitic lavas and tuffs.
Soils have been weathered in the past to a considerable depth, but they are eroded now till the bedrock due to the strong incision of the Gucha River. During this incision the presence of many dykes (mainly dolerite, quartz-porphyrite) has become conspicuous. These veins are relatively resistant to weathering, thus forming steep ridges in the area; also bars and rapids have been developed in the Gucha River due to these dykes.
The northern part of the area is covered by extensive duricrusts of laterite (1 - 2m. thick), overlying deeply weathered granitic rocks (Kitere granite - fine grained). These duricrusts are bearing at many places round or enlongated hydromorphic depressions, containing grey alluvial deposits.
Exposure of granite rock are rare ; only near deeply incised streams if the laterite crust has been cut through; inselbergs or tor-like outcrops are absent.

The Otange area (III).

In the south and south-east of the area porphyritic andesites (Sare-Oyani type) occur; in the north-east rhyolites occur. Both rock-types belong to the Nyanzian System and are slightly folded along WNW-ESE axes (dips are usually steep).
In the centre of the area a belt of Kavirondian conglomerates occur; in the north-west they are covered by Tertiary phonolitic lavas (coming from the Kanyamkago faultlines in the north-west).
The Kavirondian rocks rest discordantly as small infolded outliers on the Nyanzian rocks, which are strongly folded themselves. Almost everywhere rocks are covered with layers of alluvium or laterite and along the Gucha River outcropping conglomerates and grits are presant (Kavirondian).
In the north-west outliers of Tertiary phonolitic lavas are conspicuous as flat crests or plateaux, standing some 30 meter above the Otange Plain in the west. Large areas, particularly along the Gucha River and in the wide valleys, are covered with alluvial material and laterite of recent date. The geomorphology of the areas will be discussed in chapter 5.

2.4. Soils, vegetation and landuse

Originally this part of Kenya was covered with forest or woodland-savannah; locally in steep rocky areas (shallow soils) grassland-savannahs occurred. This vegetation has been recently replaced by cultivated land and secondary forest.

The Miriri area (I)

Due to the high altitude and high precipitation the whole area has been covered by a moist montane and intermediate forest, which is replaced nowadays completely by permanently cultivated land.
The forest soils are mostly very deep, dark red friable clays with an excellent physical structure. A-horizons are dark with a high content of organic matter (5 -8%). Both infiltration capacity and permeability are high due to the good porosity and structure of the soils.

The edges and spurs of the plateax are bearing shallow, gravelly soils with grasses and shrubs.
In the broad flat floored valleys grey hyromorphic soils occur with a dense vegetation of reeds, papyrus and sedges and with grazing land on the somewhat higher parts.
In the wet season frequent flooding occurs as also water from the surrounding slopes is collected in the valley floors.

The Kitere area (II)

Due to the lower amount of rainfall (1700 mm.) and the presence of two pronounced dry seasons, the Kitere area is covered with a different vegetation.

The well drained parts on the rhyolites and granites carry a moist Combretum and allied broad-leaved savannah.
Soils are shallow, moderately deep, developed on rhyolites or granite. Locally on steeper parts (valley sides) soils are absent or extremely rocky.
On the flat, laterite-capped ridges and in the hydromorphic depressions drainage is impeded and in the wet season swampy conditions prevail. On the laterite caps shallow soils occur (locally soils are absent).

Here, a vegetation of evergreen clump grassland exists with intermediate Diospyros/Olea forest on the better drained parts.
In the hyromorphic depressions grey mottled clays occur (grey, leached A-horizon + dark grey, plastic clay in B-horizon.)
They have usually a 'clump-tree' vegetation, growing on abandoned termite-mounds; in between only grasses occur due to the wet conditions during part of the year.
The 'clump' vegetation consists mainly of Euphorbia spp, and Carissa edulis.

The Otange area (III).

The lower parts of the broad concave valleys carry shrinking and swelling clays of the montmorillonite type (Vertisols).
At these sites a Acacia seyal/Balanites savannah type occurs.

The higher slightly concave parts carry leached grey-brown planosols with a light grey loamy A-horizon, overlying a brown clayey B-horizon (abrupt change of texture).
On these soils an Acacia seyal/Balanites savannah is present too.
On the gently, convex ridges and summits shallow, reddish gravelly sandy loams occur (porphyritic andesites, rhyolites and mixed rock material).
In the north-western part of the area phonolitic and nephelinitic lavas are present, carrying moderately deep red loams; on these loams the original vegetation has been replaced by arable land.
On all the better drained parts a Combretum savannah is present with semi-evergreen thicket on rocky outcrops.

3. Survey methods

The aim of this geomorphological survey is to make an inventory and description of the different slope forms, present in the area. The survey can be divided into 3 stages:

1) pre-interpretation of aerial photographs.
2) field-check and description of slope characteristics.
3) map compilation and supplementary photo-investigations.

1) Pre-interpretation of aerial photographs.
Before going into the field, aerial photographs have been investigated. Different slope units have been distinguished on the basis of gradient and form.
This units have been plotted with the help of a mirror stereoscope on the photographs (1:12.500 and 1:50.000).
Subsequently, fields have been lined out in order to carry out fruitfull field-crosses.

2) Fieldcheck and description of slope characteristics:

The fieldwork can be seen as an extension of stage 1.
The plotted slope-units have been checked with a Haga inclinometer or an Abney level, indicating angles in %.
Profile curvature has been examined: slopes, i.e. appearing as nearly straight in the photo-stereo-image might possess a considerable concavity in reality.

Soil depth and soil horizons have been determined with an Edelman soil auger; locally it could be examined in road-cuts.
Natural vegetation if present, and landuse have been described.
Special attention have been given to rocktype and local impurities.
Surface exposures appear to be present only in the drier Otange and Kitere areas.

The fieldwork has been carried out in July 1974, of which in the first 2 weeks were extremely wet.
Rainshowers has hampered the work rather seriously as many steep roads or tracks turned into streams and gullies, therefore becoming temperorarily impassable.

3) Map comilation

After the collecting of field data, the plotted lines on the photographs have been corrected and new boundaries have been drawn.

In order to have a base map with an adapted scale for both 1:12.500 and 1:50.000 photographs, topographical maps have been enlarged to a scale of 1:25.000.

Boundaries on both types of photographs have been transferred with the aid of a Keuffel and Essen sketchmaster to the base-map.

After this being done, missing information (slope gradients and forms) have been derived from the contourline intervals on the topographical maps and filled in.

The valley cross-sections have been largely derived from topographical maps.

4. Set up of legend (see map-legends)

4.1. Slope gradient and form

The areas have been divided into slope units, which are defined by slope gradient (%) and slope form (profile curvature).

The following classes have been distinguished:

slope gradient		slope form	
I	0 - 5%	cc.	= concave
II	5 -10%	cv.	= convex
III	10-15%	ir.	= irregular
IV	15-20%		
V	20-25%		
VI	25-30%		
VII	30-40%		
VIII	> 40%		

slope gradient

Only 8 gradient classes comprising 5%- intervals have been made in order to simplify the image on the slope map.
Within each unit parts occur, which are steeper or gentlier than indicated, however a reliability of at least 80% has been aimed at.

slope form.

Convex or concave slopes are indicated by a suffix cv. or cc. irregular slopes with many outcrops (rock) are indicated by a suffix ir.; straight or nearly straight slopes have no suffix.

Physiographic terms have been avoided deliberately in order to keep the legend and map as surveyable as possible.
Moreover, physiographic boundaries are mostly gradual and not easily mappable, except for the Otange area.
Here slopes units could be clearly related to physiographic elements. So the original legend has been extended with physiographic and lithological symbols and descriptions.

These are as below:

Physiography		Lithology
f.cr.	= flat crest	v = volcanic rock (mainly nephelinite)
r.cr.	= round crest	A = porphyritic andesite
c.	= outcrop/inselberg	R = rhyolite
sc.	= scarp	M = rocks of mixed origin
p.sl.	= piedmont slope	
st.sl.	= stepped slope	

4.2. Valley types

Valleys are mapped and classified separately and as a totality; although slope gradient slope gradient and form have been incorporated in the legend.

This has been done for two reasons : viz:

1) valleys usually cover alarge range of slopes, so they should have been mapped as slope complexes, which is rather digessive

2) valleys occur as characteristical and recurrent phenomena in the field, so if is necessary to catagorize them in certain types (based on form, stream gradient or parent rock).

The following types have been distinguished:

the Miriri area	A - V-shaped valleys
	B - incised valleys
	C - flat floored incised valleys
	D - flat floored concave valleys
	E - concave gullies
the Kitere area	A - V-shaped valleys (with knickpoint)
	B - " " (without knickpoint)
	C - flat floored concave valleys
	D - incised valleys (swampy bottoms)
	E - broad concave valleys (swampy bottoms)
the Otange area	A - broad concave valleys

5. Evaluation of field data.

5.1. Main slope types.

5.1.1. The Miriri area

This area can be divided roughly into two landtypes:

Landtype Mi-I - East of the line Nyambaria-Magombo-Gekano Market (see slope map I) comprising the low weakly convex interfluves with broad flat-floored valleys.

Landtype Mi-II- West of the line Nyambaria-Magombo-Gekano market comprising the high Tombe Placau and the associated hills south of the Kuja River.

The main characteristics of the two landtypes have been listed below:

Table I. The main characteristics of landtypes Mi-I and Mi-II.

	Landtype Mi-I	Landtype Mi-II
Relief	40 - 70 m	150 - 250 m
Slope form	short, mainly convex	long, straight to slightly concave with upper and lower margins mostly convex
Slope gradient	I/II/III (0 - 15%)	IV/V/VI/VII. (20-40%)
Main valley-types	Type D (see slope map)	Types A/B/C.

Landtype Mi-I.

Considering the valley cross-sections (Mi-A_1 and Mi-B_3), which are representative for landtype Mi-I, the similarity to the Riokindo landtype as described by Kauffman and Hennemann (P.R. 5, 1974) is striking. This landtype is situated south of Riokindo (Majoge Sublocation) near the Masai border.

It consists of low undulating to rolling (3-16%) hills with convex or convex-concave slopes; running between the interfluves wide and

The main slope types in the area are reconstructed below (fig. 3).

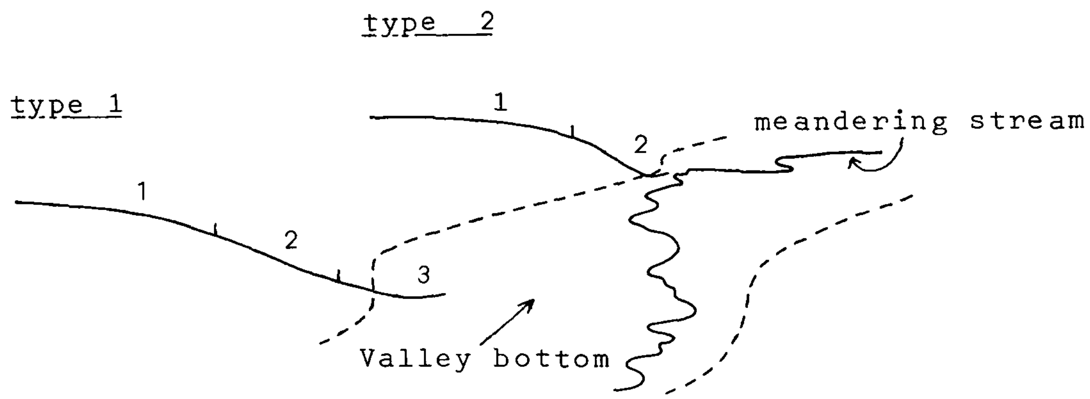

Fig. 3 Slope types of Mi - I

Slope type 1

segment 1 - broad convex (0-10%) crest and upperslope.

segment 2 - short, straight with lower concavity (5-15%), gradual transition towards valley-floor.

segment 3 - flat-floored valley-bottom (type D)

slope type 2

segment 1 - as segment 1 of slope type 1.

segment 2 - short, straight, slightly convex at uppermargin (10-20%), abrupt break of slope towards valley-bottom.

segment 3 - flat-floored valley bottom (type D) with meandering stream channel.

The difference between both slope types is located in segment 2. Type 2 is mostly situated near the meandering streamchannel in the valley.
Due to lateral corrosion a straight and locally slightly convex slope form is maintained with a sharp break of slope towards the valley. Type 1 is present at valley-sides lying opposite of slopes of type 2. On slopes of type 1 removal of slope material has not kept pace with supply from the upperslope area.
Due to this a lower concavity has been developed (see also slope processes/ Miriri area - page 26).

Landtype Mi-II.

In this landtype slopes are mostly steeper (20-40%) and longer than they are in landtype Mi-I, due to the higher relief (150-250 m).
Slope forms are mostly straight, convexo-straight or convexo-straight -concave.
Three prodominant slope forms could be distinguished; they have been reproduced according to their position along the valley in fig. 4.

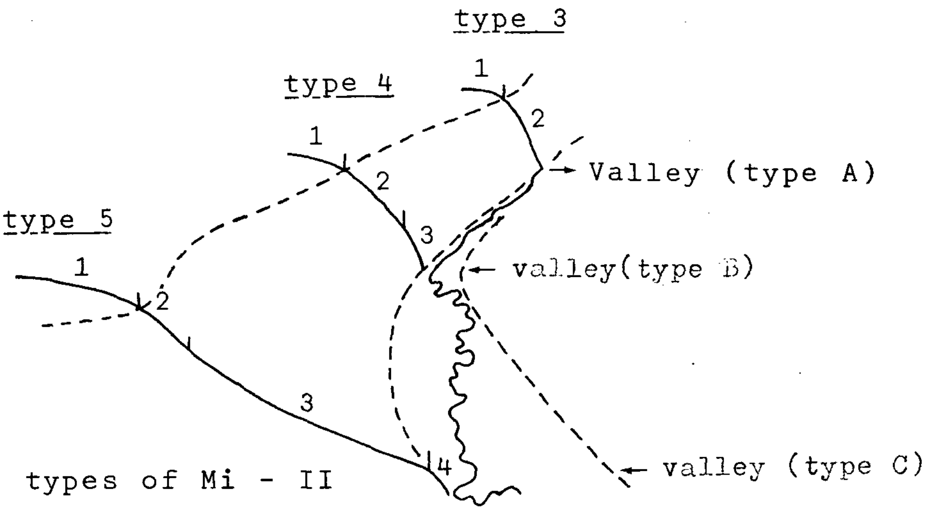

Fig. 4 Slope types of Mi - II

slope type 3

segment 1 - convex crest - and upper-slope (5-15%).

segment 2 - straight, steep (30-45%) slope with mostly shallow soils (if slope is plan-convex).

Slope type 4

segment 1 - as segment 1 of type 3

segment 2 - straight, steep slope (but less steep than segment 2 of type 3) (25-40%).

segment 3 - short, steep convex lower-slope (30%) associated with incised valleys (type B).

slope type 5

segment 1 - as segment 1 of type 3

segment 2 - as segment 2 of type 4, often somewhat shorter and less steep (25-35%), carrying mostly shallow gravelly soils (if plan convex of form).

segment 3 - very long slightly concave moderately steep slope (10-25%).

segment 4 - as segment 3 of type 4 often with slump phenomena (see slope processes / Miriri area - page 26), locally straight or slightly concave if far removed from the stream.

The 3 slope types form a slope sequence with a gradual change of chatacteristics.

These are as below:

1) A gradual decline and shortening of the straight slope segment (segment 1).
2) The development of a convex valley-slope (segment 3/type 4), which is associated with the change of the V-shaped valley (A) into the incised valley-type (B).
3) The development of a long and slightly concave basalt slope (segment 3/ type 5).

So the development of the over-all slope profile is characterized by slope decline, slope lengthening and by a transition of straight into weakly concave forms.

Profiles are mostly smooth and abrupt breaks of slope are absent. Some slopes, particularly north-west facing ones, show a remarkable constant and steep profile (mainly of type 3).

This phenomenon will be discussed on page 26-27.

Valley types.

Five valley types have been distinguished and described (see App. 1) and there are indications, that probably each of them represent a certain stage in valley development.

From the slope map it is conspicuous, that the first-order streams usually have V-shaped valleys (type A), whereas along streams with decreasing gradients valley-type B and C are common.

The valley cross-sections Mi-A, Mi-B and Mi-D offer a similar picture: where stream gradients are steepening, valleys become V-shaped; they become flat-floored and choked if gradients decline.

As gradients usually decline during stream development due to downward incision, one may assume, that the higher the gradient, the younger the valley is with valleys of type A the youngest of all.

The shallow and concave valley of type E does not fit very well in this succession.
Probably it forms the initial stage of a valley, as it is in fact little more than a broad, shallow gully having nearly the same gradient as the slope on which it is developed.

5.1.2. The Kitere area

In this area 3 main landtypes are present:

Landtype Ki-I - The laterite-capped, convex and flat ridges occurring in the northwestern part (Rakwaro)

Landtype Ki-II - The deeply incised hills along the Gucha River in the central part of the area (Kitere).

Landtype Ki-III - The undulating to rolling plain with narrow-crested elongated inselbergs.

Landtype Ki-I

It is similar to the Nyakoe landtype as described by Kauffman and Henneman (1974) particularly, where it is developed on granites. The often flat-topped long crests with massive laterite duripans in the sub-soil are conspicuous.
At many places flat-lying depressions (H) are present on these crests filled with grey mottled clays.
Slopes are mostly convex, valleys are incised with outcropping laterite at the upper margins; valley bottoms are usually swampy.
The drainage pattern is predominantly parallel (EW-direction)

Two main slope types have been distinguished (see valley cross-section Ki-B_1).

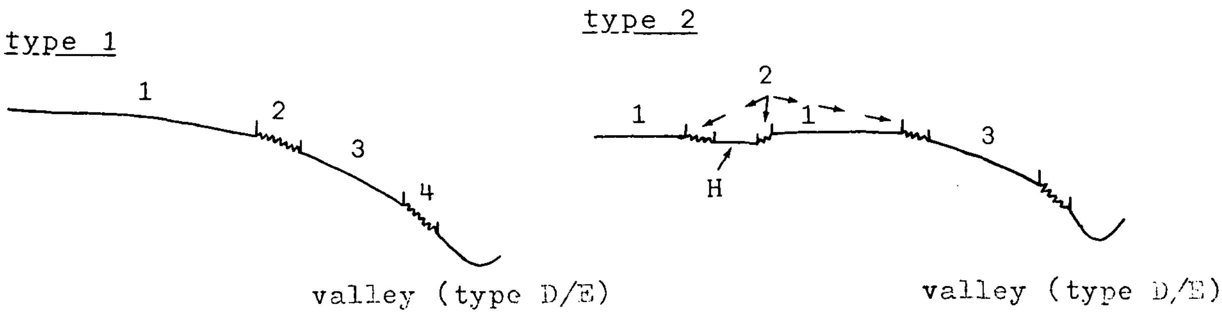

Fig. 5 Slope types of Ki - I

slope type 1

segment 1 - convex summit (0-5%) without duripan.

segment 2 - irregular 'stepped' slope (5-15%), outcropping lateritic duripans present.

segment 3 - convex gently sloping to sloping slope, covered by laterite gravel or with massive laterite in the sub-soil.

segment 4 - as segment 2, but steeper (10-20%) (see also valley type D and E on page 38).

slope type 2

segment 1 - almost flat, laterite -capped crest with seasonal water-logging.

segment 2/3/4- as type 1.

H (hydromorphic-flat-bottomed, depression see slope map II). round and elongated hydromorphic depressions, surrounded by segment 2; seasonal waterlogging.

The main difference between type 1 and type 2 is the absence of a convex crest in type 2.
The slopes of both types show the same characteristics with duripans outcropping at corresponding levels.
However, there is a decrease of the duripan-level in WSW-direction, which is followed by the parallel drainage pattern.

Landtype Ki-II

This landtype is strongly influenced by the incised Gucha River and its tributaries giving the area a dissected appearance.
Important are also the numerous rapids in the Gucha River due to the presence of resistant dykes, mainly of quartz-porphyritic origin.
The different character of the V-shaped south-west running tributarian valleys are in striking consrast with the wider east-west running valleys of Ki-I; they bear witness to their juvenile age and the rejuvenation of the Gucha valley.

The main slope profile is as below (see fig. 6)

segment 1 - irregular, rocky crest (5-25%) including a complex of steep ridges formed by resistent dykes (dolerites, quartz-porphyries and banded ironstones)

segment 2 - irregular, slightly concave upper-slope, locally

segment 3 - rocky and convex lower-slope (15-30%).

valley (type A) - often steep (30-50%) valley sides showing a
distinct break of slope towards segment 3.

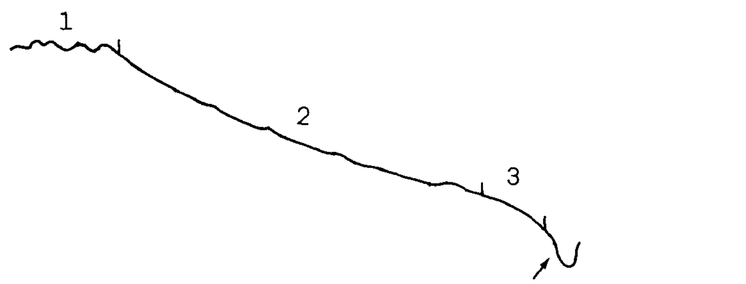

Fig. 6 Slope type 3 of Ki-II

All slopes are rocky without deep soils; rotten rock is exposed at the surface almost everywhere due to the strong incision.
Landtype Ki-III has been surveyed superficially due to the lack of time.
The steep and straight-sloped inselbergs (35-40%) of resistent rock and the concave footslopes (10-20%) are conspicuous in this landtype.

5.1.3. The Otange area

In this area 2 landtypes have been distinguished.

Landtype Ot-I - flat and steep-sided plateau of volcanic rock (mainly nephelinites) in the north-west.

Landtype Ot-II - the remainder of the area comprising low and round laterite-covered interfluves, frequently surmounted by small inselbergs and tors.

Landtype Ot-I
slope type 1

segment 1 (I-fl.cr.V) (see slope map III) - nearly flat (0-3%) crest, convex to the edges; moderately deep soils.

segment 2 (III/IV/V-sc.V) - straight, moderately steep to steep boulder-controlled scarp with convex upper margin and concave lower margin.

segment 3 - strongly concave footslope (5-14%) with distinct (II/III-p.sl.V) break towards scarp (segment 2); the lower margin is gradually flattening out in the Gucha river-plain.

Landtype Ot-II

slope type 2

segment 1 - gently sloping, weakly convex crest-slope with (I/II-r.cr.A R in the southern part locally some tor-formation; laterite near the surface.

segment 2 - gently sloping, characteristical 'stepped' slope (5-9%) due to outcropping lateritic duricrusts.

segment 3 - upper margin if wide concave valleys (black cotton soils and planosols)

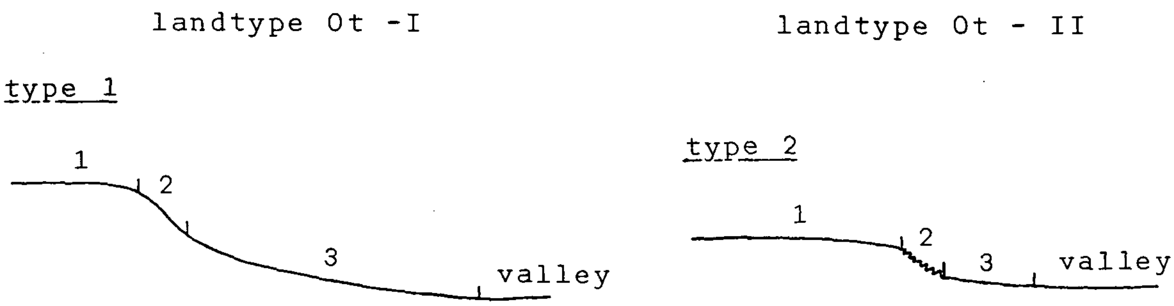

Fig. 7 Slope types of Ot - I and Ot -II

5.2. Slope processes

After the reconstruction of the main slope profiles the next step should be the establishment of a relationship between slope form and slope process. This 'process-form' approach seems far more valid than an'evolutionary' approach as the geomorphological history of this part of Kenya is rather complex, thus providing a risky starting-point for slope analysis. As slope processes could not be measured quantitatively, one has to rely merely on field-observations and logical deductions.

The presumed active slope processes are below:

1) Mass-movements (surface-slides) are likely to occur on the steeper slopes (>30%), where shear forces exceed shear strength in regolith masses. It is plausible to assume, that the straight and steep valley-sides of valley - type A (40-60%) are being maintained maintained mainly by mass-movements, thus ensuring a rapid adjustment of the slope to the strong stream incision.

Moreover, recent micro-morphological investigations indicate to large-scale mass-movements of regolith too (PR. 9, 1976)

2) Creep. Phenomena of creep action have been observed only in the Kitere area, but not in this area. However, the clearly convex upperparts of all slope types are indicating creep influence.

3) Surface wash. According to Carson and Kirkby (1972) surface wash is at an absolute minimum in climates with moderate rainfall (1500-2500mm), where both the dense vegetation and the deep permeable soils ensure a rapid infiltration of the rainwater.

In the Miriri area these conditions have been present until recently. Moreover, the rainfall has a montane character due to the high altitude of the area (1800-2000 m); rainshowers are less violent as compared to the aggressive downpours of the tropical lowlands. It seems not likely, that surface wash has played a major role in slope formation. The effect of climatical changes in the past has to be taken into account. Hamilton (1974) mentioned four pluvial periods in the Pleistocene correlated with the four glaciations in Europe.

Formerly, these pluvials have been considered as cool and wet periods, but recent pollen analyses have revealed that these periods have been cool and dry probably. It is possible, that during the drier periods a sort of savannah vegetation has been present in the area with surface wash being more active than it is under the present conditions.

The concave lower slopes of slope type (Mi-II) could be indications to the action of suface wash during drier periods.

The disappearance of the forest has resulted in an increase of surface wash (run-off + accelerated erosion) giving rise to seminatural terraces" where checkwalls have been constructed. It gives the slopes a slightly benched' appearance.

4) Chemical weathering and removal by sub-surface wash. Probably the major slope forming process is the chemical weathering and the removal of minerals and clay particles in solution or suspension by the action sub-surface wash.

Some support for this assumption is provided by the following facts:

a) The rotten rock, weathered to a considerable depth appears to be an important aquifer and is feeding many springs at the middle and lower slope portions (Scholte/oral communications - 1976). The waterflow of the springs is clearly fluctuating according to the precipitation, which is an indication, that the water is not sprung from a deeply located reservoir.

b) The occurrence of slump phenomena at valley-sides along the Gucha river appearing as local sinusoidal slope facets (see fig. 8).

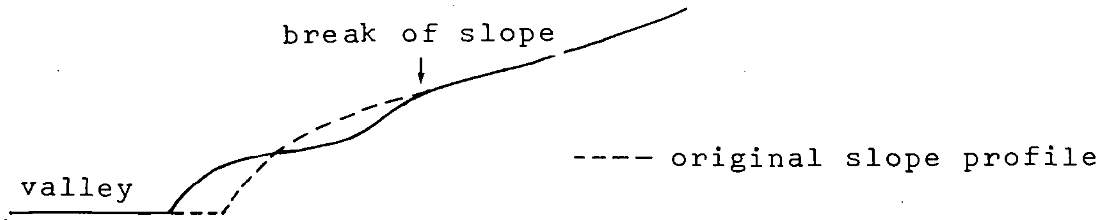

Fig. 8 Diagram of a theoretical slope form

This phenomenon can be explained by the coincidence of a high river level in the wet season and the lateral water flow from upslope. In this way, soil masses along valley-sides become watersaturated and unstable after which slump processes may occur.

There is some evidence, that geological structure is also important factor in landscape development.

This is apparent from the following fieldcharacteristics:

- the occurrence of a nearly rectangular drainage pattern (landtype Mi-II/slope map I, Appendix 4)
- the occurrence of valley asymmetry, which is conspicuous particularly in N.E.-S.W.-running valleys.
- the occurrence of resistent bars in streams giving rise to the formation of cataracts and flat-floored, choked valleys.

Huddleston (1951) determined dipslopes of 0 - 15% for the flat-bedded Kisii Series (to which the rhyolites and andesites of the Miriri area belong) in SE-direction.

Some streams in the area are following a NE-SW - direction along the strike of the dipping beds, other streams are running in a perpendicular direction following the dipslope.

In this way the drainage pattern is build up of subsequent and consequent streams.

On the slope map and the valley cross-sections (Mi-C/ Mi-D) systemical difference of gradient is evidently present in asymetric valleys; this difference range from 5% to about 15%.

It is more pronounced in valleys following the strike direction of the rocks (NE-SW).

Due to this assymmetry steeper and more straight slopes (type 3) are present on north-west facing sides.

The presence of resistent, highly silicious conglomerates as bars blocking up valleys, thus slowing down stream incision, is conspicuous throughout the area and appears to be an important controlling factor in valley development.

Huddleston (1951) mentioned the presence of conglomerates east of Girango (near Gucha River), which controls the flat-floored Gucha valley (see longitudinal river profile - fig. 2 on page 6a) and the Girango fals.

He considered them as being associated with the intercalated sediments of Ramasha (as Bac on the geological map/ associated conglomerates of the Bukoban system).

This seems rather peculiar, as Bac forms the uppersection of the Kisii Series and the Girango conglomerate are located on an intermediate level (Ba = Bukoban Andesites).

The affect of resistent bars, which are blocking up the valleys, is the domination of slope processes over valley lowering.

Hence valley formation is not strongly controlling slope development except for the slopes, where lateral corrasion by meandering streams occurs.

5.2.2 Kitere area

Considering the characteristics of the Kitere area some differences with the Miriri area are obvious:

a) the presence of resistant lateritic duricrusts (Ki-I).
b) the shallow depth of most of the soils.
c) the active role of stream down-cutting (particularly in Ki-II) dominating slope development.

The Kitere area has a drier climate (1500-1700 mm/year) than the Miriri area; the original vegetation comprises a sort of Combretum woodland (long grass savannah).

The less protective cover (as compared with the forest of the Miriri area) will tip the scales in favour of slope processes as surface wash; also the shallow soils in the area making chemical weathering + sub-surface wash rather unlikely as dominant slope processes.

Thus concave slope profiles might be expected in the area.
Concave slope, however, are only present along the Gucha River, where they are result of retreating upper-slopes.
Lower slopes along the Gucha(Ki-II) and other profiles (Ki-I) are on the contrary clearly convex in form.
This raises the supposition, that stream action is the controlling slope factor.
The clearly convex slope form of types 1 and 2 (Ki-I) can be explained by increasing stream incision into resistant material (lateritic duripans); slope processes are too slow in adjusting slopes to the new equilibrum, thus being reponsible for convex lower slopes by continuation of this process.

Besides the already mentioned duricrusts on the granites of Ki-I the occurrence of resistant dykes of different origin (mainly quartz-porphyries + banded ironstones) is important as they tend to form the cores of inselbergs and ridges (Ki-III).
Where they have crossed the Gucha River, bars are formed controlling down-cutting to a considerable degree

5.2.3. The Otange area.

In this area conditions for slope development are partially the same as in the Kitere area, because of the following:

- the presence of a savannah climate favouring processes as surface wash.
- the presence of extensive duricrusts (laterite) controlling slope development (landtype Ot-II).

The difference between both areas is situated in the balance between valley lowering and slope processes.
In the Kitere area most valleys are incised by rejuvenated streams, whereas in the Otange area valleys are wide and flat-bottomed without any incision; only the Gucha River itself is slightly entrenched in its own beds.

Consequently slope processes (surface wash) are dominating slope development, thus creating concave profiles (see slope type 1/ segment 3 and slope type 2/ segment 3).

Kauffman and Hennemann (1975) found on soils in a comparable area low infiltration rates and a high susceptibility to sealing, all of them soil properties, which are favouring surface run-off. Moreover, accelerated erosion is widespread in the area due to overgrazing by goats.
Where convex slopes exist creep action has to be taken into account (upper-margin of segment 2/ slope type 1).

The constant slope grddients of the outcropping lateritic duripans (5-9%- segment 2/ type 2) and of the boulder-controlled scarp (23-25%- segment 2/type 1) are indicating towards parallel slope re-treat.

5.3. Planation surfaces

5.3.1. General

Although a 'process-form' approach seems more valuable for the analysis of different slope forms are already have been stated, some attempt has been made to associate slope form with the presumed age of the slope.

Slope age is defined primarily by the age of the planation surface on which the slope has been developed.

Planation surfaces are often conspicuously present in the Gucha drainage basin.

The characteristics and the presumed age of the main surfaces are listed below.

Table 2 The characteristics of the main planation surfaces in the Miriri, Kitere and Otange areas.

	surface	Elevation (feet)	Elevation of sub-Miocene Bevel according to Pulfrey -1959
Miriri area	Magombo (Mi-I)	± 6200	± 5500
	Tombe (Mi-II)	± 6800	
Kitere area	Rongo (Ki-I/Ki-III)	± 4850	± 4900
Otange area	Rapogi (Ot-II)	± 4300	± 4300
	Kagaga (Ot-II)	± 4150	

5.3.2. The Miriri area

Tombe surface

The determination of the Kisii Highland surface to which the Tombe surface obviously belongs, is easy as most summit consist of conspicuous plateax, which elevations can be derived from the topographical map.

Magombo surface

Below the Tombe surface another level area is present, which has been called the Magombo surface; it comprises the low hills of land-type Mi-I in the East, which forms the headwater area of the Kuja.

It seems rather peculiar, that this headwater area is like a depression, which is considerable lower and more flattened than the

Surrounding hills of the Kisii Highlands (the Kijaur Ridge in the east is standing some 350 meter above the Magombo surface).

Stheeman (1932) found in south-western Uganda similar low and undulating depressions, surrounded by high steep scarps; he called them arena's and considered them as being formed by retarded valley-sides on which more resistant rocks are exposed.
Near Nyamache (Bobasi Sublocation) a similar extensive level floor occurs, apparently formed by aggradational processes.
However, the western part of this floor is dissected by headward extension of the rejuvenated tributaries of the Gucha River.

It might be possible, that the Magombo surface has been a similar floor formerly, defined by a weakness of the geological structure, which has been subsequently dissected by a rejuvena... Gucha River
This rejuvenation might have been controlled at the first place by the presence of lenticular bodies of conglomerates (see also page   ) in the bedrock (Bukoban andesites) and only at the second place by fluctuations of the erosion level.
The Magombo surface is apparently not part of the Sub-Miocene level itself, which is here at a much lower level (5500 ft. according to Pulfrey - 1959), but might be associsted with it.

The Magombo surface can thus bestly be considered as probable remnants of an aggradation surface, which has been shaped by successive periods of erosion and aggradation.

Considering slope development,comparison of the slope types of Mi-I (Magombo) and of Mi-II (Tombe) appears to be riskfull, as the slopes are developed in two surfaces, which are different of both age and genesis.

3.2. The Kitere area

Rongo surface

The elevations of the surfaces of Ki-I and Ki-III sre in full agreement with values of the Sub-Miocene level as given by Pulfrey (1959)
The laterite-capped Rongo surface (Ki-I) needs some further examination. Conspicuous are the presence of fluviatile,rounded pebbles (mainly quartz and quartzite) interbedded in the lateritic duricrust. Another important phenomenon is the occurrence of the round elongated

hydromorphic depressions (mapping unit H), surrounded by outcropping laterite.
Both phenomena are indications to a possible inversion of relief.
Soft plinthite, developed along and in streambeds due to lateral iron enrichment, become hardened at exposure due to the incision of streams and is transformed into a resistant lateritic pan.
The higher interfluves, which has no plinthite in the sub-soil, are now comparatively easily erodible for stream action and are shaped into the new valleys, after which the process is repeated in due course.
The depressions in the lateritic duricrust (H) might be considered as fossile stream-courses or small lakes protected by the hardened surrounding plinthite (duricrust).

So the Rongo surface may not be considered as part of the Sub-Miocene erosion surface, but more as an association of indurated stream terraces, being the former alluvial deposits of the Sub-Miocene planation surface.

Considering slope development in the Kitere area, it is clear, that landtype Ki-II of the dissected Gucha valley is having younger slopes than landtype Ki-I (Rongo surface).
The presence of V-shaped valleys and the higher stream gradients bear witness to this.

Remarkable is the sharp knickpoint on the valley sides of the Gucha and its near tributaries (valley type A), which may correspond with the outcropping duricrusts at the lower part of slope type 1 and 2 (segment 4).
Both phenomena indicates to a more recent rejuvenation.
Further comparison is difficult due to the absence of a duricrust layer in landtype II, which is undoubtedly an important controlling factor in slope development.

5.3.4 The Otange area

Rapogi surface

In the southern part of the area the convex summits with scattered tors of landtype Ot-II are present; they are part of the Sub-Miocene erosion surface, which is standing at 4300 ft. above sea-level (Pulfrey - 1959).

Kagaga surface

Some 150 feet lower than the former another surface occurs, consisting of a rather flat-lying area, which is covered by thick laterite crusts.
These crusts include alternating layers of small and large rounded pebbles and stones with an obviously fluviatile character.
Undoubtedly, this 4150-feet surface (It has been named Kagaga surface) is younger than the Rapogi surface (Sub-Miocene) and could well correspond with the P5-level, which Shackleton (1946) found along the Migori River.
This surface is correlated with End-Tertiary surface of other areas in East-Africa.

It is evident, that such a surface on which wide sheets of fluviatile gravels and stones were spread, have formed by a river, more mature than the present-day Gucha.
After the disturbance of the Sub-Miocene surface lava flows from the Kaniamwa foult (bordering the Lambwe Valley on the south-east) probably have forced the roughly east-west running ('proto'-) Gucha River to change his course into southern direction (see fig. 2).
This may have resulted into a decrease of the stream-gradient and a subsequent discharge of the river-load (gravels, etc.).

After the formation of gravelbeds some incision took place due to the subsequent subsidence of the Lake Victoria area in the Late Pleistocene (Shackleton - 1946).
The Kagaga surface might thus be considered as an indurated river terrace of wide extension.

6. Acknowledgements

This report does not claim to be conclusive as only a short period was available for field work. It should be considered more as a reconnaissance study within a frame work of extensive geomorphological investigation, which are carried out by W.G. Wielemaker. Greatfull acknowledgement is made here of the assistance and constructive ideas of the project managers, Mr. W.G. Wielemaker and Mr. H.W. Boxem during this study in Kisii.

I also wish to express my gratitude to Mogire Nyabonda, Evans Maeta, Charles Faniako, Njoroge Kamau and also Mama Kahawa for their cooperation and friendship during the fieldwork.

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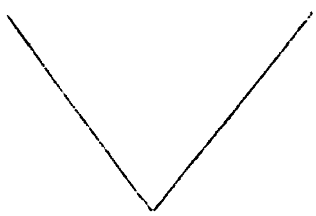
Appendix 1 - Description of valley types

I. Miriri area

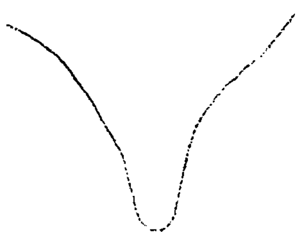
In this area 5 valley types have been distinguished.
Criteria are the curvature of the valley sides and the degree of incision; these characteristics appear to be related with stream gradients.

Type A - V-shaped valley



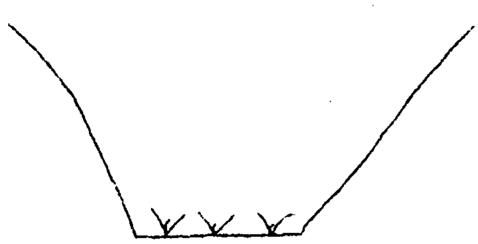
Stream gradients usually pver 8%.
Valleys of this type mostly carry small streams of the 1-st order; locally they occur along streams of the 2-nd and 3-nd order behind bars and cataracts, where stream gradients are steepening.
This valley type represents the juvenile part of the drainage system.

Type B - Incised valley



Stream gradients usually between 2.5 - 8%.
When stream gradients are falling below 8%, valley forms are gradually becoming convex and are getting a typical 'sunk' appearance due to the continuing incision.
Both valley sides are usually convex in form; gradients over 65% are present.
If stream-gradients are lessening, valleys become increasingly swampy (see type C)

Type C - Flat floored incised valley



Stream gradients usually between 0.5 - 2.5%. Where gradients have beeen lessened by continuing downcutting, flat floored valleys occur with mostly steep convex valley sides. Valley floors are swampy and choked by a vegetation of papyrus and sedges; in these valleys sluggish streams are meandering in narrow channels; in the wet season frequent flooding occurs.

The steep convex valley sides are controlled by lateral corrasion of the meandering streams.

Type D - Flat floored concave valley

Stream gradients below 1%.
Where valleys have been widened, the valley sides are less steep and mostly straight or concave in form.
Streams are usually running at one side of the broad valley floor, thus conserving the original convex valley side.
The other side of the valley floor is bordered by a gentle concave valley side; this slope is created probably by steady aggradation due to slope processes; valley assymmetry is present at many places.

Type E - Shallow concave valley (gully).

Stream gradients are variable, usually over 8%. This valley type is carrying very young, intermittent streams and is in fact little more than a broad gully.
Stream gradients are mostly slightly less than the gradient of the slope in which the valley has been carved.

II. Kitere area

In this area 5 valley types have been distinguished .
They are varying considerably in slope form and degree of incision;
Less relationship with stream gradients is showed, however, the proximity of the strongly incised Gucha River is a crucial factor.

Type A - V-shaped valley with knickpoint (in valley sides)

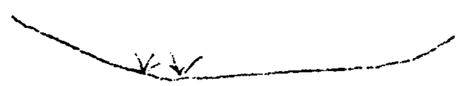
Stream gradients variable (3 - 15%)
This valley type is associated with those streams, that drain directly to the Gucha River (incised part).
Valley sides are usually slightly concave at the upper sides having gradients of about 15-25%; after a sharp break of slope, the sides pass into steep (30-60%) straight slopes.

Soils are usually shallow and consist largely of rotten rock (rhyolite).
The Gucha valley itself correspond with this image, although knickpoints are less pronounced.

Type B - V-shaped valleys without knickpoints.

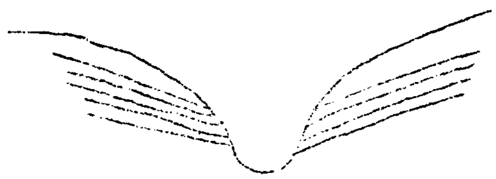
Stream gradients usually between 3-6%.
This valley type is less common and is present in the western part of the area, where incision of the Gucha River is less.
Upper-valley sides are usually slightly concave with gradients of 10-20%.
Lower valley sides are straight with gradients of 20-30%; slope transitions are mostly smooth.
The Gucha valley in this area is somewhat different as it consists of a slightly concave riverplain in which the river has been entrenched.

Type C - Flat floored concave valley.



This type fully corresponds with the previously described valley type D of the Miriri area; it is associated with streams in the western part, where stream gradients are less.

Valley types (D + E), which are controlled by LATERITIC DURICRUSTS.
Type D - Incised valley with swampy bottoms.



Stream gradients ranging from 1-3%.
This valley type occurs in the northern part of the area, where summits and lower slopes are mostly covered by 1-2 meter thick layers of laterite.
Supperficially similar to valley type D of the Miriri area, it shows some distinct differences. Streams have usually cut through the duricrust covering the lowerslope and are eroding the soft rotten rock of the underlying granites (Kitere granite). Valley floors are slightly concave, not very wide and covered with riverine bushes + reeds.

Valley sides are strongly convex, covered by outcropping laterite and laterite-gravels; boulders (core-stones) of weathered granite are often present.

Type E - Broad concave valley

Stream gradients ranging from 0-15%. This type occurs where gradients are low. The concave, broad valley floors are typical for type E; they can reach large widths of 350 meter or more.
River sediment is present everywhere, covered by a dense vegetation (riverine bush, reed and sedges).
Valley sides are convexo-concave controlled by outcropping laterite; if no laterite is present, concave forms prevail.

III. Otange area

In this area only valley type is present.

Type A - Broad, concave valley (plain)

Valley floors consist of very broad, slightly concave plains (width of 400-600 m.) with gradients ranging from 0-4% (near the margins). Flood channels are carying small muddy streams (intermittent).
Soils are mostly black, heavy shrinking and swelling clays (vertisols), covered with grazing land and trees.
Moving from the flood-channel, gradients are gradually increasing to 4-5%; there, grey leached planosols occur.

The flanks of the valley are usually marked by sloping (6-9%) lateritic slopes (due to the horizontal stratigraphy of the laterite banks, they all a typical 'stepped' appearance. The Kuja valley correspond rather well with this image: the valley width is large, while incision is more conspicuous (± 3-5 meter below the present river-plain at the end of the wet season).

Appendix 2 - Description of Mapping units

I. Miriri area: see legend of map (I) and valley description (App.I)

II. Kitere area

H - hydromorphic depressions

flat and swampy area with gradients to 2%; usually covered by a 'clump-tree' vegetation on abondoned termite mounds.
Soil are grey mottled clays with plinthite-formation in the subsoil near margins of the depression. The depressions, which are usually longitudinal in form, are bordered by outcropping laterite, giving rise to stepped' slopes (II-ir).

See also the legend of map II and the valley descriptions (App. I).

III. Otange area

Slope forms in the area are usually clearly related to lithology and phsiographic position; both factors have been discounted in the legend.

Explanation of cods system

f.cr. = flat crest
r.cr. = round crest
o. = outcrop (rock -)
sc. = scarp
p.sl. = piedmont slope
st.sl.= 'stepped' slope
v.sl. = valley slope

A = porphyritic andesite
R = rhyolite
V = volcanic rock (mainly nephelinites)
M = rocks of mixed origin

Mapping units	Cross-section (segment)	Description
I - f.cr.V	Ot - I (5-7)	Nearly flat crest or plateau developed on tertiary volcanic (mainly nephelinites), convex to the edges. Soils:mod. deep. dark red well drained clays. Use: fully occupied by arable land.

Mapping unit	Cross-section (segment)	Description
I - f.cr.	absent	Flat crest-plain, bordered by stepped slopes of outcropping laterites (II-st-sl). They carry usually planosols with leached A-horizons. The unit is present near the Otange Plain, where an extensive swamp has been developed (lower parts) Soils: planosols Vegetation: long grasses; no trees.
I/II - r.cr.A	Ot-I (12-15)	Gently sloping, slighglt convex round crest; gradients do not exceed 12%. The surface is covered with scattered rocks and gravels of er eroded laterite. Locally on andesites small tor-lik like outcrops occur. Soils: shallow and rocky Use: arable land + fallow.
I/II - r.cr.M	Ot-II (1-5-9-13)	Gently sloping, slightly convex round crests; gradients do not exceed 9%.
II - st.sl.	Ot-II (6-8-10-12-14)	Gently sloping 'stepped' slopes with gradients of 5-9%. Mainly consisting of resistent outcropping laterites, containing many rounded boulders of different origin (cherśts, jasper, quartzite etc.) Interbedded between the laterites are layers of boulders (pure) alone. Soils: absent Vegetation: short grasses or absent

II/III-p.sl.V	Ot-I (3-9)	Clearly footslope with gradients ranging from (lowerside) 5% to 14% (upperside); a sharp knick-point indicates the boundary with the boulder-controlled scarp (III/IV/V - sc.V) soils: mod. deep well - drained, reddish brown loams. Use: arable land at lower sides grazing land (bad drained).
III/IV/V-o.A	Ot-I (13-14)	Mod. steep outcrops with straight rocky slopes, developed on Rhyolite (andesite) soils: shallow, rocky vegetation: dense bushes
III/IV/V-v.sl.A	absent	Sloping-mod. steep convex valley-slopes on porphyritic andesites along the Kuja River. soils: shallow/rocky vegetation: grazing land + shrubs.
III/IV/V-sc.V	Ot-I (4-6-8)	Locally sloping, but mostly mod. steep convexo-concave scarps of volcanic rock; steepest parts ± 25% (boulder-constrolled) soils: shallow/very rocky. vegetation: grazing land + shrubs.

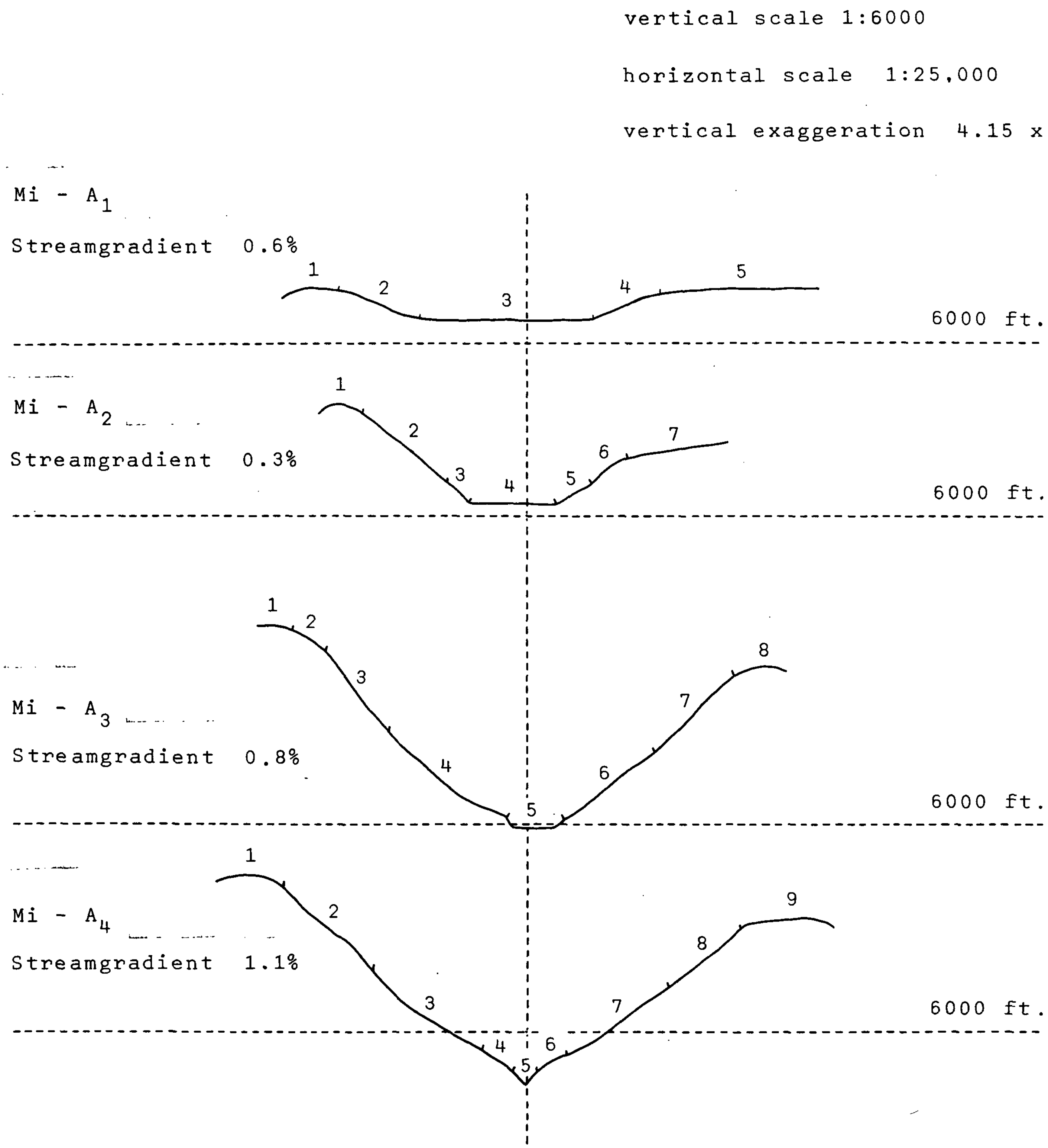


Fig. 9 Cross-profile I — Gucha at Miriri

Appendix 3 - Description of Valley Cross-sections.

Miriri area (Mi) - Gucha valley (A)

Mi-A1

Slope segment	Short description
1) Round summit	slope class: I/II/III
	slope form : convex
	soils : deep, red clays
	landuse : arable land
2) Slope	slope class: III/IV
	slope form : sl. concave
	soils : deep, well drained
	landuse : arable land
	transition to segment 3 is gradual.
3) Flat floored valley	slope class: I
	slope form : very gently concave slopes to both sides; meandering river in the axis of the valley.
	soils : hydromorphic grey soils, locally peatsoils.
	vegetation : papyrus/sedges + natural grazing land.
4) Slope	slope class: IV
	slope form : nearly strai ht, slightly concave at upper-part.
	soils : as segment 2
	vegetation : "
5) Nearly flat summit	slope class: I/II
	slope form : sl. convex near edges.
	soils : deep, well drained
	landuse : arable land.

Mi-A3

1) Round summit	slope class: I
	slope form : convex to edges
	soils : deep, well drained
	vegetation : arable land

2) Round edge	slope class: III/IV slope form : strongly convex soils : deep, well drained, passing into shallow and gravelly soils downslope. landuse : arable land + grazing land
3) Upper-slope	slope class: VII slope form : slightly concave - straight. soils : shallow / gravelly landuse : succession in downslope direction natural grazing land - trees - arable land maize.
4) Lower-slope	slope class: V/IV slope form : concave soils : deep, well drained landuse : arable land
5) Flat floored incised valley (C)	slope class: VII/VIII (valley sides) slope form : straight-convex. narrow strongly meandering channel in flat valley floor; rather abrupt break of slope towards valley sides; dense papyrus-swamp.
6) Lower-slope	slope class: V slope form : straight-sl. concave soils : deep, well drained. landuse : arable land
7) Upper-slope	slope class: VII slope form : slightly concave soils : deep+shallow, gravelly soils landuse : grazing land + trees
8) Round, narrow	slope class: III/IV slope form : strongly convex soils : shallow and gravelly landuse : natural grazing land

<u>Mi-A4</u>

1) Round summit	slope class: I/II/III slope form : convex soils : deep, well drained landuse : natural grazing land + arable land.

2) Upper-slope	slope class	VI
	slope form	slightly concave
	soils	deep- mod. deep soils
	landuse	trees + arable land
3) Middle slope	slope class	V III
	slope form	concave (long)
	soils	deep, well drained
	landuse	arable land
4) Lower slope	slope class	III IV
	slope form	convex (short)
	soils	deep, well drained
	landuse	arable land/locally grazing land.
5) Incised valley	valley type	B
	gradient	1.1%
	valley sides	convex, planted with trees.
	flood-channel	narrow and slightly meandering, incised; swampy vegetation. locally developed.
6) Lower slope	slope class	IV
	slope form	convex
	soils	deep, well drained
	landuse	arable land
7) Middle slope	slope class	V
	slope form	slightly concave
	soils	deep, well drained
	landuse	arable land
8) Upper slope	slope class	VI
	slope form	slightly concave convex
	soils	deep shallow
	landuse	arable land + natural grazing. land.
9) Round narrow crest	slope class	I/II/III/IV
	slope form	strongly convex
	soils	mostly shallow
	landuse	arable + grazing land.

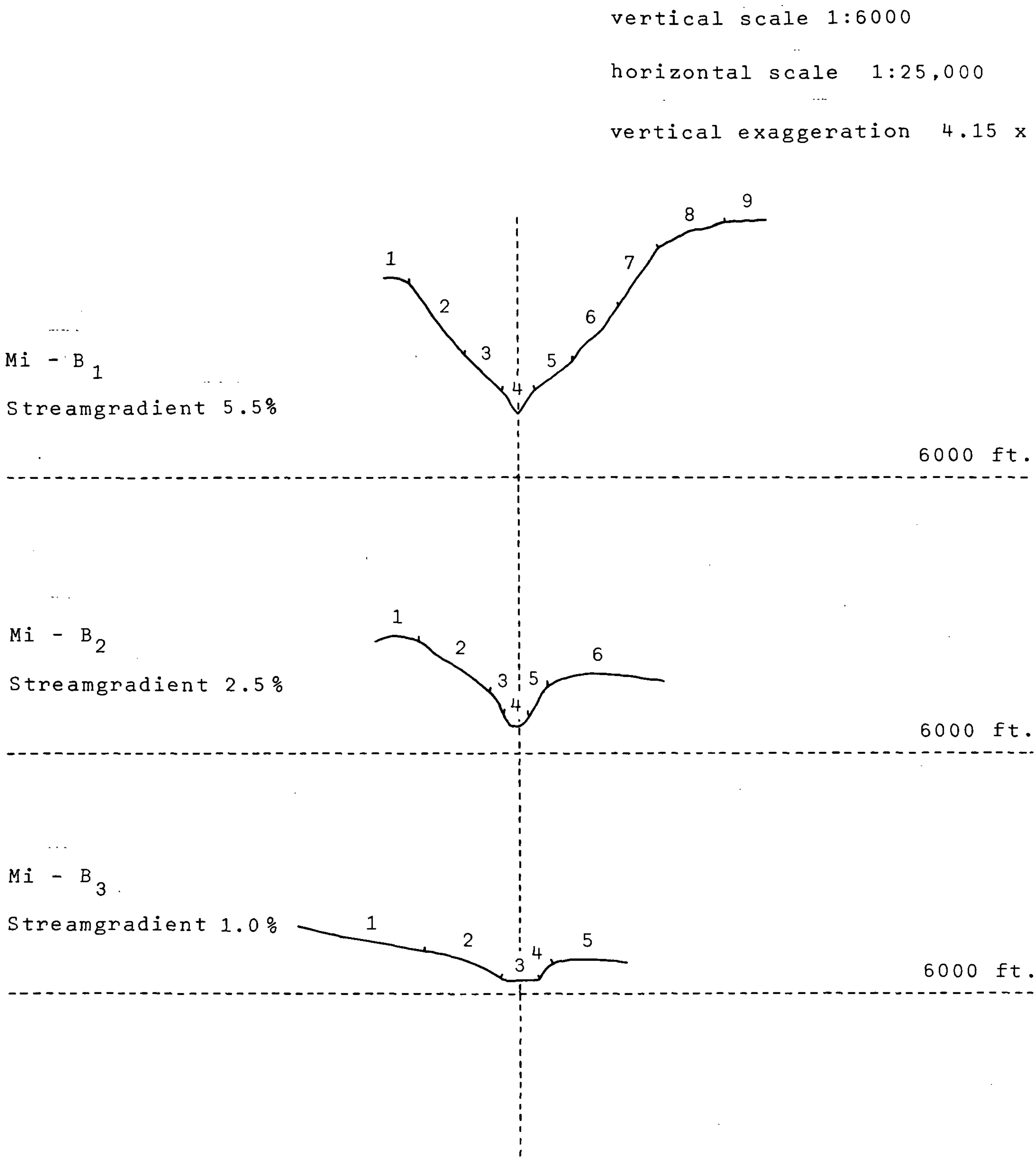


Fig. 10 Cross-profile II – tributary B (Miriri)

Tributary B

Mi-B1

Slope segment			short description
1) Round narrow summit	slope class	:	I/II/III/IV/V
	slope form	:	strongly convex
	soils	:	shallow and gravelly
	landuse	:	natural grazing land
2) Upper slope	slope class	:	VI (± 28-29%)
	slope form	:	straight
	soils	:	ahallow and gravelly mod. deep (downslope)
	landuse	:	natural grazing land + trees
3) Lower slope	slope class	:	VI
	slope form	:	straight
	soils	:	shallow and gravelly deep
	landuse	:	arable land + grazing land
4) V-shaped valley	slope class	:	stream gradient - 5.5%
	valley type	:	A (slightly convex valley sides).
5) Lower slope	slope class	:	VI/VII.
	slope form	:	convex
	soils	:	deep and well drained
	landuse	:	arable land
6) Middle slope	slope class	:	VII (30-32%)
	slope form	:	straight to sl. concave
	soils	:	deep and well drained; clear presence of semi-natural terrace
	landuse	:	arable land.
7) Upper slope	slope class	:	VII (± 38%)
	slope form	:	nearly straight
	soils	:	mainly shallow and gravelly
	landuse	:	natural grazing land + trees.
8) Plateau spur	slope class	:	III
	slope form	:	sl. concave sl. convex
	soils	:	deep and well drained
	landuse	:	arable land.

9) Plateau	slope class : I
	slope form : sl. convex
	soils : deep, well dr./arable land.

Mi-B2

1) Round summit	slope class : I/III
	slope form : sl. convex
	soils : deep and well drained
	landuse : arable land
2) Slope	slope class : V
	slope form : straight
	soils : deep, well drained
	landuse : arable land
3) Lower slope	slope class : VII
	slope form : convex
	soils : deep, well drained
	landuse : arable + grazing land
4) Incised valley	stream gradient: 2.5%
	valley type : (intergrade to type C)
	valley sides: convex and steep
	valley bottom: a flat is developing, but is still small
	vegetation : papyrus/sedges.
5) Lower slope	slope class : VII
	slope form : convex
	soils : ?
	landuse : trees (wattle-plamtation)
6) Summit	slope class : III I
	slope form : sl. convex
	soils : deep and well drained
	landuse : arable land.

Mi-B3

1) Upper slope	slope class : II
	slope form : sl. concave
	soils : deep and well drained
	landuse : arable land

2) Lower slope — slope class: II/III
slope form : convex
arable land on well drained soils.

3) Flat floored incised valley — stream gradient : 1.0%
valley type : C
western valley side: straight / arable land
eastern valley side: convex / trees/steep

4) Lower slope — slope class: VIII
slope form : convex
landuse : trees

5) Summit — slope class: III ——> I
slope form : convex.

<u>Mi-Cl</u> <u>Tributary C</u>

1) Plateau spur — slope class: I/II
slope form : convex
soils : shallow/gravelly

2) Upper slope — slope class: III
slope form : convex
soils : shallow and gravelly
landuse : natural grazing land

3) Middle slope — slope class: V/VI
slope form : convex.

4) Lower slope — slope class: VI
slope form : convex
soils : deep and well draind
landuse : natural grazing land + some arable land.

5) Flat floored incised valley — slope class: stream gradient - 1.5%
valley type: C
valley sides: steep & straight with abrupt transition to valley floor (width ± 300 meter).

6) Slope — slope class: VI
slope form : straight
soils : deep, well drained
landuse : locally shrubs + grazing land

7) Summit (plateau) — slope class: I/II
slope form : straight to slightly convex.

vertical scale 1:6000

horizontal scale 1:25,000

vertical exaggeration 4.15 x

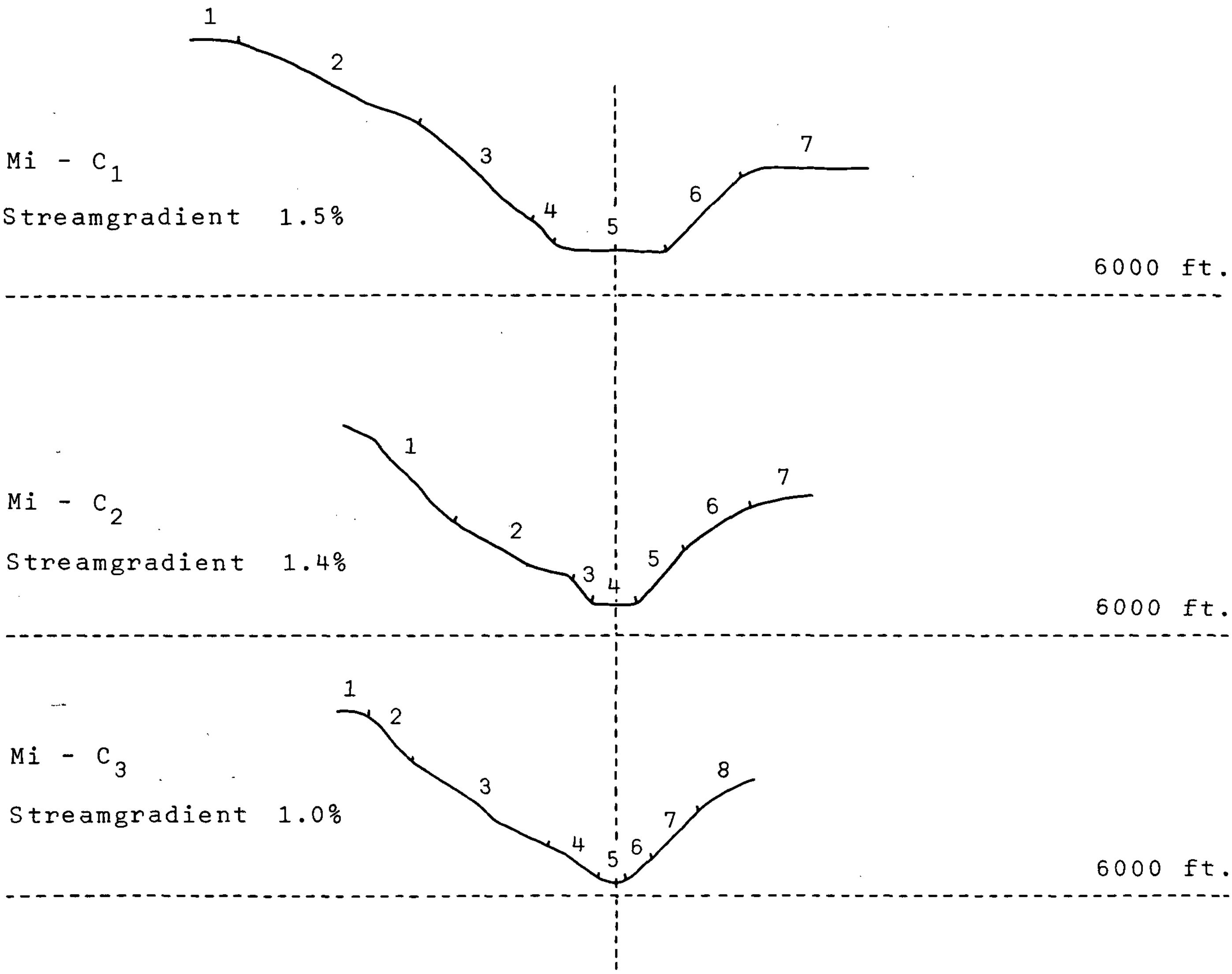


Fig. 11 Cross-profile III – tributary C (Miriri)

Mi-C2

1) Upper slope	slope class: VI slope form : straight soils : arable land on deep well drained soils.
2) Middle slope	slope class: III slope form : concave (long) soils : deep, well drained
3) Lower slope	slope class: IV/V slope form : convex (short) landuse : grazing and arable land.
Flat floores incised	slope class: stream gradient - 1.4% valley type: C valley sides:steep/straight valley floor:flat and swampy, width up to 200 meter.
5) Lower slope	slope class :VI slope form :straight landuse :trees and arable land
6) Upper slope	slope class :IV/V slope form :slightly concave
7) Summit	slope class :I/II slope form :convex.

Mi-C3

1) Plateau spur + rounded edges	slope class :I/II slope form :slightly convex soils :deep and well drained landuse :arable land + some grazing land.
2) Upper slope	slope class :V slope form :convexo-concave soils :mainly shallow landuse :natural grazing land + trees

3) Middle slope	slope class	IV
	slope form	slightly concave
	soils	deep and well drained
	landuse	arable land
4) Lower slope	slope class	IV V
	slope form	convex
	soils	deep and well drained
	landuse	arable land
5) Flat floored valley	stream gradient	1%
	valley type	C
	valley sides	convex, abrupt transition
	valley floor	narrow, swampy vegetation
6) Lower slope	slope class	VI
	slope form	slightly concave/ short
	soils	deep, well drained
	landuse	arable land
7) Middle slope	slope class	VII
	slope form	straight
	landuse	arable land
8) Upper slope	slope class	VI IV
	slope form	convex
	landuse	arable land

<u>Tributary D / Mi-D1</u>

1) Round narrow summit	slope class	I/II
	slope form	sharp/convex
	landuse	arable land
2) Upper slope	slope class	III
	slope form	convex
	landuse	arable land
3) Lower slope	slope class	V
	slope form	convex
	landuse	arable + grazing land.
4) Incised valley	stream gradient	4%
	valley type	B
	valley sides	steep, convex
	valley floor	locally swampy and flat.

vertical scale 1:6000

horizontal scale 1:25,000

vertical exaggeration 4.15 x

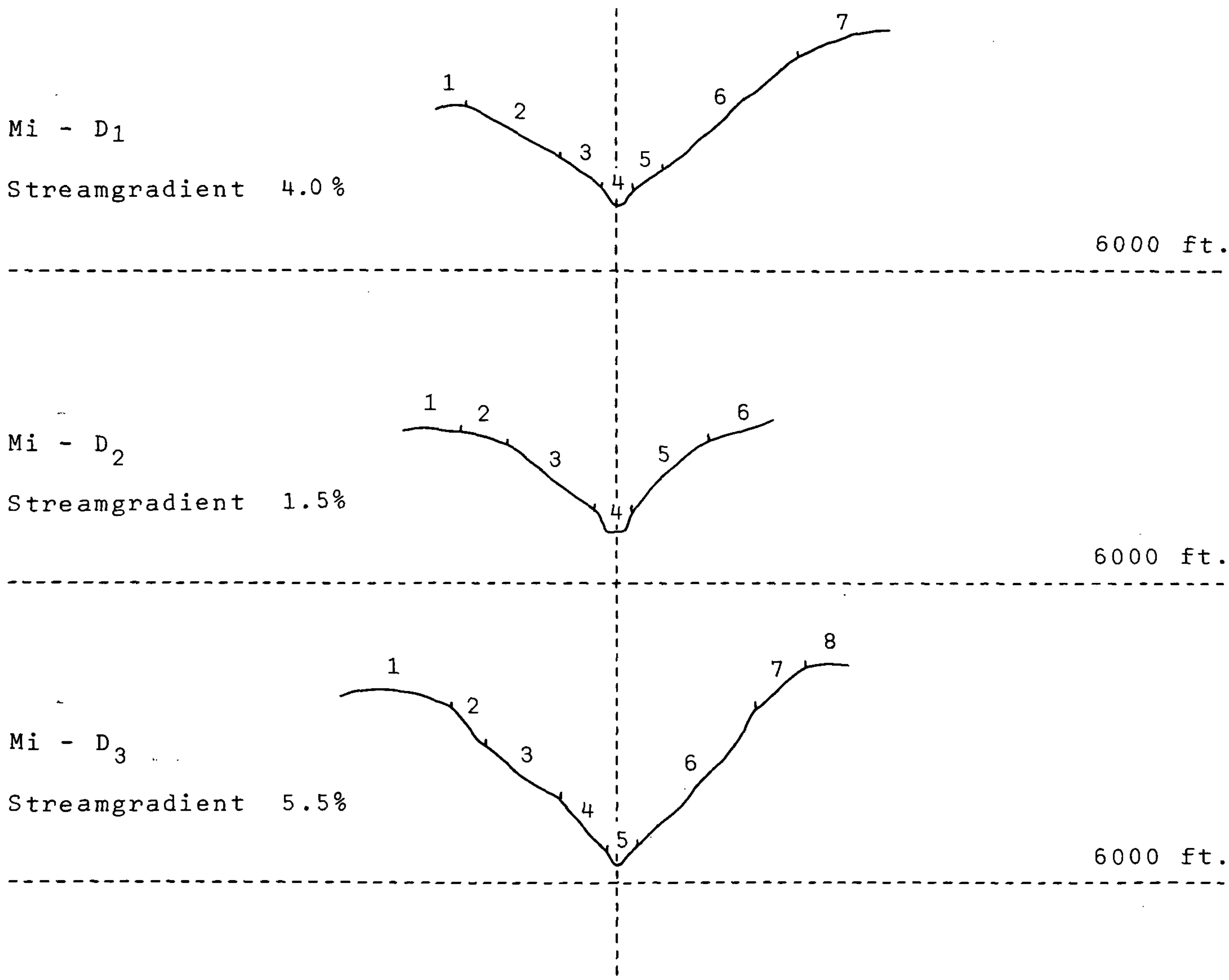


Fig. 12 Cross-profile IV – tributary D (Miriri)

5) Lower slope
slope class : VII → V
slope form : convex / short
landuse : natural grazing land + some arable land.

6) Upper slope
slope class : V
slope form : slightly concave
landuse : arable land

7) Plateau edge
slope class : III → I
slope form : convex
landuse : arable land

<u>Mi-D2</u>

1) Round summit
slope class : I/II
slope form : convex
landuse : arable land

2) Upper slope
slope class : III
slope form : convex
landuse : arable land

3) Middle slope
slope class : IV/V
slope form : slightly concave
landuse : arable land

4) Flat floored incised valley
stream gradient: 1.5%
valley type : C (intergrade to type B)
valley sides: strongly convex
valley floor: swampy, flat

5) Lower slope
slope class : VII
slope form : slightly convex
landuse : trees + arable land.

6) Upper slope
slope class : IV → III
slope form : convex
landuse : :arable land.

<u>Mi-D3</u>

1) Summit (plateau)
slope class : I/II
slope form : slightly convex
soils : deep and well drained
landuse : arable land

2) Upper slope
slope class : VI
slope form : shallow and gravelly
landuse : natural grazing land + some maize.

3) Middle slope	slope class	: IV
	slope form	: concave-long
	soils & landuse	: arable land on deep soils
4) Lower slope	slope class	: VI
	slope form	: short, convex.
	soils	: deep and well drained
	landuse	: arable land
5) Incised valley	stream gradient	: 5.5%
	valley type	: B (intergrade to A)
	valley sides	: steep, slightly convex.
	valley floor	: narrow, not swampy.
6) Lower slope	slope class	: VI VII
	slope form	: slightly concave
	soils	: deep, well drained
	landuse	: natural grazing land + arable land.
7) Upper slope	slope class	: VII
	slope form	: slightly concave
	soils	: shallow and gravelly
	landuse	: natural grazing land + trees
8) Plateau spur	slope class	: III → I
	slope form	: convex
	soils	: shallow and gravelly
	landuse	: natural grazing land.

Kitere area (Ki)- Gucha valley (A)

Ki-A1

1) Summit	slope class	: I/II
	slope form	: slightly convex
	soils	: mod. deep (rhyolite)
	landuse	: natural grazing + arable land + dense bush.
2) Irregular slope	slope class	: III
	slope form	: slightly convexo- concave irregular due to outcrops
	soils	: mod. deep to shallow
	landuse	: arable + grazing land, dense bush near rock outcrops.

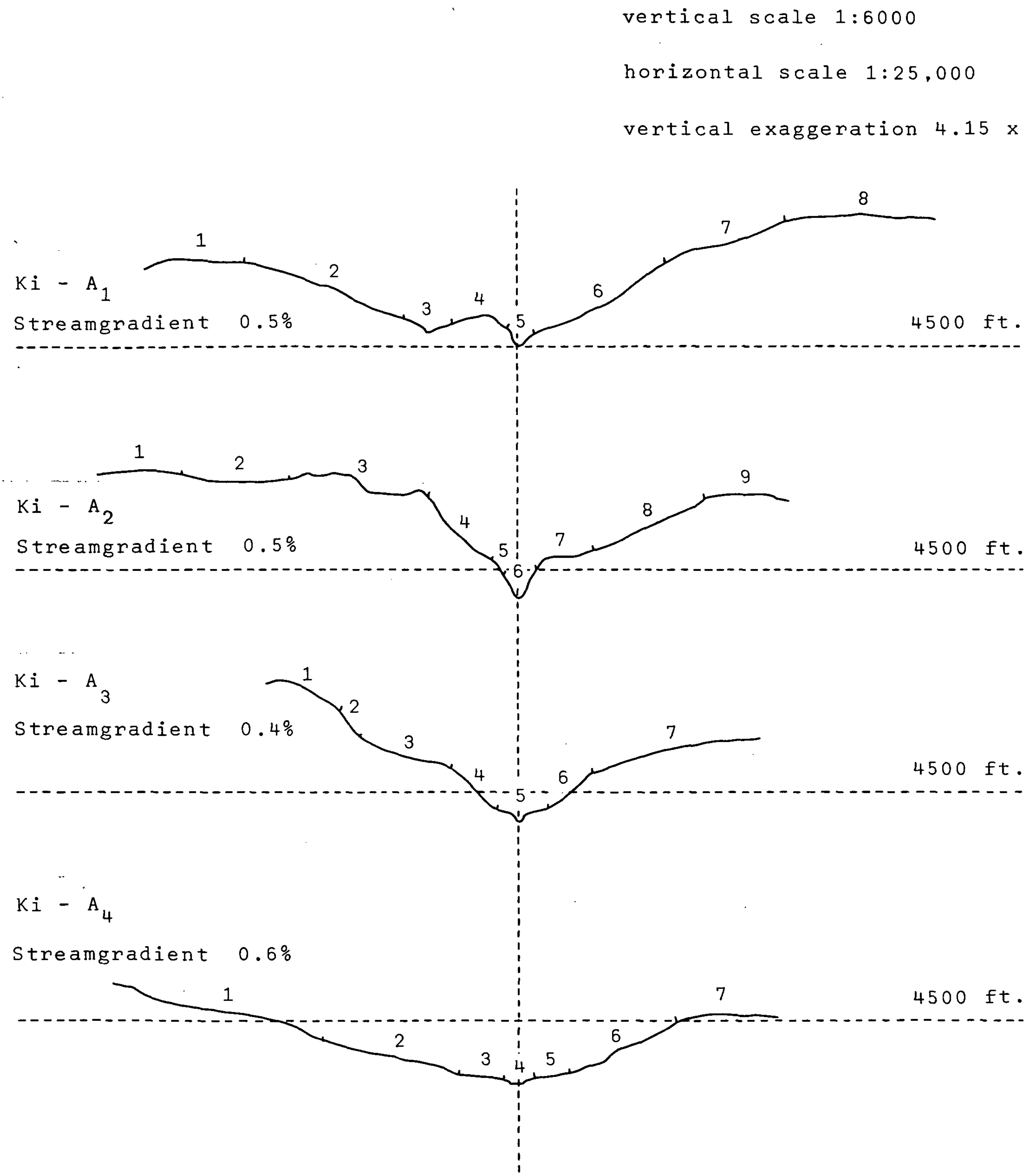


Fig. 13 Cross-profile V - Gucha at Kitere

3) V-shaped valley	valley type: A (tributary) Deeply incised stream with conspicuous knickpoint at middle slopes (valley-) presence of rock-bars.
4) Round interfluve	slope class: II/III/IV slope form : convex
5) Gucha valley	valley type: V-shaped with knickpoint (type A) steep gorges with rather convex valley sides. very rock slopes with shallow soils. landuse : maize fallows/ shrubs
6) Irregular lower	slope class: III/IV/V slope form : convexo - concave soils : mod. deep - shallow vegetation : mainly maize, dense bush near outcrops.
7) Upper slope	slope class: II/III slope form : convex soils : shallow and rocky vegetation : arable land (maize) + grazing land.
8) Broad summit	slope class: I slope form : slightly convex soils : mod. deep landuse : natural grazing land + arable land.

<u>Ki-A2</u>

1) Summit	slope class: I/II slope form : slightly convex soils : mainly shallow and mod. deep landuse : natural grazing land + arable land.
2) Valley head	slope class: ± III slope form : U-shaped, concave soils : mod. deep to deep landuse : grazing + arable land
3) Irregular crest	slope class: II/III/IV/V slope form : very irregular and rocky segment 3 includes a complex of steep ridges (convex), formed.

	by doleritic and quartz-pophyritic dykes, with concave depressions in between.
	soils : mainly shallow and rocky
	landuse : maize fallows + bushes
4) Irregular upper	slope class: VI
	slope form : irregular, concave
	soils : arable land + bush
	landuse : shallow and rocky.
5) Lower slope	slope class: VII/VIII
	slope form : convex, short.
	soils : shallow, many rock-outcrops.
	landuse : dense bush-vegetation.
6) Gucha valley	valley type: V-shaped with knick point (type A) steep-sides gorges with very steep gradients near the river (> 70%)
	soils : shallow, rocky
	landuse : bush + some grazing land.
7) Irregular lower slope	slope class: II/III/IV/V
	slope form : slightly concave convex parts are largely defined by rhyolitic rock-outcrops (maximum angles of 20-25%).
	soils : mainly shallow and rocky
	landuse : maize fallows + bush
8) Upper slope	slope class: III
	slope form : slightly concave The segment form is defined by a small tributary of the Gucha, which have created a clear concavity in the upper part of the Gucha valley side.
	soils : deep + mod. deep
	landuse : arable land.

Ki-A3

1) Round summit	slope class: I/II/III
	slope form : convex
	soils : mainly shallow and rocky
	landuse : grazing land + shrubs

2) Upper slope	slope class:	VII
	slope form :	straight
	soils :	shallow and rocky
	landuse :	shrubs + some grazing land
3) Middle slope	slope class:	II
	slope form :	slightly concave, locally irregular.
	Locally small; rock-outcrops occur with slope gradients up to 25%.	
	vegetation :	dense shrub-vegetation.
4) Lower slope	slope class:	VI
	slope form :	irregular
	Rock-outcrops and ridges (invaded dykes of quartz-porphyrite) on the main-slope.	
	soils :	mainly shallow
	landuse :	shrubs + grazing land
5) Gucha valley	valley type:	A - V-shaped with sharp knick.
	presence of slightly concave valley-bottom in which the incised Gucha is streaming.	
6) Lower slope	slope class:	IV/V
	slope form :	concave
	soils :	mod. deep/shallow
	landuse :	arable land + shrubs (steep parts).
7) Upper slope	slope class:	II/III
	slope form :	slightly convex

Ki-A4

1) Upper slope	slope class:	II/III
	slope form :	slightly convex
	Locally small outcrops with dense shrub-vegetation; mainly grazing land.	
2) Lower slope	slope class:	II
	slope form :	slightly concave
	as segment 1	
3) Terrace (?)	slope class:	I
	slope form :	flat, convex where incised.
	landuse :	grazing land
4) Gucha valley	valley type:	B (V-shaped without sharp knick, slightly incised river with smooth transitions to flat-lying terraces (segment 3 + 5)
	landuse :	grazing land.

5) Terrace (?)	as segment 3	
6) Slope	slope class:	III
	slope fomr :	concave
	soils :	?
	landuse :	grazing land + some arable land.
7) Round summit	slope class:	I/II
	slope form :	convex
	landuse :	grazing land / arable land.

<u>Tributary B- Ki-B</u>

1) Slope (Gucha valley)		
2) Round summit	slope class:	I
	slope form :	slightly convex
	soils :	mod. deep (rhyolite)
	landuse :	natural grazing land
6+10) Laterite capped summit	slope class:	I/II
	slope form :	typical 'stepped' slopes, indicating the different layers (5-10%); edges are convex, consisting of outcropping laterite.
	soils :	very shallow or absent.
	vegetation :	shrubs + grazing land; clump-grasses on poorly drained parts.
11) hydromorphic depressions	slope class:	I
	slope form :	flat
	It comprises bare, laterite-controlled, convex slopes (5-15%), surrounding the depressions (0-3%).	
	soils :	grey hydromorphic gleysols with plinthite layers in the sub-soil near the edges of the depression.
	vegetation :	natural grazing land with 'clump' trees (termite-mounds).
5+7+9+11+13+15+18)	slope class:	II ---> III
	slope form :	convex
Slopes	Only locally outcropping laterite-layers occur.	
	soils :	shallow / mod. deep/deep well to somewhat excessively drained sandy clay loams.
	landuse :	arable land + grazing land + shrubs.

Otange area: see Appendix 2 (description of mapping units).

vertical scale 1:6000

horizontal scale 1:25,000

vertical exaggeration 4.15 x

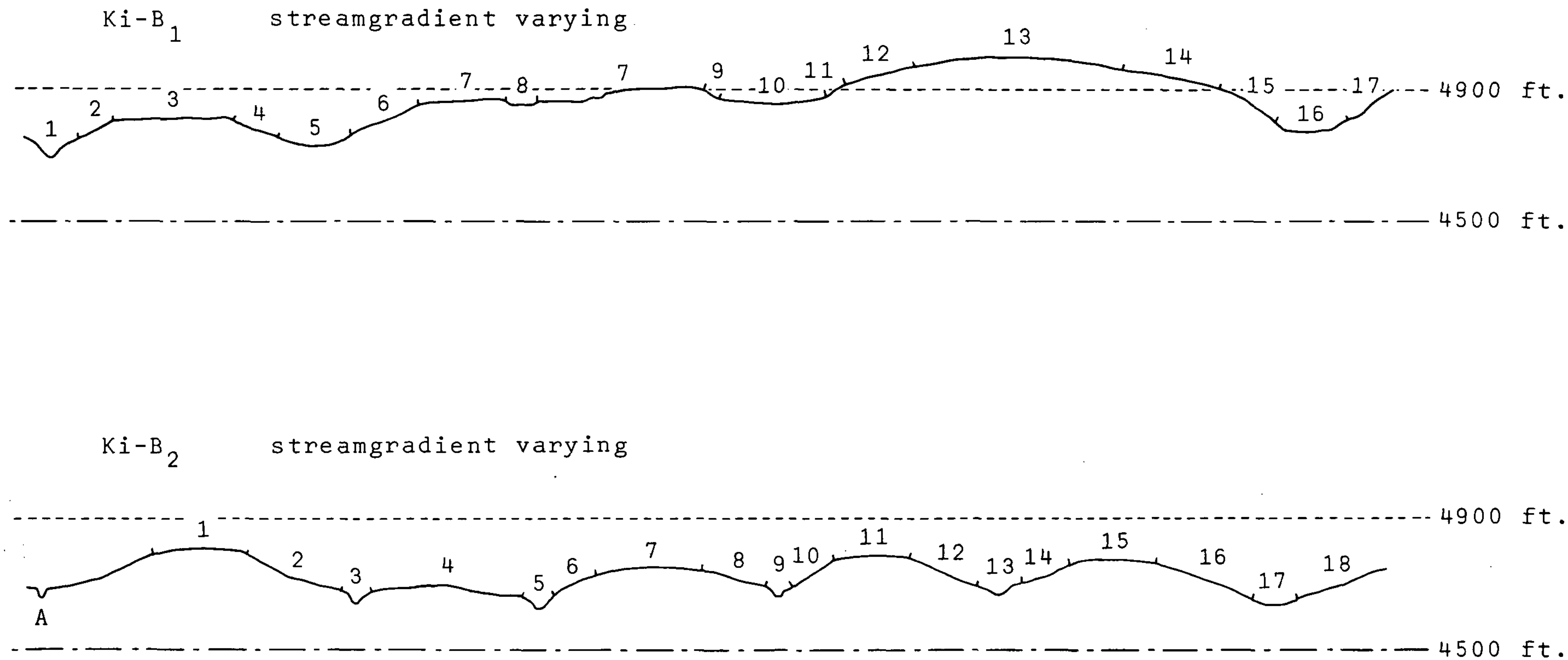


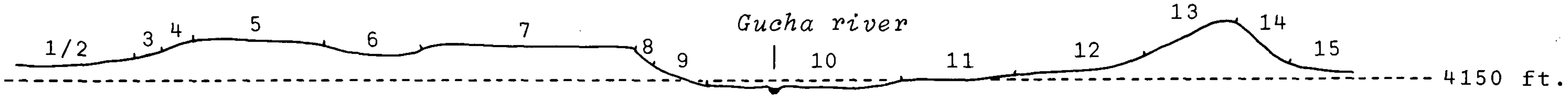
Fig. 14 Cross-profiles VI/VII tributaries at Kitere

vertical scale 1:6000

horizontal scale 1:25,000

vertical exaggeration 4.15 x

Ot-I streamgradient < 0.03%



Ot-II streamgradient <0.03%

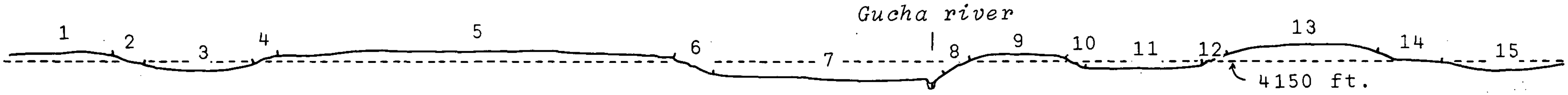
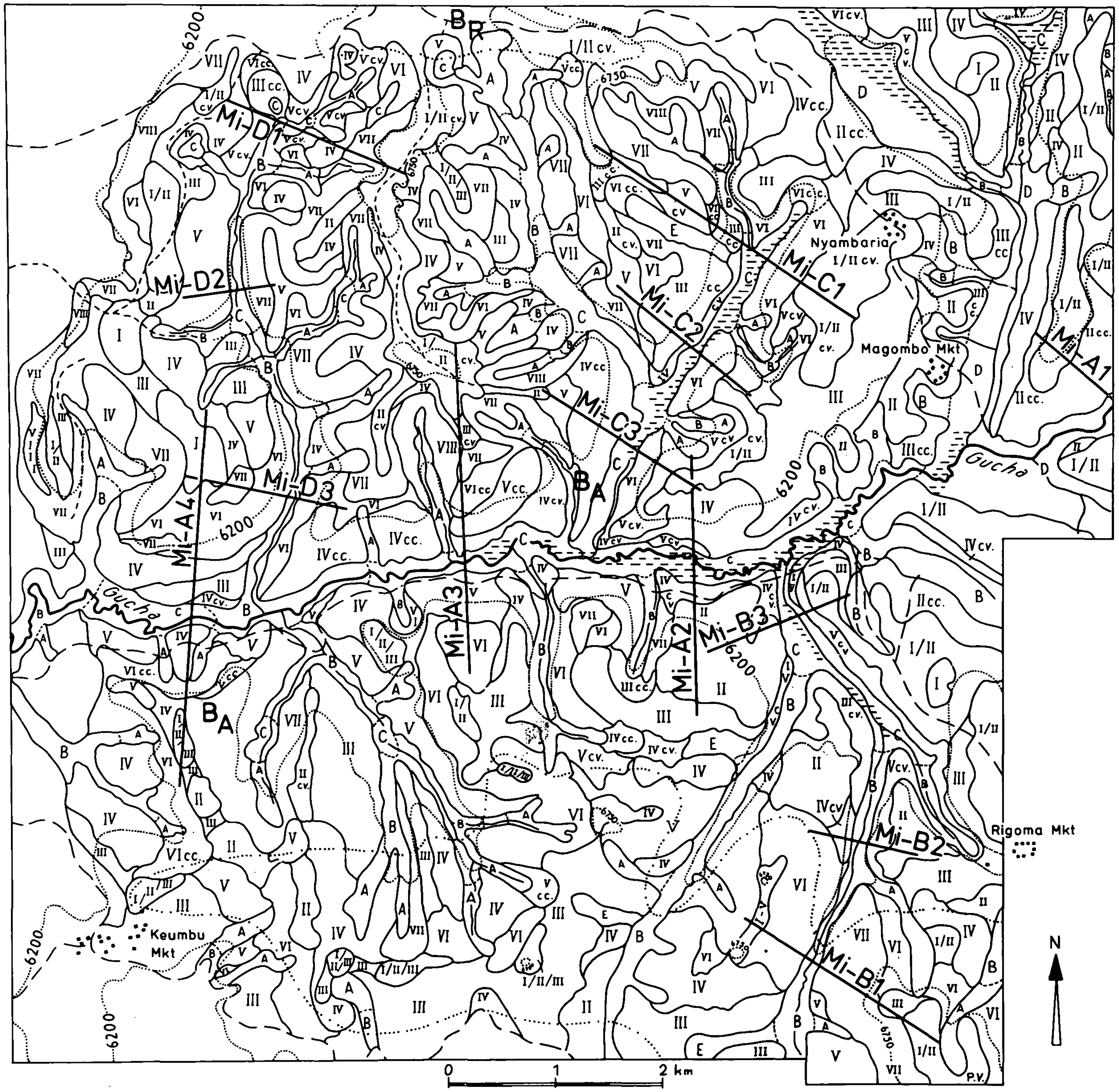


Fig. 15 Cross-profiles VIII/IX — Gucha at Otange



SLOPE MAP of the MIRIRI AREA

Appendix 4
P.R. No 14

SLOPE CLASSES

I	-	0- 5%
II	-	5-10%
III	-	10-15%
IV	-	15-20%
V	-	20-25%
VI	-	25-30%
VII	-	30-40%
VIII	-	40% or more

cv. = convex.
cc. = concave
if no suffix is added, slopes are straigt or nearly straight.

VALLEY TYPES

Type A	V-shaped, narrow valleys with straight and steep valley sides.
Type B	Incised valleys; steep, convex valley sides and narrow swampy floors.
Type C	Flat floored incised valleys, steep convex valley sides and broad flat swampy floors.
Type D	Flat floored concave valleys; asymmetric concave or straight valley sides with broad flat and swampy floors.
Type E	Concave shallow gullies.

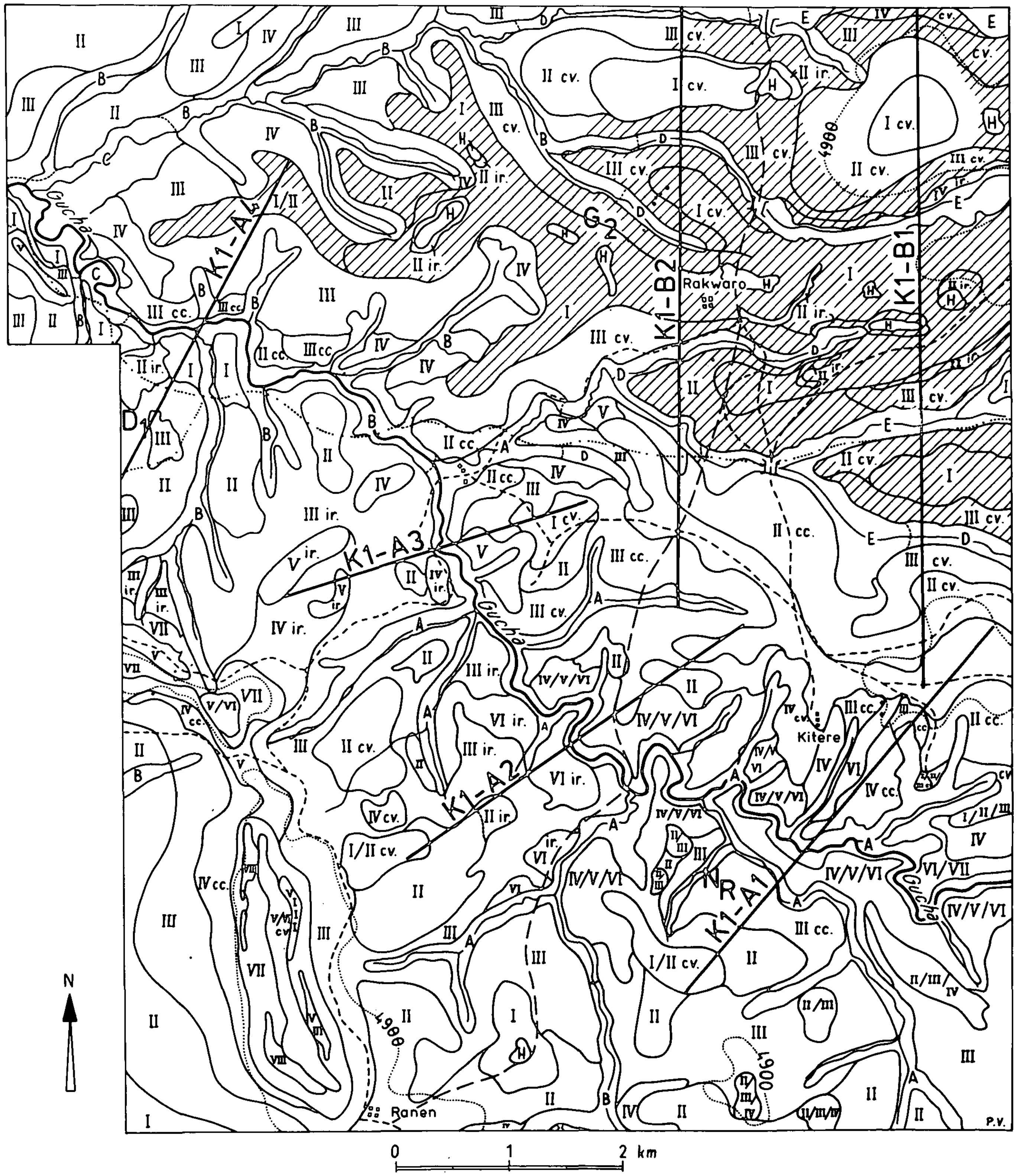
LITHOLOGY

B_R - Rhyolite (Bukoban)

B_A - Andesite (Bukoban)

Symbols:

- boundary of mapping unit.
- main road
- track
- village
- lithological boundary
- 6200–6750. contourline (feet)
- swamp
- River
- tributaries
- Mi-B1 cross section



SLOPE MAP of the KITERE AREA

Appendix 5
P. R. No 14

SLOPE CLASSES:

I	-	0- 5%
II	-	5-10%
III	-	10-15%
IV	-	15-20%
V	-	20-25%
VI	-	25-30%
VII	-	30-40%
VIII	-	40% or more

cv. = convex
cc. = concave
ir. = irregular
if no suffix is added, slopes are straight or nearly straight.

H = hydromorphic depression

VALLEY TYPES

Type A	V-shaped valleys with knickpoint in the valley sides; narrow sharp valley and straight, abruptly steepening valley sides.
Type B	V-shaped valleys without knickpoint in valley sides; rather wide and shallow valley, valley sides smooth with gentle slopes.
Type C	Flat floored concave valleys; swampy flat valley floor with gentle concave valley sides; meandering streams.

Valley types controlled by lateritic duricrusts:

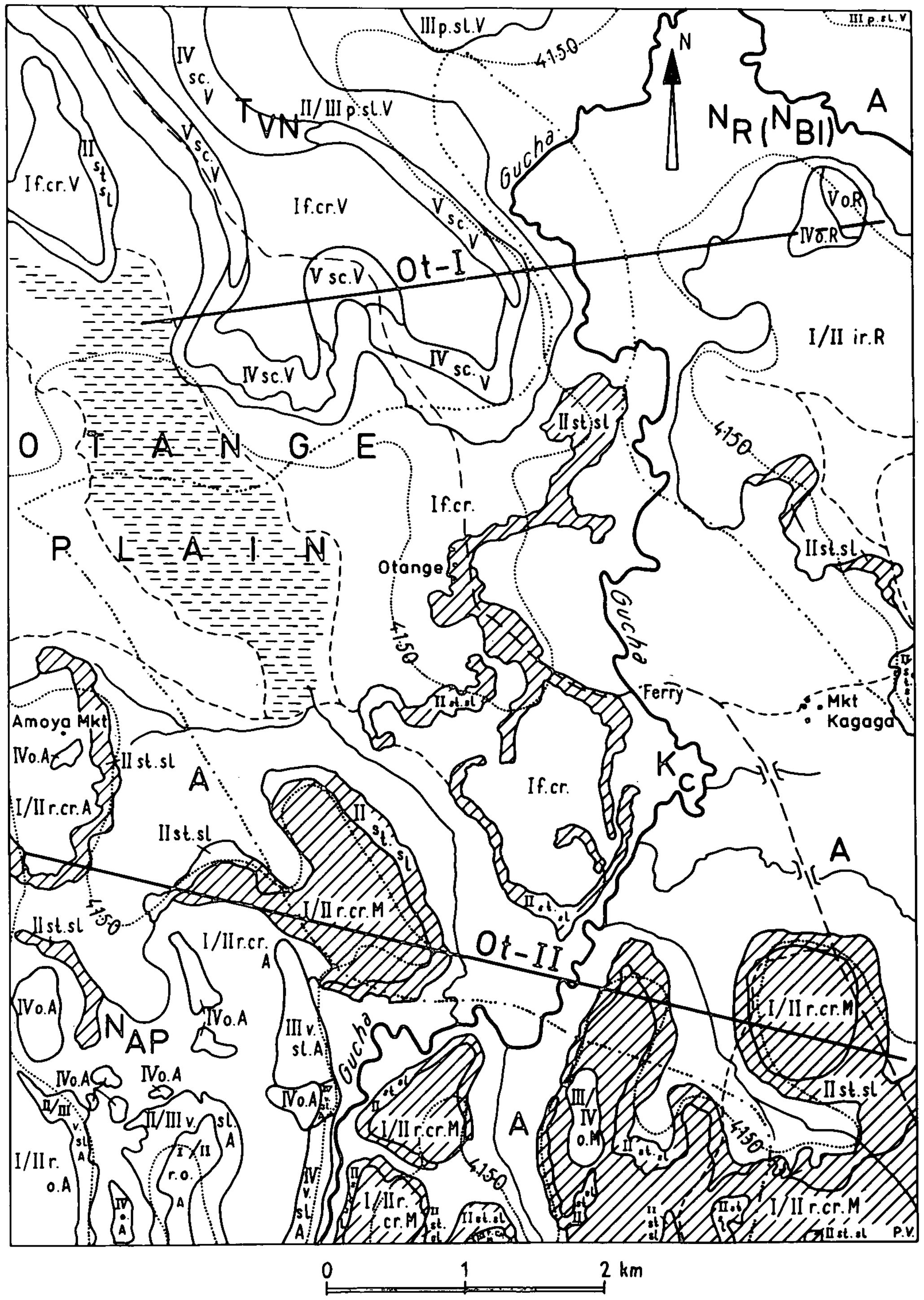
Type D	Incised valleys with swampy floors; rather wide swampy valleys (weakly concave) with rather steep convex valley sides, controlled by outcropping laterite layers.
Type E	Broad concave valleys; very wide swampy valleys (up to 350 meter) with weakly convex valley sides, formed in outcropping laterite; concave valley sides, if laterite is absent.

LITHOLOGY

N_R - Rhyolitic lavas and tuffs (Nyanzian)
G_2 - Kitere granite (fine-grained)
D_1 - Dolerite

Symbols:

boundary of mapping unit
main road
track
village
lithological boundary
4900 contourline (feet)
presence of duricrust (laterite)
River
tributaries
K1-A1 cross section



SLOPE MAP of the OTANGE AREA

Appendix 6
P. R. No 14

EXPLANATION TO THE LEGEND

f.cr.	-	flat crest
r.cr.	-	round crest
o.	-	outcrop (rock-)
sc.	-	scarp
p.sl.	-	piedmont (foot-) slope
st.sl.	-	'stepped' slope
v.sl.	-	valley slope

I	-	0- 5%
II	-	5-10%
III	-	10-15%
IV	-	15-20%
V	-	20-25%

A	-	porphyritic andesite
R	-	rhyolite
V	-	volcanic rock (nephelintes)
M	-	mixed rock (nephelintes+ andesites).

MAPPING UNITS

I-f.cr.V	Nearly flat plateau; slightly convex to the edges; developed on nephelinites.
I/II-r.cr.A I/II-r.cr.R	Gently sloping convex crests with locally small torlike outcrops; slopes do not exceed 12%.
I-f.cr.	Flat crest plain, bordered by laterite crusts; locally swamps are present; slopes do not exceed 3%.
I/II-r.cr.M	Gently sloping convex crests without outcrops and tors; presence of laterite crusts.
II-st.sl.	Gently sloping 'stepped' slopes, controlled by horizontally stratified laterite layers; slopes are ranging from 5-9%.
II/III-p.sl.V	Concave piedmont slope, smooth forms; maximum gradients of 14%.
III/IV/V -o.A III/IV/V -o.R	Moderately steep rock-outcrops and tors with straight rocky slopes
III/IV/V -v.sl.A	Sloping to moderately steep convex valley slopes (Gucha)
III/IV/V -sc.V	Sloping to moderately steep convex-straight-concave scarp (boulder-controlled).

LITHOLOGY

N_{AP}	- Porphyritic andesites (Nyanzian)
N_r (N_{BI})	- Rhyolites with banded ironstone (Nyanz.)
K_c	Conglomerates (Kavir.)
T_{VN}	- Nephelinites (Tertiary)

Symbols:

- boundary of mapping unit
- main road
- track
- village
- lithol.boundary
- 4150 contourline (feet)
- laterite (crust)
- swamp
- River
- tributaries
- Ot-I cross section