African Study Monographs, Supplementary Issue 2: 15–44, March 1984

GEOLOGY OF THE NACHOLA AREA AND THE SAMBURU HILLS, WEST OF BARAGOI, NORTHERN KENYA

Takeshi MAKINOUCHI
Faculty of Science and Technology, Meijo University
Takehiro KOYAGUCHI
Faculty of Science, University of Tokyo
Takaaki MATSUDA
Department of Geology, Himeji Institute of Technology
Hiromi MITSUSHIO
Faculty of Science, Kochi University
Shiro ISHIDA
Faculty of Science, Kyoto University

ABSTRACT The Nachola area, about 15 kilometres west of Baragoi, is underlain by Precambrian Basement Complex, above which come the Nachola Formation of Miocene age, undifferentiated, probably Pleistocene basalts and Alluvium, in ascending order (Figs. 3, 4 and 6). The Nachola Formation consists of basaltic lavas and clastic sediments. *Kenyapithecus* occurs in the Nachola Formation.

The Samburu Hills, about 30 kilometres west of Baragoi, are underlain by the Aka Aiteputh, Namurungule, Kongia, Nagubarat, and Tirr Tirr Formations, grey silts and fluviatile sediments, in ascending order (Figs. 3, 4 and 8). The Aka Aiteputh, Kongia, Nagubarat and Tirr Tirr Formations are mainly composed of accumulations of basaltic and trachytic lavas. The Namurungule Formation is of late Miocene age and consists of tuffaceous alternations of sand and mud with intercalations of mud-flow deposits. The Samburu hominoid, a late Miocene hominoid fossil, occurs in the basal part of the Namurungule Formation (Figs. 9, 10, 11, 12 & 13).

The lower part of the Nachola Formation is correlated with the lower part of the Aka Aiteputh Formation.

Many faults, trending nearly N-S, cut the volcanics and sediments in the Samburu Hills and Nachola area (Figs. 14 and 15). These faults form synthetic (western margin of the Samburu Hills) and antithetic fault systems accompanying the tectonic line along the eastern border of the Suguta valley.

INTRODUCTION

A scientific survey for researching late Tertiary hominoid fossils and their palaeoenvironments supported by a Grant-in-Aid for Scientific Research (Overseas Scientific Survey) of the Japanese Ministry of Education, was carried out in the Samburu Hills and the Nachola area from August to October, 1982 (Fig. 1). This survey followed one in Kirimun District (Ishida, H. and Ishida, S. eds., 1982), south-southeast of Maralal, central Kenya, in 1980.

The fields investigated, which are underlain by basalt and trachyte lava flows containing intercalated clastic sediments, are about 30 kilometres west (Samburu Hills) and about 15 kilometres west (Nachola area) of Baragoi.

During the surveys, Tertiary hominoid fossils were collected, the Samburu hominoid in the Samburu Hills and *Kenyapithecus* in the Nachola area. These represent the first discoveries of Hominoidea by a Japanese overseas expedition.

In this paper, we describe the geology of the Nachola area, the Samburu Hills and their surroundings.

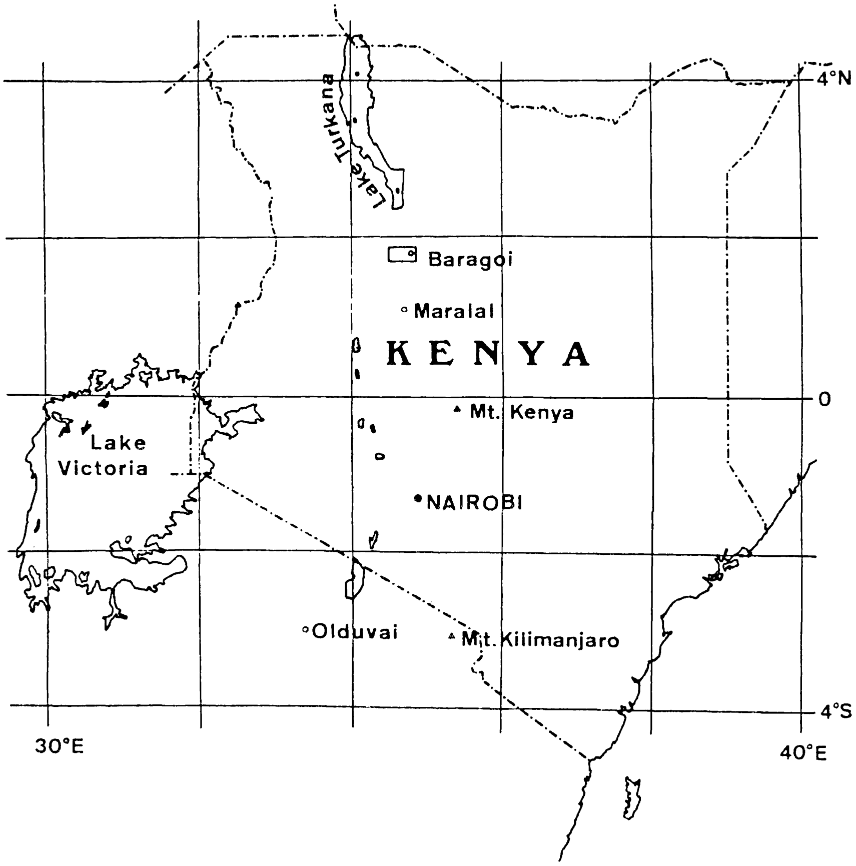


Fig. 1. Index map of the Nachola area and the Samburu hills, west of Baragoi. The surveyed area is enclosed in a quadrangle.

GEOLOGICAL OUTLINE

The Samburu Hills are bounded to the east by the El Barta plains and to the west by the Suguta valley. The El Barta plains have a gently undulating topographic surface with altitudes ranging from 1,300 to 1,500 metres. This surface is the sub-Miocene peneplain, and is underlain by Precambrian Basement Complex (Mozambique Belt). The town of Baragoi is built on this peneplain. The Nachola area occupies the western periphery of the El Barta plains (Fig. 2). The Suguta valley, about 25 kilometres in width, is part of the Gregory Rift Valley, the eastern branch of the African Rift System. The flat bottom of the valley has an altitude of about 400 metres.

The Samburu Hills which lie between the higher El Barta plains to the east and the lower Suguta valley to the west are precipitous mountain lands declining in altitude westwards. They are comprised of lava flows and clastic sediments which dip westwards. Lava flows and clastic sediments of the Nachola area are horizontal or dip slightly to the west. Many normal faults downthrowing to the east and trending N-S in direction displace the lavas and sediments in the Nachola area and the Samburu Hills.

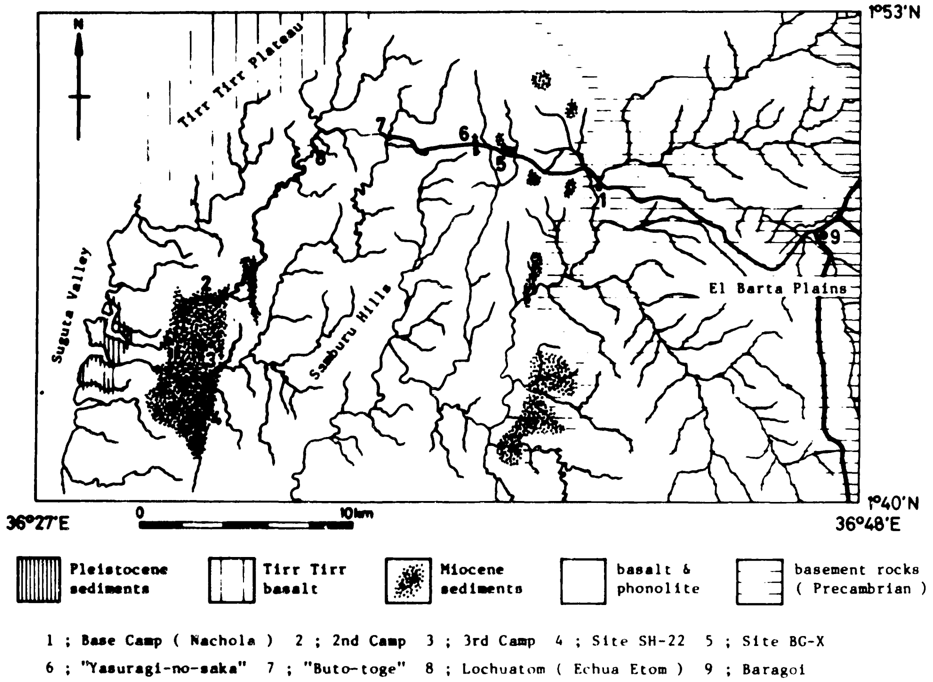


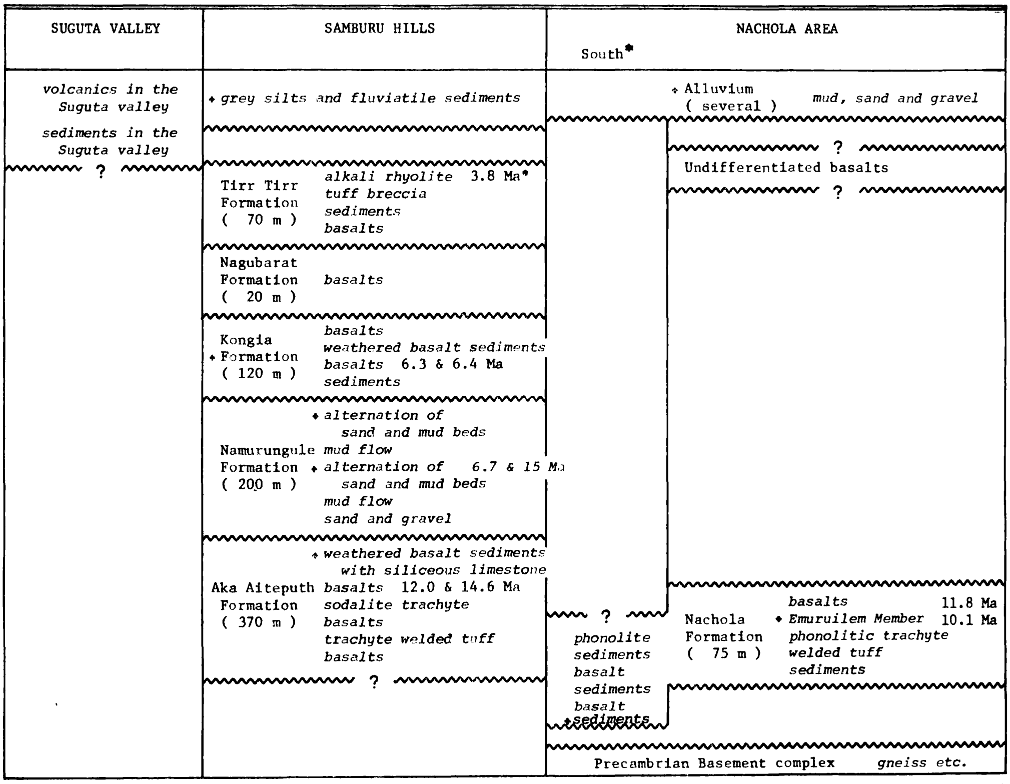
Fig. 2. Physiography and geologic outline of the Nachola area and Samburu Hills.

Precambrian Basement rocks constituting the El Barta plains are metamorphosed sedimentary and igneous rocks with migmatites and granitic intrusives derived from the metamorphic rocks by granitization (Baker, 1963).

Resting unconformably on the Precambrian metamorphic complex are Tertiary and Quaternary volcanic rocks and lacustrine and fluviatile sediments. These are stratigraphically summarized in Fig. 3.

The Nachola area is underlain by a succession of rocks comprising the Precambrian Basement Complex, the Nachola Formation, younger basalts which rest on the Basement and the Nachola Formation, and finally by alluvial sediments distributed along the Baragoi river and its tributaries. *Kenyapithecus*, a fossil hominoid, was collected from sediments in the Nachola Formation.

In the Samburu Hills, the stratigraphic sequence, in ascending order, is as follows: the Aka Aiteputh Formation overlain successively by the Namurungule, Kongia, Nagubarat and Tirr Tirr Formations. Grey silts occur intermittently on the underlying formations in the western margin of the area facing the Suguta valley. Fluviatile sediments occur along river courses. Precambrian Basement is not exposed in this area. The Namurungule Formation is composed of clastic sediments and yielded the fossil hominoid. The other formations consist mainly of volcanic rocks. Structurally, the Aka Aiteputh, Namurungule and Kongia Formations are closely controlled by normal faults which trend nearly N-S and downthrow to the east, forming westward tilting



♦ ; Fossil levels (PICKFORD et al, 1984) Numbers with Ma ; K-Ar ages (*Italic* ; F-T ages)(MATSUDA et al, 1984)
✱ ; ISHIDA and ISHIDA ed., 1982 • ; BAKER et al, 1971

Fig. 3. Stratigraphy of the Nachola area and Samburu Hills.

blocks. The Nagubarat and Tirr Tirr Formations rest unconformably on the underlying formations with gentle westward dips, and are less affected by faulting.

The floor of the Suguta valley is comprised of gravel and boulder beds forming outwash fans of the rivers draining into it. Several scoria cones with or without olivine basalt lava flows rest on the Suguta valley sediments. They are aligned along normal faults parallel to the long axis of the valley. Most scoria cones are ring-shaped hills up to 100 metres in basal diameter and a few tens

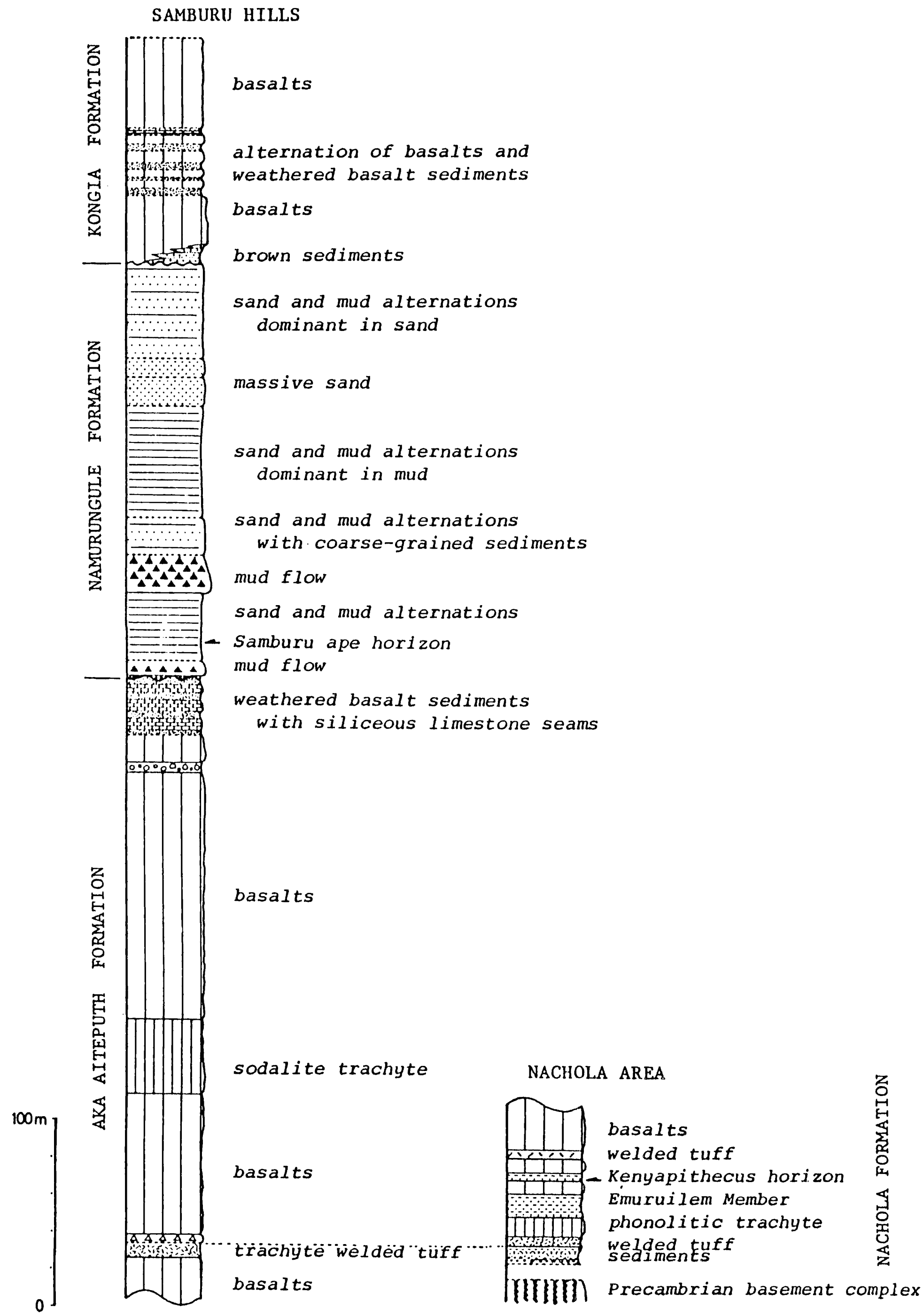


Fig. 4. Composite columnar sections of the Nachola, Aka Aiteputh, Namurungule and Kongia Formations.
The term of "Samburu ape horizon" in the middle part of the Samburu Hills column should read "Samburu hominoid horizon".

of metres in height. Their central depressions are filled with saline water. The scoria cones preserve their original topography very well and are considered to be of Recent age.

The lower part of the Nachola Formation is tentatively correlated with the lower part of the Aka Aiteputh Formation based on biostratigraphical and petrographical evidence (Pickford *et al*, 1984; Koyaguchi, 1984). K-Ar datings give ages of 12.0 Ma and 14.6 Ma for the top part of the Aka Aiteputh Formation and 6.3 Ma and 6.4 Ma for the lowest part of the Kongia Formation (MATSUDA *et al*, 1984). K-Ar ages of these formations are in agreement with the biostratigraphy (PICKFORD *et al*, 1984). Therefore, the Namurungule Formation yielding the Samburu hominoid is dated approximately between 13 Ma and 6 Ma, and is of late Miocene age.

K-Ar ages of the Nachola Formation are 10.1 Ma and 11.8 Ma (Matsuda *et al*, 1984). Values seem to be rather young in comparison with a preliminary age estimate made on a basis of limited faunal evidence (Pickford *et al*, 1984).

The composite columnar sections in the surveyed areas are summarized in Fig. 4.

GEOLOGY OF THE NACHOLA AREA

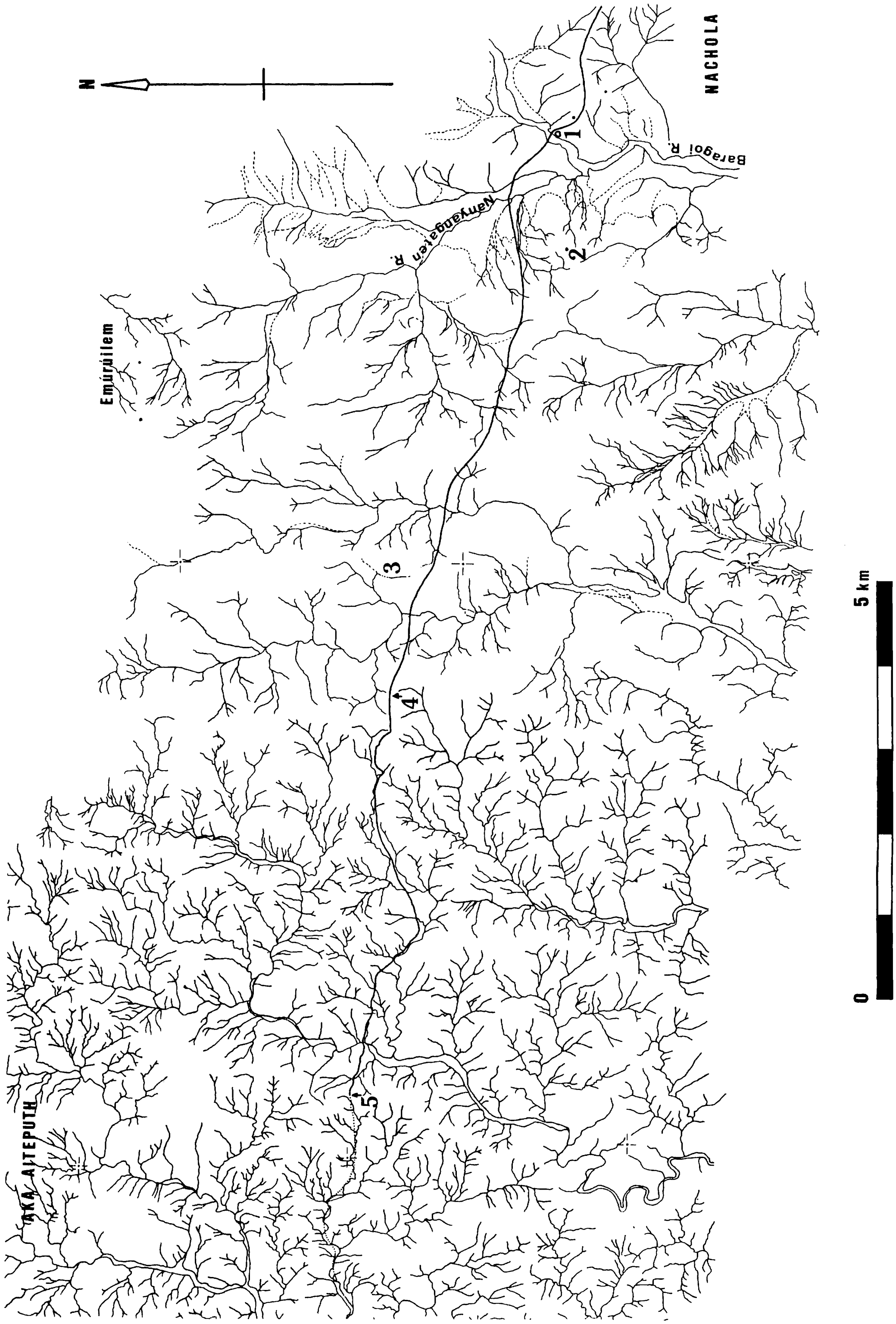
The Precambrian Basement Complex outcrops to the east of the Baragoi and Nanyangaten rivers. In the western part of Nachola, a sequence of volcanics and clastic sediments unconformably covers the Basement to the west of the Baragoi and Nanyangaten rivers (Figs. 5 and 6). This sequence is called the Nachola Formation. Basaltic lava flows which rest unconformably on the Basement Complex and the Nachola Formation occur both in the eastern part of Nachola and in the Emuru Akirim plateau about 20 kilometres north of Nachola. The stratigraphic relationships of these basalts remain unclear. Alluvial sediments occur along the river courses of the Baragoi and Nanyangaten.

Nachola Formation

The Nachola Formation consists in ascending order of clastic sediments (Unit 1), phonolitic trachyte with trachyte welded tuff at the base (Unit 2), clastic sediments and interbedded basalts (Unit 3), and basaltic rocks with an intercalation of welded tuff (Unit 4). The total thickness exceeds 75 metres. The Nachola Formation is horizontal or dips slightly westwards and is cut by normal north-south faults which downthrow to the east. Generally, the upper horizons outcrop further west than the lower horizons.

In the Nachola area, Baker (1963) classified four geologic units, namely, sub-volcanic sediments (Tm_1), porphyritic basalts and tuffs (Tvb_1), phonolites of the Rumuruti Phonolites (Tvp) and porphyritic olivine and augite basalts (Tvb_2). These are all included within the Nachola Formation in this papers.

Fig. 5. Drainage patterns and locality names in the Nachola area. 1: Base Camp, 2: the small isolated hill near the confluence of the Baragoi and Nanyangaten rivers, 3: *Kenyapithecus* site (Site BG-X), 4: "Yasuragi-no-saka", field name in Japanese meaning "a slope for relaxing" in English, 5: "Buto-toge", field name in Japanese meaning "sand fly pass" in English.


N
NACHOLA
Baragoi R.
Nanyangaten R.
Emuruilem
AKA AITEPUTH
1
2
3
4
5
5 km
0

(Unit 1) The clastic sediments comprising the lowest part of the Nachola Formation are composed of pebble bearing medium-grained sand at the base, pale orange coloured medium-grained sand in the middle and greenish tuffaceous silt at the top. Pebbles in the gravels at the base are derived from the Basement Complex. This succession, which is less than 10 metres thick, is observed about 3 kilometres west of the confluence of the Baragoi and Nanyangaten rivers. The same horizon is also exposed along the western side of the Nanyangaten river.

(Unit 2) Phonolitic trachyte with trachyte welded tuff occurs in the middle part of the Nachola area, and is also exposed in a small outcrop in the river bed of the Nanyangaten near the confluence with the Baragoi river. The lava is 10 to 15 metres thick. Long prismatic anorthoclase phenocrysts and vesicles are prominent on weathered pale grey surfaces of the phonolitic trachyte. A welded tuff bed, 5 metres thick, occurs at the base. This is greyish green coloured and shows eutaxitic texture with dark green pumice lenses. Prismatic sanidine phenocrysts are observed megascopically.

(Unit 3) Clastic sediments containing interbedded basalts are exposed in and around a small isolated hill near the confluence of the Baragoi and Nanyangaten rivers. This member also occurs to the north near a hill called Emuruilem, so we call this unit the Emuruilem Member of the Nachola Formation. The Emuruilem Member consists of (a) lower sediments, (b) middle basalt lava flows and (c) upper sediments. The lower sediments are well observed around the small isolated hill and near Site BG-X. Around the small isolated hill, the lower sediments (Unit a) 11 metres thick are composed of medium-grained sand with intercalations of tuffaceous silty beds in the middle part and gravelly beds in the lower part. Gravels in the lower part are derived from the Basement Complex. The middle basalt lavas (Unit b) are 5 to 8 metres thick. They are substantially aphyric with rare olivine, pyroxene and plagioclase phenocrysts. At Emuruilem, the upper sediments (Unit c) which are 4 metres thick are pale green coloured tuff in the lower part, a cherty bed containing silicified wood in the middle part, and white tuff in the upper part. This is the *Kenyapithecus* horizon at Site BG-X. The silified woods are observed by the thin section to be broad-leaved trees like the genus *Acacia*.

(Unit 4) Basaltic rocks with welded tuff comprise the uppermost part of the Nachola Formation and overlie the Emuruilem Member. They extend to the western and northern parts of the Nachola area, and form higher hills or mountain land with low-relief towards the west, in comparison with the lower volcanics which form gently undulating hilly land in the east. The thickness of this unit is more than 20 metres. Most of the lavas are aphyric to porphyritic olivine basalts, but ankaramites occur rarely. At Emuruilem, basalts above the Emuruilem Member are also exposed. The interbedded welded tuff bed is about 2 metres thick, and outcrops in the lower part of the long east facing slope of the motorable road ("Yasuragi-no-saka", field name in Japanese, meaning "slope for relaxing") about 1 kilometre west of Site BG-X. The welded tuff is coloured white to pale green, and shows weak welding. The tuff presents an eutaxitic texture and contains transparent sanidine crystals.

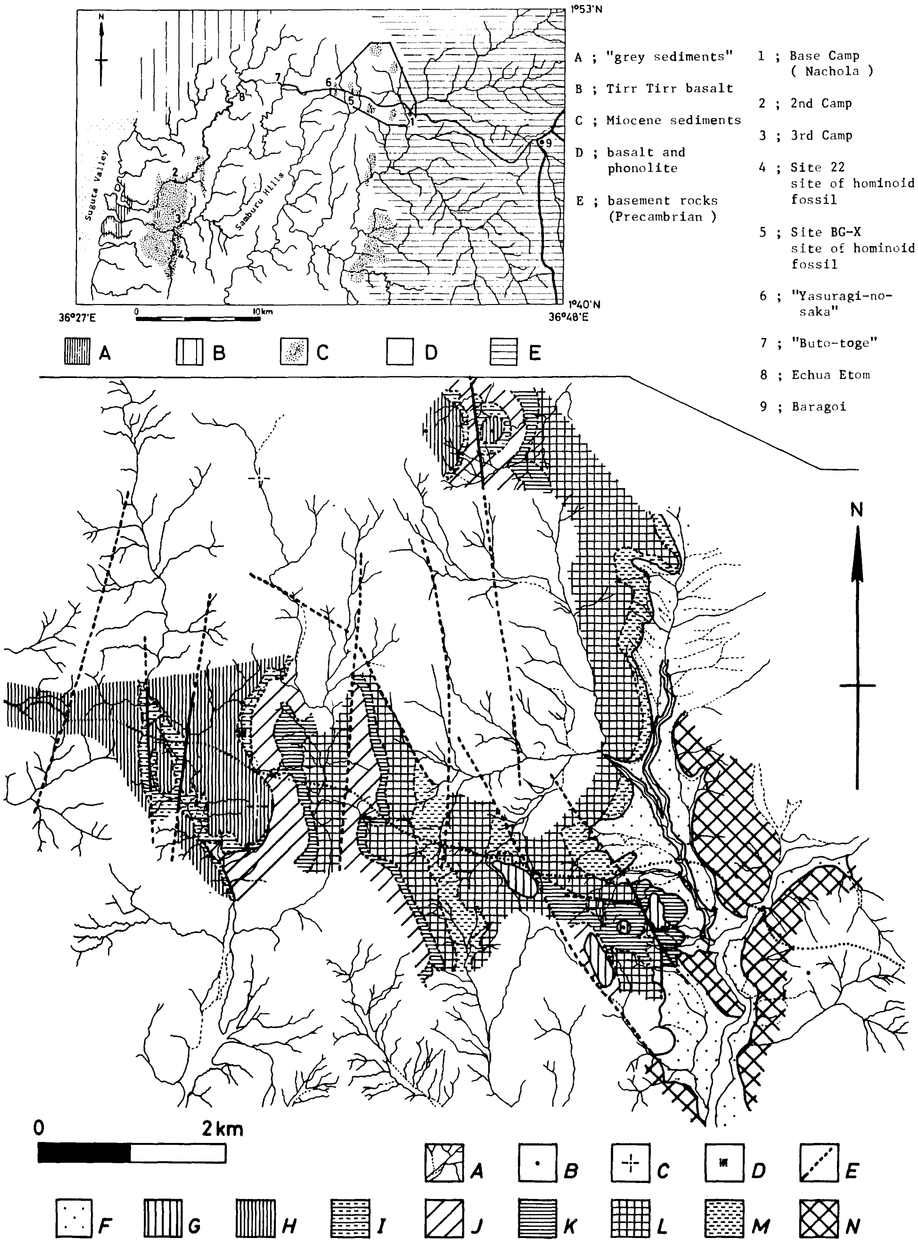


Fig. 6. Geologic map of the Nachola area. A: drainage patterns, B: isolated hill top, C: centre of air photograph, D: *Kenyapithcus* site, E: fault, F: fluvial terrace deposits (Alluvium), G: undifferentiated basalt, H-M: Nachola Formation, H: basalt above the Emuruilem Member (Unit 4), I: upper sediments of the Emuruilem Member, J: basalt intercalated within the Emuruilem Member, K: lower sediments of the Emuruilem Member, L: phonolitic trachyte (Unit 2), M: clastic sediments (Unit 1), N: Precambrian Basement Complex.

Description of the *Kenyapithecus* site (Site BG-X)

The *Kenyapithecus* site (Site BG-X) is situated in the western part of the Nachola area, about 5 kilometres west-northwest of the confluence of the Baragoi and Nanyangaten rivers. Just south of the site, a motorable road from Baragoi passes toward the Samburu Hills from Nachola. The sequence, from phonolitic trachyte (Unit 2) at the base to the basalt above the Emuruilem Member (Unit 4), dips gently westward (a few degrees), and forms a tilted fault-block.

The phonolitic trachyte outcrops along a tributary of the Baragoi river in the east. Basalt lavas in and above the Emuruilem Member form a small scale cuesta topography. The lower sediments in the Emuruilem Member around Site BG-X show the following succession from the base to top; pale green coarse-grained sand with trachyte granules in the base (5 metres thick), green fine-grained sand (1 metre), alternation of white fine-grained sand and pale grey tuffaceous silt (1 metre), green tuffaceous clay (2 metres), and pumiceous sand (2.5 metres). The lower sediments strike N-S and dip 2 to 5 W. A Fission-track dating sample was collected from the top pumiceous sand. The basalt above the lower sediments is about 7 metres thick, and gives a K-Ar date of 10.1 Ma.

The upper sediments show the following sequence from the base to top; pale yellow tuffaceous silt with silicified wood in the top (60 centimetres thick), pale grey pumiceous medium-grained sand (40 centimetres), pale grey silt with abundant pumice (30 centimetres), pale grey coarse-grained sand with scoria in the base (50 centimetres), and silicified sediments (2 metres). *Kenyapithecus* occurred in the basal bed which is 60 centimetres thick. A Fission-track dating sample was collected from the 30 centimetres thick pumice rich bed. The silicified sediments at the top of the sedimentary sequence seem to have been baked by heat from the overlying basalt lava flow, because the sediments are purplish or pinkish brown to grey in colour, and are very hard. The upper sediments strike N 15°E and dip 2°W.

The basalt above the Emuruilem Member is about 9 metres thick, and yielded a K-Ar age of 11.8 Ma.

Undifferentiated Basalts

Undifferentiated basalts probably of Pleistocene age occur sporadically at and around a small isolated hill near the confluence of the Baragoi and Nanyangaten rivers. The basalt constituting the top of the small isolated hill is a representative one, 6 metres thick, and overlies the lower sediments of the Emuruilem Member of the Nachola Formation. It is characterized by fresh and yellow olivine phenocrysts several millimetres in size which sit in a hard black matrix. The basalt also occurs at a hilltop about 1 kilometre west-northwest of the small isolated hill, where it overlies the phonolitic trachyte of the Nachola Formation. This basalt also forms a small platform immediately southwest of the small isolated hill. Just to the east of the hill occurs a reversed fault with a northwest trend. The western block has moved upward relative to the eastern block.

About 5 kilometres east of Nachola to the north of the Baragoi-Nachola motorable road, basalt makes small outliers of lava lying directly on the Precambrian Basement Complex. The lava sheet occurs mainly on the northern side of the Baragoi river at an altitude of about 1,380 metres, about 80 meters above the bed of the river (Baker, 1963). It is dark grey coloured and contains small amounts of plagioclase, clinopyroxene and olivine phenocrysts.

Another basalt lava flow forms the flat top of the Emuru Akirim plateau, about 20 kilometres north of Nachola. It is dark grey to black coloured and includes clinopyroxene and subordinate olivine phenocrysts. The lava flow is about 7 metres thick at Lekodi, where it lies directly on the Basement Complex. A basaltic lava flow near Tum, about 15 kilometres north of Lekodi, which constitutes the Emuru Akirim plateau is petrographically different from that at Lekodi.

Among the three stratigraphically undifferentiated basalts described above, the former two occur in a restricted area near Nachola, while the latter is widespread in distribution. Lava flows in the Emuru Akirim plateau and to the east of Nachola have a nearly flat upper surface, and are not deeply dissected. From topographical and stratigraphic points of view, these basalts are inferred to be not so old, in comparison with those of the Nachola Formation.

Flat lying basalt lavas to the west of Nachola look fresh, and make small platforms which are topographically distinguishable from the underlying basalt lavas which outcrop as cuestas. The basalt lavas west of Nachola have been affected by north-south faulting. The relative stratigraphic position of these basalt lavas cannot be precisely settled. However, we think they are younger than the Nachola Formation, and tentatively correlate them with the basalts east of Nachola.

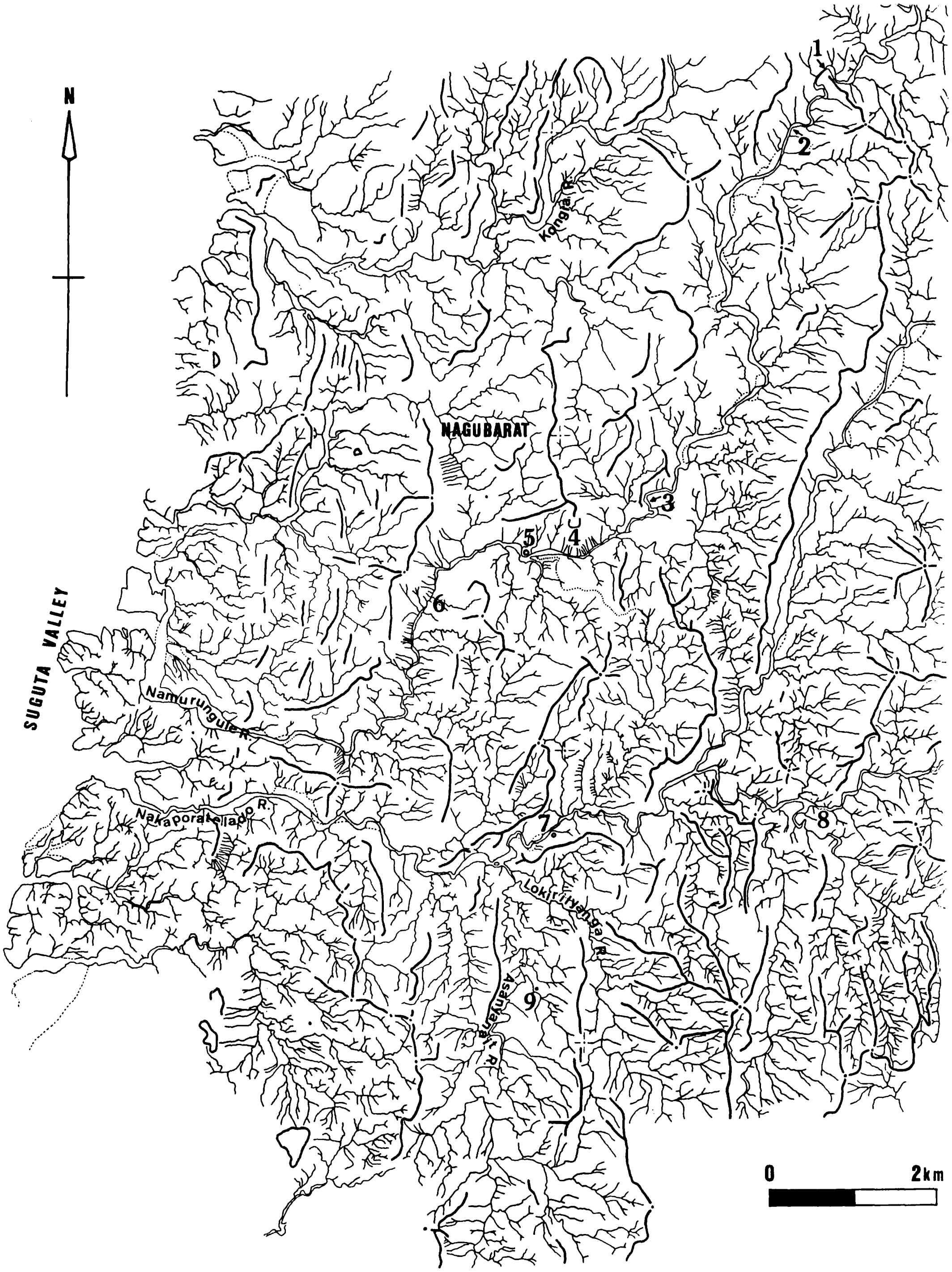
Alluvium

Alluvial sediments occur along river courses of the Baragoi and its tributaries. Along the banks of the Baragoi river, occur brown fine-grained soil-like weathered materials with pebble gravels in the base. They form a fluvial terrace, about 5 metres above the river bed. The base camp at Nachola was located on this terrace. Along the tributaries, braided streams have incised the flood-plain to a depth of one to a few metres. Brown fine-grained sediments and pale brown sands outcrop in the walls of the channels. Pebble gravels of volcanic and Basement Complex rocks are included in the alluvium.

GEOLOGY OF THE SAMBURU HILLS

The Samburu Hills are mainly underlain by an accumulation of basalt and trachyte lava flows with intercalations of clastic sediments (Figs. 7 and 8). Thick interbedded clastic sediments which yielded a late Miocene hominoid fossil, the Samburu large hominoid, are called the Namurungule Formation. Volcanics unconformably underlying the Namurungule Formation are termed the Aka Aiteputh Formation while volcanics which unconformably overlie the Namurungule Formation are called the Kongia Formation. The Nagubarat Formation rests with angular unconformity on the Aka Aiteputh and Namurungule Formations. About 20 kilometres northwest of Nachola, volcanics of the Tirr Tirr Formation form the Tirr Tirr plateau. Patches of grey silts and fluviatile sediments rest unconformably on the underlying formations in the western periphery of the Samburu Hills facing the Suguta valley, and along the river courses of Namurungule and Nakaporatelado luggas (dry river beds).

In the Samburu Hills area, Baker (1963) described five geologic units, namely, the Rumuruti Phonolites (Tvf & Tvp), lake beds and interbedded volcanics (Tm_2), porphyritic olivine and augite basalts (Tvb_2) and alkali trachytes with basalts at the base (Tvt). Among these, Tm_2 coincides with the Namurungule Formation. Tvt in the Tirr Tirr plateau corresponds nearly with the Tirr Tirr Formation, while Tvb_2 is here divided into the Aka Aiteputh, Kongia and Nagubarat Formations. The lower part of the Aka Aiteputh Formation may include rocks previously assigned to the Rumuruti Phonolites (Tvf and Tvp).


N
NAGUBARAT
Kangia R.
SUGUTA VALLEY
Namurungule R.
Nakaporatelado R.
Lokitityanga R.
Asanyanait R.
1
2
3
4
5
6
7
8
9
0
2km

Aka Aiteputh Formation

The Aka Aiteputh Formation occurs mainly in the eastern half of the Samburu Hills area. The lithostratigraphic sequence is well observed along the upper reaches of the Nakaporatelado and its tributaries, east of the third camp. In this section, the Aka Aiteputh Formation shows the following succession;

(6) Weathered basalt sediments	(ca. 40 metres thick)
(5) Basalts	(130 m)
(4) Sodalite trachyte	(40 m)
(3) Basalts	(75 m)
(2) Trachyte welded tuff	(13 m)
(1) Basalts	(70+m)

The estimated total thickness is about 370 metres.

Among these, the sodalite trachyte and trachyte welded tuff are useful key horizons. Being cut by normal north-south faults which downthrow to the east, these rocks outcrop repetitively.

(1) The basalts below the trachyte welded tuff consist of at least six lava flows. Most of them are dark coloured porphyritic and aphyric basalts, but a few are hawaiites characterized by abundant plagioclase phenocrysts.

(2) The trachyte welded tuff is composed of at least two cooling units. The lower cooling unit, 8 metres thick, is weakly welded and shows a pinkish to pale purplish red colour. This cooling unit can be further divided into several flow units. Each of the flow units is several tens of centimetres to 5 metres thick. The upper cooling unit, 5 metres thick, is densely welded and displays a brick-red colour which is unique in the Samburu Hills. The trachyte welded tuff is megascopically characterized by its reddish colour and abundant sanidine phenocrysts.

(3) The basalts above the trachyte welded tuff are composed of more than 7 lava flows, which are mostly dark coloured aphanitic olivine basalts with small amounts of clinopyroxene and olivine phenocrysts. This member includes thin intercalations of clastic sediments.

(4) The sodalite trachyte exhibits various colours, from greenish to pinkish, which are unique in the Samburu Hills, differing markedly from the dark coloured lavas. The lava flow strikes N 20° E, and dips 20° NW. This rock is megascopically characterized by a conspicuous lineation due to parallel arrangement of anorthoclase laths in the groundmass.

Fig. 7. Drainage patterns and locality names in the Samburu Hills. 1: the First fall (field name), 2: the Third fall (field name), 3: road end (field name), 4: volcanic neck of the Nagubarat Formation, 5: the Second Camp, 6: narrow gorge toward the south-southwest in the middle stretches of the Namurungule river, 7: the Third Camp, 8: a tributary of the Nakaporatelado river east of the third camp, 9: Samburu hominoid site (Site SH-22).

(5) The basalts above the sodalite trachyte consist of at least thirteen lava flows which strike N 20° to 35° E, and dip about 20° NW. Most of them show aphanitic texture, but a few are porphyritic basalts with clinopyroxene and olivine phenocrysts.

(6) The weathered basalt sediments are characterized by weathered basaltic materials with intercalations of lava flows, siliceous limestone and chert beds. The weathered materials are dark brown to reddish brown fine-grained soil-like sediments. A proportion of these were probably produced *in situ*. The reworked portions of the succession contain rock fragments, and possess slight stratification. The siliceous limestone and chert beds, several tens of centimetres to a few metres thick, occur as outstanding white bands within the brown weathered basalt sediments of cliff surfaces. Rubbly and blocky siliceous limestones form white blankets where they outcrop on ground surface. The interbedded basalts are olivine basalts containing small amounts of clinopyroxene and olivine phenocrysts.

Along the Lokirilyanga river, a tributary of the Nakaporatelado river, the Aka Aiteputh Formation is exposed. The weathered basalt sediments, the top part of the formation, outcrop in the downstream part, while the lower part of the formation outcrops upstream. Their contact is a fault with a N-S trend. This fault has an exceptional downthrow to the west, which is estimated to be about 200 metres. To the east of the fault, the lower part of the Aka Aiteputh Formation shows the following succession;

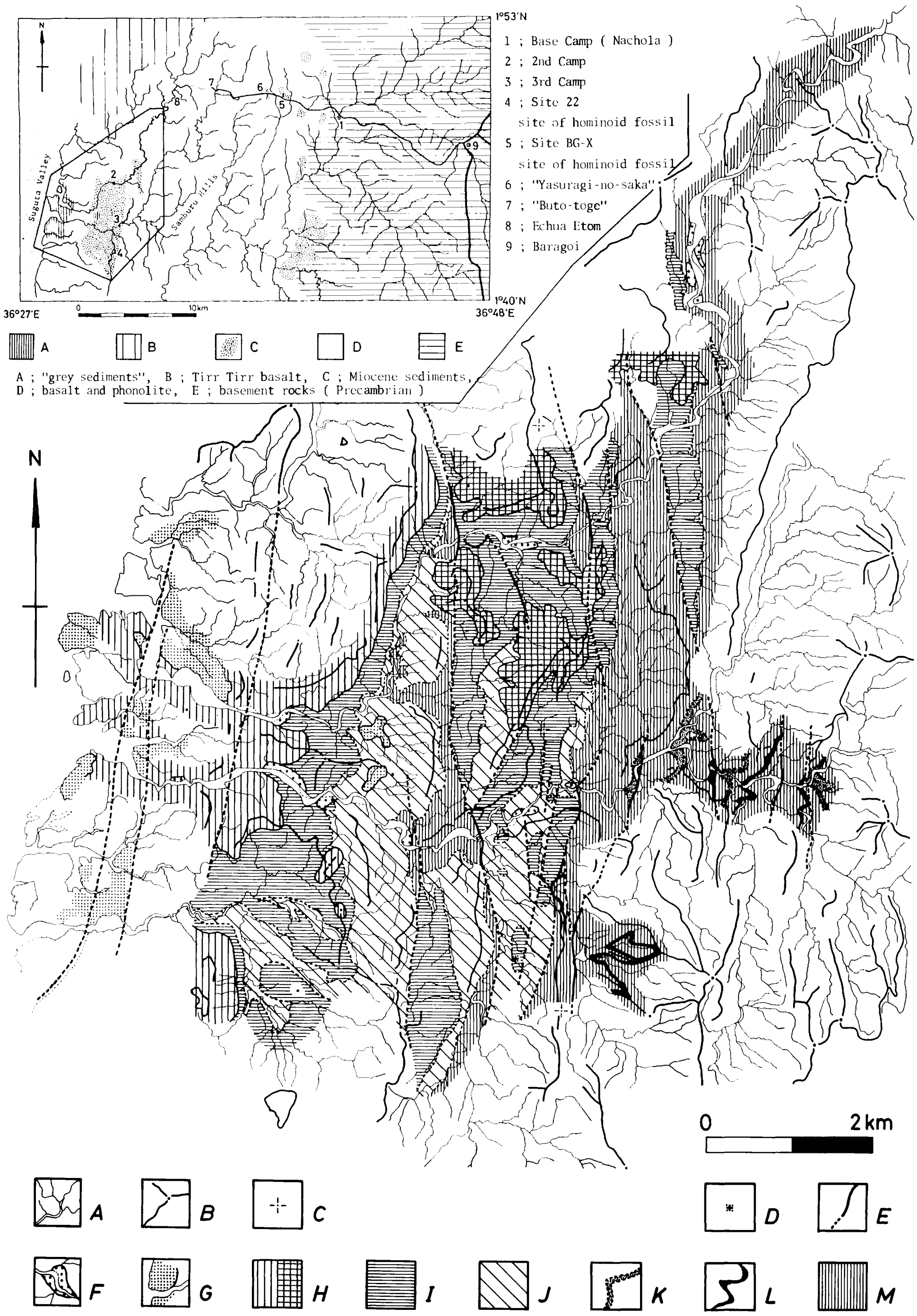
(3) Basalt	(10 metres thick)
(2) Trachyte welded tuff	(25 m)
(1) Basalts	(5+m)

Most of the lower basalts (1) are olivine basalts with small amounts of clinopyroxene and olivine phenocrysts. However, rare ankaramites also occur. The trachyte welded tuff (2) is correlated with that in the upper course of the Nakaporatelado river. The lower cooling unit reaches up to 20 metres thick. On the western wall of the Lokirilyanga valley, there is a cliff on which the welded tuff bed thins out southwards. The upper basalt (3) is aphyric olivine basalt.

Along the Asanyanait river, another tributary of the Nakaporatelado river the weathered basalt sediments (the top part of the Aka Aiteputh Formation) are exposed. Site SH-22, the Samburu hominoid site, is located in the upper reaches of this river.

In the middle reaches of the Nakaporatelado river, the upper weathered part of the Aka Aiteputh Formation is exposed. Rubbly and blocky siliceous limestones forms white blankets on the dip slopes of westward tilted fault blocks.

Fig. 8. Geologic map of the Samburu Hills. A: drainage patterns, B: ridge, C: centre of air photograph, D: Samburu hominoid site (Site SH-22), E: fault, F: fluvial terrace sediments, G: grey silts, H: Kongia Formation (mesh pattern: Nagubarat Formation), I: Namurungule Formation, J-M: Aka Aiteputh Formation, J: weathered basalt sediments with intercalations of siliceous limestone, chert and basalt lava, K: sodalite trachyte, L: trachyte welded tuff, M: basaltic rocks.
Southwestern part of the Nagubarat Formation distributed in the northwest to the second camp should be corrected the Kongia Formation.


1°53'N
1 ; Base Camp (Nachola)
2 ; 2nd Camp
3 ; 3rd Camp
4 ; Site 22
site of hominoid fossil
5 ; Site BG-X
site of hominoid fossil
6 ; "Yasuragi-no-saka"
7 ; "Buto-toge"
8 ; Echua Etom
9 ; Baragoi
1°40'N
36°27'E
36°48'E
10km
Suguta Valley
Samburu Hills
A ; "grey sediments", B ; Tirr Tirr basalt, C ; Miocene sediments,
D ; basalt and phonolite, E ; basement rocks (Precambrian)
N
0
2km
A
B
C
D
E
F
G
H
I
J
K
L
M

In the upper reaches of the Namurungule river, the Aka Aiteputh Formation is composed of an accumulation of flows of porphyritic and aphanitic basalt. The weathered basalt sediments, sodalite trachyte and trachyte welded tuff observed along the Nakaporatelado section do not outcrop. The thickness cannot be estimated in this section, because such key horizons as the trachytes of the Nakaporatelado section are not observed here. Aphanitic basalt generally occurs in the upper part and porphyritic types in the lower part.

At the end of the motorable track in Namurungule lugga, more than 15 lava flows of porphyritic and aphyric olivine basalts and rare ankaramites outcrop. Each lava flow is a few to ten metres thick.

In the vicinity of the First and Third falls (field names), and at Lochuatom (Echua Etom), lava flows and sills of porphyritic and aphyric olivine basalt and ankaramite occur. The ratio of sills to lava flows attains a maximum around Lochuatom. These lava flows and sills are frequently intruded by nearly vertical basaltic dikes in the upper reaches of the Namurungule river, many of which trend northwest.

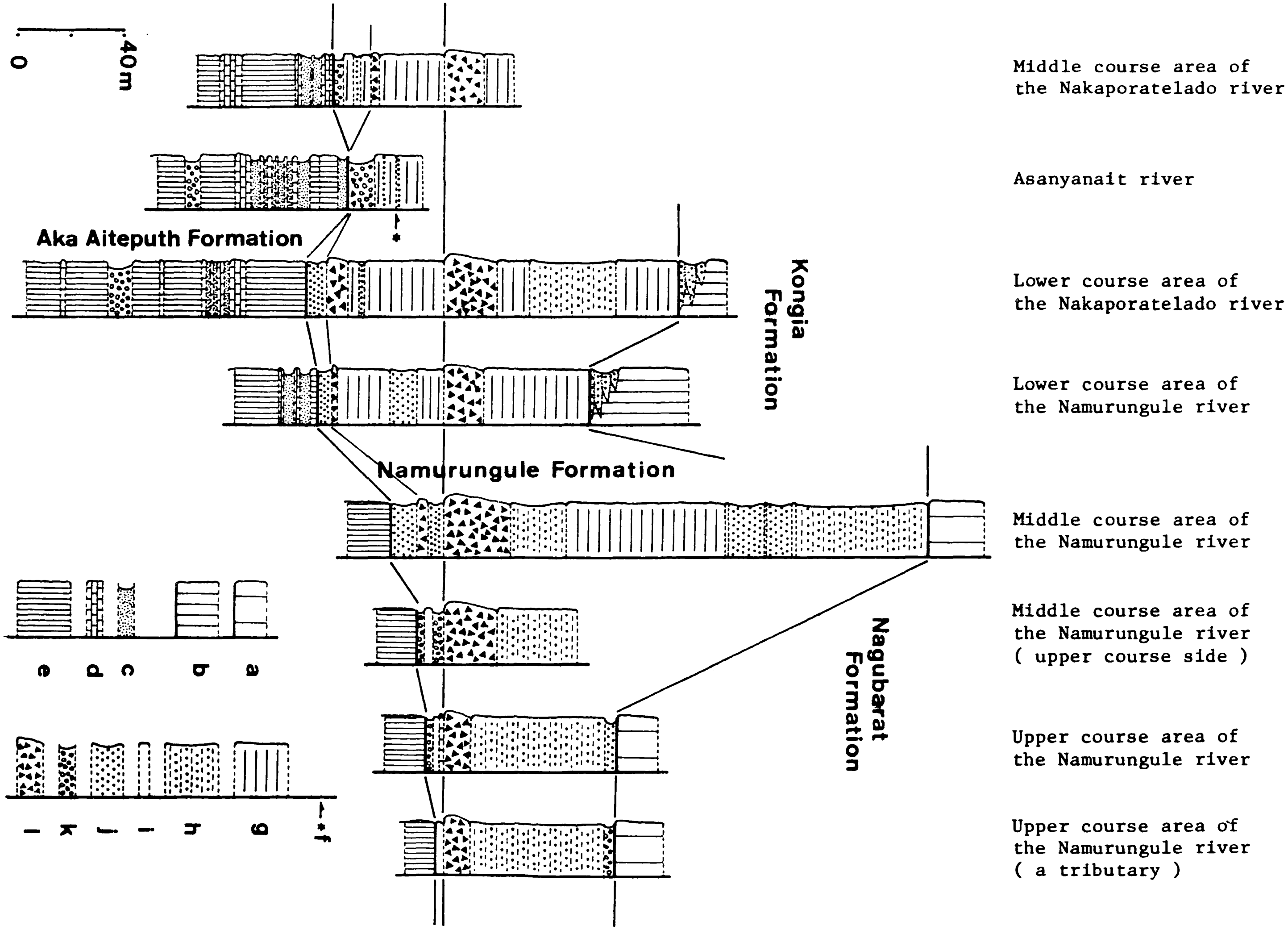
Along the middle stretches of the Namurungule river, where the river passes through a narrow gorge running south-southwest, the weathered basalt sediments and underlying aphanitic basalt lavas of the Aka Aiteputh Formation are exposed in both walls of the gorge. K-Ar dating samples were collected here, and gave values of 12.0 ± 1.0 Ma and 14.6 ± 1.2 Ma (Matsuda *et al*, 1984).

In general, the weathered basalt sediments, comprising the top part of the Aka Aiteputh Formation, are thicker in the south (Nakaporatelado section) and thinner or absent in the north (Namurungule section).

Namurungule Formation

The Namurungule Formation has three zones of exposure, the eastern, middle and western, separated by normal north-south faults which downthrow to the east. The eastern zone of exposure occurs in the upper stream course of the Namurungule river, the middle and western zones along the middle and lower stream courses of the Namurungule and Nakaporatelado rivers, respectively.

Fig. 9. Columnar sections of the Namurungule Formation. a: basalt of the Nagubarat Formation, b: basalt of the Kongia Formation, c: weathered basalt sediments, d: siliceous limestone and chert, e: basalt of the Aka Aiteputh Formation, f: horizon of the Samburu hominoid, g: sand and mud alternation dominant in mud, h: sand and mud alternation dominant in sand, i: mud, j: sand, k: gravel, l: mud-flow.


0
40m
Aka Aiteputh Formation
Kongia Formation
Namurungule Formation
Nagubarat Formation
e d c b a
l k j i h g *f
*
Middle course area of the Nakaporatelado river
Asanyanait river
Lower course area of the Nakaporatelado river
Lower course area of the Namurungule river
Middle course area of the Namurungule river
Middle course area of the Namurungule river (upper course side)
Upper course area of the Namurungule river
Upper course area of the Namurungule river (a tributary)

The type sequence is observed in the middle stretches of the Namurungule river near the second camp (the middle zone of exposure), as follows (Fig. 9):

(8) Sand and mud alternation dominant in sand (50 metres thick)
(7) Massive sand (25 m)
(6) Sand and mud alternation dominant in mud (60 m)
(5) Sand and mud alternation containing coarse-grained materials (20 m)
(4) Mud-flow (25 m)
(3) Sand (5 m)
(2) Mud-flow (5 m)
(1) Coarse-grained sand (10 m)

The estimated total thickness is about 200 metres.

The coarse-grained sand (1) at the base contains brown volcanic granule gravels. The lower mud-flow (2) includes lapilli and is pale reddish brown in colour. The matrix is medium- to coarse-grained tuffaceous material. Sand bed (3) consists of coarse-grained sand with pebbles and intercalations of pale brown silt seams. The upper mud-flow (4) is pale brown to reddish brown in colour, and contains abundant volcanic boulders up to 5 metres in maximum diameter. They are comprised mostly of rhyolitic rocks but basaltic rock types also occur. The upper part of the upper mud-flow becomes pyroclastic in facies and is pale green in colour. Sedimentary boulders which were scooped up from underlying sediments also occur in the mud-flow, and in places the underlying strata have been deformed by the mud-flow. The matrix is coarse- to medium-grained tuffaceous material and is well consolidated. The sand and mud alternation containing coarse-grained materials (5) is composed of coarse-grained sand beds and tuffaceous silt beds. The sand and mud alternation dominant in mud stone (6) consists of tuffaceous silt beds and fine-grained sand beds. The fine-grained sand beds contain coarser fractions with granules and fine pumices. Each of the beds in this unit is one to several tens of centimetres in thickness. The massive sand (7) has interbedded pale coloured silt seams in the base, middle and top. The sand and mud alternation dominant in sand (8) includes granule to pebble gravels and muddy clasts within sand beds. Generally, the sediments display good stratification and are dominantly tuffaceous in facies. The sediments are at their thickest in this section, and strike N 20° – 40° E and dip 10° – 20° NW. Thecolour is brown in this section, but in other sections they are pale green in colour. The exposure extends southwards to the northern bank of the Nakaporatelado river.

Just to the east (upstream) from the above mentioned section, the eastern margin of the middle zone of exposure, the Namurungule Formation outcrops along the Namurungule river. The upper mud-flow, here about 20 metres thick, forms a narrow pass or gorge in the river. Below the mud-flow, a pale coloured gravel bed overlies basalts of the Aka Aiteputh Formation. The gravel bed is 10 metres thick and has an intercalated white silt bed. Above the mud-flow, brown coloured alternations of sand and mud, about 30 metres thick, outcrop and are bounded on the west by a north-south fault with downthrow of about 100 metres to the east. The sediments strike N 5° E and dip 20° W, but at the fault they dip eastwards.

About one kilometre upstream from the end of the motorable track the Namurungule Formation of the eastern zone is exposed. In this section, the upper mud-flow, 10 metres thick, covers basalts of the Aka Aiteputh Formation being accompanied by thin gravelly and silty beds below. Alternations of dark grey coarse-grained sand and pale greyish brown silt overlie the mud-flow and are about 50 metres thick.

Along the lower course of the Namurungule river, the western zone of exposure of the Namurungule Formation, the upper mud-flow, 15 metres thick, occurs in the middle horizon. Pale green coloured tuffaceous alternations of sand and mud overlie the upper mud-flow. Their total thickness is estimated to be 40 metres. The pale green coloured tuffaceous alternations (10 metres thick), greenish massive sand (10 metres), pale green tuffaceous alternations (20 metres), and the lower mud-flow (2 metres) in descending order, underlie the upper mud-flow. The sequence between the upper and lower mud-flows becomes thicker than that of the type section, 40 metres in this section and 5 metres in the type area. The sediments strike N 10° – 30° E and dip 10° – 20° NW. The dip tends to become gentler towards the west. At the west end of the exposure, brown sand, white silt, and volcanics of the Kongia Formation unconformably cover the pale greenish alternations of the Namurungule Formation.

In the lower course of the Nakaporatelado river, another exposure of the western zone, the Namurungule Formation is estimated to be 125 metres thick, and has a sequence in ascending order consisting of the lower mud-flow (8 metres thick) near the base, pale green coloured alternations of tuffaceous sand and mud (30 metres) with a red sand bed in the lower part, the upper mud-flow (20 metres), pale green alternations of tuffaceous sand and mud (12 metres), alternations of mud and brown sand (33 metres), and pale green alternations of tuffaceous sand and mud (22 metres) at the top. Each bed of the alternations is a few tens of centimetres in thickness. Sand beds of the alternations contain fine pumices, but the brown sand beds of the alternations in the upper parts of the sequence include granule gravels instead of pumices. The upper mud-flow is reddish brown in the main part and pale green in the upper part. The sediments strike N 20° – 30° E and dip 10° – 15° NW. The dips become gentler in the western end of the exposure. The relationship to the overlying formation resembles that seen in the lower course of the Namurungule river.

In the middle reaches of the Nakaporatelado river, the Namurungule Formation rests on the weathered basalt sediments of the Aka Aiteputh Formation which form westward tilting fault blocks. The strata represented in this area range from the lower mud-flow to just above the upper mud-flow. The upper and lower mud-flows are 15 and 2 metres thick respectively. The sequence between the two mud-flows shows similar facies to that of the western zone of exposure and is about 25 metres thick. The strike and dip of the sediments are variable, reflecting the attitude of fault blocks.

Description on the large hominoid site (Site SH-22)*

The large hominoid site, Site SH-22, is situated near the upper reaches of the Asanyanait river, a tributary of the Nakaporatelado river. The site is about 1.5 kilometres south (upstream) of the confluence of the two rivers. Topographically, the site is part of a small elongated ridge running northwards between two tributaries of the Asanyanait river (Fig. 10). The sediments of the Namurungule Formation constitute the upper part of a fault block and below by the weathered basalt sediments of the Aka Aiteputh Formation.

*Geological units (2), (3), (4), (5) and (7) in the text correspond with the legends J, I, H, G and F in Fig. 12, respectively.
Geological unit (1) corresponds with the legend K and is shown in the left part of the figure, and (8) also correspond with K and is shown in the right part of the figure.

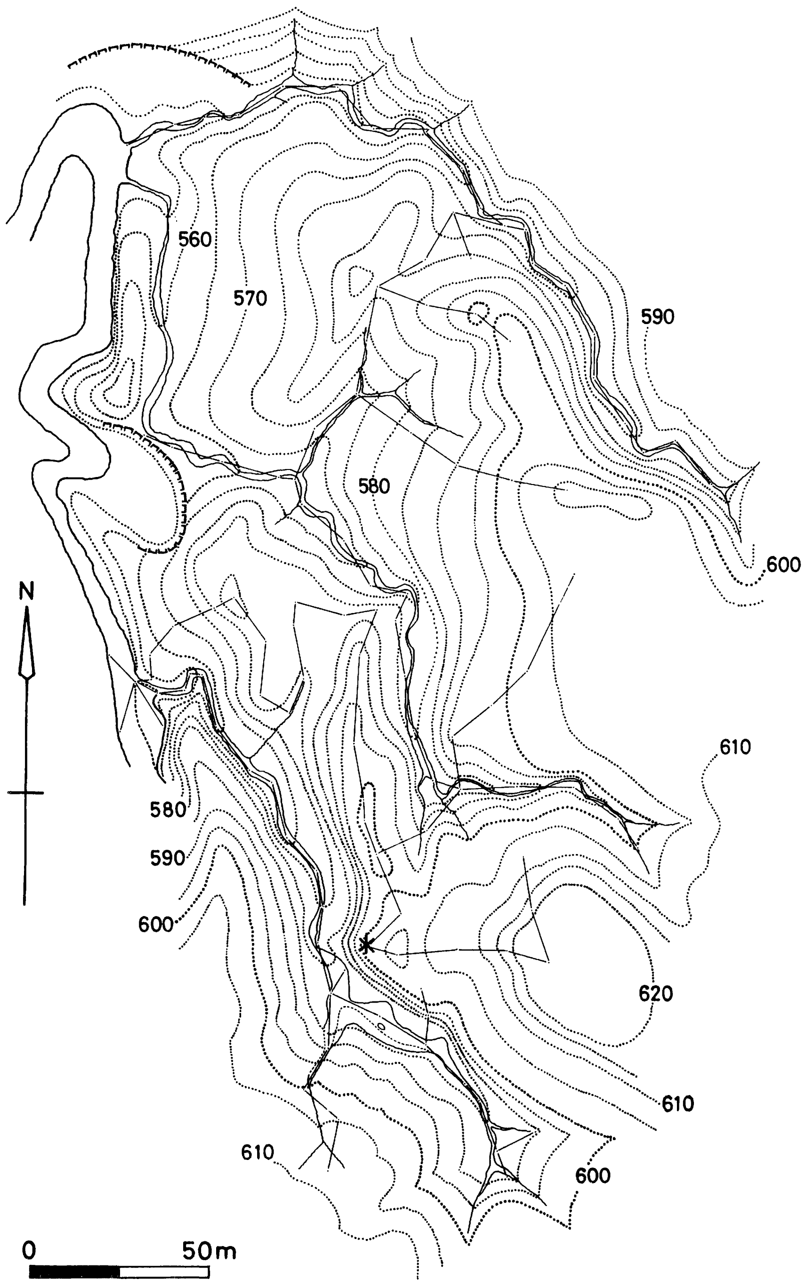


Fig. 10. Topography around the Samburu hominoid site (SH-22). The site is indicated by a asterik in the lower part of the figure (Height in metres)

The stratigraphic sequence at the site and its surroundings is tabulated as follows (Figs. 11, 12 & 13).

(8) Basalt debris		
Namurungule Formation		
(7) Alternations of sand and mud	(11 metres thick)	Legend F in Fig. 12
(6) The fossil horizon		
(5) Fine-grained sand and mud	(5 m)	G
(4) Tuffaceous fine-grained sand	(3 m)	H
(3) Sand and gravel	(10 m)	I
Aka Aiteputh Formation		
(2) Weathered basalt sediments	(4 m)	J
(1) Basalt lavas		

The total thickness of the sediments of the Namurungule Formation at the site is about 30 metres.

(1) The lava flows belonging to the top part of the Aka Aiteputh Formation are composed of purplish to black coloured porphyritic olivine basalts and ankaramites. They contain olivine and clinopyroxene phenocrysts.

(2) The weathered basalt sediments are composed of weathered basalt materials with intercalated siliceous limestone and chert beds. The weathered materials show soil-like facies and are brown in colour. Siliceous limestone and chert beds are very hard and several tens of centimetres thick.

(3) The sand and gravel occupies the basal part of the Namurungule Formation. Gravels form the bulk of this unit and are comprised predominantly of rhyolitic rocks with a few basaltic types. The clasts, ranging from several centimetres to 1 metre in diameter, are angular to subangular. The gravel beds are ill-sorted. The matrix shows brownish to greenish colour, and is well consolidated at the base. At the northern end of this area, a red coloured cobble bed, which is cemented by a tuffaceous matrix, occurs near the base of the sediments, and shows similar facies to the mud-flow.

(4) The fine-grained tuffaceous sand includes green coloured crystals and granules, and show a characteristic outcrop surface with many roundish concretions a few tens of centimetres in diameter. This unit is traceable to the horizon above the lower mud-flow in sections exposed in the middle stretches of the Nakaporatelado river.

(5) Fine-grained sand and mud forms rough alternations and contain granules in the base.

(6) The fossil horizon is a brown coloured bed with angular mud clasts, cemented by calcareous matrix, about 20 centimetres thick. Alternations of pale yellow tuffaceous silt and pale grey silt, 1.2 metres thick, underlie the fossil bed. Just above the fossil bed, occurs a granule bearing tuffaceous fine-grained sand bed, 30 to 40 centimetres thick. Above this comes a granule to small pebble bearing coarse-grained sand bed, 70 centimetres thick.

(7) The unit comprised of alternations of sand and mud is well stratified and is pale yellowish green in colour. The sediments strike nearly N-S and dip about 10° E. Pumiceous horizons are intercalated about 4 metres and 9 metres above the fossil horizon. Fission-track dating samples were collected from these horizons (Matsuda *et al*, 1984).

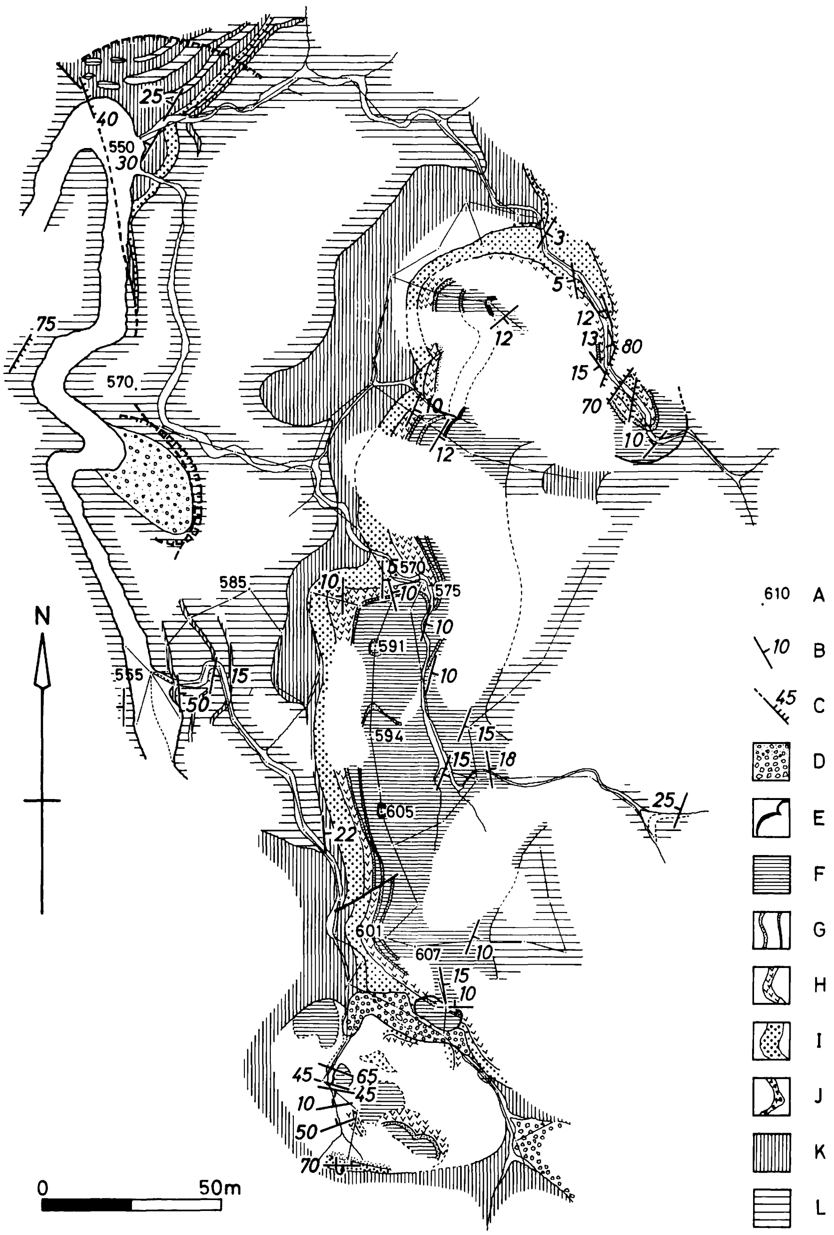


Fig. 11. Route map around the Samburu hominoid site. A: altitude in metre, B: strike and dip of stratum, C: strike and dip of the fault plane, D: recent stream debris, E: tuffaceous and pumiceous horizon, F: sand and mud alternation, G: sand, H: tuffaceous fine-grained sand, I: gravel, J: mud-flow-like gravel, K: weathered basalt sediment with siliceous limestone and chert, L: basalt.
The Samburu hominoid site is shown by a point of altitude 601 metres in the lower part of the figure.

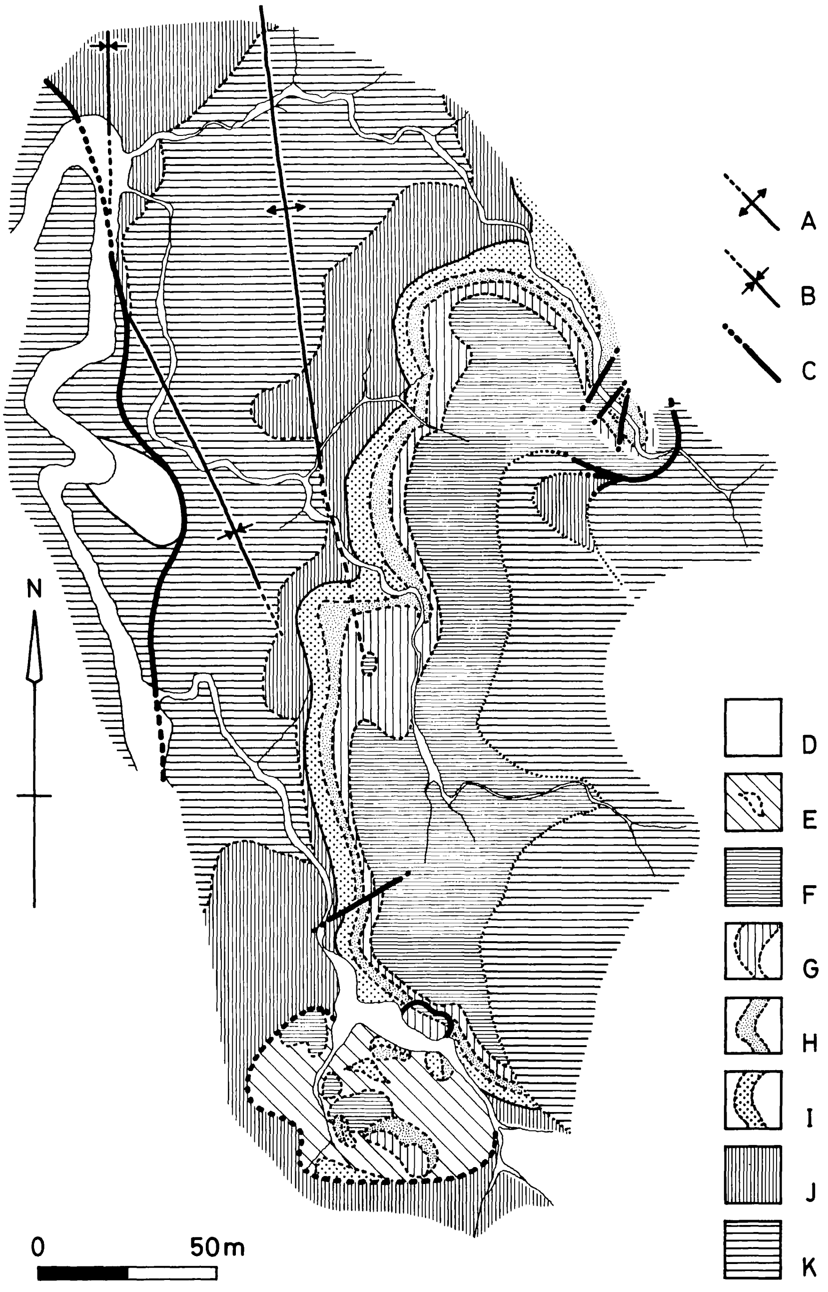


Fig. 12. Geologic map around the Samburu hominoid site. A: anticline axis, B: syncline axis, C: fault, D: recent stream debris, E: matrix of sliding mass, F: sand and mud alternation, G: sand and mud alternation coarser in the base, H: tuffaceous fine-grained sand, I: sand and gravel, J: weathered basalt sediments with siliceous limestone and chert, K: basalt.
The Samburu hominoid horizon is at the boundary between G and F.

(8) Basaltic debris covers the sediments of the Namurungule Formation. This is considered to have been derived in recent times from the ridge to the east.

Slump structures are observed within the sediments on the slope of the tributary opposite Site SH-22.

The Samburn hominoid horizon is at a level about 10 to 15 metres above the lower mud-flow, based on the observation that the tuffaceous fine-grained sand (Unit 4) is correlated with the horizon above the lower mud-flow in the section of the middle reaches of the Nakaporatelado river, and that mudflow-like gravels occur in the base of the sediments.

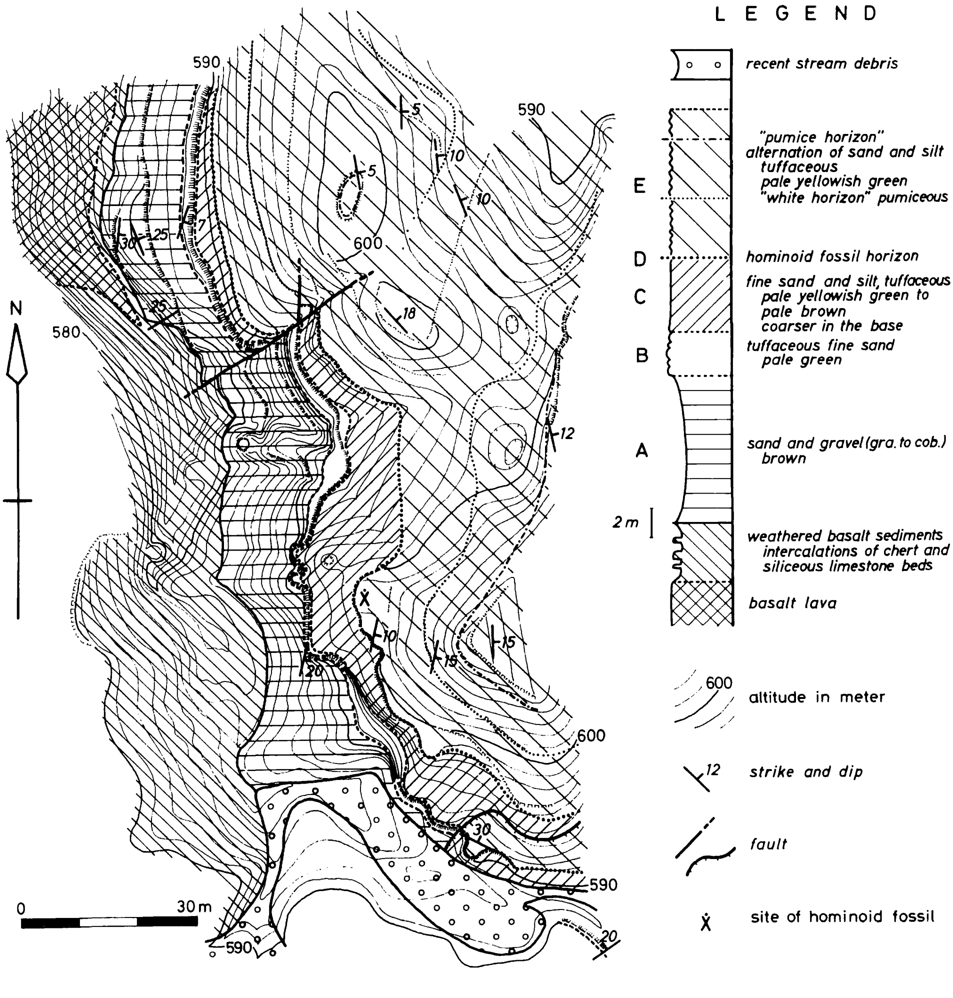


Fig. 13. Detailed geologic map of the Samburu hominoid site.

Kongia Formation

The Kongia Formation, which is exposed in the lower reaches of the Namurungule and Nakaporatelado rivers, consists of clastic sediments, lava flows and weathered volcanic materials. Its thickness is estimated to be about 120 metres. The clastic sediments occur mainly in the basal part interfingering with lavas. The main part of the Kongia Formation is comprised of lava flows with intercalations of weathered volcanic materials and tuffaceous seams. They strike N 20° – 30° E and dip 3° – 5° NW. The strike is nearly parallel with that of the underlying formations, but the dip are gentler. N-S trending faults also cut the Kongia Formation. It is considered that the western fault blocks may have been lower than those to the east. Accordingly, the thickness of the Kongia Formation may be larger than the estimated value taking account of the western downthrow of these faults.

Along the lower reaches of the Namurungule river, the Kongia Formation consists of brown sediments at the base overlain by a lower unit of lava flows above which are alternations of lava flows and weathered volcanic materials in the middle, and lava flows at the top (Fig. 4). The brown sediments at the base consist of alternations of coarse- to medium-grained sand and silt. Silt beds show pale brown to white colours. A single bed is several tens of centimetres thick and is well consolidated. The brown sediments rest with angular unconformity on the pale green coloured alternations of the Namurungule Formation which dip at steeper angles than the overlying strata.

The Kongia Formation intercalates at least twenty-one sheets of lava flow. Each lava flow is generally several metres thick. They are mostly aphyric basalt with intercalations of ankaramite and hawaiite lava flows.

Pale blue tuff seams occur within the alternations of lava flows and weathered volcanic materials in the middle of the Kongia succession.

Along the lower reaches of the Nakaporatelado river, brown sediments also occur at the base of the Kongia Formation. The lithology and the relationship of these beds to the underlying formation resembles that of the Namurungule section. Weathered volcanic materials occur sparsely in this section. There are at least thirteen lava sheets, most of which are aphyric basalts several metres thick, intercalating hawaiites (more than 10 metres thick) characterized by prismatic plagioclase phenocrysts. Ankaramite was not observed in this section.

On high isolated summits about 2.5 kilometres west-southwest of the third camp occurs hawaiitic lava containing abundant wedge-shaped plagioclase phenocrysts. These phenocrysts are several millimetres long and are white coloured.

Nagubarat Formation

The Nagubarat Formation rests sporadically on the middle and eastern zones of exposure of the inclined Namurungule Formation, and forms the top parts of ridges and summits. Viewed from a distance the Nagubarat Formation is visible as black areas on the dark brown mountainous surface, due to blocks of basalt which form rough pavements.

The Nagubarat Formation is composed of black aphanitic basalt lavas.

The most outstanding feature on the Nagubarat Formation is a volcanic neck which outcrops to the east of the second camp. It has an impressive peak on the northern side of the Namurungule river. The neck has been intruded through the alternations of the Namurungule Formation, but did not disturb its stratification. The neck is composed of basalt with ultrabasic xenoliths and shows complicated cooling joints.

The Nagubarat Formation seems to be slightly affected by N-S trending faults. The relationship between the Nagubarat and Namurungule Formations is a clear angular unconformity, and that between the Nagubarat and Kongia Formations is inferred to be an unconformity.

Tirr Tirr Formation

The Tirr Tirr Formation forms the Tirr Tirr plateau in north Samburu Hills. On aerial photographs of the plateau, N-S trending step faults, downstepping westwards, are observed in the western part, and faults downthrowing to the east are recognized in the eastern part. In the middle part, some elongate horsts trend nearly N-S.

In the southern margin of the plateau, about 3 kilometres north of Lochuatom (Echua Etom), alkali rhyolite lavas, about 10 metres thick, form the upper surface, and yellow coloured tuff breccia, about 20 metres thick, underlies the alkali rhyolite. The sequence under the tuff breccia in descending order is as follows: yellow fine-grained sediments (4 metres thick), basaltic lava (5 metres), pale coloured fine-grained sediments (3 metres) and grey silt (2 metres). The fine-grained sediments are compact and similar to diatomite. The upper part of the lower fine-grained sediments have been baked by heat from the overlying lava, and have become reddened. Basaltic lavas, about 20 metres thick, occur below these sediments. The lower boundary of the Tirr Tirr Formation is drawn below the basaltic lavas.

The alkali rhyolite forming the upper surface of the Tirr Tirr plateau is characterized by its porphyritic texture with prismatic sanidine phenocrysts and pale green glassy matrix. The basaltic lavas constituting the lower part are mostly aphyric but rarely porphyritic with plagioclase and subordinate clinopyroxene and olivine phenocrysts.

Boulders of aphyric basalt are distributed on the surface of the plateau. Accordingly, it is probable that other basalt lavas rest on parts of the plateau.

Grey silts and fluviatile sediments

The grey silts and fluviatile sediments sporadically occur on the underlying formation in the western marginal zone of the Samburu Hills. These sediments were formed at the time when the Suguta valley was occupied by a large lake in late Pleistocene time (Baker, 1963). The lower part of these sediments is composed of grey coloured tuffaceous silt (grey silts) which are several metres thick. The grey silts are mainly distributed in the mouth areas of rivers which flow into the Suguta valley, but also occur about 3.5 kilometres upstream of the mouth of Nakaporatelado river. The lower half is well laminated white silt and the upper half is pale grey massive silt. In places the grey silts are slightly inclined but the dip directions are variable and do not reflect the structure of the underlying formations. The dips are probably initial depositional ones. Fluviatile gravel beds occur above the grey silts, several metres thick, and form terraces. The terrace surfaces are about 10 metres above the modern river beds near their exits into the Suguta valley, and about 20 metres or more above the river beds about 3.5 kilometres upstream from the mouth of the Nakaporatelado river. The terrace surface is barely preserved in the upstream occurrences.

Other terrace gravels are recognized along the Namurungule and Nakaporatelado rivers. These terraces are several metres above the river bed. The second and third camps are located on this surface, which is younger than the above mentioned ones.

GEOLOGIC STRUCTURES

As already stated, the surveyed areas are divisible, from east to west, into three topographic units, namely, the higher El Barta plains, the precipitous Samburu Hills and the lower Suguta valley. Geologic structures in each of these areas conform to the topographical divisions. In the eastern division, the Nachola area, volcanics and sediments are horizontal or slightly inclined toward the west. In the middle division, the Samburn Hills, the volcanic and sedimentary strata dip westwards, at 10-30 degrees. Volcanics and sediments in the Suguta valley, the west division, seem to be horizontal.

A large scale tectonic line, which forms the eastern limit of the Gregory Rift Valley, separates the Suguta valley and Samburu Hills. From a topographical point of view, a few normal faults downthrowing to the west seem to accompany the tectonic line in the western margin of the Samburu Hills (Fig. 14). On the east side, many normal faults trending nearly N-S subparallel to the tectonic line cut the volcanics and sediments in the Samburu Hills and Nachola area. Because of these faults, volcanic and sedimentary strata form narrow lath-like blocks tilting westwards. As a whole, these faults accompany the tectonic line, and form the so-called antithetic fault system or the inward tilted, backward stepped fault system of King (1978). The normal faults downthrowing to the west which are observed in the western margin of the Samburu Hills seem to form a synthetic fault system accompanying the tectonic line. The unfaulted zone between the antithetic and synthetic fault systems constitutes structurally a horst (Fig. 15).

In the Samburu Hills, the synthetic faults occur within about 2 kilometres from the western limit of the Samburu Hills. These faults have strikes trending north by east. The downthrow of these faults has not been estimated. The antithetic faults first appear in areas about 4.5 kilometres away from western limit of the Samburu Hills. Most of them have strikes trending north by west. One of these can be observed at the confluence of the Nakaporatelado and Asanyanait rivers, the fault plane of which strikes N 10° W and dips 50° E. The vertical slip of this fault is estimated to be several tens of metres. This fault is traceable northwards and passes across the Namurungule river about half a kilometre west of the second camp, at which point the vertical slip is estimated to be about 200 metres. Accordingly, the vertical slip increases northwards. Another fault passes across the Namurungule river about 1 kilometre east of the second camp. Thefault plane strikes N 10° W and dips 80° E. The vertical slip is estimated to be about 100 metres and seems to decrease southwards. It is probable that other faults resemble the above mentioned ones in displacement pattern and scale, although detailed observations have not been made.

An exceptional fault which downthrows to the west occurs about half a kilometre east of the third camp. In the river bed of Lokirilyanga, the upper part of the Aka Aiteputh Formation is in faulted contact with the lower part of the same formation. The fault plane strikes N 5° W and dips 55° – 60° W. The downthrow to the west is estimated to be about 200 metres. This fault is traceable northwards, and passes across the Nakaporatelado river about 800 metres upstream from the third camp. At this point, an accessory fault is seen, the strike of which is N 30° W and the dip is 40° NW. Here, the vertical slip of the exceptional fault is estimated to be several tens of metres. The vertical slip decreases northwards.

Because of the faults mentioned above, the narrow lath-like blocks have a N-S trend and tilt westwards. The width of these blocks ranges from 1 to 2 kilometres. These blocks are accompanied by minor faults downthrowing to the east.

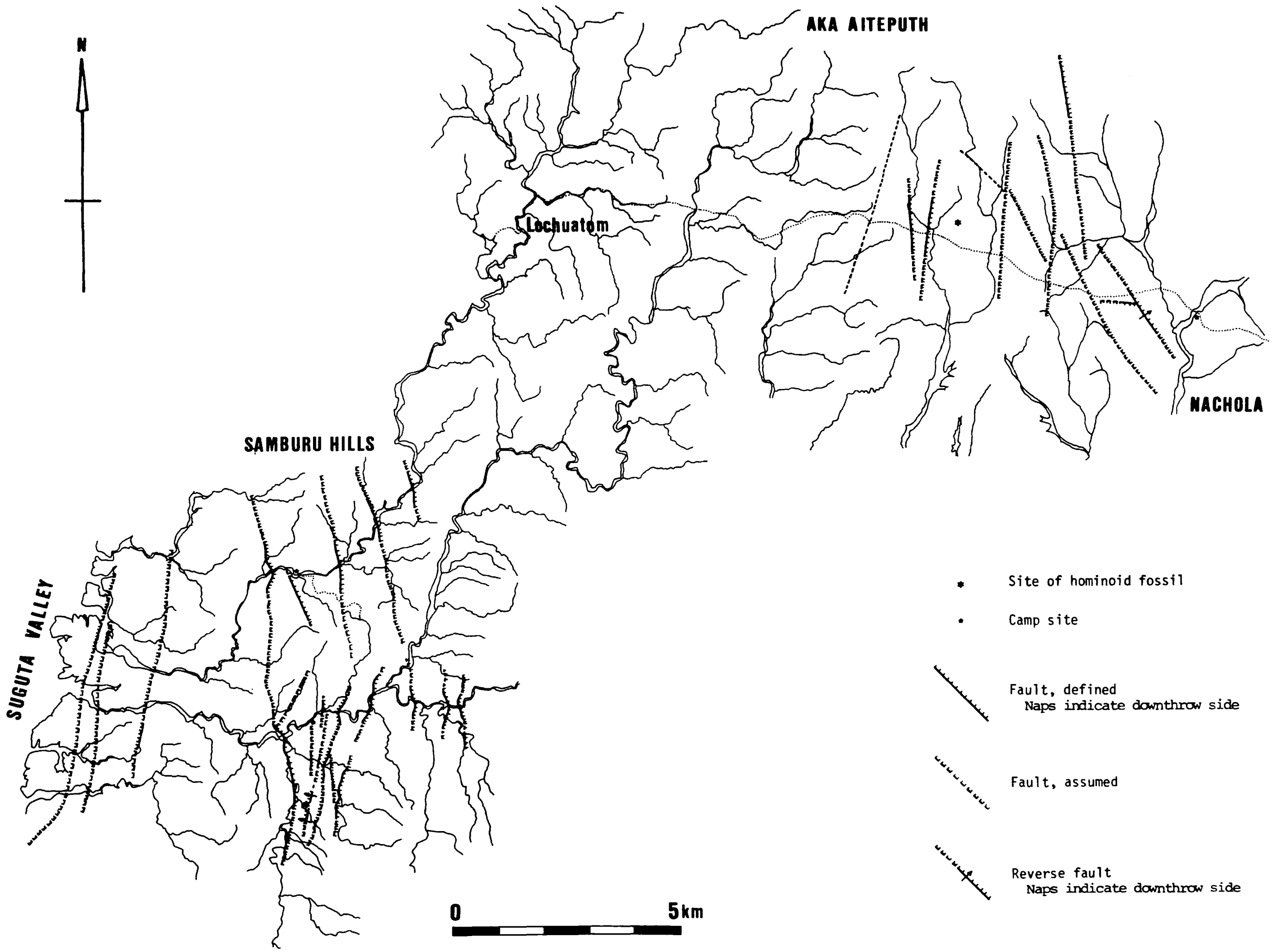


Fig. 14. Fault patterns of the Samburu Hills and Nachola area.

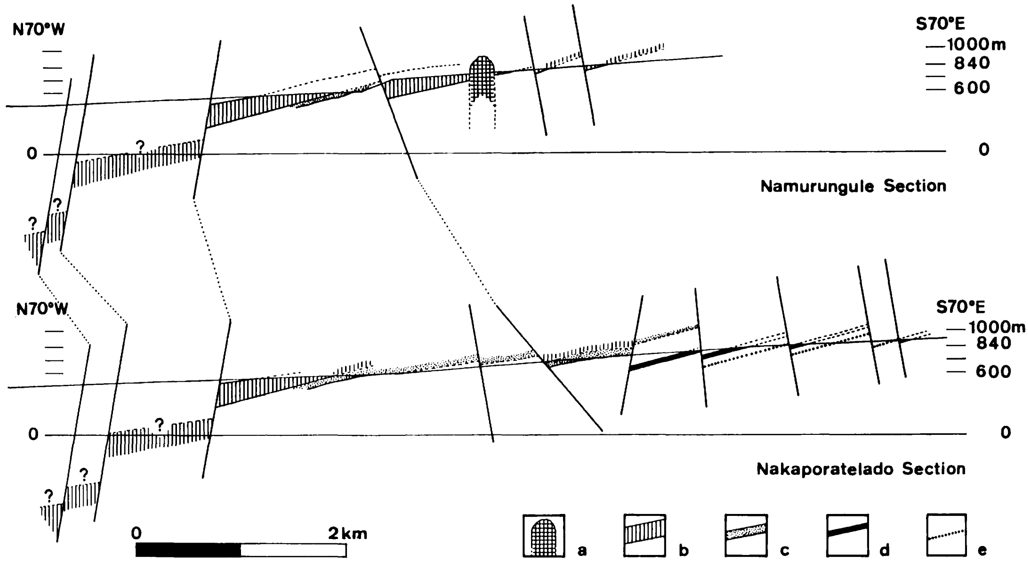


Fig. 15. Geologic profiles of the Samburu Hills. a: volcanic neck of the Nagubarat Formation, b: Namurungule Formation, c-e: Aka Aiteputh Formation, c: weathered basalt sediments, d: sodalite trachyte, e: trachyte welded tuff.

In the Nachola area, the western margin of the El Barta Plains, the geologic structure has a similar tendency to that in the Samburu Hills, except that the degree of westward tilting is gentler, and that downthrows due to faults are estimated to be only several to ten metres to the east. Accordingly, the antithetic fault system is confined the eastern border in this area. A reversed fault is observed just east of the small isolated hill near the confluence of the Baragoi and Nanyangaten rivers. The fault plane strikes N 40° W and dips 80° SW.

Phases of tectonic activity

In the Samburu Hills, the following three geologic groups, the Aka Aiteputh and Namurungule Formations, the Kongia Formation, and the Nagubarat and Tirr Tirr Formations, are characterised by structural differences. The Aka Aiteputh and Namurungule Formations have been severely affected by faulting and tilting movements. The dip of the Kongia Formation is clearly gentler than that of the underlying formations. The Nagubarat and Tirr Tirr Formations have been subjected to faulting, but have suffered only slight tilting movements.

Accordingly, the main phase of tectonic activity apparently intervened between the Namurungule and Kongia Formations. The tilting movements almost ceased before the deposition of the Nagubarat and Tirr Tirr Formations, but the faulting continued after the deposition of these formations. More recently, the faults have been rejuvenated forming the present major relief between the Suguta valley and Samburu Hills.

ACKNOWLEDGEMENTS

We would like to thank Dr. Hidemi Ishida of Osaka University, the leader of this expedition, for his invitation to the expedition and encouragement. We are much indebted to Dr. Martin Pickford of the National Museum of Kenya for his many suggestions during the field survey and critical reading of this manuscript. We wish to express our sincere thanks to Mr. Hideo Nakaya of Kyoto University, Mr. Yoshihiko Nakano of Osaka University, Mr. Nobutaka Kishida of the Transworld Minerals Inc. (Nairobi), Mr. Kiptalam Chepboi of the National Museums of Kenya, and the Turkana people of Baragoi, who strenuously supported our field works.

Without these kind helps by many persons mentioned above, we could not complete this manuscript.

REFERENCES

Baker, B.H., 1963. Geology of the Baragoi Area, with coloured geologic map. *Rept. Geol. Surv. Kenya*, No. 53, 74 pages, Government of Kenya.

Baker, B.H., Williams, L.A.J., Miller, J.A. and Fitch, F.J., 1971. Geochronology of the Kenya Rift volcanics. *Tectonophys.*, 11, 191–215.

Ishida, H. and Ishida, S. eds., 1982. Report of Field Survey in Kirimum, Kenya, 1980 – *Study of the Tertiary Hominoids and their Palaeoenvironments in East Africa,* 1: 1–181, Osaka University.

King, B.C., 1978. Structural and volcanic evolution of the Gregory Rift Valley in (W.W. Bishop ed.) *Geological background to fossil man.* Geol. Soc. London, Scottish Academic Press 29–54.

Koyaguchi, T., 1984. Volcanic Rocks in the Samburu Hills, Northern Kenya. *African Study Monographs, Supplementary Issue* 2: 147–179.

Matsuda, T., M. Torii, T. Koyaguchi, T. Makinouchi, H. Mitsushio and S. Ishida, 1984. Fission-track, K-Ar Ages Determinations and Palaeomagnetic Measurements of Miocene Volcanic Rocks in the Western Area of Baragoi, Northern Kenya: Ages of Hominoids. *African Study Monographs, Supplementary Issue* 2: 57–66.

Pickford, M., H. Nakaya, H. Ishida and Y. Nakano, 1984. The Biostratigraphic Analyses of the Faunas of the Nachola Area and Samburu Hills, Northern Kenya. *African Study Monographs, Supplementary Issue* 2: 67–72.