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# FISSION-TRACK, K-Ar AGE DETERMINATIONS AND PALAEOMAGNETIC MEASUREMENTS OF MIOCENE VOLCANIC ROCKS IN THE WESTERN AREA OF BARAGOI, NORTHERN KENYA: AGES OF HOMINOIDS

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ABSTRACT Miocene rocks in the west of Baragoi, northern Kenya, consist of the Nachola, Aka Aiteputh, Namurungule and Kongia Formations in ascending order. Two kinds of hominoid, *Kenyapithecus* and a large hominoid (Samburu hominoid), were found from the Nachola and Namurungule Formations, respectively, in summer 1982. Two fission-track and six K-Ar ages were determined on the volcanic rocks to clarify the ages of the hominoid fossils. Paleomagnetic reconnaissance was also conducted for the sake of magnetostratigarphic correlation. The ages of the Nachola, Aka Aiteputh, Namurungule and Kongia Formations were around 11, 13, 7 and 6.4 Ma, respectively. The ages of *Kenyapithecus* and Samburu hominoid are considered to be the Middle Miocene and Late Miocene, respectively.

## INTRODUCTION

Two hominoid species, *Kenyapithecus* and a large hominoid (Samburu hominoid) have been found in the western area of Baragoi, northern Kenya in the 1982 field survey of the Japan/Kenya expedition. Preliminary age estimates have been made on the basis of mammalian fossils which came from the same horizon as the hominoid fossils; *Kenyapithecus* is considered to be Middle Miocene, while the Samburu hominoid is thought to be Late Miocene in age (Pickford *et al.*, 1984). In order to estimate their ages in more detail, five samples for fission-track and six for K-Ar age determination were collected. Palaeomagnetic measurements were also carried out for samples from eleven horizons including both volcanic and sedimentary rocks.

## GEOLOGICAL SETTING AND SAMPLES COLLECTION

The western area of Baragoi is underlain by Miocene and Pliocene volcanic rocks composed of basalt, trachyte and alkali rhyolite intercalated with sedimentary rocks, unconformably overlying Precambrian metamorphic complex which belongs to the Mozambique Belt (Fig. 1). The Miocene and Pliocene rocks are divided into two formations such as the Nachola Formation and the younger basalt in the Nachola area, and five formations such as the Aka Aiteputh, Namurungule, Kongia, Nagubarat, and Tirr Tirr Formations in the Samburu Hills (Makinouchi *et al.*, 1984) (Fig. 2 A, B). *Kenyapithecus* was obtained from the Nachola Formation and Samburu hominoid was from the Namurungule Formation. Radiometric age determinations in these areas have been restricted to three K-Ar dates from the Tirr Tirr Formation which were around 3.6 Ma (Baker *et al.*, 1971).

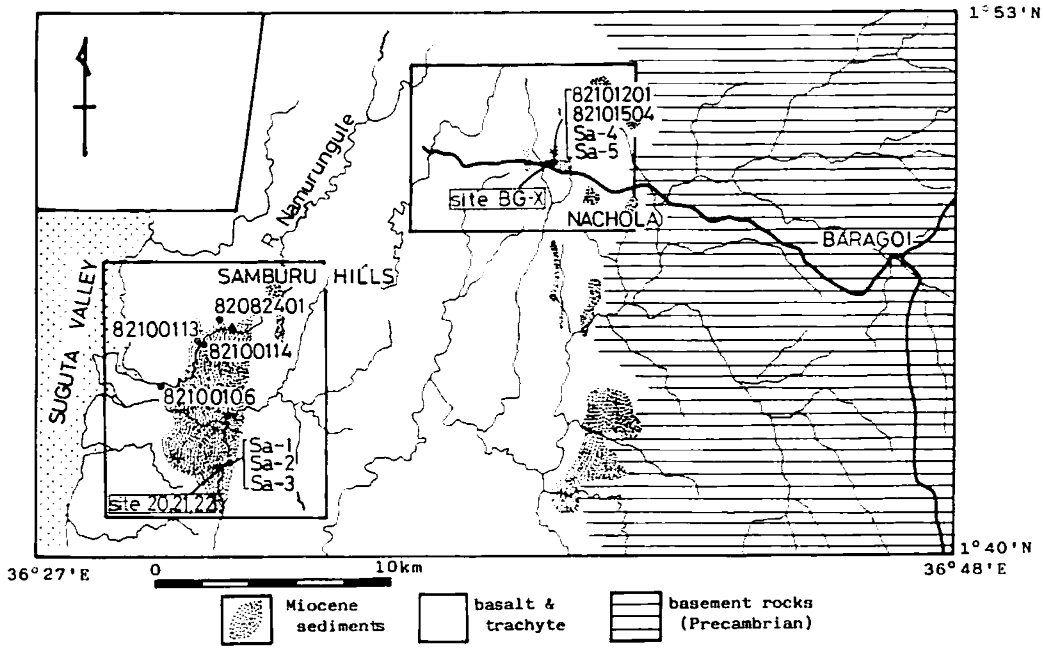


Fig. 1. Simplified geologic map of the west of Baragoi and sample localities for K-Ar and fission-track dating.

Samples for radiometric age determination were collected from the horizons stratigraphically and areally close to the sites from which the hominoid fossils came (Figs. 1 and 2). For K-Ar dating, four basaltic lava flow samples were collected along the Namurungule River in the Samburu Hills, where detailed stratigraphy of the Aka Aiteputh, Namurungule and Kongia Formation was studied (Makinouchi *et al.*, 1984). Two of them (numbers; 82082401 and 82100106) were obtained from the lower part of the Kongia Formation and two samples (82100113 and 82100114) were from

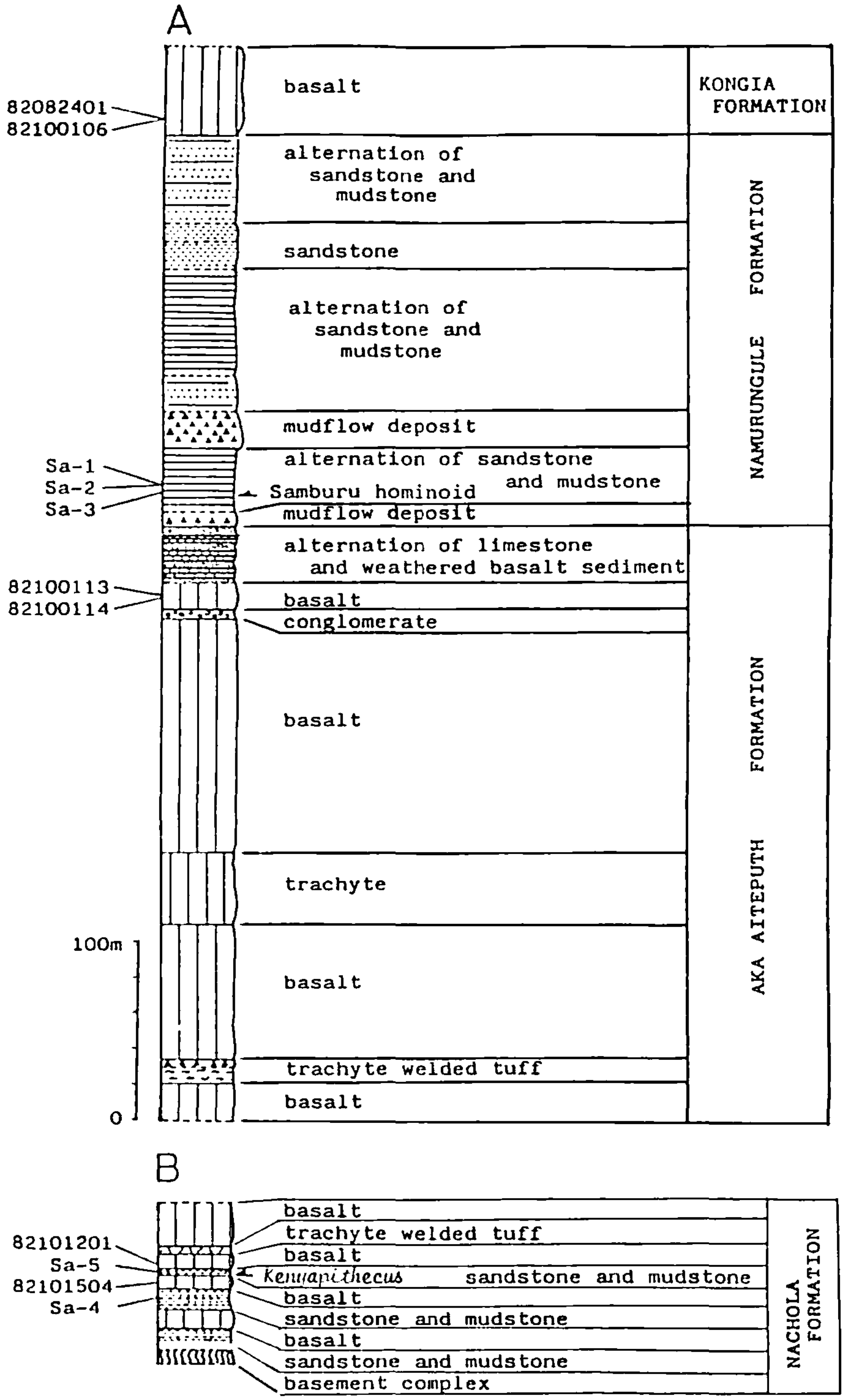


Fig. 2. Sequence of Miocene rocks in the Samburu Hills (A) and Nachola area (B), and the horizons of sample for radiometric dating.

the upper part of the Aka Aiteputh Formation. 82082401 is obtained from the second lowest lava of the Kongia Formation on a cliff 200 m northwest of the Second Camp. 82100106 is from a lava flow which directly overlies the Namurungule Formation at an exposure about 1 km southwest of the confluence of the Namurungule River and Suguta Valley. A lava flow from which 82100113 was collected underlies the alternating beds of weathered basalt and siliceous limestone, and lies on a lava flow of 82100114 at an exposure about 700 m west of the Second Camp. Additionally, two samples (82101501 and 82101504) of basaltic lava flows were collected from the Nachola Formation near Site BG-X in the Nachola area. Their petrography was described by Koyaguchi (1984).

For fission-track dating, three tuffaceous and pumiceous samples, Sa-1, Sa-2 and Sa-3, were collected from the Namurungule Formation at Sites 21, 22 and 20 in the Samburu Hills (Makinouchi *et al.*, 1984), respectively, and two tuffaceous samples (Sa-4 and Sa-5) were from the Nachola Formation at Site BG-X in the Nachola area. Sa-1, Sa-2 and Sa-3 are obtained from 9 m, 4 m and 1 m above the Samburu hominoid horizon, and Sa-4 and Sa-5 are from about 8 m below and 0.5 m above the *Kenyapithecus* horizon, respectively.

Samples for palaeomagnetic study were collected as 29 oriented hand samples from 11 horizons (A to E and a to f) in the Samburu Hills. The samples from the horizons of A to E are volcanic rocks, and a to f are sedimentary rocks as shown in Fig. 5. The horizon E is just below the trachyte lava of the Aka Aiteputh Formation. The horizon D is the same to that of K-Ar sample of 82100113, and A and B are stratigraphically adjacent to D. Basalt samples, C, are collected from the horizon slightly above that of K-Ar sample 82100106. The samples from horizons a, b, c and d are muddy sediment of Site 22 (Samburu hominoid site), and e and f are that of Site 21 (Fig. 1). Total thickness of sedimentary sequence from a to f is about 18 m, and the Samburu hominoid horizon is about 8 m above the horizon of a.

## FISSION-TRACK DATING

The only materials suitable for fission-track dating collected from Sa-2 and Sa-3 were apatite crystals. Although apatite grains were also obtained from Sa-5, their quantity was too small to permit a reliable determination of fission-track age. Any kind of material suitable for fission-track dating was not obtained from Sa-1 and Sa-4. Therefore, the ages were determined on two samples, Sa-2 and Sa-3.

The fission-track age, T years, can be represented by the following equation (Price and Walker, 1963).

$$T = \frac{1}{\lambda} \ln \left(1 + \frac{\lambda}{\lambda_f} \frac{\sigma\Phi}{\eta} \frac{\rho_s}{\rho_i}\right)$$

where $\rho_s$ is fossil fission-track density ($cm^{-2}$), $\rho_i$ is induced fission-track density ($cm^{-2}$). $\lambda$ is total decay constant for $^{238}U$, $\lambda_f$ is fission decay constant for $^{238}U$, $\Phi$ is thermal neutron flux irradiated ($cm^{-2}$), $\sigma$ is thermal neutron cross section of $^{235}U$ ($cm^2$), and $\eta$ is the isotope ratio $^{235}U/^{238}U$. The constants adopted here are as follows:

| | |
|---|---|
| $\lambda = 1.551 \times 10^{-10}/yr$ | (Steiger and Jäger, 1977) |
| $\lambda_f = 7.03 \times 10^{-17}/yr$ | (Roberts *et al.*, 1968) |
| $\sigma = 5.77 \times 10^{-24}/cm^2$ | (Goldmann, 1965) |
| $\eta = 137.88$ | (Steiger and Jäger, 1977) |

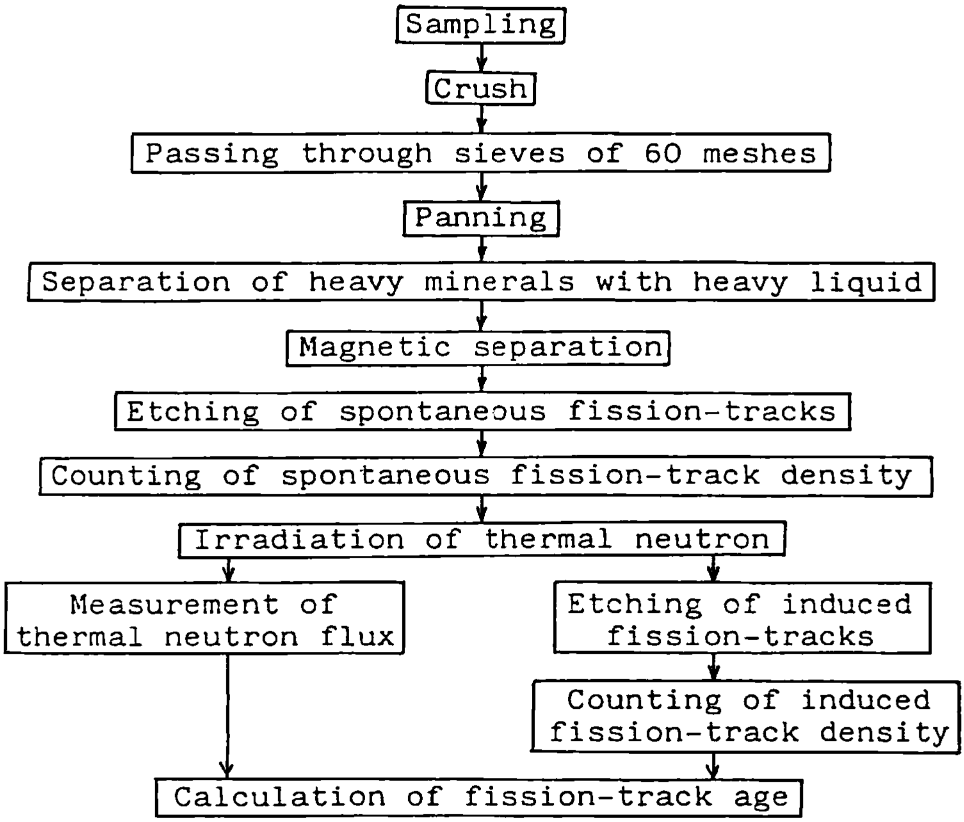


Fig. 3. Procedure of fission-track dating.

Procedure of the fission-track dating performed is shown in Fig. 3. Fission-tracks on apatite internal surfaces were etched with 1% $HNO_3$ at room temperature. The crystals were irradiated by thermal neutron doses in the Research Reactor (KUR-1) of Kyoto University. Thermal neutron dose was monitored by the standard glass No. 612 from the U.S. National Bureau of Standards. The standard glass was covered by an Indian uranium-free muscovite detector, and irradiated with the samples (geometry factor = 2.0)

The results are presented in Table 1. The fission-track ages of Sa-2 and Sa-3 are 6.7 ± 2.0 and 15 ± 4 Ma, respectively.

**Table 1.** Results of fission-track age determination on the Namurungule Formation which has yielded a large hominoid.

| Sample number | Number of grains | Spontaneous fission-tracks number | Spontaneous fission-tracks density (/cm²) | Induced fission-tracks number | Induced fission-tracks density (/cm²) | Thermal neutron flux (/cm²) | Age (Ma) |
|---|---|---|---|---|---|---|---|
| Sa-2 | 8 | 30 | $6.84 \times 10^3$ | 728 | $1.66 \times 10^5$ | $5.45 \times 10^{15}$ | 6.7 ± 1.8 |
| Sa-3 | 7 | 26 | $6.74 \times 10^3$ | 271 | $7.04 \times 10^4$ | $5.45 \times 10^{15}$ | 16 ± 4 |

## K-Ar DATING

Whole-rock K-Ar age determination on six samples were carried out by Teledyne Isotope (New Jersey, U.S.A.). Details of the results are listed in Table 2. The age of 82101501 and 82101504 from the Nachola Formation are 11.8 ± 1.4 and 10.1 ± 4.0 Ma. These ages coincide in their error limit.

The ages of 82100113 and 82100114 from the Aka Aiteputh Formation are 12.0 ± 1.0 and 14.6 ± 1.2 Ma, and those of 82082401 and 82100106 from the Kongia Formation are 6.4 ± 0.5 and 6.3 ± 1.0 Ma, respectively. These samples are fresh and the ages obtained within each horizon are quite similar, so these ages can be considered to be sufficiently reliable.

Table 2. Results of K-Ar dating of Miocene volcanic rocks from the Samburu Hills and Nachola area in the west of Baragoi.

| Sample number | Isotopic age (Ma) | scc $Ar^{40}Rad/gr \times 10^{-5}$ | % $Ar^{40}Rad$ | % K |
|---|---|---|---|---|
| 82082401 | 6.4 ± 0.5 | 0.036 | 37.8 | 1.49 |
| | | 0.038 | 28.1 | 1.50 |
| 82100106 | 6.3 ± 1.0 | 0.028 | 16.0 | 1.12 |
| | | 0.028 | 17.7 | 1.15 |
| 82100113 | 12.0 ± 1.0 | 0.032 | 27.7 | 0.69 |
| | | 0.033 | 14.8 | 0.70 |
| 82100114 | 14.6 ± 1.2 | 0.061 | 36.5 | 1.11 |
| | | 0.063 | 27.8 | 1.12 |
| | | 0.066 | 29.3 | |
| 82101501 | 11.8 ± 1.4 | 0.033 | 20.8 | 0.73 |
| | | 0.034 | 21.9 | 0.73 |
| 82101504 | 10.1 ± 1.4 | 0.036 | 17.7 | 0.91 |
| | | 0.036 | 20.4 | 0.92 |

$\lambda\beta = 4.962 \times 10^{-10}\ yr^{-1}$
$\lambda\epsilon = 0.581 \times 10^{-10}\ yr^{-1}$
$K^{40} = 1.167 \times 10^{-4}$ atom per atom of natural potassium

## PALAEOMAGNETIC MEASUREMENTS

Cylindrically shaped specimen from each hand sample was first tested by a stepwise thermal demagnetization up to the temperature of 670°C. Some typical results are illustrated in Fig. 4. In most cases, blocking temperature of secondary overprints are relatively high both for volcanic and sedimentary rocks. Consequently the thermal demagnetization was performed up to 500°C or more for each specimen to recover primary direction of the remanence. After the thermal treatments, polarity of the remanent vector was decided for each horizon as shown in Fig. 4; samples from horizons of C, E, e, d and f show normal polarity, and A, B, D, a, b and c are reversed.

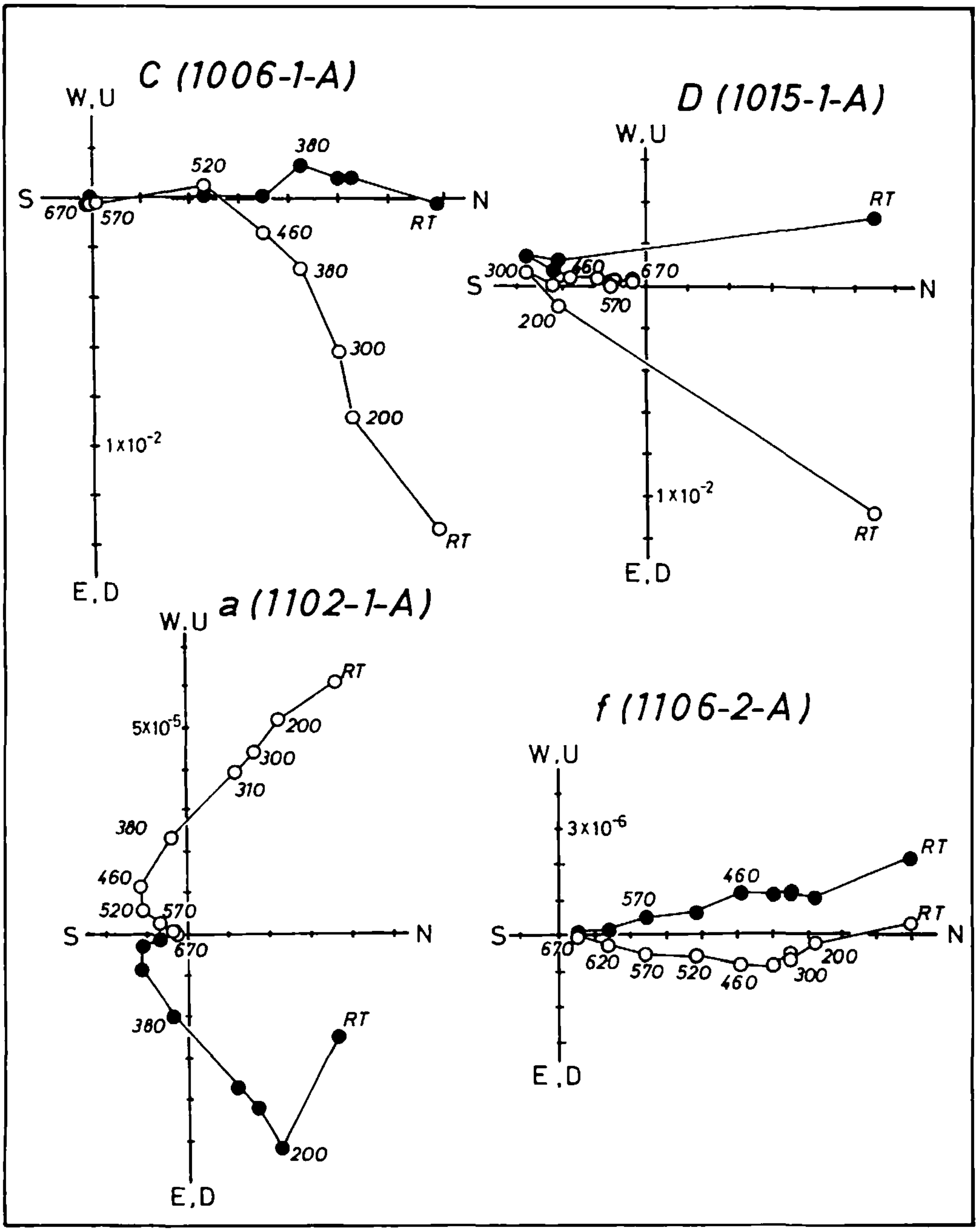


Fig. 4. Four examples of progressive thermal demagnetization are illustrated on cartesian projection. C and D are for the volcanic rocks, and a and f are sedimentary rocks. Open and solid circles are projection of vector end-points on N-S vertical and horizontal planes, respectively. Numerals adjacent to symbols are demagnetization temperature in °C. Unit of each coordinate is emu.

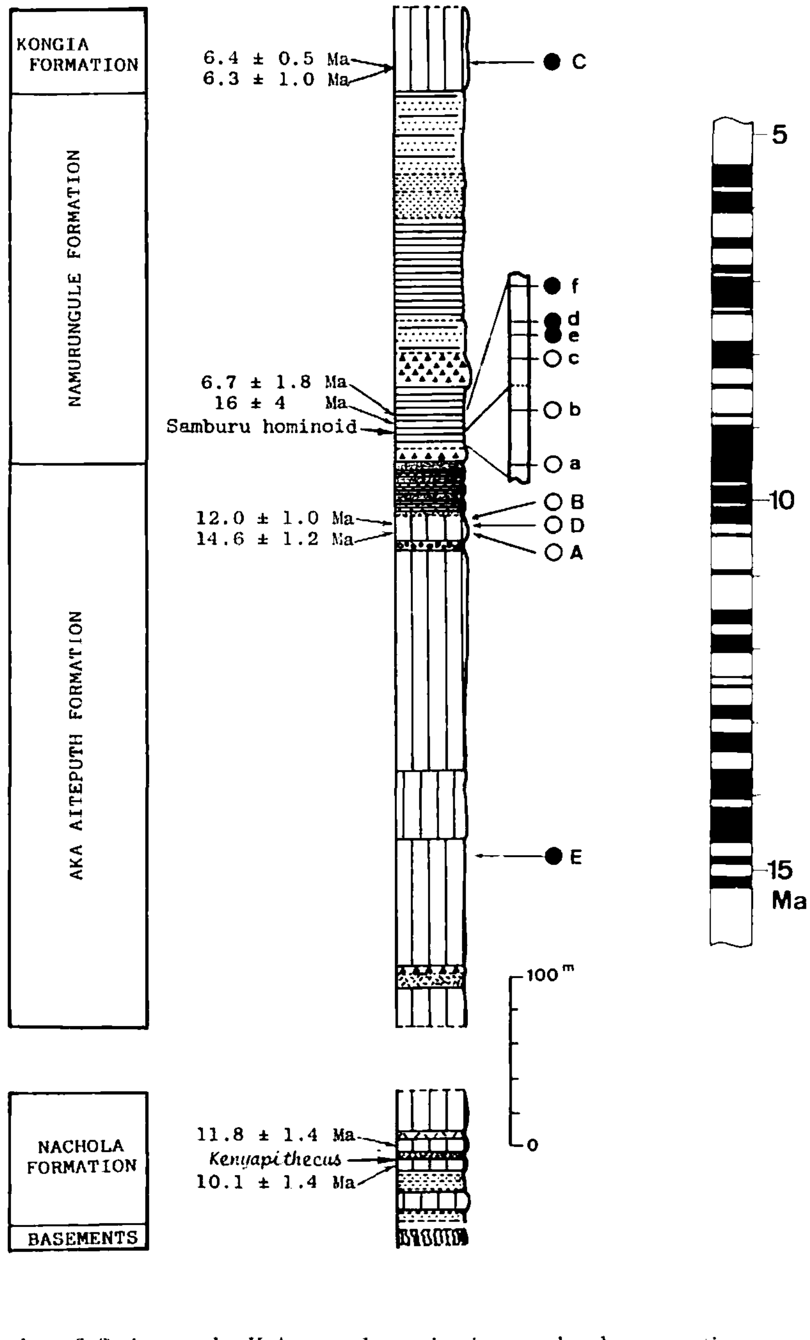


Fig. 5. Results of fission-track, K-Ar age determinations and paleomagnetic measurements of Miocene rocks of the Samburu Hills and the Nachola area in the west of Baragoi, northern Kenya. Solid and open circles indicate normal and reversed polarity of horizons, respectively. Right column is the standard reversal time scale from 5 to 15 Ma proposed by Harland *et al.* (1982).

o – reversed ● – normal

## DISCUSSION

The results of the K-Ar and fission-track age determination are shown together with the palaeomagnetic polarity in Fig. 5. The K-Ar ages of the horizon of *Kenyapithecus* of the Nachola Formation are around 11 Ma of the Middle Miocene, which coincide with the biostratigraphical results (Pickford and Nakaya, 1984). The age is 2 or 3 m.y. younger than the K-Ar ages, about 14 Ma, of *Kenyapithecus* from Fort Ternan, west Kenya (Baker *et al.*, 1971). The age of the Nachola Formation is slightly younger than that of the upper part of the Aka Aiteputh Formation, although the Nachola Formation has been considered to underlie the Aka Aiteputh Formation (Baker, 1963). Accordingly, more detail stratigraphic and chronological studies would be required in the Nachola area and Samburu Hills in the near feature.

The K-Ar ages of the horizons stratigraphically below and above the site of the Samburu hominoid are around 13 Ma and 6.4 Ma, respectively. The age of the Samburu hominoid, therefore, is between these two ages. The apatite fission-track ages of the Samburu hominoid horizon are 6.7 ± 2.0 and 15 ± 4 Ma. The former age is concordant with the K-Ar ages, but the latter shows very old age and does not coincide with the results of stratigraphical and K-Ar studies. The reason that the Sa-3 indicated an older age than the expected one is not clear. One acceptable interpretation is that the apatite crystals in Sa-3 are detrital grains from older rocks. The age of the Samburu hominoid, consequently, is supposed to be around 6.7 Ma of the Late Miocene which is in concord with the results of biostratigraphy (Pickford and Nakaya, 1984). However, the small amount of the number of spontaneous fission-tracks and grains measured makes the age error large. Therefore, we should obtain much more apatite or zircon grains and determine their ages to refine the age of the Samburu hominoid.

As far as palseomagnetic results are conserned, it is rather difficult to make a correlation with the standard reversal time scale because of the restricted number of sampling horizons (Fig. 5). Nevertheless, most of the samples subjected to this study showed the presence of stable primary component of remanence after the thermal treatments. And further sample collection in the next season will enable us to utilize the paleomagnetic data as the tool of age estimation of fossil bearing horizons.

In East Africa, Neogene hominoid fossils were scare from Pliocene *Australopithecus afarensis* to determined by K-Ar and $^{40}Ar/^{39}Ar$ method are 3.0 ± 0.2 Ma from Hadar, Ethiopia (Johanson and Taieb, 1976) and between 3.59 and 3.77 Ma from Laetolil, Tanzania (Leakey *et al.*, 1971). The age determined here on two hominoids, *Kenyapithecus* and Samburu hominoid, from the west of Baragoi are about 11 Ma and 7 Ma, and are between the ages of *Kenyapithecus* from Fort Ternan and *Australopithecus afarensis*.

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