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Cover Page Footnote
IMR thanks many people who have assisted the MEECRP over the years, in particular, for advice, hospitality, and innumerable favors, the Barnley family, Tony and Adrianne Mills, Richard Leakey, Anthony Sutcliffe, Carole and P. Hughes, and the Wardens and staff of the MENP. We also acknowledge Gary H. Marchant and Barbara Kowaleski, for his help with the figures, and her assistance with the literature. A whole hearted appreciation is extended to the organizations listed under the section 'Fund-Raising' for their help and to these we add the Kenyan Wildlife Conservation and Management Department (WCMD) for its tremendous conservation efforts.

MOUNT ELGON'S ELEPHANTS ARE IN PERIL

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ABSTRACT: The elephants at Mount Elgon National Park (MENP) are unique and exceptional. They are the only elephants known to excavate for salt in underground caves. Data on the ecology of elephants at MENP were collected over a period of seven years with a total of 130 days of field observations. Methods employed included: direct observations, spoor, photographs, and sound recording. Elephants visited the caves singly or in groups of up to 19 individuals; visits lasted up to 6 hours in Kitum and Makingeny Caves. Most visits began around dusk, but occasionally they entered in daytime or later at night. The frequency of visits by elephants to the caves seemed to increase as the rainfall decreased. Also observed at the caves were bats, ungulates, monkeys, rodents, carnivores, birds, and insects. Plants, rocks, and water samples are being analyzed. It appears that the formation of these caves resulted from the combined "efforts" of salt mining and/or eating activities over millions of years by elephants and other animals and also by pastoral African tribes. In the early 1970's the elephant population in MENP was estimated to be 1,200 $\pm$ 100; today perhaps only 50-130 are left. This decline of 10- to 26-fold is mostly due to ivory poaching, which increased dramatically since 1986. If this trend continues, Mount Elgon's already depleted elephant population will become extinct. This would also mean the end of the unprecedented mining behavior - a potential tourist attraction comparable to Rwanda's mountain gorillas in its appeal to tourists. Recommendations and proposals for action include publicity and fund-raising in order to better equip and enlarge anti-poacher patrols, to encourage controlled tourism, and to define research and conservation work related to Mount Elgon's ecosystem.

INTRODUCTION

A. GENERAL

The Mount Elgon elephant population is unique for its unusual behavior of mining and eating salt-bearing rocks in approximately 160-meter long caves at about 50-100 m below ground surface. This subterranean geophagical behavior was largely unknown to the scientific community until the beginning of this decade when Ian Redmond began the Mount Elgon Elephant Caves Research Project (MEECRP). Conventional processes of cave formation (speleogenesis, e.g., wave action, underground water courses, lava tubes, and so on) fail to account for the features of Mount Elgon's caves; the idea that geophagous elephants have, perhaps for millions of years, been the principal agents of erosion in creating Elgon's caves is provocative, yet logical. It appears that results of this study may be applicable to a wider scope of disciplines than initially believed. For example, it would be interesting to examine caves which mammoths are believed to have visited for signs of tuskings. Much interest has arisen in the peculiar habits of these elephants and they have attracted the attention of scientists and the general public worldwide. Sadly, this intriguing phenomenon of a 5-ton mammal mining salt deep underground may soon be only recorded in the history. Demand for ivory knows no bounds and this population has, like many others, been decimated by poachers. Urgent study must be conducted to save whatever remains of these elephants. We hope that our research will trigger further interest among conservation-oriented organizations and that enough funds may be raised to protect this relict population and provide viewing facilities for visiting scientists and tourists to observe the elephants' underground activities.

Our research goals are: (1) to census the elephant population at MENP, (2) to study the elephants' seasonal movements and assess their dependence on caves for minerals and salts, (3) to collect quantitative data to test the hypothesis of elephant speleogenesis [by tracking individual elephants and recording amounts and frequencies of rocks ingested, seasonal variations if any, amounts of soluble sodium extracted by elephants' digestive systems and, when possible, by physiological analysis of elephant body fluids], (4) to find out whether they eat the fruit bats' guano, (5) to search for signs of human habitation and mining activities in order to make recommendations for archaeological excavation, and (6) to prepare a comprehensive management plan for the park, with particular emphasis on the caves and their associated fauna.

B. GEOGRAPHICAL AND GEOLOGICAL SETTINGS

MENP is located on the eastern slope of Mount Elgon, whose summit (a ring of peaks around a caldera 5 miles/8 km in diameter, highest peak Wagagai, 14,178 ft/4,321 m, located at approximately 34.5^{o} east and 1.1^{o} north) is bisected by the international border of Uganda to the west and of Kenya to the east (see Fig. 1). The diameter of the mountain at its base is about 95 km (or 60 miles) which suggests that when active, and before erosion reduced its summit, it may have been the highest mountain in Africa. Mount Elgon first became active in the late Miocene period, some 8-10 million years ago, and continued well into the mid-Pliocene - a result of the movements of the earth's crust associated with the formation of the East African Rift Valley (Baker and Wohlenberg, 1971). The mode of Elgon's formation was principally explosive, with huge quantities of lava boulders, volcanic bombs, ash and dust being thrown out and settling over the surrounding area to form the volcanic agglomerate, or 'pudding stone' which is much in evidence in outcrops today. This pyroclastic material is occasionally interbedded with lava flows, most of which occurred during the final stages of Elgon's activity but which comprise less than 1% of Elgon's total bulk (Davies, 1952). They cooled to form erosion resistant layers of basalt-like melanephelinite (Searle, 1952). Most of the caves are found in agglomerate layers immediately beneath the lip formed by the leading (downhill) edge of a lava flow. In many of the caves, petrified trunks, branches and roots of trees are visible in the agglomerate that engulfed them, and in some sites, the tree-trunks appear to radiate from the mountain in the direction of the blast which probably felled them.

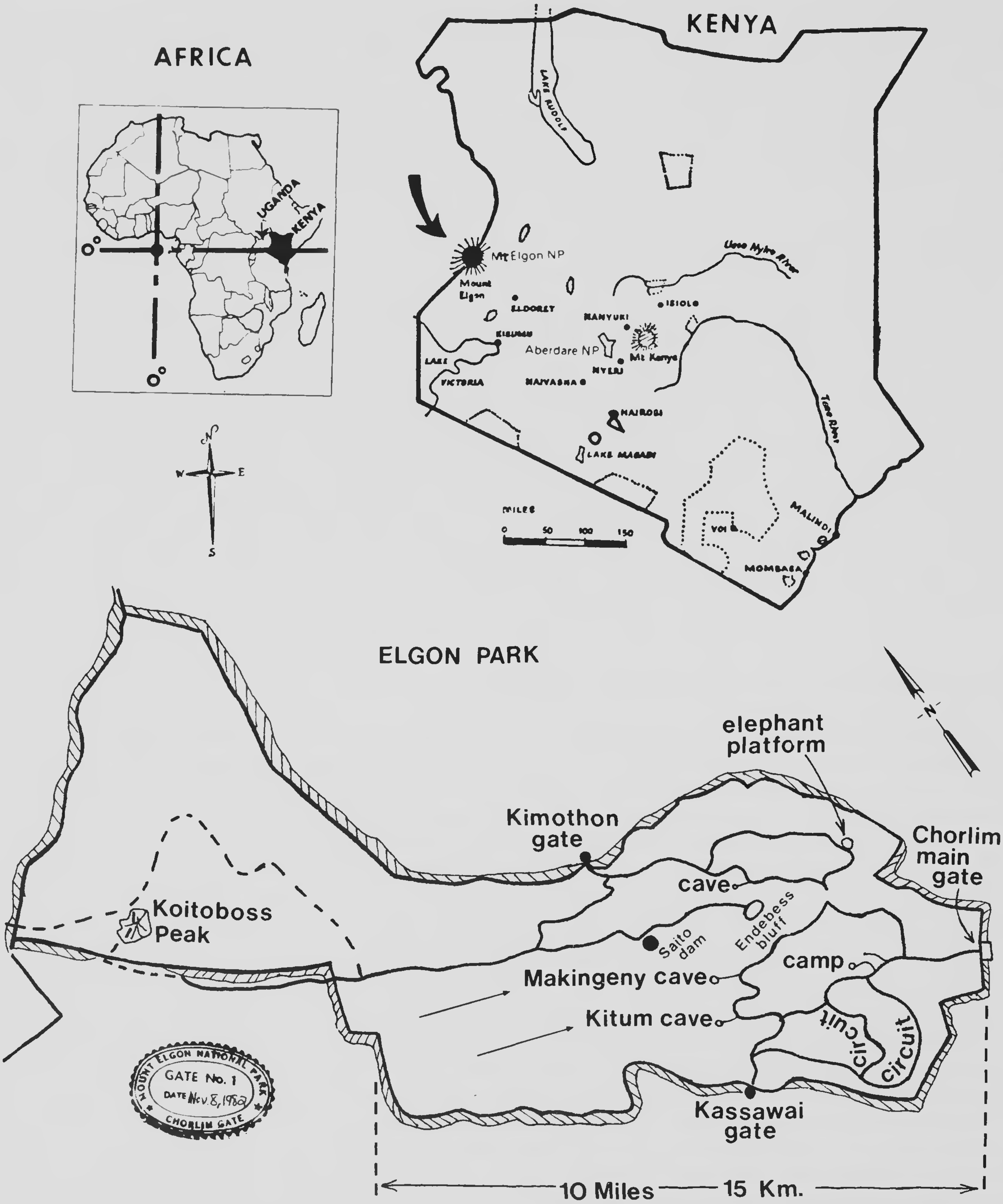

Figure 1. TOP LEFT: Map of Africa with the nation of Kenya darkened. TOP RIGHT: Map of Kenya with an arrow pointing to Mount Elgon on the border between Kenya and Uganda. Mount Elgon National Park (MENP) is located in Kenya. BOTTOM: A sketch of the major dirt roads at MENP; arrows show the locations of Mackingeny and Kitum Caves [redrawn by G.H. Marchant].

Although it is 3-4 million years since Elgon last erupted, there is still geothermal activity. Hot springs emerge in the caldera at a temperature of 49^{o} C (according to Searle, 1952). We measured the temperature at 1400 on the 9th of November 1982 and found it to be 44^{o} C, (but it was a cold day, and the water in the raging Suam River, which drains the whole caldera, was only 8.5^{o} C, and was perhaps mixing with the spring and causing the lower reading.) On a global scale, Mount Elgon is one of a series of volcanic peaks, up-thrust plateaus and graben faults with a high frequency of geothermal activity (geysers, hot springs and steam vents) that comprise the Afro-Arabian Rift System, which stretches from Turkey in the north, via the Dead Sea, Red Sea, and East African lakes, to Mozambique in the south.

Caves at MENP are mostly variants of the same theme - a cul-de-sac extending horizontally into the hillside from a cliff or valley-side with varying amounts of fallen roof obstructing access. The development of Elgon's caves fits neatly into a five-stage process from a simple chamber, through high roof with many rock falls, to complete collapse. The time span for a single cave to pass through all five stages can only be known when we have ascertained the rate of excavation. The two caves where most of the data were collected thus far are Kitum Cave and Makingeny Cave. The former was surveyed and mapped by Ian Redmond and Mike Carter in 1980 (see Fig. 2), using a standard surveying Plane Table technique.

The caves on Mount Elgon were first discovered by Europeans in 1883 when Joseph Thompson visited the southern slopes of the mountain and examined "numerous artificial caves" (Thomson, 1885). Hobley (1897) described how the caves were used by the El Kony tribesmen and their cattle as dwellings and sources of salt. It is remarkable how little attention has been paid to the caves since these early references. Ollier and Harrop (1958) described several groups of caves, members of the Cave Exploration Group of East Africa (whose logo is an elephant in a cave) have explored many caves since 1964 (Peter Holden, pers. comm.), and in 1967 and 1970, Anthony Sutcliffe described several caves on the Kenyan side during a study of lairs of spotted hyaena [Crocuta crocuta (Sutcliffe, 1973) this paper contains a sketch map of Kitum Cave erroneously labelled as Mackingeny, but is otherwise the best summary of Elgon's caves to that date]. But it was only in 1980, when one of us (IMR) joined the Operation Drake Expedition in Kenya and monitored Kitum cave for several nights, that any attempt was made at a systematic study of the use of the caves by wildlife. The results of that study, and several subsequent field trips, are reported below, including examples of the first ever photographs of elephants deep underground (Figs. 3 and 4).

C. THE ENVIRONMENT AND ITS INHABITANTS

Dense montane rainforest dominates the slopes of Elgon from the lower boundary of the Kenyan National Park (at 7,000 ft/2,133 m) where impressive Podocarpus, Juniperus and Euphorbia trees tower over prickly leaved thickets of Acanthus up to about 8,500 ft/ 2,600 m where it is replaced by almost continuous stands of bamboo (Arundinaria alpina). This is replaced by about 10,000 ft/3,000 m by patchy Hagenia woodland and Afro-Alpine vegetation, and

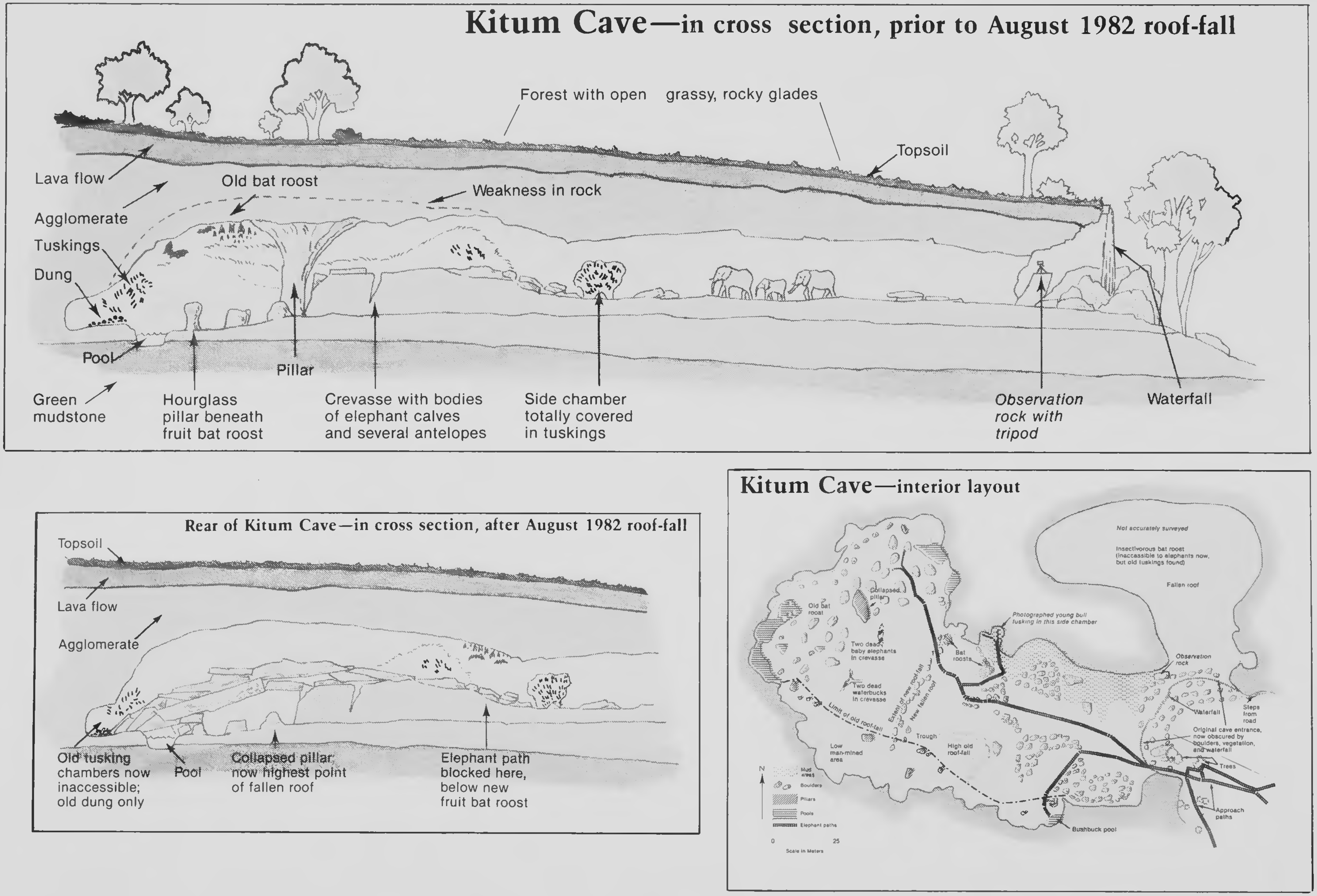

Figure 2. TOP: Side view of Kitum Cave (not to scale) prior to the August 1982 roof-fall. BOTTOM LEFT: Deeper part of Kitum Cave (not to scale) after the August 1982 roof-fall. BOTTOM RIGHT: A floor map of Kitum Cave surveyed by I.M. Redmond and M. Carter [all redrawn by J.O. Connell, and reproduced with kind permission of Animal Kingdom].

Figure 3. TOP: Entrance of Kitum Cave from inside; from left to right are: Park ranger John Ndiwa, Ian Redmond, and Rafael Geron. Observation Rock is on left (not in the picture). BOTTOM: African elephants, Loxodonta africana africana, entering Kitum Cave in search of salt, such as Sodium Chloride [photo credits: TOP by J. Shoshani, BOTTOM by I. Redmond].

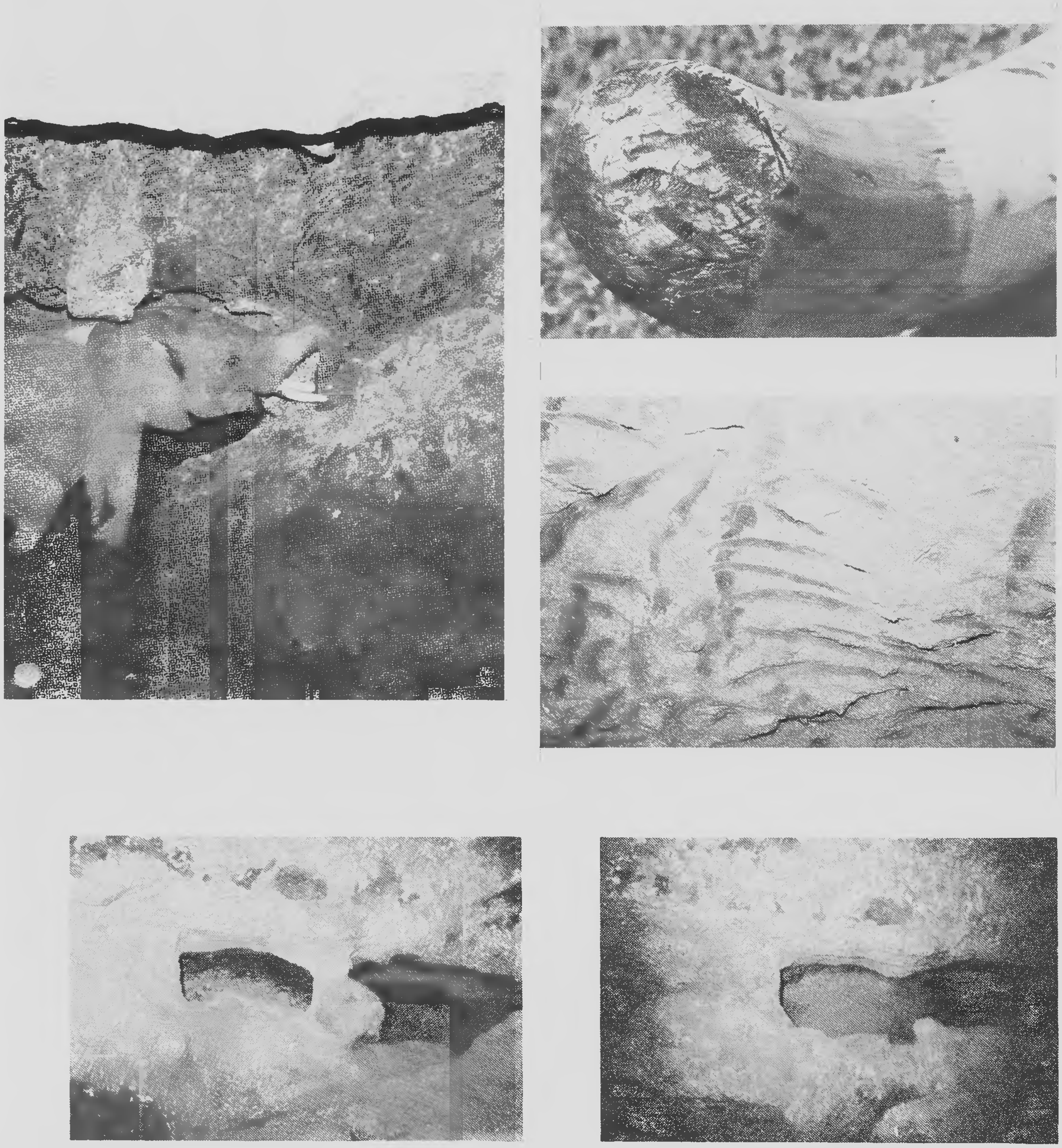

Figure 4. TOP LEFT: A young bull seen "tusking" in Kitum Cave. TOP UPPER RIGHT: Tip of an elephant tusk, worn from mining rocks. TOP LOWER RIGHT: A close up of tusk marks on the wall of Kitum; largest gouges measured about 30 cm (1 foot) long and 5 cm (2 inches) wide. BOTTOM LEFT: The "Television set" - a side chamber in Kitum cave, mined by man but with elephant tuskings observed on 28th July 1982. BOTTOM RIGHT: The same "TV Set" on 22nd August 1985, showing erosion by elephants. Note that the "pillar" had been eaten away [photo credits: all by I. Redmond, except TOP UPPER RIGHT (by A. Sutcliffe) and TOP LOWER RIGHT (by J. Shoshani)].

the trees become more and more stunted as the altitude increases, so that the moorland scenery around the caldera is characterized by low ground cover much of it Alchemilla, and the weird forms of giant Lobelias and Groundsels. In places north and south of the park, the indigenous forest has been felled and replaced with stands of exotic conifers grown for timber, and below 7,000ft/2,133 m the lower slopes of Elgon are almost entirely devoted to large-scale mechanized farming (for introduction to Elgon area and advice on visiting, see Redmond 1983).

Meteorological data are not available for the forest zone, with the exception of readings taken by IMR in November 1981 with a hydrograph and a Maximum/Minimum thermometer (kindly loaned by the National Museums of Kenya), and occasional readings from hand-held thermometers. Maximum temperature on top of the cave (at 8,000 ft/2,438 m) occurred 1400 and 1500 on November 11, 1981 and reached 24^{o} C in the shade; minimum temperatures occurred between 0400 and 0530 hours and reached 8.5^{o} C in the shade. It is likely that both these readings would be exceeded upwards and downwards, respectively, if equipment was installed over a longer period. The temperature in the fruit bat chamber of Kitum Cave remained almost constant at 14.25^{o} C, with slight fluctuations of up to 0.5^{o} either way. Relative humidity (RH) was inversely proportional to temperature in the glade on top of the cave, dropping to 36% at 1500 hours on November 11, 1981 (a fine sunny day) and rising to 87% at 0400 hours the following morning (when temperature was 11^{o} C). In the fruit bat chamber, RH remained steady, with slight fluctuations over the 24 hour cycle, between 85 and 90%. Rainfall data are available for Lokitela Farm (Table 1, from March 1971 to June 1983, courtesy of Tony and Adrianne Mills).

Table 1. Rainfall data - in inches - for Lokitela Farm [about 16 km (10 miles) south of the entrance of MENP, Kenya] for the years of 1971 to 1983, with a few months missing in different years, n = number of years.

Month	Average	Mean	Range	n
January	1.97	2.095	0.60 - 3.59	7
February	2.67	3.06	0.50 - 5.62	11
March	3.275	6.985	0.13 - 13.84	12
April	6.08	6.535	1.90 - 11.17	13
May	8.19	8.94	4.01 - 13.87	13
June	4.82	4.685	2.65 - 6.72	13
July	5.02	5.05	1.55 - 8.55	12
August	5.20	5.95	2.25 - 9.65	12
September	2.85	3.285	0.98 - 5.59	12
October	4.04	3.34	1.08 - 5.6	11
November	2.93	5.16	0.20 - 10.12	12
December	0.58	0.91	0.15 - 1.67	5

Annual rainfall figures are only available for 1978 - 50.51 inches and for 1982 - 57.72 inches, but the sum of the monthly averages gives an annual averages of 47.625 inches. Searle (1952) observed that the average annual rainfall in Kitale was 44.9 inches, but that this increased to 50 inches at the Elgon Saw Mills (in the forestry plantation about 7,000 ft/2,133 m) with a range of 40 to 60 inches. Higher up the mountain, precipitation is even greater owing to frequent cloud cover, drizzle, mist, hail, and - around the caldera - snow. During rainy weather, the park is open only to, and accessible in, four-wheel drive vehicles, and even these sometimes get stuck!

Wildlife in MENP is plentiful and typical of that found in other East African montane forests, but with the added interest of some species with West African affinities. Most noticeable to the average visitor are the mammals, especially the ungulates, primates, and elephants. There are two subspecies of elephants in Africa: the African bush or savanna elephant, Loxodonta africana africana, and the African forest elephant, Loxodonta africana cyclotis (order Proboscidea, family Elephantidae). MENP's elephants belong to the savannah subspecies, despite their forest habitat (note: Redmond, 1982b and 1982c erroneously referred to them as forest elephants, a point corrected in Shoshani and Geron, 1986).

According to Douglas-Hamilton (1987) elephant numbers in the MENP rose from 500 in 1973 to 1,000 in 1977, then fell to 200 by 1987. These figures are based on educated guesses. No accurate census has yet been carried out on Elgon, and the figures are complicated by the fact that elephants move freely in and out of the park from non-protected forests to the north and south. New information has recently come to light from John Wreford-Smith (pers. comm.), a naturalist who used to live on Elgon and who "got to know the many elephant herds and their localities in detail, often spending many days in the forest." His estimate for the early 1970's was 1,200 ± 100 on the Kenyan side of the mountain, and none on the Uganda side. He found that the majority of the elephants spent most of their time outside the park boundary. When IMR began the MEECRP in 1980, the park warden spoke of 'about 500' elephants in the MENP, but no mention was made of whether any still existed outside the park. The recent spate of ivory poaching detailed below has decimated the park's population, and probably (although we have no evidence for this) any surviving elephants outside the park. Our best estimate in August 1987 (based on C. Moss, Pers. comm. and Redmond's discussions with park staff and local naturalists) is that only 50 - 130 elephants remained in MENP.

METHODS USED

Briefly, the methods used in this study were:

Observation - direct and indirect (i.e., spoor such as tracks and droppings);

Data collecting - readings of temperature, humidity, rainfall, altitude;

Photography - daylight flash with 35 mm color and black and white films, and infra-red flash and film;

Sound recording - stereophonic sound recording with Sony cassette recorder loaned by the BBC;

Specimen collecting - animal, rocks, soil, water and plant samples were collected for identification and analysis.

RESULTS AND DISCUSSION

A. GENERAL

The results presented here are based on data collected on the ecology of the elephants at MENP in Kitum and Makingeny caves over a period of seven years (1980 - 2 weeks, 1981 - 7 weeks, 1982 - 9 weeks, 1985 - 2 days, 1987 - 2 days) with a total of 130 days and nights of fieldwork (note: observers slept in caves so as not to miss nocturnal elephant visits). Elephants were observed visiting the cave singly and in groups of up to 19 (there is no reason why much larger herds could not enter at once). Most elephant visits began around dusk, but occasionally they took place during the daytime or late at night. Also observed in the caves were bats, ungulates, hyraxes, monkeys, rodents, carnivores, birds, insects, spiders and other invertebrates (see Appendix A). The interrelationships of this ecological community have yet to be studied in detail.

Elephants cannot lick the rock (their tongues aren't long enough) and so they must loosen earth or pry off bits of rock with their tusks, then convey the particles to the mouth with the trunk (referred to as 'mining'). Rock is ground briefly between the molars and swallowed, the material thereby removed from the cave as the animals leave. Elephants prefer certain caves to others; different social groups visit the same cave on different nights. An 'elephant visit' might last up to six hours, but not all this time is spent in mining rock. They indulge in other activities (e.g., play, rest, bathing, rubbing on rocks) in the dark and relative warmth of the cave - night temperatures on the mountain usually fall below the constant temperature in the depths of the caves. Samples of the layer of volcanic agglomerate in which many caves are found had, on analysis, more than one hundred times the amount of available sodium per gram than the average level found in the ten food plants sampled. One observation in MENP is of particular interest, for it may affect tourism: data obtained in 1981 suggests that the frequency of elephant visits to the caves may increase as the rainfall decreases.

Although we have few quantitative data, the results indicate that elephant mining has played a major role in the formation of the caves. Observations made in other localities indicated that elephant mining over long periods of time causes a gradually receding cliff, as overhangs are dug out and collapse (MacKinnon, 1974, in Ranun River area, North Sumatra; Redmond, pers. obs. in Ngorongoro Conservation Area, near Gibbs Farm, Tanzania). On Mount Elgon the hard layer of lava capping the caves prevents such a total collapse and enables a deep cave to be formed. The presence of a waterfall cascading over the cave mouth in many cases suggests that the mining was concentrated where rock was softened by splashing water, and this alluvial erosion would also have contributed to the early stages of cave formation.

B. HERBIVORES, MINERALS AND SALT BALANCE

Why do MENP's elephants and other herbivores eat and/or lick salt-bearing rocks? All animals require certain minerals and salts (particularly in the form of sodium ions) to carry on their daily physiological functions (for a review of the phenomenon of salt appetite, see Denton, 1972, 1982; and Jones and Hanson, 1985). Termite mounds, soils, wood ash, and borehole water are potential sources from which animals may redress their sodium balance if there is a deficit in their normal diet. Some are able to conserve and store sodium ions in their tissues (e.g., by eliminating sodium-diluted feces and urine), a phenomenon which is advantageous in low sodium environments (Weir, 1972). Denton (1965) examined the effect of adrenocorticotrophic hormone secretion by the anterior pituitary gland as a stimulus to aldosterone secretion. The latter hormone reduces sodium excretion but not urine volume. Hormonal and neural mechanisms are the major regulator for salt appetite; crowding and stress, however, increase aldosterone secretion and increase salt intake (see summary in Wheelock, 1980).

In habitats where sufficient salts and minerals are obtained through forage, mammals do not commonly visit salt-licks (exposures of mineral and salt-rich strata). But in areas of high rainfall, where soluble salts are leached from the topsoil, plants contain low levels of ions, such as sodium and potassium. Herbivores in these areas must visit salt-licks to redress the balance by eating this earth or rock - a behavior known as geophagy (Jones and Hanson, 1985). On Mount Elgon, caves seem to be the best source of minerals (most of the available sodium is bound up in sodium sulphate) available to herbivores since exposures of mineral-rich strata above ground appear too hard to be exploited effectively. Several species of herbivore (appendix A) enter the caves, though not all penetrate into the dark zone, in search of mineral-rich rock. Above-ground elephant salt-licks have been documented in the literature for Africa (Roosevelt, 1910; Weir, 1969, 1972, 1973), for Asia (Hubback, 1939; Morris, 1933; see also Fig. 5), and for North America (Jones and Hanson, 1985, Holman et al., 1988) and a review on the subject has been provided by Wheelock (1980). Underground elephant salt-licks have been documented only at MENP by Sutcliffe (1973), Redmond (1981, 1982a-c, 1983, 1984a-c, 1986a-b, 1987a-d) and as a result of the Operation Drake work and MEECRP, by various popular authors (Jackman, 1982; Blashford-Snell, 1981, 1983; Hadley, 1985; Anonymous, 1987). A television documentary, "Kitum - the Elephant cave", was made by Genesis Films for Channel 4 (a British independent television company) and first shown in 1983. Some of Redmond's articles have been translated into several languages and published worldwide.

Figure 5. Elephant digging for salt at the Ark (Safari Lodge), Aberdare National Park, Kenya [photo credit: by I. Redmond, 1985].

C. ROCK INGESTION AND TOOTH WEAR

Elephants, both African and Asian, have six sets of cheek teeth (molars and premolars) during their lifetime which is about 70 years. The age at which each of the six cheek teeth is shed and the rate of wear, i.e., number of plates or lamellae worn per one year, is also known or can be calculated (see Laws, 1966; Sikes, 1971; Roth and Shoshani, in press). The rate of wear of teeth has been assumed to be affected by the abrasive material in the food. A logical correlate to this assumption is that the faster the teeth are worn, the shorter the lifespan of the elephant. This correlate also raises the question as to whether or not the rate of tooth eruption is influenced by the rate of wear. If new cheek teeth erupt at a genetically predetermined rate, increased wear from geophagy would mean that at intervals throughout the elephant's life it would suffer from smooth, worn-down grinding surfaces until the next set erupted to replace them; but the elephant's lifespan would only be shortened by the difference in time taken to wear out the sixth, and last, set of molars. If we express the lifespan (L) as the sum of time taken to wear out each set of teeth ($t_1 + t_2$, etc.) and the difference made by geophagy (as g), then the elephant's lifespan can be calculated as

$$L = t_1 + t_2 + t_3 + t_4 + t_5 + t_{6-g}.$$

If, on the other hand, cheek teeth eruption is regulated by the speed at which tooth-wear occurs, then the shortening of life due to geophagy would be much more - the sum of the difference in time taken to wear out each set of teeth, which can be calculated by the equation:

$$L = (t_1-g_1) + (t_2-g_2) + (t_3-g_3) + (t_4-g_4) + (t_5-g_5) + (t_6-g_6).$$

Should sufficient skeletal material becomes available in MENP (and sadly, this may well already be the case if skulls of poached animals can be recovered), it may be possible to decide which of these equations applies.

The elephants at MENP ingest a surprisingly large quantity of rock, yet much appears to pass through the gut undigested; 45% of dung piles examined at random in 1982 (n=84) contained particles of rock ranging in size from grit (less than 1 cubic mm) to stones (20-30 cubic cm in volume) with a maximum length of about 5 cm. With such quantities of rocks ingested, the natural question to be asked is whether or not the elephants at MENP have, as a result of this extraordinary geophagy, a shorter average lifespan than elephants in other parts of Africa. To answer this question fully will require much data over a long time period; such data is not available at the present. We do know, however, that most adult elephants at MENP have shorter and rounder stumps of tusks (modified incisors) than other elephants in other areas in Africa, probably due to constant use of the tusks in their salt excavating technique (Fig. 4). Despite the continuous tusk growth during the elephant's life, some of these are so short that they barely protrude beyond the bases of their trunks. Pregnant and lactating cows probably require more salt in their diet than other elephants (by extrapolation of results from research with other mammalian species, see Denton, 1982); in these individuals tusk wear is evidently faster than tusk growth.

D. HOW WERE THE CAVES AT MOUNT ELGON FORMED?

Ever since Thomson (1885) came to the conclusion that Elgon's caves were man-made, most writers who have discussed the caves have also speculated on how they were formed (Hobley, 1897, 1918; Johnston, 1902; Oswald, 1918; Ollier and Harrop, 1958; Perkins, 1965; Sutcliffe, 1973). Only Sutcliffe and Perkins questioned whether elephant mining activity might have had a significant role to play in the creation of the caves, and they both presupposed that the caves existed when the elephants arrived, and that elephant mining simply enlarged them. This hypothesis does not, however, explain why Elgon's elephants should venture deep into the dark zone - a behavior exhibited nowhere else in the world. And none of the conventional hypothesis of cave formation (speleogenesis) offered by the above authors (e.g., wave action, dissolution, running water, gas bubbles in lava, lava tubes) satisfactorily explain all the unique features of Elgon's cul-de-sac caves. Following the early results of MEECRP, Redmond (1982b-c, 1984a-c) offered an alternative explanation, that the principal agent of erosion which created the caves was excavation and ingestion of the mineral-rich rocks by elephants, perhaps over a period of many thousands of years. A rough, 'order of magnitude' calculation was given to demonstrate the plausibility of elephant speleogenesis; the volume of Kitum cave was estimated at 5 million liters (1.3 million gallons) and for the sake of conservative argument, an excavation rate of one liter (or one quart) of rock per week gave a figure of 100,000 years to create Kitum. Measurements and observations made since then have shown that the volume of Kitum was greatly underestimated but that the probable rate of excavation was also underestimated; so that the principle still stands.

The area of Kitum Main Cave available to elephants (excluding the low side-chambers which are clearly dug out by pastoral tribesmen digging out rock for their cattle) is approximately 10,000 square meters. The height of the roof varies considerably but is mainly between 2 m and 4 m, which puts the volume somewhere between 20 and 40 thousand cubic meters (20-40 million liters). At the above rate of excavation, this increases the creation time four- to eight-fold, and as will be discussed below we believe that one liter per week is an over-cautious estimate of the rate of excavation.

Exactly what volume of rock is carried out each year in the stomachs of elephants has yet to be accurately determined, but we now have some evidence which suggests that it is more than the conservative estimate above. One observation by Shoshani and Geron (1986:48) showed that a young bull elephant at the Ark Safari Lodge (Aberdare National Park, Kenya) ingested between 13.8 and 20.7 kg of salty soil in 45 minutes, or 23 kg in one hour {[(13.8+20.7)/2] x 60/45 = 23}. If, for the sake of simplicity and conservative argument we assume that 2 kg of soil occupies about 1 liter volume, thus one elephant might consume about a 10-liter volume in 1 hour (it is probably more than that, but we leave room for the less halophilic elephants). Another observation concerns a young (about 12 years old) bull elephant watched and photographed by Redmond in Kitum Main Cave in October 1982. After spending about 3.5 hours in the cave but out of sight, the bull, who became known as Charles, was followed into a side chamber where he chiselled lumps of rock off the wall with his tusks. When disturbed by Redmond's flash photography, Charles then went deeper into the main chamber and spent about 80 minutes feeding on freshly broken rock on the floor - the result of the major roof-fall which occurred in August 1982 (see Fig. 4). While engaged in photographing the elephant's behavior, Redmond was unable to count the exact number of rock fragments ingested, but his field notes written after Charles had left read, "... each time the trunk was put into the mouth, he would exhale through it (presumably to blow smaller particles into the mouth). Each 'furtle' (feel) with the trunk in the rocks on the ground would last from about 1 second if he quickly found a bit (occasionally 2 or 3 in quick succession if he found an area of loose little bits) up to maybe a minute or so if he had to move a rock and keep it from falling back, with his foot, into the hole he was making. The crunch of his molars grinding the rock particles was clearly audible at times, plus smacking of lips and tongue." It was not possible to see the size of each rock fragment ingested, but some of them were clearly the size of a man's fist before chewing, and some were eaten as trunkfuls of gravel. To try and quantify this in terms of volume of rock removed from the cave, we might estimate that Charles averaged 6 trunkfuls per minute for 80 minutes (aside from the rock he had already ingested while out of sight and in the side-chamber) and that if each trunkful contained, on average, 10 cc of rock (a fragment measuring 2 cm x 2 cm x 2.5 cm, again for conservative argument), then Charles would have ingested 4.8 liters. Given that on some nights there were 19 elephants in the cave, an average of one or two liters per night seems more likely than one per week, and so the annual rate may be 0.75 cubic meters or more.

A third observation concerns visible changes to some of the features in Kitum Cave over the years. Figure 4 (BOTTOM LEFT) shows a small, man-made side chamber with a small pillar which gives the impression of a "Television Set" set into which a man could crawl and sit (the 'screen' was about 1 m wide), as it was in June 1982. Figure 4 (BOTTOM RIGHT) shows the same site as it was in August 1985. Probably one cubic meter of rock has been removed from around the 'set', including the pillar which formed the right of the screen, and this despite it being close to the new (1982) roof-fall edge, with all its readily available, broken-up rock fragments. There is also a noticeable enlargement of the side-chamber where Charles was photographed (see Fig. 4, TOP LEFT), in which attention has been concentrated by the roof-fall blocking access to the deeper mining bays.

Based on the above observations and conservative calculations, it appears that the hypothesis of elephant erosion as the major causative agent in the formation of Elgon's caves is shown to be entirely plausible. These thoughts need to be viewed in the context that Mount Elgon has not erupted for several million years and that the African elephant (genus Loxodonta) is known to have existed for about 5 million years (Maglio, 1973).

MOST RECENT POACHING AND RELATED ACTIVITIES

The summary below covers events from February 1986 to November 1987, and is based on recent visits (July 19 and 20, 1987) by I. Redmond to MENP, and his detailed discussions with the Park Warden, Mr. Ben Amoko, and several local residents with an interest in the Park (notably, T. and J. Barnley, J.K. Ikunyua, Curator of Kitale Museum, and T. Mills, a local farmer).

Approximately from February to May 1986: Elephants have been heavily poached for ivory with automatic weapons; the poachers apparently come from both sides of the border, Kenya and Uganda, which crosses the summit of Mount Elgon.

Approximately from June to December 1986: The situation worsened and the Warden felt obliged to close the Park for three months and bring in reinforcements from the Kenyan army and police, even using helicopters on one occasion. In their pursuit the poachers blew up bridges to hamper the movements of the rangers. Rumors were also heard that the poachers used anti-tank guns to kill elephants. Attacks on the elephants became less frequent towards the end of the year.

Between January and March 1987: Eleven poachers were captured and imprisoned. Three dilapidated log bridges were replaced with concrete ones and some of the park roads were greatly improved. A special anti-poaching unit was stationed in the Park by the Kenyan Wildlife Conservation and Management Department (WCMD).

Approximately from February 1986 to July 1987: Forty-two elephant carcasses had been found. This number is probably a minimum estimate of the degree of poaching, for if the July 1986 attack was typical, a far greater number of elephants have been wounded, to die at a later date. The greed for ivory has been insatiable. The poachers killed elephants whose tusk size was barely greater than a pencil. Not only were the poachers equipped with automatic rifles but also with chain-saws. One of the worst attacks occurred on July 8, 1987 when poachers ambushed a small herd on a cliff above the mouth of Kitum Cave. As the lead elephant walked up the steep path to the entrance, they opened fire indiscriminately with automatic weapons (see Fig. 6).

Figure 6. The carcass of a 12-year old bull gunned down by ivory poachers using automatic weapons in the vicinity of Kitum Cave of MENP [photo credit: by I. Redmond, July 1987].

This event was witnessed by a party of Kenyan women on a field trip arranged by the Kitale Museum. By the time they reported the incident to the rangers (3 km away), who rushed to the scene, the poachers had disappeared in the darkness, taking the ivory with them.

November 1987: The East African Wildlife Society has released emergency funds to repair some of MENP's vehicles as a result of the report arising from this visit (Redmond, 1987b).

Elephant numbers are declining throughout Africa, and the Mount Elgon population is a case in point. According to Iain Douglas-Hamilton (pers. comm., August 27, 1987), "If the offtake for ivory is not drastically reduced, we can expect to lose all the major populations of elephants in the great national parks of East Africa, other than a small remnant." In the 1970's the elephant population on Mount Elgon was estimated to number 1,200; today the estimate is between 50 and 130.

FUTURE RESEARCH AND CONSERVATION PLANS

Outlined below are our research plans and recommendations for management. Time and funds permitting, we plan to:

1) Census present elephant numbers inside and outside the park area on Mount Elgon - scheduled for April/May 1988.
2) Carry out a study of the elephant population in the MENP and environs for a minimum of 12 consecutive months. This would include: a) a regular census of the elephant population, b) a study of seasonal movement over the year, c) assessing the extent of their dependence on caves for mineral salts, d) collecting physiological data, and e) determining whether the use of particular caves is random or whether certain social groups utilize certain caves;
3) Locate, explore and map caves on the eastern flank of Mount Elgon, assessing their past and present usage by elephants and other non-cave dwelling animals;
4) Assess the former extent of human mining for cattle mineral-lick in all caves visited and make recommendations on any promising sites for archaeological excavation;
5) Compare our results to those from studies in captivity (e.g., Benedict, 1936) and from other sites in the wild where elephant mining has resulted in caves or overhanging cliffs;
6) Prepare a plan for management and conservation of the MENP and its relict elephant population.

RECOMMENDATIONS

A. **Urgent needs:** (1) <u>Ranger numbers</u> - the current team is insufficient to deal with the present level of poaching. Individuals who know the mountain and forests well should be sought, possibly even recruiting ex-poachers turned game-keepers. (2) <u>Ranger mobility</u> - greatly hampered by the state of the fleet of vehicles at the Park; most are out of action for want of spare parts.

Vehicles are not the whole answer though; more foot patrols are needed to get to parts of the park inaccessible to cars. (3) Rangers stations - more should be built and manned, especially in remote areas of the Park. Radio contact with the Park Headquarters should be maintained so that reinforcements can be called up when needed.

B. **Longer term needs:** (1) Management Plan - to help fill some of the gaps in our knowledge of the mountain and its ecology. (2) Research Center - to be established for resident and visiting scientists. (3) Visitor Center: - for education and public awareness, including items such as Audio Visual slide/tape packs to be distributed to wildlife Clubs of Kenya, education centers and schools in other countries. (4) Improvement of tourist facilities - a concerted effort must be made to attract more tourists and provide them with better facilities. This would include a viewing platform and low-level lighting in Mackingeny Cave (the best place for this construction would be in the roof dome on the left side of the cave, so as not to spoil the arch of the entrance chamber, see Fig. 7). Fees that would be collected from tourists for this and other services would be re-channelled towards park management.

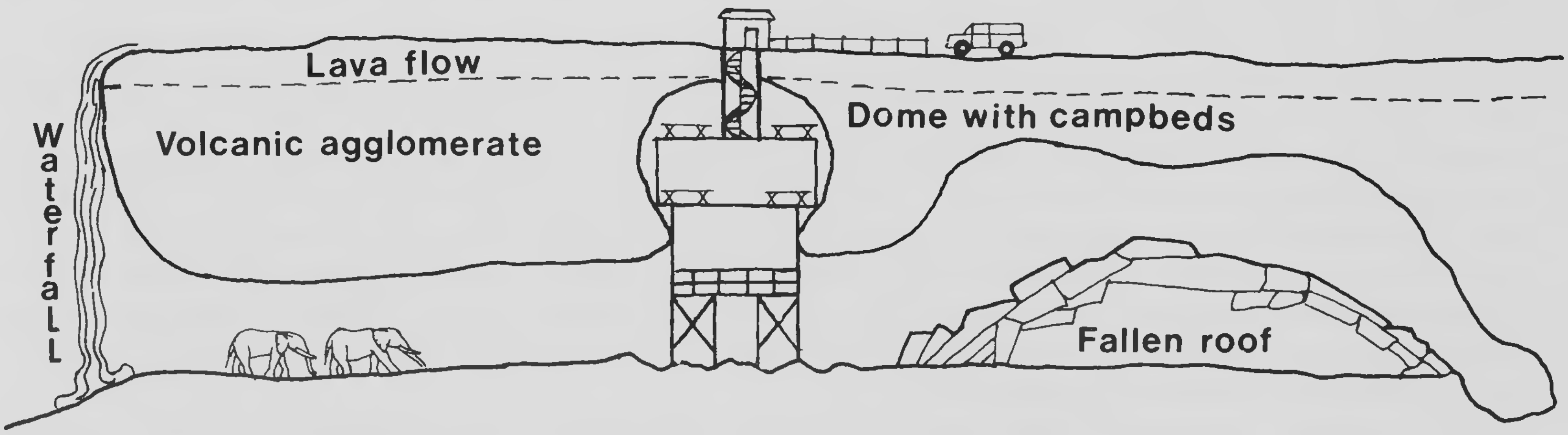

Figure 7. A diagramatic cross section (not to scale) of a proposed viewing platform at Mackingeny Cave in MENP [redrawn by G.H. Marchant].

C. **Park enlargement**: Ben Amoko, the Warden at MENP and Dr. Perez Olindo, Director, WCMD, informed us that plans are still afoot to enlarge the Park by gazetting the forest reserve to the south and to encompass the Lodge and the surrounding open grassland. This excellent idea is a very positive bit of news amidst all pessimism, and one which reflects very well on the efforts of the Kenyan conservation authorities. Of course, more fencing, guards/rangers, and equipment will be needed to maximize the effect of this expansion. In this regard, it is noted that protecting elephants in as wide a home range as they require also implies preserving smaller species and the ecosystem in which they live; the reverse is not true, i.e., saving small animals would not save the elephants. This idea of microfauna preservation within the megafauna's habitat was mentioned by Shoshani (1980:77) and restated by him more recently (Shoshani, 1987:74).

FUND-RAISING

As part of the overall fund-raising campaign to conserve the African elephant, the "African Ele-Fund" has been created (Redmond 1987a-b, 1988). The aims of this international appeal are: 1) to improve protection of elephants and their habitat wherever they are threatened; 2) to alert the general public worldwide to the present rate of destruction of elephant populations by ivory poachers; and 3) to campaign to reduce the ivory trade to a level sustainable by natural mortality and legal culls. The African Ele-Fund is organized by volunteers and administered at no cost. Every penny and/or cent donated will be spent in the field. A group of conservationists and field biologists comprise the Steering Committee of the African Ele-Fund to ensure that funds are channeled to those elephant populations most urgently in need. The elephants at MENP are indeed in peril; the Park needs a minimum of US $6,020 (or 3,500 English Pounds) for vehicle repairs, and US $25,800 (or 15,000 English Pounds) per year to cover the cost of extra anti-poacher patrols. Donations can be made payable to the African Ele-Fund and mailed to one of these organizations:

IWC/Care for the Wild, 26 North Street Horsham, West Sussex, RH12 1BN England
IWC USA, 1807 H Street NW, Washington D.C. 20006, USA
IWC Canada, 542 Mount Pleasant Road, Suite No. 104, Toronto, Ontario M4S 2M7, Canada
East African Wildlife Society, P.O. Box 20110, Nairobi, Kenya.
or to WWF International, via local WWF offices in any country.

SUMMARY AND CONCLUSIONS

A. On cave ecology: The animal community dependent upon caves such as Kitum is far more complex than had been suspected. Species associated with the caves studied fall into four main categories:

1) Residents by virtue of seeking a suitable home, e.g., bats, birds, hyraxes;
2) Visitors attracted by the salt-rich rock, e.g., elephants, monkeys, antelopes, buffaloes;
3) Residents dependent upon feces of 1) and 2), e.g., scatophagous insects and bacteria, or upon dead bodies of 1) or 2), e.g., scavenging insects, bacteria; and
4) Residents and/or visitors that are either predators (e.g., leopards, insects, bacteriophagous copepods) or parasitize (e.g., fleas, mites, ticks and bugs) that utilize any or all of the above species.

B. On Loxodont speleogenesis: Conventional hypotheses of cave formation (speleogenesis) fail to account for features common to many of Mount Elgon's caves. An alternative is proposed: the cliffs of salt-rich agglomerate in which caves are found are capped by impervious basalt; water cascading over the cliffs acts as a focal point for elephant activity; splashing water helps to soften the rock initially, and as the cave grows behind the fall, tusking becomes the major force of erosion. Each subsequent generation of elephants learns the location of salt-licks from its elders. Despite the cave deepening its use becomes a "cultural" feature of the Mount Elgon elephant population. Boulders in Kitum show how successive roof falls are eaten away to create the vast proportions of mature caves like Makingeny. The geology of Mount Elgon is unique in allowing the caves to extend deeply into the hillside supported by the lava roof. In other places, such as Ngorongoro Crater, where geophagous elephants excavate overhangs, they soon collapse.

C. On elephant conservation: The sharp decrease in elephant numbers in MENP was, ironically, a "blessing in disguise" because it alerted conservationists worldwide to the plight of elephants, in particular those of MENP. Foremost on our agenda is to save the MENP elephants before the poachers kill them. There appear to be many listening ears among the general public, as the initial efforts for fund raising have proved encouraging. We hope that our research will provide the necessary data for a realistic management program and that visitors will be able to observe these unique elephants in the future.

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Appendix A. Animal species or spoor of them that were observed (mostly by I.M. Redmond) in or in close proximity to Kitum Cave, MENP, Kenya. [Note that listing is not in any specific order but major groups within a class are listed alphabetically; Dorst and Dandelot (1970) and Honacki et al. (1982) were consulted for the mammalian species, and Williams (1963) for the bird species.]

VERTEBRATES (Phylum Chordata)

Class Mammalia
- Order Artiodactyla (even-toed ungulates)
  - Family Suidae (includes pigs)
    - *Hylochoerus meinertzhageni* (giant forest hog)
  - Family Bovidae (includes antelopes and cattle)
    - *Tragelaphus scriptus* (bushbuck)
    - *Syncerus caffer* (African buffalo)
    - *Cephalophus callipygus* (Peters' duiker)
    - *Cephalophus nigrifrons* (black-fronted duiker)
    - *Kobus defassa* (Defassa waterbuck)
- Order Carnivora (carnivores)
  - Family Viverridae
    - Undetermined spoor of a genets or civet
  - Family Hyaenidae - *Crocuta crocuta* (spotted hyaena)
  - Family Felidae - *Panthera pardus* (leopard)
- Order Chiroptera (bats)
  - Suborder Megachiroptera (fruit bats)
    - Family Pteropodidiae
      - *Rousettus* cf. *aegyptiacus*, possibly *lanosus*
  - Suborder Microchiroptera (insectivorous bats)
    - Undetermined species
- Order Hyracoidea (hyraxes)
  - Family Procaviidae
    - *Procavia capensis* (rock hyrax)
- Order Primates (includes monkeys)
  - Family Cercopithecidae
    - *Papio anubis* (olive baboon)
    - *Cercopithecus mitis stuhlmanni* (blue monkey)
    - *Colobus guereza matschiei* (black and white colobus monkey)
- Order Proboscidea (elephants)
  - Family Elephantidae
    - *Loxodonta africana africana* (bush elephant)
- Order Rodentia (rodents)
  - Family Muridae (includes rats)
    - *Cricetomys gambianus* (giant Gambian rat)
  - Family Hystricidae (Old World porcupine)
    - *Hystrix cristata* (North African crested porcupine)

Class Aves (birds)
- Family Apodidae (includes swifts)
  - *Apus niansae* (Nyanza swift)
- Family Hirundinidae (swallows and martins)
  - *Psalidoprocne holomelaena* (black roughwing swallow)
  - *Hirundo angolensis arcticincta* (Uganda swallow)
  - *Hirundo daurica* (red-rumped swallow)
  - *Hirundo* (*Ptyonoprogne*) *fuligula* (African rock martin)
- Family Sturnidae (starlings)
  - *Onychognathus tenuirostris* (slender-billed chestnut-wing starling)

Class Reptilia - *Lacerta jacksoni* (Jackson's lizard)

Class Amphibia - *Rana angolensis chapini* (Angolan frog)

INVERTEBRATES (Phylum Arthropoda)

- Family Calliphoridae (blow flies)
- Family Muscidae (dung flies)
- Family Scarabeidae (dung beetles)
- Families undetermined: *Culex* sp., *Limonia* sp. (long-legged flies), *Bradysia* sp. (small flies), *Psychoda* sp. (owl midges or moth flies), *Mesovelia* sp. (water skating hemipterans), *Afrocimex leleupi* (bed bugs), *Daphnia*-like (copepods).