Chapter 1

Introduction: Paleontological and Geological Research in the Manonga Valley, Tanzania

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1. Introduction

During the summer of 1990, a small international team, representing the first Wembere–Manonga Paleontological Expedition (WMPE), initiated a long-term field program of geological and paleontological research in the Manonga Valley of north-central Tanzania (Fig. 1). Although the occurrence of fossil sites in the Manonga Valley was first recognized in 1929 (Stockley, 1930; Grace and Stockley, 1931), there was little subsequent paleontological exploration, and the 1990 expedition represented the first concerted effort to document in detail the geology and paleontology of the region (Harrison, 1991a, b; Harrison *et al.*, 1993; Harrison and Verniers, 1993). The expedition recovered vertebrate fossils from

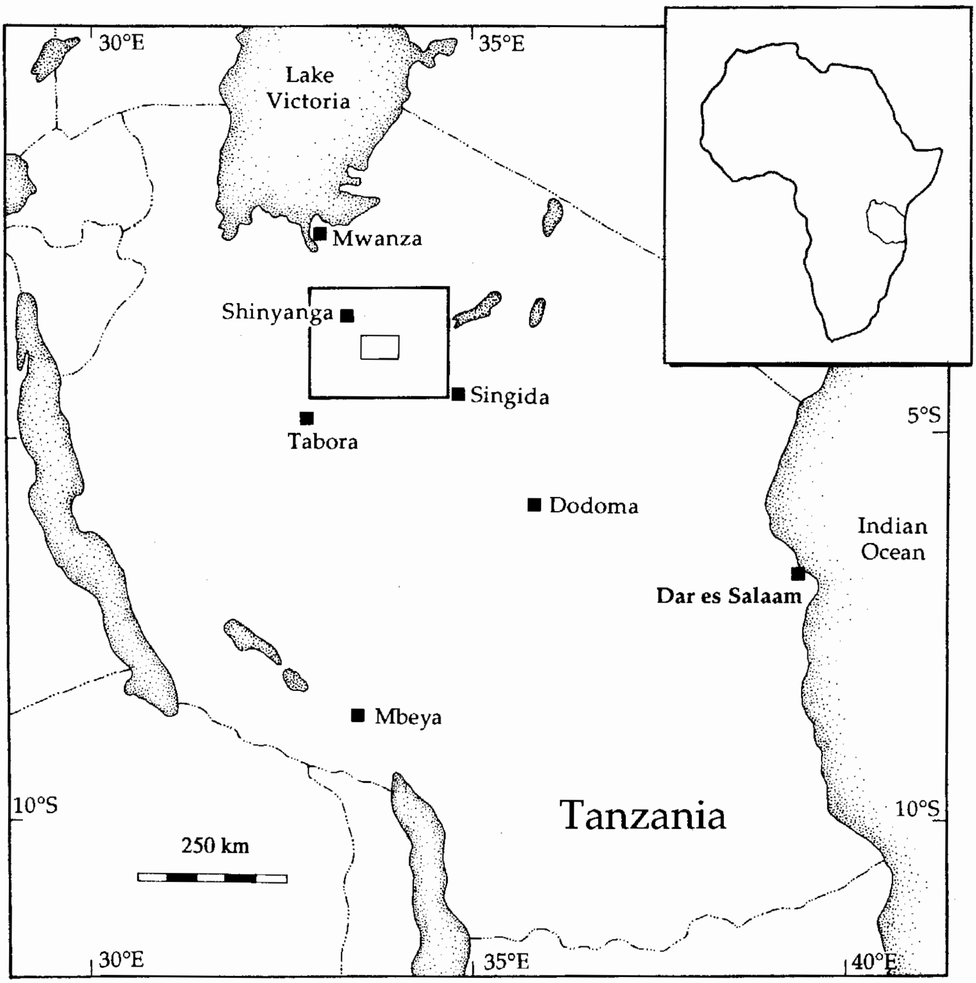

FIGURE 1. Map showing the location of the main research area in north-central Tanzania. See Figs. 2 and 3 for detail of large and small insets, respectively.

10 different localities, and preliminary studies of the fauna confirmed initial observations based on the 1929 collections in the Natural History Museum in London, that the sediments probably ranged in age from late Miocene to early Pliocene (Hopwood, 1931; Harrison, 1991a, b; Harrison *et al.*, 1993; Harrison and Verniers, 1993). The 1990 survey was sufficiently promising that full-scale expeditions were organized in 1992 and 1994. A total area of over 1000 km^2 has now been explored, and more than 30 productive paleontological sites have been identified (Table I). Brief preliminary reports on the 1990 and 1992 expeditions have been published (Harrison, 1991b, 1993a, b, 1994; Harrison and Verniers, 1993; Haileab and Harrison, 1993; Winkler, 1993; Harrison *et al.*, 1993), but the present volume represents the first detailed account of the history of research (Chapter 1), geology (Chapter 2 and 3), paleoecology and taphonomy (Chapter

Table I. List of Fossil Localities in the Manonga Valley

Name of locality	SASES No[a]	Coordinates	Year of discovery
Tinde West	Hi Ix/1	4°02′S 33°46′E	1929
Tinde East	Hi Ix/2	4°02′S 33°46′E	1929
Mwambiti 1	Hi Ix/3	4°01′S 33°50′E	1990
Mwambiti 2	Hi Ix/4	4°01′S 33°50′E	1990
Mwambiti 3	Hi Ix/5	4°02′S 33°47′E	1992
Mwambiti 4	Hi Ix/6	4°02′S 33°47′E	1992
Mwambiti 5	Hi Ix/7	4°01′S 33°49′E	1994
Lubeho	Hi Ix/8	4°02′S 33°45′E	1994
Kiloleli 1	Hh Iw/1	3°51′S 33°42′E	1990
Kiloleli 2	Hh Iw/2	3°52′S 33°43′E	1930s
Kiloleli 3	Hh Iw/3	3°52′S 33°42′E	1990
Kiloleli 4	Hh Iw/4	3°52′S 33°42′E	1990
Shoshamagai 1	Hh Iw/5	3°53′S 33°42′E	1990
Shoshamagai 2	Hh Iw/6	3°53′S 33°42′E	1990
Ipembe	Hh Iw/7	3°56′S 33°37′E	1992
Inolelo 1	Hh Iw/8	3°53′S 33°43′E	1992
Inolelo 2	Hh Iw/9	3°54′S 33°44′E	1992
Inolelo 3	Hh Iw/10	3°54′S 33°44′E	1992
Kalitu	Hh Iw/11	3°54′S 33°45′E	1992
Ngofila 1	Hh Ix/1	3°55′S 33°47′E	1992
Ngofila 2	Hh Ix/2	3°55′S 33°49′E	1992
Ngofila 3	Hh Ix/3	3°55′S 33°49′E	1992
Ngofila 4	Hh Ix/4	3°54′S 33°49′E	1992
Ngofila 5	Hh Ix/5	3°53′S 33°49′E	1992
Beredi North	Hh Ix/6	3°53′S 33°51′E	1992
Beredi South 1	Hh Ix/7	3°55′S 33°52′E	1992
Beredi South 2	Hh Ix/8	3°55′S 33°52′E	1992
Beredi South 3	Hh Ix/9	3°56′S 33°52′E	1992
Beredi South 4	Hh Ix/10	3°55′S 33°53′E	1992
Beredi South 5	Hh Ix/13	3°55′S 33°53′E	1994
Nyawa	Hh Ix/11	3°50′S 33°58′E	1959
Kininginila	Hh Ix/12	3°59′S 33°56′E	1992
Mihama	Hh Ix/14	3°53′S 3°55′E	1994

[a]Standardized site enumeration system for Africa.

4), vertebrate and invertebrate paleontology (Chapters 5–13), and paleoanthropological significance (Chapter 14) of the Manonga Valley.

2. The Modern Geographic Context

The Manonga River originates near the village of Igunda, northwest of Isaka, and flows eastward through the Manonga Valley to discharge into Lake Kitangiri (Fig. 2). The river represents the boundary between Shinyanga and Tabora Regions, the two main administrative provinces that encompass the Manonga Valley. The Manonga Valley is between 10 and 20 km wide, and is bordered to the north and south by low cliffs and slopes no more than 30 m in height. The general area has a low relief, ranging in elevation from 1000 m to 1200 m above sea level. The presence of a number of small hills, formed by remnants of the Precambrian basement, results in a gently undulating terrain. Formation of the valley was presumably initiated by the action of the Manonga River as it cut through the underlying Neogene lake sediments, but the continued retreat of its margins is due to active erosion of the exposed faces of the cliffs by heavy seasonal rains.

The region is hot and dry, with unreliable rainfall. The average annual precipitation is slightly more than 800 mm, which is generally considered close to the minimum to support intensive grazing and cultivation. From June to November, during the dry season, ephemeral streams and rivers, including the Manonga River, are completely dry, except for small stagnant ponds excavated and maintained by the local inhabitants. Tracks and river gullies are impassable during the rainy season (January to April), making it impractical to conduct fieldwork at this time of the year. In the course of three summer field seasons (May to August), WMPE has recorded no rainfall whatsoever in the Manonga Valley. Mean ambient temperatures range between 21–25°C, but there is considerable daily and seasonal variation.

The vegetation is predominantly dry thornbush, composed of *Acacia–Commiphora–Lannea* association, and grasslands with a sparse covering of *Combretum* and gall acacia (Grantham *et al.*, 1945). Toward the eastern margin of the basin, where the Manonga Valley grades into the Eyasi–Wembere depression, a flat, treeless expanse of grassland occurs, representing the southernmost extension of the Serengeti Plains. The western portion of the Manonga basin, where human population densities are generally much lower, miombo woodland predominates. This type of woodland, dominated by several species of trees belonging to *Julbernardia, Isoberlinia*, and *Brachystegia*, is typical of the Central Plateau of Tanzania (Gillman, 1949; Kingdon, 1974; Lind and Morrison, 1974). Woodland habitats were probably more widespread in the Manonga Valley in the recent past, but rapid population growth in the last 60 years, and the subsequent increased demand for firewood and suitable agricultural and grazing lands, has led to wide-scale clearance (see Harrison and Baker, this volume, Chapter 13). In some areas, overgrazing and poor agricultural management have caused extensive soil erosion and badlands formation.

The Manonga Valley is largely populated by the Wasukuma, the largest tribal group in Tanzania. The closely related Wanyamwezi are also encountered in the western and southern portions of the valley, and Iramba and Nilotic pastoralist peoples belonging to the Tatoga group (known locally as Taturu) are found in the Wembere–Eyasi Steppe, at the eastern margin of the Manonga Valley. Population densities in the area are quite low, usually not exceeding 30 persons/km^2, but are often as sparse as 10 persons/km^2 (Thomas, 1971).

The Sukuma are industrious agriculturalists and cattle herders. Shinyanga Region, which represents the heart of Usukuma, has the highest concentration of cattle in Tanzania (supporting more than 25% of the nation's cattle), along with sheep and goats (Moore, 1971). This success is due to a combination of skilled husbandry, the availability of good grazing lands, and the absence of tsetse flies (*Glossina* spp.). Staple crops include millet, sorghum, maize, beans, sweet potato, and cassava. In addition, rice, groundnuts, and cotton are grown as cash crops. The cotton industry has proved extremely profitable for the Sukuma, whose use of cattle as draught animals has greatly enhanced their capability to transport cotton harvests to centralized ginneries. Additional

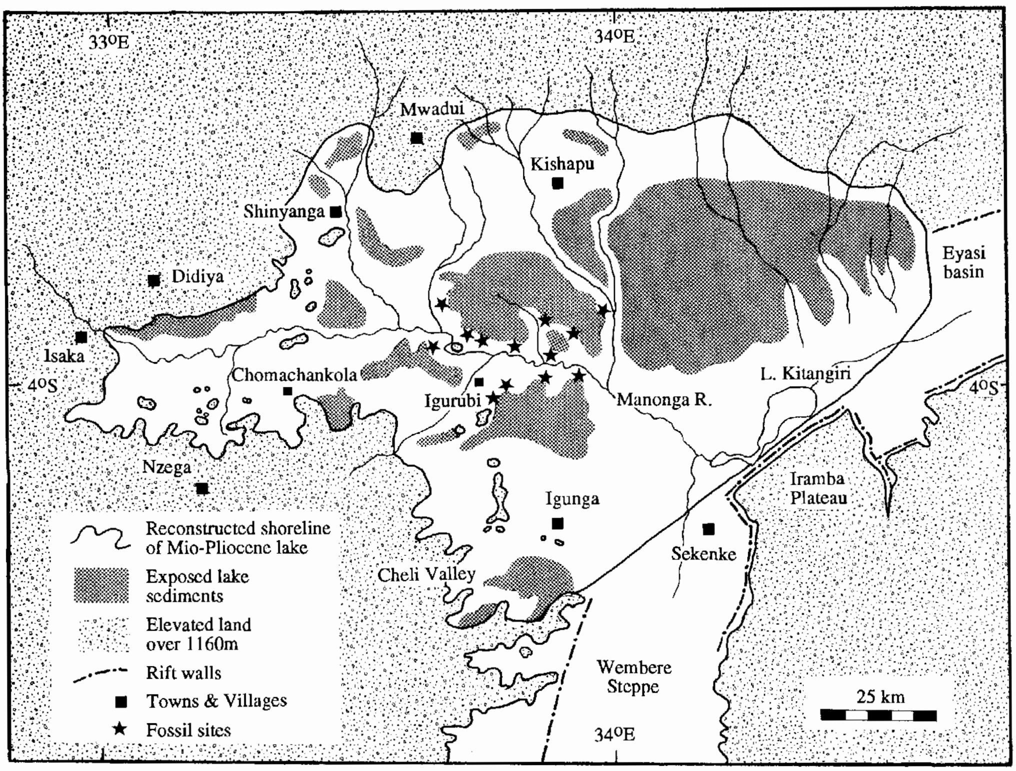

FIGURE 2. Reconstruction of the extent of the paleolake in the Manonga basin during the late Miocene and early Pliocene (after Harrison, 1993).

sources of income are derived from the collection of natural resources, such as honey, beeswax, and gum arabic. A major commercial diamond company is located at Mwadui in Shinyanga District, and itinerant prospectors also operate small-scale concerns in the region in search of gold and diamonds, but with very little return. Abandoned quarries in the vicinity of Shinyanga and elsewhere indicate that the extraction of limestone was formerly a viable concern, but the difficulties of transportation have served to limit its economic potential (Williams and Eades, 1939).

Igurubi, close to the center of the Manonga Valley, is a small market town that provides the focal point for communication with other parts of the region. Situated on the main road from Singida to Shinyanga, Igurubi is located 40 km north of Igunga and 80 km south of Shinyanga (Figs. 2 and 3). Because of the sparse vegetation cover, the flatness of the terrain, and the network of small oxcart tracks that crisscross the valley, most areas of the Manonga basin are easily

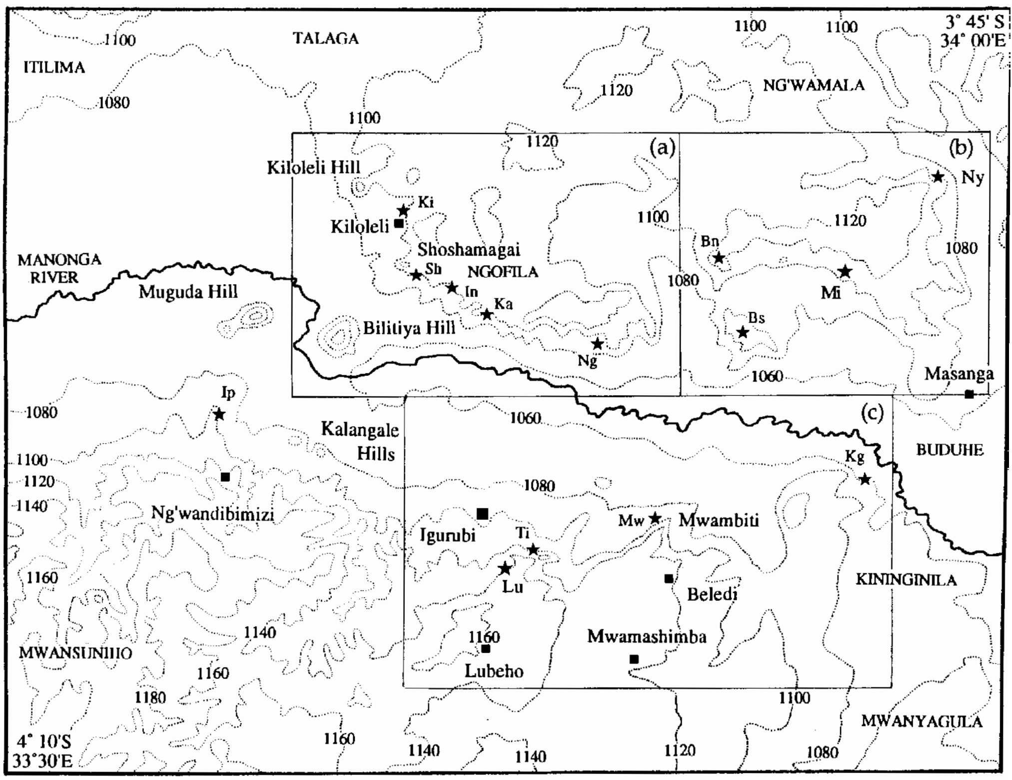

FIGURE 3. Topographic map of the center of the Manonga basin showing the location of the main paleontological site complexes (marked by stars). See Figs. 7–9 for details of insets (c), (a), and (b), respectively. Abbreviations: Bn, Beredi North; Bs, Beredi South; In, Inolelo; Ip Ipembe; Ka, Kalitu; Kg, Kininginila; Ki, Kiloleli; Lu, Lubeho; Mi, Mihama Mw, Mwambiti; Ng, Ngofila; Ny Nyawa; Sh, Shoshamagai; Ti, Tinde.

reachable by car (or by foot) from Igurubi, at least during the dry season. Since 1990, WMPE has been based at temporary tented camps, located 5 km east of Igurubi on the south side of the Manonga River, close to the village of Mwamakona.

3. History of Research

Fossils were first discovered in the Manonga Valley in 1929 by C. Grace, a geologist who was mapping the area for a Belgian mining syndicate. Grace made a small collection of fossils from a locality close to the village of Tinde,* just to the east of Igurubi (Stockley, 1930; Grace and Stockley, 1931). The site was located at a distinct break or gap in a line of bluffs situated about 2 km south of the Sakamaliwa–Nzega road. Grace was later joined by G. M. Stockley of the Geological Survey of Tanganyika Territory, and together they collected further specimens at Tinde, and attempted several trial excavations without much success. Fossils were recovered mainly from the surface, after having eroded out of the cliff face. Excavations showed, however, that the fossils were all derived from a single horizon, a nodular limestone band interposed between "stiff greenish clays" (Grace and Stockley, 1931). Stockley (1930) and Grace and Stockley (1931) described these beds as the Tinde beds, and referred to the fossil horizon as the Tinde bone-bed.

These collections were forwarded by Dr. E. O. Teale of the Geological Survey to the Natural History Museum in London, where they were examined by A. T. Hopwood. In a letter to Teale, dated 12 September 1929, Hopwood, referring to the Tinde fossils, stated:

> So far as I can say at present there is nothing very startling among them, but, all the same, they are interesting as being the first fossil mammals, so far as I know, which have been collected in Tanganyika. [Hopwood was evidently unaware of Reck's material from Olduvai Gorge (Reck, 1914a, b; Dietrich, 1916, 1925, 1928).] They are chiefly remains of Hippopotamus but there is one piece of Elephant which may be important later on and there are in addition fragments of fish and turtles. The age is very late, I don't see any possibility of an earlier date than the middle of the Pleistocene. The Hippo does not help at all in this respect, it all turns on the Elephant, and there isn't sufficient of him.

Hopwood (1931) later published a brief report on the fauna from Tinde. He made passing reference to a species of *Hippopotamus*, which he suggested was prob-

*The location of the village of Tinde is clearly shown on Grace and Stockley's (1931) sketch map as being very close to the fossil site. However, it should be noted that no village exists in this location today, and that the present village of Tinde is located at some distance. Moreover, local inhabitants have no recollection of a nearby village called Tinde, although they do identify a small river gully further to the northeast by this name. This is not surprising, given the ephemeral nature of small villages in the area, and the fact that the main Nzega–Sakamaliwa road today follows an entirely different course. The name Tinde, however, seems to recur throughout the region, and although the etymology is uncertain, local Sukuma informants suggest that the name implies the stump of a large tree.

ably *H. amphibius*, and a medium-sized antelope, but he was most intrigued by the lower jaw fragment of a juvenile proboscidean, mentioned in his correspondence, which he referred to as *Elephas* sp. Hopwood noted its primitive molar morphology and the presence of a fragment of an unerupted P_4 still preserved in its crypt, and he compared it most favorably with elephantids from the Siwalik Hills and Kaiso (see Sanders, this volume, Chapter 9, for further discussion of the taxonomy of this specimen). Hopwood (1931) tentatively assigned a Pleistocene age to the material.

Williams and Eades (1939) presented a detailed account of the geology in the area of Shinyanga, which includes the northwest quadrant of the Manonga Valley. They outlined a geological succession in the region, and included the Tinde beds of Grace and Stockley (1931) into a broader stratigraphic unit, the Manonga–Wembere lake beds. The latter comprised an extensive series of calcareous lake sediments in the center of the basin, along with sandy littoral facies (Teale, 1931; Williams, 1939). Williams and Eades (1939) suggested that the Manonga–Wembere lake beds were laid down sometime during the Plio-Pleistocene, prior to the formation of the Eyasi trough, and that this latter event led to the eventual degradation of the earlier terrestrial and lacustrine sediments in the Manonga Valley. They also briefly reported the discovery of a fossil assemblage, similar to that from Tinde, recovered from marl bluffs along the Negezi–Igurubi road, about 3 km north of Shoshamagai. The exact location of the site is not given, but based on the evidence presented, it would seem to be equivalent to the locality identified as Kiloleli 2 by WMPE (see 5.3 below).

In 1959 the area was visited briefly by Kleindienst and Haldemann, who made small paleontological collections at the sites of Tinde, Kiloleli, and Nyawa. Several fragmentary specimens from each of these sites were sent to K. P. Oakley at the Natural History Museum in London, as possible samples for absolute dating. As far as we can discover, however, the samples were never analyzed. In correspondence with Oakley, dated 2 February, 1960, Kleindienst stated:

> The sediments are fine tuffs, silty-clays, and sands with several definite red marker beds that have not been previously recorded. They could well be Lower-Middle Pleistocene. I was unable to find any associated artifacts, although some Middle-Late Stone Age occurs on the surface.

At a later date, Kleindienst was contacted by Shirley Savage (née Coryndon), who had made a brief study of the fauna. In a letter dated 4 October, 1973, Savage writes:

> I'm afraid all the material is very scrappy and contains few diagnostic items. There is only one specimen which would suggest an age earlier than Upper Pleistocene/Holocene, and that is two small fragments of elephant tooth which have rather thick enamel and widely separated plates—as far as one can see any detail on a worn couple of fragments. Otherwise the fauna appears to contain living genera and probably species.

However, it seems likely that at least part of this fauna was derived from the superficial mbuga clay layer, which is much younger than the late Neogene Manonga–Wembere lake beds (see below, and Harrison and Baker, this volume, Chapter 13).

Finally, in 1976, while Mary Leakey was working at Laetoli in northern Tanzania, Philip Leakey and a geologist, Mark Monaghan, made a brief reconnaissance trip to the Manonga Valley. They recovered a small collection of fossils, which are currently stored in the Laetoli lab at Olduvai Gorge (M. D. Leakey, personal communication).

As can be seen from this brief review, the Manonga Valley was largely unexplored when WMPE mounted its first expedition in 1990. The initial idea to work in the Manonga Valley stems from discussions between the coauthors of this chapter in New York in 1985, about the potentials and prospects of conducting paleontological research in Tanzania. Following brief visits to study fossil collections in the Natural History Museum in London and the National Museums of Tanzania in Dar es Salaam in 1986, a collaborative research effort between New York University and the National Museums of Tanzania was established.

One of the major problems with establishing a long-term field program in the Manonga Valley was that there was little or no background information already available on the geology, vertebrate paleontology, or age of the sites. This had serious implications for scientific planning, field logistics, and the fund-raising potential of the project, and meant that initial stages of the research would need to concentrate on a number of basic issues and problems (Harrison, 1992). Several key objectives were identified, as follows: (1) to relocate the known paleontological sites in the Manonga Valley, and to prospect for additional productive localities; (2) to make intensive surface collections and excavations for fossils from these sites to improve on the very limited data available on fossil faunas from the Manonga Valley; (3) to make detailed studies of these fossils for taxonomic, phylogenetic, biogeographic, and biochronological purposes; (4) to conduct geological investigations at both the local and regional levels, and to assess the nature of the geological context of the major fossil localities to obtain a detailed understanding of the local stratigraphy and geological history of the Manonga Valley; (5) to obtain more secure estimates of the age range of the fossil-bearing sediments through faunal correlation, paleomagnetic stratigraphy, and, if possible, radiometric dating; and (6) to attempt to reconstruct the paleoecology of the Manonga basin using evidence from geological studies and paleontology.

4. Geological Context

The basement rocks in the Manonga Valley are part of the Precambrian-age Nyanzian System, formerly referred to as the Upper Basement Complex (Stockley, 1935, 1943; Grantham and Temperley, 1939; Grantham *et al.*, 1945; Teale and Oates, 1946; Quennell *et al.*, 1956). They consist primarily of a series of acidic and basic volcanic rocks, schists of sedimentary origin, and banded ironstones, up to 7500 m thick (Grace and Stockley, 1931; Eades, 1936; Eades and Reeve, 1938; Williams and Eades, 1939; Grantham *et al.*, 1945; Stockley, 1947; Quennell *et al.*, 1956; Cahen *et al.*, 1984; Borg, 1992; Walraven *et al.*, 1994). The sediments are not highly metamorphosed, in contrast to those of the earlier Dodoman

System (formerly the Lower Basement Complex), which occur in other parts of Tanzania (Quennell *et al.*, 1956).

The most distinctive component of the Nyanzian System is the Banded Ironstone Formation (BIF), with a U-Pb zircon age of 2.7 Ga (Borg, 1992; Walraven *et al.*, 1994). Owing to its resistant nature, the banded ironstone, consisting of a chert with magnetite-rich laminae, is commonly found as irregular pebbles among the surface debris at Precambrian outcrops. The Nyanzian beds were subject to several episodes of batholithic intrusion of granitoid rocks, principally migmatites, biotite gneisses, gneissose granites, and biotite granites, commonly associated with dykes or sills of pegmatite, acidic volcanics, quartz veins, and other minor intrusions (Kuntz, 1909; Eades, 1936; Wade, 1937; Stockley, 1948; Quennell *et al.*, 1956). Rb-Sr and K-Ar dating of the granitoids indicates a widespread event of migmatization at ca. 2.4–2.6 Ga (Old and Rex, 1971; Dodson *et al.*, 1975; Cahen *et al.*, 1984; Walraven *et al.*, 1994). The oldest granites are dated at 2.85–3.12 Ga, which establishes the younger limit for the Nyanzian (Cahen *et al.*, 1984). As a consequence of these intrusions, the Nyanzian shows evidence of contact metamorphism and steep isoclinal folding (Quennell *et al.*, 1956; Walraven *et al.*, 1994). The resulting granitoid shield occupies a major portion of the Central Plateau, leaving a series of roof pendants of the Nyanzian System as isolated outcrops of limited extent (Grantham *et al.*, 1956; Cahen *et al.*, 1984).

The Nyanzian was subsequently disrupted by the intrusion of dykes of olivine dolerite and kimberlite pipes (Williams, 1939). The kimberlites in the vicinity of Nzega, just to the southwest of the Manonga depression, has a U-Pb date of 53 Ma, placing the intrusive event in the early Tertiary, close to the Paleocene–Eocene boundary (Dawson, 1970; Mitchell, 1986).

During the later Tertiary, the Central Plateau was subject to peneplanation, which resulted in the accumulation of extensive terrestrial deposits in shallow valleys and depressions (Teale, 1931; Williams and Eades, 1939; Grantham *et al.*, 1945). The terrain at this time was of relatively uniform relief, except for low, rounded inselbergs formed from outcrops of the more resistant granitic and basement rocks. The combination of arid conditions and low elevations resulted in broad, shallow valleys that quickly became filled with coarse, poorly sorted granitic brash and metamorphic detritus of local origin (Williams, 1939; Williams and Eades, 1939; Harrison and Verniers, 1993). These aggradational sediments are generally not bedded, but are cemented together by a calcareous, siliceous, or ferruginous matrix. Similar terrestrial sediments appear to be quite widespread on the Central Plateau, and may include the "Kilimatinde cement" (Krenkel, 1925; Wade, 1937; Quennell *et al.*, 1956; Pickering, 1958) and the ferruginous "cement" of the Gila Hills (Eades and Reeve, 1938). Evidence from boreholes has shown that these deposits may be up to 60 m in thickness (Grantham *et al.*, 1945).

By the end of the Miocene, initiation of regional rifting led to distant warping of the basement complex, which produced a shallow lake basin in the Manonga depression (Stockley, 1930; Williams and Eades, 1939). At its maximum, the lake covered an area in excess of 10,000 km^2—which today would rank it as Africa's fifth largest lake (Harrison, 1993a, 1994; Fig. 2). However, it is evident from the nature of the sediments, especially in the lower part of the sequence, that the lake underwent periods of regression, during which the floor of the lake emerged subaerially. The Precambrian hillocks of the Tertiary peneplain remained sufficiently elevated to form small, low-lying islands. Fine calcareous clays were deposited toward the center of the lake basin, and these have yielded the fossilized remains of vertebrates and invertebrates that lived in and around the lake during the Neogene (Grace and Stockley, 1931; Williams and Eades, 1939; Harrison, 1991b, 1993a, 1994; Haileab and Harrison, 1993; Harrison *et al.*, 1993; Harrison and Verniers, 1993). Coarser sandy and pebbly littoral facies were produced along the shorelines of the lake. The Sekenke conglomerates, composed of quartz pebbles with ferruginous staining and cherty beds, represent a localized occurrence along the flanks of the Sekenke ridge at the eastern margin of the Wembere depression (Kuntz, 1909; Eades, 1936; Eades and Reeve, 1938; Williams and Eades, 1939). The particles are medium-size, well rounded or subangular, and they are derived locally from the underlying Nyanzian complex (Eades, 1936). These conglomerates have been interpreted as shoreline or shoal accumulations, and they possibly represent the easternmost extent of the Manonga lake basin (Pickering, 1958). No fossils have yet been recovered from these sediments.

The regional geology has not yet been studied in sufficient detail to allow the reconstruction of the hydrographic relationships of the Manonga basin. Nevertheless, some interesting clues can be garnered from analyses of the biogeographic associations of the fish fauna (Stewart, this volume, Chapter 11) and mollusks (Gautier and Van Damme, this volume, Chapter 12), as well as from inferences about possible paleodrainage patterns. This is a topic of considerable interest given the location of the Manonga basin close to the great divide between the Zaïre (Atlantic), East Rift/east coast (Indian Ocean) and Nile (Mediterranean) drainage systems (Fig. 4).

There is no evidence to suggest that Lake Manonga was a dischargeless basin, comparable to that of Lake Eyasi today. Instead, the geomorphological and paleontological evidence both suggest that there was at least a periodic connection of the Manonga basin with the east coast and the Nile hydrological provinces during the late Neogene. It has been noted previously that Lake Manonga may have drained eastward into the Indian Ocean via the Pangani River system prior to the development of the Eastern Rift in northern Tanzania (Cooke, 1958). This is certainly a possibility, but there is very little empirical support for such an inference, and the geological evidence runs counter to such a suggestion. The subsequent formation of the southern end of the Gregory Rift in northern Tanzania has obscured the topographical and geomorphological relationships of the eastern portion of the Manonga basin. Today, the Manonga basin and Pangani Valley are separated by the Eyasi–Wembere troughs and the main southern axis of the Gregory Rift. It is, therefore, difficult to reconstruct the hydrological relationship between the east coast and Lake Manonga during the later Neogene, prior to regional rifting. It is evident, however, that the modern-day Pangani River

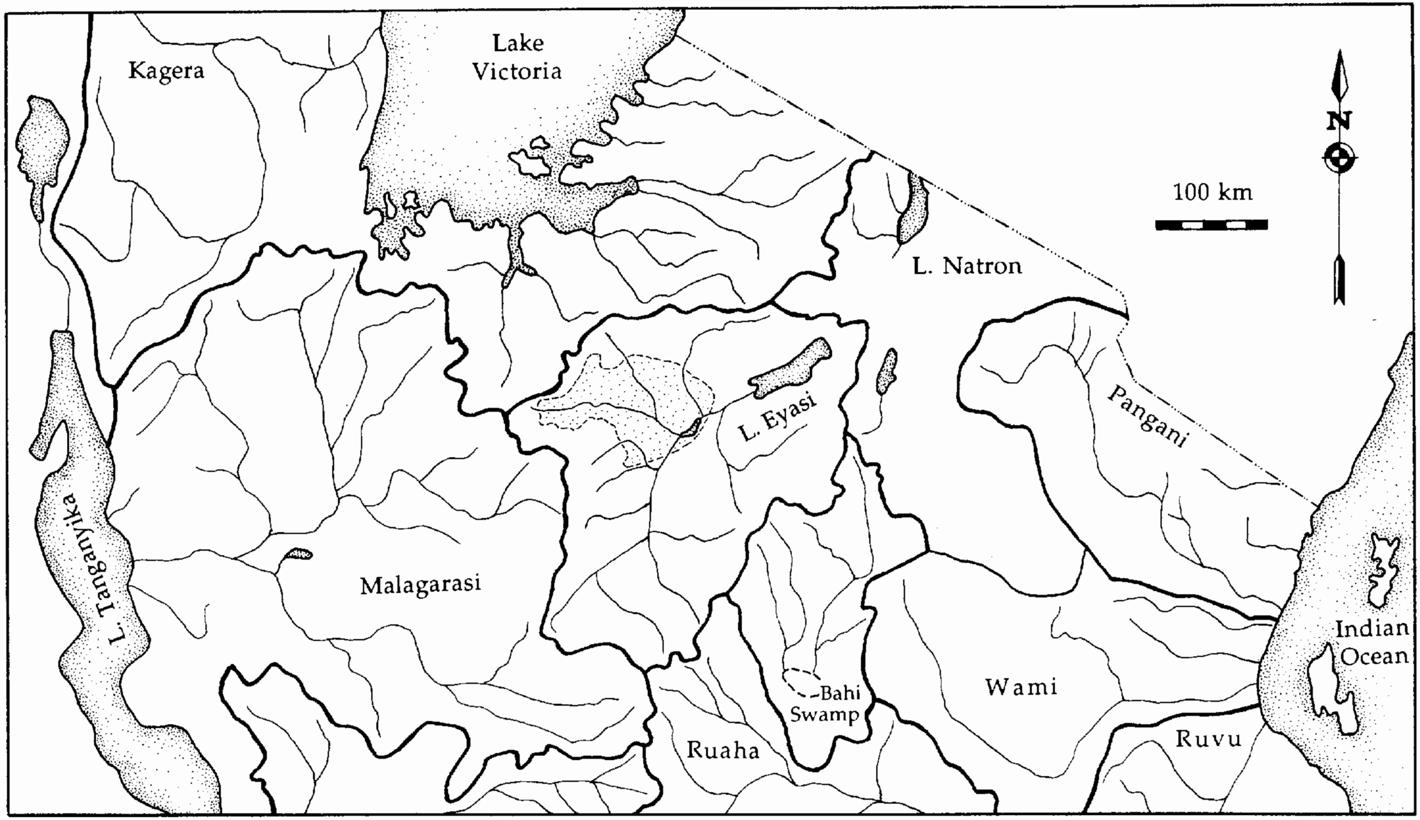

FIGURE 4. Hydrological map showing the main river basins in northern Tanzania. The Manonga River, which passes through the center of the Manonga basin (shown in light stipple in the center of the figure) is part of the present-day Lake Eyasi drainage basin, but it is located close to the divide between the Lake Victoria (Nile) and Lake Tanganyika (Zaire) drainage systems. Adapted from Berry (1972).

is a product of the rifting process itself, and that its current pattern of drainage antedates the depositional sequence in the Manonga Valley.

Nevertheless, a connection between the Manonga Valley and the east coast province is implied by the zoogeographic relationships of the fish faunas (Stewart, this volume, Chapter 11). It would seem that this connection was extant during the early part of the sequence, when Lake Manonga was relatively shallow, but that its drainage toward the east was eventually impeded by the development of the rift valley (Williams and Eades, 1939). In the western portion of the basin, away from the extreme margins of the Tanzanian craton, and where the effects of rift formation have been minimal, it is possible to reconstruct more precisely the topographic and hydrological relationships of Lake Manonga during the late Neogene. Presently, the lowest point in the divide between the Manonga basin and the Lake Victoria basin is at Igundu, 1154 m above sea level, and only 20 m above the present-day level of Lake Victoria. Lake sediments in the Manonga Valley currently range in elevation from just over 1000 m to about 1160 m (Williams and Eades, 1939; Verniers, this volume, Chapter 2). Even taking into consideration the slight tilting of the lake beds and changes in the position and elevation of the divide, we can infer that when Lake Manonga reached its maximum extent it overspilled into what is now the Lake Victoria basin. At the time, the latter basin was occupied by an extensive river system (the Kagera–Katonga basin), now largely submerged under the present-day lake (Cooke, 1958; Kendall, 1969; Kingdon, 1989; Pickford *et al.*, 1993). Water flowed into the center of the basin from the east and south, and eventually fed into the Kagera River. This then flowed west, presumably into the developing Western Rift via Lake Rutanzige (Lake Edward), and was eventually captured by the Nile River system (see Pickford *et al.*, 1993, for discussion of drainage in the Western Rift). Smith Sound and Stuhlmann Sound, which enter the Mwanza Gulf along the southern margin of Lake Victoria, represent the remains of deep channels cut by major rivers that flowed northwest into the Kagera–Katonga basin (Cooke, 1958). It seems likely that these were major drainage outlets from the Manonga basin during the early Pliocene, when Lake Manonga was at its deepest (but see Pickford *et al.*, 1993, for an alternative explanation of the formation of "Lake Wembere").

The Eastern Rift in northern Tanzania is deflected around the resistant craton to produce a 300-km-wide fracture zone of diverging faults and downwarps, (King, 1970, 1978; Baker *et al.*, 1972; McConnell, 1967, 1972; Williams, 1978; Fig. 5). Rifting and active volcanism at the southern end of the Gregory Rift appear to have occurred much later than that along the main axis of the rift. The Sonjo–Eyasi fault, which is partly buried by volcanics dated at 3.2 Ma (i.e., the Mozonik tuff at Peninj), is most probably early Pliocene in age (Isaac, 1967; King, 1970; Baker, 1986), while the faults in the central part of the divergence zone are slightly younger, probably late Pliocene to Pleistocene in age. Nevertheless, based on an assessment of the local paleo-drainage patterns, Hay (1987) has suggested that the Eyasi fault scarp did not exist at 3.5 Ma when the Laetolil Beds were deposited, and that most or all of the displacement occurred subsequent to the eruption of the Ogol lavas at 2.41 Ma. However, a critical review of the stream

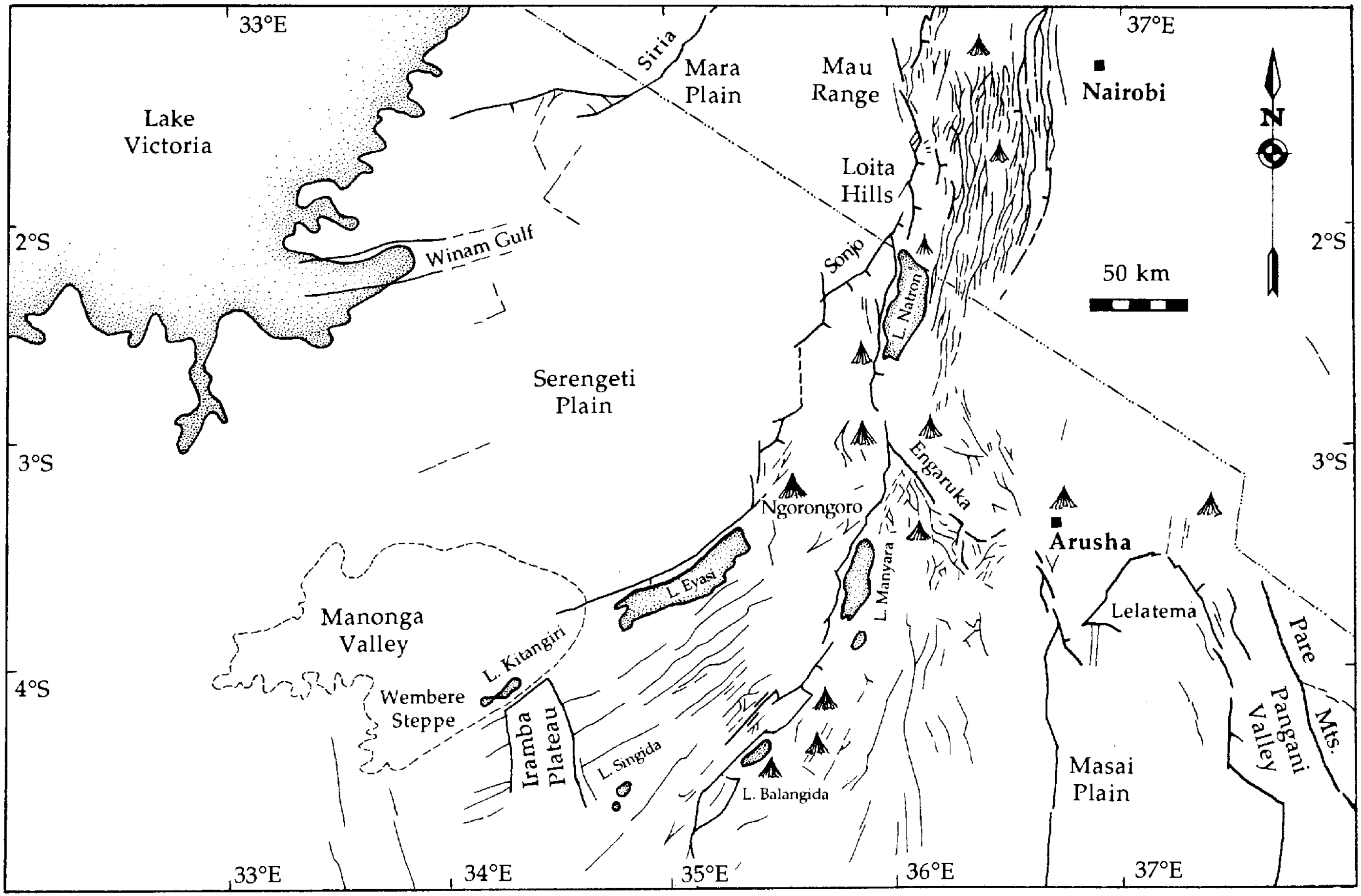

FIGURE 5. Map showing the fault pattern and major volcanic centers in southern Kenya and northern Tanzania in relation to the Manonga basin. Adapted from King (1970).

system of the present-day Eyasi basin, as revealed from aerial photographs and topographic maps, shows a complex pattern of directionality, one that would not readily provide convincing evidence today for the existence of a fault scarp along the northern margin of lake, especially when viewed at a local level. We can, therefore, conclude that development of the Eyasi trough, just to the northeast of the Manonga Valley, was probably initiated at the beginning of the Pliocene. The occurrence of a tuff, outcropping in a scarp near Olpiro, 15 km southeast of Laetoli, dated at 4.32 Ma, certainly confirms that volcanism, associated with the rift valley, was active in the region at this time (Drake and Curtis, 1987; Brown, 1994).

With the development of the Eyasi–Wembere grabens during the early Pliocene, Lake Manonga drained toward the northeast into the deeper Eyasi trough. The rifting process also apparently produced a slight downwarping of the Manonga lake beds. This directed the Manonga River eastward through the center of the depression toward Lake Kitangiri and Lake Eyasi, thus initiating the development of the modern Wembere–Manonga drainage system (Harrison and Verniers, 1993). Although the Manonga Valley is located at some distance from the major volcanic centers of the Eastern Rift, it is still affected by tectonic movements, with seismic activity reported up to several times a year (Eades, 1936). In fact, during the summer of 1990, the expedition experienced a strong tremor at the base camp.

Since the mid-Pliocene, the Neogene lake sediments have been exposed at cliff faces and eroded by the action of the Manonga River and its tributaries, as well as by heavy seasonal rains. The Manonga Valley, which cuts through the center of the lake basin, is associated with the most productive fossil sites.

The Neogene beds are overlain in places by quite extensive layers of undifferentiated alluvial sands and mbuga clays, which probably accumulated during the late Pleistocene and Holocene (Williams and Eades, 1939). Lake Victoria was formed during the middle to late Pleistocene, as a consequence of sagging of the Tanzanian craton to the north of the Manonga Valley, and by uplift in the west through continued maturation of the shoulders of the Western Rift. This led to tectonic back-ponding of westward flowing rivers, and subsequent drowning of the Kagera–Katonga river systems (Kendall, 1969). The height of Lake Victoria is now 1134 m above sea level,* some 20 m below the height of the Victoria–Manonga divide. However, evidence from ancient lake terraces and from lake cores suggests that at about 12,000 years ago Lake Victoria may have reached levels more than 20 m higher than the present lake (Temple, 1964, 1966, 1967; Kendall, 1969; Livingstone, 1975; Hamilton, 1982). This occurred at a time (12,700–11,100 BP) when climatic conditions in East Africa were warmer and wetter, and before significant down-cutting of the Nile outlet at Jinja in Uganda had developed (Kendall, 1969; Livingstone, 1975; Roberts *et al.*, 1993). Lake Victoria may have overspilled into the Manonga Valley at this time, thereby

*This is the pre-1961 level of Lake Victoria, since which time it has risen several meters (Kendall, 1969).

forming part of a huge system of swamps and shallow lakes across much of northern Tanzania. It is possible that some of the superficial sediments in the Manonga Valley, including the mbuga clays, are the result of inundation by higher water levels in the Victoria basin (Verniers, this volume, Chapter 2), or alternatively they were deposited by shallow lakes and swamps that formed in the previous lake basin as a consequence of wetter conditions than those prevailing today. Further evidence of contact with the Victoria basin is confirmed by the common occurrence of large bivalve mollusks in the mbuga clays (see Gautier and Van Damme, this volume, Chapter 12; Harrison and Baker, this volume, Chapter 13).

Verniers (this volume, Chapter 2) presents a revised stratigraphy of the Manonga basin, following the initial studies of Harrison and Verniers (1993) and Harrison *et al.* (1993). A generalized stratigraphic scheme, based on the revised interpretation of Verniers is presented in Fig. 6. The Tertiary sediments are divided into two formations, the Mwansarara Formation and the Wembere–Manonga Formation, the latter of which is further subdivided into three members, the Ibole, Tinde, and Kiloleli. To date, no fossils have been recovered from the Mwansarara Formation, but they are well represented in each of the major stratigraphic subunits of the Wembere–Manonga Formation. Biostratigraphic analysis of the mammalian fauna (Harrison and Baker, this volume, Chapter 13) indicates an age estimation of ~4.0–5.5 Ma for the Wembere–Manonga Formation.

<table>
<tr><th>Estimated age</th><th colspan="2">Stratigraphic unit</th><th>Fossil mammal localities</th></tr>
<tr><td>Late Pleistocene or Holocene</td><td colspan="2">Mbuga clays, yellow clays</td><td>Ipembe, Kalitu, Ngofila 1–2, Nyawa, Shoshamagai Hill, Shoshamagai 2, Inolelo 1–3, Tinde West, Kiloleli 2–3, Beredi South 1, Kininginila, Ngofila 2</td></tr>
<tr><td>Early Pliocene ~4.0–4.5 Ma</td><td rowspan="3">Wembere–Manonga Formation</td><td>Kiloleli Member</td><td>Kiloleli 1–4, Ngofila 1–5, Beredi South 1–3</td></tr>
<tr><td>Early Pliocene ~4.5–5.0 Ma</td><td>Tinde Member</td><td>Tinde East, Tinde West, Mwambiti 1, 2, 5, Ipembe, Shoshamagai 1–2, Ngofila 1–5, Beredi North, Mihama, Kininginila, Nyawa</td></tr>
<tr><td>Late Miocene ~5.0–5.5 Ma</td><td>Ibole Member</td><td>Inolelo 1–3, Shoshamagai 2, Mwambiti 3–4, Lubeho, Beredi South 5, Kalitu, Ngofila 1–2, 5</td></tr>
<tr><td>?Miocene</td><td colspan="2">Mwansarara Formation</td><td></td></tr>
<tr><td>Precambrian</td><td colspan="2">Nyanzian System</td><td></td></tr>
</table>

FIGURE 6. Generalized stratigraphic scheme of the sediments in the Manonga basin, and the stratigraphic distribution of fossil mammal localities.

5. Paleontological Localities in the Manonga Valley

As the majority of fossil sites in the Manonga Valley have not been formally described, a brief review of each collecting locality is presented below. Additional information about their geographic location, stratigraphic position, and the fossil material recovered is presented in Table I and Fig. 6. Figures 2 and 3 illustrate the location of the main collecting areas in the Manonga Valley. All of the fossil sites are located in the center of the Manonga basin, not far from the Manonga River.

5.1. Tinde

The site of Tinde, first described by Stockley (1930) and Grace and Stockley (1931) is located in Igunga District (Tabora Region), about 7 km southeast of the village of Igurubi (Fig. 7). It is situated close to the center of the Manonga depression, about 10 km south of the Manonga River. The site consists of two low bluffs, less than 10 m high, separated by a flat gap, about 110 m wide. Owing to the spatial separation of the fossil-producing beds, it was considered convenient to divide the former site into two separate collecting localities, Tinde East and Tinde West, situated on the eastern and western side of the gap, respectively (Harrison, 1991b, 1993a; Harrison and Verniers, 1993; Harrison *et al.*, 1993).

As this locality represents the type locality for the Tinde Member (=Tinde Beds), geological and paleontological work was initiated here during the 1990 season. Detailed geological mapping was untaken in order to provide a standard stratigraphy for regional comparison. Fossils *in situ* are restricted to a single horizon, about 1 m in thickness, consisting of a light gray calcareous clay layer impregnated with a hard honeycomblike calcite matrix. Almost all of the fossils obtained from this site have been recovered by surface collection after they have eroded out of the fossiliferous layer.

The two sites at Tinde are among the most productive localities in the Manonga Valley. To date, almost two thousand taxonomically identifiable large mammals have been recovered, representing 48% of the collections from all localities in the Manonga Valley. Further details of the paleoecology, taphonomy, and vertebrate paleontology of Tinde are presented by Harrison (this volume, Chapter 4) and Harrison and Baker (this volume, Chapter 13).

5.2. Mwambiti

Five fossil localities have been designated in the vicinity of Mwambiti point, a distinct promontory on the southern edge of the Manonga Valley, located 5.4 km south of the Manonga River and 7.6 km northeast of Tinde West. The sites are associated with an arc of cliffs, 10.7 km long, that run from Tinde West to Mwambiti point. Intensive exploration of these cliffs and the neighboring valley since 1990 has shown that the sediments are mostly unfossiliferous. Nevertheless, several areas of rather limited extent have produced vertebrate fossils.

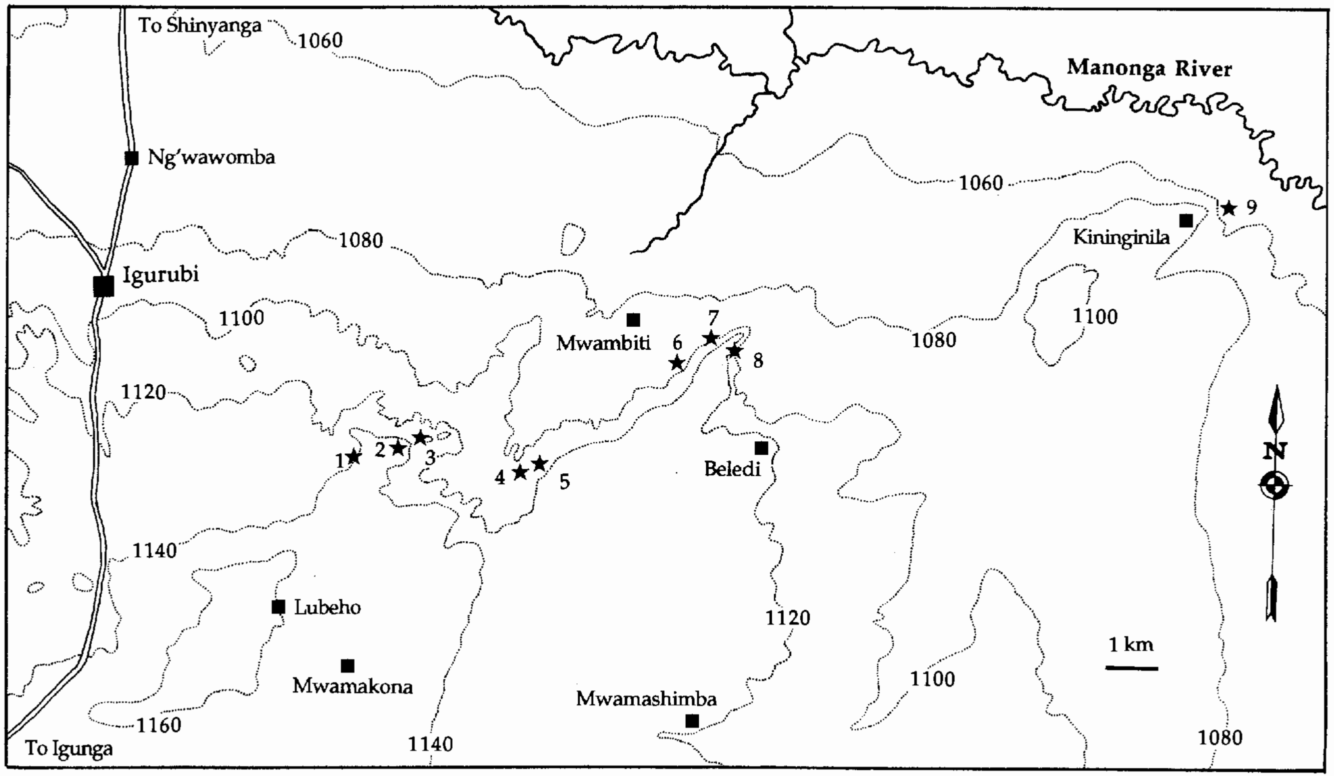

FIGURE 7. Topographic map showing the location of the fossil localities (marked by stars) at Lubeho, Tinde, Mwambiti, and Kininginila: 1, Lubeho; 2, Tinde West; 3, Tinde East; 4, Mwambiti 4; 5, Mwambiti 3; 6, Mwambiti 5; 7, Mwambiti 1; 8, Mwambiti 2; 9, Kininginila. Detail of inset (c) from Fig. 3.

In 1990, two sites, Mwambiti 1 and Mwambiti 2, were discovered on the northwestern and eastern flanks of Mwambiti point, respectively (Fig. 7). Fossils were recovered from the surface debris, having previously eroded out of a hard calcareous band close to the top of the cliff, intercalated within sediments equivalent to the Tinde Member. Fragmentary fossils were also recovered from a thin red clay layer at the base of the cliff, initially designated as the Mwambiti Member (Harrison, 1991b, 1993a; Harrison and Verniers, 1993; Harrison *et al.*, 1993), but now subsumed into the Ibole Member. A widened search of the general area in 1992, with teams prospecting as far as 2 km from the cliffs, led to the discovery of two further sites, Mwambiti 3 and Mwambiti 4 (Fig. 7). Mwambiti 3 is a relatively restricted locality situated quite close to the base of the cliffs, 5.2 km southwest of Mwambiti point, and 2.8 km east of Tinde West. Mwambiti 4 is located about 1 km north of the cliffs, 5.7 km southwest of Mwambiti point, and 2.3 km east of Tinde West. Fossils from both of these sites were found eroding out of a thick layer of red calcareous clays within the Ibole Member. They are exposed and concentrated in small ephemeral river gullies that have cut down several meters into the floor of the valley. In addition, at Mwambiti 3, fossils were also recovered from the cliff face, derived from calcareous clays of the Tinde Member.

In 1994, a further site, Mwambiti 5, was discovered 2 km southwest of Mwambiti point (Fig. 7). The locality consists of a low denuded hillock, situated less than 100 m north of the main cliffs. The hillock, which rises only about 5 m above the general surface of the valley floor, exposes an alternating series of hard calcareous clays and softer swelling clays of the Tinde Member. Fossil vertebrates are extremely rare, but well-preserved jaws and associated postcranial elements of a small species of rodent were recovered after having washed out of a light gray and reddish-tinged swelling clay at the base of the hillock. The number of large mammals known from the localities at Mwambiti is relatively small, representing less than 1% of the total material from the Manonga Valley.

5.3. Kiloleli

In 1990, several productive fossil localities were discovered along a line of low cliffs situated just west of the main Igurubi–Shinyanga road, in the vicinity of the village of Kiloleli. The sites have been subdivided geographically into four collecting localities, Kiloleli 1 through Kiloleli 4. Kiloleli 1 is located just north of the village of Kiloleli, while Kiloleli 2–4 are located south of the village (Fig. 8). The sites are located in Shinyanga District (Shinyanga Region), beginning 6.8 km north of the Manonga River, 14.0 km north of Igurubi, and 19.1 km northwest of the site of Tinde West. Williams and Eades (1939) made reference to a fossil site just north of Shoshamagai, but gave no specific information on its location. From the evidence available, however, it seems likely that the locality is equivalent to Kiloleli 2, as defined by WMPE (Harrison, 1991b).

The best exposures at Kiloleli consist of low slopes and cliffs, which rise to less than 15 m above the valley floor. Careful examination of the surface exposures has revealed that fossils are eroding out of a series of hard calcareous bands intercalated within a thick bed of swelling clays, representing the Kiloleli Member. At least two of the hard layers at Kiloleli 2 have yielded fossils *in situ*. The faunas from each layer are identical, and there is no reason to assume that a significant time interval elapsed between their deposition. However, quarrying activities for suitable raw material for brick-making by the local inhabitants has recently exposed a layer of yellow clay at the top of the Kiloleli sequence that yields what appears to be a much younger fauna. The bones and teeth from this horizon, which have a distinctively yellowish coloration and friable texture, tend to be more complete and better preserved than the more heavily mineralized and brittle fossils from the underlying Kiloleli Member. Although very little material has been recovered from this upper clay horizon, the identifiable taxa can probably be referred to modern species, implying a late Pleistocene or Holocene age (see Harrison and Baker, this volume, Chapter 13).

It is worth noting that when Kiloleli was first visited by WMPE in 1990, brick-making activities at the southern end of Kiloleli 2 made it impossible to obtain fossils because of the disturbed stratigraphy and the superficial coverage by excavated debris. Following discussions with the local authorities at Kiloleli,

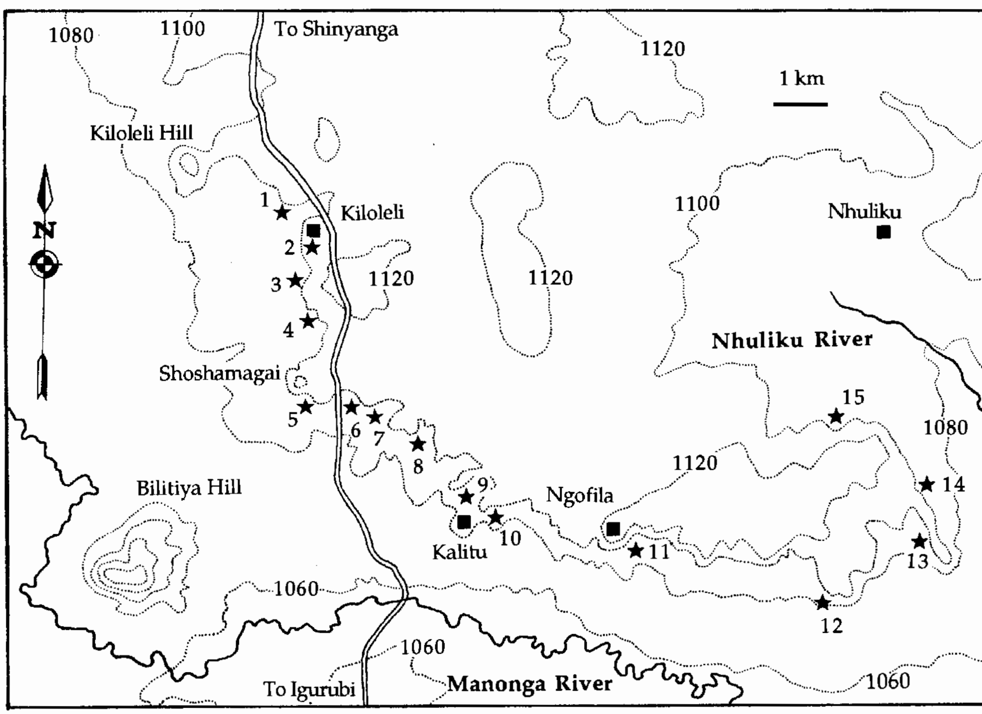

FIGURE 8. Topographic map showing the location of the fossil localities (marked by stars) at Kiloleli, Shoshamagai, Inolelo, Kalitu, and Ngofila: 1, Kiloleli 1; 2, Kiloleli 2; 3, Kiloleli 3; 4, Kiloleli 4; 5, Shoshamagai 1; 6, Shoshamagai 2; 7, Inolelo 1; 8, Inolelo 2; 9, Inolelo 3; 10, Kalitu; 11, Ngofila 1; 12, Ngofila 2; 13, Ngofila 3; 14, Ngofila 4; 15, Ngofila 5. Detail of inset (a) from Fig. 3.

a ban was imposed on brick-making in an attempt to conserve the site, and these restrictions were still in effect when WMPE returned in 1992. However, by the time of our next visit in 1994 excavation of the clays had resumed, and, in fact, exploitation had intensified. Although this has led, at least initially, to a higher yield of fossils on the surface, the increased breakage and the lack of primary stratigraphic association associated with indiscriminate excavation has undermined the utility of the collections.

The localities at Kiloleli, especially Kiloleli 2, are among the most productive fossil localities in the Manonga Valley. Together they have produced 17.3% of the taxonomically identifiable large mammals, second only in importance to the sites at Tinde.

5.4. Ipembe and Lubeho

In 1992 and 1994, WMPE conducted a brief survey in the region of the Kalangale Hills, an elevated series of Precambrian outcrops, located on the southwestern margin of the Manonga basin. A search of the exposed sediments in the vicinity of the villages of Ng'wandibimizi and Ipembe led to the discovery of a single new fossil locality. The site of Ipembe is located 1.8 km southwest of the village of Ipembe, 12 km northwest of Igurubi, and 7.3 km south of the Manonga River. The locality consists of a low plateau, less than 10 m high, with east- and west-facing cliffs that meet at a precipitous north-facing promontory. Mammalian fossils were not abundant. They were found scattered along the entire length of the eastern flank of the plateau, derived from light gray calcareous clays of the Tinde Member.

The site of Lubeho was first discovered in 1994. It is located just to the north of the village of Lubeho, 2.3 km southwest of Tinde West, and 6.6 km southeast of Igurubi (Fig. 7). The low, northwest-facing cliffs at the site grade gently down to a series of shallow gullies in the valley floor that expose the red clays of the Ibole Member. The contact between the light gray swelling clays of the Tinde Member and the red beds of the Ibole Member are obscured by a thick sheet of mbuga clays. Initial prospecting of the site led to the discovery of a partial mandible of an elephantid, still *in situ* in the Ibole beds. A subsequent visit to the site led to the recovery of further proboscidean remains, presumably belonging to the same individual, but no additional fossils (apart from an equid molar from the mbuga clays) were found. It would appear that the elephantid remains are an isolated occurrence at this site.

5.5. Shoshamagai

In 1990, a preliminary survey of the exposed sediments at the foot of Shoshamagai Hill, about 2 km south of Kiloleli village, revealed that the deposits were fossiliferous. Shoshamagai is subdivided into two collecting localities, Shoshamagai 1 and Shoshamagai 2 (Fig. 8).

Shoshamagai 1 is situated on the southern flank of Shoshamagai Hill to the western side of the main Igurubi–Shinyanga road. The sediments consist of a thick blanket of undifferentiated light gray to olive swelling clays, with several thin intercalated lenticular layers of hard white powdery calcareous clay. These sediments are assigned to the Tinde Member. The surface exposures in close proximity to the hill are littered with coarse, angular nodules of banded ironstone and other detritus derived from the Precambrian basement. Further from the hill, the sediments are better exposed, and the lake beds are deeply excised by small ephemeral drainage channels that radiate out from the base of the hill. Shoshamagai 1 is poorly fossiliferous. Recovered remains consist mainly of fish and aquatic reptiles, although isolated bones and teeth of large mammals do occur.

Shoshamagai 2 is adjacent to Shoshamagai 1, but is situated on the eastern side of the Igurubi–Shinyanga road, just to the southeast of Shoshamagai Hill. The Tinde beds at Shoshamagai 2 are the lateral equivalent of those at Shoshamagai 1, but they are better exposed, with steep-sided cliffs up to 10 m in height. Fossils are quite rare, however, and the Tinde beds in this area are much less productive than those at Tinde. Further from the cliffs at Shoshamagai 2, a rich concentration of fossils was found in sediments situated lower down in the local sequence, associated with the red beds of the Ibole Member (Harrison and Verniers, 1993; Verniers. this volume, Chapter 2). This site has yielded more than 11% of the large mammals from the Manonga Valley, and is one of only three sites to have yielded samples of micromammals (Winkler, 1993, this volume, Chapter 10).

5.6. Inolelo

From Shoshamagai Hill, a continuous series of low cliffs extends eastward for about 15 km, forming the northern margin of the Manonga Valley. These cliffs end at the Nhuliku Valley, formed by a shallow, ephemeral river that runs from the northwest, and eventually drains into the Manonga River. The cliffs form distinct promontories, which conveniently allow demarcation of the northern portion of the Manonga Valley into a series of eight geographically contiguous localities. Starting east of the Igurubi–Shinyanga road with Shoshamagai 2, discussed above, the collecting localities passing from east to west are Inolelo 1, Inolelo 2, Inolelo 3, Kalitu, Ngofila 1, Ngofila 2, and Ngofila 3 (Fig. 8).

The sites at Inolelo extend southeast along the northern margin of the Manonga valley for a distance of 5 km from Shoshamagai Hill. As at Shoshamagai 2, few fossil mammals have been obtained eroding out of the cliff faces from horizons within the Tinde Member. Most of the fossils, and certainly the best-preserved material, have been recovered from the Ibole Member, exposed on the surface of the Manonga Valley or in shallow gullies located up to 500 m from the cliffs. The red beds, which may be up to 6 m in thickness, consist of a laterized calcareous clay, grading down from light gray in color through gray-green, orange, pink, to bright red at its base. Fossils appear to be concentrated, but not exclusively found, in the upper portion of this layer. The red beds are overlain in places by mbuga clays, which support a sparse vegetation dominated by gall acacia. These vegetated patches serve to demarcate the eroded fossiliferous exposures into separate collecting localities. The fossils recovered from the red beds at Inolelo are derived from the same horizon as those from Shoshamagai 2, and the material obtained from all four sites can be considered as representing a single fauna.

Inolelo 1 is the largest exposure, and the most productive of the three sites. It is centered around a single main gully, up to 3 m in depth. Along with Shoshamagai 2, Inolelo 1 represents the most productive locality sampling fossils from the Ibole Member. In addition, an intensive program of screening at the site, directed by Dr. Kathlyn Stewart (Canadian Museum of Nature), has yielded a small, but important, collection of microvertebrates, including teeth and isolated bones of rodents, small carnivores, and several species of fish (see Winkler, this volume, Chapter 10; Stewart, this volume, Chapter 11). Inolelo 2 consists of three parallel gullies, much shallower than that at Inolelo 1 and heavily choked with mbuga clay and superficial sediments. Inolelo 3 extends eastward as far as the village at Kalitu, where a shallow gully and surface exposures of the red beds, some located only 10 m from the nearest house, have yielded well-preserved fossil mammals. The sites at Inolelo have yielded 10.6% of all of the large mammals from the Manonga Valley.

5.7. Kalitu

This site is situated northeast of the village of Kalitu, 1.3 km north of the Manonga River and 10 km northeast of Igurubi (Fig. 8). The site extends eastward for 2.3 km from the village of Kalitu to the village of Ngofila. A search of the exposed sediments of the Ibole Member in the village itself and to the east of the village has failed to yield any indications that fossils are present. However, a few fossils were recovered from the base of the cliffs nearby, and these are presumably derived from the swelling clays of the Tinde Member. The Neogene sediments at the base of the cliff are covered by patches of mbuga clay of variable thickness. A sample of isolated teeth of large mammals, presumably of late Pleistocene or Holocene age, was recovered from these latter deposits (Harrison and Baker, this volume, Chapter 13).

5.8. Ngofila

Ngofila is a continuation of the series of fossil localities that follow the line of cliffs on the northern side of the Manonga Valley, extending from Shoshamagai Hill in the west to the Nhuliku Valley in the east. The localities begin at the cliffs just below the village of Ngofila and continue east and north into the Nhuliku Valley (Fig. 8). A series of five collecting localities have been designated, based on geographic features and the distribution of fossils. These sites have yielded 6.4% of the large mammal specimens from the Manonga Valley.

Ngofila 1 is contiguous with the locality of Kalitu to the west, and comprises a series of low cliffs that extend eastward from the village of Ngofila for 4.3 km (Fig. 8). Its eastern boundary is demarcated by a low eroded hillock ("Ngofila Hill") that rises from the valley floor, and it is located less than 1 km west of Ngofila school. Few fossils have been recovered, and these are largely derived from beds of the Tinde Member. In 1994, a collection of fossil mammals was obtained from equivalent beds at Ngofila Hill.

Ngofila 2 is located east of Ngofila 1, and comprises a line of south- and east-facing cliffs, about 3 km in length, that pass below Ngofila school (Fig. 8). These cliffs reach a maximum elevation of 15 m above the valley floor, but eastward they descend to a low, densely bush-covered saddle, forming the boundary between Ngofila 2 and 3. Fossils from this locality derive from several horizons. A number of darkly stained and heavily mineralized bones and teeth were collected at the base of the cliff, presumably eroded out of a resistant calcareous clay band, located midway up the cliff, and the underlying swelling clays. These are best correlated with the Tinde Member. Directly above this is a yellowish-brown pebbly clay horizon, densely packed with gastropods, and capped by a thin grey limestone, equivalent to one of the uppermost horizons of the Kiloleli Member. On a narrow ledge very close to the top of the cliff at Ngofila 2 were a large number of poorly mineralized bones and teeth, creamy white in color, with bright yellow adhering matrix. These bones are identical in preservation to the similar occurrence at Kiloleli discussed above. Some of these bones exhibit signs of human activity in the form of butchering marks, but no stone tools were found in association. A few bones also show evidence of having been gnawed by rodents, an indication that they were exposed on the surface prior to burial. Since these fossils can be attributed to modern species, they are almost certainly late Pleistocene or Holocene in age (Harrison and Baker, this volume, Chapter 13).

Ngofila 3 consists of west-facing cliffs, separated from Ngofila 2 by a low, bush-covered saddle (Fig. 8). The cliffs, which extend for 1.5 km, are quite low to the north, but increase in elevation as they pass south, ending at a precipitous promontory at least 15 m high. The site is not richly fossiliferous, but a thin scatter of vertebrate fossils was found eroding out of beds in the Kiloleli Member. Of some taphonomic interest was the incidental recovery at Ngofila 3 of modern bone samples derived from spotted eagle owl nests, as well as from porcupine and hyena lairs. These samples are currently being prepared and studied by Wendy Dirks and Erin Dooley (New York University).

Ngofila 4 is located 7 km east of the village of Ngofila, and 4.5 km southwest of the village of Beredi (Fig. 8). Located 2 km from the Nhuliku River, the locality consists of northeast-facing cliffs, 3.3 km long, that form the western flank of the Nhuliku Valley. The low cliffs, less than 20 m high, are generally poorly fossiliferous. Fossils appear to be derived from both the Tinde and Kiloleli Members, although the best concentrations of fossil mammals were derived from horizons within the Kiloleli Member.

Ngofila 5 is located 6 km northeast of the village of Ngofila, 4.5 km southwest of the village of Beredi, and 4.1 km south of the village of Nhuliku (Fig. 8). The cliffs face northward and form the southern margin of the Nhuliku Valley, 2.5 km from the Nhuliku River. From its boundary with Ngofila 4, the cliffs extend west for more than 2 km before grading into a series of low slopes with dense vegetation cover and poorly exposed sediments. Fish and turtle remains were recovered from a narrow pink clay horizon at the base of the Tinde Member, but most of the fossil mammals were derived from the Kiloleli Member.

5.9. Beredi North and Mihama

Beredi North is located 2.7 km southeast of the village of Beredi, 9.3 km east of the village of Ngofila, and 7.5 km northwest of the village of Mihama (Fig. 9). The site consists of a low triangular plateau, bounded on the southwest and southeast by low cliffs that extend for about 4 km. The southwestern cliffs form the eastern margin of the Nhuliku Valley, 2.3 km east of the Nhuliku River. Beredi North is separated from Ngofila 4 on the western side of the valley by a flat plain about 4 km wide. Most of the cliffs are rather thickly vegetated, so erosion occurs slowly, and relatively few fossils have weathered out. Most of the fossils have been recovered from the southern tip of the plateau, where an elevated promon-

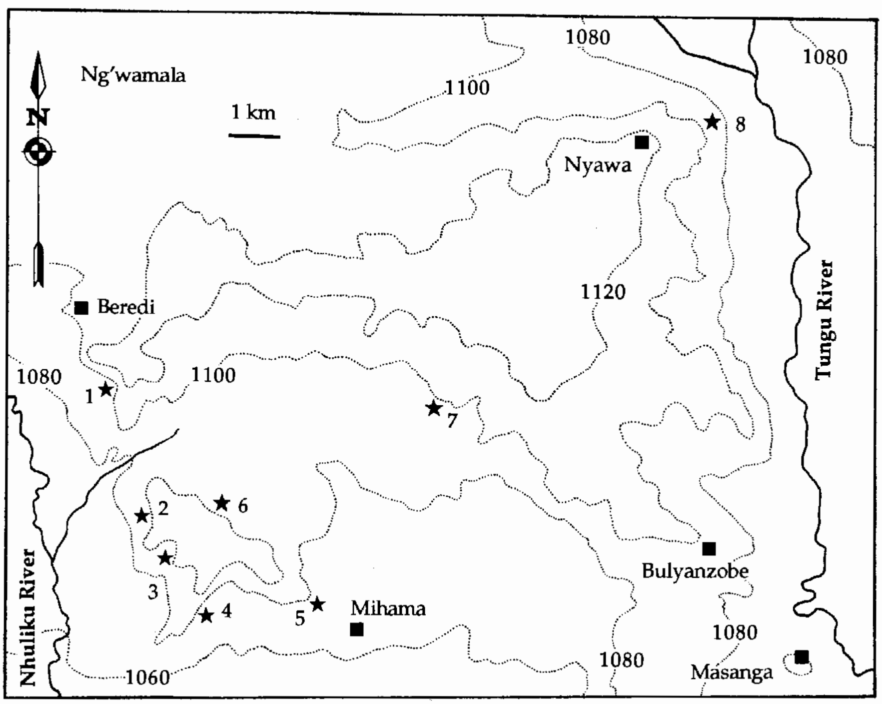

FIGURE 9. Topographic map showing the location of the fossil localities (marked by stars) at Beredi North, Beredi South, Mihama, and Nyawa: 1, Beredi North; 2, Beredi South 1; 3, Beredi South 2; 4, Beredi South 3; 5, Beredi South 4; 6, Beredi South 5; 7, Mihama; 8, Nyawa. Detail of inset (b) from Fig. 3.

tory has well-exposed sediments. Nevertheless, even here, fossils appear to be relatively uncommon.

In 1994, WMPE spent several days prospecting along the cliffs and low hills to the east of Beredi North, running from the village of Ng'wang'wika to the village of Bulyanzobe on the western flank of the Tungu River valley, about 5 km north of Mihama (Fig. 9). The slopes are poorly exposed, and are mostly covered with grass and sparse thickets. A few teeth of fossil mammals have been recovered from the surface. One specimen was collected from the mbuga clay, and is presumably Holocene or late Pleistocene in age, while the remaining material is derived from the Tinde Member.

5.10. Beredi South

Beredi South is a low plateau located 3.8 km southeast of the village of Beredi, 10.5 km east of Ngofila and 2.4 km northwest of the village of Mihama (Fig. 9). The plateau is separated from Beredi North by a flat plain 1.2 km wide. The southern and western margins of the plateau end at steep cliffs, which delimit the northern and eastern flanks of the Manonga and Nhuliku Valleys, respectively. Beredi South is located less than 2 km from the Manonga River and 1.8 km from the Nhuliku River. The cliffs forming the edge of the plateau have been subdivided into five separate collecting localities, Beredi South 1 through 5.

Beredi South 1 is located on the northwestern side of the plateau, overlooking the Nhuliku Valley and facing Ngofila 4. It is the most productive of the localities at Beredi South, and consists of a steep cliff exposing a series of well-stratified sediments. Fossils have been recovered from a number of different horizons. A hard calcareous clay, intercalated within a thick layer of swelling clays at the base of the cliff, represents the Tinde beds. This has yielded the remains of fossil fish and mollusks. Higher up the sequence, in the Kiloleli Member, a rich concentration of fossil mammals has been recovered, including a skull and forelimb skeleton of *Eurygnathohippus* (see Bernor and Armour-Chelu, this volume, Chapter 8). In addition, poorly mineralized and friable bones are derived from a yellow clay layer at the top of the cliff. This is presumably the lateral equivalent of the lithologically similar layer at Kiloleli 2 and Ngofila 1. The fossils are estimated to be late Pleistocene or Holocene in age (see Harrison and Baker, this volume, Chapter 13).

Beredi South 2 is a small exposure of sediments on a low range of cliffs, just to the southeast of Beredi South 1. The site has yielded fossils from the Kiloleli Member (Fig. 9).

Beredi South 3 is a long line of cliffs on the southeastern flank of the plateau running northeast from the southernmost promontory of Beredi South, close to the village of Buking'wanzuki (Fig. 9). A thin scattering of bones, mostly of fish and aquatic reptiles, was collected from the base of the cliff, derived from the Tinde Member. A rich concentration of fossils was also discovered from the Kiloleli Member, in a thick series of alternating calcareous clays and mudstones toward the top of the cliff.

Beredi South 4 consists of a southwest-facing cliff to the east of Beredi South 3, and 2.3 km northwest of the village of Mihama (Fig. 9). The northern section of the site consists of relatively low slopes, with dense grass and bush cover, and few good exposures. The cliff at the southwestern extreme of the site is more precipitous, with an elevation above the floor of the valley of more than 20 m. At the base of the cliff, small gullies cutting through the floor of the valley have exposed the red beds of the Ibole Member. Above this layer is a thick bed of swelling clays, up to 8 m thick, with at least six intercalated bands of hard calcareous clays. The lowest two bands, each less than 10 cm thick, consist of fine white calcareous clays containing small, well-rounded pink clay nodules. These layers contain a rich concentration of fossil fish, mostly *Clarias*, but the remains are extremely fragmentary and abraded, suggesting fluvial transportation prior to burial. However, they do not exhibit signs of rolling, certainly not to the degree exhibited by the associated pebbles, which have presumably been transported some considerable distance. Above the swelling clays is a series of fluvial sediments, up to 13 m thick, that comprise the Kiloleli Member, but no fossils have yet been recovered from these horizons.

Beredi South 5 is a line of cliffs and low slopes, 4.2 km long, forming the northeast margin of the plateau, and facing the locality of Mihama (Fig. 9). Kiloleli and Tinde Member beds are both represented, but the combination of low inclines and dense vegetation cover provides few good exposures. Fossil remains from these horizons tend to be fragmentary and scarce. At the base of the cliffs the Ibole Member beds are well exposed. These are largely unfossiliferous, but in 1994 a partial skeleton of a massive proboscidean was discovered (see Sanders, this volume, Chapter 9).

5.11. Nyawa

Nyawa is the easternmost of the localities on the northern side of the Manonga Valley (Fig. 9). The site consists of a series of low cliffs and slopes along the western flank of the Tungu Valley, between 1 and 2 km from the Tungu River. The southern end of the cliffs starts just north of the main track that fords the Tungu River leading to the town of Masanga. The main exposures occur in the vicinity of the village of Nyawa, close to the confluence of the Tungu and Mangu Rivers, about 13 km northeast of the village of Beredi. Fossils were first collected at Nyawa by Kleindienst and Haldemann, who made a brief visit to the area in 1959.

Mammalian fossils from the Tinde beds at Nyawa are not common, although the remains of fish, turtles, and crocodiles are ubiquitous. The floor of the valley, immediately to the north of the village of Nyawa, has a series of deep gullies that expose the Ibole Member. These appear to be unfossiliferous. The red beds are covered with a thin layer of mbuga clay that has yielded a good number of bones and teeth of large mammals, associated with quartz artifacts. The association of a Late Stone Age assemblage and modern fauna suggests that the mbuga clays were deposited during the late Pleistocene or Holocene.

5.12. Kininginila

The cliffs and exposed sediments in the vicinity of the village of Kininginila were first prospected during the 1992 field season. The site is situated on the southern edge of the Manonga Valley, less than 1 km from the Manonga River. It is located 11.5 km east of Mwambiti point, 7 km south of the village of Mihama, and 14.3 km northeast of the town of Mwamashimba (Fig. 7). Fossils are scarce, but a number of remains of large mammals, fish, and reptiles have been recovered from the Tinde Member.

6. Significance of Paleontological Research in the Manonga Valley

The recent expeditions to the Manonga Valley have provided evidence of the paleontological potential of the area. The large lake basin, with its extensive, well-exposed sediments and numerous productive fossil localities, can now be considered an important new paleontological research area in eastern Africa. The sequence of fossil-bearing sediments in the Manonga Valley covers an estimated time range (~4.0–5.5 Ma) that is generally poorly represented in sub-Saharan Africa. The paleontological collections, therefore, provide important new information on the evolutionary history, taxonomic diversity, paleobiology, and paleoecology of fossil mammals in East Africa during the late Neogene.

The Manonga Valley is, perhaps, of especial importance for researches into human origins. Even though paleoanthropologists have been painstakingly piecing together an increasingly complete record of human evolutionary history in Africa over the past 70 years, the hominid fossil record prior to 4.5 Ma remains extremely meager. At present, a jaw fragment and two teeth from Lothagam and an isolated tooth from Lukeino, dated at 5–7 Ma, represent the sum total of the evidence available (Patterson *et al.*, 1970; Pickford, 1975; Hill and Ward, 1988; Hill *et al.*, 1992; Hill, 1994; Leakey *et al.*, 1996). Therefore, the eventual recovery of fossil hominids from the Manonga Valley could contribute significantly to our currently limited understanding of the anatomy and paleobiology of the earliest stages of human evolution (see Harrison, this volume, Chapter 14). However, it is important to stress here that there is more at stake than merely extending the human lineage back in time and being able to lay claim to the earliest human ancestor. According to many paleoanthropologists and molecular biologists, 5–6 Ma may be close to the point in time when the human lineage diverged from the other African hominoids (e.g., Weiss, 1987: Hasegawa *et al.*, 1989; Caccone and Powell, 1989; Andrews, 1992; Hasegawa, 1992; Boaz, 1994; Hill, 1994). The discovery of the remains of early hominids from the late Miocene (or perhaps even more intriguingly, the remains of the antecedents of the last common ancestor of humans and African apes) would represent a major advance in our understanding of the evolutionary history of humans. In any event, even if hominid fossils continue to elude us in the Manonga Valley, analysis of the fauna from this poorly understood but critical time period may ultimately allow us to advance new hypotheses concerning the ecological and biogeographic factors, as well as the adaptive consequences, associated with the initial differentiation of the hominids in Africa (Hill, 1987, 1994; Boaz, 1994; Leakey *et al.*, 1996; Harrison, this volume, Chapter 14).

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